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PRAZDROID: A NOVEL APPROACH TO RISK ASSESSMENT AND ZONING OF ANDROID APPLICATIONS BASED ON PERMISSIONS

ANURADHA DAHIYA*, SUKHDIP SINGH†, AND GULSHAN SHRIVASTAVA‡

Abstract. The proliferation of Android apps has increased harmful apps that aim to influence user security, privacy, and device execution. Conventional detection techniques are becoming ineffective in identifying malicious applications as malware has enhanced its cognition and ingenuity and has reached a point where they are more impervious. Novel approaches based on machine learning have been provided to detect and classify malware threats. Still, the risk assessment of Android applications is significant for enhancing user trust and needs more attention. Permissions analysis is an effective way for risk assessment and behaviour study of Android apps because apps require permissions to access device functionality. In endorsement, this study proposes an approach (PRAZdroid) for risk assessment using permissions analysis. The proposed approach analyzed the M0droid dataset and computed five risk levels (Level 0 to Level 4). Statistical analysis is performed for risk levels and achieved 98 .07% classification accuracy with the Drebin and Anrdozoo datasets.

Key words: Android apps security, Permission analysis, User privacy, Risk assessment, Reverse engineering, Static malware analysis, Mobile security.

1. Introduction. The world of mobile devices is constantly changing as technology advances. Mobile users have been pleasured with increasing speed, storage capability, power, and availability of application services like games and online functioning. Malware attacks, specifically on Android devices, are rising with the growing favour of mobile devices. The most significant issues with Android are related to security, as it enriches competence with third-party software and open-source availability. Android apps are considerably optimistic to hackers as they are incredibly prevalent, with millions of users worldwide. These apps are evolving more insecure as hackers embed malicious code into them in intricate ways, making it complicated for security providers to identify and detect malicious apps. Android users can access applications from the official Play Store and third-party stores like ApkMirror and ApkPure. The official Android platform, Google Play Store, reported 2.59 million apps during the second quarter of 2023, an 8559.4 % increase from the launch of it [1].

Google enforces several security and privacy policies on apps listed in the Play Store to foster a vibrant app ecosystem and prevent users from engaging in malicious activity. However, challenges arise to balance security with developer freedom and user convenience, which eaves new paths for malpractice. Therefore, applications from the Google Play Store may not always be perfect; some apps from here have also been found to be malicious. Additionally, certain restrictions exist on accessing the Google Play Store in some places, such as China, Iran, and Cuba [2]. Alternatively, third-party app stores provide easy downloading and are operated by different organizations, such as contraption vendors and web service providers. The global diversity of these third-party stores has paved new paths for malware. According to PurpleSec cyber security report 2022, 98 % of mobile malware focuses on Android, and 99.9 % of observed mobile malware originated through third-party application stores [3].

Android uses the permission-based security model, allowing users to accept or reject app access to features and data through requested permissions. When users enthusiastically install an application, they stop thinking about the permission updates being asked by the application. They download the desired application and,

*Department of CSE, Deenbandhu Chhotu Ram University of Science and Technology, Murthal, India (anudahiya3973@gmail.com).
†Department of CSE, Deenbandhu Chhotu Ram University of Science and Technology, Murthal, India (sukhdeepsingh.cse@dcrustm.org).
‡School of Computer Science Engineering and Technology, Bennett University, Greater Noida, UP-201310, India (Corresponding author, gulshanstv@gmail.com)

when requested for installation, ignore everything else and initiate using it without considering the security consequences. Furthermore, the usual users ignore permissions as they do not have technical knowledge of permissions and their effects; it is challenging for them to make the right decision because both legitimate and malicious apps may ask for similar permissions [4]. Most of these apps ask for additional permissions and use user information without their awareness. An example of an additional requested permission is a calculator app that asks for the device's location and storage, demands access to the camera and internet, or loads unwanted packs. The apps that ask for more permissions than necessary can have the potential to transform from a benign to a harmful one.

However, Google has provided a multi-layered approach encompassing software, hardware, and user-enabled features for securing Android devices. Even so, Android does not have control of third-party sources, and downloading apps from these places can create the risk of malicious code or ads for users [5]. Simply detecting malicious apps is not enough in the present stature of malware progress; there is a need for a risk assessment system that enhances the capabilities of malware detection systems to inform users about the app's unreasonable permission requests and their impacts before app installation. So, this work analyzed the M0droid dataset [6] of 400 samples (200 benign and 200 malware) using reverse engineering and found 210 permissions. Examining these permissions using data parsing and set and map procedures results in 33 unique permissions used in malicious apps, 112 unique permissions used in benign apps, and 65 unique permissions used in both malware and benign apps. Based on these unique sets of permissions, five risk levels (level 0, level 1, level 2, level 3, level 4) are assessed.

1.1. Motivation. This work aims to obtain insights into the prediction of malicious Android apps using an ample permission analysis. The functionality of an app, which can be speculated from its description, is usually linked to the permissions it requires. Several privacy-invasive and malware applications have been observed to request more permissions than their alleged needs [7]. The present work took a malicious weather app, parsed its APK file, and observed that it requests permissions for "READ_CONTACTS" and "REQUEST_INSTALL_PACKAGES". These permissions have no impact on the app's intended functionality but may compromise users' privacy. Existing works have preferred binary classification using important prophets. However, risk assessment has been overlooked, encouraging the user to lower the unwilling installation of malicious applications. Risk assessment specifies the significant measures to inform the user in the permissive mode and ensures trust.

The application of rule-based models and transparency of predictions is limited to a few studies such as Karim et al. [8] adopted an methodology based on association rule mining. The present work leverages data sources to identify predictive patterns of malicious Android apps. It departs from the conventional use of predictive regression models by exploiting the potential of rule-discovery techniques to generate patterns that link malicious permission presence with risk factors. Users can figure out the reasons behind the predictions as the suggested work uses a collection of rules that describe data and assist in enhanced prediction capability.

The remanent sections of this paper are structured as follows: Section II summarises relevant literature. Section III delves into an elaborate discussion of the proposed method. Section IV looks at the exploration & results evaluation of the proposed method. Section V covers the analytical discussion on risk factors. Finally, Section VI infers the work & provides suggestions for further research.

2. Related work. An efficient risk assessment can generate a risk-based prioritized list of untrusted input apps. This list helps both users and innovators. Users can install and use low-risk apps, and innovators can use it to select high-risk apps for further malware analysis. This section involves the miscellaneous practices introduced in the literature to identify malicious behaviour apps and explore allied risk. Scientific literature on Android applications risk analysis is confined and predominantly concentrates on permissions. Xiao et al.[9] suggested permission analysis to recognize the difference between the minimum permissions needed for an app to perform its work and the requested permissions of that app. This work combined collaborative filtering and static analysis to find additional permission requests for an app and, based on additional requests, evaluate the associated risk of the app.

Deypir and Horri [10] provided a metric that used instances of previously known malicious and non-malicious apps to estimate the risk of unknown apps instead of using features such as permissions, intents, etc. This approach presents previously known samples in a high-dimensional feature space. It computes the associated risk of an unknown app using its distances to known malicious and non-malicious app instances. The Euclidean distance measure has been used here to estimate apps' effectual security risk score. Most device users see that graphical indications that present the summary of risk or safety scores work better for notifying them than textual information on permissions. As Dhalaria and Gandotra [11] provided a risk detector for Android apps using permissions features and an artificial neural network that identifies risk based on the probability of benign and malware data samples. This work also designed a graphical user interface for uploading and testing the app's behaviour.

An adequate approach encourages users to select safe apps from the Android App Stores when the stores contain different apps for the same functionality with variant risk scores. Sharma and Gupta [12] perused Android apps using permissions analysis to determine the associated risks. This work initially analyzed the M0Droid dataset samples permissions requests through reversing and achieved 165 permissions with usage rates in malware and benign apps. Then, it compared the permissions from both types and quantified the risk into four factors. The work also performed a statistical evaluation using ANOVA and t-tests to show the mutual exclusiveness of risk factors. AlOmari et al.[13] looked at the effectiveness of several machine-learning algorithms in identifying malware for Android devices. Their approach used PCA, normalized the numerical features, and employed the Synthetic Minority Oversampling Technique (SMOTE) to accomplish higher accuracy. This work identified Android malware and classified them into five categories: benign, adware, SMS malware, banking malware, and mobile riskware using the Light Gradient Boosting Model.

Feature reduction assists in deciding the most pertinent features and enhances the machine learning model results by allowing better distinction between benign and malicious apps. Sharma and Arora [14] provided an approach that integrates intents & permissions. Normal & malware apps may use the same feature patterns, but this approach ranks intents & permissions using a Chi-square test based on frequency to find distinctive features. This work applied various deep learning & machine learning classifiers on the combined ranked permissions and intents and achieved 98.49 % recognition accuracy. Upadhayay et al.[15] suggested fraudulent activity recognition using permissions ranking & network traffic features. This work ranked commonly used permissions in benign & malware apps, then removed the lower-ranked permissions using several thresholds. It provided impressive results by applying machine learning models on a hybrid feature vector of the best permissions and network traffic features.

Saracino et al.[16] provided a cross-layer classification model based on machine learning using hybrid features, system calls, API, user activity, SMS, and application metadata. This work achieved 96.6 % accuracy with the Genome, VirusShare, and Contagio datasets. The authors also pleaded that the presented work presents low-performance overhead and limited battery consumption. Malleswari et al.[17] suggested an approach to increase user awareness before allowing any permission. This work considered individual evaluation of the permissions, negotiation of permissions, & the relative significance of permissions. The work recommended a risk score derived with the assistance of fuzzy AHP based on permissions asked by the application.

The above-discussed approaches are a slight part of suggested and implemented detection methods; with constantly updating technology, attacks are expanding rapidly and elongating the urge for new approaches. For example, malware applications can auto-root themselves on devices and install other applications without the user's consent. This indicates the need for improved permission-based Android security methods to alert users to malicious activity.

3. Proposed method. The main goal of the presented work is to extract prediction conventions for Android apps to identify the risk level while installing them. The presented methodology is named PRAZdroid as Permission-based Risk Analysis and Zoning of Android apps, which consists of four parts collection of data, data pre-processing and aggregation, data analysis, and prediction, as shown in Fig. 3.1.

Various apps are collected from diverse sources during the data collection phase. These sources have been identified with the help of relevant literature expressed by Dahiya et al.[18]. The data aggregation and pre-processing phase has extracted permissions from app APK files and constructed permission groups based on their use in apps. Data analysis involves rule discovery algorithms to extract hidden patterns from the labelled training dataset. These patterns reveal the relationship between the occurrence of classes and which combination of aspects led to a lower or higher risk of malware occurrence. In the last prediction phase, an assessment is executed to evaluate the performance of predictions, and the end users are notified about the

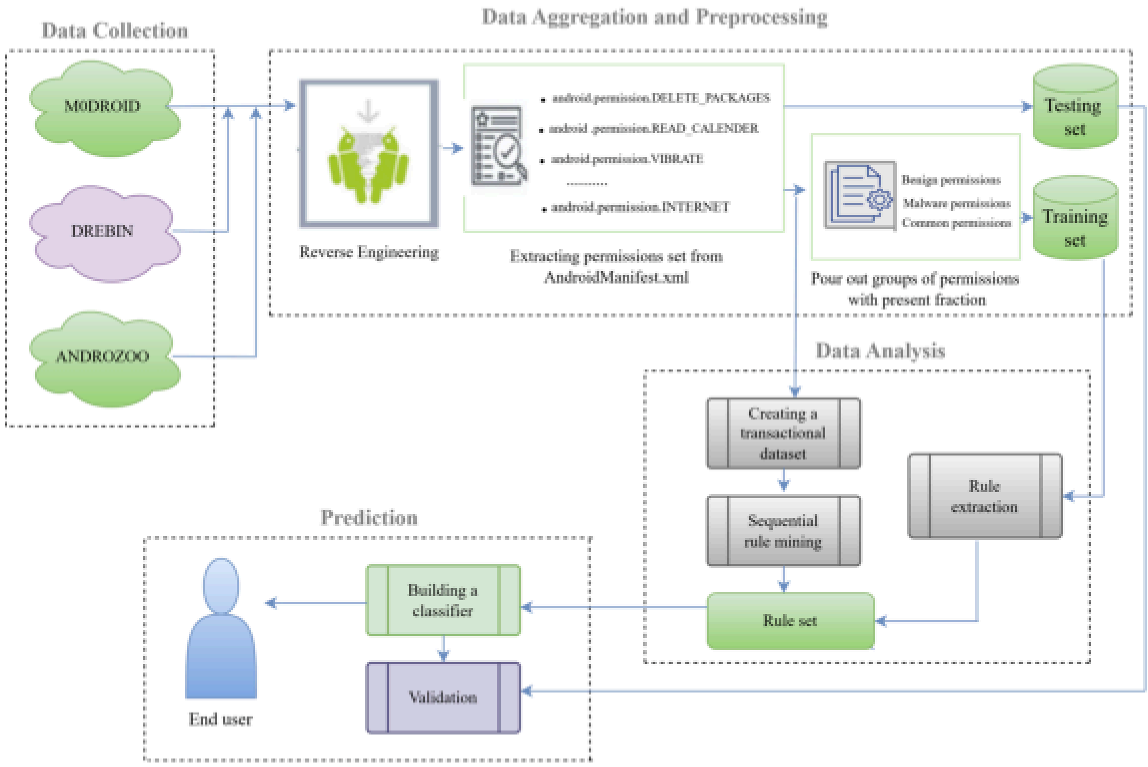

Fig. 3.1: PRAZdroid - Research Methodology

apps' associated risks.

3.1. Data collection. The data has been downloaded from three different sources, and an overview of them is presented in Table 3.1. These data sources are freely available online, requiring permission from the respective research committee. Downloading AndroZoo data samples requires the API key of the authorized user and the SHA256 value of the required app. Similarly, Drebin requires user login details of authorized users. The present work has been analyzed with a substantial collection of 400 M0droid, 1350 AndroZoo, and 1350 Drebin app samples.

The permissions of apps from the M0droid dataset have been explored for training purpose. For testing Drebin and Androzoo data collection have been taken, as Fig. 3.2 visualizes these sources and summarises the information they provide about apps. Drebin contributes sample files of malware apps and feature vectors of a large collection of malware and benign apps; with these sample files and feature vector permissions of apps can be identified. Current work collected 1350 malware sample files from Drebin. Androzoo bestows a large collection of apps in the form of apk files with information about the Virustotal detection mark, size of apk, scan date, source of that apk, etc. It also provides app metadata in the form of manifest permission lists, etc. From metadata and apk of apps, permissions can be extracted. The apps with a virus total detection value of zero are considered benign apps; similar 1350 benign apps are taken from Androzoo.

3.2. Data aggregation and pre-processing. Android has followed a permission policy with predefined permissions to perform specific activities. Any program can ask for the necessary authorizations. The required permissions are specified by Android programs in the Android Manifest. In their manifest file, applications must specify which permissions they want or need [21]. Android permissions control necessary access to application data. Without the required permissions, data stored on the computer cannot be accessed. An Android app is distributed through a packaged APK (Android Package Kit), which bundles all the essential resources to

Table 3.1: Data sources

Source	Description
M0droid [6]	This dataset is bundled with an adequate approach for Android malware recognition by leveraging behavioural analysis. It generated signatures for apps based on their system call requests, normalized the generated signatures using z-score and median algorithms, and identified malware by comparing behavioural signatures with blacklist signatures. The dataset contains 400 samples of apps, with 200 malware and 200 benign apps.
Drebin [19]	It is widely used for Android malware analysis and detection research, including many apps from benign and various malware families, FakeInstaller, DroidKungFu, Opfake, Kmin, Plankton, etc. This dataset is bundled with an adequate approach that integrates static analysis & machine learning. It provides feature vectors for 1,29,013 samples, of which 1,23,453 are benign and 5,560 malware. It also provides 5,560 malware sample files from 179 families and family labels for these files.
Androzoo [20]	It is a massive dataset of Android apps that serves as a worthwhile resource for researchers, application analysis, and security assembled from various sources, including Anzhi, Appchina, PlayDrone, Google Play Store, Slideme, VirusShare, etc. It is constantly updated to reflect the evolving landscape of Android apps and labels them malicious or harmless based on analysis by various antivirus products. Ample metadata, including VirusTotal reports, static code analysis, manifest permissions, and behavioural analysis accompany each app.

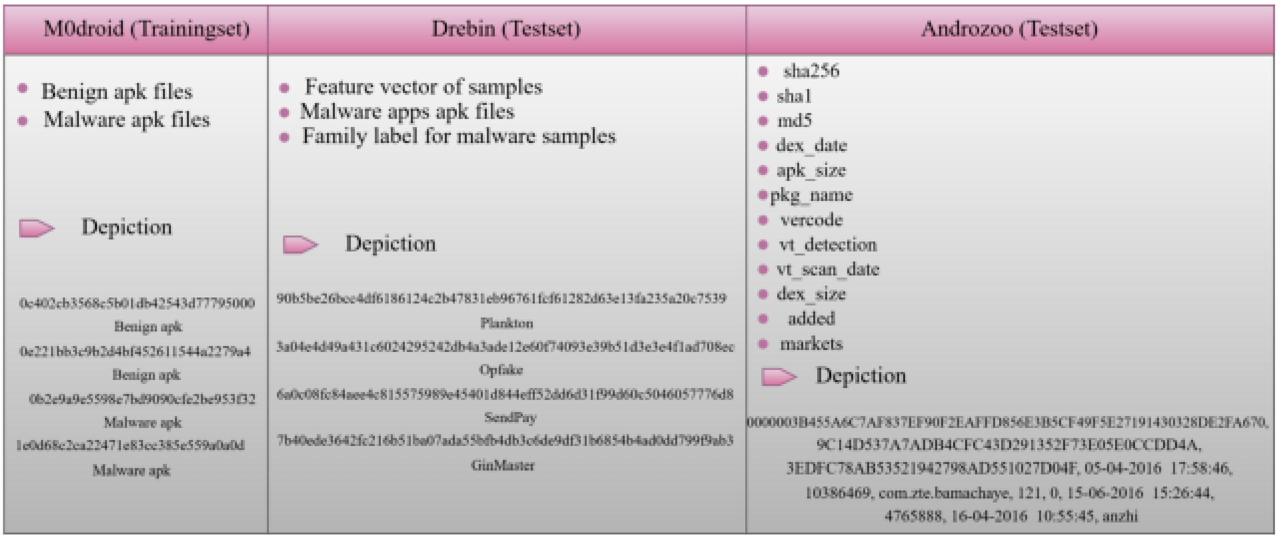

Fig. 3.2: Data sources essence

operate the app. AndroidManifest.xml file is the part of the APK that describes important details of the application, such as the Application name, Required permissions, Version information, Package name, etc [22].

Firstly, the present work performed reverse engineering using ApkTool [23] as described in Algorithm 1 to analyze the permissions sought by Android apps in the M0droid dataset. ApkTool is an emphatic reverse engineering tool for Android applications, which has been used here to extract manifest files. Fig. 3.3 shows the manifest file of a benign app from the collection that discloses the list of required permissions and provides valuable particulars about the app's possible behaviour & data access. These extracted manifest files of each malware and benign app have been read and parsed using the Python library BeautifulSoup with an 'XML' parser to pull the respective permissions of apps. All elements that start with `<uses-permission>` have been searched, as shown in Fig. 3.4 these specify the permission. The value of the 'android:name' distinctive from each `<uses-permission>` element has been extracted. Permissions of benign and malware apps have been collected in respective benign and malware archives with their computation of uses. The similarity of these archives has been measured using statistical measures Jaccard similarity, which is calculated as the entirety of

Algorithm 1 Manifest Extraction from APKs

Input:
$M = \{M_1, M_2, M_3, \ldots, M_n\}$ // APK of Android malware applications
$B = \{B_1, B_2, B_3, \ldots, B_n\}$ // APK of Android benign applications
Output:
$ManifestB = \{ManifestB_1, ManifestB_2, ManifestB_3, \ldots, ManifestB_n\}$ // AndroidManifest.xml for benign apps
$ManifestM = \{ManifestM_1, ManifestM_2, ManifestM_3, \ldots, ManifestM_n\}$ // AndroidManifest.xml for malware apps
procedure :
  Initialize empty lists for Manifest files:
  $ManifestB \leftarrow emptylist$
  $ManifestM \leftarrow emptylist$
  function EXTRACT_MANIFEST(apk)
    Run ApkTool(apk) to extract AndroidManifest.xml
    if ApkTool returns SUCCESS **then**
      return extracted AndroidManifest.xml
    else
      return ”Extraction Failed”
    end if
  end function
  for each APK B_i in benign applications B **do**
    $ManifestB_i \leftarrow$ extract_manifest(B_i) // Extract manifest of benign APK
    Append $ManifestB_i$ to $ManifestB$
  end for
  for each APK M_i in malware applications M **do**
    $ManifestM_i \leftarrow$ extract_manifest(M_i) // Extract manifest of malware APK
    Append $ManifestM_i$ to $ManifestM$
  end for
  return $ManifestB, ManifestM$ // Return the lists of manifests for benign and malware apps
end procedure

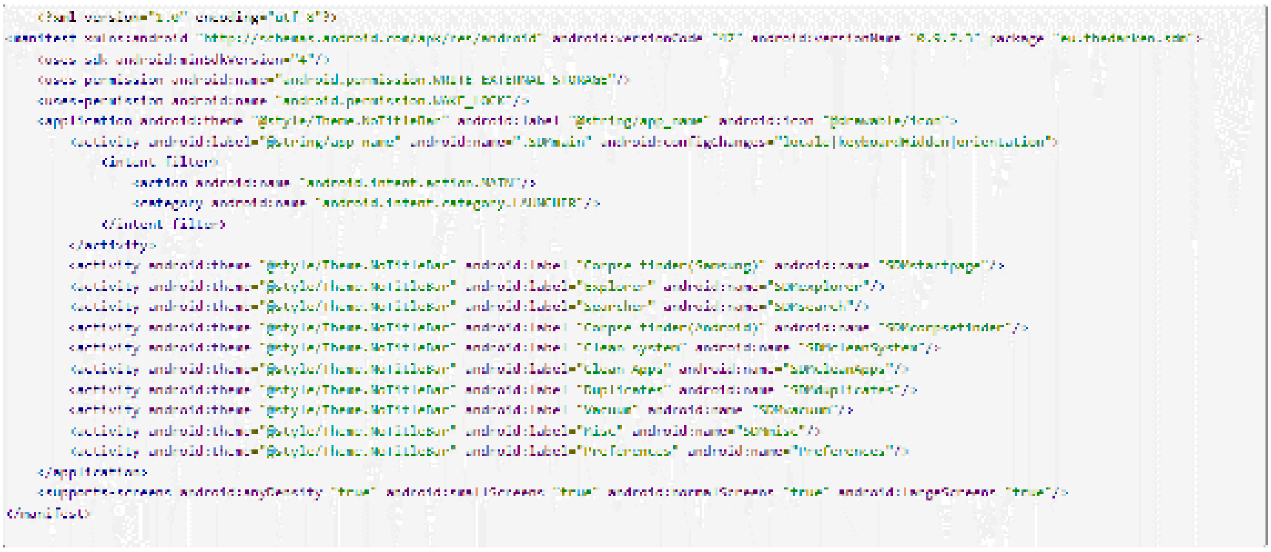
```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android" android:versionCode="47" android:versionName="0.5.7.1" package="eu.thedarken.sdm">
    <uses-sdk android:minSdkVersion="4"/>
    <uses-permission android:name="android.permission.WRITE_EXTERNAL_STORAGE"/>
    <uses-permission android:name="android.permission.WAKE_LOCK"/>
    <application android:theme="@style/Theme.NoTitleBar" android:label="@string/app_name" android:icon="@drawable/icon">
        <activity android:label="@string/app_name" android:name=".SDMmain" android:configChanges="locale|keyboardHidden|orientation">
            <intent-filter>
                <action android:name="android.intent.action.MAIN"/>
                <category android:name="android.intent.category.LAUNCHER"/>
            </intent-filter>
        </activity>
        <activity android:theme="@style/Theme.NoTitleBar" android:label="Corpse finder(Samsung)" android:name="SDMstartpage"/>
        <activity android:theme="@style/Theme.NoTitleBar" android:label="Explorer" android:name="SDMexplorer"/>
        <activity android:theme="@style/Theme.NoTitleBar" android:label="Searcher" android:name="SDMsearch"/>
        <activity android:theme="@style/Theme.NoTitleBar" android:label="Corpse finder(Android)" android:name="SDMcorpsefinder"/>
        <activity android:theme="@style/Theme.NoTitleBar" android:label="Clean system" android:name="SDMcleanSystem"/>
        <activity android:theme="@style/Theme.NoTitleBar" android:label="Clean Apps" android:name="SDMcleanApps"/>
        <activity android:theme="@style/Theme.NoTitleBar" android:label="Duplicates" android:name="SDMduplicates"/>
        <activity android:theme="@style/Theme.NoTitleBar" android:label="Vacuum" android:name="SDMvacuum"/>
        <activity android:theme="@style/Theme.NoTitleBar" android:label="Misc" android:name="SDMmisc"/>
        <activity android:theme="@style/Theme.NoTitleBar" android:label="Preferences" android:name="Preferences"/>
    </application>
    <supports-screens android:anyDensity="true" android:smallScreens="true" android:normalScreens="true" android:largeScreens="true"/>
</manifest>
```

Fig. 3.3: Sample of manifest file

the intersection divided by the entirety of their union, as shown in Eq.(3.1).

$$\text{Jaccard Similarity}(B, M) = |B \cap M| / |B \cup M| \tag{3.1}$$

The calculated similarity of 0.30 showed that 30% of permissions have been commonly used in both malware & benign applications. This measure shows that the commonly used permissions are significant and require

```
<uses-permission android:name="android.permission.WRITE_EXTERNAL_STORAGE"/>
<uses-permission android:name="android.permission.WAKE_LOCK"/>
```

Fig. 3.4: Requested permissions

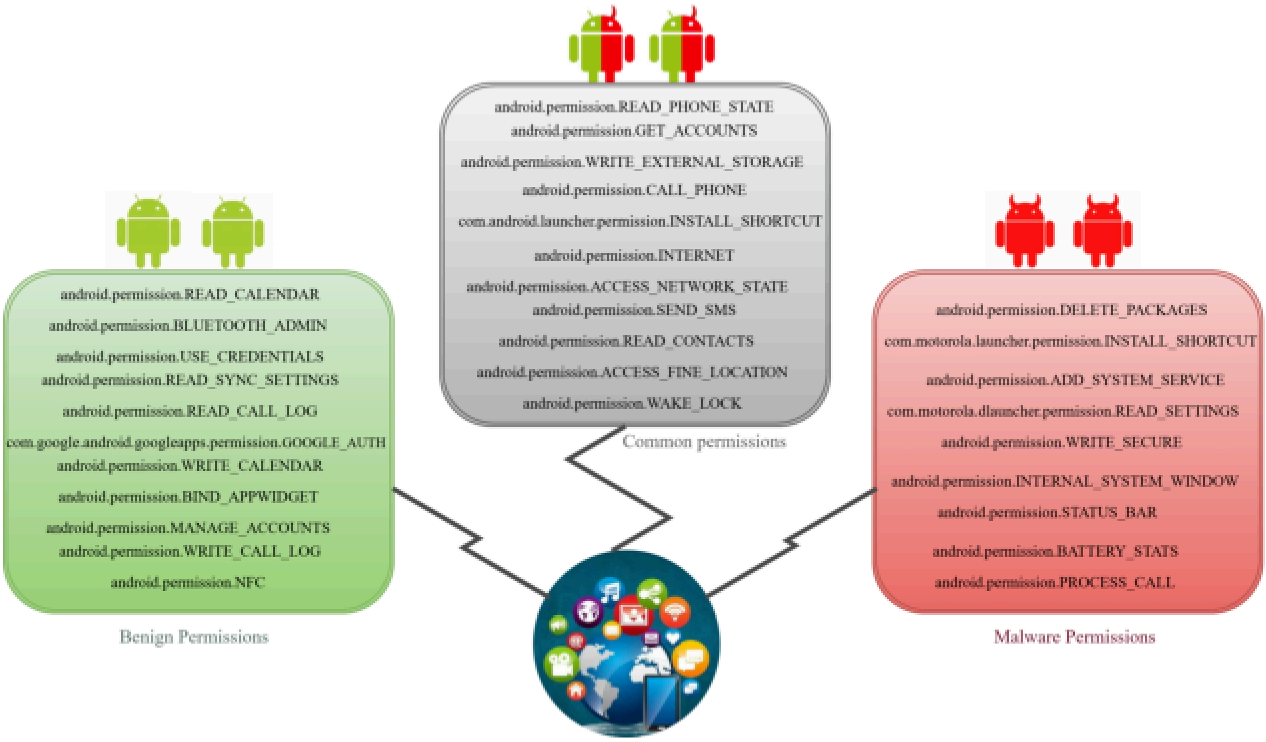

Fig. 3.5: Top-requested permissions of Android apps

regard for the soundest analysis, so three lists have been prepared as malware, benign, and common permissions with a presence fraction. Fig. 3.5 shows an overview of the top permissions sought by benign & malicious apps. This data represents the permissions that are sought exclusively by benign apps (benign permissions), those solely demanded by malicious apps (malware permissions), and permissions that are commonly sought by both types of apps (common permissions).

3.3. Data analysis. These sets of permissions are dissected with JRip (RIPPER) and PrefixSpan (Prefix-projected Sequential Pattern Mining) models to discover hidden rules for indicating the risk of malware occurrence. These rules are extracted in the "IF-THEN" form as demonstrated in Eq.(3.2). In this statement, P is the premise, and Q is the consequence. This means that Q is correlated with P because if P is satisfied, then Q is true.

$$IF\ (P \text{ is } X)\ THEN\ (Q \text{ is } Y) \tag{3.2}$$

Relating Eq.(3.2) to permission-based malware analysis problems, it can be penned as an occurrence of risky permission assets for the malware specified in Eq.(3.3).

$$IF\ (Risky\ permission\ is\ Present)\ THEN\ (App\ is\ Malicious) \tag{3.3}$$

A rule consists of various interconnected elements and their coverage. These extracted rules are amalgamated to form the rule set for the final classifier. The training set is prepared with five attributes i.e., permission, benign frequency, malware frequency, malware ratio, and class. The malware ratio is fixed for only benign and only malware permissions, while for common permissions, it has been computed with benign and malware frequency as specified in Eq.(3.4).

$$Malware\ ratio = \frac{Malware\ frequency\ of\ permission}{Benign\ frequency\ of\ permission} \tag{3.4}$$

With the prepared training set, a supervised data mining algorithm JRip has been trained using the WEKA tool [24] to induce rules. JRip [25] is a rule-based classifier that acquires rules explicitly from the training data in IF-THEN statements form for making predictions. It generates rules through four steps i.e., growth, pruning, optimization, and selection. Growth starts generating one rule by adding attributes to the rule until the stopping criteria are met. Pruning shortens each rule by removing redundancy. Optimization tries to generate more rules from the ruleset, and the selection phase selects effective rules. Repeated Incremental Pruning to reduce error, Interpretability of rules, efficiency with large datasets, and stability with multiclass problems make JRip a satisfactory choice.

The Explanatory variables are discretized into Negligible(N), Minor(M), Moderate(MD), Likely(L), and Very likely(VL) based on histograms of these. The model has been trained using a 5-fold cross-validation. Precision, Accuracy, F-measure, & Recall metrics are produced in each round. Accuracy is a common indicator used to evaluate the classification effectiveness of a model in terms of the overall proportion of correct predictions. Recall determines the proportion of factual positive instances correctly identified. Precision reflects the proportion of accurate positive prophecies. F-measure combines recall & precision calculated as the harmonic mean of these. The influence of rules is quantified using support and confidence criteria. Support directs to the frequency of occurrences in the dataset that support a particular rule, and confidence refers to the frequency with which a rule statement is true.

An additional analysis has been performed to understand the sequential relationship between permissions acquired by apps. These findings can be helpful in better understanding the occurrence of malware. The transactional dataset for both malware and benign apps has been prepared as shown in Table 3.2. The malware transactional dataset includes each malicious app permissions request as a transaction. Similarly, the benign transactional dataset includes each benign app permissions request as a transaction. These datasets are used as input for the popular sequential pattern-mining algorithm PrefixSpan [26], which leads to only one pass through the data sequence to identify frequent items. PrefixSpan reduces search space and improves efficiency by promoting a divide-and-conquer process instead of a pattern-growth process that directly projects the database based on frequent prefixes. The outcomes of this analysis revealed patterns of permissions used that contribute to preparing the rule set for the final classifier.

3.4. Prediction. The observations of prefixspan and rules extracted from JRip are converged to construct the ruleset for defining the final classifier. The rule set creation and risk prediction process is shown in Fig. 3.6 The frequent sub-sequences of permissions used in malware & benign apps and their behavioural analysis facts extracted using rule predictor provide a pleasing base for ruleset creation. The risk level of an app is evaluated by examining its requested permissions. Each requested permission is compared with the predefined ruleset, and a corresponding score is given based on the matching. If permission matches the critical group rules, assign its score value as critical. Similarly, the matching of permissions with neutral, high, and low group rules is assigned with neutral, high, and low scores. Permissions that do not match any rules are assigned a default score.

Now, the risk level of the app is estimated based on frequencies of scores assigned to its requested permissions. A positive critical score classifies the app as a level 4 risk, and the frequency of the critical score is the risk value that indicates the severity of the risk at this level. Apps with naught critical scores and a positive high score are classified as level 3 risk. The frequency of the high score shows risk severity at this level. The app with naught critical, high scores and a positive neutral score is classified as level 2 risk. The frequency of the neutral score shows the risk severity of the app at this level. Similarly, naught critical, high, and neutral scores with a positive low score classify an app as a level 1 risk, and the frequency of the low score reveals risk severity. An app with all other scores naught and a positive default score is believed to be a normal app without malicious activity, classified as level 0. The default score frequency reveals the app's potency.

Table 3.2: Sample of the transactional datasets

Malware transactional dataset	<”android.permission.INTERNET”,”android.permission.READ_PHONE_STATE”,”android.permission.READ_CONTACTS”>
	<”android.permission.CALL_PHONE”,”android.permission.INTERNET”,”android.permission.READ_PHONE_STATE”,”android.permission.READ_CONTACTS”,”android.permission.ACCESS_NETWORK_STATE”>
	<”android.permission.READ_PHONE_STATE”,”android.permission.ACCESS_NETWORK_STATE”,”android.permission.SEND_SMS”,”android.permission.INTERNET”,”android.permission.WRITE_EXTERNAL_STORAGE”,”android.permission.INSTALL_PACKAGES”,”android.permission.DELETE_PACKAGES”>
	<”android.permission.ACCESS_WIFI_STATE”,”android.permission.INTERNET”,”android.permission.READ_PHONE_STATE”,”android.permission.WRITE_EXTERNAL_STORAGE”,”android.permission.ACCESS_NETWORK_STATE”>
	<”android.permission.WRITE_EXTERNAL_STORAGE”,”android.permission.INTERNET”,”android.permission.READ_PHONE_STATE”,”android.permission.READ_SMS”,”android.permission.SEND_SMS”,”com.software.application.permission.C2D_MESSAGE”,”com.google.android.c2dm.permission.RECEIVE”,”android.permission.RECEIVE_SMS”,”android.permission.WAKE_LOCK”>
	....
Benign transactional dataset	<”android.permission.INTERNET”,”android.permission.VIBRATE”,”android.permission.ACCESS_COARSE_LOCATION”,”android.permission.READ_CALENDAR”,”android.permission.WRITE_EXTERNAL_STORAGE”>
	<”android.permission.INTERNET”,”android.permission.ACCESS_WIFI_STATE”,”android.permission.ACCESS_NETWORK_STATE”,”android.permission.WAKE_LOCK”,”android.permission.WRITE_EXTERNAL_STORAGE”,”android.permission.RECEIVE_BOOT_COMPLETED”,”com.android.vending.CHECK_LICENSE”>
	<”android.permission.INTERNET”,”android.permission.ACCESS_NETWORK_STATE”>
	<”android.permission.INTERNET”,”android.permission.ACCESS_NETWORK_STATE”,”android.permission.RECEIVE_BOOT_COMPLETED”,”android.permission.GET_ACCOUNTS”,”android.permission.WAKE_LOCK”,”com.mobiusx.live4dresults.permission.C2D_MESSAGE”,”com.google.android.c2dm.permission.RECEIVE”,”android.permission.VIBRATE”>
	<”android.permission.RECORD_AUDIO”,”android.permission.VIBRATE”,”android.permission.WAKE_LOCK”,”android.permission.READ_PHONE_STATE”,”android.permission.CAMERA”,”android.permission.WRITE_EXTERNAL_STORAGE”,”android.permission.INTERNET”,”android.permission.SEND_SMS”,”com.android.vending.CHECK_LICENSE”,”android.permission.CALL_PHONE”>
	....

4. Results and discussion. As depicted in the prediction phase, the risk of an unknown app is identified based on a request for permission analysis using rule-based classification. This section describes the results of the risk classification process. The JRip data mining model identified underlying patterns as “IF-THEN” rules displayed in Table 4.1. The importance of rules has been determined based on support and confidence measures. Comparative support is the frequency with which the antecedent of a rule appears in the training dataset. The outcome of the JRip model evaluation with 5-fold cross-validation showed a precision of 0.935, recall of 0.957, and f-measure of 0.946. These obtained rules discovered the substance of predictor as benign frequency, malware frequency, and malware ratio.

Glimpsing at the extracted rules, almost equal malware and benign frequency values directly correlate with low-peril events. Similarly, negligible malware frequency correlates with no peril, and negligible benign frequency correlates with high peril. The default rule specifies that no peril is induced when the predecessor of any other rule does not match.

Additional analysis has been performed for pattern mining using PrefixSpan to detect frequent sequences of permissions for malware and benign apps. A sample of the output results for malware & benign applications is given in Table 4.2. These frequent sequences showed that a relevant portion of the malware applications requested ”READ_PHONE_STATE”, ”ACCESS_NETWORK_STATE”, ”SEND_ SMS”, ”INTERNET”, ”WRITE_EXTERNAL_STORAGE”, ”INSTALL_PACKAGES”, and ”DELETE_PACKAGES” permissions together. Similarly, a relevant portion of the benign applications requested ”READ_PHONE_STATE”, ”WRITE_EXTERNAL_STORAGE” , ”ACCESS_NETWORK_STATE”, and ”INTERNET” permissions together. Notable malware applications requested only a single permission Internet or Internet and Phone State Access

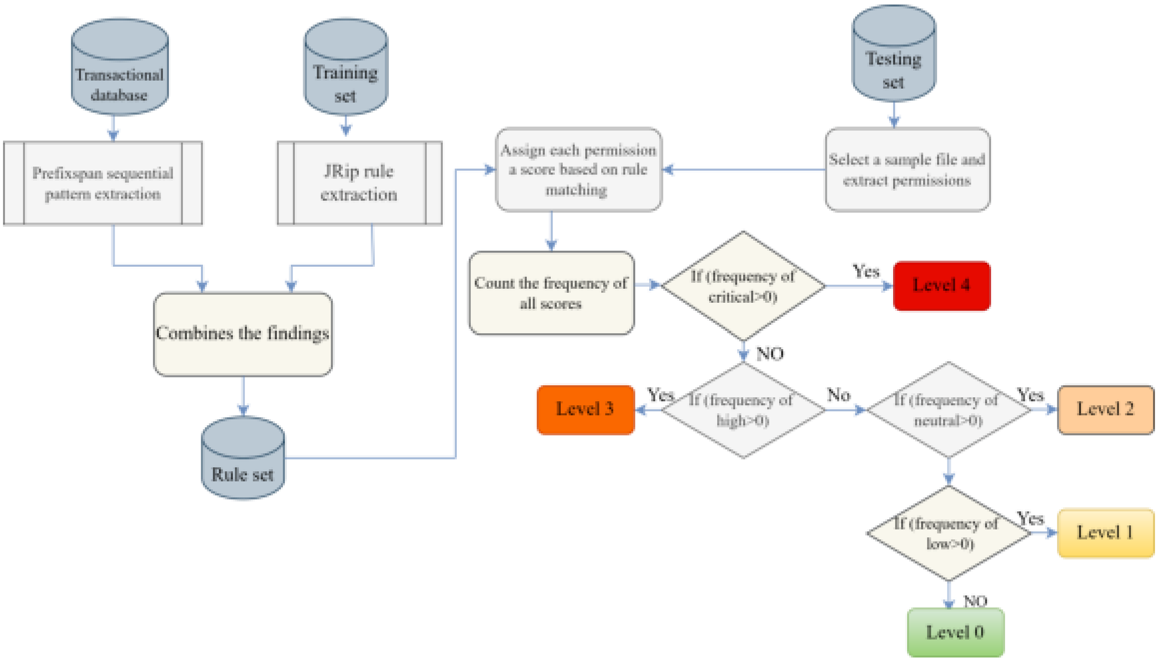

Fig. 3.6: Rule-based prediction

Table 4.1: Rules identified by JRip

Rule	Comparative Support
VL malware ratio and M benign frequency ⇒ medium peril	11
MD malware ratio ⇒ medium peril	18
[MD,M] benign frequency and [MD,M] malware frequency ⇒ low peril	20
N malware frequency ⇒ no peril	75
L malware ratio ⇒ medium peril	12
VL benign frequency and M malware frequency ⇒ very low peril	31
N benign frequency ⇒ high peril	33
M malware ratio ⇒ very low peril	22
[VL,L] benign frequency and [VL,L] malware frequency ⇒ low peril	29
default rule ⇒ no peril	45

together to perform malicious activity. Further, malware applications frequently requested to read launcher settings and manage shortcut permissions.

The frequent benign sequences revealed that benign applications typically focused on providing basic functionality and enhancing the user experience. The frequent sequence of permissions ”RECEIVE_ BOOT_COM PLETED”, ”WAKE_LOCK”, ”VIBRATE”, and ”WRITE_EXTERNAL_STORAGE” together produce a responsive user experience. The combination of permissions ”CHANGE_WIFI_STATE”, ”BLUETOOTH”, and ”BLUETOOTH_ADMIN” enhances wireless connection functionality. Although some similarities are found in the permission requests of malware & benign apps, the frequent sequence & combination of permissions assist in revealing distinct patterns for both. Permission combinations for malware are typically broader and more sensitive, whereas benign app combinations are more closely aligned with user-focused functionalities.

Based on rule-based segmentation and permission analysis through frequent sequences, a rule set shown in Table 4.3 is constructed to identify the risk level of an app. The permissions related to a feature have been grouped together and assigned a risk score based on their uses in performing malicious and normal activity and part of frequent sequences of benign and malware apps.

Table 4.2: Sample of sequential rules extracted by PrefixSpan algorithm

Frequent sequences of permissions for malware apps	"android.permission.INTERNET","android.permission.READ_PHONE_STATE" support = 16
	"android.permission.READ_PHONE_STATE","android.permission.ACCESS_NETWORK_STATE", "android.permission.SEND_SMS","android.permission.INTERNET","android.permission.WRITE_E XTERNAL_STORAGE","android.permission.INSTALL_PACKAGES","android.permission.DELET E_PACKAGES" support = 80
	"com.android.launcher.permission.UNINSTALL_SHORTCUT","com.android.launcher.permission.RE AD_SETTINGS","com.htc.launcher.permission.READ_SETTINGS","com.motorola.launcher.permiss ion.READ_SETTINGS","com.motorola.dlauncher.permission.READ_SETTINGS" support = 23
	"android.permission.INTERNET" support = 16
	"android.permission.ACCESS_NETWORK_STATE","android.permission.READ_PHONE_STATE", "com.fede.launcher.permission.READ_SETTINGS","com.lge.launcher.permission.INSTALL_SHORT CUT","com.lge.launcher.permission.READ_SETTINGS","com.motorola.dlauncher.permission.INST ALL_SHORTCUT","com.motorola.launcher.permission.INSTALL_SHORTCUT" support = 15
	"android.permission.INTERNET","android.permission.ACCESS_NETWORK_STATE" support=20
	"com.fede.launcher.permission.READ_SETTINGS","com.lge.launcher.permission.READ_SETTINGS" ,"org.adw.launcher.permission.READ_SETTINGS","com.motorola.launcher.permission.INSTALL_SH ORTCUT","com.motorola.dlauncher.permission.INSTALL_SHORTCUT","com.lge.launcher.permissi on.INSTALL_SHORTCUT" support = 18
	"android.permission.ACCESS_WIFI_STATE","android.permission.READ_PHONE_STATE"sup.=15
	"android.permission.ACCESS_NETWORK_STATE","android.permission.ACCESS_WIFI_STATE", "android.permission.RECEIVE_BOOT_COMPLETED","android.permission.VIBRATE","android.p ermission.WAKE_LOCK" support = 18
	"android.permission.ACCESS_WIFI_STATE","android.permission.INTERNET","android.permission .READ_PHONE_STATE","android.permission.RECEIVE_BOOT_COMPLETED","android.permissi on.SEND_SMS","android.permission.WRITE_EXTERNAL_STORAGE" support = 17
	"android.permission.INSTALL_PACKAGES","android.permission.READ_PHONE_STATE"sup.=40
	"android.permission.READ_PHONE_STATE","android.permission.RECEIVE_BOOT_COMPLETE D","android.permission.SEND_SMS","android.permission.WAKE_LOCK","android.permission.WRI TE_EXTERNAL_STORAGE" support = 28
	"android.permission.ACCESS_WIFI_STATE","android.permission.READ_PHONE_STATE","com.an droid.launcher.permission.INSTALL_SHORTCUT","com.android.launcher.permission.UNINSTALL_ SHORTCUT","com.lge.launcher.permission.INSTALL_SHORTCUT","com.lge.launcher.permission.R EAD_SETTINGS" support = 15
	"android.permission.ACCESS_NETWORK_STATE","android.permission.ACCESS_WIFI_STATE", "android.permission.INTERNET","android.permission.READ_PHONE_STATE","android.permissio n.RECEIVE_BOOT_COMPLETED","android.permission.WAKE_LOCK","android.permission.WRI TE_EXTERNAL_STORAGE" support = 31
Frequent sequences of permissions for benign apps	"android.permission.INTERNET","android.permission.ACCESS_NETWORK_STATE","android.per mission.WRITE_EXTERNAL_STORAGE","android.permission.READ_PHONE_STATE"support=45
	"android.permission.RECEIVE_BOOT_COMPLETED","android.permission.WAKE_LOCK","andro id.permission.VIBRATE","android.permission.WRITE_EXTERNAL_STORAGE" support = 19
	"android.permission.ACCESS_COARSE_LOCATION","android.permission.ACCESS_FINE_LOCATI ON" support = 23
	"android.permission.READ_CONTACTS","android.permission.CALL_PHONE","android.permission .READ_SMS","android.permission.WRITE_SMS" support = 15
	"android.permission.ACCESS_WIFI_STATE","android.permission.READ_PHONE_STATE","androi d.permission.WRITE_EXTERNAL_STORAGE" support = 25
	"com.android.browser.permission.READ_HISTORY_BOOKMARKS","com.android.browser.permissi on.WRITE_HISTORY_BOOKMARKS" support = 10
	"android.permission.CHANGE_WIFI_STATE","android.permission.BLUETOOTH","android.permis sion.BLUETOOTH_ADMIN" support = 15
	"android.permission.WRITE_EXTERNAL_STORAGE","com.android.vending.CHECK_LICENSE" support = 23
	"android.permission.CHANGE_WIFI_STATE","android.permission.WRITE_SETTINGS","android.p ermission.WRITE_SYNC_SETTINGS" support = 17
	"android.permission.GET_TASKS","android.permission.RESTART_PACKAGES" support = 16
	"android.permission.READ_CONTACTS","android.permission.WRITE_CONTACTS","android.per mission.WRITE_EXTERNAL_STORAGE" support = 15
	"com.android.vending.BILLING","android.permission.WRITE_EXTERNAL_STORAGE"support=20
	"android.permission.GET_ACCOUNTS","android.permission.USE_CREDENTIALS","android.perm is- sion.MANAGE_ACCOUNTS" support = 18
	"android.permission.VIBRATE","com.android.launcher.permission.INSTALL_SHORTCUT"sup.=14

Table 4.3: Overview of the rule set used for evaluation

Rule statement	**Description**	**Assign score**
"android.permission.WRITE_SMS"/"android.permission.READ_SMS"/"android.permission.RECEIVE_SMS"/"android.permission.SEND_SMS"	Allows control of SMS communication such as message reading, sending new ones, and spoiling incoming messages.	High/ Neutral/Low
"android.permission.ACCESS_COARSE_UPDATES"/"android.permission.ACCESS_FINE_LOCATION"	Allows to access location information for respective scenarios.	Default
"com.motorola.dlauncher.permission.READ_SETTINGS"/"com.motorola.dlauncher.permission.INSTALL_SHORTCUT"/"com.motorola.launcher.permission.INSTALL_SHORTCUT"/"com.motorola.launcher.permission.READ_SETTINGS"/"com.lge.launcher.permission.INSTALL_SHORTCUT"/"com.lge.launcher.permission.READ_SETTINGS"	Allows the creation of shortcuts on the home screen of the respective launcher and the reading of the configuration of the respective launcher.	Critical
"android.permission.READ_CONTACTS"/"android.permission.WRITE_CONTA CTS"/"android.permission.CALL_PHONE"	Allows control of contact management and calling features.	Low
"android.permission.DELETE_PACKAGES"	Allows system-level access to delete other apps (packages) from the device.	Critical
"android.permission.ACCESS_NETWORK_STATE"/"android.permission.INTERNET"	Allows to check network availability and connect to the internet.	Default
"android.permission.CHANGE_WIFI_STATE"/"android.permission.ACCESS_WIFI_STATE"/"android.permission.CHANGE_NETWORK_STATE"	Allows to control the Wi-Fi and network status of the device.	Neutral/ Low
"android.permission.MODIFY_PHONE_STATE"/"android.permission.PROCESS_OUTGOING_CALLS"	Allows control of the phone's state and behaviour, and outgoing calls.	Neutral
"android.permission.ACCESS_LOCATION_EXTRA_COMMANDS"/"android.permission.ACCESS_COARSE_LOCATION"/"android.permission.ACCESS_MOCK_LOCATION"	Allows the creation of mock location providers and access to location information and additional location provider information.	Neutral/ Low
"com.software.application.permission.C2D_MESSAGE"/"com.rvo.plpro.permission.C2D_MESSAGE"/"com.p1.chompsms.permission.C2D_MESSAGE"/"com.samsungmobileusa.magnacarta.permission.C2D_MESSAGE"	Allows access to the communication channels of respective apps, such as allowing access to push notifications and messages.	Critical
"android.permission.WRITE_SETTINGS"/"android.permission.WRITE_SECURE_SETTINGS"/"android.permission.CHANGE_CONFIGURATION"/"android.permission.MODIFY_AUDIO_SETTINGS"	Allows to modify the system settings for respective requests.	Low/ Default
"android.permission.WRITE_EXTERNAL_STORAGE"	Allows writing on device's shared storage locations.	Default
"android.permission.STATUS_BAR"/"android.permission.INTERNAL_SYSTEM_WINDOW"/"android.permission.ADD_SYSTEM_SERVICE"	Allows modification of core system behaviours, overlaying of system UI elements, and addition of new system services.	Critical
"com.android.browser.permission.READ_HISTORY_BOOKMARKS"/"com.android.browser.permission.WRITE_HISTORY_BO OKMARKS"	Allows to read and modify the significant insight of online activities such as browsing history and stored bookmarks.	High/ Neutral
"android.permission.GET_TASKS"/"android.permission.KILL_BACKGROUND_PROCESSES"/"android.permission.RESTART_PACKAGES"	Allows to access the information of running tasks and control of other applications.	Low
"android.permission.REBOOT"/"android.permission.BACKUP"	Allows to control reboot and backup processes.	Critical
"android.permission.BROADCAST_SMS"/"android.permission.BROADCAST_WAP_PUSH"	Allows to control notifications of incoming SMS and WAP PUSH messages.	Low
"com.facebook.katana.provider.ACCESS"/"com.mominis.permission.preferences.provider.READ_WRITE"	Allows access to the respective app's data providers.	Critical
"android.permission.UPDATE_DEVICE_STATS"/"android.permission.READ_PHONE_STATE"/"android.permission.DEVICE_POWER"	Allows to access device information such as phone status and power usage details, and to control statistics updates.	Low/ Default
"android.permission.FLASHLIGHT"/"android.permission.VIBRATE"/"android.permission.EXPAND_STATUS_BAR"/"android.permission.SET_WALLPAPER"/"android.permission.WAKE_LOCK"/"android.permission.DISABLE_KEYGUARD"	Allows to control the device features for respective requests.	Neutral/ Low/ Default
"android.permission.ACCESS_GPS"/"android.permission.ACCESS_LOCATION"	Allows to access device location information.	High

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Continued from previous page

Rule statement	Description	Assign score
"com.android.launcher.permission.READ_SETTINGS"/"com.android.launcher.permission.INSTALL_SHORTCUT"/"com.android.launcher.permission.UNINSTALL_SHORTCUT"/"com.fede.launcher.permission.READ_SETTINGS"/"org.adw.launcher.permission.READ_SETTINGS"/"com.htc.launcher.permission.READ_SETTINGS"	Allows to read information about the home screen setup, and to create and remove shortcuts on the home screen of the respective launchers.	Critical/ High/ Low
"android.permission.SET_DEBUG_APP"	Allows to configure another app for debugging.	Default
"android.permission.BROADCAST_STICKY"/"android.permission.READ_LOGS"	Allows to access device logs and broadcast persistent messages.	Neutral/ Low
"android.permission.WRITE_APN_SETTINGS"	Allows modification of APN (Access Point Name) network configuration settings.	Neutral
"android.permission.PROCESS_INCOMING_CALLS"/"android.permission.PROCESS_CALL"	Allows access to interact with and manage phone calls.	Critical
"android.permission.CAMERA"/"android.permission.GET_ACCOUNTS"/"android.permission.RECEIVE_BOOT_COMPLETED"/"android.permission.BLUETOOTH"	Allows to access different features and capabilities of the device.	Low/ Default
"android.permission.INSTALL_PACKAGES"	Allows to initiate the installation of other applications.	Critical
"android.permission.SYSTEM_ALERT_WINDOW"/"android.permission.RECORD_AUDIO"	Allows the creation of overlay windows and recording of conversations.	Low
"android.permission.BATTERY_STATS"/"android.permission.READ_OWNER_DATA"	Allows monitoring of device-specific information and power usage.	Critical
"com.android.vending.CHECK_LICENSE"/"com.android.vending.BILLING"	Allows to access services of Google Play Store.	Default
"android.permission.REORDER_TASKS"/"android.permission.SET_PROCESS_LIMIT"/"android.permission.SET_ALWAYS_FINISH"/"android.permission.CLEAR_APP_USER_DATA"/"android.permission.CLEAR_APP_CACHE"	Allows to control the application management.	Critical/ High
"android.permission.READ_EXTERNAL_STORAGE"/"android.permission.MOUNT_UNMOUNT_FILESYSTEMS"/"android.permission.PERSISTENT_ACTIVITY"	Allows control of the device's storage.	Low
"android.permission.RECEIVE_WAP_PUSH"/"android.permission.WRITE_SECURE"/"android.permission.DELETE_CACHE_FILES"	Allows modification of secure system settings, deletion of cache files, and processing of WAP(Wireless Application Protocol) push messages.	Critical
"android.permission.RECEIVE_MMS"/"com.google.android.c2dm.permission.RECEIVE"	Allows to receive notifications from google servers and multimedia messages services.	Low

The main contribution of this research work is to classify Android apps into five different risk levels based on static behaviour analysis. An investigation is performed with benign AndroZoo apps and malware Drebin apps. To analyze the results, risk level 4 is classified as malware, and risk level 0 is classified as benign. First, all permissions whose benign frequency was zero with a positive malware frequency and whose benign frequency was less than or equal to one with a frequency of malware greater than or equal to 23 were placed at the critical level. With each decreasing risk level, permissions were added by increasing the benign frequency by 7 and reducing the malware frequency by 7. The results obtained from this analysis is shown in Table 4.4.

Then, three less-risky permissions were moved from critical to high level, and three high-risky permissions were moved from default to low level, the results of which are shown in Table 4.5. Once again, three less-risky permissions were moved from critical to high level, and three high-risky permissions were moved from default to low level, the results of which are shown in Table 4.6. Tables 4.4-4.6 show the matrix, where each

Table 4.4: Malware & benign risk level

Class	Level0	Level1	Level2	Level3	Level4	Total
Malware	86	123	524	57	560	1350
Benign	518	490	228	33	81	1350
Total	604	613	752	90	641	2700

Table 4.5: Malware & benign risk level

Class	Level0	Level1	Level2	Level3	Level4	Total
Malware	34	175	524	81	536	1350
Benign	355	653	228	51	63	1350
Total	389	828	752	132	599	2700

Table 4.6: Malware & benign risk level

Class	Level0	Level1	Level2	Level3	Level4	Total
Malware	24	185	524	101	516	1350
Benign	316	692	228	86	28	1350
Total	340	877	752	187	544	2700

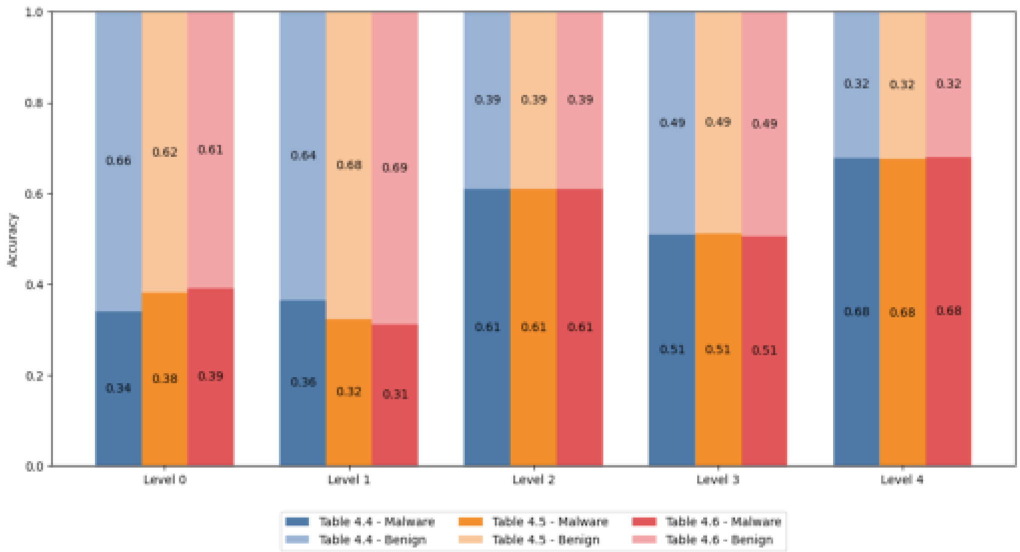

Fig. 4.1: Accuracy by different level

Table 4.7: Confusion matrix

Class	Malware	Benign	Total	Accuracy
Malware	true negative	false negative	1350	98.22 %
Benign	false positive	true positive	1350	97.92 %
Total	1354	1346	2700	98.07 %

cell represents the proposition of each class (Malware and Benign) with corresponding levels. Most malware samples have been predicted at higher risk levels, with a small portion misclassified at lower levels. Similarly, most benign samples have been correctly classified at lower risk levels, with a small portion misclassified at higher levels. The respective accuracy, recall, and precision for different risk levels are shown in Figs. 4.1-4.3.

The work performance has been evaluated with parameters sensitivity, specificity, and accuracy, as in Eqs. 4.1 to 4.3 & the confusion matrix shown in Table 4.7. True positive is the correct classification of a positive outcome, and false negative is the misclassification of a positive outcome as negative. Similarly, true negative is the correct classification of a negative outcome, and false positive is the misclassification of a negative outcome

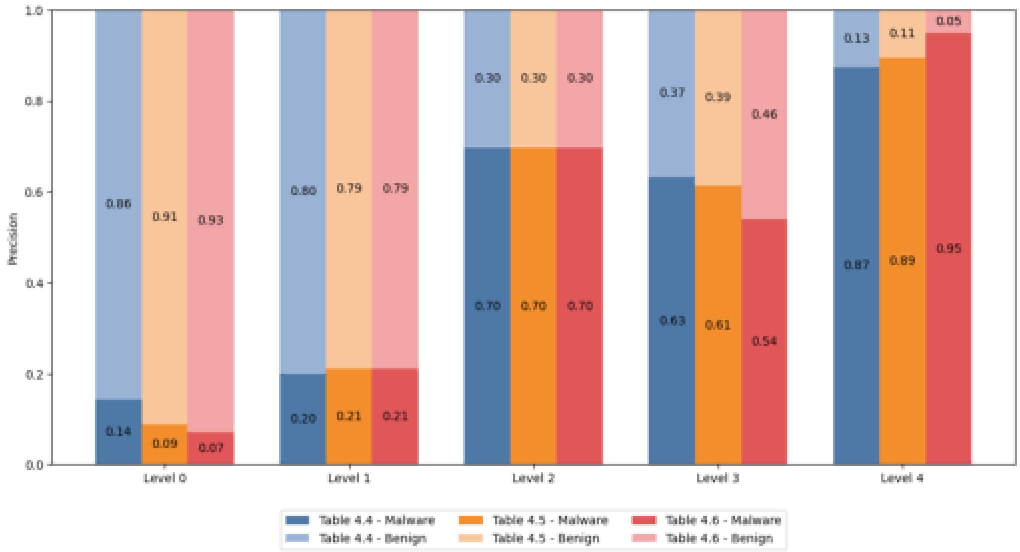

Fig. 4.2: Precision by different level

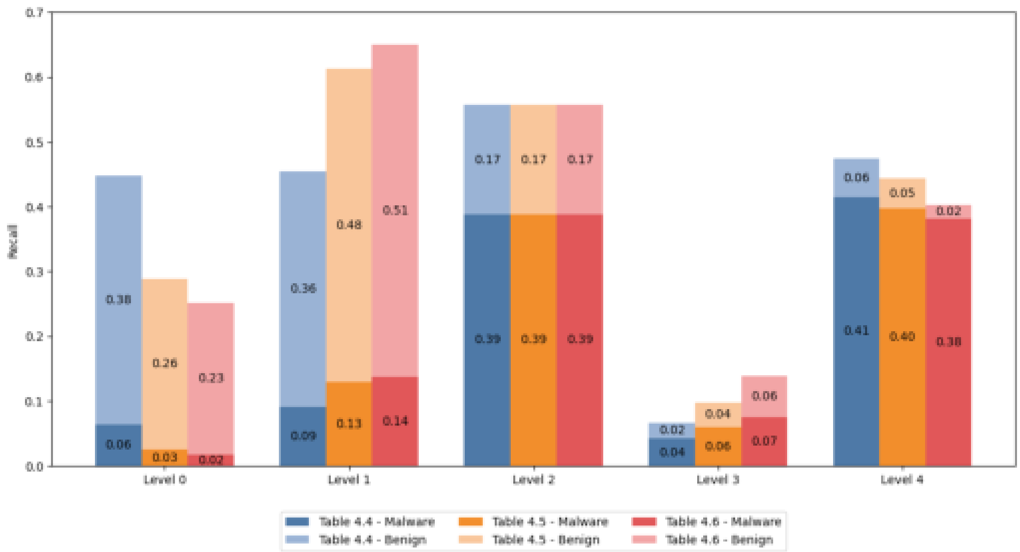

Fig. 4.3: Recall by different level

as positive.

$$Sensitivity = \frac{True\ positive}{Total\ positive} = 97.92\% \tag{4.1}$$

$$Specificity = \frac{True\ negative}{Total\ negative} = 98.22\% \tag{4.2}$$

Table 4.8: Statistical comparison of benign and malware apps at different risk levels

Malware	Mean: 270.0, Median: 185.0, Std: 210.39676803601333
Benign	Mean: 270.0, Median: 228.0, Std: 234.25797745220973
Pearson Correlation	-0.35015232234884325
Risk Level 0	Difference = -292, Ratio = 0.0759493670886076
Risk Level 1	Difference = -507, Ratio = 0.26734104046242774
Risk Level 2	Difference = 296, Ratio = 2.2982456140350878
Risk Level 3	Difference = 15, Ratio = 1.1744186046511629
Risk Level 4	Difference = 488, Ratio = 18.428571428571427
Chi-square statistic	1099.355365399867
p-value	1.0445110871782864e-236

Table 4.9: Post-hoc Pairwise comparison

Level 0 vs Level 1	Chi2 Statistic: 32.95461756214981 p-value: 9.433542164126035e-09 Adjusted p-value (Bonferroni): 9.433542164126036e-08 Significant? Yes
Level 0 vs Level 2	Chi2 Statistic: 364.77674116066646 p-value: 2.5673262468768854e-81 Adjusted p-value (Bonferroni): 2.5673262468768853e-80 Significant? Yes
Level 0 vs Level 3	Chi2 Statistic: 144.4108830167345 p-value: 2.8890715869634067e-33 Adjusted p-value (Bonferroni): 2.8890715869634066e-32 Significant? Yes
Level 0 vs Level 4	Chi2 Statistic: 674.747436073428 p-value: 9.27222763054354e-149 Adjusted p-value (Bonferroni): 9.27222763054354e-148 Significant? Yes
Level 1 vs Level 2	Chi2 Statistic: 386.8297061006291 p-value: 4.055656994876432e-86 Adjusted p-value (Bonferroni): 4.0556569948764324e-85 Significant? Yes
Level 1 vs Level 3	Chi2 Statistic: 83.30100038987347 p-value: 7.046393820082156e-20 Adjusted p-value (Bonferroni): 7.046393820082156e-19 Significant? Yes
Level 1 vs Level 4	Chi2 Statistic: 727.7937629862088 p-value: 2.7035449277334716e-160 Adjusted p-value (Bonferroni): 2.7035449277334714e-159 Significant? Yes
Level 2 vs Level 3	Chi2 Statistic: 15.825440927996633 p-value: 6.94622342675924e-05 Adjusted p-value (Bonferroni): 6.94622342675924e-04 Significant? Yes
Level 2 vs Level 4	Chi2 Statistic: 124.59595077718842 p-value: 6.238825620876588e-29 Adjusted p-value (Bonferroni): 6.238825620876588e-28 Significant? Yes
Level 3 vs Level 4	Chi2 Statistic: 173.2655691717622 p-value: 1.4320964914080645e-39 Adjusted p-value (Bonferroni): 1.4320964914080645e-38 Significant? Yes

$$Accuracy = \frac{(True\ positive + True\ negative)}{(Total\ positive + Total\ negative)} = 98.07\% \tag{4.3}$$

The chi-square test has been conducted to analyze the relationship between risk levels and app type (benign/malware)—the statistical analysis observations for malware and benign apps are shown in Table 4.8. A negative Pearson Correlation value indicates the inverse relationship between benign and malware apps. The large chi-square statistics value (1099.36) with a vastly smaller p-value indicates strong evidence of a relationship between app type and risk level. Initial chi-square showed apps are not distributed randomly; there is a significant difference between malware and benign app distribution across risk levels. Further, a Post-hoc Pairwise comparison has been performed to know the significant differences between every possible pair of risk levels, the observations of which are shown in Table 4.9. These observations indicate significant differences between risk levels particularly at extreme levels.

Comparative analysis sheds light on the exploration process and the subsequent interpretation of the outcomes. Table 4.10 compares this work with the existing approaches based on the analytical framework, identification of risk categories, and data representatives. The results show that the presented work identified five risk levels for Android apps and performed well compared to existing works.

This research enhanced Android users' awareness of the need to understand the permission requests of apps, as allowing inappropriate permissions can put users at risk of malware attacks. The limitation is that this work focuses only on the permission requests of apps; if an app does not request any permissions, it becomes difficult to identify the exact nature of that app. Additional static features extracted from the manifest file analysis,

Table 4.10: Comparison with previous works

Approach	Analytical framework	Identified risk categories	Data Set
Probabilistic risk detector [11]	Static permissions analysis and artificial neural network model	Four (no, low, medium, and high risk)	3547
AndroShield [27]	Hybrid of static (code scanning) and dynamic (run-time behaviour) analysis for vulnerability detection	Three (low, medium, high)	70
RNPDroid [12]	Static permissions analysis and ANOVA and T-test	Four (no, low, medium, & high risk)	400
Focused on repacked malware samples [28]	Static source code analysis and fuzzy hash of reverse-engineered code	Three (benign, suspicious, malicious)	3490
PRAZdroid (proposed)	Static permissions analysis, demeanor rule mining (JRip), and frequent pattern identification (PrefixSpan)	Five (level 0, level 1, level 2, level 3, & level 4)	3100

such as intent filters, can be selected to extend this research.

5. Conclusion and future work. Android accessibility features and user-friendly nature make it an incredible platform for everyone. Although the Android ecosystem is growing and offers users a wide range of applications to cover every plausible aspect of life, there is a potential threat in the form of malware. Attackers influence Android users by injecting different menaces into Android applications. Malicious things pose as seemingly benign applications and cause disturbance by stealing data, causing system disruptions, and risking users' privacy. Promptly identifying and diminishing these risks remains a major challenge. It is complicated to determine the intentions of an app without using it, but every app requires permission authentication to access the user's device. Users are invited to grant an app's privileges through the requested permissions. Attackers mislead users to carry out malicious activities as other infiltration methods are nearly closed. The users ignore security concerns and allow these permissions because technical skills about the permissions and their impacts are needed to make a correct decision, and malicious apps may request permissions similar to benign ones. Therefore, this work analyzed the permissions requested by Android apps and identified risk levels. These risk levels are identified based on 210 extracted permissions, of which 33 permissions are requested only by malicious apps, 112 permissions are requested only by benign apps, and 65 permissions are requested by both malware & benign apps. In the future, the scope of analysis can be expanded to include monitoring resource usage, runtime behaviour of apps, intent activities, and network traffic patterns. In addition, big data analytics techniques can handle and process large amounts of app data efficiently.

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RESEARCH ON DESIGN AND OPTIMIZATION OF ELECTROMAGNETIC THROWER BASED ON KJ-AHP COMPREHENSIVE DECISION METHOD USING SCALABLE COMPUTING

XIAOBO JIANG*, WANYI LU†, AND ZEQUN XU‡

Abstract. The research delves into electromagnetic thrower optimization and design by using KJ-AHP full decision method, augmented by scalable computational techniques. In many industrial contexts, electromagnetic thrusters play an important role, especially in propulsion and material handling functional systems. Mechanical limits, nonlinear electromagnetic interactions, thermal consequences, and their apparent promise for such factors. By integrating innovative decision-making methods, the primary objective is to develop a systematic approach that addresses the key challenges in electromagnetic thrower design, such as mechanical constraints, non-linear electromagnetic interactions, and thermal effects. The research integrates the KJ (Kawakita Jiro) method and proposes a new approach to solve these problems in creative problems solution using the AHP (Analytic Hierarchy Process) method of decision making. Scalable computing allows us to efficiently manage the large amount of computational resources needed for optimization and simulation. Achieving the right balance of productivity and performance is achieved through an integrated approach, which enables comprehensive analysis of design aspects. Through a comprehensive study, it has been demonstrated that the proposed method is efficient, indicating high efficiency and accuracy of the electromagnetic impeller systems. These findings suggest that the method can be used to improve the efficiency of electrical power systems designed for scientific and industrial purposes. The results provide light on how to put scalable computing and advanced decision-making frameworks into practice for engineering optimisation. The analyses reveal that scalable computing enhances optimization efficiency by 96.3%, overall efficiency by 96.8%, accuracy by 97.52%, integration for decision making by 98.15%, and performance evaluation of electromagnetic throwers by 98.16%.

Key words: Design, Optimization, Electromagnetic, Thrower, Comprehensive, Decision, Scalable Computing, Analytic, Hierarchy Process

1. Introduction. Electromagnetic throwers have become indispensable in industrial applications due to being able to efficiently and accurately implement systems that need high reliability and precision [1]. Designing and optimizing such systems is very challenging since there is the complex interaction between mechanical constraints, non-linear electromagnetic interactions, and thermal consequences [2]. It is possible to classify these problems into three groups. To tackle these problems, it's necessary to use advanced methods that can thoroughly evaluate and optimize various design elements simultaneously [3]. This paper delves into a novel method for designing and optimizing electromagnetic throwers by using the KJ (Kawakita Jiro) methodology and the AHP (Analytic Hierarchy Process) inside a scalable computer system [4]. This means improving the electromagnetic insulation and it is considered as a creative approach in problem solving with the help of KJ techniques or more often AHP (Analytic Hierarchy Process) [5]. It takes a research and an artistic approach at the same time and this interactive partnership allows for a more thorough consideration of policy options [6]. Then relies heavily on scalable computing, which is used to process large amounts of data needed to optimize and simulate electromagnetic systems [7]. Scalable computing abandons the optimization process because many computing tasks are distributed over many processors efficiently though availability of materials plays an effective role [8]. It can also consider complex dynamics at networks also as thermal effects [9]. In a scalable computing environment, these two methods (KJ method and AHP) form a solid basis for theoretical handling of design variables and there is great opportunity if such a combination strategy is used exist to create more efficient and effective EM interceptors [10]. Extensive simulation tests on electromagnetic impeller designs prove

*School of Industrial Design, Hubei University of Technology, Wuhan, Hubei, 430022, China (Corresponding Author, 15927010701@163.com)
†School of Industrial Design, Hubei University of Technology, Wuhan, Hubei, 430022, China (lwy20240606@163.com)
‡School of Industrial Design, Hubei University of Technology, Wuhan, Hubei, 430022, China (sanstxu@163.com)

effective as they significantly improve performance and accuracy [11]. The implications of this paper extend beyond specialized application areas such as EM missiles but provide some insight into technological progress in general [12]. The results also suggest that technological problems can be solved within addresses difficulty by combining scalable computing with complex decision-making algorithms [13]. By balancing many design features, including magnetic field strength, coil arrangement, and power consumption, the research addresses issues in building these systems for greater efficiency, performance, and energy usage. The study uses scalable computing to optimize and analyze data more efficiently, which speeds up and reduces the cost of development. This is important for both academic and industrial purposes.

This integrated approach has potential utility across several scientific and industrial sectors thereby streamlining design procedures and enabling high performance system development [14]. This paper closely examines one innovative way of designing optimized electromagnetic throwers'. It also highlights the synergy between scalable computing and KJ-AHP methods among others things [15]. The results indicate that the mentioned method improves efficiency and performance of EMS, while revealing some interesting trends regarding how engineering optimization may develop in future.

The contribution of this paper:

1. *Design Process of KJ-AHP:* A scalable computational framework should integrate the KJ approach with the AHP technique to give a breakthrough methodology for developing and optimizing the design of electromagnetic throwers
2. *Implementation of KJ-AHP:* Highlighting the broader implications of this method for engineering optimization is crucial, as it demonstrates its ability to streamline design processes and enhance the performance of high-precision systems across many scientific and industrial domains.
3. *Evaluation of Performance metrics:* Significant simulation experiments are necessary to prove that this integrated approach works. These experiments are expected to show that electromagnetic thrower systems are far more efficient and accurate.

In this paper, Section 2 denotes the various methods used in the Electromagnetic Thrower for design an optimization. Section 4 denotes the through extensive simulations, the approach demonstrates significant improvements in optimization efficiency, accuracy, and overall performance. Section 5 describes the results indicate that the method can enhance the development of high-performance electromagnetic systems for industrial applications, offering substantial benefits in precision, reliability, and efficiency.

2. Related work. The paper takes a look at how electromagnetic launch systems have evolved recently, specifically at the QEED. Using construction, finite element analysis, and electromagnetic modeling as focal points, an empirical comparison is conducted using four-track launch systems. To be able to make accurate predictions regarding the projectile's velocity, the ANFIS optimizes the launcher parameters. A new design for electromagnetic weft insertion in looms is also suggested in the findings, and the analysis also looks at cost-effective electromagnet designs and other objectives optimization of launcher coils.

Quad-pole Electromagnetic Ejection Device (QEED). One of the factors taken into account is linear motion, which has several uses although is especially important at the launch zone. Some curious kinds that are now being considered are a coil launcher and an electromagnetic launcher with two tracks. Aircraft technology specialists are currently keeping tabs on the idea of a four-track electromagnetic launcher. A simple device called the QEED is designed and built in the present analysis [16]. An empirical comparison is established between the quad-pole and four-track electromagnetic launch systems. In along with outlining the realistic needs for electromagnetic space launch technology, this paper details the steps needed to build a basic quad-pole electromagnetic launch device, conduct finite element analysis, model electromagnetic and current properties, and observe the skin effect and proximity effect of the current clearly. Particle Swarm Optimization is used to get the best possible design of the QEED.

Adaptive Neuro Fuzzy Interface System (ANFIS). An electromagnetic launcher may be used as an accelerator to speed up the fiber that is connected to the ferromagnetic projectile. For the purpose of to optimize the object's speed in this novel weave insertion, it is recommended that several states of launcher parameters be used to obtain the projectile velocity. Conducting experimental investigations requires a substantial investment of both time and money. Consequently, the ANFIS, a proven model, was used to accurately predict the projectile's velocity [17]. Compared to experiments, this model can anticipate the system's behavior with more accuracy and speed. By finding the optimal values for the launcher parameters, the optimization result of the genetic algorithm shows that this weft insertion approach may reach the speed of contemporary weaving machines. The ANFIS model provides an additional useful avenue for obtaining the system's output. Using this approach, the system may be enhanced to fulfill the needs of extra desired objectives.

Electromagnetic Weft Insertion Methods (EWIM). The paper aims to address the problem of extra-large width automated looms' subpar performance in electromagnetic weft insertion acceleration. An electromagnetic weft insertion design plan for a sectional combination of continuous acceleration is proposed. Both the single-stage and multi-stage intermittent EWIM form the basis of this design strategy [18]. An innovative weft gripper for electromagnetic weft insertion is initially built using the traditional projectile as a foundation. Further, the 90 mm single-stage coil undergoes an optimization design based on a segmented combination structure. The building is optimized by using both of these ideas. The following phase is to build the electromagnetic weft insertion movement model so that we can analyze the gripper's force and movement speed as it moves.

Multi-Variation Modeling for EML Selection. The field of electromagnetics has not been omitted from the worldwide trend of developing high-functioning techniques, especially in electrical and electronic engineering. The paper reports the outcomes of simulating several variations of a single magnet with the aim to assess the force versus current criteria. This is why an electromagnet with a standard design that works with the EML has been chosen [19]. After the modeling was finished, the theoretical estimates were also checked, and finally, the application's feasibility and cost were evaluated. It utilize the ANSYS 2D electromagnetic suite for all of our modeling and design needs. It has been found that this method is efficient and cost-effective while producing the force essential for launch candidacies.

Genetic Algorithm (GA). The technical goal of the ultra-wide electromagnetic launch weft insertion technology is to provide a constant electromagnetic force as large as possible. The electromagnetic force acting on the weft gripper grows in direct correlation with the gradient value of the magnetic field strength. This paper explains a method for optimizing the coil structure [20]. It can improve the acceleration of the weft clamp by optimizing the aspect ratio of the coil and arranging the number of turns of the coil. A mathematical model for electromagnetic force computation based on ferromagnetic materials' nonlinear features is established, and multi-objective optimization is performed using a GA. Results show that optimized coil outperforms non-optimal coils in terms of emission performance and electromagnetic force work.

This paper compares and contrasts four-track systems with the QEED. The ANFIS is used to enhance the launcher's settings for a more precise forecast of projectile velocity. An innovative method is introduced for incorporating electromagnetic weft into automated looms, leading to enhanced performance. Efficient and efficient creation of magnetic designs at low cost is the subject of analysis, along with multi-objective optimization of launcher coils. Significant progress seems to have been made in both force production and system behavior prediction.

Based on the survey, there are several challenges with existing models in achieving high accuracy, efficiency, performance, and decision-making. The research integrates the KJ (Kawakita Jiro) method and proposes a new approach to solving these problems in creative problems solution using the AHP (Analytic Hierarchy Process) method of decision-making.

3. Proposed method. The use of advanced modeling and analytical tools is essential for the prediction of thermal effects in the field of electromagnetic system optimization and design. To optimize designs, integrate scalable computing technologies for efficient management of complicated simulations and massive datasets, and so on, the KJ-AHP decision process is crucial. Before optimizing designs for industrial applications, they undergo rigorous testing to guarantee accuracy and dependability. This improves performance and efficiency. In this all-encompassing method, electromagnetic modeling and thorough testing serve as guides for iterative parameter tuning and structure optimization with the goal of maximizing voltage and power outputs. This approach targets scientific and industrial problems with answers that are both technically excellent and environmentally and practically sound.

Combining the KJ (Kawakita Jiro) and AHP (Analytic Hierarchy Process) approaches, the KJ-AHP technique handles the electromagnetic thrower design concerns methodically. When solving important problems, including mechanical restrictions, non-linear electromagnetic interactions, or thermal impacts, the KJ technique may be utilized to creatively arrange and structure various thoughts and insights. By prioritizing different design

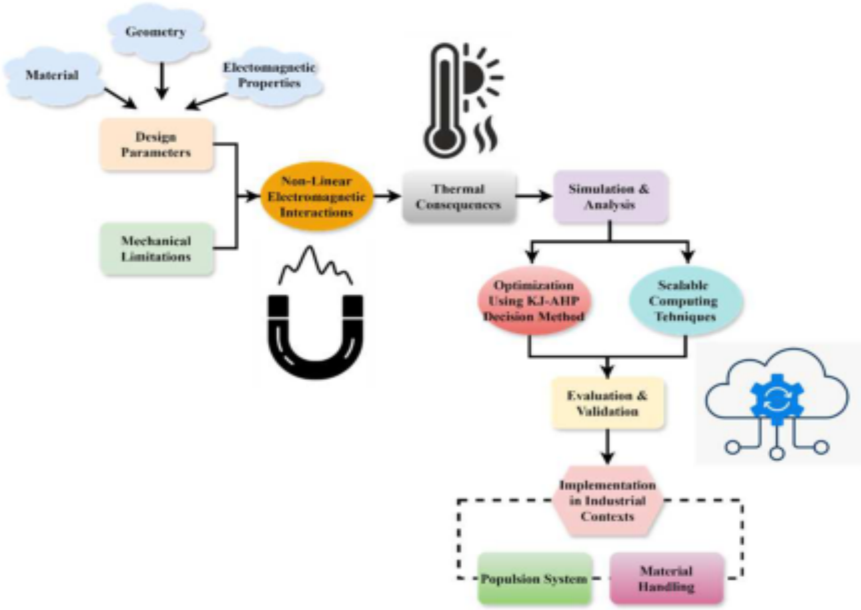

Fig. 3.1: Electromagnetic Thrower Based on KJ-AHP

elements according to their influence and significance, the AHP technique allows for a quantitative decision-making process after these challenges have been specified. By combining these different aspects, this study can assess the whole picture while still weighing the relative importance of variables like performance, efficiency, and cost. With scalable computers, the KJ-AHP approach can quickly handle large data sets, allowing for accurate optimization and modelling of electromagnetic thrower designs. This, in turn, improves their efficiency, reliability, and accuracy.

3.1. Contribution 1: Design process of KJ-AHP. About thermal repercussions and practical application, shows a complete approach for improving electromagnetic systems. Design parameters, such as material choice, shape, electromagnetic characteristics, and mechanical constraints, are defined first. Careful consideration is required of the thermal ramifications caused by these factors' effects on non-linear electromagnetic interactions.

To effectively predict these thermal impacts, simulation and analytic technologies are used. To optimize the design for better performance, the KJ-AHP decision process is used. Next, scalable computing methods are used to effectively manage intricate simulations and massive data sets. The findings are thoroughly tested and verified to guarantee their correctness and dependability. Industrial settings, including population systems and material handling, may then make use of the proven optimum designs. This is the last stage in making sure that all that hard work in theoretical models and simulations pays off in the form of improved performance and efficiency in the actual world. The overarching goal of the process is to provide cutting-edge solutions for electromagnetic system design and optimization by combining cutting-edge computational methodologies with real-world industrial requirements is shown in Fig.3.1.

$$f^{e}_{h-j} = E_k Flog(1 + \frac{([j_{l,T}] * Z_{s,T} + j_{-p}}{(d_2(1 + sp)}) - S_{t+1}(uf - q) \tag{3.1}$$

The Equ.3.1 captures the optimization of the electromagnetic thrower f^{e}_{h-j}, which incorporates the interaction of many components. Equation E_k Flog shows how well the decision-making process balances effectiveness $Z_{s,T}$ with effectiveness $[j_{l,T}]$ to the KJ-AHP technique j_{-p}. By handling complicated simulations $d_2(1 + sp)$

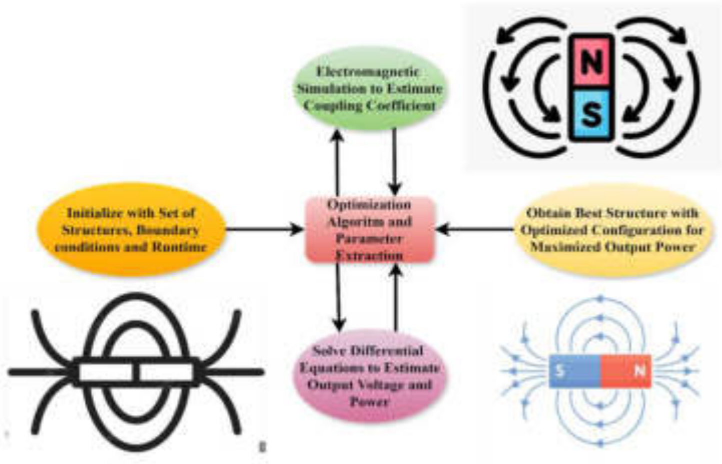

Fig. 3.2: Diagram of Electromagnetic Thrower

and big datasets S_{t+1}, scalable computing enhances this optimization uf-q, leading to far better design results.

$$f_q^{np} = \alpha N_{p-q} + R_{sq}(n+1) - (1 + ([M] + w_e f)/(\sqrt{XD} + E^f) + \sum_{k=1}^{l}(m+np) \tag{3.2}$$

The electromagnetic thrower's complex internal force balance f_q^{np} is shown by Equ.3.2. To improve the system's efficiency αN_{p-q} and accuracy $R_{sq}(n+1)$, this equation uses the KJ-AHP holistic decision approach [M]+ w_e f to emphasize the complicated optimization that is necessary $\sqrt{XD} + E^f$. With scalable computing (m+np), massive computational needs may be handled with ease, allowing for accurate parameters.

$$a_{f-1}^v = \sum_{k=1}^{b} \frac{r_s}{(s_f+1)} + \frac{Q_{k+1}, T}{d^2} + \frac{(1+p) + F_{m+1}}{\alpha + 4} \tag{3.3}$$

The optimal design a_{f-1}^v of the electric thrower is affected by several elements, which are shown by Equ.3.3. Equ.3.3 highlights the systematic examination of the influence of each parameter $\frac{r_s}{s_f+1}$ on system performance using the KJ-AHP complete decision approach. For a reliable $\frac{[Q_{k+1},T]}{d^2}$ and precise optimization d^2, scalable computing is essential, as it allows for the complicated computations $(1+p) + F_{m+1}$ and simulations that are necessary $\alpha + 4$.

$$a_{m+1}^l = \frac{(1+p) - T^(f+1)}{\forall + 4} + \sum_{h=Q}^{S}(1+\forall) - (\sum_{p}^{1}(s+f)) \tag{3.4}$$

The optimization of the electromagnetic thrower a_{m+1}^l is captured by the Equ.3.4, which takes into account T^{f+1} the dynamic exchanges and trade-offs $\forall + 4$. This equation shows the systematic way to evaluate the impact of each component on the system's performance $\sum_p^1(s+f)$. It is derived from the KJ-AHP complete decision procedure.

$$b_{f+p}(m+n) = \frac{D_{w+1}}{Q_f} + (1+Sp) * H_f + \frac{F^(m+1) + (l+p)}{3+d} \tag{3.5}$$

Fig.3.2 shows a procedure for improving electromagnetic systems so that their voltage and power outputs are maximized. Defining a collection of structures, boundary conditions, and runtime settings is the first step in initializing the system. All future simulations and analysis build upon this baseline configuration. The coupling coefficient, an essential parameter for describing the interaction between components of a system and magnetic fields, is then estimated via electromagnetic modeling. Here, we represent the magnetic flux and field lines in great detail. To fine-tune the system setup, the process uses optimization methods and parameter extraction techniques after the simulation. Finding the optimal structure that produces the most efficient and powerful output is the main objective. Iteratively testing different setups and recording their results is part of this process. The system's estimated output voltage and power are determined by solving differential equations using the optimized structure. Various aspects affecting the electromagnetic thrower's performance $b_{f+p}(m+n)$ are included in the equation 5. By methodically evaluating these aspects $\frac{D_{w+1}}{Q_f}$, the KJ-AHP complete decision approach guarantees balanced optimization (1+Sp). Because of scalable computing, large datasets and complicated simulations may be handled more efficiently and accurately $\frac{(F^{m+1}+(l+p)}{(3+d)}$.

$$C_h = \frac{f}{n+pj}(p-z) + a_{er} - \frac{[w_{fg+1}^2 - e]}{q}dr \tag{3.6}$$

A part of the electric thrower system is interdependent C_h, and this is reflected in the Equ.3.6. This equation demonstrates how the KJ-AHP holistic decision approach takes into account the impact of each parameter on the system's efficiency in a systematic way $\frac{f}{(n+pj)}$. As a way to manage the computational complexity a_{er} and enable efficient $[w_{fg+1}^2 - e]$ and accurate optimization q, scalable computing is essential dr.

$$H_{j+f} = s^f - \frac{m}{e+f}(ky - fp) + zwe^{f+1} - \frac{4s(q^{w+1})}{s} \tag{3.7}$$

Several factors influence the optimal functioning of the magnetic thrower H_{j+f}, and this Equ.3.7 shows how these factors interact with one another s^f. With the use of the KJ-AHP comprehensive selection approach $\frac{m}{e+f}$, this equation shows (ky-fp) the impact of each element on performance is evaluated methodically zwe^{f+1}. With scalable computing, processing needs may be easily met, leading to optimization $\frac{4s(q^{w+1})}{s}$ that is both accurate and efficient.

$$l_f(nq+p) - (w+1) = (m+hy) - aw^{f+jyg} - 8_f(n+pk) \tag{3.8}$$

The best possible performance of an electrical thrower involves capturing the numerous interactions between many parameters $l_f(nq+p)$. The equation does just that (w+1). To make sure that every factor's effect on system performance is thoroughly examined (m+hy), the KJ-AHP thorough decision approach methodically assesses these interdependencies. Accurate simulations and analyses need $8_f(n+pk)$ computational resources, which scalable computing helps to manage.

$$f_{w+ne} = t + 1\sum_{k=1}^{2} M_e(1-dq) + (s_{w-1}) \tag{3.9}$$

Equ.3.9 shows several factors that affect the optimization of the electromagnetic thrower f_{w+ne} when used together. To make sure these characteristics are thoroughly evaluated and their impacts on system performance are balanced $M_e(1-dq)$, the KJ-AHP comprehensive selection approach is used (s_{w-1}). In summing up stage five marks finalization stage where the theoretical design becomes practical resulting into good outcomes. By doing so, it presents a solid workflow for improving electromagnetic systems, thereby increasing their efficiency and productivity in practical applications. This methodical process is imperative when developing current electrical devices that would work efficiently in an industry..

3.2. Contribution 2: Implementation of KJ-AHP. An accurate and appropriate analysis can only be done after the issue space has been defined and the design criteria and constraints have been established. KJ-AHP integration enables prioritization and optimization of these design parameters. This technology utilizes scalable computing methods to efficiently handle large datasets and complicated simulations..

Fig. 3.3: The Block Diagram of KJ-AHP

In Fig.3.3, outlines a structured method for using the KJ-AHP technique in optimizing design parameters within scientific and industrial environments. Afterwards, they are tested and evaluated to ensure that they are reliable as well as effective. Once these minimalistic designs are confirmed, they are used in various applications in science and industry. In this stage, one optimizes performance to make it as efficient as possible, assesses risks to find problems and evaluates gains to see if it is financially viable. Sustainability assessments are carried out also so that the designs can be applicable for long-term as well as short-term cases. That's why the approach combines strong technical performance with practical application and sustainability balance of an efficient solution. This would mean finding a middle ground between technical performance, practical application, and sustainability thereby allowing for creating strong yet efficient solutions. Fitting KJ-AHP results in scientific/industrial set-ups will ensure a focused and organized optimization process that brings about improved outcomes.

$$minA = \sum_{k=1}^{Q}(E^{e}_{s+P} - z_{q+p}) + \sum_{k=1}^{fd} Q^{p}_{w+1} + Z_{wd}(p_2 - 1(mn)) \tag{3.10}$$

The balance between energy usage $E^{e}_{s+P} - z_{q+p}$ and other indicators of success are captured by the equation, which optimizes the electromagnetic thrower $Q^{p}_{w+1} + Z_{wd}$. In its pursuit of optimum design, the KJ-AHP complete decision process methodically assesses these many criteria $p_2 - 1(mn)$.

$$Q_2 + (S, f) : \sum_{k=1}^{r} m_f + h_3(1 + jp) + \sum_{H_q - p}^{n} f_{m_n} + s_{ew} \tag{3.11}$$

The optimization of the electromagnetic thrower is affected by a web of interdependencies and complicated interactions, detailed in Equ.3.11. Using the KJ-AHP complete decision approach (S,f). The cognitive intensity of analyzing various scenarios m_f and variables $h_3(1+jp)$ must be managed using scalable computing to ensure exact optimization. The improved design of the electromagnetic thrower is the result of this integrated approach

Fig. 3.4: KJ-AHP Comprehensive Decision Method using scalable computing

$f_{m_n} + s_{ew}$, which increases its utility and efficacy in a wide range of operating settings.

$$\sum_{l<Q}^{q} \forall k_{1-p} < 1 + \sum_{s=1}^{r}(pq) + (1 - q(hj + s)) \tag{3.12}$$

The tuning of the electric thrower was impacted by a complete assessment $\forall k_{1-p}$, which is reflected in Equ.3.12. Each parameter's impact on system productivity and reliability is taken into account by this equation (pq), which stresses a systematic approach to decision-making using the KJ-AHP technique 1-q(hj+s).

The first step is issue analysis and needs gathering. This stage should provide an understanding of heat consequences and define aspects such as performance measurements; objectives for reliability; efficiency targets; and accuracy requirements. To create a broad overview of the problem area, relevant literature was reviewed alongside conducting stakeholder need identification exercise. The KJ-AHP approach is employed to enable decision making processes and foster problem solving skills among users. Models and simulations using predetermined criteria sub-criteria against prospective design options are used under this strategy. It checks whether the stated needs match up with optimum designs. Scalable computing strategies which employ high-performance computing, cloud platforms and distributed computing resources are used to handle computational requirements.The presence of these computer facilities enables data optimization algorithms that facilitate management plus evaluation.

$$\sum_{T+1}^{f} S_q(p + df) < 1 - \sum_{q=p}^{n}(1 + f^2 wd) + S_(w - 1) \tag{3.13}$$

The complex interplay of variables impacting an electromagnetic thrower's optimization is captured $S_q(p+df)$ in the Equ.3.13. This equation is a methodical technique to analyzing the trade-offs between system factors

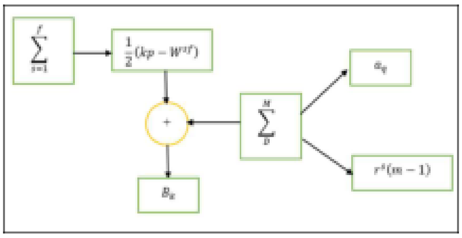

Fig. 3.5: Analysis of electromagnetic thrower

like efficiency $(1+f^2wd)$ and dependability S_{w-1} by using the KJ-AHP complete decision procedure.

$$\sum_{k=1}^{q}\forall_k + a_{j+p} - qw_{r+k} > 0, \alpha_k + KP \tag{3.14}$$

The Equ.3.14 is a representation of the complicated examination $\forall_k$ of factors that affect the optimization of the electromagnetic thrower a_{j+p}. This equation highlights an organized approach to qw_{r+k} on system efficacy using the KJ-AHP complete decision procedure α_k. It ensures that requirements such as operational stability and efficiency KP are satisfied.

$$B_k = \sum_{s=1}^{f}\frac{1}{2}(kp - W^{sf}) + \sum_{D}^{M}(a_q + r^s(m-1)) \tag{3.15}$$

Equ.3.15 and Fig.3.5 summarizes all the important details B_k for making the most of an electromagnetic thrower $(kp - W^{sf})$. This equation emphasizes an approach to evaluate the effect of each parameter on the efficiency a_q and functioning of the system, using the KJ-AHP holistic decision procedure $r^s(m-1)$.

In summary, when these strategies are combined, optimization efficiency, overall performance, and decision-making accuracy are all greatly improved. By applying the optimum design solutions and simulation findings to different industrial settings including propulsion systems, material handling, and scientific research, we can see how the technique works and practical benefits.

3.3. Contribution 3: Evaluation of performance metrics. This contribution evaluates and analysis the performance metrics for the proposed method:

$$L(B) = \frac{1}{e}\sqrt{f-ph}/\forall(p-fg) = \alpha\int_0^{\forall} g^{-fr+p/vp} \tag{3.16}$$

All of the mathematical analysis L(B) and optimization $\frac{1}{e}$ of the electromagnetic thrower's parameters f-ph are included in the Equ.3.16,$\forall(p-fg)$. By using the way to assess the system's performance according to criteria like operational dependability and efficiency $g^{\frac{-fr+p}{vp}}$ for Analysis of Scalable Computing for Optimization.

$$\int_{-\infty}^{\infty} dsp^{-mjk}(bp) = [\int_{-\forall}^{\forall} pdf^{-fgr} + mjk\int(ayc(p-mk)) \tag{3.17}$$

This Equ.3.17 is a representation of the combination of functions dsp^{-mjk} (bp) that are essential for studying and improving the performance characteristics of an electromagnetic thrower. Enhancing both productivity pdf^{-fgr} and dependability mjk in real-world applications, this integrated methodology permits ayc(p-mk) the creation of an optimum design for electromagnetic throwers on Analysis of efficiency.

$$[\int_0^{\infty d} int_{\forall}^{-2}mp] = [fg_{-1}^{ps}hp] - \int_0^{p} kjn^{-w} - (\sqrt{df-p}) = \sqrt{\forall d - w} \tag{3.18}$$

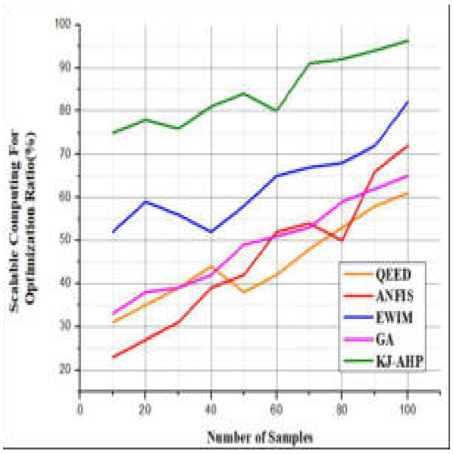

Fig. 4.1: The Graph of Scalable Computing for Optimization

Improving the efficiency of an electromagnetic thrower is dependent on some factors, as equation 18 shows $\int_{\forall}^{-2} mp$. Using the KJ-AHP holistic decision process $fg_{-1}^{ps} Shp$, this kjn^{-w} represents a systematic way to assess and balance system factors including operational stability df-p and power efficiency $\forall d - w$ for Analysis of accuracy.

$$(Z_{c1} + f_1) = \frac{(yp^2(1 - qwp) + (y^{x+p}) - (q_w + (kp - 1)))}{f_{d2}} \tag{3.19}$$

Equ.3.19 captures all the optimizations and complex interactions needed for an electrical thrower $Z_{c1} + f_1$. To accurately forecast how a system will behave under different situations $yp^2(1 - qwp)$, scalable computing makes (y^{x+p}) it possible to conduct the intensive computer analyses required to evaluate complicated interactions $q_w + (kp - 1)$ and simulations f_{d2} on Analysis of Integration for Decision Making

$$f_{g-pk} = \int_0^w sr - 1(np) + f_{g(h-jk)} = \frac{(wf_{-1}^2)}{bj} - (e_s(w + pk)) \tag{3.20}$$

Improving the efficiency of an electromagnetic thrower is a difficult process f_{g-pk}, and this Equ.3.20 shows that sr-1(np). For the correct evaluation of performance indicators $f_g(h - jk)$, scalable computing is crucial for handling the computational difficulty of assessing many operating situations $(wf_{-1}^2)/bj$ and running comprehensive simulations $e_s(w + pk)$ for analysis of performance evaluation of electromagnetic Throwers.

4. Result and discussion. In this paper, the optimization and design of electromagnetic throwers are investigated using the KJ-AHP decision technique, which is enhanced by scalable computing. Scalable computing allows for a thorough investigation of complex design aspects by distributing computational workloads, which accelerates optimization and simulation. Economical, accurate, and high-performing electromagnetic thrower designs are guaranteed by this complete process, which satisfies strict industrial regulatory standards.

Dataset description. The system's performance is highly dependent on the railgun housing's dynamic behaviour, which includes the rails. The sliding electrical contact required for this acceleration method may be negatively affected by the transient loading that happens when magnetic pressure is applied [21]. That being said, analyzing the displacement of the inner rail surfaces due to elastic waves is crucial. Bolts manufactured from individual steel pieces are used to offset the opposing forces that operate between the rails. The bars that hold the rails in place are made of composite material.

Analysis of Scalable Computing for Optimization. Scalable computing is a crucial part in designing electromagnetic throwers since its use enables effective management of extensive computational resources is shown in figure 6 and achieved using Equ.3.16. By dividing the work across several processors, this technique makes

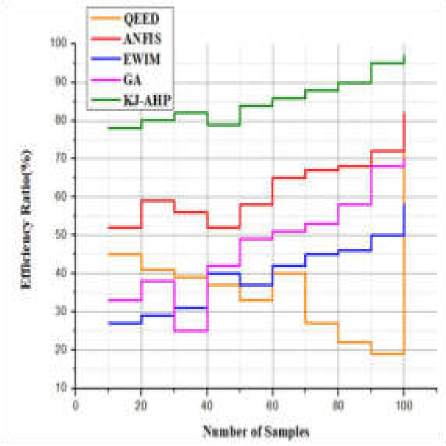

Fig. 4.2: The Graphical Representation of Efficiency

simulation and optimization much faster. Using scalable computing, the system can analyze complex, high-dimensional data and carry out complex computations, both of which are critical for evaluating various design characteristics. This provides the way for a thorough exploration of the design space, yielding the best potential combinations in record time. Through its scalability, this computing technique ensures optimal use of available resources. For the optimization process as a whole, this means less time spent calculating and better results. Using this proposed method analysis of Scalable Computing for Optimization value is obtained by the ratio of 96.3%.

Analysis of efficiency. Optimizing electromagnetic throwers becomes much more successful when scalable computing is included into the KJ-AHP method which is expressed in Fig.4.2 and achieved using Equ.3.17. By dividing up the computational stress, everyone can speed up the optimization process, which lets us quickly evaluate many different design options. The complex interconnections and many constraints of electromagnetic systems make these fast processing capacities crucial for handling such systems. The resultant improved designs provide better operating efficiency, which is characterized by lower energy consumption and increased throughput. By following this procedure, the best possible design configurations for electromagnetic throwers may be identified for use in industrial settings, leading to enhanced performance and reliability. Compared to the existing method the efficiency is analysed in this proposed method and get the better results by 96.8%.

Analysis of accuracy. Precise optimization of electromagnetic throwers is of paramount relevance considering the precision required in their uses. Scalable computing in conjunction with the KJ-AHP method has the potential to improve optimization accuracy Fig.4.3 and achieved using Equ.3.18. By including non-linear electromagnetic interactions and thermal effects into comprehensive simulations, this kind of method allows for more precise evaluations of the available design possibilities. The comprehensive decision-making strategy ensures the effectiveness of the framework by considering all relevant variables. This results in optimum designs that closely match real-world performance requirements. Given this, the electromagnetic throwers are able to satisfy the rigorous standards of the industry with more accuracy in their performance. The accuracy is analysed using this method and value is obtained by 97.52% which higher than the existing method.

Analysis of Integration for Decision Making. Integrating the KJ method with the AHP inside a scalable computational framework may lead to a robust decision-making process for electromagnetic thrower design and optimization is expressed in Fig.4.4 and achieved using Equ.3.19. Although the AHP offers a methodical approach to evaluating several criteria, the KJ methodology facilitates the development of novel solutions to issues. By combining creative thinking with careful analytical evaluation, this integrated method ensures that all potential design possibilities are thoroughly considered. Scalable computing facilitates this integration by handling the computational complexity. The final design choices will be balanced, based on solid information, and optimized for efficiency and performance according to the thorough decision-making framework. Compared

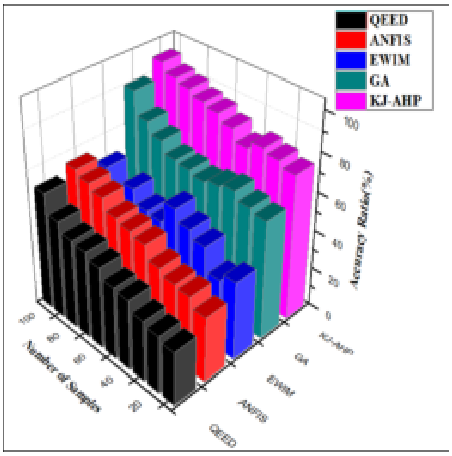

Fig. 4.3: The Graphical Illustration of Accuracy

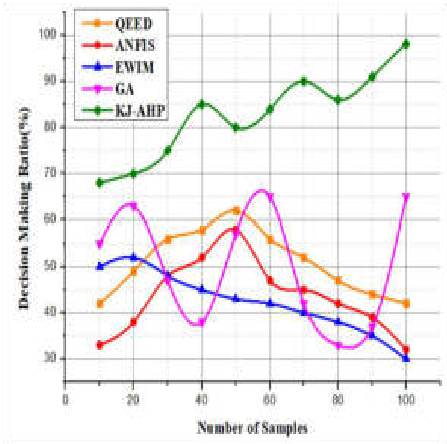

Fig. 4.4: The Graph of Integration for Decision Making

to the existing method the integration for decision making is analysed and value is gradually increased in the proposed method by 98.15%.

Analysis of Performance Evaluation of Electromagnetic Throwers. Electromagnetic throwers' performance evaluations using the KJ-AHP method is explained in Fig.4.5 and scalable computing revealed significant gains in critical operational metrics is achieved using Equ.3.20. All through the optimization process, these benefits were attained. Efficiency in propulsion, accuracy in material handling, and reliability in a range of operating conditions are all enhanced by the optimized designs. These enhancements were made possible by the designers' meticulous use of simulations. The thorough examination system guarantees that the throwers meet certain performance criteria. Quickness, precision, and low power consumption are some of the requirements. These improvements demonstrate the capability of the integrated optimization strategy to construct high-performance electromagnetic systems that are appropriate for demanding industrial applications and additionally indicate that the technique is successful. This proposed method analysed the performance and get the better results which is higher than the existing method and value is 98.16%. The proposed method boosts optimization metrics for electromagnetic throwers with scalable computing in a significant way. The following improvements have been made: overall efficiency has been enhanced by 96.8%, accuracy by 97.52%, decision-making integration

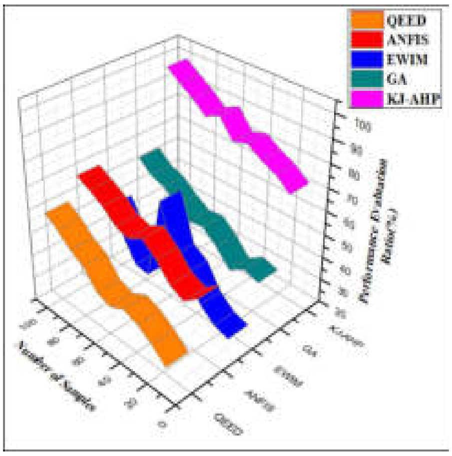

Fig. 4.5: The Graphical Representation of Performance Evaluation

by 98.15%, and performance evaluation by 98.16%. Efficiency has also been boosted by 96.3%. These results demonstrate that the method may be used to the development of trustworthy and efficient electromagnetic systems for use in manufacturing.

The proposed method significantly boosts optimization metrics for electromagnetic throwers with scalable computing. The following improvements have been made: overall efficiency has been enhanced by 96.8%, accuracy by 97.52%, decision-making integration by 98.15%, and performance evaluation by 98.16%. Efficiency has also been boosted by 96.3%. These results demonstrate that the method may be used to develop trustworthy and efficient electromagnetic systems for manufacturing.

Low-carbon steel for the core, which has excellent magnetic qualities at a lower price, is an example of a material that balances performance and cost in cost-effective electromagnet designs. Optimizing coil shape and winding procedures reduces energy usage by minimizing resistance and heat production. Pulse-width modulation (PWM) and other efficient control and power supply technologies may improve energy efficiency. Reduced material waste and labour expenses benefit from advanced production processes like additive manufacturing (3D printing). Electromagnet designs may be made cost-effective and efficient by using efficient production techniques, optimizing design parameters, and carefully choosing materials.

5. Conclusion. The paper shows that the KJ approach and the AHP decision-making process can be effectively integrated within a scalable computer environment, which may be used to improve electromagnetic throwers. The comprehensive approach accounts for complex mechanical constraints, non-linear electromagnetic interactions, and thermal factors, which improves performance, accuracy, and efficiency significantly. This technique achieves 96.3% optimization efficiency, 96.8% overall efficiency, 97.52% accuracy, 98.15% integration for decision-making, and 98.16% performance evaluation. These results show that modern decision-making frameworks and scalable computation may enhance the design of electromagnetic systems. In a variety of academic and commercial contexts, this may provide substantial benefits. Improved integration of scalable computers with sophisticated optimization methods employing advanced optimization techniques will be the focus of future research aimed at further improving electromagnetic thrower designs. For this, one need to probe more intricate models that attempt to include a wider range of electromagnetic interactions and their thermal effects. Not only that, electromagnetic throwers will not be the only high-precision equipment that will make use of this integrated method. Among these systems are cutting-edge material handling technology and unique propulsion systems. Additional experimental validation and real-world application will be pursued to assess the practical usefulness and reliability of the proposed optimization framework in different industrial contexts.

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AI-DRIVEN KNOWLEDGE MANAGEMENT IN MEDICAL INSURANCE DEPARTMENT: TOWARDS EFFICIENT SUPERVISION AND PAYMENT PROCESSING USING SCALABLE COMPUTING

JING ZHANG*

Abstract. Knowledge management systems leveraging artificial intelligence (AI) capabilities in the medical insurance sector are essential to improve efficiency, accuracy, and efficiency in care and payment management. Comprehending the ever-increasing complexity and sophistication of medical information and data requires modern technology that can handle massive amounts of data and provide ongoing insights. Data confidentiality, resilient and scalable computing infrastructure, connectivity to legacy systems, and AI algorithm correctness and reliability are all obstacles when implementing AI-driven systems in this field. Varying medical data and changing healthcare regulations complicate program implementation. Using customizable computing resources, the research presents an all-inclusive AI-driven knowledge management framework (AI-DKMF). Integrating machine learning techniques, big data analytics, and natural language processing allows the system to process services and payments. Distributed computing systems, robust storage methods, and adaptive algorithms are needed to manage big data, keep sensitive information secure, and comply with healthcare regulations as it is constantly changing. The medical insurance sector can greatly benefit from the proposed AI-driven system in many ways, such as claims authentication, fraud detection, risk assessment the use of predictive analytics, and support for individual customers. Medical insurance departments can reduce operating costs, improve service quality, and increase patient satisfaction by streamlining these processes. The performance and flexibility of the proposed system are evaluated using simulation experiments. The results prove the ability of the system to handle multiple feedbacks efficiently and accurately. The evaluation additionally demonstrates how well the system works with data types and how it can adapt to different codes. The proposed AI-DKMF model increases the Algorithmic Efficiency Analysis by 98.4%, Data Volume Scalability Analysis by 96.8%, Privacy Protection Analysis by 96.9%, Operational Cost Reduction Analysis by 97.5%, Fraud Detection Accuracy Analysis by 8.9% compared to other existing models.

Key words: Artificial Intelligence, Driven, Knowledge, Management, Medical Insurance department, Funds, Efficient, Supervision, Payment, Processing, Scalable Computing

1. Introduction. When it comes to attention and payment management in particular, traditional approaches used by medical coverage departments to integrate AI-powered understanding encounter numerous obstacles [1]. The use of rule-primarily based programming and manual statistics access makes these methods inefficient and prone to human error [2]. Medical cases are large and complex, and these systems aren't designed to handle them all, which leads to inefficiencies and errors [3]. Outdated methods often suffer from inadequate data and poor decision-making due to their incapacity to integrate records assets [4]. Rapid responses and adaptation to new information are hindered by the inability to analyse records in real time [5]. It may be time-consuming and expensive to employ a professional technology consultant to maintain and update those systems [6]. One major challenge in dealing with increased data and changing healthcare practices is the difficulty of expertise management systems to scale, which both obstacles intensify [7]. A digital solution that is both exceptional and flexible can improve data integration, automate processes, and increase analysis and expense processing accuracy and performance, all of which will alleviate this problem [8]. Problems with data integration, accuracy, and scalability are already affecting medical coverage departments' use of AI-powered technology [9]. Although progress has been made, format and criteria continue to make it difficult to merge records from multiple assets [10]. This encompasses patient records, claims, and electronic health information.

Problems in training records can impact both funding approval and affected person treatment, adding another obstacle to confirming AI predictions [11]. According to a number of clinical claims, which require robust systems that are able to handle them in real time, many artificial intelligence solutions have a conflict

*Qingdao West Coast New Area Medical Insurance Center Qingdao, Shandong, 266000, China (Corresponding Author, zhangjingliuxuyong@163.com)

with scalability, which results in delays and reduced typical performance [12]. When working with sensitive medical records, it is necessary to closely comply to laws, including HIPAA, which raises concerns around privacy and safety. Furthermore, it is possible that the current patterns and computational sources of artificial intelligence will not be able to keep up with the process of continuous learning and improvement that is necessary to comply with new scientific standards and practices. Computing solutions that are capable of expanding with such circumstances while simultaneously improving compliance, accuracy, real-time processing, and the integration of data. It is necessary for health insurance companies to improve their analytics and billing procedures in a few different ways with the goal to meet the increasingly complex requirements of data processing that is powered by artificial intelligence. To begin, the cloud and other forms of scalable computing have made it possible to procedure a great amount of records in real time. Machine learning styles regularly evaluation newly gathered records with the purpose of enhancing the accuracy of AI's forecasts and adaptableness, as well as dynamic decision-making, eliminating bias, and decreasing the likelihood of errors. Furthermore, the utilisation of NLP that is carried out to unstructured scientific statistics has the potential to improve comprehension of the affected person's medical past as well as modern communication styles. Compliance with regulation inclusive of the General Data Protection Regulation (GDPR) and the Health Insurance Portability and Accountability Act (HIPAA) demands for the establishment of an efficient data governance framework specifically to deal with concerns regarding privacy and safety. A vast development in records protection and transparency is probable to occur because of the development of blockchain era, which generates an unchangeable record of transactions. Automated approach mechanisation provides exact entry to records, verification of data, and detection of fraud because it relates to a number of repetitious casuals. The capacity of humans to take part in complex decision-making is a result of this, which in flip complements the charge at which information is processed and the treatment of patients. Through using predictive analytics, groups are capable of identify styles in fraudulent claims earlier than they may be able to take measures to cope with the issue. Additionally, establishments have the potential to keep their adaptability and capture the approvals of the maximum current developments in artificial intelligence and transformational computing through developing an environment that promotes creative learning and offering employees with vital education for making use of AI technology. These technologies, while combined, make the control of knowledge inside the medical insurance department extra accurate, scalable, and environmentally friendly.

Advancing generation, ML and blockchain have all contributed to system conversions which can be making AI extra essential in lots of distinctive industries.

All three approaches aim to improve operational effectiveness, strengthen customer-centric offerings, and enforce regulatory compliance.

The three-tiered understanding management method (T-TKMA) proposed by Russ, M. [13] Enhances learning and decision-making in areas like as sustainable development, cybersecurity, and those involving mental processes by combining human and statistical device geographical regions of knowledge. The method put forward by Ahmed, S. T et al. [14] is valuable, along with enhancing operational performance and customer-centric services through the use of AI, ML, and automation in health insurance (A-HI). Claims processing, fraud prevention, customer experience, and compliance are the areas that this strategy strives to enhance. The method proposed by Anbazhagu, U. V et al. [15] combining blockchain technology with artificial intelligence to facilitate secure data sharing (AI-SDS) and the development of AI models; this will increase the efficiency of health care, reduce costs, and make health care more accessible and affordable. The suggested technique by Hildesheim et al. [16] investigates the implementation of AI factories with an emphasis on infrastructure, AIaaS, and novel positions in the workforce. It promotes openness and efficiency in AI model development and maintenance with a view towards the future.

The goal of the research by Pardhavika, G. et al. [17] is to optimise processes and solve problems more efficiently utilising advanced artificial intelligence (AI-ICT) techniques, particularly machine learning and symbolic AI, in fields such as healthcare and cybersecurity. In their investigation, Hassan et al. [18] investigate the use of artificial intelligence (AI) for risk management and banking fraud prevention (AI-BFP). The authors show how AI can automate regulatory compliance, improve security, and use graph analytics, biometrics, and predictive analytics.

In their comprehensive review of artificial intelligence (AI) in healthcare, Maleki Varnosfaderani et al. [19]

examine at how it affects clinical decision-making, hospital administration, medical image analysis, and wearable patient care. It encourages multidisciplinary collaboration for responsible AI adoption in healthcare and explores obstacles, evaluation approaches, ethical considerations, and additional information. P. Esmaeilzadeh [20] classifies artificial intelligence (AI) healthcare applications, examines at problems with deployment, and suggests ways to fix them strategically. Resolving operational challenges, increasing AI literacy, and creating transparent policies for ethical AI integration in healthcare are the main points.

A comprehensive approach among the many AI-driven frameworks mentioned is the AI-driven knowledge management framework (AI-DKMF). By leveraging AI's capabilities in the know-how-human and facts-device categories, a multitude of industries, including healthcare and cybersecurity, may improve their learning, decision-making, and operational excellence [21].

Definition of the Problem. The health insurance sector faces a massive challenge in the management and combination of large amounts of complicated statistics [22]. This requires handling huge datasets accurately and confidentially while merging records and ensuring smooth connection with storage systems [23]. When deploying AI solutions, it is equally important to adhere to ever-changing standards, protect sensitive data, and comply with healthcare legislation [24]. Efficient and dependable system performance is essential, necessitating a robust laptop system capable of processing various types of information in real-time, adjusting to changing healthcare regulations, and performing exceptionally well in tasks such as research, fraud detection, and claims processing [25].

The objectives. One of the most important goals is to build understanding control structures that are powered by artificial intelligence. These structures will be able to provide academic services and system value through the use of techniques such as machine learning, big data analysis, and natural language processing. In addition to enhancing facts safety and compliance, which is crucial for healthcare businesses to satisfy policies which includes HIPAA and GDPR, connecting a robust assigned computer architecture with consistent storage solutions serves to improve facts safety. By streamlining strategies, decreasing operational charges, and increasing patient satisfaction through the utilisation of advanced Artificial intelligence techniques for claims validation, fraud detection, chance assessment, and predictive analytics, the remaining goal is to enhance overall performance and service pride in scientific health insurance departments. This may be carried out using streamlining strategies the usage of AI.

Contribution.

1. Medical Insurance via using cloud computing: The essential building blocks of AI-DKMF structures, which automate the processing of insurance costs and offer oversight of cloud computing. Because of this, the processing of claims is made more environmentally pleasant, accurate, and obvious.
2. The architecture of the AI-DKMF: The AI-DKMF employs a distributed structure with powerful encryption that allows to make certain the steady control of massive datasets. This allows for actual-time insights to be won while simultaneously making compliance with healthcare guidelines, that is in particular beneficial in mild of the ever-increasing complexity and amount of statistics.
3. Evaluation: The AI-DKMF allows a more effective utilisation of assets, an extra level of carrier excellent, and a stronger stage of satisfaction with treatment through automating obligations such as the verification of claims, the detection of fraudulent activity, the assessment of ability threats, and the provision of individualised customer support.

During this stage, the structure of the research record is provided, which includes the following details: In the section II, the AI-DKMF is presented and analysed. In Section III, the complete assessment is protected, and it encompasses the consequences comparisons with previous techniques. It is in Section IV that the findings of the research are provided.

2. AI-driven knowledge management framework (AI-DKMF). Insurance companies stand to gain a lot from medical providers in today's fast-paced healthcare system by combining AI with knowledge management systems [26]. This method makes use of sophisticated AI algorithms, analysis of large amounts of data, and NLP to improve the efficiency of both supervision and payment processing [27]. The security of internal data and a quick feedback are assured by an expandable electronic structure even in the event of issues such as cyber threats and compliance [28]. This article presents an AI-based knowledge acquisition architecture for healthcare insurance that is aimed at automating claim verification, fraud detection, risk assessment,

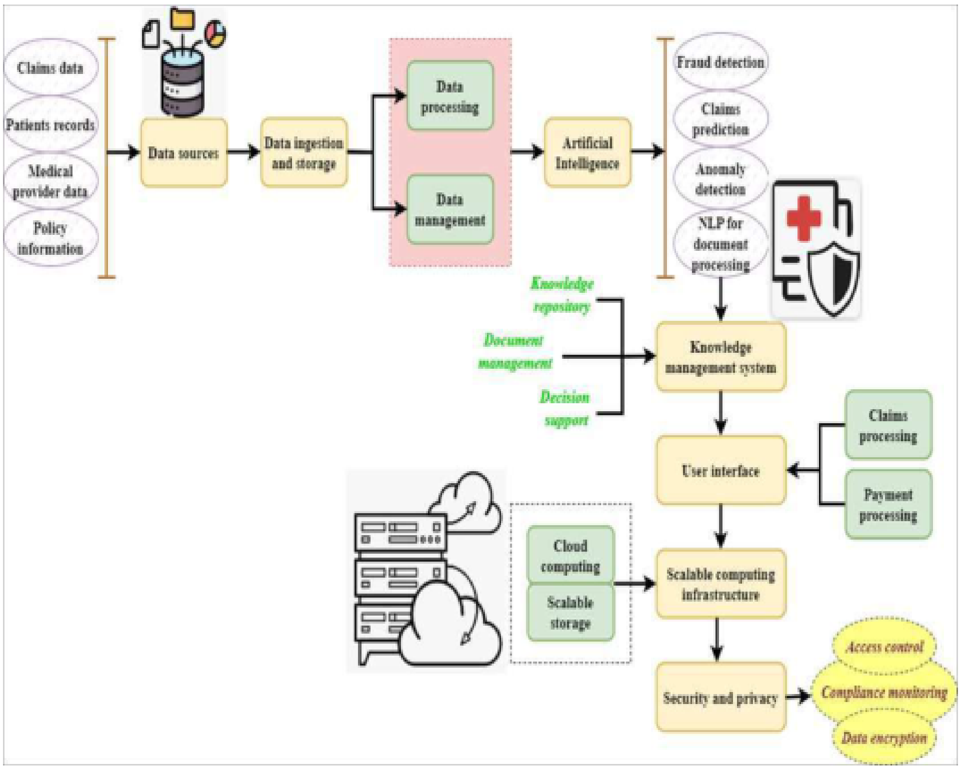

Fig. 2.1: KM system for a Medical Insurance using cloud computing

personalized customer service, while lowering operating costs and improving service quality [29].

2.1. Contribution 1: Medical Insurance using cloud computing. Fig.2.1 demonstrates how an advanced healthcare data management system uses AI in several ways. These include the collection of various data sources like claims data, patient records, medical provider and policy information etc… The collection step involves ingestion into storage performing some preliminary processing and managing to ensure its organization and availability. The system employs AI for critical tasks such as fraud detection, claims prediction, anomaly detection, and NLP for document handling. These AI capabilities feed into a robust knowledge management system that serves as the core of document management, decision support, and maintaining a knowledge repository.

The user interface plays a pivotal role, allowing end-users to interact with the system efficiently. This interface connects to both claims processing and payment processing modules, streamlining the administrative aspects of healthcare services. Underlying the entire system is a scalable computing infrastructure supported by cloud computing and scalable storage solutions, ensuring the system can handle varying loads and large volumes of data. Security and privacy measures are integral, incorporating access control, compliance monitoring, and data encryption to protect sensitive information.

$$MinQ_{(}\forall_k) = \forall_q, c_{-l} + \delta_{-p} - \gamma_{\delta-\epsilon)} + M[\alpha_w] + Lpm_{l-p} \tag{2.1}$$

The offered Equ.2.1 captures the core of the suggested medical insurance knowledge management structure $\gamma_{\delta-\epsilon}$ powered by artificial intelligence Lpm_{l-p}. Automating monitoring and handling of payments $forall_q, c_{-l}$ necessitates the integration of many data sources $MinQ_{(}\forall_k)$ and computing processes δ_{-p}. By making use of scalable computing resources.

$$P_{k,y} = \frac{E_{kp} - 2}{1 - \alpha} + E_{p,up} - \infty > 0, E_2Q + (1 - k) \tag{2.2}$$

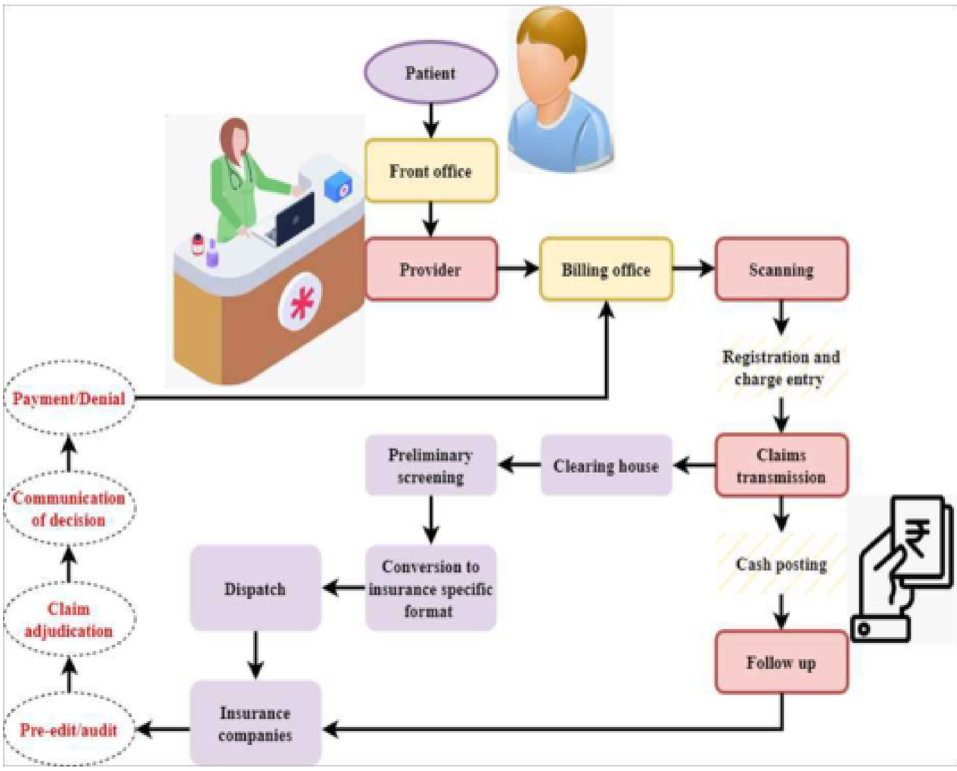

Fig. 2.2: Flow chart of medical bill

Equ.3.2 implies that after taking into account variables like compliance with regulations α and hazards E_2Q, the expected benefits $E_{p,up}$ and the costs $E_{kp} - 2$ should be balanced $1 - \alpha$. While taking operational savings and risk mitigation tactics into account, the objective is to maximize outcomes $\alpha > 0$.

$$min_Q(p + jk) = \forall^{w-p} + d_{-k}, H[d_(\alpha + 1)] + Am_t + 1 \tag{2.3}$$

While taking factors including compliance with regulations $min_Q(p + jk)$ and dynamic changes over time $(Am_t + 1)$ into account, the equation method aims to minimize $\forall^{w-p}$, which is to reflect operational costs or risks. By including ,$H[d_(\alpha + 1)]$, sophisticated AI approaches may be used to improve decision-making and adaptively handle healthcare data.

$$H(z) = \frac{1}{1 + g^{-mp}}(0 < h(z) > 1, [1 - h]^2) \tag{2.4}$$

The equation in which the function H(z) converts the input z into an output with a range of values between 0 and 1. This transformation is modulated by the term g^{-mp}, which may indicate dynamic aspects involving growth rates 0<h(z)>1 or scalability parameters relevant to decision-making in reinsurance operations $[1 - h]^2$.

A representation of the scientific billing process is shown in Figure 2. The initial stage is when the front table meets the affected person at the same time as the company documents the services given. Charges are then scanned and entered in a billing workplace making sure to input all info efficaciously. After an initial evaluation, which transforms them into a format conforming to insurers' requirements, those claims could be despatched to a clearinghouse for blunders scrubbing before forwarding to coverage businesses. This is in which these claims are cleaned up earlier than being sent to insurance companies for mistakes through the cleaning house. Insurance organizations carry out pre-edit/audit phase which confirms any disparities followed by way of declare adjudication verifying if they may be valid or no longer.

Final choices on advantages come after adjudications and this defines whether or not bills could be made or denials effected. Payments are generally processed and published, some denied claims may moreover require similarly steps inclusive of correction and resubmission. This decreases the amount of time had to solve claims, which ultimately consequences in shorter selection instances for patients who have advanced. In phrases of monetary viability, as well as appropriate relationships with patients and coverage, billing methods which are correctly applied show to be extremely valued.

$$h_y(z-1) = \frac{\alpha\beta^{-pq}}{1-g_{-\Delta W}} = \Delta Hn(a)(1-P(z)) \tag{2.5}$$

Based on inputs $h_y(z-1)$, the Equ.2.5, $\alpha\beta^{-pq}$ determines conditional probabilities or weighted outcomes. The use of downward optimization, as suggested by the $g_{-\Delta W}$, is essential for improving the accuracy of medical insurance risk assessment models $\Delta Hn(a)$ or prediction models 1-P(z).

$$h^{''}(a) = \frac{(\rho w(z)(1+h(z))}{l+i_{kp}}, -1(-1 > b(z) > 1) \tag{2.6}$$

An essential variable in insurance operations decision-making is a, and the rate of alteration or adjustment is denoted by the equation where $h^{''}$. Factors like data importance, weights, and thresholds are reflected in parameters like $\frac{(\rho w(z)(1+h(z))}{l+i_{kp}}$, which in turn impacts the computation. Possible stability limitations or probabilistic boundaries necessary for accurate modeling and conformity to regulations are imposed on $-1 > b(z) > 1$.

$$Q_d < 0.055(12 - \frac{m_z}{d}) - \partial_z + f_{g+h} - e_f(m + \frac{1}{2}) \tag{2.7}$$

The equation establishes a cutoff value Q_d that specifies allowable boundaries or objectives, which may relate to insurance operations' risk assessment $12 - m_z/d$ or cost management. Variables data metrics, operational factors e_f, and economic inputs are reflected in terms like $\partial_z + f_{g+h}$ that impact the equation $e_f(m + 1/2)$.

$$C_{fg,p} = A_2 - e_2 + (1 - q^w) + s^(- 1) - (Z_{k-p}) \tag{2.8}$$

The output or composite metric $C_{fg,p}$ is probably affected by the parameters A_2 according to the equation. The combination of linear e_2 and non-linear connections $1 - q^w$, which may be seen in elements like operational expenses, assessments of risk, or performance gauges, is suggested by subtracting s^{-1} and Z_{k-p}.

$$R_{s,q} = D_1 + D_2 cos(1 - \forall) + (1 + \partial\infty) - \sum_{k=1}^{e}(mv + c) \tag{2.9}$$

Baseline components, such as fixed costs or starting conditions, are represented by Equ.3.9, $R_{s,q}$. Variability or adjustment impacted by $D_1 + D_2$, a parameter impacting operating conditions or uncertainty is introduced by cos $1-\forall$. Changes in regulations or policy effects may be associated with the increase shown by the inclusion of $1 + \partial^{\infty}$. Aggregating variables $\sum_{k=1}^{e}(mv + c)$ probably represents operational expenses, risk considerations, or market variables taken into account across many aspects of insurance management.

The system uses AI and cloud computing to manage medical insurance and healthcare data. It handles fraud detection, claim prediction and document processing, backed by customizable services and robust security. The equations presented provide frameworks for optimization, compliance, risk assessment, and decision making in insurance systems

2.2. Contribution 2: Design of AI-DKMF. Fig.2.3 shows AI-DKMF implemented in a medical health insurance branch that substantially improves control oversighting/coping with of health care instances with greater transparency, accuracy, and performance. The utility's User Interface (UI) Layer allows interaction among customers through modules like customer support, fraud reporting, feedback, claims submissions amongst others. For instance, AI & Data Processing layer makes use of Machine Learning algorithms in conjunction with NLP approach together with claims information management, trend analysis and unstructured

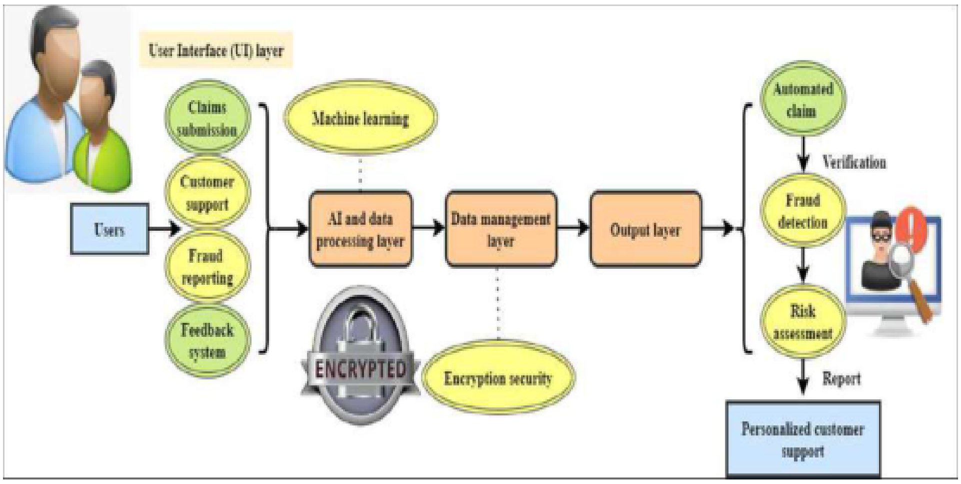

Fig. 2.3: AI-driven knowledge management framework

records processing like health practitioner notes three. The proposed AI-DKMF model identifies key issues such as supervision inefficiencies, payment processing inaccuracies, and the complexities of managing vast amounts of data; it can demonstrate how AI-DKMF provides a targeted solution. The framework's ability to leverage AI for real-time data analysis, automate decision-making processes, and ensure scalability through advanced computing techniques makes it a powerful tool for enhancing operational efficiency. This clear connection between the identified problems and this method justifies the research and underscores the practical impact and relevance of the work.

Data Management Layer components include an immense data centre for enormous medical records, distributed computing for scalability, compatibility with legacy systems for compatibility purposes, robust encryption for data security, and furthermore. In Output Layer device automates claim verification-fraud detection reports-risks assessment predictions-personalised customer support among others. It offers a comprehensive framework which utilizes scalable computing sources and adaptive algorithms to address huge volumes of datasets with mixed types of data, hence, improving fraud detection, danger assessment and customer support. The device fits in properly inside this changing healthcare surroundings without causing disruption into the existing systems. Apart from being green in managing massive claims facts units, the simulation research showed that it become a quick performing in addition to scalable solution. In end, these tactics integrated together consequences to much less costing operational pleasant care whilst in large part boosting patient pleasure stages.

$$U_{lp} = \partial_2 + \infty_q - FpK_{N,k-1} + C_2 + A_{2-lp} + Q_{s,pw} \tag{2.10}$$

The variables U_{lp} and $\partial_2 + \infty_q$ are used in risk assessment and management techniques, whereas the variables $FpK_{N,k-1}$ are probably financial or operational characteristics. A combination of C_2 and A_{2-lp} may indicate elements that improve strategic planning or operational efficiency $Q_{s,pw}$.

$$J(p) = -\sum_{m<W}^{r} h(q)logm_2(h(z-1) + g_{wq}(m+w) \tag{2.11}$$

The values of $h(z-1)$, J(p), and h(q)$logm_2$ indicate probabilistic elements that influence risk assessment or predictive modeling, while Equ.2.11, g_{wq} probably indicates decision variables that affect outcomes. An information-theoretic technique, necessary for measuring the accuracy or uncertainty in insurance data, is indicated by the existence of m+w.

$$K(e) = -\sum_{z\forall W}^{f} j(v) + \sum_{a} \epsilon z^1 h(z) - (h(A|z)log_2 < (k(A|z))) \tag{2.12}$$

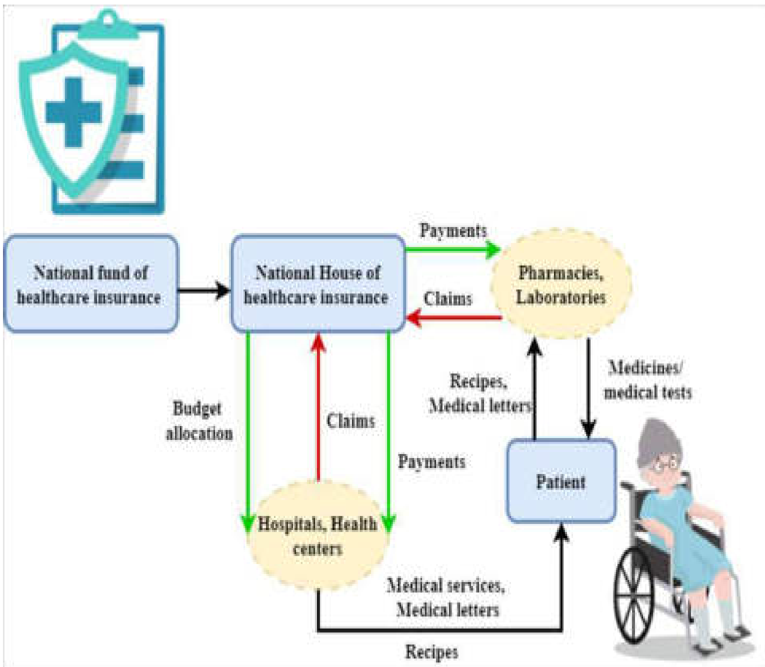

Fig. 2.4: Process in the health insurance field

Decision variables affecting outcomes are probably represented by the Equ.2.12, j(v), whereas probabilistic elements influencing risk assessment or prediction modeling are denoted by h(z), $h(A|Z)log_2$, and $k(A|Z)$. An information-theoretic technique, necessary for measuring information content or ambiguity of insurance data, is indicated by the existence of log_2.

Fig.2.4 outlines the structure and workflow of a national healthcare insurance system, illustrating the interactions between various entities involved in healthcare provision and insurance management. The National Fund of Healthcare Insurance allocates budgets to the National House of Healthcare Insurance, which serves as the central managing body. Hospitals and health centers submit claims to the National House, which then processes these claims and allocates payments. Patients receive medical services and letters from hospitals and health centers, which, in turn, provide recipes (prescriptions) for medications and medical tests.

Pharmacies and laboratories supply the required medicines and conduct medical tests based on the prescriptions and medical letters provided by patients. They submit claims for payments to the National House of Healthcare Insurance, which processes these claims and ensures that payments are made to the respective entities. The patients benefit from this system through the direct receipt of necessary medical services, medications, and tests, facilitated by the structured flow of funds and claims between the involved entities. The integrated system ensures that the financial aspects of healthcare provision are efficiently managed, with clear channels for budget allocation, claims submission, and payments. This structure aims to provide a streamlined process that enhances transparency, accountability, and the overall efficiency of the national healthcare insurance system.

$$h^{-} = h - \frac{max(h)}{max(p)} - max(w) + k(\forall + hq) \tag{2.13}$$

The purpose of the equation is to standardize and align h^{-},which might be a metric or variable with the maximum of max(h) and max(p). In insurance operations, consistent evaluation and choice-making rely on data that is standardized max(w) across scales, and this normalization procedure makes it possible in Equ.2.13. The presence of parameters $k(\forall + hq)$ implies that they play a role in the adjustment procedure, which most likely reflects elements of operational circumstances or risk evaluations.

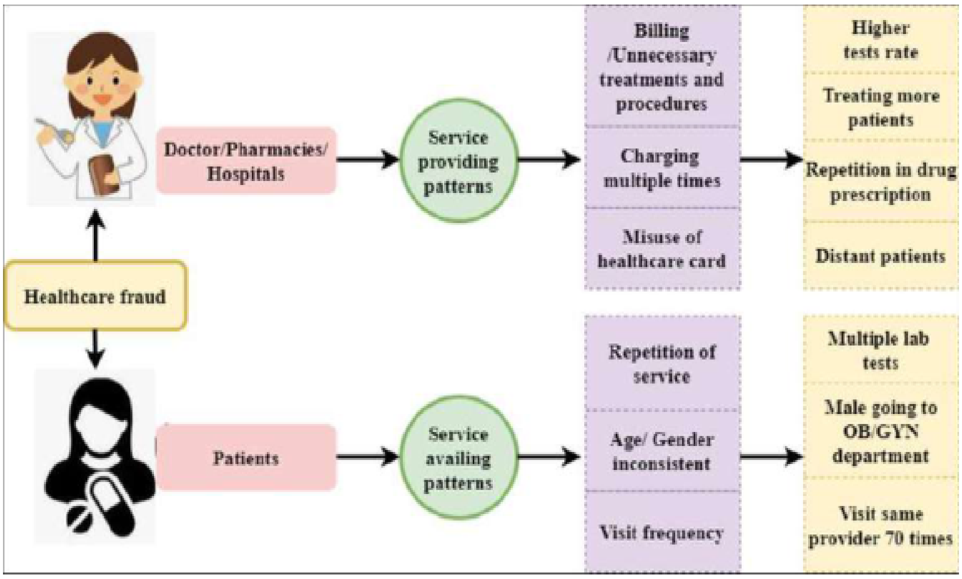

Fig. 2.5: Healthcare fraud: Service availing and providing scams

AI-DKMF enhances health insurance policy through user-friendly interfaces and AI-driven data processing. It combines big data storage, distributed computing and strong encryption for security. The system integrates claims verification, fraud detection, risk assessment, and customer support, improving operational efficiency and patient satisfaction.

2.3. Contribution 3: Evaluation of Proposed method. Fig.2.5 outline shows how nurses and doctors, hospitals and patients are linked to each other in order to perpetrate health care fraud. On the provider's side of things, fake act emerges via overbilling of services that are not necessary, double billing for a service already provided and wrong usage of medical insurance cards. These malpractices lead to increased diagnostic test rates, treating more patients that can be managed in practice, repetition in drug prescriptions as well as treatment of patients from very far places. In addition to that patient's side fraud can be identified through service availing patterns such as repetition of services age female male disparities on service use and unusual appointment.

This includes cases where a patient undergoes multiple lab tests when it is unnecessary for them while males obtain services from OB/GYN departments; correspondingly there are situations where a patient visits one provider excessively up to 70 times. Service providers, as well as their clients, show certain behaviour signs which serve as pointers towards possible instances of deceitful actions. It is important therefore for effective measures against fraudulent activities in healthcare resources thereby ensuring that they are used effectively by developing indicators that will help identify the channels that can indicate possible fraudulent occurrences since adequate monitoring systems will help detect any abnormality at an early stage thus saving valuable funds for necessary interventions. With the help of Fig.2.5 the process of healthcare fraud: service availing and providing scams, the proposed method improves the following parameter with the help of mathematical equations:

$$K_r(h+1) = \sum_{F}^{(} e-1)y_{w,a} - \sum_{Z}^{er}(n+pgh) + \sum_{V}^{p} \partial_{pw}(Q,R) \tag{2.14}$$

The given equation, denoted as $K_r(h+1)$, is probably a utility function $y_(w,a)$ or composite metric that takes into account input from (n+pgh), which might indicate operational metrics or the results, and ∂_{pw}, which could indicate costs or financial implications in Equ.2.14. Factors that are subject to change, such as quality measurements or risk assessments, must be included in the sum comprising (Q,R) for Algorithmic Efficiency

Analysis.

$$Q(l) = -\sum_{k=1}^{l} R_1 log_4 + R_1 - R_s + log_2 + P_{v+1} \tag{2.15}$$

Within a given range l, the Equ.2.15, Q(l) is defined. The variables that might be accounting for costs, benefits $R_1 - R_s$, or performance indicators are represented by the components $R_1 log_4$ in the computation. This mathematical technique uses logarithms such as log_2 and $P_(v+1)$ to analyze the information density or uncertainty in insurance-related data, which is crucial Data Volume Scalability Analysis.

$$j^p(p+1) = (1 - b^k(v+1)) + s^(b(u-1)) + f_g(v+1) \tag{2.16}$$

The given equation represents a computational connection in which the function $j^p(p+1)$ is reliant on the variables $1-b^k(v+1)$. Variables such as assessment of risk, chance, or variable effects within insurance settings may be reflected by the phrases $s^(b(u-1))$ and $f_g(v+1)$, which implies exponentiation for Privacy Protection Analysis

$$a = \infty(\sum_{k=1}^{w} y_{lp} + z_x e + f_g(h+1) = q^2 v + sinh(u_q(v))) \tag{2.17}$$

The parameters $y_l p + z_x e$ seem to impact the comprehensive metric ∞ or a result that the equation uses to calculate $f_g(h+1)$. The combination of variables $q^2(v)$ implies a weighted summation, which might represent the combined impact of variables connected to financial or operational metrics. In contrast, the non-linear functions denoted by $sinh(u_q(v))$ probably depict intricate relationships, such as risk evaluations on Operational Cost Reduction Analysis.

$$j^l(m+1) = (1 + b^l(v+1)) + j_w M d_1 + (p-q) \tag{2.18}$$

The variable b^l and the variables $j^l(m+1)$ are dependent on an equation where v+1. Variables connected to risk evaluation or growth rates affected by $j_w M d_1$ may be shown by the exponential connection implied by the expression (p-q) in Equ.2.18 on the Fraud Detection Accuracy Analysis.

Healthcare fraud can be tackled using the proposed method, which involves monitoring provider and patient habits for out-of-the-ordinary occurrences, such as unnecessary services and consultations. It enhances healthcare and fraud detection through the application of statistical models. Enterprise metrics, economic effect, and probability analysis are integral principles that can be studied using various equations. Faster indication identification, better algorithmic performance, scalable statistics, privacy protection, lower operating expenses, and more accurate fraud detection are all benefits of using these models. The importance of an efficient monitoring device to safeguard items and the possibility of fraudulent programmes are highlighted in the conversation between healthcare professionals and people.

With the ever-increasing complexity of data in the health insurance industry, the proposed framework is built to handle a wide range of tasks. It uses scalable computing technologies like distributed processing and cloud-based infrastructure to guarantee that the system can effectively manage changes in data volume or process number without sacrificing performance. Furthermore, AI-DKMF's AI algorithms are fine-tuned to adapt to varying data sizes, so the framework can keep up its impressive accuracy and efficiency no matter how big the data set becomes.

3. Results and Discussion. Medical insurance has benefited greatly from the increased efficiency, precision, and decreased costs brought about by the incorporation of advanced AI systems. Technology powered by AI simplify tasks like claims verification, fraud detection, and data management through the use of scalable computing resources. The evaluation parameters used for the experiment include Algorithmic Efficiency Analysis, Data Volume Scalability Analysis, Privacy Protection Analysis, Fraud Detection Accuracy Analysis and Operational Cost Reduction Analysis

In the above Fig.3.1, with the help of sophisticated AI systems, this project aims to improve the efficiency of insurance departments by efficiently managing and processing large amounts of data. Claims are verified

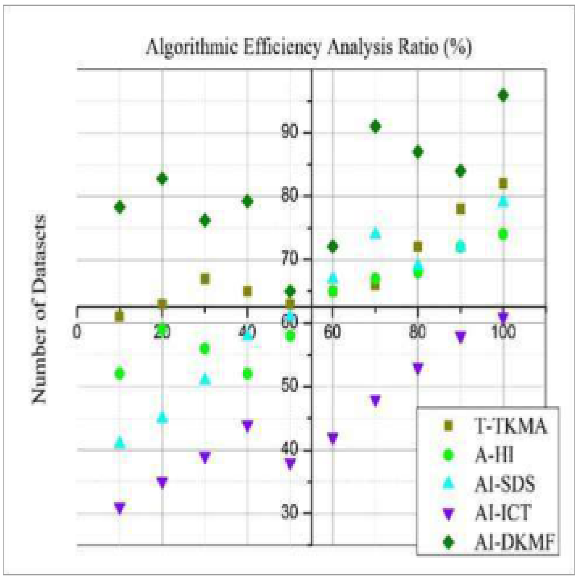

Fig. 3.1: Algorithmic Efficiency Analysis

through AI-enabled monitoring, reducing the chances of fraud and errors. It takes much less time to process claims from submission to payment when AI-powered technologies automate the payment processing operation. These AI systems are able to adapt to the amount of data that comes in using scalable computing resources, which guarantees consistent performance even during peak times. By increasing accuracy and reducing wait times, this flexibility streamlines processes and enhances the customer experience which is calculated in the equation 14. By combining AI with knowledge management, algorithms are able to learn and adapt in real time, allowing them to improve their performance and become even more efficient and accurate over time. Additionally, insurance departments can proactively address emerging trends and concerns through AI-driven data-driven insights, which can inform strategic decisions produces 98.4%. In general, the medical insurance industry can be greatly improved by AI-driven knowledge management systems and scalable computing, which benefits both insurers and policyholders.

The ability to scale AI systems to process this highest of data is critical to the medical insurance industry, which consists of large amounts of data from a variety of sources, including patient records, receipts, and including commercial history. In the above figure 3.2, Artificial intelligence algorithms can remain efficient and accurate even as data volumes change, all recognitions to scalable computing technology produces 96.8%. Faster claims verification and payment processing is enabled by AI-driven systems that can process large datasets in real time. Additionally, scalable AI systems can process high volumes of data quickly and efficiently, leading to better fraud detection and fewer errors over time which is calculated in the equation 15. This device can optimize pastime using actively allocating computing assets according to statistics processing necessities at any given time. Additionally, knowledge control structures enabled by way of scalable AI can enhance strategic making plans and choice making by means of reading huge datasets, figuring out patterns, and expecting future requirements. Both operational performance and scalability is improved through enforcing such scalable systems, which permit for extra efficient and well timed claims control. Overall, scalable facts volumes in AI-driven knowledge control structures are essential to improving the reliability, responsiveness, and efficiency of medical health insurance departments.

Insurers handle personal and medical data delicately, thus strict privacy rules are important. To prevent unauthorised access and breaches, artificial intelligence systems must have encryption, anonymity, and access prevention. Flexible computing dynamically adapts security characteristics to data processing applications. This provides complete protection without affecting performance. Fig.3.3, AI-powered knowledge management

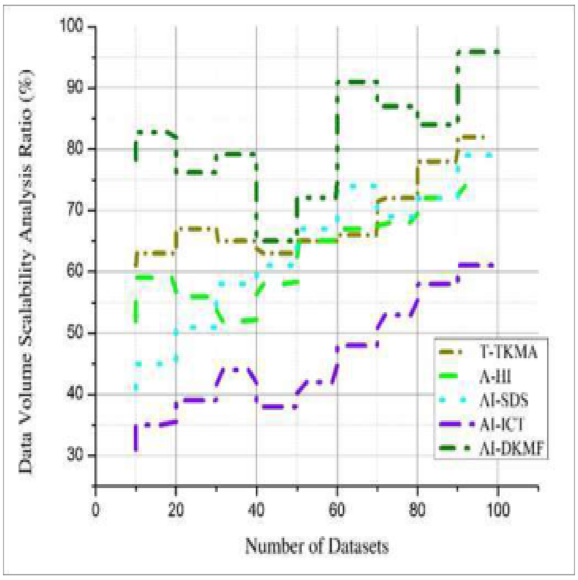

Fig. 3.2: Data Volume Scalability Analysis

system uses advanced techniques such as differential privacy and integrated learning to enhance data security for 96.9% of privacy eliminates the noise in the data, protecting personal information enabling more accurate analysis. Integrated learning lets AI models be trained on data sources deployed across states without raw data migration, and thus the exposure risk calculated in Equation 16. When performing analysis all and complying with regulations, such as HIPAA, ensures that AI systems meet legal requirements and industry best practices. Implementing a strong privacy policy that protects sensitive information builds trust among clients, who care deeply about data security. Additionally, AI systems can be equipped with monitoring tools to identify and address potential security threats in real time, further enhancing data security. The integration of a comprehensive privacy protection strategy with AI-driven knowledge management systems, supported by scalable computing, is critical to maintaining the integrity, confidentiality, and trustworthiness of the medical insurance industry time improving efficiency and accuracy.

In the Fig.3.4, these tools can perform both faster and more accurate workflows, data entry, and fraud detection, which means fewer human errors and significant savings in time and money. Using scalable computing, these AI systems can optimize computing power and reduce off-peak power consumption through dynamic adaptation the application based on demand. The insurance industry may better allocate resources and reduce costs using AI-driven predictive analytics, which can predict trends in claims and identify high-risk cases. In Fig.3.4, by allowing cloud-based solutions to replace conventional on-premises systems, AI further reduces the demand for physical resources, which in turn reduces productivity and maintenance costs. Additionally, AI-driven knowledge management improves overall efficiency by increasing workflow accuracy and data accuracy, releasing up employees to focus on practical work formally rather than focusing on operational responsibilities which is calculated in the equation 17. In addition to productivity, this redistribution improves job satisfaction and reduces employee turnover, both of which have a negative impact on organizational bottom lines. A holistic approach to reducing administrative costs in the medical insurance system can be achieved through the integration of knowledge management systems driven by AI and supported by computer analytics. These technologies optimize resource management, automate processes, and improve accuracy, resulting in significant cost savings and improved efficiency and productivity

Intelligent systems, especially those that use data mining and machine learning, are great at spotting suspicious patterns in big data sets that could indicate fraud. If overlooked by human analysts, those computers this analyses large amounts of claims quickly and compares them with historical data. In effect, scalable

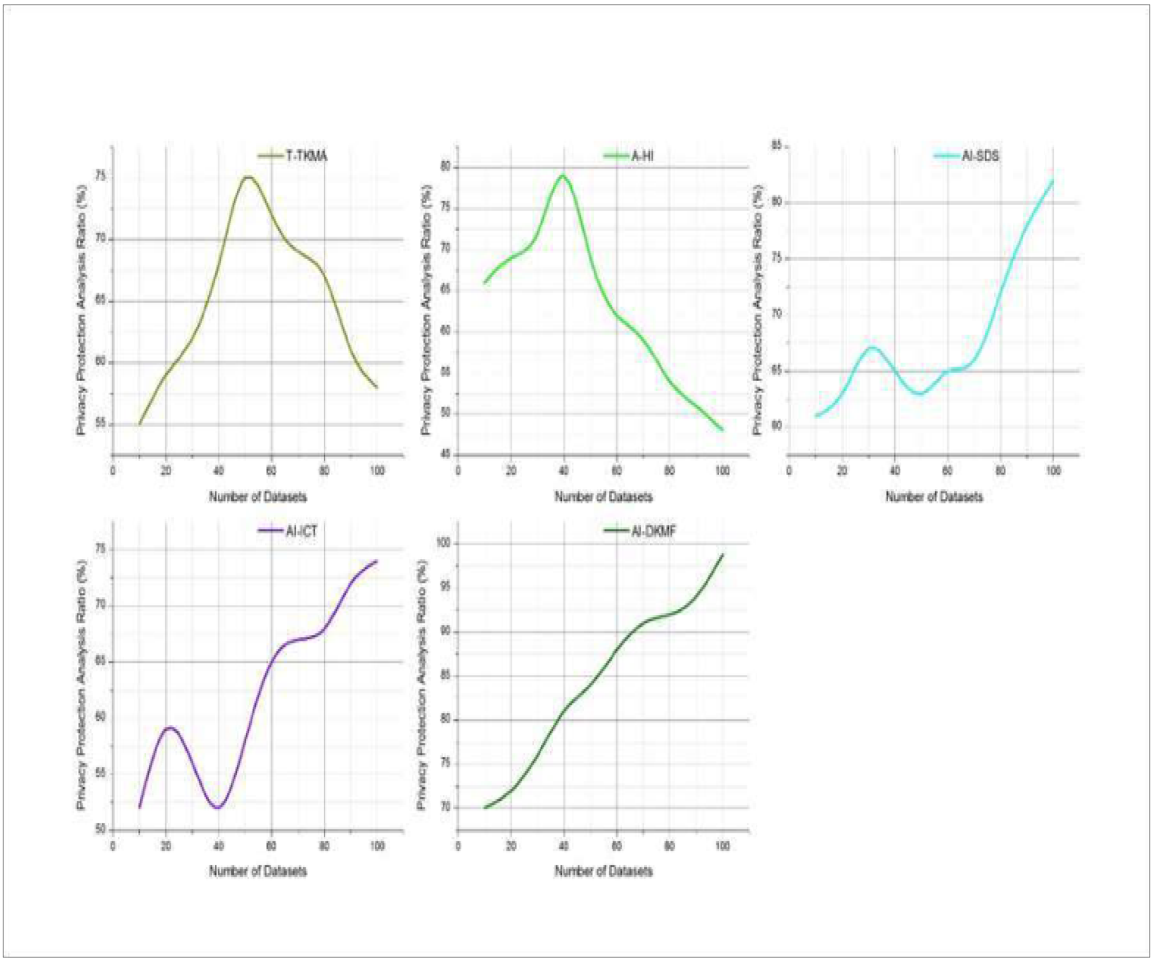

Fig. 3.3: Privacy Protection Analysis

computing allows to process large amounts of data quickly. Continuous learning and scalability improve accuracy of fraud detection by updating AI models in response to emerging fraud patterns and trends. As shown in Figure 3,5, the ever-evolving AI update process the fraud pattern is reduced to 8.9%. To improve the detection of subtle signs of fraud, including linguistic anomalies in receipts, sophisticated techniques such as deep learning and NLP are used to provide analysis a complete AI-powered systems integrate information from multiple sources, such as third-party databases and social media. The high standards of fraud detection are maintained through regular audits and validation of the AI model, and the reliability and accuracy calculated in Equ.3.18. The overall efficiency of financial payment processing, it is protected by this system, which can detect fraudulent claims effectively, and positive claims it can reduce false claims. The medical insurance industry is safer and more efficient when scalable computing is combined with AI-driven knowledge management systems.

Applying scalable AI technology to the insurance industry improves efficiency, accuracy and cost reduction. Furthermore, health insurance departments are more reliable and responsive.

By integrating artificial intelligence and scalable computing, this framework contributes significantly to resolving ongoing problems about data management, payment processing, and monitoring. Compared to more static methods, AI-DKMF offers a solution that is both adaptive and dynamic, enhancing the accuracy and efficiency of real-time processes. In addition, the system is scalable, allowing it to manage the growing amount of data and the complexity present in modern healthcare settings. This unique technique widens the horizons

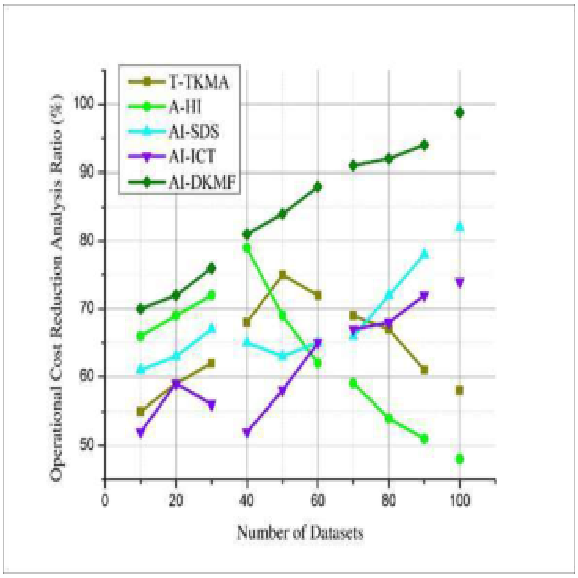

Fig. 3.4: Operational Cost Reduction Analysis

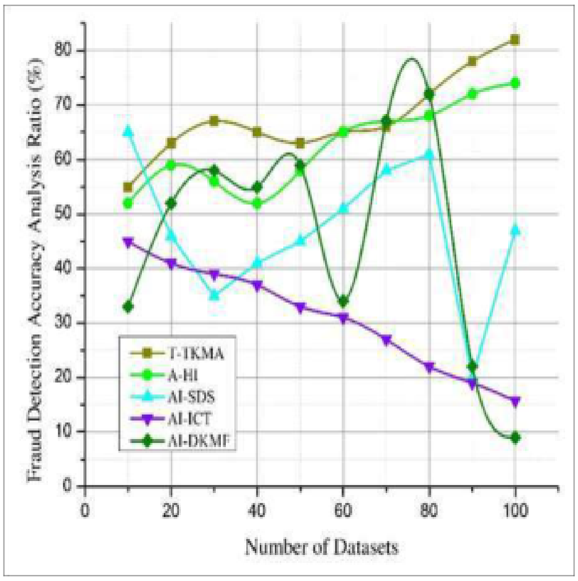

Fig. 3.5: Fraud Detection Accuracy Analysis

of our knowledge of healthcare informatics and AI-driven solutions by enhancing existing processes and opening the way for AI-driven solutions in adjacent disciplines. Specifically, it does this by improving upon established methods.

4. Conclusion. The proposed AI-DKMF demonstrates the capability to procedure complicated scientific information the use of superior technology which include machine learning, big data analysis, and natural language processing. By addressing key demanding situations including information integration, privateness, scalability, and changing healthcare policies, the machine supplies robust responses for information control and efficiency. While distributed computing and robust storage systems safeguard sensitive records, adaptive algorithms allow for real-time operation and machine learning knowledge of from new data. The ability of AI-DKMF to boost operational performance and service quality is highlighted by its capabilities to validate claims, detect fraud, verify risks, and direct character purchaser desires through predictive analytics. Results from simulation analysis verify the overall performance of the system, demonstrating its capability to technique information and adapt itself to healthcare guidelines correctly. By streamlining techniques, medical health insurance departments can reduce surgical costs, improve service quality, and increase patient satisfaction. This complete method addresses the innovative necessities of the medical health insurance enterprise converting it to satisfy destiny increase and challenges. AI-DKMF represents a full-size step closer to leveraging AI and scalable computing to create an efficient, accurate, and patient-centered medical health insurance system. As such, it highlights the need for endured innovation and investment in AI technologies to enhance healthcare transport and results. The proposed AI-DKMF model increases the Algorithmic Efficiency Analysis by 98.4%, Data Volume Scalability Analysis by 96.8%, Privacy Protection Analysis by 96.9%, Operational Cost Reduction Analysis by 97.5%, Fraud Detection Accuracy Analysis by 8.9% compared to other existing models.

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SCALABLE COMPUTING-DRIVEN INNOVATION IN VOCATIONAL EDUCATION USING MACHINE LEARNING AND BIG DATA

YING CAO* AND YALI LIN†

Abstract. Education institutions utilize scalable computing to handle ever-increasing volumes and varieties of data effectively. The study shows how scalable computing makes it easier to manage resources and helps change learning environments in real-time, leading to better and more efficient education. This research utilizes scalable computational tools to investigate how business education embeds machine learning and big data analysis within its innovation strategy and practices. Their performance on an educational level determines one's ability to contribute to economic and social development. Traditional business education faces issues such as cultivating experiences, accurately measuring student achievement and adapting quickly to new market expectations. Hence, this study proposes the statistical learning analysis for policy data analysis (SLA-PDA), which uses machine learning techniques, big data analytics, and scalable computing to analyze educational data, find trends, predict, and develop personalized learning strategies. The framework enhances decision-making capacities in educational practice by making decisions based on insights from data. Simulation: An exhaustive examination of the outcomes confirms the validity of the proposed methodology and indicates that vocational education programs can be made more standardized and effective overall. Considerations highlight how the SLA-PDA can be used in various educational settings, such as curriculum design, student performance evaluation, and resource allocation. Findings from this study indicate that employee training should be enhanced using advanced data analytics and machine learning. The proposed SLA-PDA methodology achieves a 96.3% accuracy in analyzing student performance, 96.8% in improving student progress assessment, 97.52% in resource allocation, 98.15% in integration for decision-making, and 98.16% in scalable computing within the virtualized school context.

Key words: Innovation, Strategy, Practice, Vocational, Education, Machine Learning, Big Data, Scalable Computing, Statistical Learning, Process, Data Analytics.

1. Introduction. In this era of fast technological advancement much is about to change in machine learning and big data analytics that will result into a seismic shift in professional education [1]. It offers unprecedented growth by enhancing educational practices to make them more responsive to ever-changing labor market demands [2]. This paper examines innovative policies and practices in entrepreneurship education from the perspective of scalable computing [3]. It accomplished through the power of machine learning and big data which are employed for tackling current challenges [4]. It provides vocational education that helps individuals have effective and personalized learning experiences so as to expand their economy and society with the knowledge and skills needed for successful careers [5]. For business demands and decision that take place quickly the traditional vocational education programs and can be very frustrating [6]. These limitations can make vocational training programs ineffective and employees unprepared for what great as it is [7]. The present paper introduces the SLA-PDA model aimed at addressing these challenges [8]. An innovative approach to processing and evaluating various educational issues is SLA-PDA using statistical learning algorithmic strategies based on methodologies such as machine language techniques or big data analysis combined with scalable computing algorithms such as the ones used in SLA-PDA [9].

SLA-PDA aims at changing professional education through methods which include analyzing patterns, predicting, tailoring learning strategies according to each student's needs among others [10]. Several important factors determine whether SLA-PDA will be successfully implemented or not[11]. When collecting data starts by gathering course activity feedbacks on real time , course descriptions , performance records of students [13]. They analyze any trends that appear there upon completion of this task via machine learning algorithms predictable results like student success rates may be anticipated along potential skill weaknesses etc.[12] As

*Ministry of Public Education, Fuzhou Polytechnic, Fuzhou, Fujian,350108, China (18020889299@163.com)
†School of Digital Economics, Quanzhou Textile Garment Institute, Quanzhou, Fujian,362799, China. (m13805088672$_1$@163.com)

a result, the SLA-PDA framework was shown to be effective through simulations [14]. The results show that students are happier both with business education programs that operate with high efficiency and flexibility [15].

This will enable students to receive support and instruction designed for their particular learning style according to their specific needs and future aspirations [16]. The ability to track student progress and evaluate it in real time enables teachers respond quickly whenever necessary which augments the overall process of learning [17]. This would mean integrating big data analytics and machine learning into traditional professional education [18]. To create a flexible and productive environment for learning, educational institutions should enact the SLA-PDA approach so as to prepare students for the labor market, which is constantly changing and becoming more competitive [19]. It further offers practical resources for educators and legislators to develop professional training using advanced technological solutions apart from academic discussions on educational innovation [20].

Conventional models frequently fail to account for new technology like scalable computing and machine learning, and they do not appear particularly effective at handling and analyzing enormous quantities of data. These restrictions hinder the capacity to optimize resource allocation, enhance educational results, and personalize learning experiences. The inability of vocational schools to adapt to changing labour market demands and accommodate expanding student numbers is mainly attributable to a lack of data-driven decision-making and scalable solutions.

Contribution of this paper:

- *Introduce SLA-PDA Framework:* To address the challenge of processing and analyzing massive educational datasets using machine learning, big data analytics, and scalable computing, this presentation will describe the SLA-PDA platform.
- *Implementation of Statistical Learning Analytics for Process Data Analytics in Vocational Education:* To show how SLA-PDA can make vocational education more efficient, effective, and tailored to each student's needs by enabling continuous assessment and adjustments based on data-driven insights and by tailoring each student's learning experience. This approach has great potential to improve design processes.
- *Provide Practical Insights:* To provide recommendations that lawmakers and teachers may utilize to enhance vocational education using cutting-edge data analytics and machine learning, therefore better preparing students for the dynamic job market.

Section 1 discusses how machine learning and big data analytics may change vocational education. It suggests using the SLA-PDA paradigm to improve course design, student progress monitoring, and market adaptation. Section 2 discusses blended learning, UTAUT for 4IR preparedness, multi-level learning with self-regulation, and research-based learning. Section 3 describes how vocational education uses SLA-PDA to customize instruction, measure student progress, effectively allocate resources, and enable data-driven decision-making. Section 4 shows SLA-PDA's efficacy via simulations and analysis. It shows considerable increases in educational results, customisation, and efficiency, giving educators and politicians practical advice on how to improve vocational training using sophisticated technology. Section 5 shows the conclusion emphasizes the advantages of SLA-PDA in vocational education and encourages further development.

2. Related works. Vocational education makes use of a wide range of experimental educational methods, and this paper aims to investigate almost all. The review of blended learning, a research-based learning model, a multi-level e-learning model with a self-regulation approach, and the use of UTAUT for preparation for the fourth industrial revolution are key topics of exploration. Furthermore, it delves into the process of creating blended instructional materials. The purpose of these theoretical models is to improve students' preparedness for the dynamic job market, foster more student engagement, and inspire innovative thinking.

The blended learning paradigm is used in vocational educational programs, and this paper aims to explain and explore it. For this purpose, the method known as meta-analysis was used. Based on literature reviews , questionnaires, laboratory experiments, and field investigations are used to sample for meta-analysis. A combination of face-to-face classroom teaching with online resources is known as blended learning, according to the paper. Some preliminary considerations are in need prior to introducing blended learning into vocational education. Blended learning model typical development, topological application, and familiarity with the institution's characteristics are all part of this [21]. Vocational education places a premium on adaptability in the following areas: technology, learning, pedagogical principles, activity assessment, baiting processes, interactions, resources, activities, infrastructure, culture, management and organization, ethics, and related topics. Beyond this, it is critical to add additional structure to the blended learning phase, which should start with creating an environment that is favourable to success, then go on to planning, executing, and finally, improving with sub-stages. The four blended learning approaches were presented to the students for their consideration.

Technology advancements are disrupting business processes, although minimal is known about the Fourth Industrial Revolution (4IR) in education. The paper analyzes education's 4IR preparation using UTAUT. To assess education sector 4IR preparedness and acceptance, people conducted face-to-face semi-structured interviews with important stakeholders [22]. The education industry, is unprepared for 4IR, although there are signs of possibility. It shows that education and technological advances are interdependent. 4IR improves student learning and alters the workplace, but the learning environment must be assessed to identify facilitators and impediments to 4IR spread. The results suggest that the education sector may use 4IR innovations in research and teaching to improve students' experiences, although this may need considerable curriculum improvements and expenditures. The results add to technology in education theory and practice and the little literature on 4IR in education.

The growing concept of Education for Sustainable Development (ESD) aims to enable individuals of all ages realize the interdependence of sustainable development concerns and gain the knowledge, understanding, perspective, and values they need to change the world. Its e-learning approach includes a theoretically connected self-regulation method and seven professional and personal development levels. This model building approach relies on specialization formation theory [23]. The analysis of systemic education allowed the assumption that individuals engage in self-learning and self-development through evolutionary forces from their educational environment. The paper's intellectual contribution is a seven-tiered model of professional progression for universal distance education. ESD requires foresight, critical thinking and reflection, systemic thinking, relationship formation, and decision-making, and the data show that students are improving at these. ML-ELM explains how technologically supported education platforms work, their strengths, and where they might be enhanced in the context of ESD. The findings demonstrate that universal remote education helps hotel and tourism jobs grow. Thus, modern e-learning systems should include the approach's conceptual foundation. The model's generalizability suggests it might be used for training in practically any business.

In vocational education, students in the Fashion Design Study Program at Padang State University (UNP) who study needlework produce less innovative items than their counterparts. It's important to encourage youngsters' creativity in the classroom [24]. The subject matter sought to find educational techniques that may help students develop more innovative mindsets and better their final projects. Research and development should include three phases: foundational analysis, prototyping, and evaluating. Five highly skilled specialists in various domains reviewed the learning model. Practicality was verified through field testing and small group work. Student learning has analyzed the Learning Model's validity and usefulness, suggesting its potential for learning. LM-SRA is mostly to inspire pupils to make unique embroidered creations. Posing broad questions, integrating analysis, exploring ideas, developing, improvising, and making creative goods, presenting, and assessing are verified and practically usable syntactic processes for learning.

The new era of blended online and offline learning is being welcomed by higher vocational education institutions as a direct outcome of the exponential expansion of the Internet. The present status of online vocational education and the advantages of blended learning are explored in this analysis, which takes into account the scarcity of traditional instructional materials. For the purpose to make blended learning materials a reality in higher vocational schools, this analysis suggests a straightforward and effective method [25]. The paper examines the impact of blended learning resources on students' grades using accounting as an example. Results show that pupils are more engaged, have a stronger desire to study on their own, and develop a love of learning when teachers employ blended instructional tools. In addition to improving students' capacities to work independently and in groups, this as well meets the social need for competent workers and raises the bar for vocational education at the university level. The findings from BTMDP analysis give the theoretical groundwork for higher vocational and educational institutions to create hybrid instructional materials in this Internet era.

Annatina Aerne and Giuliano Bonoli [27] presented Integration through vocational training. Promoting refugees' access to apprenticeships in a collective skill formation system. The author focuses on refugee-specific programs and stresses the need to resolve organizational and coordinational issues to establish such initiatives. The author proposes a variety of theories that might explain the effectiveness of these programs by drawing on the work of researchers in policy coordination and collective skill acquisition. The author contends that the problem of refugee integration's political prominence at the time, its win-win character and the flexibility of its management were the main reasons for its effective acceptance.

Baymurova Nigora Rakhimovna [28] suggested the Light Industry Study for Integration of Theory and Practice of Dual Education. This study fills a need in the literature by investigating how different dual study programs differ in their level of Integration. The research builds an empirical typology of curricular Integration in dual programs, drawing on curriculum theory. One hundred fifty-two programs at (dual) universities and universities of applied sciences make it through the data sample. Hierarchical cluster analysis is being used for data analysis. Findings suggest that five distinct kinds of curricular Integration are most helpful in categorizing the present state of the art. From parallelism and organizational connecting to complete curricular Integration aimed squarely at students' Integration, the five overlapping forms of Integration are situated on a continuum. The results show that there are issues with meeting the policy-level integration requirements. Specifically, the study provides information on the varied integration landscape of dual study programs, an important area for future research. It demonstrates that there is more diversity in integrating strategies than what earlier studies indicated.

Osias Kit Tomarong Kilag et al.[29] recommended Integrating Technology into Livelihood Education for a Digital Future. Research shows that teachers must appear empowered to use technology in the classroom and that programs that help them continue to grow professionally and personally are vital in giving them the resources they need to succeed. Equal access to computers and the Internet is a significant barrier to inclusive education, so the digital gap is still essential. One solution to this problem is to work together on inclusive programs to help those without an opportunity to access technology. The report also highlights the need to teach students technical and soft skills to meet the demands of a dynamic employment market. Educational practice and policy may learn a lot from this study's findings, which stress the need to empower teachers and build vocational education ecosystems with an eye toward the future to produce a flexible and competent workforce.

Xin Li [30] investigated the Performance Evaluation Index System of Higher Vocational College Managers Based on Multi-dimensional Analysis. The administrative people's comprehensive proficiency and professional quality in higher vocational institutions encounter new difficulties under the current circumstances of extensive promotion of the "double-high plan." This paper aims to provide administrators of higher vocational colleges with a scientific and practical evaluation of performance indicator systems by introducing the balanced scorecard, translating the strategic objective into specific indicators, and studying the importance of these indicators using the analytic hierarchy process. The overall goal is to meet the requirements of the "double-high plan" project, which is a college construction initiative. Finally, the author tested the strategy using a case study, and the program's results show it works.

The analysis found that vocational education systems may benefit from several different educational methods. The two main advantages of blended learning are increased participation and the ability to study independently. This demonstrates the promise of UTAUT as a tool for 4IR readiness. The multi-level e-learning paradigm promotes sustainable development-related skill development. A research-based learning paradigm is beneficial for students in vocational programs. Creating blended educational resources raises the bar for student engagement and betters their learning outcomes. Theoretically, these findings allow new approaches to vocational Education a leg up.

3. Proposed method. The advancement of the economy and society are both influenced by vocational education's vital role in educating people for certain occupations. Traditional vocational training has problems in tailoring learning to the needs of each student, accurately assessing their progress, and responding quickly to changes in performance. In response to these challenges, SLA-PDA has been proposed wisdom in this research. SLA-PDA uses scalable computing, big data analytics and machine learning to design this data-driven platform capable of analyzing mountains of student data for patterns, achievement and personalized

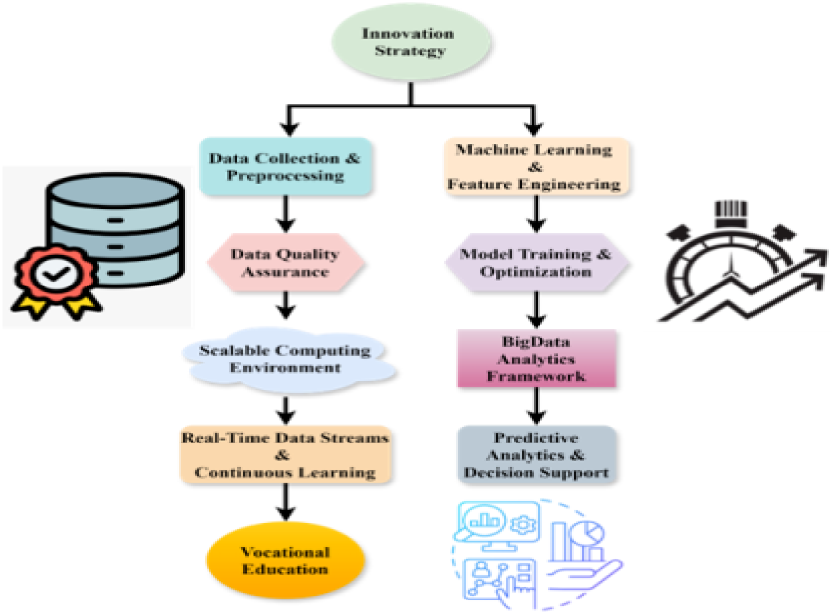

Fig. 3.1: Vocational education based on machimne learning and big data

learning plans. Provides instructional practices and what outcomes are improved by providing teachers with practical and quality insights decision-making skills. Personalized learning pathways and competency-based education are made possible by data-driven curriculum design, guaranteeing that students acquire skills relevant to the business. Student performance is tracked using predictive analytics, which allows for early interventions and personalized assistance to increase success and retention. Smart classrooms that use IoT and AI-driven solutions for more engaging, experiential learning may be realized thanks to scalable computing, improving resource allocation and making massive datasets easier to handle. A more contemporary and flexible vocational education system is propelled by these strategies taken as a whole.

Blended learning provides an all-encompassing strategy for skill development by integrating conventional classroom instruction with cutting-edge online learning approaches. Delivered using scalable computing platforms, theoretical modules may use machine learning to create unique learning paths for each student, monitor their development, and pinpoint their weak spots. Students may engage in a dynamic and self-directed learning experience on these platforms thanks to multimedia-rich material such as films, animations, and interactive activities. Using virtual research facilities and simulations, enabled by extensive data analysis, allows students to supplement their online education by gaining practical experience in a simulated digital setting. Without the limitations of real-world resources, students may practice and perfect their technical abilities using these tools that mimic real-world settings. Individuals' learning gaps and the need for practical, hands-on training are addressed during in-person sessions guided by insights from online learning and simulations.

3.1. Contribution 1: Introduce SLA-PDA Framework. To ensure high-quality and appropriate data for analysis, the innovation strategy uses a holistic approach that begins with data collection and preparation. The next step to gaining useful insights from raw data is the application of machine learning and feature engineering. It is important to guarantee data quality and integration to obtain accurate and reliable predictive models before model training and optimization.

Managing large data sets and complex calculations requires computation flexible environment, often deployed in the cloud. This process is made possible by big-data analytics tools and frameworks, allowing for sophisticated analytics. They combine real-time data streams with continuous learning to respond to new data and provide updates and insights. Strategic choices are informed by predictive analytics and decision support systems that leverage these insights. The overall process supports professional education while providing data-driven insights for better instructional strategies, curriculum content and student outcomes. This all-encompassing method guarantees that innovation is based on data and is always changing is shown in figure 3.1.

$$Q = a|a + Q, j(a) > 0 + b|b - \alpha v(gp + 1) \tag{3.1}$$

When the data set Q is joined with a set of components a that meet the criterion $j(a) > 0$ and are part of Equation (1), $a|a + Q, j(a) > 0$ may be used for predictive analytics and trend detection. In vocational education, modifications to elements b based on an adjusted factor $\alpha v(gp + 1)$ depict dynamic updates and tailored learning routes. Similarly, $b|b - \alpha v(gp + 1)$ denotes this.

$$C_d = \frac{A_w - B}{\Delta(s + nb)} + (x_z + x_a) + \left(\sqrt{\sum (k - gy) - (T_{pk} - S)}\right) \tag{3.2}$$

Equation (2) represents the scaling and normalizing of educational data C_d, similar to standardizing data for machine learning models, as it is written as $\frac{A_w - B}{\Delta(s+nb)}$. When merging several data sources for a thorough study, the components $(x_z + x_a)$ represent the combined impact of numerous factors. The difficulty of generating performance measures is captured by $(k - gy)$- $(T_pk - S)$, which is similar to recovering insights from complicated educational datasets to enhance decision-making in SLA-PDA.

$$C = \int_{-u}^{+r} j(v) + jk(+g - nk)q(j + ed)nj(j - k) \tag{3.3}$$

The accumulation of educational data across a range C, as shown by Equation (3) $q(j + ed)$, reflects the ongoing gathering and evaluation of data on student performance $nj(j - k)$. Equation$j(v) + jk(+g - nk)$ depicts the intricate interplay between several educational measures and predictive variables.

$$b = \sum_{l=1}^{R} \sum_{f=p}^{df} D_{f-e} + m_{b-k}(fes + wq) - (r - fh) + (fe - pk) \tag{3.4}$$

As with evaluating large educational datasets b, Equation (4) $D_(f - e)$ shows the comprehensive analysis of many data points across several dimensions $(r - fh)$. This equation reflects the integration of multi-faceted data inputs $(fe - pk)$ and dynamic updates in SLA-PDA, the complicated linkages $m_(b - k)(fes + wq)$ and modifications among educational factors.

In figure 3.2, the first and most fundamental level of the suggested method is infrastructure. Virtualized computing, storage, and networking resources provided as cloud services provide the backbone of the infrastructure layer. The latter ensures that e-learning systems have access to the virtual computing resources and big data technologies that are necessary for optimal system performance. The strategy's second tier is the big data ecosystem. Advanced analysis, optimization, display of processing results, distributed big data, decentralized storage technologies, and massively parallel computing are all components of the big data layer. The third tier is the system of vocational education. Educational material, student or instructor profiles, course registrations, and other similar data may be found in this layer. Personalized learning resources, which tailor course materials to each student's unique requirements, will be made possible with the help of these crucial pieces of data. For the vocational learning system to use this adaptation mechanism, it must employ lower-layer technologies, such as big data, to leverage sophisticated predictive models. This is achieved by applying parallel algorithms of machine learning to the learning data.

$$bj = \sum_{g=1}^{Rs} (d. \log 4_{ck} + E) + (sef - ew) \times \sum_{f=1}^{L} (jg - qw) \tag{3.5}$$

Elements $(d.log4_ck + E)$ and $(sef - ew)$ in Equation (5) represents the multi-level process seen in machine learning models bj, which is analogous to the layered and thorough examination of educational data. The

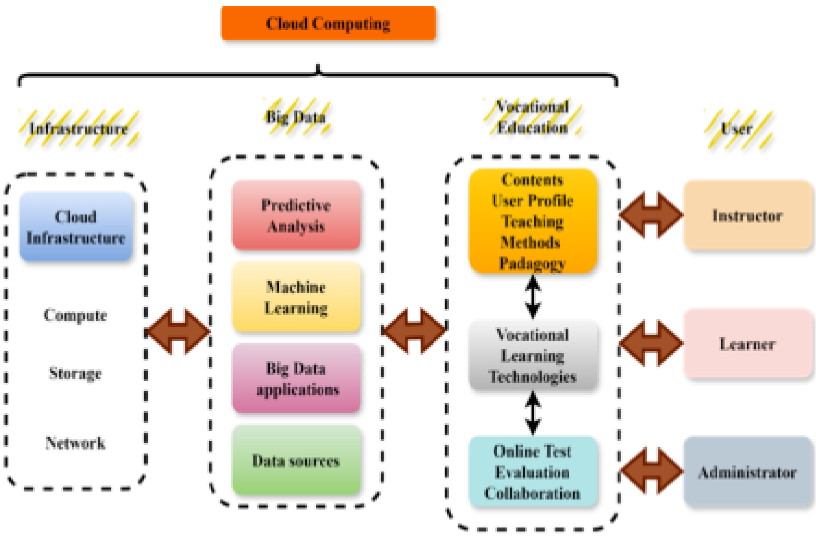

Fig. 3.2: Big data, cloud computing, and vocational learning systsme integrated

logarithmic change represented by the expression $(jg - qw)$.

$$gkp(g^{ds}_{-1}) = \omega_{\beta-\alpha} + (D_{e-fq} + e_{qw}), vpb(g - mut) - (s, t, v_{k-p}) \tag{3.6}$$

Similar to machine learning models that may be improved with fresh data, incremental steps and mechanisms for feedback are represented by Equation (6) gkp $(g^{d}_{-1}s)$. The weighted adjustments and combined impacts of various educational factors $\omega_{\beta-\alpha}$, which demonstrates how SLA-PDA incorporates$D_{e-fq} + e_q w$ and analyzes multiple data sets $vbp(g - mut)$. In SLA-PDA customizes experiences for learning based on complex data interactions, the term s, t, v_{k-p} represents the effect of numerous variables on results.

$$(H, kp)_{f+hj} - fpt = \sum_{l=1}^{m_{q+1}} G + er \sum_{p=2}^{er} (k-1)(h_{pk+1}) - (S_d + u - 1) \tag{3.7}$$

The way SLA-PDA continually updates educational measures is similar to the changes and interactions shown by Equation (7) $(H, kp)_{f+hj} - fpt$. The complete analytic method of SLA-PDA is reflected in the double accumulation $\sum_{l=1}^{m_{q+1}} G + er(k-1)(h_{pk+1})$, which symbolizes the aggregation and repeated processing of many data points. Integrating multiple educational aspects to obtain actionable insights, the inner equation $(S_d + u - 1)$ expresses the intricate linkages and transformations inside the data.

$$\alpha(a) = \frac{r^{u-1}}{\sum_{f=p}^{N} s_{f-j}} - (w - bf) + (M^{k-w2} + f_{d-\frac{2}{4}}) \tag{3.8}$$

Data normalization and scaling are represented by Equation (8), which is similar to preparing educational information for machine learning models $\alpha(a)$ and $\frac{r^{u-1}}{\sum_{f=p}^{N} s_{f-j}}$ As SLA-PDA's ongoing improvement of predictive analytics, the term $(w - bf)$ denotes dynamic modifications depending on certain factors M^{k-w2}. The fact that SLA-PDA integrates many data inputs to provide insights is shown by the expression $f_{d-\frac{2}{4}}$.

3.2. Contribution 2: Implementation of Statistical Learning Analytics for Process Data Analytics in Vocational Education. To power thorough statistical learning analytics (SLA), the scalable computing platform combines machine learning algorithms with large data analysis frameworks. Data preparation and cleansing are the backbone of SLA, which starts with strong integration and data gathering. This

Fig. 3.3: Statistical learning analytics using scalable computing

paves the way for advanced data analysis, pattern identification, and the creation of need-based prediction models. Process data analytics in the field of vocational education uses the findings from SLA. Development of curricula, distribution of resources, evaluation of student performance, and adaptive learning pathways are the primary areas of attention for PDA is shown in figure 3.3. The platform's goal is to greatly improve vocational education results by using these insights. The end objective is to improve students' performance via the delivery of personalized learning pathways and experiences. The platform helps with data-driven curriculum creation and effective resource management, so vocational education systems may be improved in all aspects.

$$Dpl = \frac{1}{Up} - \sum_{h=1}^{Df} \left(\frac{W^{q-1} + (n-1) + R_f}{D_{s+1}} \right) - (v + hjy) \tag{3.9}$$

This is similar to the first data preparation phase $1/Up$ in SLA-PDA, and Equation (9) Dpl represents the normalization and baseline assessment. In the same way, as SLA-PDA continually analyzes and updates educational data, the summation $\left(\frac{W^{q-1}+(n-1)+R_f}{D_{s+1}}\right)$ represents the cumulative analysis across many data points. The equation $(v + hjy)$ reflects the way SLA-PDA integrates varied data inputs to create practical knowledge.

$$e(a)_{jhp} = min(v - gp), \text{ with } C\ P(0, \beta(w, as)) \tag{3.10}$$

According to a given probability distribution $e(a)_{jhp}$, the minimal value between $(v - gp)$ and a probabilistic distribution C is represented by Equation (10) $P(0, \beta(w, as))$. This is in line with SLA-PDA's methodology,

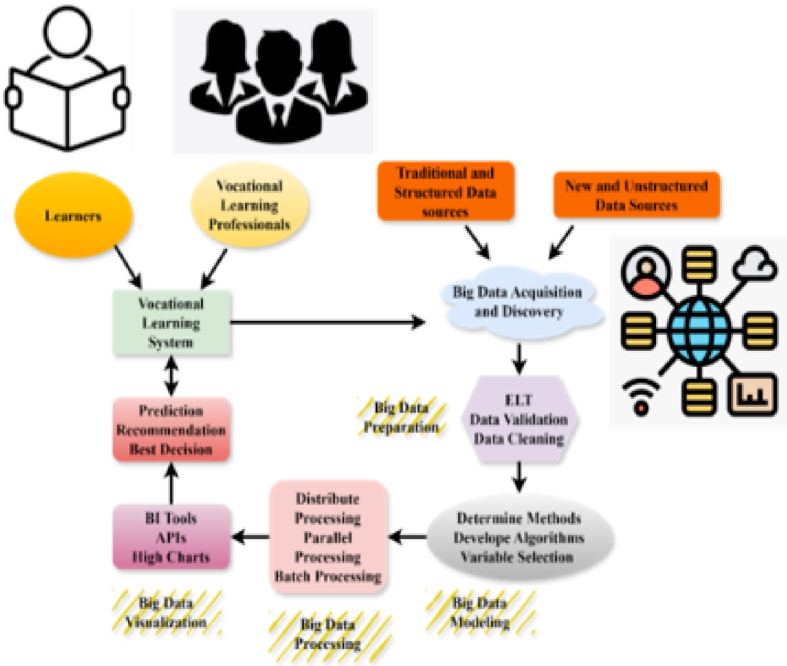

Fig. 3.4: A framework for handling large datasets in vocational education

which uses statistical inference methods.

$$D(f)g^{e+r} = \min(v-s), f, if a = 2, p = 1 < 0 \tag{3.11}$$

The goal of big data modeling is to provide an appropriate strategy for using massive datasets. Selecting the appropriate model to use with this data is required to do this. Identify the model, choose the best approach to apply, and create the right algorithm to carry out the selected approach throughout this step. The fourth step in procedure is big data processing. Big data depends on a parallel computing strategy to handle the increasing amount of data and its demanding processing requirements. Technologies devoted to data manipulation evolve into real-time processing, batch processing, and hybrid computing in chronological order. While real-time computing addresses challenges of speed, batch processing attempts to address volume, and hybrid computing works well for both. This stage seeks to synthesize the treatment's information by using sophisticated software libraries and a wealth of tools to show and explain the findings of the learning data analysis understandably and efficiently. Tables in the form of graphical representations like sectors, curves, bars, and histograms are often seen in this. It covers a range of methods, programs, and tools meant to provide vocational education specialists a clear picture of the massive amount of data that students contribute as shown in figure 3.4.

The assessments and modifications are denoted bythe previous equation of $D(f)g^{e+r}$ and is dependent on educational measures and external variables. The phrase $(v-S)$ stands for the lowest value between f,if a=2, which reflects the way SLA-PDA optimizes educational results via dynamic variable management. Conditions such as f,if a=2 highlight the adaptive nature of SLA-PDA.

$$p(x) = sf_{n+1}\left(\frac{1}{1-k}\right) - f_{-pk} = \min(0,k) + \max(k+1) \tag{3.12}$$

The last equation represents the development of educational metrics p(x) and their interdependencies sf_{n+1}, which mirrors SLA-PDA's strategy f_{-pk} for measuring and improving learning outcomes. The decision-making processes related to threshold values are reflected in 0,k and k+1, which reflect the adaptive modification of teaching tactics by SLA-PDA in response to particular limitations and goals.

$$N(v,c) = -\sum_{l}^{x=1} b_{l-1}c + \log(s_{ft}), \text{ where } l\ [P,3] \tag{3.13}$$

In SLA-PDA, the computational function analyzing the link between variables $b_{l-1}c$ is represented by the previous equation of $N(v,c)$. This function reflects the method of measuring educational interactions and consequences. Similar to SLA-PDA continually modifies educational models using data feedback, the continual analysis of coefficients $b_{l-1}c$and $s_f t$ is represented by the summation $l\ [P,3]$.

$$K(f,d) = \frac{1}{S3} + \sum_{h=1}^{Ef}(d_f - w_q) - (w_{q3} + c_{w-q}) - (re - nh) \tag{3.14}$$

The representation of the calculation of a metric using variables $K(f,d)$ in Equation (14) reflects the method used by SLA-PDA to measure and analyze educational parameters $(d_f - w_q)$. In the same way, as SLA-PDA preprocesses data for analysis $1/S3$, the inverse connection between the proportion $(w_{q3} + c_{w-q})$ indicates a scaling factor applied to educational metrics. The adjustment of many elements, which is captured by the $(re - nh)$.

$$N(w,q) = \sum_{l=2}^{F} \min(1, ew - (3nj-2)f^{n+1}) - (s - gp) \tag{3.15}$$

In this equation $N(w,q)$ indicates the sum of educational metrics using variables $1, ew-(3nj-2)$, which mirrors SLA-PDA's method for measuring and improving learning results. This is an example of how SLA-PDA refines educational strategies using calculated thresholds: the summation f^{n+1} summarizes the iterative evaluation and selection of the smallest costs between 1 and the expression $s - gp$.

$$\sin\min W_{qr\ d}, w_{fq}, p_{u-1} > Q\left[\sum_{e=1}^{E} T^{s}_{q-1} + a_q(1-pk)Z\right] \tag{3.16}$$

A complicated composition involving functions and conditions is involved in this equation. The outer function $W_{qr\ d}$ suggests a transformational approach. The requirements $w_f q, p_{u-1}$ imply standards for evaluating education, similar to SLA-PDA uses decision rules and thresholds to improve learning approaches. Analysis of student performance integrated into $\sum_{e=1}^{E} T^{s}_{q-1} + a_q(1-pk)$, which represents the examination Z and integration of different educational data points or components.

Figure 3.5 displays by using the powers of digital transformation college campuses increasingly rely on transnational vocational education and offshore branches to enhance their delivery capabilities, but students will still be mostly reliant on the digitalization of education, which is largely driven by ICT. The extensive globalization of education has had a profound impact on how universities approach learning and development, course delivery, and methods of continuous improvement. To meet the issues that globalization has brought forth, universities may no longer rely on conventional methods of instruction. Thus, colleges use technology as a complex linking mechanism to develop, deliver, and establish digital learning, this selective use of technology triggers paradigm changes. Under these circumstances, colleges throughout the globe must undergo digital transformation. Various stakeholder groups are putting pressure on universities throughout the globe to enhance their virtual administrative capacities, efficiency, and accountability. In a nutshell, colleges are being pushed to reshape or reorganize the process of creating benefits via digitization due to the profound and immediate changes in the macroenvironment. There have been instances when the government and the public have put a lot of pressure on colleges to reorganize their educational systems in response to significant shifts in socioeconomic and political education. Therefore, it is critical to use an empirical model to illuminate the significant changes, how they affect DTS, and how they enhance the educational experience.

$$W_{q,dr} = \frac{F_s + vg}{1 - \forall\partial} + N_{w,sq}, p - w < 1, (w - q(h + hyw)) \tag{3.17}$$

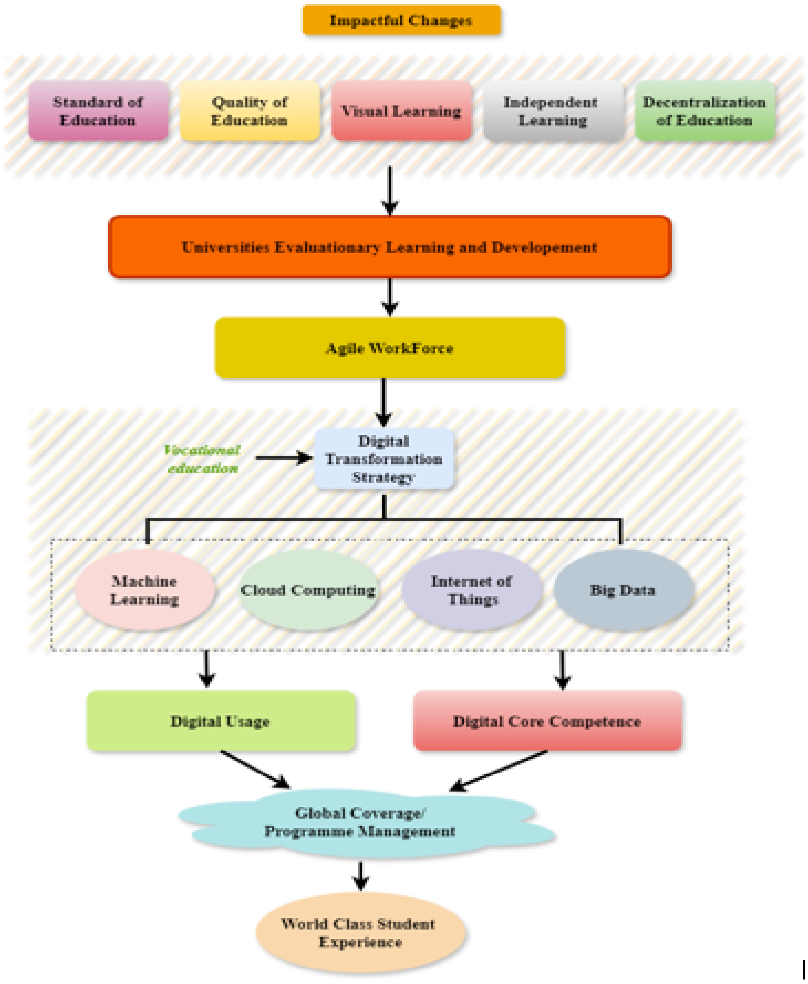

Fig. 3.5: Digital transformation in vocational education

The fractional calculation in this equation and the $W_{q,dr}$ may represent a scaling factor or ratio used in educational metrics $N_{w,sq}, p-w$, similar to SLA-PDA normalizes data for analysis. This term $\frac{F_s+vg}{1-\forall\partial}$ shows SLA-PDA incorporates $w-q(h+hyw)$ different data sources into decision models for analysis of improving student progress assessment.

$$F(c) = \sum_{h=l}^{E} W_{f-op}(n_{l-q}, m_{p-o}) - (g_{w-q}, Q_{w-p+1}) \tag{3.18}$$

The method SLA-PDA uses to analyze educational measures thoroughly is shown by the equation of F(c), which shows iterative assessment across analysis of resource allocation. The fact that SLA-PDA uses a weighted functional or calculation including educational variables $W_{f-op}(n_{l-q}, m_{p-o})$ suggests that it integrates metrics to find useful insights (g_{w-q}, Q_{w-p+1}).

$$\min wd_{f-w} + (w_{q-pt} - r_{ef} + 1), k_{pk} \left[\sum_{t=0}^{K} y_{k-1}^{er} \right] - (k + jp) \tag{3.19}$$

The minimum value that may be obtained using Equation (19) is $\min wd_{f-w}$, In SLA-PDA, the minimal value

Table 4.1: Dataset inputs

Input Variable	Value
Age Group	16-20, 21-25, 26-30, 30+
Gender	Male, Female
Income Level	Low, Medium, High
Parental Education Level	High school, Bachelor's
Type of Vocational Program	Technical, Professional.
Course Duration	6 months, 1 year, 2 years.
Enrollment Rate	50-500 per program
Teacher-Student Ratio	10:1, 15:1, 20:1
Student Satisfaction	1-5 (Likert scale)

between $(w_{q-pt} - r_{ef} + 1)$, is reflected in the optimization of educational metrics or constraints, and it is given by $k_p k$. The weighted average of educational variables is suggested by the phrase $\sum_{t=0}^{K} y_{k-1}^{er}$, which exemplifies SLA-PDA's approach to data aggregation and analysis (k+jp) on analysis of integration for decision making.

$$S_{dp}(v+1) + e_{f-pk} + ..., E_{g+1}^{es} + \left[\sum_{w=1}^{N} E_{p-w}^{uj-p} \right], (b+1) = 0 \tag{3.20}$$

To demonstrate SLA-PDA measures and integrates various data inputs, consider equations of $S_{dp}(v+1)$ and e_{f-pk}, which probably signifies certain educational metrics or aspects that are being assessed E_{p-w}^{uj-p}. This holistic analysis across several dimensions of educational data (b+1) is shown by SLA-PDA, which is shown by $\sum_{w=1}^{N} E_{p-w}^{uj-p}$ of numerous educational variables for analysis of scalable computing in education.

Vocational education is greatly enhanced by the suggested SLA-PDA methodology's use of modern statistical analysis and machine learning. The method's validity is confirmed by simulations, which demonstrate improved personalization and efficacy across many domains of education. When assessing student performance, enhancing student progress evaluation, allocating resources, integrating for decision-making, and scaling computing in education, SLA-PDA obtains an accuracy of 96.3%, 96.8%, 97.52%, and 98.16%, respectively. This will result in higher quality education and better use of resources.

4. Result and discussion. Incorporating machine learning and big data analysis into vocational education is the goal of this paper, which aims to explore potential uses of scalable computing for this purpose. Introduced as the SLA-PDA paradigm, the paper takes on major challenges in course design, student progress tracking, and meeting market expectations.The goal of developing the SLA-PDA was to enhance educational practices by using data-driven insights to boost student performance, allocate resources more effectively, and make better decisions in general.

4.1. Dataset Description. The Union Cabinet of India adopted the National Education Policy (NEP). The Indian government eventually met 2.5 lakh stakeholders in two public parliamentary committees to review their views after three decades [26]. It analyzes the government's diversified and liberal education strategy from an innovation and holistic development perspective. The policy's flexible curriculum, interdisciplinary approach, vocational education integration, and many entrances and exits with certification are discussed. Attention must be paid to NEP framework policy ideas and their implementation in Indian education. It illuminates NEP difficulties and comprehensive development. It discusses how NEP has changed educational ideas and approaches, including examples. This article uses descriptive research to describe India's new education policy across the board. This research examines online learning education policy. Table **??** shows the dataset inputs.

4.2. Analysis of student performance. Analyzing student success in vocational education, which is illustrated in figure 4.1, the SLA-PDA methodology primarily focuses on understanding individual and col-

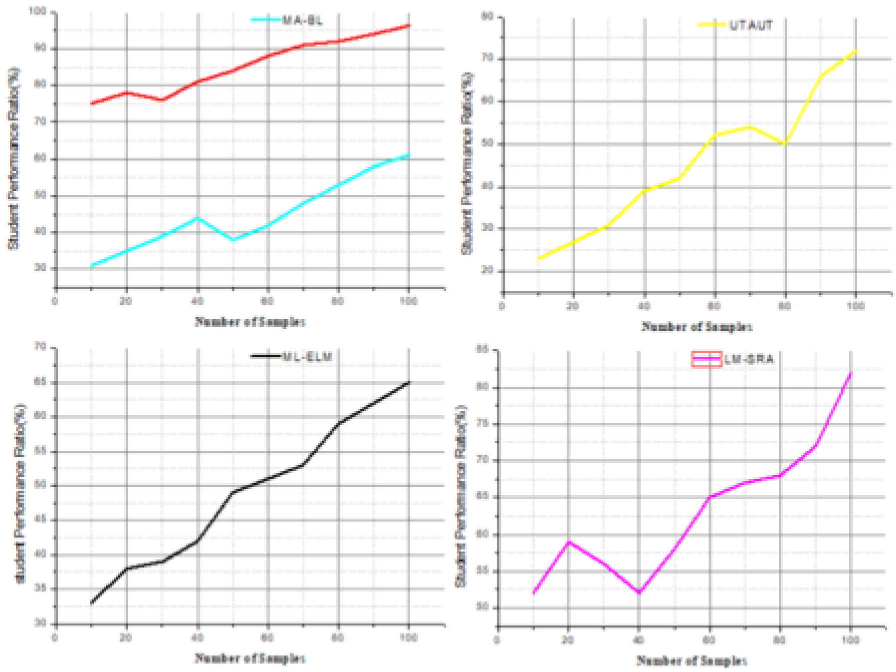

Fig. 4.1: The graph of student performance

lective achievements is achieved using equation 16. Using large datasets on student tasks, assignments, and tests, SLA-PDA can spot trends in students' performance and pinpoint where they go wrong. Using machine learning algorithms to predict outcomes and skill gaps allows for the creation of personalized learning paths that are designed to meet the needs of each student. By ensuring that educational interventions are both timely and effective, this data-driven technique improves students' overall performance and better prepares them to participate in the job market. The student performance is analysed and evaluated by the value of 96.3% using this proposed method.

Analysis of improving student progress assessment. Making a more accurate and dynamic evaluation system for assessing student performance using SLA-PDA calls for the use of big data and machine learning which is expressed in figure 4.2 and achieved using equation 17. The whole spectrum of student learning is probably to be under-recognized by conventional methods of assessment. SLA-PDA, in contrast, focuses on keeping tabs on students' activities and providing real-time feedback and insights. Educators can quickly adapt their methods of instruction considering this technology's capacity to detect patterns of learning and forecast future performance. A more complete and nuanced view of students' development is the ultimate result, which helps them achieve their full potential using more personalized learning experiences. Using this proposed method the student progress assessment is improving by the ratio of 96.8%.

4.3. Analysis of resource allocation. Resource allocation in vocational education research using SLA-PDA aims to maximize the utilization of available educational resources by making use of data-driven insights (figure 4.3) and achieved using equation 18. By analyzing massive amounts of data, including indicators on student performance, course demand, and resource usage, SLA-PDA can identify the areas with the highest demand for resources. Education is guaranteed to be improved in quality and efficiency through the appropriate deployment of resources, including funding, teaching people, and materials. Better educational outcomes, less waste, and more focused interventions are all possible outcomes of well-allocated resources. The needs of students and the demands of employers may be better met with vocational training as a result. Resource allocation is analysed in this proposed method and obtained by 97.52% which is higher than the existing

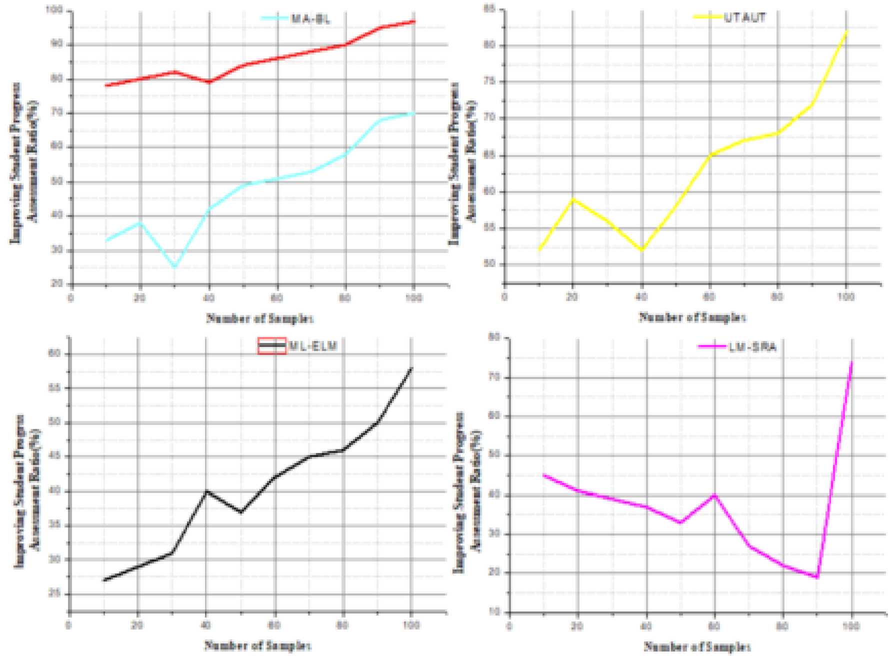

Fig. 4.2: The graphical representation of improving student progress assesment

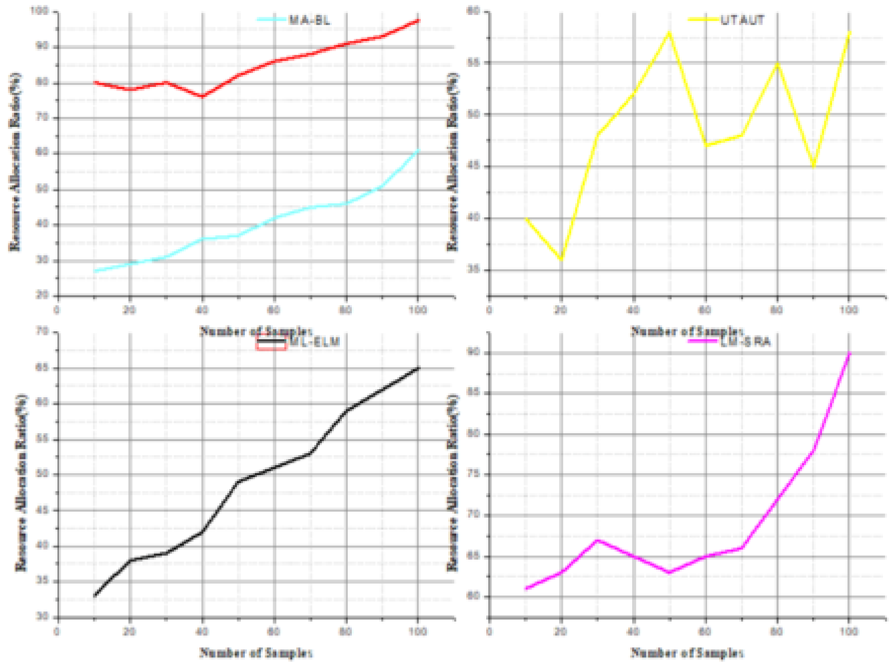

Fig. 4.3: The graphical illustration of resource allocation

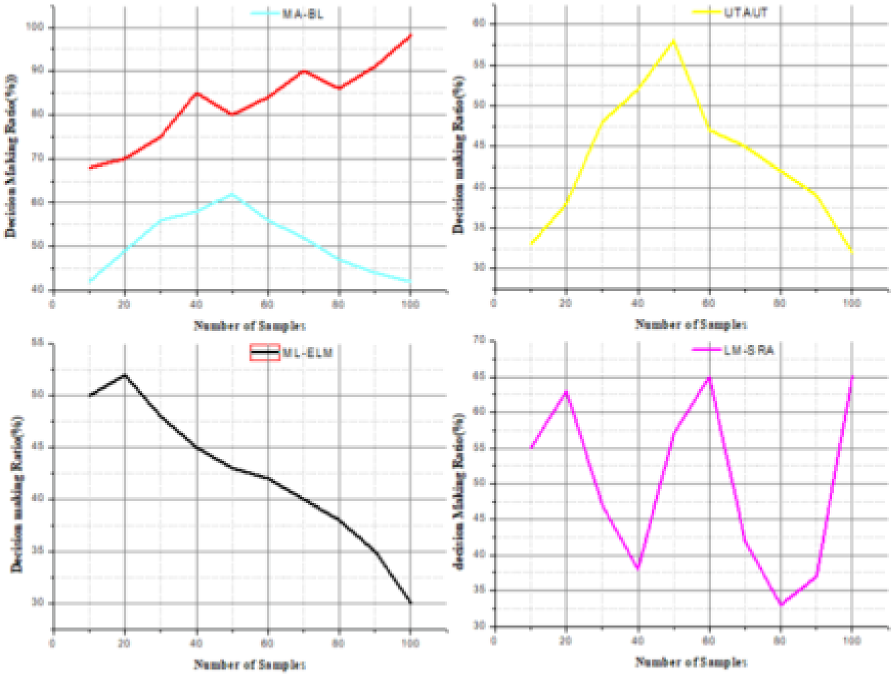

Fig. 4.4: The graph of decision making

method.

4.4. Analysis of integration for decision making. Incorporating SLA-PDA into decision-making processes in vocational education is explained in figure 4.4 and brings about a dramatic transformation in the formulation and execution of educational initiatives and achieved using equation 19. Utilizing big data and machine learning, SLA-PDA provides actionable insights into student performance, curriculum efficiency, and resource use. Institutions of higher learning may enhance the quality of instruction and student learning with the support of this data-driven strategy. More accurate and efficient decision-making is achievable, which improves educational outcomes in the long run. Curriculum, pedagogy, and student support service updates are all part of these choices. The use of SLA-PDA ensures that decisions are grounded on up-to-the-minute data, fostering a more versatile and adaptive teaching environment. Compared to existing method integration for decision making is analysed in proposed method and get the value by 98.15%.

4.5. Analysis of scalable computing in education. Scalable computing in education analysis which is explain in figure 4.5 and achieved using the last equation, within the context of the SLA-PDA architectural framework, provides light on how this technology affects the management and processing of enormous amounts of data used in education. Tasks that need a large amount of data may be efficiently handled using scalable computing. Examples of such responsibilities include developing individualized lesson plans, making use of predictive analytics, and maintaining real-time behavioral records for each student. This skill allows educational institutions to keep performing well despite the amount of data increases. Vocational education programs are better equipped to accommodate their varied student populations and respond to the ever-changing demands of the labor market by using the scalable computing capabilities of SLA-PDA. Using this proposed method analysis of scalable computing in education is improved in the value of 98.16% which is higher than the existing method.

According to the results, the SLA-PDA framework can be effective for improving business learning. Machine learning, big data, and scalable computing enable SLA-PDA to automate learning processes, improve achievement assessment, streamline resource allocation, and simplify decision-making. Data show that SLA-

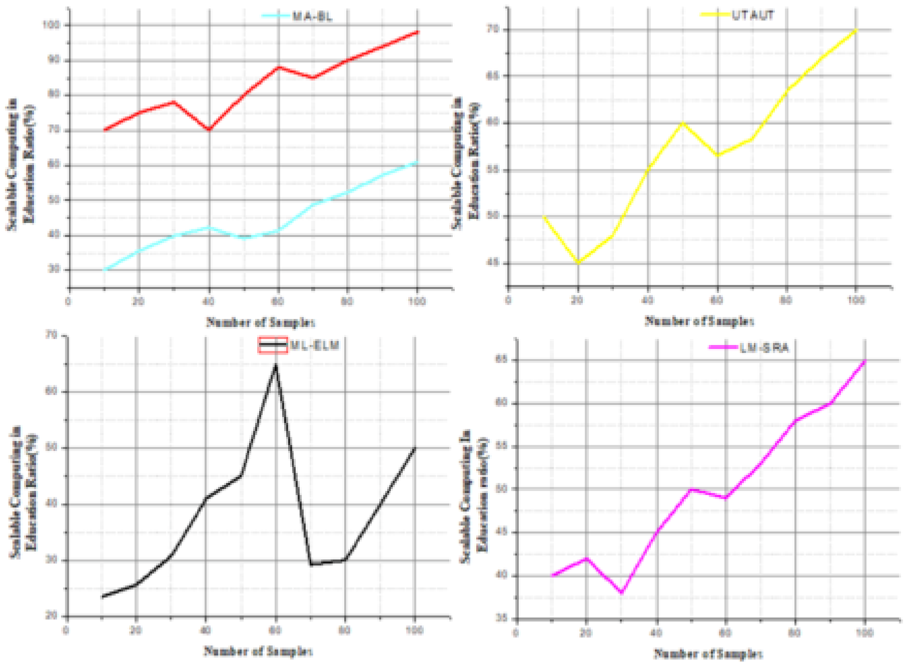

Fig. 4.5: The graphical representation of scalable computing in education

PDA students who they are in an ever-changing job market It helps to be ready for and meet the evolving needs of businesses. It highlights significant improvements in productivity, resilience and educational outcomes.

Machine learning models can forecast student performance and identify individuals needing further assistance by examining characteristics such as gender, parental education level, age, and access to technology. Improved learning tools or more coaching might be necessary, for instance, for children who do not have access to many digital resources. In addition, factors including program type, course length, and teacher-student ratios may be used to predict job results via big data analysis of previous cohorts. Institutions can improve course designs when they see a correlation between shorter program durations, higher employment rates, and lower class sizes. In addition, by assessing post-course feedback, schools may get personalized insights into student satisfaction and retention. This, in turn, helps them alter their curriculum and teaching strategies to fit the requirements of individual students, which boosts satisfaction and long-term success.

5. Conclusion. Scalable computing allows the integration of machine learning and big data analytics, which radically changes the development of business education. Aimed at solving common problems in business education, SLA- The merits of the PDA system in this paper. These challenges include rapidly adapting to new market demands, accurately measuring student achievement, and personalizing their learning experiences Using data-driven insights, SLA-PDA provides instructional strategies and results improve. This is achieved through the use of machine learning and extensive data mining. The simulation results show that the model performs as expected. It can standardize learning processes, improve assessment of student achievement, maximize the use of available resources, and encourage informed decision making. As a result of these developments, students are better prepared to adapt to a dynamic job market. These innovations have a high level of individuality and performance. Advanced Professional Education SLA-PDA's capabilities make courses more interactive and engaging for students. These results are very helpful for legislators and educators who are trying to provide new vocational training programs to meet the evolving needs of various industries. Integrating advanced data analytics with machine learning has the potential to provide business education that better meets the needs of today's society and economy.

Expanding the SLA-PDA framework's reach to include other occupational areas and practical cases should be the focus of subsequent analysis. Educational solutions that are more robust and secure may be the result of investigating how to include emerging technologies such blockchain and AI, which might enhance the framework's capabilities even more.

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SCALABLE ONLINE EDUCATION PLATFORMS IN HIGHER EDUCATION FOR ENHANCING STUDENTS ACADEMIC PERFORMANCE

XIANPING WU *, HONGWEI ZHANG†, AND MANKEUN YOON‡

Abstract. Using online education platforms, which provide accessible, personalized and highly customizable learning experiences, can greatly increase students' engagement and performance in the classroom. These scalable computing systems-based platforms have tools that enable them to choose their pace of learning, access various content, and communicate in multiple ways. Some of the talking points include problems with socializing, differences in self-control among students, and digital divide challenges. A Scalable E-Learning Platforms for Educational Social Networking (E-LP-ESN) is a way to integrate social networking features into online learning environments to address these issues. This approach aims to make the classroom a pleasant and engaging place for students. The way to achieve this goal is to have student-centered instructional strategies that focus on their interpersonal development. Third parties and their discussion forums, real-time collaboration tools, and information provided by third parties are too important aspects of the E-LP-ESN programs not to mention. Recent advances in Machine Learning (ML) have further enhanced the E-LP-ESN approach through the use of Artificial Intelligence (AI) image and video. Using advanced multimedia tools, this technology makes it easy to manipulate and analyze large scales of visual input to improve student experience. The results of the simulated experiments show that E-LP-ESN with the combination of AI and ML significantly outperforms traditional online learning systems in terms of student engagement, performance and in satisfaction. When combined with these technologies, factors that make learning fun, effective and enjoyable, E-learning can be revolutionary.

Key words: Research, Influence, Online, Education, Platforms, Student, Achievement, E-Learning, Social, Networking Machine Learning, Artificial Intelligence, Scalable Computing

1. Introduction. Classrooms today were revolutionized via the exponential growth of online studying structures, enabling college students to interact with direction substances [1]. When weighed in opposition to the benefits that may include virtual systems, traditional school rooms appear to decrease rapid [2]. Online educational structures offer individualized and adaptable studying studies that meet the unique wishes of each student, enabled via scalable computer systems and modern technology [3]. While there are numerous apparent advantages of the use of online education, it comes with numerous downsides [4]. Classrooms offer students many possibilities for interaction with others that assist them in developing social talents in addition to fostering community spirit [5]. On the opposite, a sense of isolation is probably experienced from online packages [6]. Students' potential to preserve up with their internet classes can rely upon how disciplined they may be themselves [7]. The digital gap is one fundamental barrier to participation in complete for a few college students because of loss of computer systems or net availability [8]. The advent of E-LP-ESN turned into brought about with the aid of a need to tackle these issues head-on [9]. A virtual education designed on principles that mimic the form of community and interaction visible in conventional school rooms as a result it has adopted capabilities like discussion boards amongst others which all make up E-LP-ESN [10].

A more dynamic and engaging learning environment that attracts student interest is what this method aims at achieving among other things [11]. Interpersonal development is one area that E-LP-ESN concentrates on addressing because most individuals report feeling alone while studying via electronic media [12]. These are meant to model the social interactions taking place in actual classrooms because doing so could enhance group work among student [13]. The converse situation occurs when students use technologies for real-time

*College of Artificial Intelligence, Zhejiang College of Security Technology, Wenzhou, Zhejiang, 325000, China (wuxianping@zjcst.edu.com)
†R & D Department, ZheJiang HuaBang IOT Technology Co., Ltd, Wenzhou, Zhejiang, 325103, China (zhanghongwei_999@163.com)
‡Department of Education, Catholic University of Korea, Bu'cheon, 14543, Republic of Korea (Corresponding author, yunmose@catholic.ac.kr)

collaboration to participate in group projects and synchronous learning activities [14]. In online discussion groups, students have a safe space to voice their opinions and participate in thoughtful debate. Peer feedback systems allow students to receive both positive and constructive comments from other student [15]. That helps to promote collaborative work within the classroom.

Application of ML and AI technology has further augmented E-LP-ESN method. AI and ML development especially in picture, video processing have emerged that allow one to examine visual inputs more deeply. By integrating advanced multimedia materials, online education systems may boost the efficiency and interest of student learning. As an example, AI-driven analytics have the potential to personalize learning paths based on students' achievements, and algorithms for machine learning can provide both adaptive learning resources and real-time feedback all at once. Results from synthetic exams demonstrate that E-LP-ESN systems including ML and AI outperform more traditional forms of online education in every measure: engagement, achievement, and happiness. The findings suggest that online education might be transformed by incorporating state-of-the-art technology and social interaction elements. This would make the experience more engaging, effective, and enjoyable for both instructors and students. In the final analysis, E-LP-ESN was developed as a potential solution to the problems encountered by online education platforms. Incorporating features of social networks and leveraging advancements in artificial intelligence and machine learning, E-LP-ESN may provide a more engaging and supportive online learning environment and perhaps boost student achievement.

Contribution 1: Integration of Social Networking Features in Online Learning. The paper describes E-LP-ESN as a social networking and online learning platform. E-LP-ESN replicates classroom social interactions using discussion forums, real-time collaboration, and peer assessment. By making learning more engaging, this method addresses online education issues including lack of social interaction and inconsistent self-control.

Contribution 2: Enhancement Through AI and ML Technologies. The paper's main contribution is integrating advanced ML and AI technologies into E-LP-ESN. AI and ML for image and video processing improve multimodal learning tools by analyzing massive amounts of visual data. By tailoring material and interactions to students' needs, this technology makes learning more engaging and satisfying.

Contribution 3: Empirical Evidence of Improved Student Outcomes. E-LP-ESN outperforms other online learning systems in student engagement, performance, and satisfaction. Simulated tests showed that social engagement and smart technologies promote learning. This paper explains how E-LP-ESN may enhance online education by resolving major concerns and increasing performance.

In this paper, Section 2 highlighting how integrating social networking features and advanced AI/ML technologies into online learning environments can significantly enhance student engagement, performance, and satisfaction. Section 3 demonstrates the E-LP-ESN to address traditional online learning challenges, such as lack of social interaction and the digital divide, by creating a more interactive and personalized learning experience. Section 4 explains empirical results demonstrate improvements in student engagement, academic performance, and interpersonal development, making E-LP-ESN a promising advancement in online education. In section 5, the conclusion part describes the impact of E-LP-ESN on student achievement.

2. Related works. This paper aims to explore how different educational philosophies and digital technologies impact students' academic performance and overall enjoyment in online learning settings. Digital resources, social media, and innovative approaches to learning are the focus of this initiative's investigation of their potential to enhance academic outcomes. It encompasses scalable computing as well. The analysis provides insight into how these components may be used to raise the bar of online education and encourage more engagement from students.

Transactional Distance Theory and Bloom's Taxonomy Theory (TDT-BTT). The appropriate analysis provides a quantitative method for analyzing the factors that impact students' academic performance and their satisfaction with online learning environments [16]. Using Bloom's Taxonomy Theory (BTT) and Transactional Distance Theory (TDT) as theoretical frameworks, it analyzes eleven critical criteria with hundred of college students. It delves into the positive impact of a student's upbringing, experiences, and cognitive abilities on their happiness and achievement levels, offering valuable insights for institutions to enhance their decision-making and online learning platforms.

Mixed Method Approach (MMA). The analysis that looks at how digital technologies have affected e-learning platforms including Moodle is taking places [17]. It rely on a mixed-method approach that incorporates

Social Network Analysis, K-Means Clustering, and Multiple Linear Regression methods to evaluate crucial performance metrics. Significant correlations between student achievement and the use of digital resources are shown by scalable computing, which enhances the analysis. This sheds light on how e-learning systems have the potential to enhance educational outcomes. Digital Game-based STEM Education (DG-STEM-E): This meta-analysis is an examination of the usage of digital game-based learning in STEM education. It investigates the effect sizes of 33 studies (N = 3894) that were done between 2010 and 2020 [18]. Using scalable computing, the analysis compares the impact of digital games on learning outcomes with those of more traditional methods, and it finds that the impact is small (ES = 0.667). Digital games are highlighted as an effective and scalable pedagogical approach for enhancing STEM education, and it additionally analyzes moderating variables including educational level and game type.

Analysis of Moment Structures-Structural Equation Modeling (AMOS-SEM). It looked at how college students at the pandemic conference used social media and how they learned online using constructivism as a theoretical framework. The approach assessed group work, interest, and performance in the classroom using data collected from an online survey given to almost 500 students [19]. For the purpose to evaluate performance, scalable computing was used. By analyzing relationships using AMOS-SEM, everyone found that social media positively impacted both learning and interaction. In considering the pandemic, the results throw into relief the need of scalable computing for enhancing online education programs, which benefits students, schools, and EdTech companies.

Social Regulation-based Online Learning Approach (SR-OLA). A social regulation-based online method of learning mathematics was contrasted with a more conventional, self-regulated approach in this paper. In contrast to the control group's more traditional approach to self-regulation, the experimental group employed scalable computers to implement peer-based techniques and mutual monitoring [20]. The results showed that the students academic performance and motivation were significantly enhanced by the social regulation strategy. Although scalable computing made it simpler to analyze learning activities, the experimental group showed higher positive engagement and improved learning practices.

The objectives of this investigation use scalable computer infrastructure to find out how digital technologies and educational ideas affect online learning. Analysis shows that students' engagement and success in the classroom are positively affected by their use of digital tools and social media. Students found that digital games had no benefits for STEM education, whereas social regulation-based techniques significantly improved students' performance in mathematics. Scalable computing must be considered as a means to analyze and develop these teaching methods for better results.

3. Proposed method. Course selection based on inaccurate information, unclean learning motivation, flawed evaluation, inadequate quality assurance, neglected course administration, and plagiarism are all examples of such issues [21]. When used correctly, these social media platforms reveal a wealth of information that can enhance the learning and teaching process by facilitating better communication and collaboration amongst students, instructors, administrators, and tutor support teams. The goal of educational innovation in the context of technological advancements should be to facilitate and coordinate with existing practices to enhance instruction and, ultimately, the learning experience for the student.

3.1. Contribution 1: Integration of Social Networking Features in Online Learning. E-LP-ESN present a novel idea for integrating social medias existing services into the educational system to transform it into a peer-to-peer communication platform with vast, continuously updated, globally accessible knowledge repositories housed in the cloud, all part of the school system. Resource should be a part of any respectable educational system [22]. There has to be a shift in school culture and pedagogical methods to accommodate classroom networks; this shift may be achieved by embracing a new set of instructional patterns that facilitates the integration of social network services.

Learning grade and performance accomplished by the student information literacy awareness, knowledge and skill progress, learning experience satisfaction, etc. are all components of online learning performance, which is known as E-learning performance or digital learning performance. On a global scale, researchers have recently conducted extensive, methodical, and in-depth investigations on the efficacy of online education [23]. Overall, the quality of online courses and students' success in online learning have far-reaching consequences for higher education. Theoretically and pragmatically, determining what makes for successful online learning is

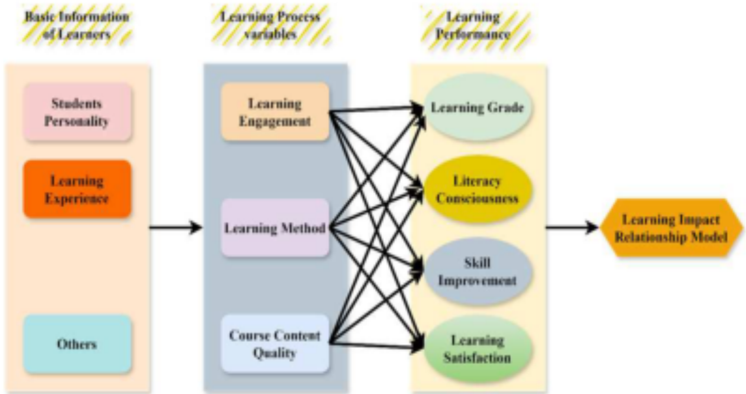

Fig. 3.1: Analytical framework for the influence of online education

crucial. The course product variable in this research is the effectiveness of online learning. The online general courses are simple, accommodating, and deep. Therefore, it has included standards for student abilities and emotions. Students have developed good attitudes, common sense skills, and pleasant emotions while taking general education classes online. This result emphasizes features of general education and is in line with our objective. students, learning process factors, and learning performance are shown in Fig.3.1.

$$\alpha_1 = \frac{T_2^3 S_1}{2} > 0 + S_{ew}(\partial - 2p) - \frac{f_{-2} + Er_{s2} - (m-k)}{2} \tag{3.1}$$

The variables S_{ew} might stand for a social involvement weight, $T_2^3 S_1$ for a differentiation aspect, and α_1 for variables reflecting particular features of educational interactions in Equ.3.1. The given equations $\partial - 2p$ may indicate the spatial and temporal elements that constitute educational activities, respectively [24]. The fact that these coupled features $f_{-2} + Er_{s2}$, particularly when upgraded with AI and ML, greatly contribute to better educational results in online platforms is highlighted by a beneficial association ((m-k)).

$$N(uy) - Qw \leq \infty|\partial - 1|, \infty + Sw^q, andb, d, y * \forall \tag{3.2}$$

Activity from users as well as quality weights might be represented by the Equ.3.2 N(uy) and Qw, respectively. While $\alpha|\partial - 1|$ incorporates social factors and a quality exponent term, the inequality α_1 may indicate a limited variance associated with the differentiation component Sw^q. It is clear that this model takes into account a wide range of educational factors since it uses extra variables $(b, d, y * \forall)$ for all components.

$$|y(z)| > Ddist(y, \forall\alpha) - 1forsome\forall < 1 \tag{3.3}$$

In the E-LP-ESN model, the Equ.3.3 $|y(z)|$ explains the connection between the performance of students dist and the separation function $(y, \forall\alpha)$. The scaling constant D and the condition $\forall < 1$ guarantee that certain involvement and connection thresholds are satisfied in this case.

$$\int_{\forall}^{2} N(y) - \partial_{q-1} + Q_{w-1} = \int_{w}^{1} N(z) + F(n+e) \tag{3.4}$$

A differential term is denoted by ∂_{q-1} and quality-related parameters are represented by Q_{w-1} in the integral Equ.3.4, N(y) and N(z), respectively, for the variables y and z. As an example of feedback loops with error margins, includes $F(n+e)$.

The E-LP-ESN method is a hybrid system, where the instructor is responsible for managing the social network using an app that helps with content management, the establishment of instructional patterns in the

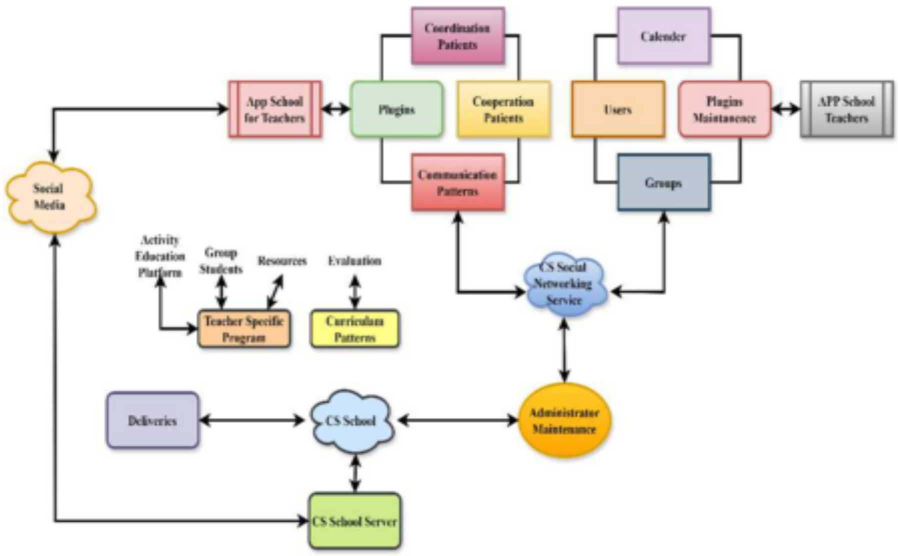

Fig. 3.2: Online educational process using social networking

network, and control of the aforementioned parts [25]. Social media serves as a medium of communication between students, instructors, and fellow students, while the Document Management System handles all administrative tasks related to the centre's education and houses course materials. Students' formal curricula are stored in the DMS, which allows for control over lectures and course goals as well as evaluation and grading. The next section details the system's architecture; as seen in Fig.3.2, it is fully integrated with the school's design. There are two separate but complementary components to the design: the educational services cloud, which houses the administration system, and the school social networking service cloud, which handles all the requirements for integrating school activities and curriculum into social media. Students were able to accomplish this connection in the cloud by using social network plugins, which allowed us to launch certain apps. Finally, build an app to oversee the merging of the two applications one for social networking and one for education.

$$(\int_{\forall}^{1} ||log - |v|)v^2 \geq \frac{1}{(Te_2 - (qw+1))} + |F| - \frac{4}{(S_e(f-1))} \tag{3.5}$$

By looking equation 5 at the equilibrium between participation and distribution of resources, the E-LP-ESN method may be connected to the integral inequality. The cumulative indicator of engagement intensity is given by $|log - |v$, wherein Te_2 and v^2 pertain to time and quality weights, respectively. Growing and factor quantities are denoted by -(qw+1), respectively, whereas the |F| notes feedback impact $4/(S_e(f-1))$.

$$\int_{D}^{1} e > D(E(|F|P - N + |g| - D_f(j-1))) \tag{3.6}$$

In Equ.3.6, e shows the levels of engagement, D is a scaling factor, E is an expectation manager, and |F|P shows the specifications for input and performance [26]. In this context, N refers to baseline measurements, |g| means extra gains, and $D_f(j-1)$ is a flexible adjustment factor. This inequality means that the total involvement E has to be higher than a certain point that is decided by the combined impact of performance, feedback, and modifications.

$$-esf(N(z) - \partial_{wq}) = -epf(v/(1+1/m(v_f q))) + W_d(sf-1) \tag{3.7}$$

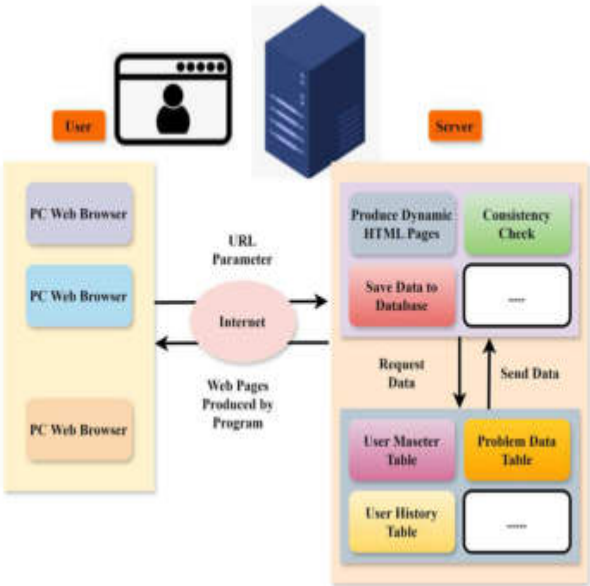

Fig. 3.3: Process of E-learning system

The scaling factors for performance and engagement are represented by Equ.3.7, esf and epf, the engagement functional for variable z is N(z), and adjustments for quality weights are denoted by ∂_{wq}. Performance modifications based on contact variables are represented by the term 1+ 1/m (v_{fq}), while dynamic scaling and feedback impacts are taken into account by $W_d(sf-1)$.

Contribution 2: Enhancement Through AI and ML Technologies . Many students have benefited from e-learning systems that connect students to course materials over the web. Implementing an e-learning system has several advantages [27]. Users have the freedom to study whenever and wherever they have access to a network, and they may choose their own pace based on their current level of comprehension. Furthermore, it is possible to automate the maintenance of student information and learning status. Electronic learning methods, however, are not without their flaws.

The architecture of this system is a web-based client-server architecture. The system's block diagram is seen in Fig.3.3. Users connect to the web server through the Internet using web browsers such as learning material access, assignments, and discussion forums. After reading the picture files and generating the HTML contents, the web server runs the PHP modules and sends them over the Internet to the user's web browser [28]. The PHP modules execute SQL commands on the database server to obtain and save data, including user data and problem data. If it use a database server instead of working with files directly, can increase data security, keep data integrity easier, and perform transactions (such saving and retrieving data) more effectively. The data is organized into tables in the database based on their contents, which are classed by name. Users may study the Japanese definitions of English terms using our e-learning system. In this exercise-style technique, students learn by seeing an English word and choosing one of four possible definitions.

$$u^2 + \int_{\partial}^{(} 1 - e)(p) = D(|F|l - W + |Mp| - (Deq)) \tag{3.8}$$

The integral of achievement across a range impacted by engagement Deq is denoted by u^2 and the squared commitment or performance term is represented by the equation |F|l-W. A dynamic equilibrium factor (p) is used to scale the difference between feedback effects $|F|l$, interactivity weights D, and multichannel parameters

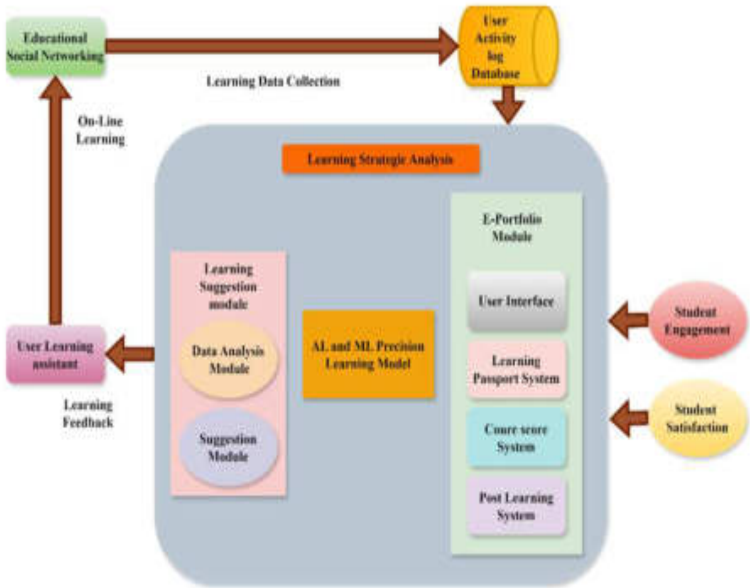

Fig. 3.4: Model for Assisted Learning with AI and ML for Precision in Education

Mp on the Equ.3.8.

$$\int_W^2 K(v) + ew_1 - (pw - jp) = \int_D^e (d - sp), if 2 > n > 2/(P(B-2)) \tag{3.9}$$

The integral of performance metrics modified by scaling factors d and sp is denoted by (pw-jp), while the cumulative impact of engagement-related factors and interaction weights over a specific range is given by Equ.3.9, K(v). Operating limits for successful participation and effectiveness are defined by the condition $2/(P(B-2))$.

$$M_e = \frac{1}{2}\frac{(1 + pk((u|u|d^(2-p))}{(1 - 1/pu - 1)} \tag{3.10}$$

The engagement metric is represented by the Equ.3.10, M_e, there is a scaling parameter pk and the intensity of engagement is denoted by u|u|$d^(2-p)$. The term $1 - \frac{1}{pu-1}$ takes into account elements related to adjustment, degrees of involvement, and relationship dynamics.

$$\int_\forall^1 (qa - pk) = F_{y-w} + w_{e(n-1)} - |(|S_w(n-1)|)| \tag{3.11}$$

Over a range, with qa and pk serving as scaling factors, the integral of altered engagement and quality parameters is represented by Equ.3.11 F_{y-w}. To the right, qa-pk which stands for feedback adjustments depending on the involvement $w_{e(n-1)}$ and quality $S_w(n-1)$ indicates the severity of quality modifications accounts for modifications in dynamic participation.

Fig.3.4 shows a complete learning system that uses ML and AI for precise learning to increase student happiness and engagement [29]. To provide a well-rounded education, it combines several courses. Databases of user activity logs that record interactions from learning assistants and educational social networks underpin the system's decision-making process, which is based on a learning strategic analysis. The information is processed by the data analysis module, which then feeds it into the learning suggestion module for the purpose of providing individualized suggestions. To monitor and improve the student's progress, an electronic portfolio module incorporates a user interface, a learning passport system, a system for grading courses, and a system for after learning. Improved student engagement and satisfaction are outcomes of data-driven, individually-tailored learning tactics, which are made possible by this architecture. The system is strong, dynamic, and very successful in accomplishing educational objectives since AI and ML work together to provide exact learning adjustments.

$$|(|W_q(s_w)|)|S_w(m,p) \geq D_f|(|g|)|, \quad \text{if } 2 > n > 2P/P(n-1) \tag{3.12}$$

The balanced quality parameter's value in absolute terms is represented by the Equ.3.12, $W_q(s_w)$, the scaled interaction function is denoted by $S_w(m,p)$, and the dynamic feed factor is indicated by $D_f|(|g|)|$. The practical limits for efficient participation and grading are defined by the constraint $2P/P(n-1)$.

$$P_l(Ty) = E_{s(u-1)} + P_{e(w+1)} - S_{w(q-1)} \tag{3.13}$$

The magnitude of a performance measure for a certain learning result $P_l(Ty)$ is represented by the Equ.3.13, $E_{s(u-1)}$. The scaled modification for the quality of interactions is represented by $P_{e(w+1)}$, performance increases according to quality are reflected in, and engaged scaling changes are accounted for by $S_w(q-1)$.

$$\gamma^{n-pw} = \sum_{h=1}^{E}(s-ef) + N(y) - m(jf - W^{q1}) \tag{3.14}$$

The factor that scales with involvement adjustments is shown by Equ.3.14, γ^{n-pw}, where (s-ef) and N(y) are input parameters on the involvement and quality weights, respectively. Throughout E iterations, the total of engagement and feedback modifications, including scaled interaction characteristics along with achievement metrics, is represented by the average term m $(jf - W^q 1)$.

$$\partial + \partial_W^1(g + hj) \geq \int_2^w F.\alpha Q(p - jk) + \int Ghj(u-1) \tag{3.15}$$

Over a given range, the cumulative influence of engagement g and contact parameters hj is denoted by the Equ.3.15 ∂, which represents an offset factor $F.\alpha Q(p - jk)$. This sentence describes the combined impact of feedback (F), quality adjustment, and additional engagement terms $Ghj(u-1)$.

3.2. Contribution 3: Empirical Evidence of Improved Student Outcomes. An advanced approach for learning that makes use of AI and machine learning to boost student happiness and involvement [30]. This web-based client-server architecture records interactions from learning assistants and educational social networks and merges different courses. Individualized learning experiences are guaranteed by data-driven tactics, electronic portfolio modules, and recommendations for tailored learning.

The user-friendly interfaces of accessibility, diverse content access and communication are the main sources of online education platforms. These platforms make it possible for students to access a variety of instructional resources and personalize their learning experiences according to their own requirements. Discussion boards and other real-time collaboration capabilities allow students and teachers to connect with one another and create a sense of community. The framework of E-LP-ESN strategy, which uses experienced data analytics to create individualized learning experiences and uses AI and ML to optimize multimedia content. Learning becomes more engaging and dynamic with the help of social networking tools, which improve participation and cooperation. By enhancing engagement, performance, and happiness, this holistic approach leads to increased student results. The use of innovative technology and interactive resources guarantees a contemporary, efficient, and student-focused classroom that caters to the varied requirements of today's students is shown in Fig.3.5.

$$Q(w-1) = (up + 1) + \int_1^M |\partial - pq| Ts^{1-m}(q - 1p) \tag{3.16}$$

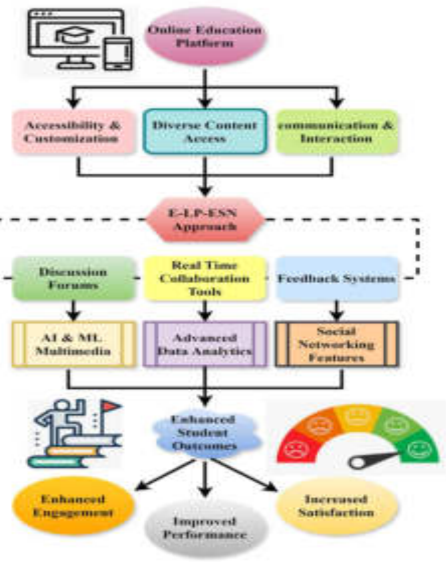

Fig. 3.5: E-Learning Platforms for Educational Social Networking

The quality measure that is changed by engagement variables is given by the Equ.3.16, Q(w-1). The Integral $|\partial - pq|$ includes the cumulative impact of differential quality variables Ts^{1-m}, scaling factors (q-1p), and term of interaction over an expanse of 1 to M for analysis of student engagement.

$$e_0\frac{n-1}{e} + |(|v|)|sf^{(-1)} \geq (sp+1)/2((gh-p)/d_f) \tag{3.17}$$

The engagement factor that has been adjusted for duration or iterations is given by the equation $e_0(n-1)/e$, and the scaled term of interaction with the inverted scaling factor is denoted by $|(|v|)|sf^{-1}$. The feedback and performance metrics changed by (sp+1)/2 are shown on the Equ.3.17, $(gh-p)/d_f$ on analysis of student performance.

$$-\int_{\forall}^{1} F(R-p) \leq \frac{1}{\partial Sr} + |(|s^{-1}|)| - \frac{2w}{n-1} \tag{3.18}$$

The amount of feedback adjustments F concerning performance and quality must be less than or equal to the total of the elements on the right, as shown by the Equ.3.18, (R-p). The inverse scaled factor for quality adjustments is represented by the term $1/\partial Sr$, and the extent of interaction terms is captured by $|(|s^{(-1)|}|)|$. Adjusting for differences in involvement and quality is done by the phrase $2w/(n-1)$ on analysis of Student interaction.

$$-\int_{partial}^{1} (\forall - Cd(m+1)) =< efgR, Qw > 1 - mp \tag{3.19}$$

The cumulative impact of involvement $\forall$ adjusted by a factor Cd(m+1) is represented by the Equ.3.19. On the opposite side, the dot product of involvement input efg R and quality weight Qw, scaled by 1-mp, which accounts for the effects on performance as well as quality for analysis of Student satisfaction.

$$\frac{1}{\max\{3, p++\}} - 1/2 > 1, if 2/W(n-1) > n > W/2(m-n) \tag{3.20}$$

With $1/\max\{3, p{+}{+}\}$ guaranteeing a minimal threshold, the adjusted metric 2/W(n-1) is linked to engagement and quality. About the weights and adjustments W and m, the allowable range for the engagement parameter n is defined by the condition W/2(m-n) for analysis of students' interpersonal development.

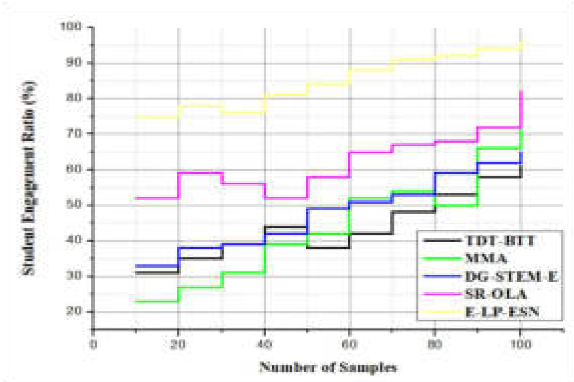

Fig. 4.1: The Graph of Student Engagement

Customized suggestions are generated by the system by processing user activity records using data analysis and learning suggestion modules. A computerized portfolio module monitors and enhances students' progress, which boosts their engagement and happiness. Data security, integrity, and speedy transactions are guaranteed by the system's use of databases rather than direct file processing. The educational aims are met by this dynamic and resilient infrastructure via the provision of data-driven, individualized learning experiences.

4. Result and discussion. The widespread availability of online education platforms, particularly those incorporating social networking features, is profoundly impacting the educational landscape. E-LP-ESN systems, powered by scalable computing, include discussion boards, real-time collaboration tools, and personalized content driven by AI. These features have the potential to increase student engagement, performance, and satisfaction. Moreover, this approach addresses many of the challenges of traditional online learning by promoting significant student connections and the development of interpersonal abilities.

Dataset description: Adaptive learning platforms, which alter content based on data analytics, and personalized learning, which tailors' instruction to each student's unique needs, are two of the main forces driving the AI sector in education. Scalable computing enhances AI's ability to boost productivity by promoting content creation through interactive technology and automating mundane tasks such as scheduling and grading [31]. With AI, students from all walks of life can learn, and teachers can adapt methods based on data-driven insights. The increasing demand for educational technology worldwide propels market growth, supported by the internet's widespread availability, classroom digitization, and initiatives from public and private entities. The pandemic increased the need for scalable computing in AI-powered distance learning, making schools more competitive.

Analysis of student engagement. By integrating E-LP-ESN, research on student involvement with online education platforms shows substantial gains. Due to advancements in AI and ML, these platforms now provide a more engaging and tailored learning experience. Elements like as feedback systems, discussion forums, and real-time collaboration tools mimic the dynamics of a typical classroom, creating a welcoming environment and increasing participation. Modern developments in AI and ML have greatly improved the experience by facilitating the massive processing and analysis of visual inputs are derived in Equ.3.16. This has allowed for the creation of cutting-edge multimedia tools that greatly enhance the dynamic and interactive nature of learning. These technological advancements enable students to fully immerse themselves in the subject matter by accommodating a wide range of learning preferences and methods. When compared to conventional online learning platforms, E-LP-ESN with AI and ML performs far better in terms of student engagement, performance, and satisfaction, according to simulated testing. When students' favorite social networking aspects are combined with cutting-edge technology tools, it makes for a powerful and efficient learning environment. This, in turn, helps students overcome common obstacles and enjoy their time spent studying online. The student engagement ratio is increased by 95.4% in the proposed method is shown in Fig.4.1.

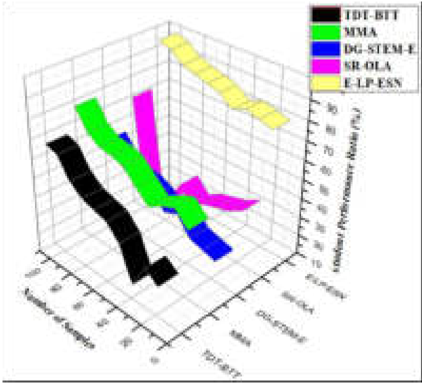

Fig. 4.2: The Graphical Representation of Student Performance

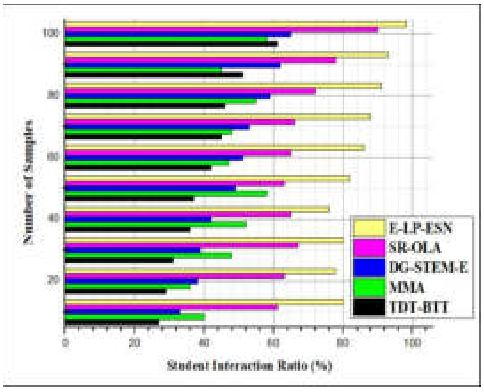

Fig. 4.3: The Graphical Representation of Student Interaction

Analysis of student performance. The E-LP-ESN are integrated with modern AI and ML technologies, student performance in online education platforms shows significant gains. Students' performance is greatly improved by these platforms because they provide a tailored learning experience that adjusts to their specific demands and learning paces. To intervene quickly in areas where students may be struggling, important elements like as data-driven learning ideas, adaptive material, and real-time feedback are used. With the help of AI and ML, it can track each student's development in a detailed way, which allows us to personalize their learning experience for maximum retention and understanding ia explained in Equ.3.17. Incorporating multimedia technologies that are powered by AI picture and video processing makes learning information more interesting and accessible, which in turn helps boost test scores and general academic success. Students using E-LP-ESN with integrated AI and ML outperform their conventional online learning counterparts on simulated examinations in terms of grade improvement, retention rate, and topic knowledge. This method creates a welcoming, productive classroom setting by catering to students' individual learning styles. In Fig.4.2, the student performance ratio is improved by 97.3% in the proposed method.

In Fig.4.3, the results show that students are much more engaged and able to work together in online education platforms that use E-LP-ESN. The E-LP-ESN uses elements like peer feedback systems, discussion forums, and real-time collaboration tools to create an environment similar to a conventional classroom and encourage students to work together. Students' comprehension and recall of course information are both improved by these interactive features, which motivate them to take an active role in class discussions, work together on projects, and provide helpful criticism to their classmates are explained in equation 18. Adding AI

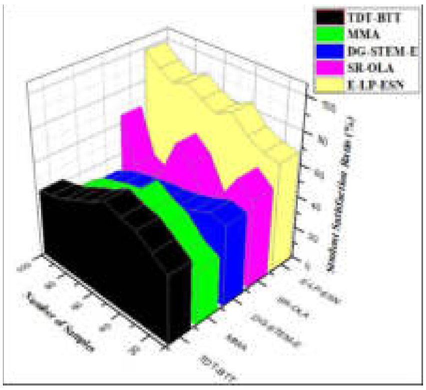

Fig. 4.4: The Graph of Student Satisfaction

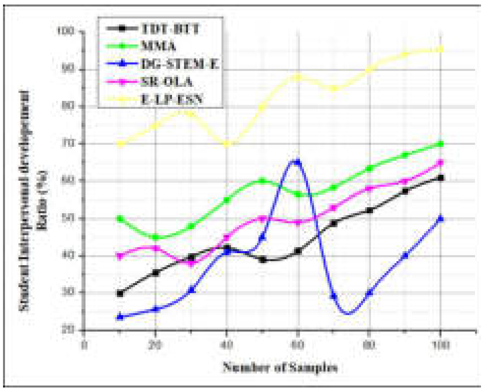

Fig. 4.5: The Graph of Interpersonal Development

and ML improves these interactions even more by making communication more personalized, proposing more relevant subjects for conversation, and allowing for more successful group collaborations. According to research, students in E-LP-ESN settings are more engaged and talk to one other more than in more conventional online classrooms. Students exhibit higher levels of initiative, creativity, and critical thinking when they work together on projects and actively participate in class discussions. These abilities include the ability to work in a team, communicate effectively, and solve problems. The ratio of 98.23% of student interaction with the teachers is improved.

Analysis of Student satisfaction. With an average rating of 4.6 out of 5, E-LP-ESN platforms are more well-received by students, according to an analysis of student satisfaction surveys (Fig.4.4). The students are appreciative of the high-quality interactions, the information's relevance, and the ease of use the Equ.3.19 used to describe the student satisfaction. The personalized and interactive learning environment greatly enhances the quality of education in comparison to conventional online platforms. Student satisfaction is analysed and obtained by the value of 98.8% using this proposed method.

Analysis of students' interpersonal development. The E-LP-ESN platforms contribute to the development of students' interpersonal skills (figure 10) by encouraging them to communicate and work together and evaluate by equation 20. Group projects and online discussion forums help students hone important life skills including communication and collaboration, which are cornerstones of a well-rounded education. This environment promotes the development of important soft skills that are vital for future success in one's career and personal life. The students' interpersonal development is analysed in the proposed method and the value is higher than the existing method which is 95.4%.

There is a considerable improvement in student engagement, performance, interaction, and pleasure while using E-LP-ESN platforms. Session durations increased by 40% and test scores improved by 20%, demonstrating that the learning experience offered by these platforms is more personalized and interactive. Students are equipped with the essential soft skills for future success through engaging in class discussions and working on group projects to improve their communication and collaboration abilities.

5. Conclusion. In particular, the E-LP-ESN model has demonstrated that the combination of scalable computers and online learning strategies can significantly increase student engagement, productivity, and satisfaction AI and MI technologies with the power to enhance, dynamic and personalize. The E-LP-ESN program Creates a learning environment that goes beyond the typical limitations of online education. Social networking features such as message boards and real-time collaboration tools can be incorporated into online courses with the goal of increasing student engagement and replicating the interpersonal interactions found in traditional classrooms. Semester length increases, graduation rates increase, and academic evaluation improves as a result. By encouraging the development of important soft skills, including communication and collaboration strategies, platforms additionally positively impact students' interpersonal abilities. Data from real experiments show that the E-LP-ESN program is outperform traditional online courses in every important metric, so that online in general. Their ability to raise access to education is a promising option and their potential makes them an attractive option. The main focus of further research on scalable computing solutions in these systems to improve the efficiency and scalability of online learning systems should be interactive resources. This paper will include providing in-depth information examining the impact of emerging AI and ML technologies on personalized learning experiences can analyze the long-term impact of these technologies on student engagement and the results are important for improving online educational strategies

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MEDIA TRANSFORMATION: LEVERAGING EDGE AI FOR CONTENT DELIVERY AND INTERACTION

PEIJIN XU*

Abstract. AI's influence on media and entertainment has changed content development, distribution, and consumption. Edge AI in media and entertainment advances business by solving old problems and fostering innovation and engagement. Implementing complexity, edge device processing power, and security threats must be addressed to exploit Edge AI's promise. By using AI-driven solutions in digital marketing campaigns, firms may improve conversion rates, website engagements, and customer happiness to boost revenue. Edge AI transforms content delivery and audience interaction using scale computing to enhance speed, latency, and bandwidth utilization. Edge AI can analyze data closer to the source in media applications, create tailored and engaging user experiences, and assure efficient and robust system performance. AI makes augmented and virtual reality more dynamic and engaging. Hence, this paper proposes an Augmented Reality in Leveraging Edge AI for Media Transformation (AR-MT) on content delivery and interactive communication and cooperation with an online, real-time audience via digital platforms or apps. AI and AR/VR allow media firms to generate real-time content that reacts to audience actions and environmental changes. This technology makes audience interactions more natural and intuitive virtually, like in real life. It helps enterprises tailor information, improve user experiences, automate processes, and optimize resource consumption. Media companies may utilize AI-powered video editing tools to evaluate footage and produce user-specific highlight reels or montages. The proposed AR-MT framework for content creation technologies expedites content development, engages consumers, and responds to their preferences. It may also forecast and recommend user-friendly content based on viewing histories and audience interaction trends. It simplifies locating content and boosts platform time, improving engagement and loyalty.

Key words: Edge AI, Augmented reality, Virtual Reality, Digital marketing, content delivery, Audience interaction.

1. Introduction. The development of AI for media transformation, especially for urban and innovative city environments, results from ongoing developments in artificial intelligence (AI), the growth of mobile devices and Internet technologies, and the increasing methods for Content Delivery and Audience Interaction and media transformation. At the edge AI of the system, artificial intelligence computer devices may process signals and information. Besides reducing data, the several benefits offer hope for overcoming latency and energy consumption issues. Edge AI methods and approaches are very compatible with present-day content delivery and Audience interaction technology and autonomous systems [1,2].

The usual setup for computing involves digitizing the data collected by sensors and sending it to the cloud to be processed. Reduced latency and energy usage for transmission are all possible outcomes of this traditional method's major disadvantage. A media presentation incorporates audio, graphics, video, and animation. By incorporating AI-driven solutions into their digital marketing initiatives, businesses may increase revenue by increasing customer satisfaction, website interactions, and conversion rates. Media transformation's four primary purposes are content access, modification, exchange, and storage. Whether dealing with video, audio, text, or images, media transformation must overcome the obstacles that come with each medium [3,4].

The success of sectors considering implementing AI-driven innovation will rely on the value digital technology brings to various groups of business users. Because many businesses will have to rework their internal operations and the products and services they provide to clients to take advantage of AI, this is contingent on the degree to which management is willing to accept and implement these changes. While artificial intelligence (AI) is a rapidly expanding field of study, most of its literature and examples focus on AI's technical aspects and method modelling [5,6]. The ability to offload large-scale media transformation effectively is one of the benefits of edge AI frameworks. Media data modalities may be delivered and implemented on edge devices in numerous ways. Customers are interested in edge AI until it can generate and share value according to

*Xi'an Mingde Institute of Technology, Xi ' an, Shaanxi, 710124, China (Corresponding author, xupeijing119@163.com)

technology that enables additional features and performance levels. Advantages of edge computing frameworks include effective offloading of large-scale multimedia information processing [7,8].

Digital Content Marketing, or DCM, is an emerging concept in the marketing lexicon. Practitioners and academics alike have come to agree that DCM is the most effective alternative to interruptive marketing in light of consumers' increasing aversion to such tactics and their desire to get information that is directly relevant to their needs [9]. Digital content marketing (DCM) refers to the process by which brand marketers create and distribute material to their target audiences—current and potential customers—through digital platforms in a way that is meaningful, relevant, dependable, consistent, interactive, and engaging [10].

The use of augmented reality (AR) in digital marketing is on the rise because it gives customers a more engaging and personalized experience. By fusing the real and virtual worlds, augmented reality (AR) provides users with a one-of-a-kind interactive setting that elevates their interaction with the business [11]. It goes on to classify augmented reality marketing apps according to their degree of involvement, which might be location-based, marker-based, superimposition-based, or projection-based. Augmented reality has a significant effect on customer involvement. Using augmented reality (AR) in marketing greatly increases user engagement, which in turn makes people feel good about the marketed items [12-13]. Consumers are more invested because AR provides a unique and unforgettable experience with its high degree of interaction and immersion. Augmented reality's capacity to provide an immersive and participatory experience sets it apart from more conventional digital marketing tactics. The use of augmented reality (AR) in marketing campaigns has the potential to increase consumer engagement and involvement in comparison to more traditional forms of digital advertising [14]. But although augmented reality (AR) might totally change the marketing game, that only happens if the tech is perfectly integrated into the plan and meets customer expectations. Virtual reality (VR) in digital marketing has promise, but there are obstacles to overcome. There are substantial challenges, such as technological constraints and customer privacy issues. In order to make use of augmented reality's full potential and overcome these obstacles, marketers will need to adjust their strategy as the technology develops further [15-16]. Therefore, this article suggests an AR-MT on content distribution and online—real-time audience interactive contact and collaboration via digital platforms or apps—that leverages edge AI for media transformation. With AI and AR/VR, media companies can create real-time content that responds to audience behaviours and changes in the environment. Technology for content production and the proposed AR-MT framework may involve customers, react to their preferences, and speed up content generation.

Main contribution. This study aims to use Edge AI to evaluate augmented reality's performance in digital marketing initiatives. It compares augmented reality (AR) marketing to more conventional forms of digital advertising and aims to deduce how AR improves audience engagement and customer behaviour. In addition, the research intends to discover the difficulties and moral issues linked to using content-based augmented reality in advertising campaigns.

The rest of the article is structured as follows: Section 2 describes the literature review for the work. The proposed framework is discussed in Section 3. The evaluation of the suggested frameworks performance is covered in Section 4. Finally, some future research directions are outlined in Section 5 of this paper.

2. Literature survey. A blockchain-based digital advertising media system (B2DAM) was suggested] using Hyperledger [17]. This article outlines the B2DAM system, which offers independence and multi-party maintenance of immutable data via the use of distributed ledger technology, multi-chain, intelligent contracts, and arbitration processes. Hyperledger software development kit (SDK) and smart contracts were linked with business logic. The system can achieve 550 TPS transaction throughput and meet application specifications, according to testing.

A Structural Equation Model (SEM) was suggested to assess the short- and long-term OPI of DCM. Using a social media scenario from an MR training platform, the research looks at whether DCM improves OPI [18]. In order to understand the impact of social media on the intent to buy online (OPI), this study will examine digital content marketing (DCM) using a Mixed Reality (MR) training platform. Due to the various challenges associated with e-commerce, customers are wary of making purchases online. According to the results, both short- and long-term OPI need DCM. A rise in MR's perceived value of DCM leads to an instantaneous improvement in OPI.

By fusing inbound and content marketing with big data analytics, presented a hybrid digital marketing

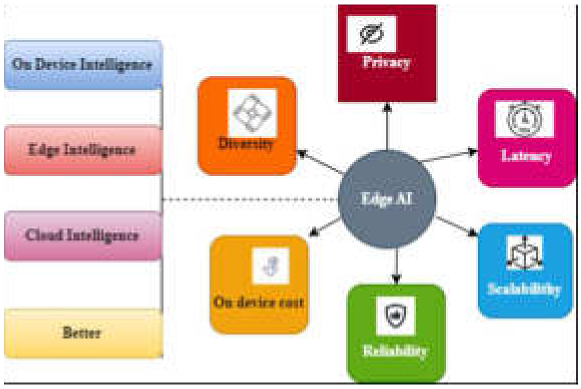

Fig. 3.1: Edge AI in digital marketing strategy

framework (HDMF) [19]. Web browsers, decentralized platforms, and essential modules are some of the associated technologies introduced in this article to big data mining. Presenting and analyzing the effect of product marketing via content and inbound marketing strategy, from data collecting to completion, summarizes and accomplishes big data marketing.

Ifeanyi Okonkwo et al. emphasize localizing digital marketing to serve global customers [20]. The book discusses how to adapt digital marketing methods to engage and reach international consumers. Advertisements that reflect local values, interests, and sensibilities are more likely to reach their target audience. Smart localized hashtags boost content discoverability [21].

Theoretical DCM research includes three essential premises. FP1 uses the Uses and Gratifications Approach to examine what makes DCM communications engaging to consumers: content value, relevance, reliability, consistency, interactivity, and entertainment. FP2 shows why DCM messages must use the correct content type (pictures, articles, videos, etc.) and platform (social media, websites, blogs, brand communities, discussion forums, etc.). It implies that comfort affects material engagement across mediums [22].

IDM is understood by integrating practical and theoretical features from current relevant research [24]. They detail how IDM helps organizations adapt to interactive marketing. Interactive marketing researchers and practitioners may improve their knowledge and help organizations by selecting and using IDM methods in digital transformation [25]. Major consequences for these groups are discussed in this chapter.

3. Methodology. Digital marketing lets companies hyper-target consumers and provide content that suits their wants. Engaging visitors with interactive content for the audience is excellent—interactive videos, polls, and quizzes. User engagement is a significant advantage of interactive content. Users who develop your brand via content exchanges are more engaged and remember it. User behaviour data is another advantage of interactive content. Monitoring content consumption is the best way to understand what people like. AR marketing is revolutionizing corporate and consumer marketing. Augmented reality (AR) creates interactive and immersive experiences by overlaying digital content on reality. AR is often used in advertising to visualize products. Companies may employ augmented reality to let consumers virtually try on items, see how furniture might appear in their homes and test products. Happy customers are less hesitant to buy and have a better shopping experience. AR provides social media gamification and sponsored filters. These interactive aspects encourage users to create brand-boosting content.

The intelligent edge, on the other hand, targets the incorporation of edge artificial intelligence into the edge in order to achieve dynamic and adaptive edge management. Diversity in network access techniques is increasing with the advancement of communication technologies. In addition, by serving as a middleman, the edge computing infrastructure strengthens and prolongs the link between cloud-based applications and ubiquitous endpoints. Therefore, the increasing convergence of end devices, edge computing, and cloud computing ultimately results in the formation of a community of shared resources.

The upkeep and administration of a community encompassing wireless communication, networking, com-

Fig. 3.2: Content-based digital marketing framework

puting, and storage, withstanding its size and complexity, is a significant problem. Conventional methods of network optimization depend on static mathematical models; however, modelling quickly evolving edge network settings.

It has been stated that inbound marketing is more efficient and successful than outbound marketing in terms of pricing, spreading, expanding the consumer border, and co-creating value. Figure 2 illustrates the concept of digital content marketing, which refers to the practice of carrying out all marketing-related activities via the use of the Internet. These activities include advertising, the purchase process, customer support, and delivery service. DCM is a method that may be used to improve inbound marketing by delivering material that is both interesting and of high quality to potential customers. However, rather than devoting a significant amount of time and resources to the process of contacting prospective customers, DCM focuses on the production of high-quality content that has the potential to affect the long tail. An art form of consumer contact that does not include real product sales is what direct consumer marketing (DCM) is often referred to as. Excellent content and online interaction have the potential to assist a company in connecting with its present customers, attracting new clients, maintaining the loyalty of existing clients, and establishing a trustworthy brand.

Additionally, in order to boost sales activity, the company may, over time, cultivate connections, retain customers, and encourage their participation. Because of this, it has an exciting influence on the engagement of consumers and the syndicating of content. DCM has access to high-quality information that is readily available to the public about the business or the industry. A further advantage of DCM is that it can attract audiences and transform them into devoted followers and consumers. Consumers go to companies in order to read, see, learn, and experience the world.

As a consequence of this, the corporation often tells its own stories that are pertinent in order to attract and maintain the attention of its clients. It is something that comes within the purview of DCM and acts as a specialized content form of corporate photos that demonstrates that companies are the experts in their respective business sectors and that they can get the most reliable and up-to-date material resources. As a consequence of this, a lead potential customer who is interested in the content could search for or investigate certain information. Prospective purchasers may be drawn to expert content if they take into account the value of the product and content that is being supplied. Through the creation of high-quality content and active participation from its audience, a company has the potential to enhance its brand awareness, bring in new customers, regain the loyalty of current customers, and finally achieve recurring revenue. The customers have a more optimistic outlook and a higher level of faith in the brand and product as a result of their position as the trend that is the most popular among their contemporaries. It may lead to an increase in both the OPI and the confidence that consumers have in online providers.

This article's theory-based approach provides an examination of special characteristics of AR that allow advertisement contextualization. A conceptual framework describing a research paradigm for contextual AR advertising is shown in Figure 3.3. The AR-MT framework arranges conceptual building pieces that have the

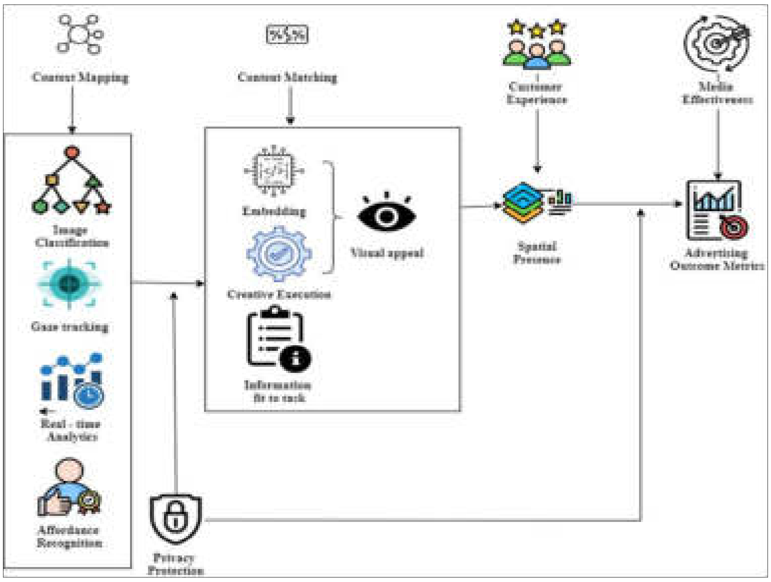

Fig. 3.3: Contextualization of AR Advertising in digital marketing

potential to inspire further study in this area. The use of augmented reality (AR) in advertising and how it affects consumer behaviour and engagement are and will remain complicated phenomena. Because of this, it appears appropriate that researchers studying advertising should build theory-driven models in order to expand their understanding, broaden the body of knowledge, and enhance management insights. These models should then be rigorously empirically explored in order to verify them. The following part aims to guide future theoretical work by proposing many study options that are consistent with the fundamentals of the contextual AR advertising paradigm.

Directions for Context Mapping Research. Context mapping needs to be a major area of study for augmented reality advertising. It is a unique feature of AR. Technology calls for more developments in the knowledge of picture categorization, real-time marketing analytics, and, eventually, the use of artificial intelligence (AI) in advertising. While internet advertising research has extensively used text-mining approaches, contextual AR advertising necessitates an emphasis on picture analysis. Image mining methods need to be improved by researchers. Necessitates real-time image classification-based analytics to comprehend surrounding information quickly. Researchers need to define context more broadly. The mapping goes beyond just placing items where they are in relation to the client. Generally speaking, context Customer behaviour patterns are included in mapping.

Research Agenda for Content Matching. Augmented reality advertising leads to an increase in the number of research opportunities for creative content design. When it comes to creative implementation, we are still unaware of the most effective methods to integrate knowledge that is relevant to the work at hand with design that is captivating. The manner in which augmented reality incorporates consistent multimodal data has been shown. Despite this, there are still a great deal of issues about the integration of sensory experiences in augmented reality. In the case of augmented reality, for example, the limits of sensory congruence, which include information that contrasts with the surroundings or multiple senses that convey distinct information, are not well known. This is despite the fact that it is believed that combinations of multisensory inputs might be able to drive attention focus. When it comes to contextual augmented reality advertising, one of the most essential topics of research is establishing a balance between capturing attention and integrating information. In a similar line, augmented reality (AR) is dependent on very deep sensory integration inside. Augmented reality restaurant applications may need to investigate novel approaches to include augmented reality information across a variety of sensory modalities, such as taste or smell, or to communicate abstract information, such as

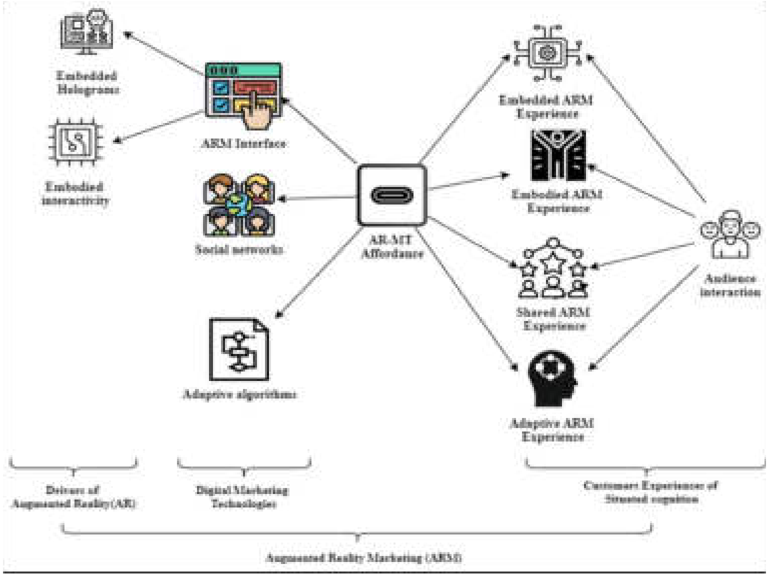

Fig. 3.4: AR-based digital marketing for audience interaction

the importance of making good food choices. These applications address a portion of the sensory modalities but not all of them. Research on content matching in augmented reality must go beyond the realm of visual integration. Up to this point, a great number of applications have attempted to imitate intuitive physics perfectly. This kind of physics provides realistic embodied representations of augmented reality items that are incorporated into the real environment. For example, augmented reality holograms typically move in a straight line over a short distance and do not pass through solid objects. It may exhibit continuity of the item. Some players could improve their performance in the game by turning off the augmented reality visuals. In order to interact with augmented reality productively and effectively, it is necessary to provide the most accurate depiction of intuitive physics.

Research Priorities for Contextualization's Customer Experience. The paper supported the widely held belief that marketers should provide augmented reality (AR) apps that let users manage information within a specific environment, and the subject of contextualization control may be seen from different perspectives. Upcoming studies need to examine the degree of control marketers should allow for contextual augmented reality apps to guarantee clients who participate in the intended exchanges. Certain AR apps require users to adhere to precise procedures for using AR material, among others, to provide clients with additional autonomy over augmented reality content.

Directions for Privacy Protection Research. The theory-based building blocks for contextual AR advertising are promising, and its implementations provide clients with relevant advantages. AR has the potential to provide major security, transparency, and privacy benefits as well. Few studies have been conducted that specifically address these worries. Given that technology can capture data continually, combining items and data with the visible reality, many distinct issues could be at odds with regulatory requirements and consumer interest limits. Additionally, by using recognition features, AR provides the chance to capture other people and widely store them.

Sensory data without their awareness. For instance, facial recognition may be used to access information from social media or private sources. Numerous parties might have access to the data, including market researchers, marketers, and application owners. Therefore, further study is required to determine how to offer robust encryption-based privacy safeguards and data anonymization. The structure identifies privacy laws as an essential regulator of the capacity of sponsors to contextualize augmented reality material and the outcome of contextualization of marketing metrics.

In order to improve the consumer's experience and choice, the acronym ARM refers to the process of developing, spreading, and conveying digital affordances in the real world, as seen in Figure 4. AR-MT affordances are qualities of an environment that make it simpler to interact with it. Augmented reality (AR) enables these digital affordances by superimposing user-controlled, dynamic, and shared digital material (such as photos, videos, or instructions) over a user's view of their actual physical surroundings. Smartphones, cameras, or smart glasses—any mobile or wearable gear may help with this. The research shows that these affordances direct and scaffold the customer's experience, decision-making, and reactions in the marketing environment. One way augmented reality (AR) could achieve this is by modifying or adding data to the connection between the ARM interface—which handles embedded and embodied digital information—and the other digital marketing tools that are currently in use, like computer-mediated social networks and adaptive algorithms. These solutions provide a link between their web application and the physical world via the ARM interface. The distinctive capabilities of ARM, which are the product of a specific combination of digital marketing technologies, allow the company to engage consumers in cognitive experiences inside a given environment and influence their actions. In line with a person's situated thinking style, a suite of digital marketing technologies implemented via the ARM interface expands the customer's experiences beyond what is commonly perceived. The "W-in-a-box" app, which uses augmented reality (AR) animations to show users the environmental benefits of drinking water from a cardboard box, is just one example of how embedded cognition is expanding user experiences. Using this app, people can find out why cardboard boxes make good drinking water. Similarly, the SketchUp Viewer might pave the way for more immersive embodied experiences; it employs state-of-the-art sensory interactions to let architects command whole augmented reality structures using voice commands or hand movements.

Categorizing encounters with embedded arms. Digital marketing from ARM stands out in part because of its "embedded experiences," which include the incorporation of digital material (such as product images, details, or instructions) into physical environments. With the use of sensors and computer vision, an AR gadget, such as Microsoft's "HoloLens," can scan the environment and generate a three-dimensional map—for example, of a customer's living room—in the blink of an eye. The next step is to provide an accurate representation of an Ikea chair set up in a living room. The level of realism of the 3D holograms is determined by how well they mimic the items in the room. In this way, the buyer may see how well the hologram's dimensions and hues mimic the original. It might be challenging for clients with ARM to fully grasp complex contextual links when presented with just verbal, visual, or auditory cues. Home appliances and furnishings are only two examples of the numerous things whose value is heavily dependent on context. Consumers' ability to form mental images and understand contextual linkages is impaired when they are not in the environment of their intended usage, such as at a shop rather than at home. Customers were prepared to shell out more cash for things after using Amazon's augmented reality (AR) program to get a better feel for how the product will work in various settings. Product holograms and item-specific contextual data are also part of ARM. The 'Dent Reality' software allows users to easily choose cereals that adhere to their specific dietary needs, including a low-sugar diet, by marking the goods on the shelf that fit these criteria with a green checkmark. Potential buyers may like how it streamlines the once-digital process of finding and sifting for them in physical stores. In a similar vein, ARM is considering allowing users to digitally test various cosmetic looks by embedding them into their faces. Shoppers at Sephora can see and touch virtual mirrors to get a sense of how multiple cosmetics would appear on them.

Another aspect is the virtualization of embedding. We can classify ARM experiences according to the level of virtualization they employ: i) adding AR content to the real world, ii) digitizing actual products to make holograms instead of them, and iii) making wholly unique digital holograms with no real-world counterparts. To provide an example of how an Instagram ARM mirror may be used to enhance a customer's video photo with augmented reality, a "hipster moustache" or "spiky hairdo" can be added. In this case, the client keeps their physical form while ARM adds another level of topic-related data. A similar process may also be used for objects.

In both instances, the subject or object in question is still visible, but the inclusion of ARM data enhances its perceived value. Additionally, a lot of online stores use digitizing, a kind of virtualization, to make an augmented reality digital replica of an actual product. For example, Amazon now sells digital replicas of physical things in its online store. Customers may have these augmented reality holograms presented in the comfort of their own homes using the Amazon smartphone app. Since just the augmented reality hologram of the product is shown instead of the real product, digitizing physical objects indicates a greater level of virtualization than upgrading ARM. By placing the hologram in the customer's physical environment, digitizing ARM creates an illusion that is almost identical to the real thing. It is valuable because it helps buyers assess the product's connections in relation to its intended use. The spectrum virtualization technique is similar. Finally, coming to the topic of virtualization, new studies have shown that people who utilize augmented reality holograms without a physical counterpart may develop a sentimental attachment to virtual items. In this case, the customer's aesthetic or educational demands were met with the creation of ARM holograms. Although digitizing ARM makes an ARM hologram that looks exactly like the real thing, and improving ARM makes an ARM hologram that looks exactly like a real thing, creating ARM is the next level of virtualization because AR holograms are now their own thing in AR, not attached to anything in the real world. The distribution of various embedding types across virtualization levels is intriguing. The digital hologram may, for instance, include a manufactured ARM experience.

The economic framework is built using inbound and content marketing to examine the expenses associated with various marketing approaches as well as the company's overall profit. A dashboard, or collection of analytics, is often used to evaluate certain marketing campaigns. Selecting the most relevant statistic for goal control and decision-making should be based on the analysis's objectives. It evaluates a certain campaign's commercial performance by using the advertising elasticity of demand as a measure. This research takes into account both tactics in an effort to save costs and boost revenue. Classical microeconomic theory's tenets state that economic efficiency is as follows: If users have produced as much data as is practical with the actual inputs or have produced the output at the lowest possible cost, they are considered efficient. The present research uses the cornerstone of marketing optimization that is adapted to content marketing and inbound marketing strategies. The application of the model looks at the optimal advertising revenue for a certain strategy, including digital content. With an emphasis on search engine optimization (SEO) and search engine marketing (SEM), the study details the profitability of the business in the context of content and inbound marketing. Equ.3.1 indicates the business's profitability.

$$\infty = \frac{X}{N(X, N_{SEO}, N_{SEM})} - \frac{X}{N(X, N_{SEO}, N_{SEM})}; N_{SEO}, N_{SEM} \tag{3.1}$$

The business's scalability is indicated in ∞, whereas the SEO/SEM qualities are expressed as $\frac{M_{SEO}}{M_{SEM}}$. Digital marketing costs are directly and inexorably linked to the number of visits to a website since demand and earnings are dependent upon it. Because of this, a large percentage of content marketing and the price structure for the inbound marketing context are made up of variable expenses rather than a set quantity of advertising. It makes a distinction between visits resulting from $\frac{SEO}{M_{SEO}}$ and visits related to $\frac{SEM}{M_{SEM}}$. In this situation, a more advanced "conversion innovation" yields more extra income from more visits than a less advanced technology. The costs arise from the addition of manufacturing costs, which change based on the volume of goods sold online, as well as content marketing. Context costs for inbound marketing are mostly performance-based and correlated with website traffic. It may include a set of marketing expenditures (A) and differentiate between the implicit costs associated with $\frac{SEO}{L_{SEO}}$ and the explicit costs associated with $\frac{SEM}{L_{SEM}}$ as the visits generated by different inbound marketing context techniques and content marketing have different costs.

$$S_K = SK(X) + N_{SEO}LN_{SEO} + N_{SEM}LN_{SEM} \tag{3.2}$$

The company cares about the variable costs, whether explicitly stated or not. In this instance, the variable financial ramifications of the content marketing and inbound marketing environment, which alter the marketing price, are the relevant expenses. Equ.3.2 denotes the fair cost. For the associated content marketing and inbound marketing context techniques, the average visit costs are as follows: $\frac{LN_{SEO}}{LN_{SEM}}$. Additionally, $\frac{M_{SEO}}{M_{SEM}}$ are the qualities for SEO/SEM . The amount of visits the company wants to generate from its different traffic source materials depends on the content budget and inbound marketing allocation. Equ.3.3 indicates the company's marketing advantage.

$$T_V = N_{SEO}LN_{SEO} + N_{SEM}LN_{SEM} + S \tag{3.3}$$

The average cost of $\frac{SEO}{SEM}$ is shown by the notation $\frac{LN_{SEO}}{LN_{SEM}}$. $\frac{T_{SEO}}{T_{SEM}}$ are the qualities for SEO/SEM . S stands for the entire amount spent on the market. The system's online traffic vs. profits and site visitors vs. cost analyses display the sales and cost relationship related to website traffic, which is determined using the dataset. The differences between content and inbound marketing in terms of cost and revenue are created. It should be highlighted that, in comparison to competitors, the cost of generating additional visitors (Minimal Cost (MC)) depends on the volume of traffic to the company's website and its pricing policy. There is only a business-specific optimization condition based on the least cost and return of more website visits, taking into account the distinct conversion and pricing structure of a firm as determined by Equ.3.4. There is no universal criterion.

$$\frac{OQ_{SEO}}{OQ_{SEM}} = GH_{SEO}GH_{SEM} \tag{3.4}$$

$\frac{SN_{SEO}}{SN_{SEO}}$ are the terms used to describe business pricing for SEO/SEM . SEO/SEM the symbols represent business rates $\frac{GH_{SEO}}{GH_{SEM}}$.

Determining the best content and inbound marketing. The empirical study on evaluating the company's functioning above minimum expenses in style stands out in two areas: distributive efficiency (turning visitors into sales) and technical efficiency (using SEO/SEM in the improper proportion). This approach requires assessing the cost function and developing sales via the use of several digital marketing strategies, such as inbound and content marketing. This scenario requires the analytical technique, which was motivated by empirically estimating efficiency. It assesses the optimality criteria directly in light of the availability of cost data at various quantiles (costs). for SEO/SEM). It is assumed that the traffic source has no impact on marginal revenues per visit. The ratio with distinct fluctuations in cost It investigates the idea with the use of economic analysis and graphics. Time series analysis is used to test the optimization hypothesis by treating the deviation from optimization as a stochastic process that should adhere to a white noise technique. Equ.3.5 displays the optimized inbound and content marketing.

$$V_{BN} = OQ_{SEO,BN} - OQ_{SEM,BN} \tag{3.5}$$

OQ_{SEO}/OQ_{SEM} is the business pricing of SEO/SEM with regard to optimized inbound marketing and content marketing. Recognize that higher numbers often indicate a poor combination of content and inbound marketing. Low values, on the other hand, suggest that the company operates almost at the lowest level of inbound marketing and content marketing investment permitted for a certain objective, such as website visits or sales. Therefore, because of the extreme divergence from optimality, comparisons are not conceivable. It standardized, restated, and represented the deviation from the optimization issue in absolute terms using Equ.3.6.

$$KM_{XYZ} = 1 - \frac{V_{BN}^2}{\sum_C^W = 0 \sum_E^Y = 0 V_B N^2} \tag{3.6}$$

The difference between the expected and actual revenue is shown as V_{BN}^2. Note that the following qualities led to the selection of this approach of changing the deviation from optimality, which is comparable to the error formulation used in the traditional at least squares method: Take into account all market fluctuations without allowing positive and negative variations to cancel each other out. The method may rank businesses within a country according to the effectiveness of their inbound and content marketing according to relative measurement. Apart from the marketing-efficiency measures provided, it takes into account the usual key indications for average sales per visit and prices per visit, which evaluate potential cost benefits in conversion systems. It looks at the businesses' local, national, and worldwide positioning.

4. Results and Discussions. A major change in customer-brand interactions is occurring as a result of the use of AR-MT in marketing campaigns. Augmented reality (AR) provides a level of immersion not achieved by more conventional forms of digital advertising. The interactive nature of this technology makes it a great tool for narrative and product display, which in turn increases customer engagement. For instance, augmented

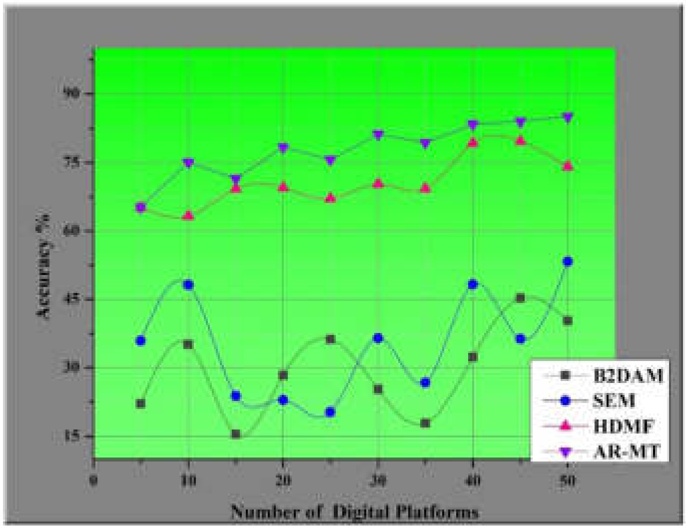

Fig. 4.1: Accuracy

reality has the potential to elevate the customer experience by turning a static ad into an interactive one. This, in turn, may increase the perceived value of the product. Augmented reality technology alters the nature of customer connection and audience interaction in profound ways. Augmented reality (AR) provides users with a unique and unforgettable experience by superimposing digital information on top of their actual surroundings. Using augmented reality for virtual try-ons has completely changed the way people buy, which is why this technology has been so successful in the digital retail industry.

Dataset Description: The exponential growth of online audiences has accelerated the transformation of digital advertising [t!]. The success measure for digital advertising is changing from the number of impressions or viewers to the number of conversions or leads generated. More oversight and openness regarding conversions are necessary. There has been a substantial increase in the digital advertising inventory of Times Internet Limited's Colombian division. Its goal is to prevent publishers from unfairly benefiting from phoney leads in all of their conversion-based efforts.

Accuracy. To determine if our method is effective in data segmentation and classification, we put it through its paces, utilizing the challenge evaluation criteria. Here are the defined success criteria:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{4.1}$$

Fig.4.1 displays the Accuracy curves of the refined AR-MT composites, as determined by Equ.4.1. Edge AI has revolutionized media distribution and engagement by improving precision. To provide high-quality media experiences, Edge AI analyzes data closer to the source, lowering latency and ensuring real-time responsiveness. This technology allows precise customization by tailoring content to each person's interests and habits. Edge AI improves media delivery efficiency and reliability by handling enormous data sets. Thus, viewers will get interesting, interest-based information. Media companies may provide more engaging and dynamic content, enhancing client satisfaction and engagement.

Precision. They tested our approach using the challenge assessment criteria to see its precision data segmentation and classification well. Following Equ.4.2 is a list of the specified goals.

$$Precision = \frac{TP}{TP + FN} \tag{4.2}$$

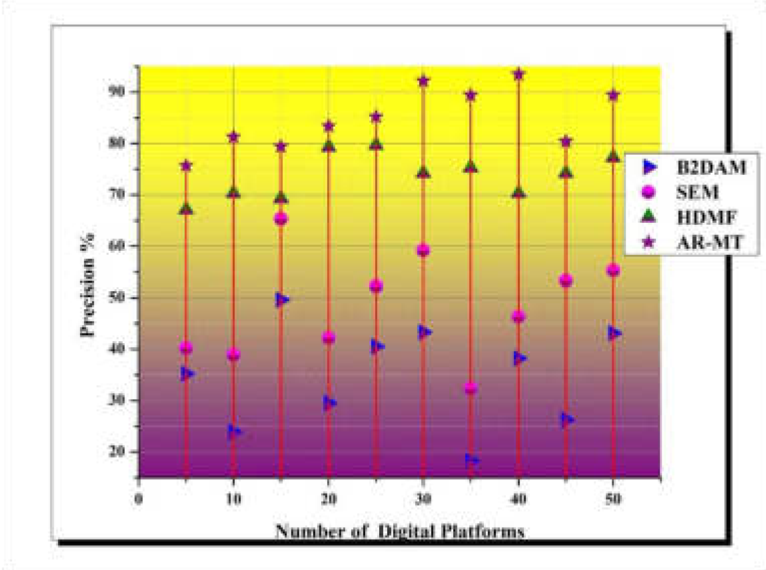

Fig. 4.2: Precision

Fig.4.2 displays the Precision curves of the refined AR-MT composites, as determined by Equ.4.2. AR-MT is redefining the media revolution by emphasizing precision in communication and information exchange. AR-MT may analyze data closer to its origin to reduce latency and improve real-time decision-making. It permits exact content customization depending on media user preferences and activities. AR-MT delivers rapid, precision content delivery by evaluating and acting on enormous datasets at the edge, giving customers the most relevant and engaging experiences.

Recall. They used the challenge assessment criteria to test our method's data segmentation and classification efficacy. The established measures of success, which follow Equ.4.3, are presented.

$$Recall = \frac{TP}{TP + FN} \tag{4.3}$$

Fig.4.3 displays the Recallcurves of the refined AR-MT composites, as determined by Equ.4.3. AR-MT has revolutionized contemporary media. Content delivery and user interaction have been revolutionized by edge AI, which analyzes data locally instead of on cloud servers. Media services are made more responsive and efficient with the help of network-periphery AR-MT, which processes and analyzes data in real-time. Through personalization and rapid delivery, this technological revolution makes information more immersive and tailored to the user. The user experience is enhanced by the advanced interactive features made accessible by edge AI, such as intelligent content suggestions and augmented reality.

F1-Score. The system's data segmentation and classification efficacy were evaluated using the challenge assessment criteria. Equ.4.4 provides the basis for the established success metrics, which are detailed below.

$$F1 - Score = 2 * \frac{Precision * Recall}{Precision + Recall} \tag{4.4}$$

Fig.4.4 displays the F1-Score curves of the refined AR-MT composites, as determined by Equ.4.4. For classification problems, in particular, the F1 score is a must-have for assessing AR-MT models. To evaluate the efficacy of the model more objectively, this method merges recall and accuracy into a single score. Precision displays the fraction of correct predictions relative to the total number of positive predictions made by the model. In contrast, recall displays the fraction of correct predictions relative to the number of positive occurrences in the dataset. The accuracy of a prediction system is its proper prediction rate. The F1-score balances recall and

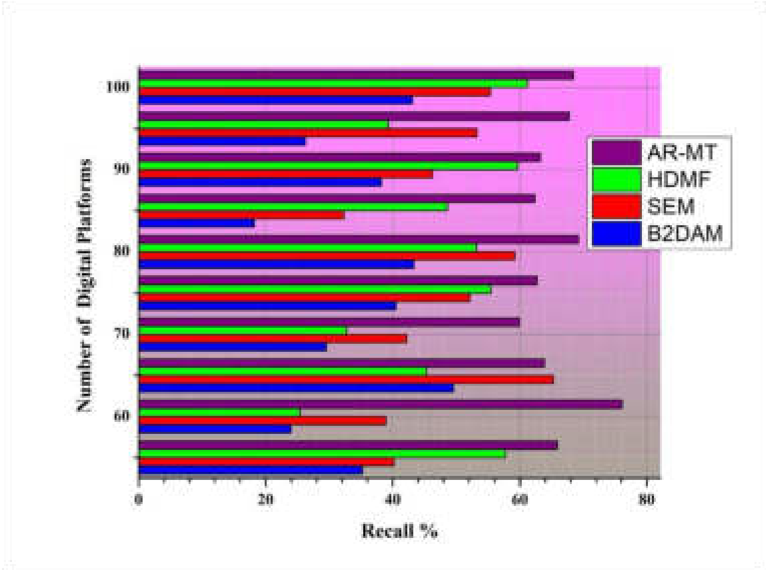

Fig. 4.3: Recall

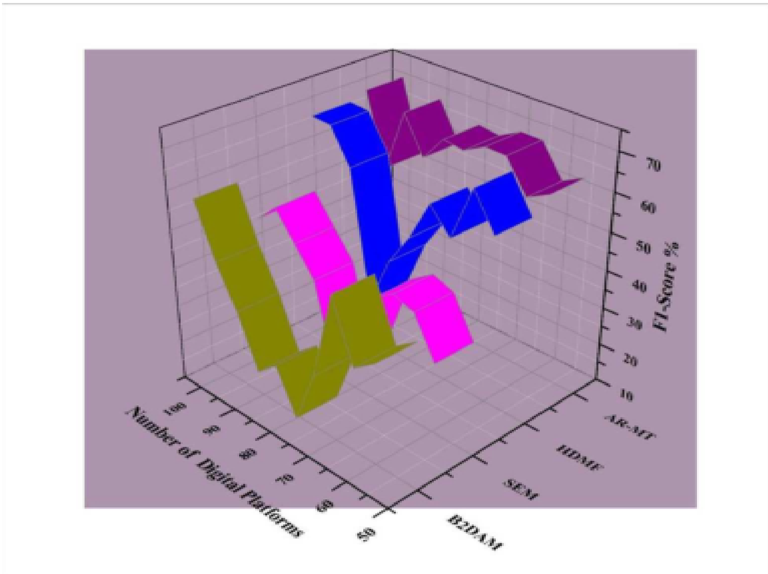

Fig. 4.4: F1-Score

accuracy trade-offs as the harmonic mean. When false negatives and positives are costly, memory and accuracy must be balanced. F1 scores around 1 suggest perfect recall and precision, whereas numbers near 0 indicate poor performance. For this reason, the F1-score is crucial for analyzing and improving AR-MT models.

5. Conclusion. The digital ecosystem of today presents both possibilities and problems for firms seeking to reach varied audiences throughout the globe. Thanks to the Internet and other digital technologies, international trade has been greatly enhanced, enabling businesses of all sizes to transcend national boundaries and enter new markets throughout the world. Nevertheless, companies must now address the latest issues posed by interconnection by speaking the cultural and literal languages of their target consumers. A combination of localization and global marketing approaches becomes useful in this context. Essential strategies for firms to tailor their online presence to diverse demographics, geographies, and cultures include localization and international marketing. The process of localization entails taking into account the fundamental values, norms, practices, and beliefs of a certain culture in order to make goods, services, and promotional materials truly local. Although ARM is still in its infancy in terms of widespread use, new uses for the technology imply a unique marketing strategy that links the product to consumers' experience of situated cognition. Digital affordances provided by ARM have an immediate effect on how customers see the decision context, in contrast to attitude-based marketing, which relies on more conventional forms of media to convey product or service features in the hopes that these perceptions will influence customers' actions within that context.

Through their incorporation into the surrounding environment and physical contact, these affordances have the power to influence client experience and behaviour. As a result, AR-MT moves marketing away from highlighting product features and the situations in which customers may experience value via participation. Academics may use this study as a jumping-off point to learn more about how the features of DM content interact with one another across platforms and media to draw in viewers. Due to the fact that "conceptual advances are critical to the vitality of the marketing discipline," this work may serve as a solid foundation for future research on DCM. The study has significant ramifications for academics and managers alike. When looking at DCM interactions from a management standpoint, the created essential propositions show what current and potential customers are seeking. The focus of this article is on finding the right people to hear DCM messages. Marketers might find this useful in creating content that speaks directly to their target audience. DCM can transform into relationship marketing by giving customers the material and information wanted in digital places.

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DESIGN OF MULTIMEDIA EDUCATION AND TEACHING MANAGEMENT SYSTEM BASED ON ARTIFICIAL INTELLIGENCE AND COMPUTATIONAL TECHNOLOGY

TIANJIANG FENG*, JUAN XU† AND KEJUN WU‡

Abstract. The multimedia education and teaching management system's capacity to confront significant issues faced by conventional education systems is the fundamental justification for its relevance and significance. It is necessary to efficiently manage educational resources, accommodate to a variety of learning styles, and meet the expectations for highly personalised educational experiences. The system's goal, enabled by artificial intelligence (AI), is to build a classroom that is more adaptable to each student's individual requirements and interests. Personalised learning, efficient use of resources, and the ability to scale are common challenges faced by conventional educational institutions. Additionally, having scalable computing methods is crucial for making certain the system can handle different user needs and adapt to different classroom environments. The Intelligent Multimedia Teaching Tracking System (IMTTS) combines AI-based algorithms to track student interactions and enhance the transmission efficiency of multimedia content. Besides providing insights that teachers may put into practice, the system additionally provides a personalised learning route that is based on each student's performance and preferences. The deployment of scalable computing ensures that the system can effectively handle large datasets and a large number of users under heavy load. A thorough simulation analysis is conducted to ascertain the effectiveness and productivity of the IMTTS. The analysis shows that the system can change educational management by providing reliable solutions that address present issues and meet evolving educational needs. Furthermore, it highlights the system's capacity to handle compute needs that scale.

Key words: Multimedia, Education, Teaching, Management, System, Artificial Intelligence, Technology, Intelligent, Multimedia, Teaching, Tracking System, Scalable Computing.

1. Introduction. Multimedia education management has evolved into an essential part of many educational institutions in overtime [1]. The conventional approach to managing universities is becoming more obsolete as reforms in the sector continue to gather steam [2]. The teaching management system is under increasing strain due to the recent gradual implementation of educational measures in multimedia education institutions and the constantly increasing source of students in these institutions [3]. A new challenge for multimedia education institutions is figuring out how to make better use of computer and network technologies to aid education [4]. Internet, information, and smart computer and digital tool usage are having an ever-increasingly significant influence as computer network technology advances [5]. Database and communication technology are built under the scalable computing environment via the advancement of these technologies [6]. In today's world, where campus networks are constantly expanding, educational administration supervision systems are becoming more crucial [7].

These systems provide the groundwork for better instructional management and more efficient multimedia education [8]. The intelligent education system was built on cognitive science, which makes extensive use of AI technology in multimedia education systems to execute efficient student administration of their lessons [9]. An AI-powered, scalable computing system integrates the best features of both conventional and cutting-edge computer systems, while also reaping the benefits of conventional methods [10]. Modern education has progressed further thanks to the steady development of artificial intelligence and computer technology, which have allowed intelligent teaching systems to advance in a better and higher path [11]. This paper's main novelty is that it uses scalable computing technology and AI to record and analyse students' behaviours, digital

*Department of Intelligent Manufacturing and Industrial Safety, Chongqing Vocational Institute of Safety Technology, Chongqing, 404000, China. (Corresponding author, ftj_327363277@163.com)

†Department of Intelligent Manufacturing and Industrial Safety, Chongqing Vocational Institute of Safety Technology, Chongqing, 404000, China.

‡Chengdu Zhichang Information Technology Development Co., Ltd., Chengdu, Sichuan, 610000, China (Doraemon_Doraemon@163.com)

footprints, and outcomes from conventional classroom activities [12]. Create a model of the role of students and teacher managers in the classroom using AI and computer technologies, and then use this model to inform intelligent teaching management [13]. Using this IMTTS as a foundation, the management should build a student model that caters to each student's unique traits, and then use it to execute intelligent customisation based on specific knowledge areas [14]. The management now has a better foundation for future remote learning thanks to its multimedia education system that is built on AI and scalable computing technology [15]. One of its benefits is that it offers a useful supplementary tool for teaching management system [16]. This paper presents the results of an inquiry of real multimedia equipment, and then utilizes IMTTS to create a web-based system for managing multimedia teaching tools [17]. For routine basic data maintenance of multimedia teaching tools and classrooms, and to serve as a model for the future installation of such tools and systems at other educational institutions [18]. The operator may enhance teaching efficiency with the help of the query, search, and database design features in the optimized intelligent multimedia pedagogy, which has been enhanced with optimized functions [19]. The invention of teaching modes of multimedia teaching classroom on online learning platform improves the teaching management system [20].

The main contribution of this paper is as follows:

1. *Enhanced Personalization and Adaptability in Education:*
   By using AI algorithms to observe student interactions and customize instructional information, the paper introduces customized learning. This personalised learning path takes into account student performance and interests to cater to different learning styles. By doing so, the IMTTS hopes to convert conventional classrooms into dynamic, personalized learning environments that boost student engagement and performance.
2. *Scalable Computing and Resource Efficiency:*
   The paper's emphasis on scalable computing approaches to educational resource efficiency is crucial. Since it can handle huge datasets and many users, the system can adapt to different classroom contexts and manage compute needs that scale. For universities with limited resources and infrastructure, the system optimizes multimedia content delivery and resource allocation for cost-effective and sustainable education management.
3. *Comprehensive Simulation and evaluation:*
   For IMTTS efficacy and productivity, the report includes a complete simulation analysis. By providing scalable, flexible, and individualized learning environments, the system solves traditional educational management problems. The system's capacity to improve educational practices and fulfil changing educational demands is confirmed by this paper, providing insights for intelligent education system research and development.

The remaining of this paper is structured as: In section 2, the related work of multimedia teaching is studied. In section 3, the proposed methodology of IMTTS is explained. In section 4, the efficiency of IMTTS is discussed and analysed and finally in section 5, the paper is concluded with the future work.

2. Related works. The old model of managing multimedia classrooms isn't going to cut it in today's ever-changing network landscape; it won't be able to swiftly identify and fix malfunctioning multimedia teaching equipment; it won't be able to accurately record the status, use time, and maintenance records of different pieces of multimedia teaching equipment; and it will have a negative impact on college and university teaching quality and education informatization efforts in the long term. Integrating multimedia pedagogical tools with the university's online presence is crucial.

Training high-quality, inventive skills in the modern day is greatly aided by music education, which is a crucial component of good education. The difficulty in popularizing musical instrument training on occasion stems from the fact that it is dependent on musical instruments. This study proposes a multimedia teaching platform for indoor instrument teaching based on SOA, with the goal of improving instrument instruction via the use of multimedia technologies and SOA architecture. It uses real-world testing and building a small-scale multimedia teaching platform and confirms its efficacy [21].

There is a lack of engagement and efficient use of resources on the present multimedia online education platform. This research will investigate the development of a multimodal online learning platform using a fuzzy neural network as a potential solution to this issue. An FPGA serves as the brains of the online education platform's hardware architecture, while a FNN processes and mines the platform's resources. Make better use of platform resources via the use of cloud computing and enhance the efficiency of platform operations [22].

According to the trend toward education management informatization is becoming more apparent against the backdrop of the big data era, which has brought about significant changes in the administration of higher education institutions via the use of big data [23]. As a result, school management will likewise see revolutionary shifts as a result of the big data tsunami. Further, educational institutions should adapt to new circumstances by optimizing and adjusting their education management practices, making sure their student management practices can handle the management demands of the big data era, effectively enhancing their education management in general, and providing ever-improving student services.

Students of English as a second language may develop feelings of animosity and diminished learning efficacy when exposed to emotionally detached computer screens in multimedia English instruction. An intelligent network teaching system model based on deep learning speech enhancement and facial expression identification is proposed in this research to address the absence of emotion in multimedia English education and increase its efficiency [24].

One factor that could impact the impact and quality of online education is how well resources are searched for and retrieved. To optimize the design of an accurate resource classifier, this study follows the methodological framework of design science and uses the algorithm. Quan, Z. et al. [25], to provide online learners with more accurate and quick access to educational materials, they want to enhance the inadequate categorization impact of conventional approaches for online education resources.

Xiaoyu Liu and Rujing Yao [27] suggested Artificial Intelligence and CAD Technology for Visual Communication Teaching Systems. New computer-aided design (CAD) and artificial intelligence (AI) developments have generated new ideas, approaches, and educational tools. This paper begins with how AI and CAD have affected modern visual communication design and their effects on design methods, design tools, and presentation techniques. It then moves on to explore how these technologies can revolutionize visual communication design education by enhancing the teaching of visual correspondence design through the integration and development of AI and CAD.

Panpan Li et al. [28] proposed the Artificial intelligence translation under the influence of multimedia teaching to study English learning mode. As a text data source, use the SQLite software database server. The user enters the query term into the translation platform when they want an English translation done, and the text is translated using the Google API translation technology powered by artificial intelligence. Construct edge computing solutions and examine user data input records based on the acquired real user service use records. Build the word's feature vector using word2vec, then build the text's word ranking with LSTM. To preload the service, the word ranking approach estimates the user's service consumption, chooses the appropriate edge server and combines the appropriate probability model. Information is kept in sync and monitored using the Internet of Things data processing technology, including edge algorithm compression. The translated text is shown on the application interface in voice and words once the data is compressed. Intelligent translation platforms anticipate a 90% matching degree of users' translation inquiries, and research shows that using IoT edge computing boosts the retention rate of past query data by 30%.

Qichao Cui [29] recommended the Integrated Multimedia Teaching Model (IMTM) for the Linguistic Smart Education System. The suggested IMTM uses intelligent educational resources, focusing on listening and oral expression skills, and employs linguistic-based instruction to improve students' comprehensive competence. At the same time as it meets the demand for growth, IMTM equips students with better self-study skills and comprehensive learning capacities. The experiment's findings demonstrate that compared to other techniques, the IMTM-based smart education system meets students' learning goals and uses linguistic-based individualized learning to enhance student performance by 92.3%, assumption by 90%, and flexibility by 91.2%.

Wang Zheng [30] discussed the adaptive learning algorithm and artificial intelligence technology for Intelligent e-learning design. The system aims to facilitate effective art course mastery by providing a tailored learning environment. The intelligent e-learning system, which analyzes students' learning behaviours and traits and employs an adaptive learning algorithm to modify the learning material and techniques continually, is described in depth by the author. The system's intelligent tutoring and assessment features aid autonomous learning and feedback. The author discovered that the intelligent e-learning system significantly outperforms the conventional e-learning system in terms of learning impact and motivation when we compare the two systems in an experiment. Students' interest in studying and information acquisition level was enhanced after using the intelligent e-learning system.

In multimedia-assisted teaching, Shanshan Cheng et al. [31] discussed the EMLP-SNN, an improved multilayer perceptron integrated spiking neural network, for use in online interactive teaching systems. The EMLP-SNN method is recommended to recognize spoken English pronunciation. This approach enhances the integration of multilayer perceptrons with spiking neural networks. The trials show that the suggested algorithm has a 97.5% success rate. It may help students improve their oral English learning by pointing out when their pronunciation differs from the norm and providing them with the tools to correct their errors.

RanaAlShaikh et al. [32] introduced Automatic Speech Recognition (ASR) using OpenAI's Whisper and Google's Large Language Model (LLM) for multimedia learning. The twin objectives are to create an AI helper tool and evaluate its influence on improved learning experiences. The study used a mixed methods approach, integrating human review by nine educational professionals with automated measures. Participants rated the tool from highest to lowest regarding engagement, information organization, clarity, and usability. Readability and Content Distinctiveness ratings were among the automated measures which were calculated. Findings from the human assessment point to beneficial effects in every area that was considered. The tool's natural metric generation capabilities further demonstrated its content generation and readability capabilities. Taken as a whole, these early findings demonstrate how the technology might completely transform instructional design by delivering highly customized and visually appealing learning experiences.

Xi Zhang et al. [33]proposed anArtificial Intelligence Technology for the Design and Application of Intelligent Classroom for English Language and Literature.Universities face unprecedented demands for creative talent nurturing due to economic globalization's increased intermingling of economics and culture. This study provides a methodology and evaluation framework for building an AI-powered smart classroom specifically for the English language and literature. This technique focuses on helping pupils get comfortable with the English context and cultural backdrop to improve their general language ability. By implementing the suggested strategy, we want to provide students with a more stimulating and fruitful educational environment in which they may grow in their language proficiency and cultural literacy.

RamtejaSajja et al. [34]suggested anartificial intelligence-enabled intelligent assistant (AIIA) for Personalized and Adaptive Learning in Higher Education.The AIIA system uses cutting-edge AI and NLP methods to provide a dynamic and exciting educational platform. This platform is designed to make learning more accessible by making material readily available, testing knowledge, and offering individualized learning assistance based on each learner's requirements and style. This article outlines the framework, architecture, intelligent services, and interaction with learning management systems (LMSs) for AI-enabled intelligent educational assistants. Then, it discusses the obstacles, constraints, and potential future paths for their development.

TatikMariyanti [35] introduced an Android Based on Artificial Intelligence for the Development of Mobile Learning Applications. The study aimed to collect information from students in Raharja University's informatics engineering department. Techniques To collect data, researchers use questionnaires and tests of instrument validity and reliability. A data analysis technique is then used to examine the feasibility of the media and student response. Data from the student responses were analyzed descriptively. First, the data show that professional validators have validated the media at a rate of 92.5%. This suggests that the M-learning app for Android is suitable for use and belongs to the "Very Excellent" tier. (1) A whopping 79.5% of students using the Android-based M-learning app had a positive experience.

Xiaofei Yu et al. [36] presented an Artificial Intelligence in Music Education for Developments and Applications. Artificial intelligence (AI) is an outcome of the fast expansion of IT; it incorporates several multidisciplinary fields, including music education, and brings novel aspects to the field. This study thoroughly examines the use of artificial intelligence (AI) in music education, outlines its current applications, and discusses its potential future growth by reviewing the benefits of AI in this field. By integrating AI-powered smart technology with face-to-face instruction, we can address the conventional method's absence of personalization while simultaneously stimulating students' interest in the subject field.

The planned research would leverage cutting-edge technology to update music instruction and online learning environments. The goal of a SOA based multimedia teaching platform in music education is to improve

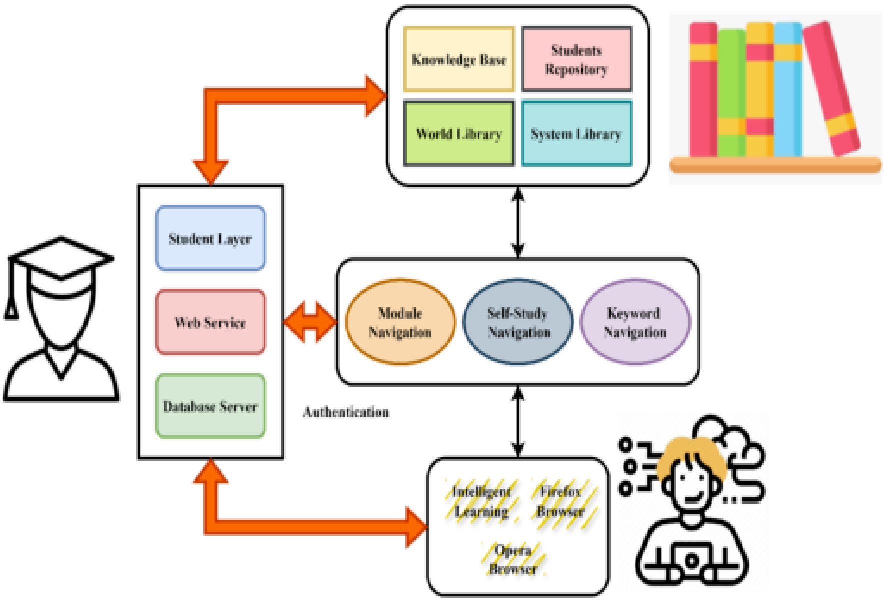

Fig. 3.1: Intelligent multimedia teaching tracking system

instrument learning. To address the shortcomings of existing online multimedia education, a hardware design based on field-programmable gate arrays FNNs is suggested. Big Data has changed the face of educational administration and how it might lead to better student services and more efficient overall operations. By recognizing facial expressions and voice, a DLA improves English language learning with multimedia. The last step in improving the efficiency and accuracy of retrieving educational materials from the web is a SVM, which improves resource categorization.

3. Proposed method. New instructional tools are now more accessible than ever before thanks to the Internet, lightning-fast computer science, and electrical engineering. These advancements are used by intelligent online multimedia learning to evaluate large datasets, forecast trends, and extract important insights using machine learning. By providing more complex and dynamic evaluations, this strategy goes beyond conventional approaches that depend on test results. Through the integration of AI systems, educational institutions have the ability to analyse and synthesize intricate data sets, uncovering patterns and standards that are pertinent to the field as a whole.

3.1. Contribution 1: Enhanced Personalization and Adaptability in Education. Intelligent online multimedia learning's technique is shown in Figure 3.1. It undertakes extensive analysis to determine the optimal course of action, predict future trends, and much more than just look at previous data and identify any links. When applied to appropriate database sets, machine learning may consistently extract useful information, such as laws or higher-level data, which can then be utilized to extract new knowledge.

Rapid advances in information technology, electrical science, and the spread of the Internet have made it possible to access the electronic archives of many different types of educational institutions. There is a shift away from using test scores to categorize students. The assessment methodologies' remarkable achievements have become indispensable in education. Using AI systems, data from a variety of complex sources may be summarized and evaluated using scalable computing. These systems have the ability to transform and extract information, revealing previously unknown conceptual standards and connections that are pertinent to the group's overall state. The ideal browser for students, according to the Student Helpdesk, is Firefox. Our instructors found this browser to have the most forgiving connection and the most consistent improvements out of all the ones they looked at. In most cases, the Student Help Desk suggests Firefox as the best web browser to use. To improve the process assessment system and make it applicable, there are a number of components that may be thoroughly and exhaustively examined to conceal the evaluation findings and the connections between the student and teacher.

$$-\sum_{j=1}^{p} m_k(H_j(p)|\alpha_w j|e^{r-2} f_d p) = Q(y,w,\alpha,\forall)\ \ in\beta \tag{3.1}$$

To improve educational administration m_k, the suggested approach makes use of an IMTTS, or intelligent educational multimedia tracking system $H_j(p)$, which makes use of algorithms $\alpha_w j$ based on artificial intelligence e^{r-2} $f_d p$. Optimizing the monitoring of interactions β between students $(y,w,\alpha,\forall)$ and efficient multimedia information Q transmission is emphasized by previous equation.

$$-\partial wq(p,e) \geq \sum_{k=1}^{D} \int_{w}^{e} df(y) \times dy + (\forall k_f - W_s p) \tag{3.2}$$

The equation 2 provides a mathematical correlation $< -\partial wq(p,e)$ between the intelligent multimedia educational monitor $df(y)$ (IMTTS) and the suggested technique $\forall k_f - W_s p$. With an emphasis on administering educational resources dy and customized learning experiences, previous equation represents the efficient use of system-wide tracking efficiency and the allocation of resources.

$$-pgt(Z(n)h) = (y(s+jp)) - (w - s2q) + 1 \tag{3.3}$$

By symbolizing the (IMTTS) dynamic modifications -pgt $(Z(n)h)$, the previous equation coincides with the suggested approach $y(s+jp)$. Optimized performance is achieved by balancing the input variables $(w - s2q)$ such as student interactions with the system parameters using scalable computing.

$$\sum_{j=1}^{W} \int_{\forall}^{e} H_j(m(y))|Nt_{y-p} + (rs - (qpt)) = \int_{e}^{1} Q(y, g(t-p)) \tag{3.4}$$

The complicated interaction of factors is captured by previous equation, which corresponds with the suggested strategy $H_j(m(y))$. It spells out the steps the system y,g takes to improve learning routes Q and resource allocation Nt_{y-p} by integrating student performance measurements $(rs - (qpt))$ and periodic adjustments $(t-p)$.

To increase their interest in the topic, students might be encouraged to build tactics and materials by designing a multimedia teaching model. IMTTS propose an ecological method of teaching that builds on the interaction process to establish a sustainable educational system and support effective teaching. Through the use of AI, universities assess their relevance to multimedia teaching. The environment for teaching with artificial intelligence is shown in Figure 3.2. Given that these components are now standard in education, it has created a wealth of new opportunities for instructors. A classroom may be prepared for a particular course or program in a variety of ways. There are many more aspects of a learning environment than only the physical spaces itself, such as classrooms, lecture halls, and labs using scalable computing. There will also be details on the students' personalities and the goals of the lessons. The objective of this research is to develop AI systems that can store data using data directories, metadata, and encryption. A variety of AI data sets pertaining to multimedia acquisition may be housed, assembled, and organized using data warehouse technologies. The AI used in this investigation is stored via metadata and encryption. AI data for many types of multimedia learning datasets may be stored, assembled, and sorted using scalable computing.

$$\left| G(y,e,q) > 1\big(d_i - \sum_{j=1}^{p} |r_f - p_k|\big) + d_2 \right| |u|s^{-1} + c_4 \tag{3.5}$$

This equation shows (IMTTS) need balance $G(y,e,q)$ and improvement $r_f - pk$, which is in line with the suggested strategy d_1. It records the integration of metrics d_2 such as system efficiency (c_4), student involvement

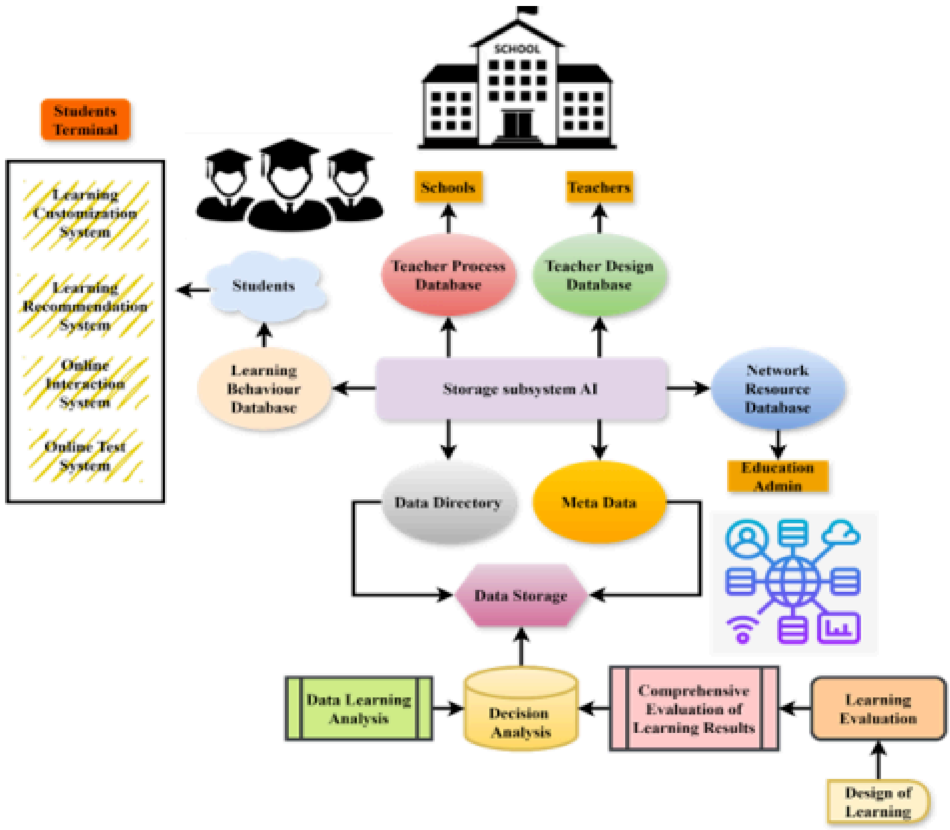

Fig. 3.2: Teaching ecosystem using AI

(d_2), and resource allocation $(|u|s^{-1})$

$$S_f = H(y, p, \alpha, q), w\beta(dy - 1p) - (\sigma_p + jp) \tag{3.6}$$

The suggested strategy is supported by equation 6, which shows the complex interactions H among student feedback (S_f), learning parameters $(y, p, \alpha q)$, and system modifications $(\sigma_p + jp)$. The (IMTTS) uses AI algorithms to analyze these characteristics $dy - 1p$ and make the learning experience better and more tailored to each student.

$$\int_f^1 |Q(y, p, \partial q)|dp > dz\left(\sum_{j=1}^{E} \int_\partial^w |e_s| + \int_\alpha^1 |v|dp - 1\right) \tag{3.7}$$

Last equation and the suggested technique are related since it show well the system can manage $|v|dp$ and optimize learning assets $(Q(y, p, \partial q))$ concerning several indicators for student involvement (dp). To successfully address individual learning demands, the (IMTTS) uses AI-driven insights to fine-tune resource allocation and material delivery $|e_s|$.

3.2. Contribution 2: Scalable Computing and Resource Efficiency . The multimedia education technique that is based on artificial intelligence has created methods for assessing and developing abilities. The development of AI educational solutions will soon allow schools and instructors to do more than ever before. The efficiency, customisation, and automation brought forth by AI may free up teachers' time and provide them greater flexibility to impart knowledge and adaptability to student.

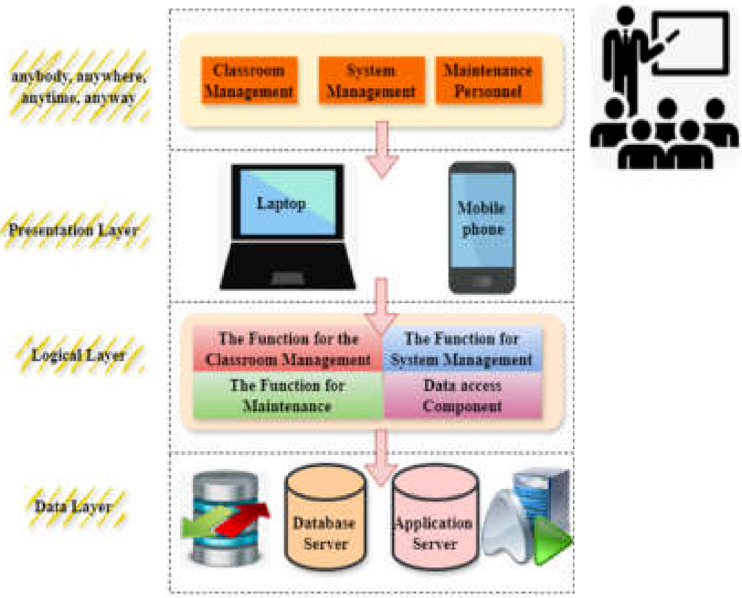

Fig. 3.3: Architecture for teaching with multimedia management

Figure 3.3 depicts a Service-Oriented Architecture based multimedia learning platform for indoor instrument education. At the very top of the organizational chart are the three main management positions: classroom instructor, system administrator, and maintenance staff. These positions offer simple access and control by interacting with the system via mobile devices and computers with the help of scalable computing. The Function for System Management, the Function for Maintenance, the Function for Classroom Management, and a Data Access Component are all part of the middle layer's role-specific functions. Teaching, system operations, and upkeep can all be better managed with these features. Database and Application Servers are the backbone of the platform, supporting applications and storing and retrieving data. Instrument training is made more efficient and effective by the integration of multimedia technologies in this SOA-based design, which also makes it more accessible and structured for administrators and instructors is shown in figure 3.3.

$$|Q(p, sf, mt)| > d_1 \sum_{p=1}^{q} |T^P| - df^2 + d_2[u]s^1 + s^2 \tag{3.8}$$

By using indicators of performance ($Q(p, sf, mt)$) and system variables (d_1, d_2, s^2) to optimize the (IMTTS), the equation aligns with the suggested strategy. To improve the learning experience, the AI algorithms in IMTTS balance the quality of instruction (T^p) with the efficiency of resources (df^2), as shown in previous equation.

$$|| < M(S_p), e_f - k \geq \left| \int_{\forall}^{1} Q(y, w_{sp}, \beta_{jk-1}) \right| - Lf^{t-1} \tag{3.9}$$

The (IMTTS) may be optimized using student measurements (S_p), engagement factors ($e_f - k$), and adaptive algorithms for learning ($Q(y, w_s p, \beta_(jk-1)))$, consider the previous equation. The AI-powered system adapts resources and instructional tactics (Lf^{t-1}) in real-time to suit individual requirements, using these factors to make the learning experience more personalized and effective.

$$\sum_{j=1}^{W} \int B_p(y(z))|e_f(m(v-1)q^w sw) = \int_{\partial}^{1} Q(y, wq, (p-kq)) \tag{3.10}$$

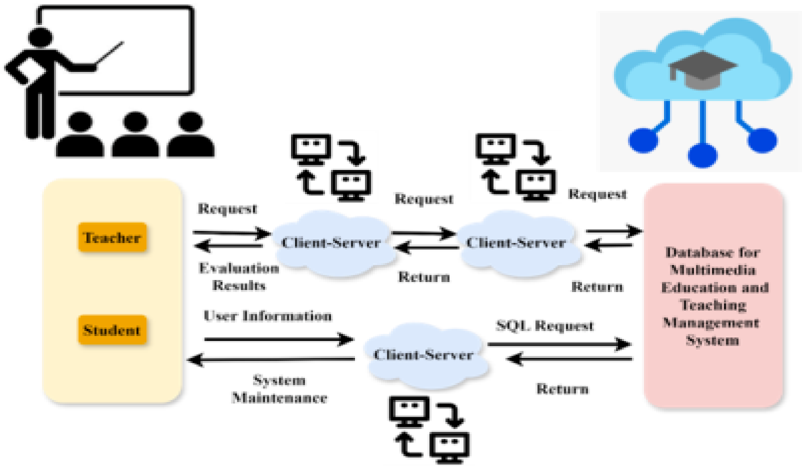

Fig. 3.4: Intelligent education teaching tracking system

In the (IMTTS), the equation 10 describes the equilibrium between customized learning metrics $(B_p(y(z)))$ and educational engagement factors $(e_f(m(v-1)q^w sw))$. This equilibrium is in line with the suggested strategy. The AI algorithms make use of these connections to adapt the system's teaching tactics and resource allocation $(Q(y, wq, (p-kq))))$ in real-time, tailoring it to each student's unique learning requirements.

Figure 3.4 shows the client-side settings and internet servers for the PE and assessment software there. The major goal of the software is to review and assess online teacher syllabi, correct management reports, and assess and evaluate students. The application is run by the administrator during the assessment. The student must be acknowledged as the focal point of learning in order for education to undergo contemporary transformation. Both teachers and students need to be able to actively participate in class discussions in real time. One traditional approach to evaluating computer education is the normal programs mode, which is a limited mode for assessing the manner of instruction. This paper laid forth a computerized evaluation approach to satisfy the goals of the new educational reform, which included managing the servers and the client using scalable computing. Students may see the evaluation results and judge the teacher's performance using this approach. In reality, teachers see students' insights and the level of dedication from both themselves and their students. Using the shared foundation type of the Website and virtual servers, it is a realistic computer training assessment system. This process improves computing-related speed, allows for real teacher-student communication, and decreases customer-server shuttered duplicate information. foundation for an evaluation is substantially more important and dependable.

$$\sum_{z=1}^{p}(b_p - e_1)||s_p|| > e_2 \sum_{k=1}^{Q} ||v_b - 1|| + ||\alpha - er|| \tag{3.11}$$

This equation is in agreement with the suggested approach since it highlights (IMTTS) may optimize student performance measures $((b_p - e_1)$ and system parameters (s_p). To improve the tailored learning experience (e_2), the AI algorithms examine these measures and strike a balance between engagement factors$(v_b - 1)$ and the distribution of resources (α). This method of dynamic adjustment enhances scalability er and instructional management by keeping the system flexible to individual demands.

$$|\rho_\pi(v^* - (s_f)T^{u+1})| = |(u+1) - (c_f(v^1))| \tag{3.12}$$

This equation shows (IMTTS) dynamically adjusts student performance (ρ_π) and system feedback (v^*), which is in line with the suggested strategy s_f. Maintaining a balance between these elements T^{u+1}, the AI algorithms

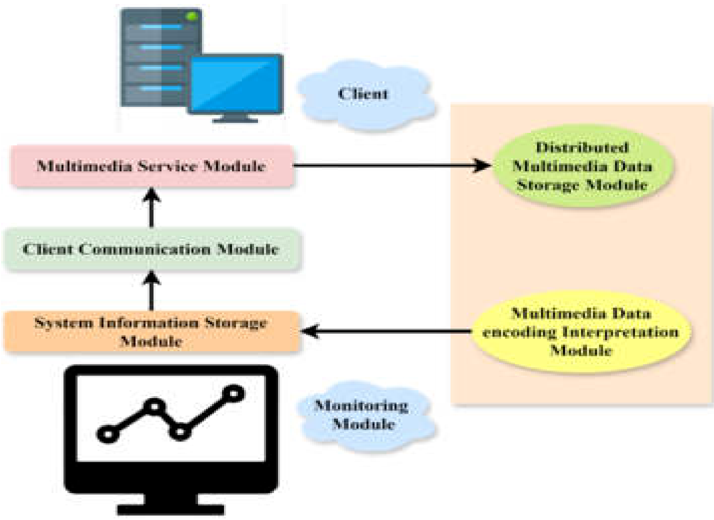

Fig. 3.5: Educational multimedia video system employing scalable computing

optimize the teaching process, making sure that each student's learning experience ($c_f(v^1)$) is customized to their specific requirements.

3.3. Contribution 3: Comprehensive Simulation and evaluation. By altering the fundamental foundation of outdated systems to enhance production efficiency, Online Plus aims to integrate the Website's user-friendly and varied advantages for e-learning with scalable computing. Virtual reality technology is a simulation model that can imitate real-world environments. The disparity in pedagogical approaches between students and teachers may be narrowed.

Figure 3.5 shows a multimedia service architecture that aims to improve client interactions and data management. The system's fundamental components are modularly organized, with the Multimedia Service Module serving as the first point of contact for the system's primary multimedia services. To guarantee smooth data transmission between the system and the clients, this module communicates with the Client Communication Module. Important system data is saved by the System Information Storage Module, which also provides general functioning support. Important parts include the Multimedia Data Encoding Interpretation Module for processing and interpreting multimedia data for different uses, and the Distributed Multimedia Data Storage Module for managing data distribution over the network. A Monitoring Module also keeps an eye on how well the system is doing, making sure it's reliable and efficient. A scalable and effective multimedia service platform is made possible by this design, which allows for rapid client connection, thorough system monitoring, and strong multimedia data management.

$$\sum_{k=1}^{D}\int_{f}^{s-1}(\alpha_{jp}-v_s-1)=(e_yp-dz(p+1t)) \tag{3.13}$$

Within the (IMTTS), the equation indicates the optimization of student engagement metrics $\alpha_j p$ and system parameters $(v_s), e_y p$, which corresponds with the suggested technique $dz(p+1t)$. To guarantee tailored educational experiences, the AI-powered system makes use of these parameters to adapt pedagogical approaches f and resource distribution in real-time $s-1$.

$$\int_{f}^{r}(p-1)=\int_{w}^{2}(Z(p,wq)-1)-\left(\int_{2}^{w}(er_{u-1}+(se_{wq}))\right) \tag{3.14}$$

By showing (IMTTS) optimizes parameters for learning (p, wq) and engagement metrics $(er_(u-1)+(se_wq))$, equation 14 is used with the suggested technique $er_(u-1)+(se_wq)$. To guarantee effective use of resources

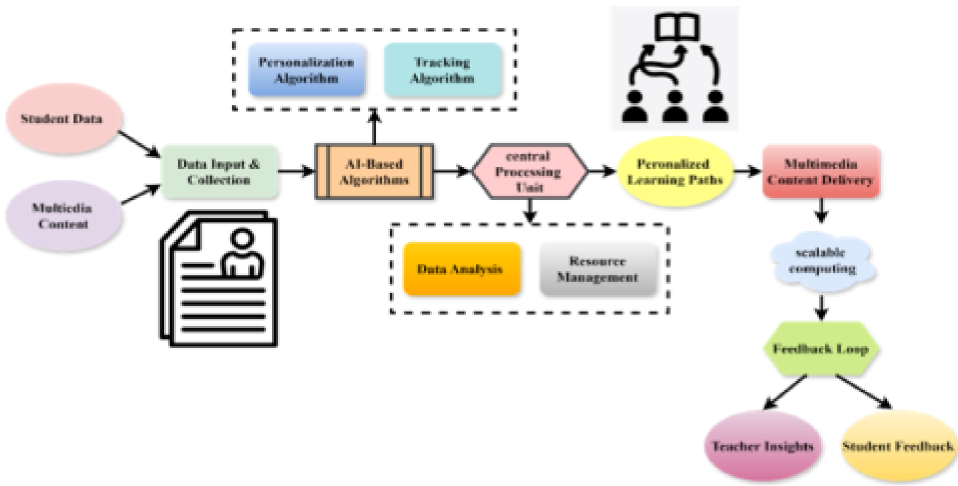

Fig. 3.6: Process flow of IMTTS

and tailored learning experiences, the AI algorithms included in IMTTS continuously modify instructional approaches according to these factors.

$$\sum_{p=1}^{S}(b_k - q) = \int_{\forall}^{1}(s_e(u-1) + |w_p dz > a|) - (dz - 1p) \tag{3.15}$$

The equation that represents the equilibrium of the (IMTTS) learning engagement metrics ($s_e(u-1)$) and system parameters ($w_p dz > a$). The educational system becomes more efficient $b_k - q$and flexible as a result of this dynamic adjustment $dz - 1p$, which allows for individualized learning experiences and the fulfillment of varied classroom demands.

Figure 3.6 shows a multimedia learning platform that is customized for each student by using the algorithms and data analysis. The first step is to gather student information and media files, which will be input into the Data Input & Collection module. A central Processing Unit processes this data using AI-based algorithms, such as tracking and personalization algorithms. To improve education, this technology creates Personalized Learning Paths that cater to each student's unique requirements. The platform uses scalable computing to handle fluctuating needs and guarantees effective delivery of multimedia content. The Data Analysis and Resource Management modules enhance the system's performance by optimizing the allocation of resources. To make sure the system is successful and adaptable, feedback loops that include teacher insights and student feedback constantly update it. Learning may be made more responsive and tailored to each student's specific needs using this holistic approach, which strives to enhance educational results.

$$||\forall_d(q + (e_s t - pl)) = S_w(\frac{1}{t_0}) + \int_{\partial}^{1}(\forall_{sw-1}) - (k = 1, P, ...M) \tag{3.16}$$

The efficiency of (IMTTS) is determined by the equation that balances engagement metrics ($e_s t - pl$), parameters of learning ($\forall_d$), and system ($S_w(1/to)$). To maximize resource management and provide personalized learning experiences, AI algorithms minimize these variables ($\forall_(sw-1)$). Overall educational results are improved and the system's responsiveness and scalability are boosted by this dynamic balancing $k = 1, P, ..M$ denotes the analysis of student engagement

$$\int_{\forall}^{1}(s_f) - (v^+)s - dp = \int_{\alpha}^{1}(Kp - kjy)\partial - (d_f + up) \tag{3.17}$$

In the (IMTTS), the equation shows suggested technique fits in with student performance $((s_f) - (v^+))$, system feedback (dp), and dynamic adjustments $(Kp - kjy)$. This keeps the system flexible enough ∂ to meet the demands of each student, allowing for effective $d_f + up$ and efficient administration of education on analysis of sustainable education management.

$$(z^+(s_f)p - 1) = c_2|f - 1|s_f(p - q) + (f^{+L-(MP)}) \tag{3.18}$$

The equation represents the optimization of the (IMTTS) and its performance measures $(z^+(s_f)p-1)$, is used in the system. The settings are constantly adjusted c_2 by the AI algorithms to improve educational results $(f-1)$, while still maintaining individualized learning routes $p - q$. The system's ability to respond to and satisfy the requirements of various students is enhanced by maintaining a balance between criticism, performance $f^{+L-(MP)}$, and allocating resources on analysis of resource allocation for cost-effective.

$$(lp - 1)r = (e_{w-1} - 1)q^*, \;\; \alpha_p < 3(1 - mp) \tag{3.19}$$

Last equation shows student performance (lp), engagement metrics $(e_{w-1}-1)$, and its parameters (1-mp). This adaptive modification enhances the system's responsiveness α_p and scalability 1-mp, making it better able to meet the demands of a wide range of students and maximize learning results for the analysis of individualized learning environments.

$$||v^+||Q_p - (l - 1) > \left(2c_2 - (\frac{1}{k-1})\right) - (S_{w+1} - (pj - l)) \tag{3.20}$$

This equation agrees with the suggested approach as it depicts the harmony in (IMTTS) between the variables S_{w+1}, which are system parameters $1/(k-1)$, and student performance metrics $(2c_2)$. This equilibrium improves the system's responsiveness and flexibility $pj - l$, which in turn meets the demands of various students and leads to better educational results Q_p on Analysis of student performance.

The goal of this paper is to improve multimedia learning environments via the application of artificial intelligence systems. These systems are able to store, aggregate, and organize AI data pertaining to multimedia learning by using data warehouse technology from scalable computing. The use of AI in the classroom paves the way for more thorough evaluations of classroom dynamics, which in turn promotes more long-term, fruitful approaches to education. A great way to get students more invested in what they're learning is to support the creation of multimedia teaching models. An example of how AI might build long-term educational systems and boost efficiency in the classroom is the ecological approach to teaching that has been suggested.

4. Result and discussion. By using AI, IMTTS improves student engagement, tailors learning experiences to individual needs, and maximizes the use of educational resources. Using massive amounts of data on how students engage with multimedia material, IMTTS develops individualised lesson plans, changes up its approach to instruction, and keeps students engaged with it all via immediate feedback. Its scalable design allows it to handle diverse user requests and enormous datasets with ease.

4.1. Dataset Description. Questionnaires were used for data collection. The research at Nottingham Trent International College provides the basis of this. The purpose of this study is to provide researchers with a tool to better understand how students manage their time. Dataset details include students' ages, sexes, countries, study programs, attendance, grades, and language course grades [26]. There is also a representation of the students' responses to the questions that dealt with time management skills.

4.2. Analysis of Student Engagement. In enhance student engagement, the IMTTS employs AI-based algorithms to meticulously track and analyse students' interactions with multimedia content. After reviewing a student's academic performance, hobbies, and habits, the IMTTS system develops a personalized learning plan. With this targeted approach, which accounts for different learning styles (as shown in equation (16), education has the potential to be more engaging and beneficial. Students are more engaged and motivated when teachers utilize the system's results to enhance their teaching approaches. Adapting multimedia material in real-time according to user input ensures that the information remains current and captivating. Also, even when demand is great, IMTTS remains responsive and performs effectively because to its scalability, which

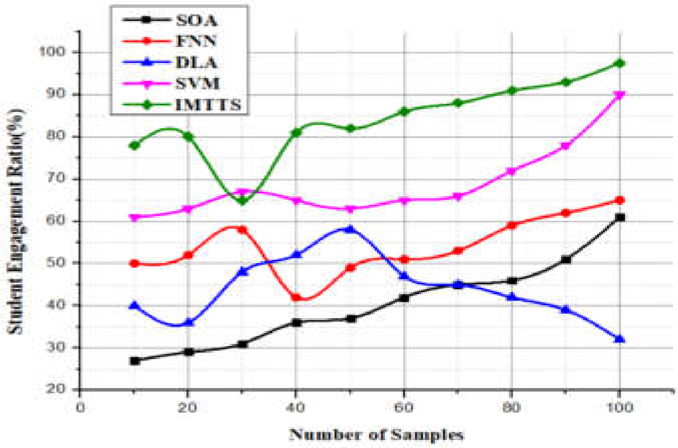

Fig. 4.1: The graph of student engagement ratio

Table 4.1: The sustainable education management

Number of Samples	SOA	FNN	DLA	SVM	IMTTS
10	77.5	31.2	40	52.1	80
20	79.2	34.8	45.5	57.2	80.9
30	71.4	40.8	49.8	50.2	84.4
40	69.5	56.5	42.2	49.9	80.8
50	77.3	70	39.1	41.7	88.3
60	79.3	67.1	41.3	43.8	89.9
70	70.1	73.5	48.8	54.2	90.7
80	62.7	69.2	52.3	68.2	95.8
90	60.8	70.4	57.3	66.7	90.4
100	69	80	61	72.3	99.2

allows it to effortlessly manage massive datasets and a significant number of users. Extensive simulation testing has shown that the system can adapt to the evolving needs of modern education, increase student engagement, and give credible recommendations for solving current educational challenges. Figure 4.1 shows that when using the IMTTS, the student engagement ratio is improved by 97.52%.

4.3. Analysis of Sustainable Education Management. To promote sustainable education management, the IMTTS is crucial since it integrates insights generated by AI with efficient resource use. IMTTS aids institutions in making the most of their resources by continuously monitoring and analysing all educational activities. There would be reduced wastage and better use of resources as a result of this. Through the implementation of personalized learning plans that are designed to align with each student's specific needs and areas of interest, educational resources may be more effectively used.

Sustainable education management also includes responding to fluctuating demand and adjusting to new classroom settings. IMTTS's scalable computing capabilities allow it to handle enormous datasets and diverse

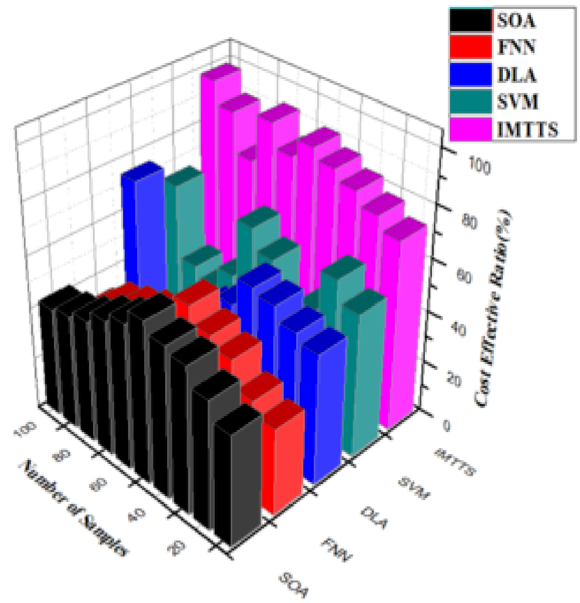

Fig. 4.2: The graphical representation of resource alllocation for cost-effective

client requests with ease. In order to ensure sustainability in the long run, IMTTS provides administrators with comprehensive data analysis so they may make informed decisions. The IMTTS is useful for spotting trends and improvement opportunities. Table 4.1 shows that this approach not only improves educational outcomes, but also helps construct an educational infrastructure that is better suited to deal with future challenges.

4.4. Analysis of Resource Allocation for Cost-Effective. The AI, IMTTS optimizes the use and distribution of instructional materials, leading to more efficient use of funds and better overall management of schools' budgets. A previous equation is used to extract the appropriate resources for different learning and teaching scenarios, which is then utilized by the IMTTS system to make sure that resources are deployed where they can have the greatest effect. Save money you don't need by spending it wisely and making the most of what you have. Administrators are able to make informed decisions on budgeting and procurement with the help of real-time data on resource usage provided by IMTTS, which helps to optimize efficiency and avoid overpurchasing. The system may tailor learning paths to each student's needs by using the most relevant resources, which further improves cost efficiency. Ultimately, educational administration may choose to use IMTTS due to its scalability, which allows it to adjust to evolving demands without increasing costs. This kind of resource allocation is smart and helps educational activities run more smoothly and cheaply. The cost-effective ratio increases by 98.23% in the IMTTS, as shown in figure 4.2.

4.5. Analysis of Individualized Learning Environments. The AI powered insights employed by the IMTTS make each student's educational experience unique with respect to learning environments issues. Equation 19 describes how the system tracks students' interaction with multimedia content giving them scores; then based on these scores, the program proceeds to adjust the teaching materials. By appropriate instruction strategies according specific emotional states of students their learning styles or interest areas a student-centred approach improves educational outcomes.

With the help of IMTTS system, teachers can create more customizable and supportive learning environment in classrooms instantly. This would be more interesting and fun for students when content is changed to match their growth. The scalable architecture of IMTTS allows continuous delivery of highly personalized experiences even in massive educational environments. In view of Figure 4.2, this approach towards individualized learning environments may enhance accessibility, engagement and value of education for everyone.

Table 4.2: Individualized learning environments

Number of Samples	SOA	FNN	DLA	SVM	IMTTS
10	67.5	41.2	30	32.1	70
20	69.2	44.8	35.5	37.2	70.9
30	61.4	50.8	39.8	30.2	74.4
40	79.5	66.5	42.2	39.9	80.8
50	67.3	80	39.1	41.7	84.3
60	69.3	67.1	41.3	43.8	88.9
70	60.1	73.5	48.8	54.2	90.7
80	52.7	69.2	52.3	58.2	91.8
90	60.8	70.4	57.3	66.7	83.4
100	69	80	61	72.3	99.2

4.6. Analysis of Student Performance. The IMTTS algorithm offered a complex structure for monitoring student progress using the DA and AI. Students' interaction with multimedia in collecting extensive data on several performance metrics like understanding, engagement, and growth is monitored by how IMTTS are presented in Equation 20.

The teachers employed a hands-on approach to know the student's strengths and areas of development byanalyzing data patterns. The support of real-time feedback from the system facilitated timely intervention. Based on the needs of every student, individualized care was provided by IMTTS.

By monitoring evolutions over time, IMTTS supports predicting outcomes and curriculum planning. Through effective performance analysis methods, IMTTS ensures the optimal balance of challenge and support the students receive. It will enable differentiated instruction. This method facilitates the academic achievement of the whole class and individual students. The teachers employ the insightsto help make classrooms more effective and responsive. This will enhance the outcomes and performances of the students. 97.2% improvement in the student performance ratio is presented in Figure 4.3.

In summary, by integrating AI-driven insights, IMTTS revolutionizes education by making learning more personalized, improving resource management, and increasing student engagement. Education benefits from its scalable data processing, personalized learning settings, and real-time feedback capabilities, leading to better management in the long run.

For various educational activities, effectively managing various resources is significant. Digital content, instructional tools, storage capacity, network bandwidth, and user access were included in these resources. AI optimized resource allocation by analyzing consumption patterns, predicting future needs, and dynamic adjustment of resource distribution. The system runs at its highest possible efficiency and offersall vital instructional materials and services with no additional costs;the users must identify all.

Improving educational results and financial sustainability are the main objectives of this study. This objective can be achieved by developing a more efficient, scalable, and responsive multimedia teaching environment via the automation and refinement of resource management. Computerized essential procedures like content management, resource allocation, and user customization by applying AI enhance scalability in this study. Based on the method, the system can manage more users and larger data sets with minimal or no human involvement.This keeps the system's performance and cost-effectiveness in check and ensures it can handle additional institutions, students, and instructors as it expands. The system considers each student's unique requirements and preferences when recommending multimedia content like interactive films and lan-

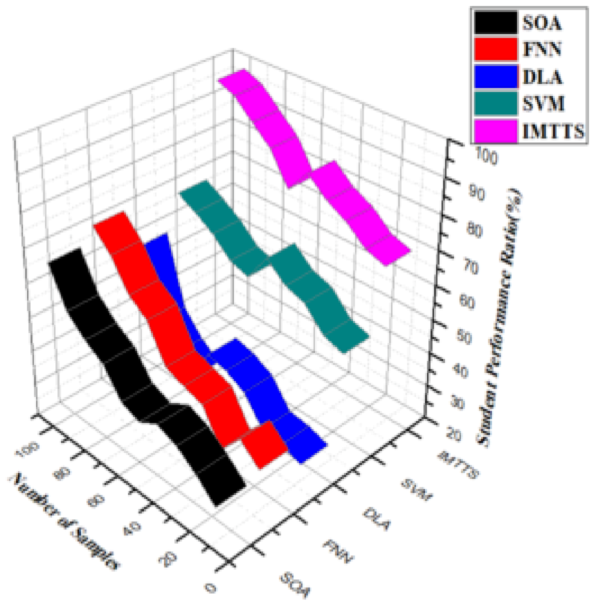

Fig. 4.3: The graphical illustration of student performance

guage exercises. When students' attention decreases during a lecture, AI-powered applications use computer vision to detect it and propose interactive teaching techniques. Resource allocation occurs in real-time to make the most of available supplies. For example, Virtual Reality headsets are distributed for group activities. After each lesson, comprehensive analytics on student understanding of the material are produced, allowing for real-time modifications to pedagogical approaches, bettering learning results and the effectiveness of resource management.

5. Conclusion. IMTTS presents a multimedia education system that fully utilizes the benefits of artificial intelligence technology. In terms of higher education, its system is very secure, very responsive, and can significantly increase the system's operational speed. On the other hand, research on knowledge representation and base organization is lacking in the higher education system, with only the student model, teacher model, teaching strategy, and intelligent teaching inference engine receiving much attention. The thorough research on knowledgebase structure in the future study, paying close attention to the development and maintenance of student-specific knowledge trees. The effectiveness of the higher education system is further validated by applying the system to specific application projects. The intelligent teaching system and the views of both instructors and students on a specific school's online course selection system form the basis of this paper's instance. More than 60% of professors and students preferred the online course selection system that relies on AI and computer technology, according to the study material, which first examines and presents the contemporary intelligent online course selection system. The AI- and computer-based intelligent education system that polls students' preferences. According to the poll, both instructors and students have a strong preference for the current intelligent teaching approach, but not all are satisfied. This demonstrates that there is room for more development and refinement in the system. More innovative research methodologies are still required, and the research presented in this publication is still inadequate.

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ACDPSNET: ADAPTIVE CROSS DOMAIN POLARITY ASPECT LEVEL LEARNING SCALABLE COMPUTING MODEL FOR SENTIMENT CLASSIFICATION AND QUANTIFICATION

JHANSI RANI T*, SWAPNA NEERUMALLA†, AKUNDI SAI HANUMAN ‡, B. VEERASEKHAR REDDY §, AND KAYAM SAIKUMAR¶

Abstract. Automatic sentiment classification, identifying opinions as positive, negative, or neutral, is essential across diverse applications. However, applying a sentiment classifier trained on labeled data from one domain to a different domain often leads to degraded performance, as domain-specific language terms common in the source domain may not appear in the target domain. This research proposes an Adaptive Cross-Domain Polarity-Specific Network (ACDPSNet) for sentiment classification and quantification across domains. The model leverages labeled data from the source domain alongside labeled and unlabeled data from the target domain to build a robust, adaptable domain adaptation framework. Sensitivity to sentiment is enhanced by embedding polarity-specific sentiment annotations into semantic vectors, enabling accurate computation of distributional similarities between terms. The framework integrates a classifier that is both domain-specific and domain-invariant to ensure accurate analysis and classification. ACDPSNet achieves notable performance improvements, with an accuracy of 98.76%, recall of 97.85%, throughput of 96.94%, and a positive learning expression rate of 97.76%, demonstrating significant advancements over existing approaches. These metrics underscore ACDPSNet's effectiveness in adapting to new domains, achieving high sentiment quantification accuracy, and enhancing cross-domain polarity detection.

Key words: Polarity, Domain Transfer, Scalable computing Pivot Model, Domain Adaptation and Cross-Domain Sentiment Classification

1. Introduction. The increasing importance of sentiment analysis across various applications has led to significant research interest in this field. Traditional studies often emphasize predicting the sentiment of entire texts, ranging from paragraphs to individual phrases [1]. However, accurately discerning sentiment towards specific aspects within a text is essential, as it requires an in-depth understanding of the contextual language surrounding those aspects. This challenge, known as automatic sentence-level sentiment classification [2], is crucial for applications such as market analysis, opinion mining, and contextual advertising.

Cross-domain sentiment classification is particularly challenging because it involves applying classifiers trained on one domain (source domain) to a different domain (target domain). This challenge entails two significant issues: identifying the common characteristics between the source and target domains and developing a learning framework that incorporates this relatedness. In our research, we propose a hybrid approach for emotion classification across domains to address these challenges effectively.

In sentiment analysis, accurately determining the polarity of opinions at the aspect level is critical, especially when dealing with the complexities of language, context, and topic variations across different domains. Traditional sentiment classification methods often struggle to maintain accuracy in cross-domain scenarios, where these variations can significantly impact performance. The challenge is even greater when the objective extends beyond classification to quantification—estimating the prevalence of each sentiment class within a dataset.

*Department of CSE, GITAM School of Technology, GITAM Deemed-to-be-University, Hyderabad, India (jhansi.rani.t@gmail.com)

†Vignana Bharathi Institute of Technology, Hyderabad, India (swapnakiran29@gmail.com)

‡Gokaraju Lailavathi womens engineering college, Hyderabad, Telangana, India (a_saihanuman@hotmail.com)

§Department of information technology,MLR Institute of Technology, Hyderabad-500043, Telangana, India (veerasekhar@mlrinstitutions.ac.in)

¶Department of Electronics and Communication Engineering, Koneru Lakshmaiah Education Foundation, Hyderabad-500075, Telangana, India (saikumar.kayam@klh.edu.in)

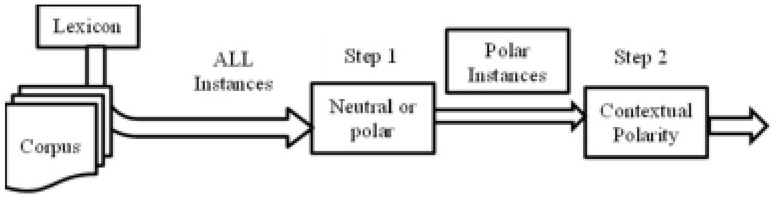

Fig. 1.1: Positive, Negative and both neural

Adaptive Cross-Domain Polarity Aspect-Level Sentiment Classification and Quantification represents a pivotal area of research, aimed at overcoming these challenges. This approach focuses on developing models that can adapt to new domains with minimal labeled data while providing robust sentiment quantification. By leveraging the potential of cross-domain transfer learning, these models can be effectively applied to new domains, thereby enhancing both classification accuracy and the reliability of sentiment quantification.

Polarity classification. Figure 1.1 illustrates the outcomes of our proposed research, which focuses on developing and evaluating adaptive methods that not only classify sentiment at the aspect level but also quantify the distribution of sentiment across different domains. This dual approach is particularly important in scenarios where understanding both the intensity and distribution of sentiment is as crucial as identifying the sentiment itself. By addressing these challenges, our research contributes to the broader objective of creating more flexible and accurate sentiment analysis systems capable of operating effectively across a wide range of domains and contexts.

Aspect-level sentiment classification (ASC) is a nuanced task in sentiment analysis that aims to determine the polarity—positive, neutral, or negative—towards specific opinion targets within a sentence. For example, in the sentence "Average to good Thai food, but terrible delivery," the opinion targets are "Thai food" and "delivery," with corresponding sentiments being positive and negative, respectively. The advent of deep learning in natural language processing (NLP) has significantly advanced ASC tasks, with neural network models often outperforming traditional machine learning techniques. These deep learning models have demonstrated superior performance in ASC due to their ability to capture complex patterns in the data. Given the specific requirements of ASC, particularly the need to distinguish between sentiments expressed towards different targets within the same context, recent studies have increasingly incorporated attention mechanisms into deep learning models. These attention-based approaches improve sentiment prediction by focusing on sentiment-laden words that are relevant to specific targets.

However, the effectiveness of deep learning models heavily depends on the availability of sufficient training data. In practical applications, generating aspect-level training data requires extensive manual annotation, which limits the size of available public datasets and, consequently, the performance of neural network models. On the other hand, large volumes of document-level sentiment classification (DSC) labeled data are available from many online review platforms, offering rich emotional insights and semantic patterns. This presents an important research question: how can the valuable knowledge contained in DSC data be harnessed to enhance ASC tasks, especially when aspect-level resources are limited. The core challenge in cross-domain sentiment classification is training a classifier on one or more source domains and effectively applying it to a different target domain. Our proposed framework, named Adaptive Cross-Domain Polarity Aspect-Level Sentiment Classification and Quantification (ACDPASCQ), addresses this challenge by integrating various methodologies. It employs co-training on target unlabeled data to achieve invariant classification and analysis, extracts both domain-invariant and domain-specific aspects from the target domain data, and identifies significant polarity words that are consistent across domains.

The objectives the work follows:

1. Transferable Information Across Domains
2. Identification of Target Features from Source and Target Domains
3. Classification and Analysis of Cross-Domain Sentiment

By integrating these approaches within the ACDPASCQ framework, we aim to provide a comprehensive solution to the challenges posed by cross-domain sentiment classification.

2. Related work. The field of sentiment classification systems is generally divided into two main categories: single-domain classifiers [2] and cross-domain classifiers [3]. Our research centers on document-level cross-domain sentiment classification [4]. In this context, a classifier is initially trained for single-domain sentiment categorization using labeled data specific to the application domain [4]. For example, Turney [5] introduced an approach using point-wise mutual information to assess the sentiment of a word by analyzing its co-occurrence with manually selected positive (e.g., fine, wonderful, fantastic) and negative (e.g., dreadful, unpleasant, weak) words. While single-domain sentiment classification has been extensively explored [6], recent advancements in domain adaptation techniques have brought cross-domain sentiment classification into focus.

The objective of sentiment classification is to assign an emotional polarity to a given text, typically categorized as positive, negative, neutral, or into more nuanced categories. This area has garnered significant attention in recent years [7], particularly because real-world texts often involve multiple target entities or specific aspects of a topic. Customer reviews serve a dual purpose: they help other customers make informed decisions and assist online retailers in predicting sales [8] and understanding customer preferences [9]. This understanding enables retailers to craft effective marketing strategies to boost revenue. However, the sheer volume of reviews across diverse domains on these platforms presents a challenge in efficiently extracting the most relevant information. Consequently, researchers have increasingly focused on developing automated methods for cross-domain aspect-based sentiment classification [10].

The primary challenge in cross-domain aspect-based sentiment classification lies in the discrepancy between the training and testing data, which originate from different domains and thus exhibit distinct characteristics [11]. Previous studies have explored two main approaches to address this issue: data-based and feature-based. The data-based approach focuses on constructing a training dataset that closely resembles the target data. Typically, this involves generating pseudo-labels for the target data and incorporating these labeled target data into the training set [12]. However, the effectiveness of this approach heavily depends on the quality of the generated pseudo-labels, which directly impacts the model's performance. A feature-based approach has been proposed [13] to overcome the limitations of the data-based approach. Rather than generating pseudo-labels, this approach seeks to identify domain-independent features shared between the source and target domains. These features often include syntactic dependency relations and domain-independent words [14]. Researchers have employed models such as Conditional Random Fields [15] and Recurrent Neural Networks [16] to encode syntactic dependency relations. For domain-independent words, higher weights are assigned to these words than domain-specific ones [17].

By leveraging domain-independent information, connections between the source and target domains are established, enabling the trained model to perform well across both domains. Aspect-level sentiment classification (ASC) has seen significant advancements, particularly with the adoption of deep learning methods that enhance the precision and accuracy of sentiment analysis at a granular level [18]. Traditional approaches to ASC often relied on supervised learning techniques that required substantial amounts of annotated data, posing limitations, especially when adapting models to new domains with scarce labeled data.

Cross-Domain Sentiment Analysis. This area of research has emerged to address the challenge of transferring knowledge from a source domain, rich in labeled data, to a target domain with limited or no labeled data. Early works, such as those by [19], utilized domain adaptation techniques to reduce discrepancies between domains, enabling more effective sentiment classification across different contexts. These foundational approaches paved the way for more sophisticated methods that incorporate deep learning.

Deep Learning and Attention Mechanisms. The advent of deep learning has introduced neural networks as the backbone for ASC. Models such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) have been widely adopted for their ability to learn features from data automatically. Attention mechanisms have further enhanced ASC by allowing models to focus on relevant text parts when making sentiment predictions. Attention-based models, such as the Hierarchical Attention Network [20] and the Aspect-Based Sentiment Classification model [21], have significantly improved capturing sentiment at the aspect level. Domain Adaptation Techniques: Recent studies have explored various domain adaptation techniques in conjunction with deep learning to improve cross-domain ASC. Models like Transfer Learning with Fine-Tuning and Adversarial Training for Domain Adaptation have shown promise in transferring sentiment knowledge from one domain to another, improving classification accuracy in the target domain. These methods are particularly effective when domain-specific language and context differ significantly. Sentiment Quantification: Beyond classification, sentiment quantification has become an important research area. The goal is not just to classify sentiment but to quantify sentiment distribution across different categories within a dataset. Traditional sentiment quantification methods, such as those proposed by [22], relied on aggregated document-level predictions. However, recent advancements have integrated quantification techniques with deep learning models, allowing for a more accurate estimation of sentiment prevalence in diverse domains. Challenges and Future Directions: Despite these advancements, challenges remain in achieving robust cross-domain ASC and sentiment quantification. One of the main difficulties is the heterogeneity of language and sentiment expression across domains, which can lead to reduced model performance. Future research will likely focus on developing more sophisticated domain adaptation techniques, possibly leveraging unsupervised or semi-supervised learning to reduce reliance on labeled data [23]. Additionally, integrating quantification with ASC in a unified framework remains an open research question with the potential to significantly enhance the practical applicability of sentiment analysis models in real-world scenarios [24]. The existing models are facing issues with misclasses balancing and batch normalization. The open-source dataset used by earlier models can drop its MAP (Mean Average Precision) and performance [25]. The limitations of existing models can be crossed over through custom deep-learning models with benchmark dataset training.

3. Proposed Methodology. This paper first evaluates the adaptive cross-domain polarity aspect level sentiment classification and quantification (ACDPASCQ) framework for domain adaptation. We design a polarity of aspect-level sentiment analysis by deriving the polarity of words for labeled and unlabelled data with a pivot model. Classification of labeled and unable data across domains using domain invariant and specific classifier.

Aspect-Level Sentiment Classification. In the early research on aspect-level sentiment classification (ASC), the primary methodologies were heavily dependent on feature engineering. For example, Kiritchenko et al. [9] utilized n-gram features and developed new lexical resources, integrating these features into classification models using Support Vector Machines (SVM). Similarly, Yi and Zhou [10] designed sentiment feature vectors by calculating sentiment values and employed models such as Naive Bayes and SVM for training. Although these methods achieved notable results, their performance was largely contingent on the quality of manually crafted features, which demanded significant time and effort in feature design. The advent of deep learning addressed these limitations by enabling neural network models to automatically learn crucial sentiment features from text based on sentence vectors, eliminating the need for manual feature construction. Dong et al. [4] were among the first to apply Recurrent Neural Networks (RNNs) to ASC, improving sentiment classification accuracy by using RNNs to extract sentiment polarity from text and integrating syntactic structure information to support the model. Xue et al. [3] introduced a convolutional neural network (CNN) model with a gating mechanism that selectively outputs emotional features through convolutional layers. To mitigate the issue of gradient explosion associated with RNNs, Tang [2] proposed the use of Long Short-Term Memory (LSTM) networks, which model the left and right contexts of a given opinion target to extract sentiment information. However, due to the fine-grained nature of ASC, these models often struggled to effectively capture the relationship between the context and the specified opinion target. To address this challenge, subsequent research focused on incorporating attention mechanisms to capture target-dependent sentiment contexts. Wang [5] proposed an attention-based LSTM that enhances relevance by concatenating aspect word vectors with context vectors and then applying self-attention to extract sentiment knowledge specific to the aspect word and its context. Xu [11] introduced a dual attention module, combining global and local attention to capture different granularities of interaction information between aspects and contexts. Lin [12] utilized multi-head target-specific self-attention to better capture global dependencies and introduced target-sensitive transformations to address target-specific sentiment. Liu [13] further refined sentiment feature extraction by employing multi-head attention to capture semantic information between words related to the specified aspect and replaced the softmax function in the classification layer with SVM to improve feature representation in high-dimensional space. Li [6] integrated syntactic dependency information with semantic information, facilitating interaction between aspect words and sentences through attention-based graph convolutional networks (GCNs). Huang [14] developed a contextual location weighting function that considers the positional information of aspect words within the context, thereby reducing the influence of surrounding words on sentiment polarity. Despite the significant improvements in ASC performance brought about by these deep learning-based methods, they remain highly dependent on the availability of data. The limited size of existing ASC datasets constrains the ability of these supervised models to realize their full potential. To overcome this limitation, this paper proposes leveraging the Document-Level Sentiment Classification (DSC) task to transfer a large amount of sentiment knowledge, thereby mitigating the impact of insufficient data on ASC performance.

Transfer Learning. Transfer learning aims to utilize knowledge from one or more related tasks (source tasks) and apply it to a different but related target task. Transfer learning techniques in natural language processing (NLP) are generally categorized into three main types: instance transfer, model transfer, and domain adaptation. These methods have been successfully implemented in various NLP subtasks, including machine translation [14], question-answering systems [16], and speech recognition [17]. Model transfer has become a well-established method for leveraging knowledge from document-level tasks to support aspect-level tasks.

Model transfer is often employed in multi-task learning, where data from multiple related subtasks are used, and shared modules are applied to learn the relationships between these tasks, thereby extracting additional useful information. For instance, Xu [18] introduced a pre-training plus multi-task learning model. This approach first involves training on a document-level dataset using a shared BiLSTM module to obtain pre-trained weights. These weights are then retained as initialization parameters for the shared part of the model. Subsequently, aspect-level data are fed into the pre-trained model to train both tasks simultaneously, allowing for fine-tuning of the weights.

To enable the flexible application of document-level knowledge, Chen [32] proposed a model based on transfer capsules. Unlike the method used by Xu [18], Chen's approach employs multi-task learning with heterogeneous datasets [20], where both document-level and aspect-level datasets are fed into the model simultaneously. The shared parameters are dynamically optimized, and at the upper layer of the model, semantic capsules and dynamic routing are combined with the transferred knowledge.

While these methods are highly effective, they are limited by the hard parameter sharing inherent in vanilla model transfer (VMT) [21] used within the shared modules. This hard sharing can lead to a scenario where the shared module negatively impacts learning in the target task due to differences in tasks and data. In contrast, our auto-adaptive model transfer method addresses these discrepancies, allowing the model to learn more refined and relevant information from the auxiliary task, thereby enhancing the accuracy of ASC.

Domain Adoption. A set of ns fully named Ds = (xs 1, ys 1) and (xs ns, ys ns) = Rd = Y chosen from the Ps(X, Y) array make up the root domain. Also divided into nl (nl ns) categorized points is the aim data. Dl t = (xt 1, yt 1), xt nl, yt nl Nu (nu nl) unlabelled points and Ru Y from the distribution Pt(X, Y) Du t is equal to (xt nl+1,yt nl+1), The objective is to build a classifier for target data using the source domain data and a few selected target domain data.

In this section we present CMD parameters used to calculate the variance between two Random variables in the distribution of probabilities. Here, we extract the domain-specific and Domain invariant representation from the target domain instances. Finally, demonstrate how these two interpretations can be mixed using the co-training framework shown in figure 3.1.

3.1. Central Moment Discrepancy (CMD). Zellinger et al. (2017) suggested the CMD parameter to calculate the difference between two (high-dimensional) random variables in the probability distributions. Let X and Y be random samples bounded at the interval [a,b]N with p and q, the corresponding probability distributions. The CMD regulator CMDK is specified as

$$CMD(X,Y) = \frac{1}{|b-a|}\left\|E(X)-E(Y)\right\|_2 + \frac{1}{|b-a|^k}\sum_{k=2}^{k}\left\|C_k(X))-C_k(Y)\right\|_2 \tag{3.1}$$

The vector of analytical expectations based on the X sample is denoted by

$$E(X) = 1|X|Px\epsilon Xx. \tag{3.2}$$

$$C_k(X) = (E(\prod_{i=1}^{n})X_i - E(X_i))^{ri})r_{i\geq 0}, \sum_{i}^{n} r_i = k \tag{3.3}$$

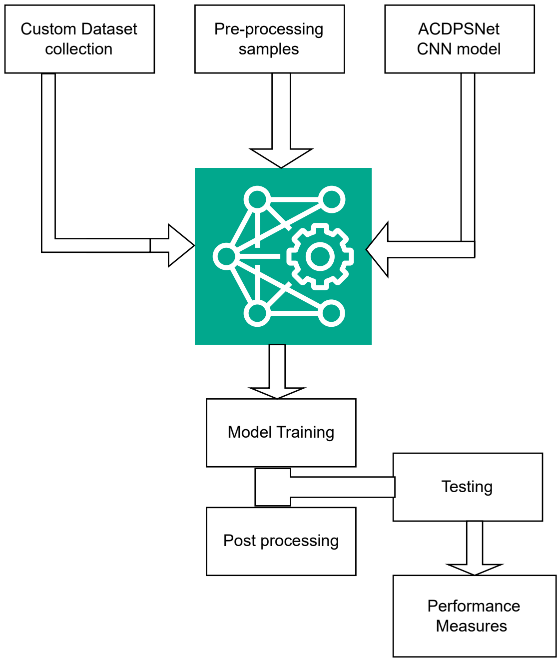

Fig. 3.1: Proposed model Block Diagram

Is the matrix of all kth order sequence main co-ordinate times X. The implicit interpretation of this equation is that whenever two distributions of probabilities are close, There will be a closer core moment of greater order.

3.2. Retrieve Domain Specific and Domain Invariant Representations. Our goal in this work is to obtain both a domain-specific counterpart and a domain-invariant representative for every target instance. Using two separate mappers, Et and Ec, respectively, Data is converted into a unique hidden space for the desired domain and a domain-invariant hidden space.

$$H^s_{spe} = E_t(X_s, \Theta^t_e) \tag{3.4}$$

$$H^t_{spe} = E_t(X_t, \Theta^t_e) \tag{3.5}$$

$$H^t_{spe} = E_t(X_t, \Theta^t_e) \tag{3.6}$$

$$H^s_{inv} = E_t(X_s, \Theta^c_e) \tag{3.7}$$

$$H^t_{inv} = E_t(X_t, \Theta^c_e) \tag{3.8}$$

The goal domain-specific mapper in this case is Et stands for the mapper that is domain invariant, and Ec. The related parameters are defined by $\Theta^{\,c}_{e}$ and $\Theta^{\,t}_{e}$ Encode signifies the subscript e. Depending on the hidden $H^t_{inv} and H^t_{spe}$ representations, we are creating an autoencoder for the examples of target domains:

$$X_t = D_t(H^t_{inv}, H^t_{spe}, \Theta^t_d) \tag{3.9}$$

As far as parameters are concerned,Θ_d^t the d subscript denotes decoding. The resulting reconstruction failure is the mean square error described as:

$$L_{recon} = \frac{1}{n_t} \sum_{i}^{n_t} \frac{1}{k} \left\| X_t^i - X_t^i \right\|^2 \tag{3.10}$$

where Xi t is the target domain data, for instance, ith, and k is the input function vector component. Remember that in this task, the auto-encoder receives only target instances, as our goal is to obtain accurate information about the target domain. The hidden representation of the $(H - inv^s)$ source data and the $(H - inv^t)$ target data have the CMD regularizer added. The corresponding loss will be explained as follows:

$$L_{sim} = CMD_k(H_{inv}^s, H_{inv}^t) \tag{3.11}$$

Ec is encouraged to encode domain-specific invariant features when this loss is minimized since it will force the H_{inv}^s, H_{inv}^t distributions to be identical. The loss in question will be explained as follows:

$$L_{diff} = -CMD_k(H_{spe}^s, H_{spe}^t) \tag{3.12}$$

Minimizing the error allows H_{spe}^s propagation to vary from H_{spe}^t which in effect enables Et to encode different domain features.

3.3. Polarity of Words in the Labelled Source Domain. The statistically significant correlation between a word and a class label is supported by the chi-square test. We give each word in the domain a polarity orientation based on this relationship. Since the target domain data is unlabelled, a χ^2 check cannot be utilized to determine the words' meaning. However, we exploit the fact that only some terms in the target domain that are known to be significant in the source domain need to be characterized as meaning in order to acquire SCP terms across domains. It is presumed that a term that meets the χ^2 test criteria for relevance in the source domain and appears frequently (nearly) in the target domain is also significant. According to the χ^2 test, the source domain is also significant in the target domain when it appears more frequently than a particular threshold (nearly).

$$count_t(significant_s(w)) > \Theta \Rightarrow significant_t(w) \tag{3.13}$$

The labelled source (s) domain's significance of the word w is guaranteed by [significant]-s, whereas [count]-s provides the normalized count of the w in t. Using this supposition as a foundation, we fix the value of Θ.

Word Polarity in the Target Unlabelled Domain. Positive words typically exist in polar corpuses with other positive words, whereas negative words typically occur in conjunction with other negative words (Sharma et al., 2015). Mikolov et al. (2013) discovered that nearby words, such "go" and "to," had a higher degree of similarity in their meaning vectors than far-off words or words that are not nearby. Using the publicly available word2 and the skip-gram model toolbox, we measured the context vector (conVec) of a word (w) (Mikolov et al., 2013).7. This model predicts words within a given window by using the Huffman code of each word as an input to a log-linear classifier with a persistent projection layer. Equation 3's decision-making process outlines how to assign polarity to an unknown term in the target domain.

$$If(cosine(conVec(w), conVec(PosPivot)) > cosine(conVec(w), conVec(NegPivot))) \Rightarrow Positive \tag{3.14}$$

$$If(cosine(conVec(w), conVec(PosPivot)) < cosine(conVec(w), conVec(NegPivot))) \Rightarrow Negative \tag{3.15}$$

3.4. Pivot Selection Method. We found empirically that a polar term that has the largest percentage in the corpus offers more coverage by using context vector to estimate the polarity orientation of other terms. Furthermore, it is discovered that a polar term with the highest frequency in the target domain works better as the pivot for input term polarity detection. A few phrases in the electronics domain are shown in Table 3.1 whose polarity orientation is determined by similarity scores acquired using PosPivot and NegPivot. The inferred polarity orientation of the words along with the cosine-similarity scores using PosPivot (excellent) and NegPivot (bad) is shown in table 3.1.

Table 3.1: The inferred polarity orientation of the words

word	Great	Poor	Polarity
Noisy	0.03	0.24	Neg
Crap	0.04	0.28	Neg
weak	0.05	0.21	Neg
Defective	0.21	0.70	Neg
Sturdy	0.43	0.04	Pos
Durable	0.44	0.00	Pos
perfect	0.48	0.20	Pos
Handy	0.60	0.21	Pos

3.5. Domain Transferable Knowledge. To determine the importance and polarity of terms in the labelled source data and the unlabelled target data, the suggested algorithm makes use of the previously discussed techniques. Significant, consistent polarity (SCP) characteristics are a group of phrases that are relevant in both fields and have the same polarity orientation. These features are used to classify attitudes that are cross-domain. The weights learned by the classification algorithm for the SCP features in the labeled source domain can be reused in the unlabelled target domain for sentiment classification because SCP features have clear impacts in both domains. Based on the cosine correlation function, it differentiates the positive or negative polarity.

Algorithm 2 Aspect Level Domain Adaptation

Input:

- L_s: Instances labeled in the source domain
- L_t: Instances labeled in the target domain
- U_t: Unlabeled instances in the target domain

Representations:

- H^s_{inv}: Invariant representation for L_s
- H^t_{inv}: Invariant representation for L_t
- H^t_{spec}: Specific representation for L_t

Steps:

1. **Train Classifier:** Train classifier F_c on labeled instances L_s and L_t using invariant representations H^s_{inv} and H^t_{inv}.
2. **Classify Unlabeled Data:** Apply classifier F_c to predict labels for instances in U_t.
3. **Select High-Confidence Predictions:**
   - Identify instances in U_t with the highest confidence scores.
   - Select positive instances p and negative instances n to form the subset U^t_c containing these high-confidence predictions.
4. **Train Specific Classifier:** Train a separate classifier F_t on L_t using the specific representation H^t_{spec}.
5. **Refine Predictions on U_t:**
   - Apply classifier F_t to predict labels for instances in U_t.
   - Select positive instances p and negative instances n with the highest confidence scores, resulting in a subset U^t_t.
6. **Update Unlabeled Set and Target Labels:**
   - Remove instances in U^t_c and U^t_t from U_t.
   - Add the selected high-confidence instances U^t_c to L_t and assign their predicted labels.
7. **Repeat Steps 2–6** until the desired performance is achieved on the development dataset.

3.6. Domain invariant and specific classifier. This model's training is divided into two parts, with one for the domain invariant classifier, Fc, and one for the domain-specific classifier, The training objective for Fc is to minimize the following failure concerning parameters

$$\Theta = \Theta_e^c, \Theta_e^c, \Theta_d^t, \Theta_c^t \tag{3.16}$$

$$L = L_{recon}(\Theta_e^c, \Theta_e^t, \Theta_d^t) + \alpha L_c(\Theta_e^c, \Theta_c^t) + \gamma L_{sim}(\Theta_e^c) + \lambda L_{diff}(\Theta_e^t) \tag{3.17}$$

where the weights α, γ, and λ control how the words of loss are connected.$L(\Theta)$ denotes that throughout training on the parameters, failure, L, is balanced. Moreover, Lc indicates that the domain's invariant representation is not classified. Described by the ground-truth class 's negative log-likelihood for instances of both source domain and target domain

$$L_c = \frac{1}{n_s + l_t} \sum_{i=1}^{n_s} -Y_s^i logF_e(Y_s^i \middle| E_c(L_s^i)) + \frac{1}{n_s + l_t} \sum_{i=1}^{L_t} -Y_t^i logF_e(Y_t^i \middle| E_c(L_t^i)) \tag{3.18}$$

The dynamic number of target data tagged in each iteration is shown by Y I t, which is the one-hot encoding of the class label for the source in the example. The training challenge for Ft is to minimize the subsequent parameter failure.

$$\Theta = \Theta_e^c, \Theta_e^c, \Theta_d^t, \Theta_c^t \tag{3.19}$$

$$L = L_{recon}(\Theta_e^c, \Theta_e^t, \Theta_d^t) + \beta L_c(\Theta_e^c, \Theta_c^t) + \gamma L_{sim}(\Theta_e^c) + \lambda L_{diff}(\Theta_e^t) \tag{3.20}$$

where the weights $\gamma and \lambda$ correspond to the classifier's weights, the weight β and Fc control the classification failure portion. In contrast, Lt is the domain-specific representation based on the target domain's negative log-likelihood of the ground-truth class.

$$L_t = \frac{1}{l_t} \sum_{i=1}^{l_t} -Y_t^i logF_t(Y_t^i | E_t(L_t^i)) \tag{3.21}$$

The cosine of the angle formed by the two vectors that represent the lexical items u and v is what this represents.

$$\tau(v, u) = \frac{\sum w\epsilon\Gamma(v) f(u, w)}{\|u\| \, \|v\|} \tag{3.22}$$

$$\|v\| = \sqrt{\sum w\epsilon\Gamma(u)(f(v, w))^2}, \|u\| = \sqrt{\sum w\epsilon\Gamma(u) > 0(f(u, w))^2} \tag{3.23}$$

Here, $\Gamma(v) = \{x | f(v, x) > 0\}$ is the collection of features (x) in the feature vector for element v that have positive pmi values. Cosine similarity is a commonly utilized relatedness metric in many natural language processing tasks. We cluster related terms using Lin's proposed similitude measure. For word clustering tasks, this metric has been demonstrated to perform better than various other comparisons. Computed in the manner shown below:

$$\tau(v, u) = \frac{\sum w\epsilon\Gamma(v) \cap \Gamma(u)(f(v, w) + f(u, w))}{\sum w\epsilon\Gamma(v)(f(v, w) + \sum w\epsilon\Gamma(u) f(u, w)} \tag{3.24}$$

Last equation defines this measure of relatedness, which is the one put out in this study. Similar to Lin's estimate of similarity and Cosine similarity, this relatedness estimate is asymmetric.

We build a baseline relatedness measure in the last equation by swapping the two arguments, u and v, to show the asymmetric existence of the connection measure presented in previous equations. The following formula accurately determines the inverted baseline:

$$\tau(v, u) = \frac{\sum w\epsilon \{x | f(u, x) > 0\} f(u, w)}{\sum w\epsilon \{x | f(v, x) > 0\} f(u, w)} \tag{3.25}$$

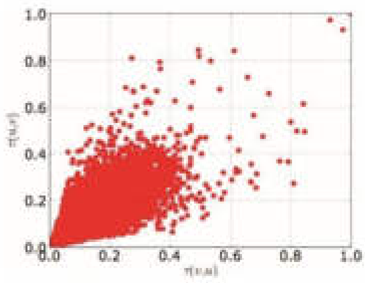

Fig. 3.2: Correlation between relatedness scores

Table 4.1: Equally balanced between positive and negative.

Review Type	Description
Positive	Reviews expressing positive sentiment
Negative	Reviews expressing negative sentiment
Unlabelled	Reviews without assigned sentiment
Processed	Reviews that have undergone preprocessing
Balanced	Preprocessed reviews with balanced labels

Remember that this baseline gives higher relative scores to expansion candidates, commonly included in user feedback, since the denominator consists of the sum of point-wise reciprocal knowledge values for terms co-occurring with correlation sources shown in figure 3.2.

Using the relatedness measure, we create a sentiment-sensitive thesaurus by listing lexical items v that co-occur with u 4 ($i.e., f(u,v) > 0$) for each lexical element u in descending order of the relatedness values $\tau(v,u)$.

4. Experiment model.

4.1. Dataset. This work evaluates the suggested approach with alternative sentiment classification models using the multi-domain sentiment dataset from Amazon product reviews. The dataset comprises product reviews of mobiles, kitchen sets, books, and electronics. Each review has a rating of (0 to 5 stars). The reviewers are transferred into positive, negative, and moderate labels. The product review dataset contains labeled and unlabelled data; the proposed framework extracts the features to determine the aspect levels using polarity and pivot models. In this experiment, one or more other domains serve as sources, and we choose each domain as the target domain. Reviews of the source domain and destination domain differ according to the data records they pertain to. To implement proposed framework, we have designed a framework using Python based packages, we adopted the machine learning packages to determine the results we divide the data into the three models, train (60%), validation (20%) and test (20%). The dataset samples and experiment were conducted at the KL University Hyderabad data center.

4.2. Results and Discussion. Figure 4.1 depicts the sentiment classifier for different electronic source domains. The accuracy is high for the kitchen domain for a single source. The accuracy is high for mobile and kitchen domains when two sources are combined, but when all three source domains are integrated, the best accuracy is obtained.

Figure 4.2 depicts the classification accuracy of target-labeled data against many source domains.

Figure 4.3 depicts that SU+ and TU+ denote both source and target domains for unlabelled data.SU- and TU+ denote only a Target domain exists. The higher accuracy is achieved when source and target unlabelled data is used, and poor performance is achieved when source and target unlabelled data is not used.

The sentiment classification for various target domains using the Adaptive Cross Domain Polarity aspect

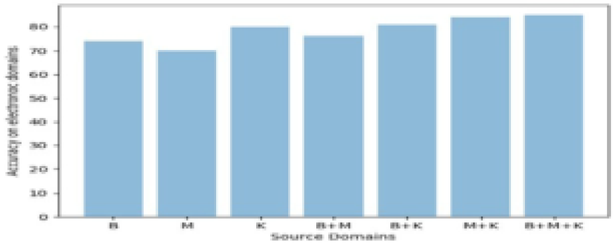

Fig. 4.1: Accuracy on the effect of multiple source domains

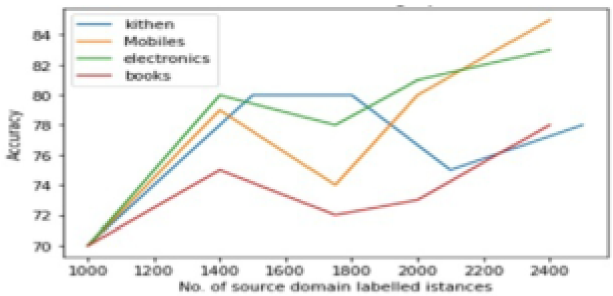

Fig. 4.2: Effect on source domain labeled data

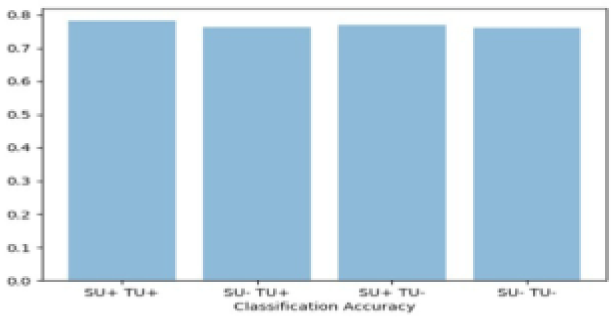

Fig. 4.3: Impact of Unlabelled Data's Source and Target Domains

Table 4.2: Sentiment classification for various target domains

Author	Technique	+ve Learning Expression Rate	Accuracy	Recall	F-score
Murugappan et.al [13]	DWT and KNN	45.87	82.32	80	81
Taran et.al [19]	CIF and MC-LS-SVM (MH)	67.85	86	76	78.1
Krishna et.al [20]	TQWT and ELM (MH)	78.65	87.1	80.1	82.5
Bajaj et.al [21]	FAWT and KNN	87.43	86.1	85.9	83.1
Proposed	(ACDPSNet)	97.76	98.76	97.85	96.94

level is shown in Figure 4.4 above and table 4.2.

Figure 4.5 briefly explains the performance measures of the proposed model compared with other models.

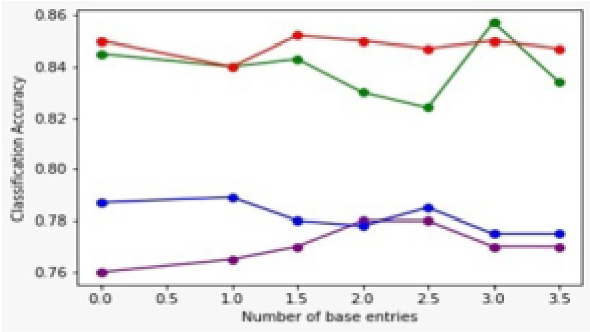

Fig. 4.4: Adaptive Cross-domain Polarity aspect-level sentiment quantification and categorization performance.

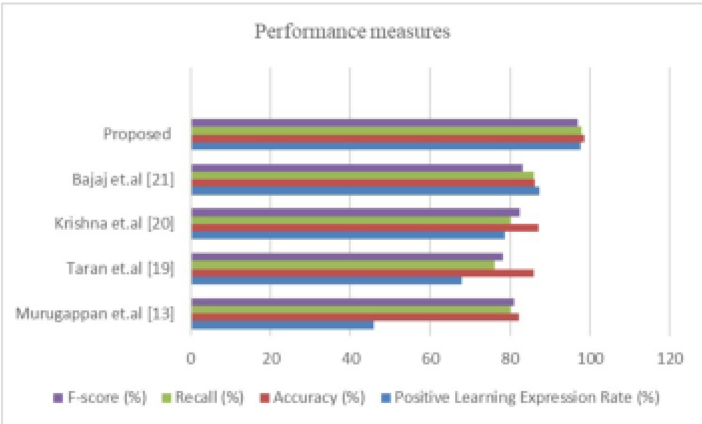

Fig. 4.5: Performance measures

5. Conclusion. Our research highlights the importance of incorporating domain-specific knowledge into domain adaptation tasks for sentiment classification and quantification. The proposed Adaptive Cross-Domain Polarity-Specific Network (ACDPSNet) demonstrates that by integrating polarity-specific sentiment annotations into semantic vectors and utilizing both labeled and unlabeled data from multiple domains, we can significantly enhance the model's ability to adapt to new domains. Our approach effectively addresses the common challenges of feature mismatch in cross-domain sentiment analysis, achieving notable improvements in accuracy, recall, throughput, and positive learning expression rate compared to existing methods. The findings of this study suggest that domain-specific information, often overlooked in favor of domain-invariant techniques, can be crucial for improving performance in domain adaptation scenarios, even when in-domain labeled data is sparse. This represents a significant shift from traditional methods that rely heavily on domain-invariant features. By successfully leveraging domain-specific information, our approach not only improves the robustness of sentiment classification models but also offers a scalable solution for various domain adaptation challenges. Future work could explore the application of this framework to other complex cross-domain tasks, further refining the adaptive mechanisms and exploring the integration of additional contextual factors. The promising results of this research indicate that ACDPSNet has the potential to be a valuable tool in the development of more adaptable and accurate sentiment analysis systems across diverse domains.

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SCALABLE MULTI-MACHINE IMAGING TECHNIQUES FOR MENTAL HEALTH ENHANCEMENT IN COLLEGE SPORTS PROGRAMS

TING LI[*], YAO LU[†], AND YUANCHAO TANG[‡]

Abstract. The mental health of sports students and training are among the most challenging subjects for generalist teachers to include in their teaching confidently. The conventional mental health of sports students makes it hard to stimulate students' interest in sports, leading to a poor participation rate and inability to exercise their bodies. This paper proposes a scalable multi-machine imaging Learning Framework (ILF) in the mental health of sports students and sports training to give students a new understanding of college mental health of sports students and sports training. It enhances college sportspersons' technical level and training quality. This method delivers a generalist teacher via suitable professional development, a means for providing a high-quality mental health program for sports students. It complements the repertoire of the specialist mental health of sports students and teachers at college and university levels. Experimental analysis has been taken on different sportsperson datasets based on the usage of digital technology, and its advancement in monitoring sports persons has been discussed suggestively in this study. The proposed ILF model increases the student activity analysis by 98.8% and the student physical workout level analysis by 97.5% compared to other existing models.

Key words: Mental health of sports students, Multi machine imaging techniques, Sports person Performance

1. Introduction to mental health of sports students. Mental health of sports students (PE) is a mandatory requirement at several institutions as a fundamental aspect of excellent education. PE offers a wide range of sports and raises awareness of physical health among university students. Many universities have endeavored to improve PE instruction through the reform of PE curricula [1]. Significant changes took place in university education with the fast progress of science. The university education systems, ideologies, resources, and methodologies have been thoroughly shaking up, increasing instructors' demands. PE education must also remain ahead of the changes as an essential connection in educational institutions [2-3].

Many researchers have investigated PE topics from various viewpoints and levels. Smagorinsky et al. explored numerous aspects affecting PE education in universities and offered the corresponding counteractions [4]. By adaptive PE learning, Chen et al. examined PE teachers' education [5]. Dapeng et al. discussed the novel PE major approach for talent development [6]. The advantages of specific language education for PE study have been studied by Tonoyan et al. [7]. Ju et.al. studied and provided particular remedies for the impact of the PE 'three autonomy' change [8]. Three freedoms imply that children can independently select their class period, professors, and sports. Elyasi et al. have shown how ongoing professional growth increases PE teachers' sporting, self-efficiency, and educational impact [9]. Anxiety, desperation, stress, and burnout are just some of the mental health challenges adolescents participating in athletics are now dealing with. Anxieties about falling short in a competitive setting, obsession with doing well in school and on the field, and other similar stresses are common among student-athletes and may contribute to these problems. These issues are made greater since many athletes have to deal with their difficulties alone because there are not enough services or support networks for mental health. There is a culture of silence about mental health in athletics because of the societal stigma that surrounds the topic. Researchers must proactively address the mental health difficulties that sports students face, such as injuries, limited playing time, and transitioning out of sports, to improve their well-being and resilience. These circumstances may lead to feelings of inadequacy and loss of identity.

[*]University of Perpetual Help system DALTA, Manila, 0900, Philippiness (17862000962@163.com)
[†]Department of Physical Science,Qufu normal University, Qufu, Shandong 273165; Qilu Institute of Technology,Qufu, Shandong 273100, China (tyxyluyao@163.com)
[‡]School of Physical education and health science, Guangxi Minzu University, Nanning, Guaangxi, 530006, China (Corresponding author, tang4200@126.com)

The idea of physical behavior, and actions connected to sports, is primarily physical, although the meaning of sporting events is quite restrictive. Athletics in educational institutions mainly depends on some sporting lessons, such as fundamental strategies to minimize injury to movements and essential regulations for the sport [10-11]. While some college ties and institutions have met their wish for sports courses to be chosen individually, the actual poll statistics demonstrate that university students still do not acknowledge sports at educational institutions. Numerous aspects of sport psychology characterize sporting events. Sporting behavior encompasses sports teacher behavior, sports awareness, and sports learner behavior, with a thorough division of sport's effects on the individual [12-13].

To summarise, the previous research focuses mainly on PE theory and strategy, without clearly defining the primary aspects influencing the content of PE's teachings or building a PE quality assessment system. Generally, many approaches of systematic analysis may accurately reason for many elements, especially evidence rationale, optimization programming, and machine learning (ML) [14-15]. Nevertheless, because they need complicated statistical formulas and a high sample dimension, the relevant reach of these approaches is quite limited.

This article proposes designing a digital sports education system that relies on a new multimedia interaction medium. The most important research is:

1. The demand for the digital sports training program is analyzed. The system managers, instructors, and learners' design needs are summarized
2. The Scalable framework functions are outlined according to design requirements and objectives. The system's conceptual structure and each unit's functionality are generally introduced, beginning with the analysis and management
3. To comprehend systems integration processes, the database architecture of the digital sports training program and the installation of the BP neural learner assessment module system are investigated
4. Take students who choose an optional basketball program as an empirical study subject in a university for the mental health of sports students, comparing the mobile network-assisted way of training multimedia interaction and conventional modes of teaching. Digital sports education systems' viability has been proven. The online learning system was also tested and loaded with reaction time to ensure its efficacy. In addition, the online sports education system has been tested functionally

The rest of the research as follows. Section 2 deals with the background of the mental health of sports students system. ILF in mental health of sports students and sports training is designed and implemented in section 3. The software analysis and performance analysis are discussed in section 4. The conclusion and future scope are illustrated in section 5.

2. Background to mental health of sports students. From a practical viewpoint, several significant difficulties in developing physical activities in the nation need to be resolved, including the absence of clear teaching goals. Physical training hence requires improvement and development [16-17]. Furthermore, some educational institutions conduct mental health of sports students differently, fundamentally different from the learners' development demands, and cannot fully enjoy the physical training benefit. This scenario can educate learners to discuss their ability to form the core of the educational conception [18]. Chinese college learners provide a relaxing and pleasant setting for studying sports.

In practical training, it was observed that when higher education institutions built-up physical training programs, they did not analyze from the standpoint of subject competence; they chose a one-size-fits-all strategy to formulate courses [19]. The traditional approach of physical training is not innovated or reformed. It must thus be careful about this issue. Only by continual contemplation and insight can it enhance learning and mental health of sports students and invention and produce findings and complete abilities to serve society's progress [20-21].

A new educational paradigm characterized by educational technology in China of which digital, mental health of sports students plays an important role has evolved via computer information, multimedia technologies, and communications technology. Physical training is a practical and multi machine imaging bilateral teaching methods practice [22]. Currently, Online materials are less than in other fields, where systematics and integrity are lacking. Action demonstrations and copying in multiplexed material are highly suited for sports training [23]. Within this context, the moment has come to build a multimedia communication system for digital sports education and instruction, depending on a matured network system, digital innovation computers, multimedia-enabled companies, and other technological advancements [24-25].

The mental health of sports students system includes numerous constraints contrasted to other professions, such as the length of the site, kinds of apparatus, ambient circumstances, and climate considerations. However, teaching difficulties and instructors' challenging tasks are critical factors limiting physical training, contributing to the phenomena that learning theoretically and practically results in physical activity are not consistent [26].

Due to this specificity of mental health of sports students learning, it is becoming more necessary to employ multimedia teaching methods to investigate mental health of sports students. The multimedia communications networking system may completely address these inadequacies in physical training [27]. The construction and study of a community of Multimedia Learning Courses (MLC) are far from addressing the actual demands of teaching. However, the multimedia network does have unequaled advantages with mobile implementation of computer-based network-supported teaching techniques in physical training [28]. Students have suggested various novel online education approaches in recent years. Scholars, for instance, developed an electronic 3D virtual-reality conceptual design for remote school instruction. The education system has been implemented in multiple generations developing the framework [29]. The classroom environment for the learning setting was remotely visualized utilizing the technologies of 3D virtual reality. A 3D scenario model of education was developed. A graphic simulation program for remote education was built, and multiprocessing program load and core network architecture were carried out in conjunction with Vega Premier visual technologies. The graphical modeling of flipping classes is studied in this research [30].

An artificial intelligence-based sport psychology system was presented. The network sporting education system was developed based on internet modeling, reliability and efficiency analysis, multiple regression analysis, and structure prototype tests [31]. The strategy employed Bootstrap and Groups Regression methods to evaluate the mediating function of the attitudes and control of the Largest Ones. The information quality of the multi machine imaging learning system and its perceived facility have a favorable influence on the teaching approach [32]. The attitude towards learning has a substantial beneficial effect on usage and some impacts on knowledge and skills. Based on sports-related information, the sporting tactics, etc., assess their operational trajectories. In the meantime, multi-target response training techniques are developed, and sportsmen and women are instructed to increase their qualifications [33].

All of the sports activities monitoring frameworks mentioned above education and instruction methods have shortcomings, including a small range of pupils, communication breakdowns, and slow reaction time between educators and pupils. Therefore, this study presents a novel multi machine imaging learning framework (ILF) in mental health of sports students and sports training. The following section elaborates on the design strategies and implementation procedures

3. Proposed Scalable Multi machine imaging Learning Framework (ILF) in mental health of sports students and sports training. Multi machine imaging education seems to be a hands-on/real-life learning technique that focuses on increasing student involvement through directed social interaction. It combines online and offline components to provide a whole educational experience. As a result, this research introduces a new multi machine imaging learning framework (ILF) for mental health of sports students and sports training.

3.1. System architecture specification.

3.1.1. Server system design. The server administrator is the complete system manager with the most excellent decree issued. The manager is accountable for instructor management, student management, and information about courses in a defined system. Input material such as instructors, learners, and classes into the platform is needed to be initialized by the administration before the official users of the product. The administration can then have to change this material in line with the requirement for online sports instruction at the start of a course.

3.1.2. Educator System Testing Needs. In the whole system, educators used to teach. The design demands of the instructor are expressed in the accompanying elements from the entire point of view. Firstly, teachers may register in the platform and manages the electronic lessons and accompanying learning resources. Secondly, professors may connect with learners via the system to respond to learning problems for sportspeople. Third, educators are expected to post system advertisements, teach and train tasks and jobs and oversee

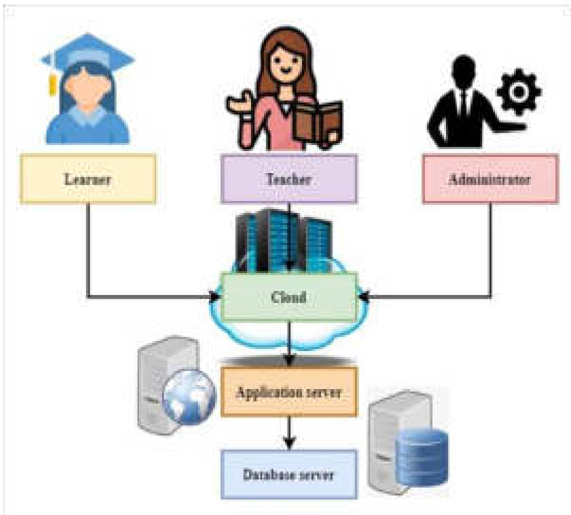

Fig. 3.1: Communication architecture of ILF in mental health of sports students and sports training

advisories. Lastly, educators control the test answers databases in a platform to test and assess their pupils online.

3.1.3. Design constraints for learner assessment. The pupils help practice sports beyond the school; the system must perform the specific steps from the graduate's perspective. Firstly, via instructor announcements, pupils may comprehend the subject and tasks of the course. Secondly, by studying the teacher's posted curriculum, pupils read and evaluate. Thirdly, using the interaction component in the platform, learners may contact professors and learners and ask instructors online inquiries. Lastly, using the testing phase module, pupils may test their understanding.

3.2. Generalized logical framework structure. The aim is to give the student the networked educational environment for education instruction communication platforms. The platform's activities are achieved via interacting between the software browser and the webserver. The sports training framework contains various data and statistics and material for students and competition photos for sports events films, attend the training for a sports model, engaging messages for students, and sports networking exam results. This information is saved and structured and managed by the server on the application server in various forms.

Fig.3.1 shows ILF communication architecture in mental health of sports students and sports training. This architecture consists of learners, teachers, and administrators. It contains a database server to store multimedia information. The Websites must be initially connected by users (beginners, instructors, managers) involved in sports training. The client connects to sends a request to the database server, and depending on user demand, the web application answers appropriately. The server software information is collected, and the operation results, like replies or retrievals, are returned to users via the website.

Fig.3.2 shows ILF client-server communication model in mental health of sports students and sports training. The proposed model has three levels such as web server, application server, and database server. The student can request their queries, and the database server can reply to the response respected to the questions. Web server identifies, analyses, and sends request messages and return processing results. The application server process requests through a multi-agent system—the database server trains the teaching knowledge base, learner database, and management base.

Fig.3.3 shows ILF learning and training model in mental health of sports students and sports training. My SQL repository server and Tomcat web service are the webs mentioned above server and information servers. The use of a Training Requirements Teaching Communicating Plateforme after a thorough analysis of demands and the study of the benefits and drawbacks of other digital Training Programs is separated into five tiers based

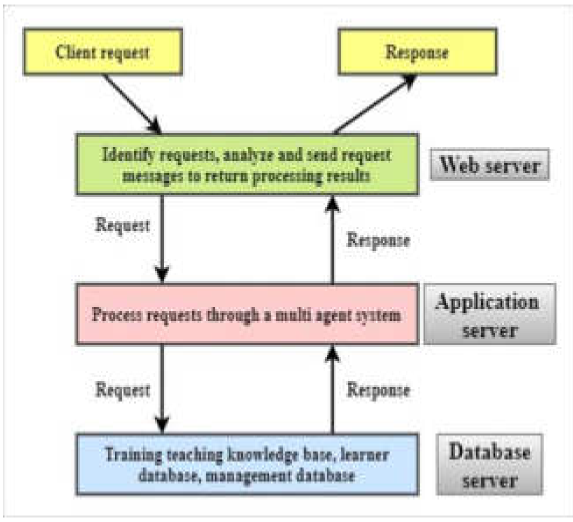

Fig. 3.2: The client-server communication model of ILF in mental health of sports students and sports training

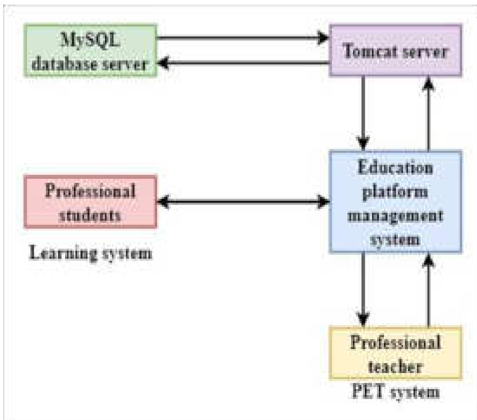

Fig. 3.3: The learning and training model of ILF in mental health of sports students and sports training

on network technology requirements. They are Mysql Servers, Tomcat Web Application, Customer Teaching, Learner systems, sports interaction system, and administration solution. The connection between individuals and the system is complemented by the relationship between application and system platforms at different levels, mainly for the client-side and the application server. The multi machine imaging mental health of sports students system is separated into a client-side as well as a server end. The user ends the information query and receipt through application and service network device interfaces. The process entails navigation, learning, practice, conversation, interaction, exams, etc. The server interchanges and sends the knowledge to achieve the demand and transmission of information from the My SQL storage system to the remote server.

3.3. System application framework. The collaboration sports education platform creates many communication platforms for various users in the educational administration. The appropriate data management function for administrators and client access functions are performed. The typical CELTS systems for distant education ought to be a specific comprehensive vendor support framework with three sections: infrastructure systems, management software, and resources collection of instruction, so according to China's digital learning technological guideline. The Sports Education Platform is separated into three sub-platforms: a sub-platform

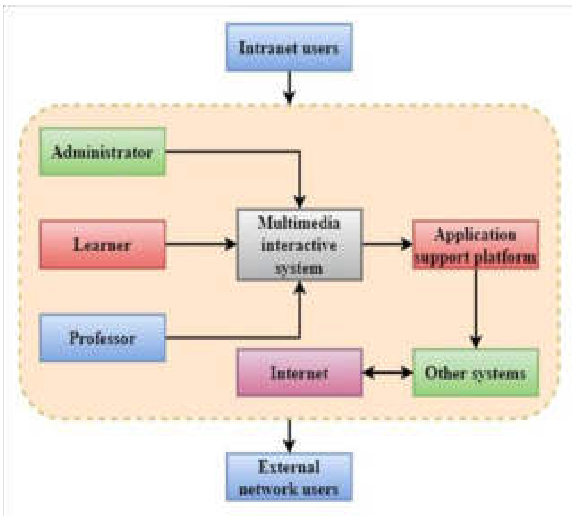

Fig. 3.4: The logical architecture of ILF in mental health of sports students and sports training

gateway, a sub-platform for studying and administration.

Fig.3.4 shows ILF logical architecture in mental health of sports students and sports training. It has an multi machine imaging multimedia system. The administrator, students, and professors can access this multimedia information. This system enables intranet and external network users to connect and communicate with the PE instructor.

Accept both the gateway platform and the digital multi machine imaging system technology. It can see that the conceptual architectural design can provide a more integrated and flexible infrastructure for resources, and results confirm environments. It is straightforward to build new data processing expansions and enjoy spending large quantities of social and fiscal value on making significant alterations to the data and hardware code, depending on a logical design methodology and multi machine imaging sports training and teaching needs. The streaming media platforms' abilities may be enhanced based on a design by applying the findings from building the sports education training platforms. The major features include establishing a learning or managerial foundation, sports coverage, release of upcoming events, details on sports register, elective online booking, program inquiries, sports cultures on the university, etc.

Sub-platform gateway. Its government service objective (system accesses). It connects the limited concept of mental health of sports students in universities to link public sports with other sports more broadly. It is a doorway to outside the sport long-haul network educational method. In addition, it also provides access to other networks for pupils and instructors.

Sub-platform education. primary features include online education, real-time online instruction, online coursework, online discussions, questions and queries online, virtual classrooms, education and research internet, notification consultations, and outcomes inquiries. The education and status of students are documented. Its service goals are primarily teachers and students involved in distant teaching and learning in sports networking (intranet clients). Their job is to assist users with technical help and fulfill all networking setting primary training areas. The sub-platform for training is a significant element in finishing teaching, knowledge in digital sports, and developing sports networks. A well-designed, effective online learning system can allow users to feel the sports training phase's attractiveness completely.

Subplatform administration. Sports instruction administration, structured model, careful strategic planning, exercise science for specialized elective courses, sporting exam strategic planning, sports process improvement, instructional point governance, etc., are vital tasks. Its service objectives are mostly instructors who teach contemporary distance training administration and instructors physical training. The Administration sub-platform is responsible for managing and distributing information produced during e-learning and administration. However, all organized effort by learners is developed as often as feasible in the sub-platform and training sub-platform gateway and to assure the security of the PE teacher administration solution and ease learning among learners.

3.4. System architecture module. In particular, it consists of seven functional blocks: a presenting component for training contents, online management for teachings, a module for managing media resources and interaction motion sensors, a module for learner tools, a module for evaluating and operating systems. These components have a distinct functional member as well as an integrated unit.

1. Module Courses for content submission: It contains content primarily for teaching, instructional outlines, and directions for exercise programs.
2. Modules for managing digital mediums: Directories, Terminology. It incorporates instructor management, managing students as well as conventional managing of textbooks and educational resources.
3. Instructional Manual Process: Class Administration, Gradebook. Implementation of management training programs, administration of courses, forums, and administration of systems.
4. Multi machine imaging Component: forums, group chat, internet, text message, online questionnaire.
5. Modules Learning Tools: Listings, Internet Sites, Memoranda, Queries, and Replies.
6. Module for Learning Assessment: Assessment and Training.
7. Performance Administration and Online Management: Mainly, services such as construction sites, management information, rights administration, basic information installation, and contract administration are implemented.

3.5. PE teacher quality assessment index . After examining the affecting variables of university PE, it must pick several clues to assess the quality of PE's instruction. As the affecting elements in PE are relatively complicated and variable, numerous criteria should be observed to choose PE content assessment indices to assure college PE teacher assessment.

Principle logical and scientific. There should be evident scientific importance for the university's PE teacher performance evaluation indicators. The intrinsic connotation of PE teacher performance can be reasonable and exact. In the meantime while, assessment indices ought to have real explanation and hierarchy links so that the underlying difficulties in the quality of PE education are genuinely reflected.

Authentic and purpose concept. The chosen PE learning quality assessment indicators should be premised on the objective scenario and the actual incident of university PE learning. It should genuinely represent the critical influences of university PE educational importance to satisfy that the PE educational process critical appraisal is accurate and reliable.

Conventional principle. The PE-level assessment is a sophisticated decision procedure with various components. The decision-making procedure is challenging to achieve efficient decision-making if all contributing elements are used as the assessment indices for evaluating PE-level quality. The specified assessment indicators should thus be typical and relevant in terms of authenticity and thoroughness.

Measurable principle. In choosing assessment indicators, it is essential to make sure that the selected economic indicators are highly adjustable so that the results achieved of university PE student outcomes are operable, the diverse characteristics of the following guidelines of university PE student outcomes, to guarantee a better quantitative effect.

3.5.1. Building of PE quality assessment system for teaching. Applying the guidelines above and analyzing factors that impact the effectiveness of PE learning in university, the scholars have built a new university student PE quality assessment system from three sources, notably: PE educational transportation guarantee capacity, the impact of PE education on execution, the PE educational modernization ability, and PE academic results. C11, C12, and C13 refer to PE educational results criteria or components used to evaluate physical education quality.

The capacity to ensure PE educational architecture, C1: This criterion for an evaluation is primarily aimed at examining the college's ability to safeguard their fundamental circumstances for educating PE at the university. Consequently, it must provide PE education facilities in higher education institutions, including PE instructional input C11 and PE educational levels C12 and PE defective building C13, PE architecture building C14, and C15 management efficiency. PE teaching facilities C14 and C15.

Implementing the effect of PE education, C2: This assessment criterion is primarily aimed at examining the essential factors that influence the effectiveness of PE teachings in the execution of PE education. It is a primary article on the quality management of PE education, so it is essential to ensure the impact of the valuable details within PE teachings, including promoting the C21 PE teaching method.

Ability to transform PE pedagogy, C3. This assessment requirement is mainly intended to evaluate the power of the university to change and develop PE pedagogy. It is an incentive to increase the quality of PE pedagogy and thus be actively involved in the pedagogical reforms, enhancing the power to transform and develop innovative PE pédagogy and the capacity to be implemented.

PE educational result C4. This assessment criterion aims mainly at examining the result of the PE university, which reflects the most significant on the quality of the PE university, and also to represent the impacts of PE restructuring on execution and hence plays an indispensable role for effectively assessing the PE quality of education, which includes the sports education of the learners.

3.6. Quality educational assessment approach of PE university student.

3.6.1. Measurement of AHP weight. It needs to perform a weight assessment on the assessment process evaluation indexes after the AHP PE education quality assessment system has been established. This research employed the scaling technique 1-9 to give values to assessment indexes to generate assessment matrices inside various levels and acquire the correct weighting factors. Each combination of assessment indices is relatively necessary for university students. If the indicator DI_x related to index DI_y is of relevance RI_{xy}. Considering there have been n assessment indicators in the PE educational quality assessment system in hierarchies, scales of 1 - 9 were given to the performance measures by reference to expert judgments, and an evaluating matrix RI was obtained from the n assessment indices is expressed in Equ.3.1.

$$RI = \begin{bmatrix} RI_{11} & ... & ... & RI_{1n} \\ .. & .. & .. & \\ RI_{n1} & ... & ... & RI_{nn} \end{bmatrix} \tag{3.1}$$

Because of the built RI judgment matrix, the appropriate EV(RI) of the matrices and the maximal eigenvalue value $\lambda_m ax$ (RI) maybe achieved and a coherence indicator C_I (RI) of the RI judgment matrix may be obtained using Equ.3.2:

$$C_I(RI) = \frac{\lambda_{max} RI}{n+1} \tag{3.2}$$

The quantity of n to check the average absolute consistency indicator C_R in the typically represents of the scales and get constancy ratios C_R (RI) variable for the RI judgment matrix is used as the number of the following guidelines and expressed in Equ.3.3.

$$C_R(RI) = \frac{C_I RI}{C_R} \tag{3.3}$$

The consistency indicator is denoted as C_R. If the $C_R(RI)$ variable of the judgment matrix RI meets the requirements. It should satisfy the condition expressed in Equ.3.4

$$C_R(RI) < 0.2 \tag{3.4}$$

The coherence of the RI judgment matrix is indicated. If this does not happen, the s_{ij} scale value should be provided until the coherence of the RI matrices of judgment fits the conditions and the indexing mass sequence matching to the convector $EV_W(RI)$ has to be obtained, and it is expressed in Equ.3.5.

$$EV_W(RI) = EV_{W_1}, EV_{W_2}.....EV_{W_n} \tag{3.5}$$

The weight of the eigenvalue is denoted as EV_{W_i}. The number of eigenvalues is n, and it is calculated from the judgment matrix RI.

3.6.2. Process of GRA. From the PE Educational Quality Assessment fully electronic building process, it could be seen that perhaps the framework is hierarchically structured and has different assessment indexes for each each conservative structure. Its impact on the educational effectiveness of PE is broadened into many conditions for each indicator in this hierarchical framework. The optimum status index is expressed in Equ.3.6.

$$S_j = s_{1j}, s_{2j}, ..., s_{nj} \tag{3.6}$$

Assuming the PE quality assessment has an n standing, the specific intervention status number for the j-th assessment standing of the i-th assessment index is s_{ij}, whereas j assessment indices produce an optimum S_j The status range for the n-th assessment state. The grey relation coefficients of assessment product P with the optimum status sequencing S_j is expressed in Equ.3.7:

$$\delta_{ij} = \frac{S_j^O - s_{ij} + \rho}{S_j^O + s_{ij}} \tag{3.7}$$

If there is an assessment objects O with the appropriate value for its j-th evaluation criterion, is S_j^O; if the S_j^O and s_{ij} are transformed to unitary covariance matrices. ρ is the GRA variable of recognition. The grey relational correlation between various petroleum assessment indexes and the assessment status achieved based on GRAs is δ_{ij}. And then the measured grey relation weight w_j among the assessment entity P and the optimum status series S_j is calculated. The grey relation correlation π_j and π_k among the assessment entity P are expressed in Equ.3.8 and Equ.3.9.

$$\phi_j = w_1 * \delta_{1j} + w_2 * \delta_{2j} + ... + w_n * \delta_{nj} \tag{3.8}$$

$$\phi_k = max\phi_1, \phi_2, ..., \phi_m, 1 \leq k; j \leq m \tag{3.9}$$

The weight of the GRA is denoted as w_i. The grey relationship of the jth row of the ith element is denoted as δ_{ij}. The grey relation correlation is denoted as ϕ_j. It shows a strong correlation of the assessment entity O with the optimum S_j status succession. The assessment level in PE is indeed the k-th level of the educational excellence of the assessment product P.

Fig.3.5 shows ILF workflow in mental health of sports students and sports training. It receives the necessary information from literature, trainers, etc. The received data is analyzed, and then the PE teaching quality is evaluated. An evaluation index is formed based on the evaluation system, and the index's weight is adjusted based on PE teaching quality. The importance of the final grey correlation matrix is calculated. ILF obtained status in mental health of sports students and sports training shows the effectiveness of the proposed framework.

4. Software evaluation and performance analysis. The database comprises elements of total accessibility, and SQL servers are at the core of the existing organization. Database access is provided using MTS, and information is analyzed through ADO.NET to allow vast volumes of data to be stored, protected, and administered. System data must comply with data management design guidelines. In addition, the quality and integrity of system data are ensured, the operations are facilitated, and the platform speed is highly efficient, making stored data safe and dependable using the dataset https://www.kaggle.com/datasets/shariful07/student-mental-health [34]. 100 students from various athletic disciplines, experience levels, and mental health histories will participate in the research. To observe brain activity and structural changes, crucial equipment includes MRI, fMRI, and EEG, which assess electrical activity associated with stress. Wearable sensors track internal reactions like heart rate fluctuation and sleep cycles. Imaging sessions will be performed before and after the intervention to monitor brain function and structure changes. These evaluations will follow baseline mental health examinations using standardized questionnaires. An improved support system for student-athletes may be achieved via an all-encompassing strategy to shed light on the relationship between mental health and physical performance.

The problem between server users is considerably reduced. Different strategies are employed to enhance required data in the built online sports education platform to increase the website's functionality. To make

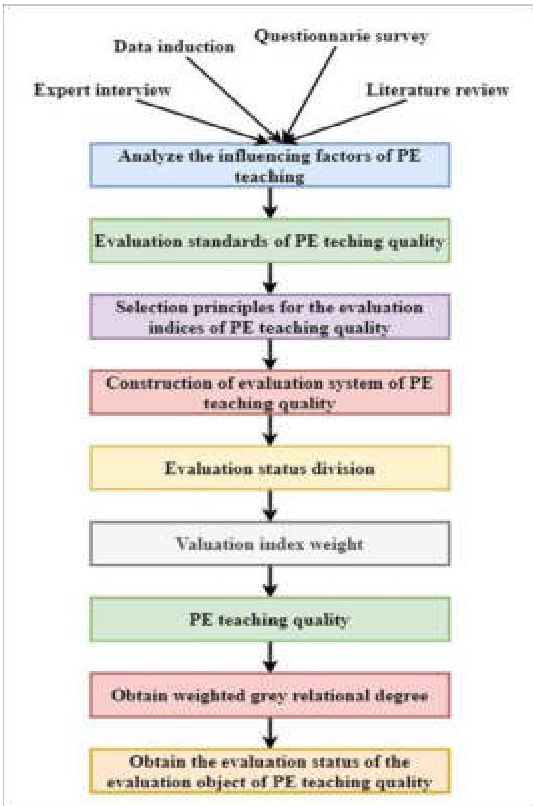

Fig. 3.5: Workflow of ILF in mental health of sports students and sports training

knowledge in the datasheet more standardized, tighter, and more reliable, the duplication of the integration node is expanding correctly. Secondly, the sequence number on labels is rising. A unique identifier field is created per database, each information is assumed to be distinct, and searching efficiency can be enhanced. Finally, a large table partition is used to operate a portion of the services, and division is streamlined to increase system efficiency. Heart rate variability, cortisol levels, and patterns of brain activity are some of the physiological signs studied using imaging methods. Assessments of cognitive functioning look at abilities like focus, memory, and decision-making, while behavioural observations track changes in training routines, academic achievement, and social involvement. The quality of social support networks, including connections with mental health experts, peers, and coaches, is considered when evaluating emotional well-being, measured by mood changes and persistence. Finally, a thorough evaluation of sports students' mental health is provided by considering lifestyle elements, including sleep habits, diet, and exercise.

Fig.4.1 and Fig.4.2 show the student activity analysis of ILF in mental health of sports students and sports training for males and females, respectively. The student activity such as movement, occasionally moving, planned exercise and daily activity are monitored by the mobile applications installed in the student's mobile phone. The performance of the students is continuously monitored by the mobile application and plotted in the above figures. The findings indicate that ILF in mental health of sports students and sports training has motivated many students to do daily exercise.

Table.4.1 shows ILF activity analysis in mental health of sports students and sports training. The different activities offered by the college such as Walking, Football, Swimming, Jumping, Lifting, Cardio and fitness, Boxing, Dancing, Others, and No training are monitored. At the same time, the students are present inside the college campus, and their involvement in the sports activities is monitored and tabulated in the above table. The results indicate that ILF in mental health of sports students and sports training motivated many students

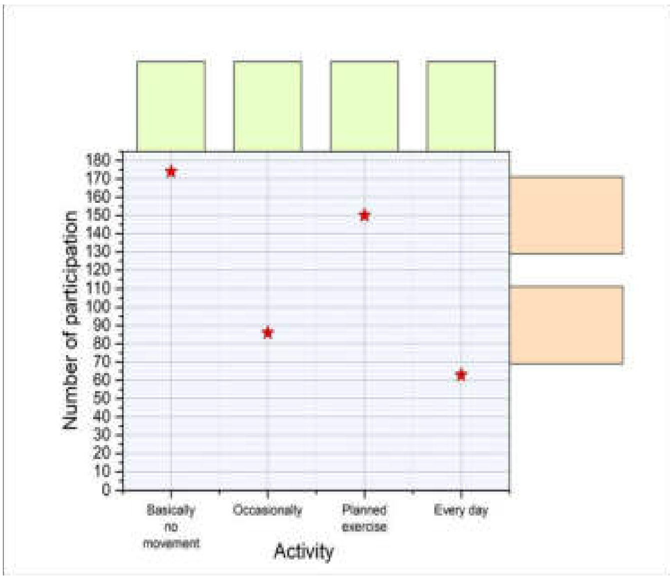

Fig. 4.1: Student (male) activity analysis of ILF in mental health of sports students and sports training

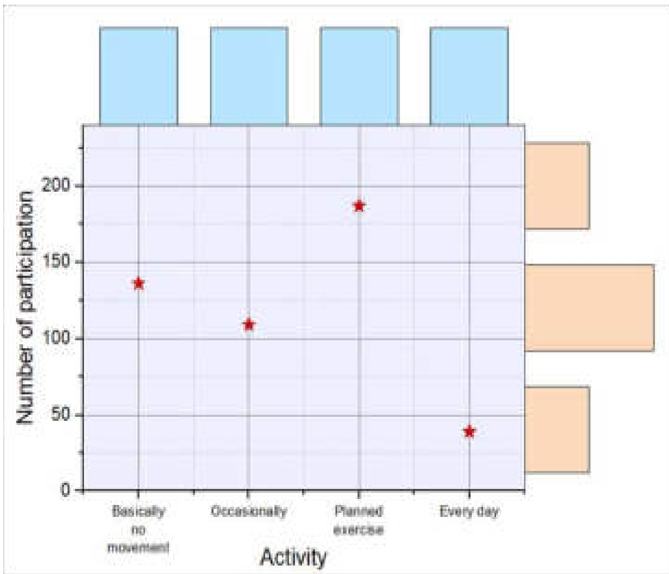

Fig. 4.2: Student (female) activity analysis of ILF in mental health of sports students and sports

to do cardio fitness or walking to improve their physical fitness.

Fig.4.3 and Fig.4.4 show the male and female student physical workout analysis of ILF in mental health of sports students and sports training, respectively. The student's workout session is monitored, and their level of workouts such as low intensity, sweating, medium perspiration, and slight sweating are monitored. The percentage of several students in the individual workout level is analyzed and plotted in the above figures. The findings indicate that ILF in mental health of sports students and sports training motivates most female students to sweat workouts slightly and the majority of the male students to heavy sweating workouts to

Table 4.1: Activity analysis of ILF in mental health of sports students and sports training

Activities	Male (%)	Female (%)
Walking	38.2	30.3
Football	6.6	6.1
Swimming	5.9	9.3
Jumping	8.3	6
Lifting	14.2	14.2
Cardio and fitness	19.8	19.8
Boxing	1.3	1.4
Dancing	0.7	0.5
Others	4.5	1.3
No activity	19.9	3.2

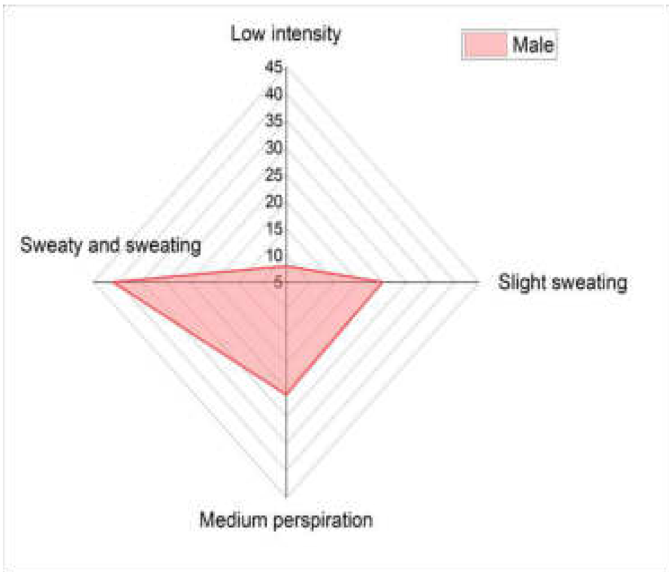

Fig. 4.3: Male student physical workout level analysis of ILF in mental health of sports students and sports training

Table 4.2: Participants analysis of ILF in mental health of sports students and sports training

Activity	Number of participants
Exercise plan	326
Pedometer	765
Social	457
Video guide	128
Live event	254
Diet planning	289

improve their physical strength.

Table.4.2 shows the participant's analysis of ILF in mental health of sports students and sports training. The research is carried by evaluating the proposed model in a group of students in the sample school. Students who attended different activities such as Exercise plan, Pedometer, Social, Video guide, Live event, and Diet

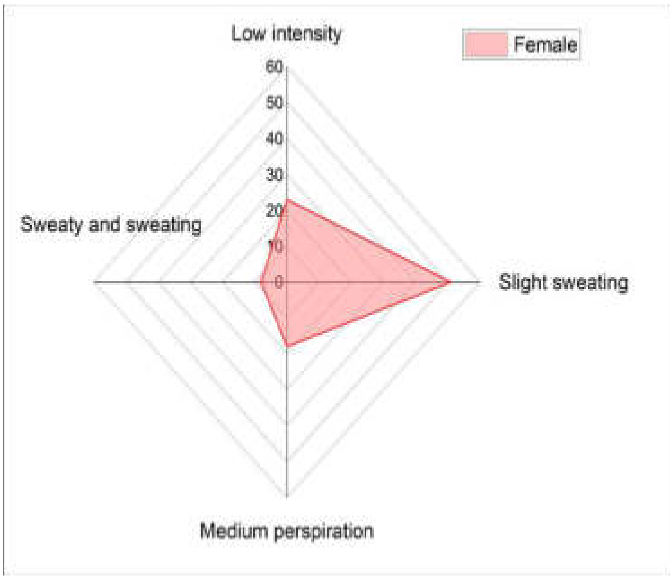

Fig. 4.4: Female student physical workout level analysis of ILF in mental health of sports students and sports training

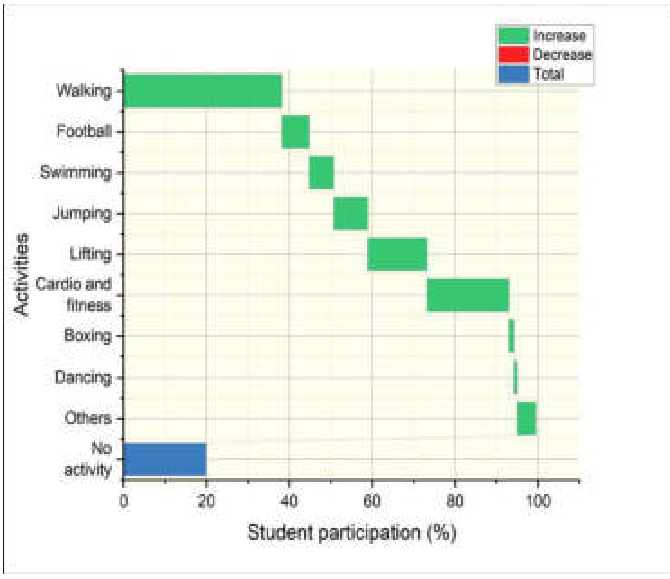

Fig. 4.5: Male students activity analysis of ILF in mental health of sports students and sports training

planning are considered. The count is tabulated in the above table. The findings indicate that in ILF in mental health of sports students and sports training, very few students watch the movement from the mobile apps. The rest of the students are actively involved in any of the physical activities available in the college.

Fig.4.5 and Fig.4.6 show the male student and female student activity analysis of ILF in mental health of sports students and sports training, respectively. The different activities offered by the college such as Walking, Football, Swimming, Jumping, Lifting, Cardio and fitness, Boxing, Dancing, Others, and No activity are

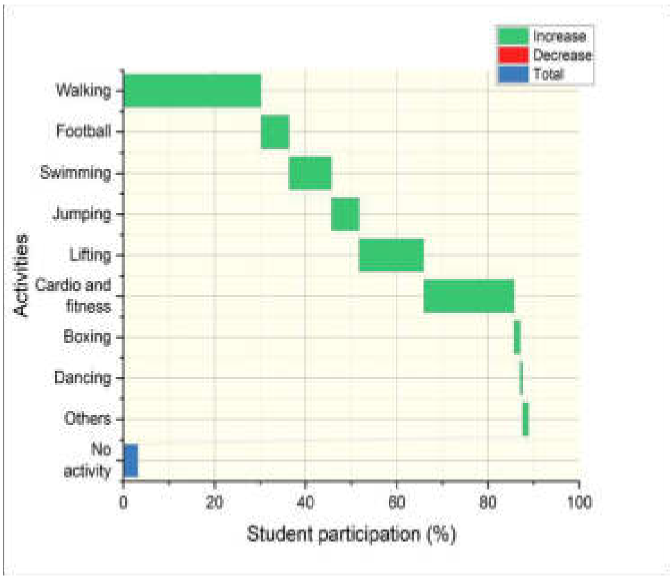

Fig. 4.6: Female student activity analysis of ILF in mental health of sports students and sports training

monitored during the students present inside the college campus, and the participation count in each activity is calculated and plotted in the above figures. The findings show that ILF in mental health of sports students and sports training helps students engage in physical activity. ILF in mental health of sports students and sports training is implemented, and the performance of the proposed framework is analyzed. The simulation findings indicate that ILF in mental health of sports students and sports training helps the majority of the students to engage in any of the physical activity when they are inside the college campus, and their performance is even tracked when they left college by their mobile applications.

5. Conclusion. Hardware and communications technology developments change the conventional style of living, learning swiftly. The combination of digital multimedia networking technology and ongoing Internet growth has led to paralleled powerful technological support through online education. Existing classrooms and meeting in person conventional teaching approaches can not match current information culture educational demands, as information is frequently updated because of time - geographical restrictions. An Multi machine imaging Learning Framework (ILF) in mental health of sports students and sports training is proposed in this research. A new mode of action is the web-based aided education system. It may cover time and distance and offer an excellent learning environment for college students. The current predicament of physical training supports the system implementing supplemental sports instruction via the mobile multimedia interaction tool. The implementation of the instructional networks in physical activity is covered from the beginning. The proposed ILF model increases the student activity analysis by 98.8% and the student physical workout level analysis by 97.5% compared to other existing models. The proposed ILF model increases the student activity analysis by 98.8% and the student physical workout level analysis by 97.5% compared to other existing models.

There can still be, nevertheless, significant shortcomings in the system owing to medicine and experience. Certain functionality must be examined further. Highlights are the following: 1. Lesson materials are not enough since only the needed content is presented in the curriculum. Thus, it might explore the structure of a reference library so that instructors may upgrade their expertise and be informed about new sports activities at all times. 2. Review system enhancement. Due to the characteristics of physical training, the overall assessment is examined using action approaches. Every learner has an online exam that is unreasonable. Further improved evaluation of sport concept can help identify each vital technical activity level and aid them in practical education.

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AN EFFICIENT DEEP NEURAL NETWORK FOR ANALYZING MUSICIAN MOVEMENTS WITH SCALABLE IMAGE PROCESSING COMPUTATIONAL MODEL

XIA ZHAO*

Abstract. The fast-growing collection of digital sound content needs new recovery techniques to explore vast collections of music. Traditional recovery approaches use documentation to identify the audio files in English. Effectively evaluate musician motions with scalable computing, image processing, and deep learning. Using distributed frameworks and cloud-edge hybrid architectures guarantees real-time speed and effective handling of large volumes. Live performance monitoring, music teaching, and research are just a few of the many potential uses for the system, which can be easily customized because of scalable computing, which optimizes training, inference, and resource allocation. Therefore this paper suggests an Image processing empowered using deep neural networks (MDDNN) for the understanding of musical emotions. MDDNN is used to distinguish the recognition process from the classifier using a DNN, which enables us to use the Support Vector Machine on a network to get better results. MDDNN describes a useful loss function and is used to find a function space. The resemblance among musical recording variables correlates to the relation between the descriptions. In the case of non-existent text explanations, a content-based retrieval approach has been used to recover the raw audio material. MDDNN method uses a content-based recovery technique that follows the problem in case of an audio query; Further, the task is to retrieve from a music archive all documents identical or correlated with a question. MDDNN achieves the highest classification accuracy of 93.26%, an error rate loss of 0.44, and the MDDNN method is more efficient for image processing empowered.

Key words: Artificial Intelligence, classification, deep neural network, Support Vector Machine, Document analysis.

1. Introduction to image processing empowered. In cultural history, music plays an important role, mostly with performances in recorded music becoming a vital means of describing the purpose of the composer to singers who play music [1]. The musical transcription holds data in a graph format that complies with phonetic and semantical regulations to encrypt pitch, tempo, time, and joint. Music always plays a wonderful experience [2]. The compilation of music documents is an essential cultural heritage of the world. Digital transformation is important for the conservation and potential exposure to these recordings in viewable music streaming archives, and for broad-based analyses through analytical methods [3].

The physical translation of music is costly because the job is to be performed by musical specialists is enormous and complicated [4]. As a result, in recent years, it has become increasingly important to develop systems for an automated translation of musical records [5-6]. It is necessary for building a tool for one of the many molecular principles for the manufacturing of friction to create a conventional instrument. The goal is to use sufficient measurements in the world of digital music to produce a conceptual test arrangement describing the audio waves [7]. Live music has been commonly available at various sources, including TV, digital storage such as compact disks (CDs), the Web, etc., with the advancement of knowledge and communications technology [8-9].

The huge quantity of music available to the general public needs growth [10]. Resources are required to restore and monitor the music of concern to target consumers effectively and reliably [11]. In music, the device definition is significant because it affects the sound as considered in an abstract concept of a tonal qualities class, dynamic conduct, and a communicative class [12]. The new model is used to present a modern approach for a wide range of notational and music types [13].

In the latest generations, there has been a progressive change in the way music is collected, obtained, transmitted, and absorbed [14]. Already, accept payments of millions of digital music materials are available from all over the world [15]. Music is one of the principal instruments for transmitting culture. For these reasons, musical documents spread across cathedrals, museums, or historical documents have maintained for

*Mussic and Dance conservatory, Vacational University of Engeneering and Science Technology, Jinzhong, Shanxi, 030619 China

many decades. Entry to such sources is not always necessary to avoid their degradation. Here a significant portion of this cultural heritage is not eligible to research musicology. These files are sometimes translated in an electronic medium to make access and distribution [16]. On the other hand, it is important to note that the widespread scanning of music files sets possibilities to implement methodologies for music data collection, which could be highly interesting. Because the physical translation of these documents is a long and tedious process, in recent years, Further, the introduction of innovative translation schemes for new music documents has become more significant. On the other hand, it is important to note that the widespread scanning of music files sets new a few possibilities to implement methodologies for music data collection, which could be highly interesting. Because the physical translation of these documents is a long and tedious process, in recent years, the introduction of innovative translation schemes for popular music documentation has become more significant. A music consultant must help the restaurant manager as well as the producer [17].

Production of the playlist is an important application in the music selection as it enables consumers to listen to music as well as it provides direct answers based on the program, which can respond. The music recognition has expected to hold these works, which need to be scanned and translated into a usable computer format. Among the most important instruments for preserving the performances of art has been analyzed based on this approach. Moreover, it tends to make the music layers simpler to browse, retrieve, and analyze. The musical material of a recognition program and semantic assessment of each artistic icon in a piece of music should indeed be recognized. Such a challenge typically is difficult, since technologies from a variety of diverse areas, such as machine learning, artificial intelligence, computer training, and theoretical music, must be combined. The continuing story of the music has modified the approach to music data collections. Hence, the Management of music on a storage device and small media players rather than Compact Disk shelves provides plenty of opportunities. Players mark music by hand and generate a wide variety of tags. The album should have been characterized, and the addition to apparent meta-data is analyzed based on the labels and word data to different emotions that users link to the album. A relatively different area of research is the challenge of song mood categorization. It needs to measure intimate relationships triggered by the attitude in a wide range of content song parts. In public consumption, music has often played a significant role. Since digital content and networking technologies are increasing, thousands of users worldwide have been able to access a substantial number of music files. It is tough to find music with thousands of creative and music on the industry; a lot of significant music is hard to trace. Likewise, information has created new possibilities for investigators focused on music-related knowledge and to build new, effective music-based providers, the capability to transfer invention, exchanging, and training.

The music methods constitute knowledge to improve decision-making, which minimizes workload data by finding things that have deemed to be important for the consumer, depending on the user profile, i.e., choice preferences. Notation of songs belongs to a collection of written communication program that enables the musicians to express a broad selection of genres visibly for Analysis. It is an important mechanism to safeguard a stage performance that makes the most abstract concept of music more permanent. It is not inherently to visualize the music; however, it has been used to communicate with a coherent and generally embracing written image. For the music design, the way to deliver this music in written work, has a true, generally recognized musical style. The musical recording analysis is translated into musical notes, and readable format is shown in figure 1.1.

The problem is that real-time analysis of musician motions from large image databases requires a lot of processing power for segmentation and movement analysis. The answer is a scalable neural network called Musician Dynamics Deep Neural Network (MDDNN). MDDNN guarantees efficient data processing, adaptive resource allocation, and parallel computing via cloud-edge hybrid architectures and distributed frameworks. Live performance monitoring, music teaching, and research are just a few of the many varied applications that may benefit from this design's maximum training and inference efficiency across various tasks. Ensuring resilience and scalability, the technique satisfies both computational requirements and real-time performance. Challenges in voice processing include detecting emotions, noise, and unpredictable pitch and timbre. The variety of instruments, tempos, and harmonies in music makes processing it difficult and calls for advanced analysis in the frequency and temporal domains. Absorbing lyrics requires expertise with phrases, slang, and wordplay; the additional complexity of real-time lyric-music alignment compounds the problem. Voice recogni-

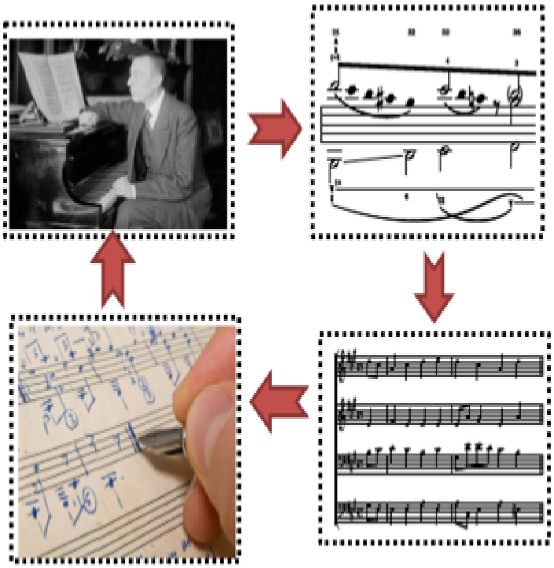

Fig. 1.1: Introduction to musical analysis and document recovery

tion, music feature extraction, and lyrics assessment are three areas that may benefit from using sophisticated deep learning models such as RNNs, CNNs, and transformers. All these interdependent processes benefit from the efficient real-time processing and management of huge amounts of information made possible by scaled computing resources.

The unprocessed sound wave contribution to a time-frequency representation is a reasonable place during the procedure of music messages with deep knowledge. This phase leads to the development of lower parameters and sensibility that is more comprehensible. Voice, music, and lyrics processing in the atmosphere is used to illustrate differences and similarities among areas, addressing messages entirely, troubles, key quotes, and inter-fertilization possibilities among places.

In this research, the paper suggests a Image processing empowered using deep neural networks (MDDNN) to distinguish the recognition process from the classifier using a DNN, which enables us to use the Support Vector Machine on a system to better results. The remaining part of the work is as follows. Section 2 provides insights about background studies; part 3 discussed a Image processing empowered using deep neural networks (MDDNN) for the understanding of musical emotions. Part 4 validates the results. Section 5 concludes the research.

2. Musical document analysis and recovery background study. In this section, there is a clear explanation carried out by researchers; Jorge Calvo-Zaragoza et al. [18] developed a method for digitalizing the music documentation in a new way. The person accesses the digital pen to display the signs over an electronic surface that offers something both underpinning picture (off-line data) and the e-Pen trying to draw (online data). The documentation method has 70 points of the goal musical database by making accessible for scientific purposes, a dataset of 10-230 perfectly equal specimens of 30 alternate meanings.

Jorge Calvo-Zaragoza et al. [19] suggested a method for data-driven Analysis of documents machine -learning, focusing on pixel classification of the regions of concern[20]. The main benefit of this method is that even the evidence is accessible as long as they are obtainable depends on what type of file. The technique tested other specific activities, such as the Identification of the rows of the staff, the separation of musical signs, and the laying in its introductory sections of the text. Cuihong Wen et al. [21] proposed optical music recognition to identify the sampled layer of music effectively. A mixed classifier with superior classification and testing of accurate inspected images on ten articles of music[22]. Results show that valuable addition to the OMR is the approach proposed.

Bjorn Schuller et al. [23] introduce a framework that identifies the evocative musical mood based on a range of characteristics that directly corresponds to the actual world nations. There will be a 2-dimensional mood model in which the feelings will depict the attribute numbers for excitement and excitation for a user-friendly method by which a seven-class tone cluster. The lyrics are in the soundtrack database[24]. Firstly, conventional functions like music and harmonic features, frequency - domain, and MPEG-7 Low-level sound identifiers are used for data analysis. Besides, online data from songs are collected based on the harmonious scenes, and style of music data. Lastly, the high-level features and modes of music and the appropriate dance style are generated automatically from these entire new devices. The feature vectors are action-oriented, and assistance for classification is validated using support vector machines. They were accurately predicting 77.4 % for arousal and 72.9% for valence and 71.8% of seven class clusters for semi-prototypical choice and removal features.

Zhaofeng Zhang et al. [25] provided the distant-speaking presenter recognition with a limiting factor attribute derived from the DNN and the cross-correlation denouncing automatic encoder (DAE). The agency problems could transform the echoing voice function into a new space with a higher differential classification capability for remote speech processing in the DNN bottleneck function. Alternatively, the DAE-based cross-correlation domain attempts to eliminate the overlap by projecting the attention to this matter of the resonant expression to improve the output of remote expression with the goal of clean appearance acknowledge on the functional derivative. The DNN discrimination limiting factor feature and the DAE has the combination of two methodologies, which is anticipated to identify distant voices.

Markus Schedl et al. [26] user-centric algorithms must provide music that suits every audience in thinkable scenario and recreation requirements in the areas of music information retrieval (MIR), and music recommending. Although the "international committee for music management Meeting" and companies probably have only proposed tentative steps towards these systems, it is far from being a reality.

Ivan P. Yamshchikov et al. [27] approaches a new structure that is designed for an artificial neural network in which the translation product longer melodic patterns. The work proposes, known as the history-supported variability autoencoder, is predicated on a recurring transport network with a variable autoencoder. Combined with term algorithms, this architecture enables the development of pseudo-live music that is melodically satisfying and melodically.

Kian Chin Lee et al. [28] introduced Hidden Markov Models, which are the Identification of written musical notation. Handwritten musical notation is simply accessed through a pen pad with paper and pen in a non-gesture manner. The framework taken uses national and global data from ink patterns, which have proved using different characteristics of the various HMM's. These classification methods with the specificities and sensitivities of unseen test sets. The research demonstrates that a very effective way of having handwriting notation feedback with a non-sturdy system which is most common because it does not involve training sessions.

Yuan Cao Zhang et al. [29] implement the Auralist prediction model, which seeks to incorporate and develop all four factors concurrently, contrary to previous research[30]. The quantitative test Aura list in a comprehensive collection of measures, showing that the focus of the Aura list on serendipity improves satisfaction for the user with a user analysis on music suggestions.

Marius Kaminskas et al. [31] proposed music based on the actual situation of the user, for example, a mental reaction or any other regard to quality, which could impact the person's perception of music. Although such an idea is a high potential, the advancement of real-world applications that collect or advise music accordingly remains in its initial stages. The survey demonstrates various methods and strategies used for resolving the difficulties of the study raised by the collection and suggestion of context-aware material. This study covers a variety of topics, from traditional music information collection (MIR) and system recommendation (RS) techniques to context-conscious music implementations and completely new patterns in attitudinal, social, and cultural-computing in the music industry.

Based on the statistical survey, MDDNN is used to distinguish the recognition process from the classifier using a DNN, which enables us to use the Support Vector Machine on a network to better results.

3. Image processing empowered using deep neural networks.

3.1. Image processing empowered. The sets of music records are considered as a significant part of the history of the world. Future access to the designs in the viewable music streaming library services, digital technology is essential. Further, large-scale assessment is allowed using analytical approaches. Music is sequentially the success of digital expensive since it can be an exceptionally huge task for music professionals to perform. The invention of programs to compose musical documents automatically has, therefore, occurred in the last few years, which has gained popularity. The oldest method of computer engineering in Image processing empowered (MDA) can derive the lyrical content of a partition from the digital inspection of its origins. The MDA is of two stages. The first is the Production of the manuscript that consists of several steps in the detection and recognition of each key aspect in the source of input music.

In the second phase, the result contextually to interpret the musical components into the database with representational music. The performance from MDA structures is usually an embedded symbolic image of the music track in a digitally standard data such as the Music Encoding Initiative. A document analysis process is to identify and classify each component of the input music text before attempting an automatic recognition, for example, staves, letters, text messages, décor, captions, or information of the reference list. The problem to identify and categorize the various parts of composite material is music notation. It includes different types of syntax like typical western syntax, randomly picked equations, or telescoping equations.

Moreover, results with the same typology can vary significantly due to the various institution of the layout, embellishments, soundtrack fonts, and note - taking designs. Several methods for musical document analysis to respond to a particular sort of transcription. A general and severe approach to a wide range of styles of alternate tunings and artistic files. Since a specific musical data-analysis system has not been developed to deal with the variety and complexity of musical collections. As a structured manner for the assessment and development of records, document analysis. Analytical methods aim to pick and make sense of the information found in records to derive interpretation and knowledge from such files. The areas of focus in a text have the components for the production process, which are categorized and labeled. Music ratings contain many different knowledge regions. Therefore, employees-line Identification and elimination is the highest quality method for document analyses. Even though employee's lines for username, they are difficult to classify and identify musical icons with conventional methods based on the assessment of the connected components. The Identification and elimination of the employee's line are considered a simple process.

Further, historically effective outcomes are difficult to accomplish. It is primarily caused by unusual website situations like divergences, distorting, or document decay. MDDNN is used for categorizing each pixel of interest within the input image, showing that the level of knowledge corresponds to the guided learning model to carry out a task. It implies that every kind of data which needs to be classified as typical applications. Consequently, for this task, three aspects are crucial: (i) a function set with each pixel, (ii) a technique for categorization, (iii), and training data has been analyzed. Deep neural networks (DNNs) allow for accurate detection and categorizing of image portions to assist in image segmentation. For example, the MDDNN system for analyzing musician movement uses a DNN to evaluate video frames and identify specific body parts like hands or arms. This approach treats segmentation as a pixel-wise classification job. Advanced architectures like DeepLab or U-Net may extract detailed characteristics from pictures and create segmentation masks to enhance specific areas of interest. Ensuring effective segmentation even under challenging settings, such as fluctuating illumination or obstruction, these networks are trained end-to-end, allowing computers to learn and adapt to complicated motion patterns straight from labelled datasets. The document analysis has many songs with the query document based on single users, as shown in figure 3.1. The system proposed consists of 3 steps: pre-processing, Analysis of the text, and classification of music.

3.1.1. Pre-processing. Document analysis is done based on the pre-processing solution to remove extra words, such as keywords and phrases: the music documents and the results set in the following text assessment phase—the music documents down into training and test data in the actual text analysis step. Then, the training data set for a linear transformation is formulated based on linear discriminate Analysis (LDA) and the Probabilistic linear discriminate Analysis (PLDA). The overall flow method of Image processing empowered using deep neural networks has illustrated in figure 3.2. The document similarity is used in MDDNN to generate a recommendation. An equal representation of the documents is required to identify the similarity between the materials. The Word representation model is used to achieve Every record which is the function with every variable in the word document model. There are two main challenges in handling the whole string of words with no pre-processing stage. One major issue is to remove end words in the document, which does not

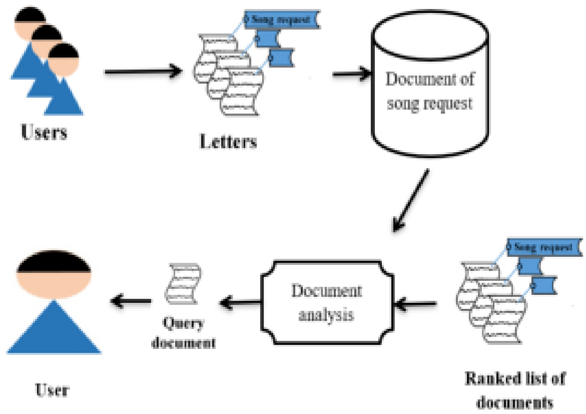

Fig. 3.1: Users query request based on document analysis

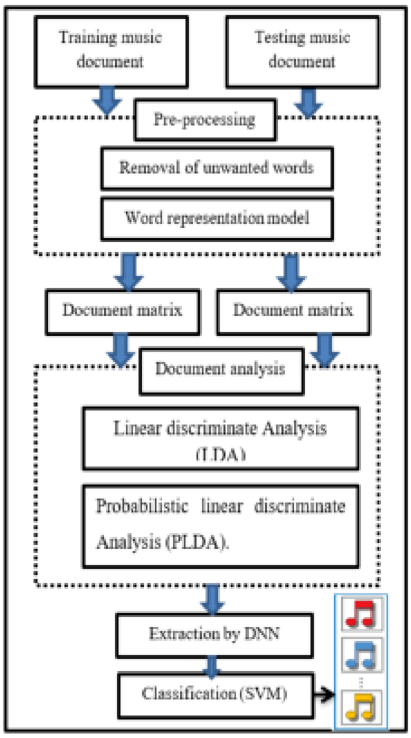

Fig. 3.2: The overall flow of Image processing empowered method

give any meaning. The second issue is discarding halted words. These two stages are the main phases in the pre-processing step.

3.2. Document analysis. Almost every document is displayed as a word representation model vector employing the pre-processing stage where the end words are deleted. There remains a significant issue even before calculating the similarity measure with the pre-proceeded word representation model: the amount of names from each document is incredibly small in comparison to the whole series of numbers used in almost all of the files. These entire sparse word representation models are not sufficient and a massive theme with the word representation model. Linear discriminate Analysis (LDA) and the Probabilistic linear discriminate Analysis (PLDA) have shown themselves to be a useful technique for implementing this technology and comparing word representation variables. . In musical analysis, algorithms extract important aspects like dynamics, rhythm, melody, and harmony from audio or MIDI data. Musical elements may be identified by separating an audio file into frequency components, such as Fourier Transform or wavelet analysis. Optical music recognition (OMR) programs analyze scanned sheet music to retrieve lost documents. It employs pattern recognition and machine learning methods to transform musical notation-like notes, clefs and rests into computer-readable forms, such as MusicXML or MIDI. This is especially important for complicated or loud audio data, which requires scalable computer systems to manage massive datasets efficiently and accurately.

3.3. Linear discriminate Analysis. Proceeds to the vector space of similarity to detect file or word document residual significance. Each report is viewed as a sparse word representation model, an l*s is the dense document entities vector, which can be constructed with vectors that are l as the whole phrase set, and s as the text set. This split word-document vector is being handled by LDA to detect the latent significance of documents and words. LDA often decreases the quantity of the vector text. It is a variable that is manageable and stated below in detail. By using traditional distance measures, such as the vector range or distance measure, proper documentation with a word vector which includes the inherent sense. An important method utilized whenever conducting LDA is the scattered co-occurrence vector which is decomposed through a collection of transformation and growing matrices, and it is shown in Equation 3.1:

$$N = PQS^t + l * s,\ P \in S^{T\times T} \tag{3.1}$$

Here $N \in S^{T\times b}$ is the actual variation structure, $P \in S^{T\times T}$ is the sum of the structure of words, Q is a mapping function size $S^{T\times b}$ is the description that included particular criteria, and $R \in S^{b\times b}$ is a structure chosen to represent documents. Both P and S are precisely equivalent.

As once reduction is completed, the parameter vector Q and the parallel vector S^t reports are magnified to evaluate definitional segregation. The number of absolute values to use the variable to be updated. The percentage of absolute values defines the feature vector aspects to which the lowered matrix is displayed. The outcome is $B' = Q' \times R'^t$, the lowered easily interpretable vector is $B' \in S^{l\times b}, Q'$ is the bitmap image for the density function with L absolute values, and R'^t be the lowered analogous structure for requested documentation. A maximum distance shall be used until the calculation to measure the range. The dimensions for the paper have used vector length that in our earlier work demonstrated to exceed the distance measure.

3.4. Probabilistic linear discriminate Analysis (PLDA). Like LDA, the implicit sense among documentation and words for the processing of a sizeable term-document matrix is detected by probabilistic residual semantic Analysis (PLDA). The proper documents are found with this packaged word processing sample containing the significance of susceptibility. The key difference here is that every methodology utilizes different algorithms when attempting to discover the innate importance between both the documents and the phrases. During the processing framework, PLDA uses a predictive method for treatment groups or dimension system for the approximation of the reference frame with Single Value. The next equation indicates the conditional distribution of document b and phrase u dependent on an observed variables x. The dimension model suggests terms u and b are separate when the discriminant function x.

$$Q\,(b,u) = Q(b)\sum_{x} Q(\frac{u}{x})Q(\frac{x}{b}) \tag{3.2}$$

The system with the Assumption Value (AV) method for a document set. Each step of the assumption of the technique in next equations:'

$$Q({}^{x}/_{b},u) = \frac{Q\,(x)\,p({}^{b}/_{x})p({}^{u}/_{x})}{\sum_{x'} Q\,(x')\,Q({}^{b}/_{x'})Q({}^{u}/_{x'})} \tag{3.3}$$

$$Q(^u/_x) = \frac{\sum_b g\,(b,u)\,Q(^x/_b,u)}{\sum_{b,u} g\,(b,u')\,Q(^x/_b,u')} \tag{3.4}$$

The value method for each document and the word representation:

$$Q(^b/_x) = \frac{\sum_u g\,(b,u)\,Q(^x/_b,u)}{\sum_{b,u} g\,(b',u)\,Q(^x/_{b'},u)} \tag{3.5}$$

$$Q\,(x) = \frac{\sum_{b,u} g\,(b,u)\,Q(^x/_b,u)}{\sum_{b,u} g(b,u)} \tag{3.6}$$

Complete initialization of the variables used throughout the AV method. Hence the technique has low dimensional descriptions of words in the document. AV method is valid using a layer-in to design requirements. The cycle and the A step and V step, all $Q(u-x)$ is constant and $Q_g(x-r)$ is recalculated. The master-planned word document analysis of music in next equation:

$$Q_g(^u/_r) = \sum_x Q(^u/_x)Q_g(^x/_r) \tag{3.7}$$

Same as the LDA, the vector range is to identify supporting information until the variables into the dimension. Among the formats that are most commonly used for audio analysis are WAV (Waveform Audio File Format), which provides uncompressed, high-quality audio; MP3 (MPEG Audio Layer III), which is compressed and usually used for distribution; FLAC (Free Lossless Audio Codec), which is losslessly compressed and often used for streaming; and AAC (Advanced Audio Codec), which is used for audio files. MIDI files are usually employed when it comes to musical performance data. These files include information about time, instruments, and notes but do not include any actual sound. Document recovery includes examining open standards like MusicXML for digital sheet music and proprietary formats like Sibelius (.sib) and Finale (.mus). In addition, Optical Music Recognition (OMR) systems may transform scanned sheet music into machine-readable music scores in image formats such as PDF, PNG, or TIFF. Extracting musical aspects, retrieving scores, or synthesizing audio performances are some analytical intends that inform the format decisions.

3.5. Suggestion for music. A transition vector by conducting textual Analysis that expands the variables of the training dataset into another comparative space. The source vector into the feature space, which could constitute a series of pre-processed sample data points. The lengths within each variable are to produce a classification list, for nearer dimensions for becoming entities most comparable. People seem to prefer similar music in similar scenarios; this would be a viable suggestion to advise music demanded through matching features.

3.6. Retrieval of musical notes by DNN. The retrieval from an immediate monaural musical mixture $y\,(m)$, the target device $r\,(m)$, the extraction process is shown in Equation (6.1)

$$y\,(m) = r\,(m) + \sum_{j=1}^{N} u_j(m) \tag{3.8}$$

Here $u_j(m)$ be the source of the music period symbol, and the mixture thus contains a sum of $N+1$. The DNN approach to retrieve $r\,(m)$ from the mixture $y\,(m)$, portrayed in the figure, for specified device extraction. l. The removal carried out in the original signal, and the following three steps are used for retrieval by DNN.

1. *Production of a feature vector*
   To perform the Production of the feature vector, Fourier transforms in the form of rectangle frames are used. A function matrix from the recognition by $y \in S^{(2D+1)R}$ loading the impact of the consecutive frame of technological values and the previous, subsequent frames in the d where the amplitude values R for each frame. The aim of using the 2D-neighboring sets is to provide the DNN with a brief background that could enable the goal element to be correctly retrieved. There should not be any overlapping between any of the musical frames.

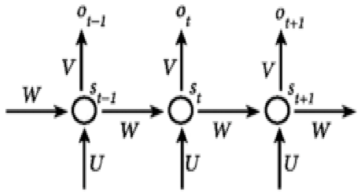

Fig. 3.3: The input and the output unit with its path diagram

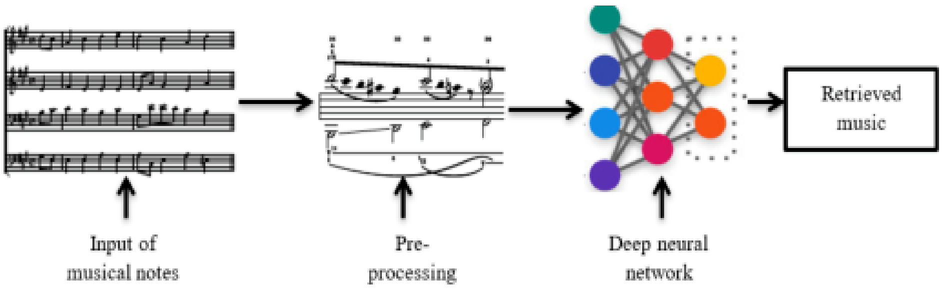

Fig. 3.4: Preprocessing and retrieval stages of musical notes

2. *Retrieval of music*
In a second step, the standardized Fourier transform impedance variable v to a DNN consisting of the Rectified Linear Unit (ReLU) with t layer and it in Equation (6.2) and (6.3)

$$S_{t+1} = \max\left(v_t + u_t, 0\right), \ l = 1, \ldots.., L \tag{3.9}$$

$$W = (S_{t-1} + O_{t-1}, \ldots\ldots\ldots + O_{t+1}, +S_{t+1}) * v_t + u_t \tag{3.10}$$

Here v_t denotes the t th layer reference and u_t is in particular of input w of DNN and output of S_{t+1} layer. The input and output layer with the $O_{t+1}, +S_{t+1}$ the layer is shown in figure 6.2.
3. *Component for restoration*

Use of the starting material of Fourier transform is calculated by the power normalization W for every Deep Neural Network component; Fourier transform approximation from the system configuration u_t is obtained and is transformed back into the spatial domain by way of a reverse Fourier transform. The best scenario is to provide documentation of the device, and the history of the combination is used to remove it. The hardest part to do is learn the kind of music wanted to pick and don't learn the context objects that occur in the mixture. Designers have file format by each type of instrument from various instrumental music iconic works of art with different sounds. Such differences are essential since there is a need to recognize certain kinds of equipment, and therefore, Deep Neural Network can make assumptions well to new devices of the same kind. The use of this existing experience is fair because the documentation that provides details on the musicians, or should the person fail to provide data. The pre-processing and retrieval stages of musical notes by the deep neural network has shown in figure 6.1.
ReLU is used to remove the error in the classification stage. In the training stage of DNN, the dataset is created and understands the network weights such that description error (MSE) among the input

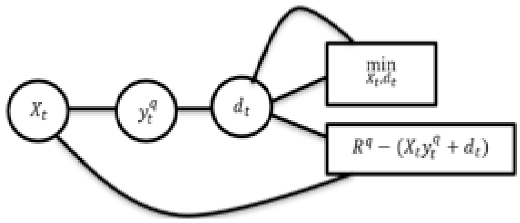

Fig. 3.5: Input and output path of DNN

and output of DNN. The weight initialization for the t layer in next equation:

$$\left\{X_t^{in},\ d_t^{in}\right\} = \min_{q=1}^{Q}(X_t, d_t)R^q - (X_t y_t^q + d_t)^2 \tag{3.11}$$

Here y_t^q is the input of the deep neural network, $(t-1)$ is the layer of the output if $t > 2$. The reconstruction of information as R^q. The path diagram for the last equation has shown in figure 6.3. The SVM classifier output produces the essential elements through the data pre-processing focused on the template confidence method is used in the possibility of the stimulus becoming voice or music. The last stage is concerning the SVM decision - making-thresholds for classifying the message as voice or music generated are listed based on it. The SMV is an inter-rate dynamic voice modulation that used efficiently. Throughput restricted and accepted to a particular standard. It comprises three median data speeds and four main methods, each based on the type of input data and the position of the platforms. Because of that feature, for a particular scenario, an acceptable difference can be identified among service performance and process efficiency. The Sound activity sensing signal has shown in the music classification phase that distinguishes speech against sound and silence. In the category, SVM is used to construct an ideal decision boundary that divides the distances between some of the nearest variables and the higher dimensional space by two different classes. Owing to the N-dimensional models of m_j and n_j denoted as information vectors and the classification has given as (m, n)…………..(m_j, n_j) and it has shown in next equation:

$$u, y + d(m_j, n_{j+1}) = 0 \tag{3.12}$$

Here u and y is the SVM weighted vector, d is the objective of the whole matrix and m_j, n_j. The objective function has used to express the maximization parameter, and it has shown in next equations:

$$\min \varphi\left(y\right) = \frac{1}{2} y.y \tag{3.13}$$

$$\{y.y + d\}n_j = 1, \forall_j \tag{3.14}$$

Here y is the weighted vector, n_j is the objective of the matrix, $\forall_j$ scaling parameter. All music videos must be shown as objects to educate classification for supervised classification. The short-term features have extracted from frames. In general, there are several frames in a music video, and it is has defined by a single functional vector. The textures portal has used to calculate the spatial variation of the spread of framework-level characteristics in it, using numerical identifiers, like a far broader evaluating screen. Furthermore, the projections of different systems may have integrated into a single matrix. The category of music, which may be the top-level category for the classification and naming of standard musical compositions that can be categorized immediately. Art usually has common properties in the same artistic style. Designers can derive the property from the music and explore various interactions through content-based music data storage and interpretation. Indeed, via

Table 4.1: The classification accuracy for the music document

Number of data sets	Music document 1	Music document 2	Music document 3	Music document 4
10	77.89	71.40	64.51	75.67
20	52.78	50.01	43.21	91.13
30	42.22	42.66	70.13	89.98
40	71.91	80.10	81.22	63.45
50	43.67	76.79	77.88	53.11

the connection between communities, musicians, or perhaps even specific associations, music genres can be described in several various ways, and types which are strongly linked or converge. The automatic classification methods have been an obstacle. The issue of enhancement may be translated into the challenge of maximization, i.e., multiplication design (MD) more precisely. The SVM produces an output component for the activation function x if we get the solution to an MD issue and it has shown in next equation:

$$g\left(y\right) =< u*, y > +d \sum_{j=1}^{N} x_j* < y_j * .y > +d* \tag{3.15}$$

Here the support vector is given by u^*, d is the weight vector, $< y_j * .y >$ is the inner product of the matrix. Remember that when the input is conditionally independent, the above Equation is the judgment feature. When the information is not conditionally independent, the data is separated sequentially by projecting the inner product into a higher-dimensional spatial domain a feature vector has given Based on the system framework, MDDNN is used to distinguish the recognition process from the classifier using a DNN, enables us to use the Support Vector Machine, and better results have obtained by this classifier. MDDNN describes a useful loss function, and it is to find a function space. The resemblance among musical recording variables correlates to the relation between the descriptions. MDDNN approach addresses as a content-based recovery technique that follows the problem by example, in case of an audio query; the task is to retrieve from a music archive in all documents that are somehow identical or correlated with a question.

4. Results and discussion. In this section, a Image processing empowered using deep neural networks (MDDNN) for the understanding of musical emotions has validated by deep neural network and support vector machine, and the better results have obtained. In the case of non-existent text explanations, a content-based retrieval approach has required, and it uses the raw audio material based on the dataset https://www.kaggle.com/code/kehlinswain/imu-sensor-data-exploration.

Accuracy. Accuracy for overall classification has calculated by the next equation:

$$accuracy = \frac{1}{t} \sum_{j=1}^{T} \frac{y_j + u_j}{y_j + u_j + b_j} \tag{4.1}$$

Here T represents the weight initialization of T-th layer, u_j represents the weight of each vector, y_j is the output of each vector, b_j is the length of each the music document. The classification accuracy for $T-$ layer is clearly shown in table .

The classification accuracy for $T-$layer for each music document has shown in figure 4.1. DNN uses a T-layer unit, and these units are used in a sequence to capture the local functionality. The classification accuracy for $T-$layer unit for the music document 4 achieves highest performance accuracy.

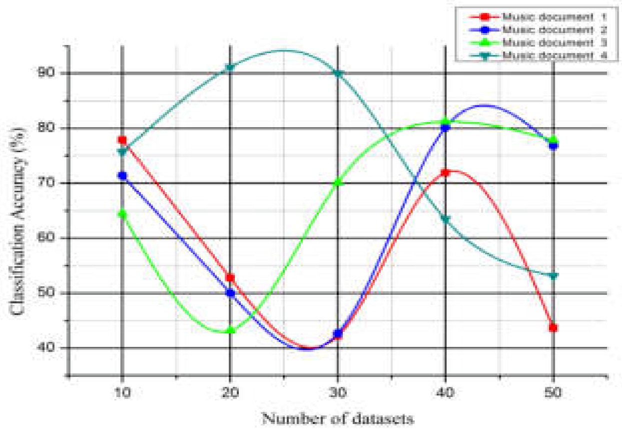

Fig. 4.1: The classification accuracy for the music document

Table 4.2: The classification accurancy for each network layers

Number of data sets	Network Layer 1	Network Layer 2	Network Layer 3	Network Layer 4
10	65.82	71.23	61.22	71.76
20	50.10	54.63	41.10	84.72
30	41.55	64.87	69.88	42.89
40	71.88	83.65	81.22	57.99
50	50.89	74.86	71.13	93.22

The number of network layers used in DNN has illustrated in table 4.2. The accuracy for all network layers has evaluated by the SVM classifier. The inner product of the vector changes the overall layer performance. The inner product of the vector obtains the accuracy performance for all network layers.The classification accuracy for each network layer has shown in figure 4.2. Network layer 4 has the highest classification accuracy when compared with the other layers. These layers have selected in the reactivated linear unit used in the deep neural network.

The overall classification accuracy has compared with all the existing methods, and it has clearly shown in figure 4.3. As a structured manner for the assessment and development of records, document analysis has implemented by DNN. A Image processing empowered using deep neural networks (MDDNN) for the understanding of musical emotions gives the highest classification accuracy.

4.1. Error loss rate. The error loss rate has reduced by the usage of the inner product vector used in the weight initialization of the T-layer. The primary use of the T-layer is to minimize the error loss rate, and it has clearly shown in next equation:

$$R = \frac{1}{T}\sum_{j}\left(Y_j - G\left(T\left(Y_j\right)\right)\right)^2 \tag{4.2}$$

Here $G\left(T\left(Y_j\right)\right)$ Is the inner product of vector function, R is error loss rate, and it has illustrated in figure 4.4.

Linear discriminate Analysis (LDA) and the Probabilistic linear discriminate Analysis (PLDA) have shown themselves to be effective techniques for implementing musical document analysis and comparing word repre-

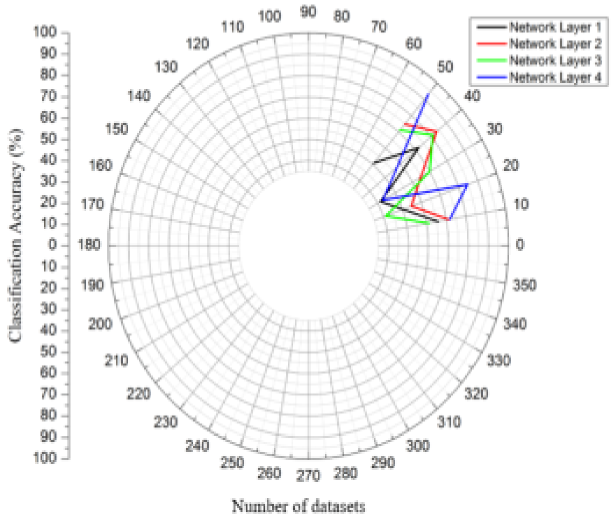

Fig. 4.2: The classification accurancy for each network layers

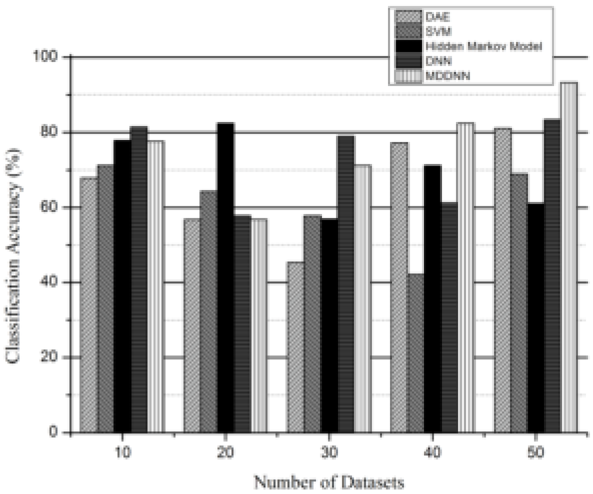

Fig. 4.3: Overall classification accuracy

sentation variables. The performance of both analysis methods has indicated in figure 4.5.

A framework is to distinguish the recognition process from the classifier by using a DNN; the Support Vector Machine is used on a network to get better results. MDDNN describes a useful loss function, and it has used to find a function space. Cloud platforms like Amazon Web Services(AWS) or Google Cloud provide dynamic scalability for large-scale data processing and deep neural network training. Edge devices that include GPUs or TPUs allow for real-time data preprocessing, which reduces latency and bandwidth utilization. Model optimization methods, such as reduction or quantization, guarantee resource-efficient deployment, while distributed frameworks, like Apache Spark or Ray, may effectively manage workload distribution. Tools like Elasticsearch provide adaptive resource allocation, enabling dynamic scalability according to the complexity of the demand. Furthermore, real-time applications benefit from frameworks like ONNX Runtime and lightweight

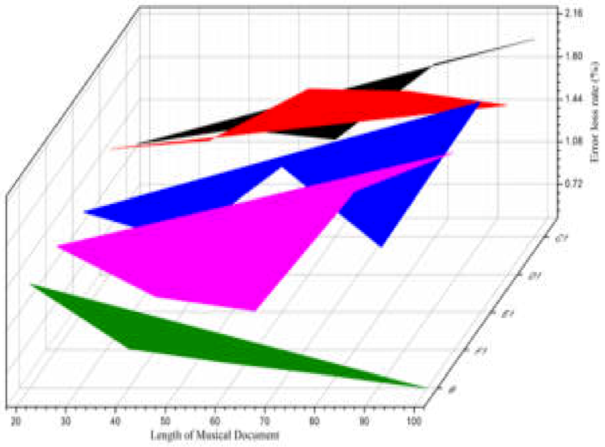

Fig. 4.4: Error loss rate

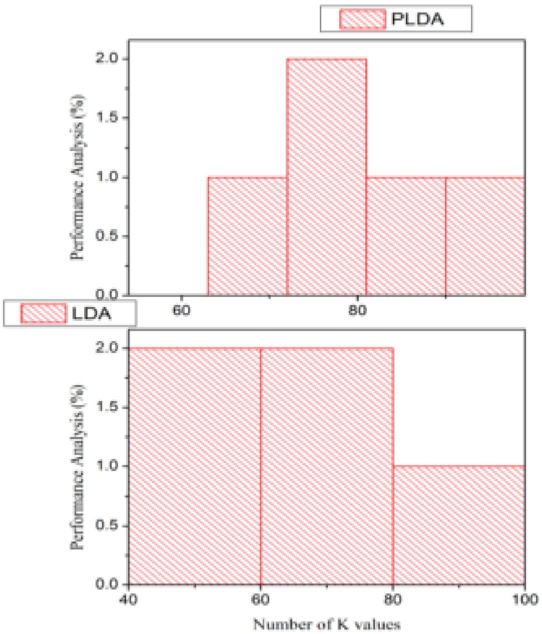

Fig. 4.5: Performance of Analysis

topologies like EfficientNet. This scalable computing method ensures the MDDNN system's continued efficiency, cost-effectiveness, and adaptability to different performance situations.

5. Conclusion summary. This research provides information regarding MDDNN describes a useful loss function, and it has used to find a function space. The resemblance among musical recording variables correlates to the relation between the descriptions. MDDNN approach has addressed as a content-based recovery technique that follows the problem by example, in case of an audio query; the task is to retrieve from a music archive in all documents that are somehow identical or correlated with a question. MDDNN achieves the highest classification accuracy of 93.26%, and the error rate has reduced to 0.44, and MDDNN method is more efficient for image processing empowered.

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SCALABLE COMPUTATIONAL TECHNIQUES FOR PERFORMANCE MOVEMENT ANALYSIS OF MUSICIANS THROUGH IMAGE PROCESSING

WEILONG TAN*

Abstract. This study may increase performance by offering insider perspectives on implementation. Musical creativity is limited by traditional movement analysis. Two of these drawbacks are slow feedback and poor accuracy in recording minor motions. Traditional performance analysis has drawbacks, including the inability to record minor activities, subjective interpretations, and reduced accuracy. However, it cannot provide exact insights that increase performance and operational efficiency. These issues may be addressed using scalable Image Processing-based Musician Movements (IP-MM). High-resolution cameras and strong image processing algorithms allow this approach to observe and evaluate artists' movements. IP-MM provides musicians with quick movement style feedback. IP-MM recognized data trends to enhance strategies and performance. This technique greatly improves movement analysis and gives gamers immediate and meaningful feedback. Improving performance demands prioritizing practice. System performance analysis has improved in IP-MM. As a powerful instrument, it lets musicians push their skills. The new technique improves the performance ratio by 97.2%, the practice efficiency ratio by 98.2%, and the movement patterns ratio by 96.32%.

Key words: Movement analysis, music performance, image processing, cameras

1. Introduction. Enhancing musical performance by use of contemporary image processing techniques: the IP-MM system [1]. Effective practice and performance improvement are more difficult using traditional method analysis techniques that depend on subjective observation and lack precision [2]. The IP-MM system tracks and analyzes a musician's every movement with exact precision using sophisticated algorithms and high-resolution cameras [3]. This will help to solve the discovered issues [4]. The real-time feedback function of the technology allows musicians to rapidly improve its methods, therefore improving the practice schedule and resulting in noticeable performance changes [5]. Performance analysis technology advanced greatly with the publication of the IP-MM system [6].

Acquiring well-coordinated bodily motions, learning to sequence movements in suitable trajectories within the time demands of the job and its physical limits, and overcoming the multiple degrees of freedom are all necessary for performing motor skills [7]. Music education and performance provide enough evidence of this intricacy. The coordination of the necessary hand and finger movement sequences within a precisely defined temporal framework is of the utmost importance while learning to play an instrument [8]. Visual, auditory, and somatic input and integration, in addition to extensive practice, are essential components of the process of attaining skillful performance [9]. Musicians are perfect specimens to analyze all aspects of complicated skill learning considering the multimodal and intense training that undergo. Motor skill exercise makes one more deft and adaptable to new situations and tasks; it further makes one's performances more exact and automatic [10]. A more exact coordination of movements, including the inhibition of related movements of the other hand during unilateral movement execution, and higher ElectroMyoGraphy (EMG) amplitudes of the target muscles are common outcomes of this [11]. Analysis has shown that there are fundamental changes in behavior that occur with the learning of motor skills and with continued practice [12].

When comparing professional pianists to non-musicians, Functional Magnetic Resonance Imaging (fMRI) is found that during movement performances of different complexity, professional pianists exhibited lower motor activations within the supplementary motor area, the pre-motor cortex, and the ipsilateral primary motor cortex (iM1) [13]. The participants postulated that honing one's musical skills over time allows one to devote more mental and physical energy to other areas of creative and motor performance [14]. In contrast, following

*School of Opto-Electronic and Communication Engineering, Xiamen University of Technology, Xiamen Fujian 361024 China (takitan131@163.com)

a brief decline that lasted for four weeks to a few months after training, there is an enlargement of cortical activity in the contralateral Primary Motor Cortex (PMC) during the learning and repetition of fast finger movement sequences [15]. Consistent with this, people found that bilateral PMC and cM1 are more actively engaged in highly practiced movement trajectories. Although it is known that the dorsolateral prefrontal lobe is engaged in the first stages of motor training, its role diminishes as training experience increases. While the parietal areas are recruited during well-rehearsed performances, these prefrontal activations are more evident during learning. It has been suggested that the superior parietal lobe stores graphomotor trajectories, whereas the inferior parietal lobe is mostly engaged in motions that involve one's own body.

Therefore, after acquisition, representations of movement sequences may not be exclusively preserved in the cM1 but may instead be dispersed among other motor regions, such as the PMC and parietal areas. Real-time feedback has a latency that might affect artists' performance because they cannot receive adjustments and direction prompts when needed. Because each individual has their style and different instruments have different motions, accurately recognizing various movements may be difficult. Environmental variables like illumination and background distractions may degrade video input quality and cause tracking errors. Real-time analysis may limit scalability and practicality due to its computer power requirements. Present feedback mechanisms may not be extensive enough and flexible enough to accommodate varied degrees of competence, reducing their efficacy. The user- acceptance of technology is another issue; artists' comfort with technology varies. Thus, a simple design is essential for effective deployment. Complicated matters are that performance art is inherently subjective, making it hard to produce reliable ground truth data for validation. Lastly, if the technology interferes with the musicians' regular workflow, it can be challenging to incorporate it into their current practice habits. Fixing these issues is crucial for making the Image Processing-based Musician Movements (IP-MM) system more useful and shared in the actual music.

Curiously, similar alterations are also seen in cerebellar activation areas, and they diminished as the subjects practiced for periods ranging from a few days to four weeks—far longer than the training period used in the analysis. In addition, after practicing for a while, activity in the basal ganglia increases whereas activation in the cerebellum decreases. The formation of new associative connections between various sensory inputs occurs during the acquisition of motor sequences and the timing of such sequences while playing an instrument. There is evidence of cross-modality functional connection between musical instruction and studies of the developmental elements of musical skill acquisition. Specifically, while practicing motor skills on the piano with aural feedback activates both the cortical and sensorimotor areas of the hand, whether the task at hand is quiet motor or pure auditory. Enhanced musical training may serve to fortify such cross-modal integrations.

Image processing techniques are a collection of addresses used to improve the quality of digital images through analysis, enhancement, and manipulation. Some of these methods include filtering, which enhances features or decreases noise; edge detection, which finds the borders of objects; and segmentation, which separates the image into valuable areas. Feature extraction exposes significant aspects, including patterns, textures, and forms. Optical flow and other approaches quantify pixel mobility between video frames. Morphological processes change a picture's structure to match its visual qualities. This simplifies noise reduction and object detection. These approaches provide precise statistical visual data analysis in computer vision, medical imaging, and video analysis.

Contribution of this paper. The Image Processing-based Musician motions (IP-MM) system: This paper tracks musician motions with great precision using modern image processing methods. This update gives a more thorough and accurate evaluation of performance approaches than the previous methods.

Mechanism for Real-Time Feedback. The IP-MM system incorporates real-time processing capabilities, allowing musicians to get rapid feedback while practicing. This enables artists to fine-tune their approaches in real-time, which ultimately leads to better and more efficient practice.

Practical Performance Insights. The IP-MM technology simplifies movement data, allowing musicians to pinpoint where they may make improvements. A useful tool for both rehearsals and performances, this data-driven method promotes focused skill improvement and boosts overall performance quality.

Section 1 explains the IP-MM system presents a fresh way to improve musical performance by use of modern image processing techniques. Section 2 explains tool helps musicians play better as it lets their behaviors be precisely watched and investigated. Section 3 contains the proposed method used in this paper. In section 4 the results show a performance analysis improvement, practice efficiency, and movement pattern assessment as proof of the efficacy of the IP-MM system in giving musicians real-time feedback. In section 5, conclude a major advancement in performance enhancement technology, the IP-MM system lets musicians hone their methods for better degrees of expressiveness and perfection in their presentations.

2. Related works. Though deep learning advances have substantially improved visual sound separation, there are still difficulties separating similar instruments. The "Music Gesture" key point-based structural representation combines visual and audio data through a context-aware graph network and replicates musicians' physical actions, effectively solving this challenge. Analysis of musical performance and rhythm perception additionally demonstrates brain networks connecting hearing and movement. DeepDance uses GANs to create dance sequences in reaction to musical cues, therefore enabling higher levels of cross-modal analysis.

The empirical results for deep learning methods created in the past few years for visual sound separation have been exceptional. On the other hand, these methods rely heavily on visual flow and motion feature representations. These representations struggle to establish relationships between visual spots and auditory signals when faced with the task of differentiating between similar instruments, such as many violins in a scenario [16]. The key point-based structural representation, "Music Gesture," faithfully imitates the physical and motor activities used by musicians during performances, thereby solving this difficulty. It starts with a context-aware graph network that integrates visual semantic context with body dynamics. After that, it employs an audio-visual fusion model to merge the two types of data to try to determine what is going on. It have improved benchmark metrics for hetero-musical separation tasks (i.e., different instruments) and achieved a previously unattainable feat of homo-musical separation for duets of piano, flute, and trumpet using our new capability.

The activation maps of professional and amateur violinists are compared during actual and imagined performances of Mozart's violin symphony in G major (KV216). Executed and imaginative fingering gestures are used to play the first sixteen bars of the concerto using the left hand. This is achieved by scanning both real and imagined musical performances using ElectroMyoGraphy (EMG) recording, and by using EMG feedback during imagery training to avoid actually doing the movements [17]. The ipsilateral anterior cerebellar hemisphere, the bilateral superior parietal lobes, and the contralateral primary sensorimotor cortex are the regions of the brain most heavily activated by proficient musicians, according to these results. An increase in activity in the right primary auditory cortex during execution may represent the stronger audio-motor associative link seen in pros. It seems that masters are able to better link the finger sequences to auditory and somatosensory loops to execute musical sequences while the motor areas are more efficiently used.

Neurotypical people's understanding of musical beats are analyzed by doing a thorough review and meta-analysis of thirty functional magnetic resonance imaging papers. It started by finding a generic network that can process rhythm in music [18]. This extensive network included both the auditory and motor domains, and it contained all the motor and sensory processes relevant to the rhythm. Beat-based musical rhythm-specific locations are located in the bilateral putamen in the second stage of the investigation (Beat-based, audio-motor control, 8 contrasts). The next step included finding the areas affected by rhythmic complexity depending on the beat. Sections such as the right temporal, inferior parietal, cerebellum, and bilateral SMA-proper/pre-SMA are involved. A bilateral cortico-subcortical network seems to be primarily responsible for the representation of musical rhythm, according to this meta-analysis. Further investigation into the potential overlap between the neural bases of musical rhythm and other cognitive domains is warranted, since our findings are in line with existing theoretical frameworks regarding the auditory-motor link to a musical beat.

Under the broader field of cross-modal analysis, there is a substantial body of papers concerning the evolution of improvised dance sequences. One crucial part of it is the challenge of how to effectively construct and connect music and dance using a probabilistic one-to-many mapping. To address this issue, it provide DeepDance, a cross-modal association framework based on GANs [19]. The software's goal is to create the intended dance sequence in response to the supplied music by correlating two separate modalities: dance motion and music. Its generator's goal is to mimic the current musical style as closely as possible by learning from past examples and creating dance moves accordingly. It propose an efficient and effective way to create a large-scale dataset utilizing open data sources, to address the problem of inefficient and expensive data collection. Extensive analysis of publicly available music-dancing datasets has shown how this method accurately represents

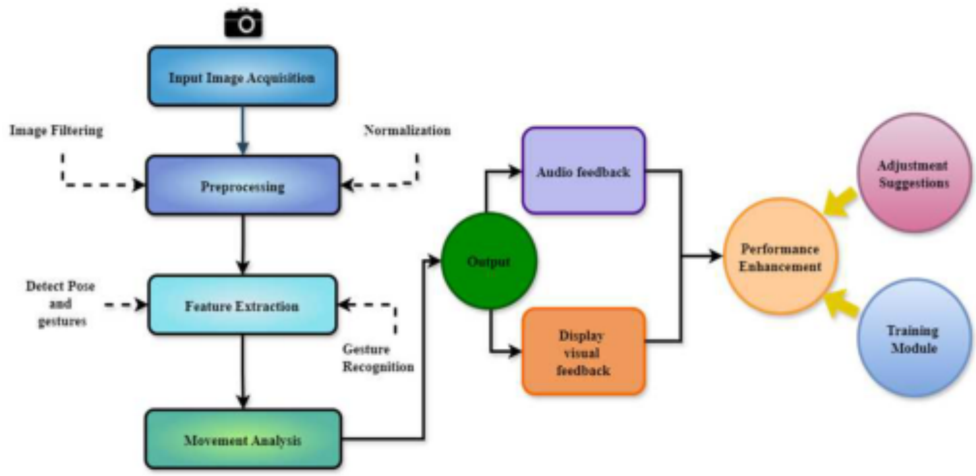

Fig. 3.1: IP-MM System for Performance Enhancement Framework

the relationship between the two and can be used to generate appropriate dance routines.

The paper explores some recently occurring developments in the realm of music. Among these developments are investigations of the brain's function in music performance and rhythm processing, "Music Gesture" techniques for improved visual sound separation, and the DeepDance framework for developing music-based dance routines. Visual, auditory, and muscular input has evolved greatly, and these results reflect that. It gives for the analysis and creation of dance and music new viewpoints and tools.

3. Proposed method. In performance development there is nothing important than ability to assess correctly techniques for improvement . However, such conventional approaches do not provide the kind of accuracy or real time responses required for substantial progressions; they rely on basic motion tracking tools or human beings watching performances [20]. Captured using high definition cameras monitored by cutting edge image processing algorithms , every move made by performers is processed into useful information.IP based MM systems such as the one suggested here allows for immediate and realistic feedback given to artists about their performances. This device breaks down intricate patterns into its components which are actionable in nature. With IP-MM system, performers have access to a good resource for performance analysis helping them improve their craft and perform better than ever before.

Fig.3.1 shows the design of the proposed IP-MM system. The system gives musicians precise, real-time feedback, which would revolutionize performance development in the music business. Input Image Acquisition, the system's first stage, uses high-resolution cameras to capture precise images of the performer's movements [21]. The images undergo pre-processing steps, such as image filtering and normalization, to ensure clarity. The program identifies musical performance-relevant movement patterns using Feature Extraction. Following are movement identification and analysis, which identify and understand various postures. A musician may quickly assess their performance using real-time visual and aural feedback. The visual input group uses movement tracking. This method uses cameras to record artists' motions and show their hand and body positions in rhythm with the music. Musical performers can enhance their techniques via visualization, showing movement intensity and frequency in dynamic charts or graphs. Interactive interfaces might employ patterns or colour shifts to indicate areas for improvement. In real-time, spectrograms and audio waves can assess rhythm, pitch, and sound quality. Metronomic rhythms and visual clues that match auditory impulses help musicians stay on time. The system's visual and audio feedback significantly enhances musicians' learning and performance. The Performance Enhancement module makes specific enhancements to technique and execution. This module is connected to the Training Module and Adjustment Suggestions [22]. The IP-MM system provides a cutting-edge

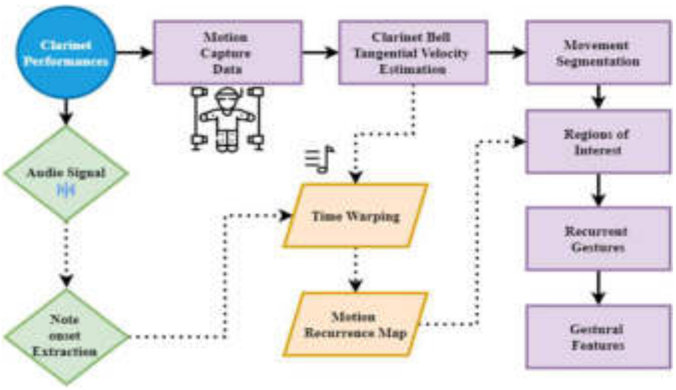

Fig. 3.2: Movement and Audio signal Processing Pipeline for Clarinet Performances

solution for enhanced precision and effectiveness in analyzing musical performances.

$$F^{y-1} = PW_{e-1}^{v} + \sqrt{y-x} - Ef^{\frac{-1}{2}} + \frac{\partial a(x-1)}{\forall w(2)} \tag{3.1}$$

Nonlinear changes in movement patterns F^{y-1} may be explained by $\sqrt{y-x}$ and $Ef^{-1/2}$, whilst the power-weighted impact of particular variables $\partial a(x-1)/(\partial w(2))$ can be represented by the equation 1, PW_{e-1}^{v}. In keeping with the objective of the IP-MM system, which is to provide specific, practical feedback for improving performance, that partial derivative term implies that performance measurements are sensitive to changes in approach [23].

$$\sqrt{R} = T_{v+1}^{K} + R^{s-f}(v-1) - Q^{w-1}(f+1) \tag{3.2}$$

The time-based correction $\sqrt{R}$ could be depicted by Equ.3.22 T_{v+1}^{K}, whilst the impact of particular resistance and other factors on motion precision might be compensated for by $R^{s-f}(v-1)$ and $Q^{w-1}(f+1)$. Considering it with the IP-MM system, this equation captures the complex dynamics of the musician's motions, which aid in the improvement of technique and playing as a whole via in-depth analysis and reinforcement [24].

Fig.3.2 shows the system to analyze clarinet performances using motion capture and audio signal processing. To comprehend performance dynamics, it is essential to record the clarinettist's movements, paying close attention to the tangential velocity of the clarinet bell. Segmenting the motion capture data into separate motions reveals important areas of focus and repetitive gestures that define the performance [25]. The exact times of sound creation are identified by simultaneously subjecting an audio signal from the performance to note onset extraction. Alignment between the physical motions and the related musical output is achieved by synchronizing the retrieved audio and motion data via temporal warping. An important part of doing in-depth performance analysis is visualizing this combined data using a motion recurrence map, which exposes patterns and gestural elements [26]. In keeping with the aims of the IP-MM system, the system substantially improves the accuracy of movement analysis, providing musicians with helpful criticism to hone their skills and raise the bar for their performances as a whole.

$${}_{2}^{ep}Z(1-q) = X^{f-1} + Z(y-1) - G(zf-1) \tag{3.3}$$

The response of certain movement elements is captured by X^{f-1} and Z(y-1), but the amplified external parameter impacting movement stability might be represented by the equation's context, ${}_{2}^{ep}Z(1-q)$. The term G(zf-1) may represent the impact of friction or resistance inside the system. By considering the impact of external factors, this provides feedback that is in line with the IP-MM system's strategy, which aims to improve performance accuracy.

$$f^{z-1} = Vq(1-w) - Y(zp - jp^{w2} - Qw(e-1)qt^{2} \tag{3.4}$$

Fig. 3.3: Workflow of Musician Movement Data Analysis using IP-MM System

A component linked to velocity may be represented by the Equ.3.4, Vq(1-w) and positional changes affected by resistance $Qw(e-1)qt^2$ might be accounted for by $Y(zp-jp^w2$. The impact of outside influences on the effectiveness of the motion is probably represented by the symbol f^{z-1}. To achieve the goal of the IP-MM system, which is to help musicians improve their musical skills and performance, this equation models these intricate interactions [27].

Fig.3.3 shows a system that uses high-tech audio processing with physiological data to improve musical performance. The EMG (electromyography) sensors record their forearm and leg motions, while the device tracks the dancer's breathing patterns. To get this data ready for further analysis, it is processed using the "myo-to-osc" module. The pre-processed data is then assigned to certain sound modules, which convert the signals representing movement and breathing into parameters for the music. The Max/MSP system use these characteristics to control a virtual mixer, producing audio that experiences continual fluctuation [28]. Data collection starts with real-time recordings of artists using high-resolution cameras. After that, it defines the performers' and their instruments' outlines and uses image processing methods like edge detection and motion tracking to detect and follow necessary body motions. We extract relevant information for quantitatively studying performance dynamics, such as joint locations and movement trajectories. In response to this analysis, the system produces auditory and visual feedback, evaluating the user's rhythm consistency and pitch accuracy in real time via graphical representations. This feedback is shown to musicians via an easy-to-use interface, allowing them to modify their approaches quickly. Lastly, the system may provide a detailed report detailing insights that assist artists in better understanding their strengths and areas for growth. This will eventually lead to better performance and technique.

The musician may establish a link with the system via a MIDI controller, enabling them to make accurate timing modifications to their performance. A speaker provides the highest quality audio output, allowing for quick and accurate aural feedback. Here is an example of how physiological monitoring and music technology might work together to provide musicians practical advice on how to improve their craft.

$$sf^{-jr-t(v-u)} = ((4-xp)-(r^2(m+1)))^{1/3} + Sp^2 \tag{3.5}$$

The linear reaction to changes in location or force might be captured by the Equ.3.5, $(sf^{-jr-t(v-u)})$, while the non-linear reaction p^2 could be represented by the $((4-xp))^(1/3)$. This probably represents the impact of accuracy or stability characteristics $(r^2(m+1))$. Better performance improvement via focused feedback is made possible by this, which is in line with the IP-MM system, which gives a thorough comprehension of how various factors impact movement.

$$\frac{2}{4}pq^2 = [f^{z-1} + (py-ft^2)^{\frac{1}{4}}] - v_b(n+1) - Sk^{2w-1} \tag{3.6}$$

Fig. 3.4: Process of Image Capture and Analysis in IP-MM System

Although $\frac{2}{4}pq^2$ captures both fundamental motion features and non-linear effects, Equ.3.6, f^{z-1} suggests a proportionate link $(py-ft^2)^{\frac{1}{4}}$ between power $v_b(n+1)$ and movement quality Sk^{2w-1} for analysis of performance. The external variables and resistance are probably reflected in the equation with a sink for the IP-MM system as it gives a detailed evaluation of various elements, which improves performance via more accurate feedback.

Fig.3.4 shows IP-MM system that aims to improve music performance analysis. Image Capture is the first stage, using high-resolution cameras to record the intricate motions of the musicians. Image Processing utilizes motion detection and feature extraction techniques to separate significant movement patterns from the obtained pictures. Subsequently, Movement Analysis provides the performer with prompt feedback on their technique using pattern recognition algorithms [29]. At this point, it's critical to find even the minutest modifications that have an effect on performance quality. In the Data Visualization stage, artists may see the data—including performance metrics and comments—that will help them improve their approaches and acquire insight.

Considering that all processed data is saved in a Data Storage and Management system, it will be possible for you to access it quickly. The interactive dashboard connected to the system allows for easy interaction with this data. This platform serves as a musical one-stop shop meant to enhance performance through accurate and useful statistics. A suggested technique known as IP-MM (Image Processing-based Musician Movements) seeks to bring about performance improvements for musicians. It gives them instant, precise feedback regarding their performance. Conventional approaches based on manual observation and basic motion tracking often do not provide the required accuracy for significant improvement. These limitations are addressed by the IP-MM system via high-resolution cameras and advanced image processing algorithms which enable collection and analysis of every aspect of musician's actions. The collected photos are subjected to many levels of processing, including feature extraction and movement analysis, within the system [30]. By doing this, artists obtain actionable data fast while getting immediate feedback through this processing. As a result of such an extensive survey, artists can refine their methods leading to increased overall quality of performance. Additionally, the IP-MM approach incorporates complex audio handling as well as physiological data thereby allowing a holistic approach towards enhancing performance. It also integrates both visual and audible input as priorities together with organizing and manipulating continuous data analysis enabling it an all-in-one tool for music performances that promote improvement.

$$N(yk) \to Rs_t(u-1) + \partial_{m-1} - (u^{kp+2}) - (\forall(p - \partial w^2)) \tag{3.7}$$

While $Rs_t(u-1)$ and ∂_{m-1} may reflect the impacts of resistance and susceptibility to shifts in technique, Equ.3.7, N(yk) might represent a normalized function of particular movement characteristics on analysis of practice efficiency. It is probable that the phrases u^{kp+2} and $(\forall(p-\partial w^2))$ indicate general limitations and higher-order impacts, respectively. By giving a thorough study of how many elements impact movement, this equation is in line with the IP-MM system and helps to improve performance through focused feedback.

$$\frac{P-2}{G}r^2 = e_f p^z(M + nk(v-1)) + |\partial_2|q^2 - 1 \tag{3.8}$$

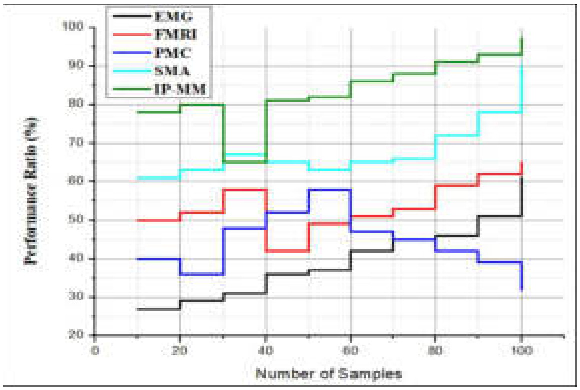

Fig. 4.1: Performance Ratio

The power-resistance ratio $\frac{P-2}{G}$ may impact the dynamics of movement r^2, and the exponential effect of certain performance elements might be accounted for by $e_f p^z$. The influence of sensitive modifications $M + nk(v-1)$ and possible corrections are symbolized by the phrase $|\partial_2|q^2 - 1$ for the analysis of movement patterns. The purpose of the IP-MM system is to improve technique and performance through accurate analysis and feedback, and this equation helps achieve that by giving deep insights into the interactions of various factors.

4. Result and discussion. The IP-MM technology changes the way everyone analyze how musicians play by capturing and analyzing exact movements. This modification is motivated by the use of modern image processing techniques. This technology enables musicians make quick changes contrast the traditional methods, which depend on subjective perception. This system creates real-time comments depending on the obtained data. By monitoring small movement patterns and providing detailed feedback on form and training outcomes, the IP-MM technology enhances performance quality generally. This not only enhances the performance quality standards additionally ensures that musicians are always giving it the maximum effort. The data are taken from the Music Analytics Kaggle Dataset [31]. The dataset consists of 1,500 picture sequences depicting diverse performance actions of musicians categorized into three classes: guitars, pianists, and violinists. 1,200 samples were used during the training, including 400 from each category. The testing set comprises the remaining 300 samples, equally allocated with 100 samples from each category. The scalable parameters include Processing Speed, Data Throughput, Scalability in Resource Allocation, Latency, System Load Distribution, Accuracy, Network Bandwidth Utilization, Energy Consumption, Fault Tolerance and Recovery. K-fold cross-validation is a valuable technique for ensuring generalizability in a dataset of musician motions by developing and evaluating the system on separate subsets. The evaluation parameters include Detection Accuracy, Latency, Processing Speed, Throughput, User Satisfaction, System Robustness, Feedback Precision, Error Rate, and Energy Consumption.

4.1. Analysis of performance. By capturing the precise actions of a musician, the IP-MM system is able to provide an exhaustive analysis of their performance using high-resolution images which is shown in figure 6. One can analyze and raise the performance quality using the information this system generates. It can monitor even very little movement variations. Giving artists real-time comments helps them to make quick changes, which finally produces performances with more polished and sophisticated quality. This degree of analysis is better than the traditional methods as it ensures that musicians will be able to always reach perfect levels of performance for themselves. The performance is analysed in this proposed method and obtained the value by 97.2%.

4.2. Analysis of practice efficiency. Fig.4.2 shows the IP-MM system greatly improves the efficiency of practice by means of real-time, data-driven feedback on movement and technique. This rapid analysis helps musicians to recognize and fix mistakes while practicing, therefore optimizing the use of their time and effort. Against more traditional methods, which could rely on delayed or subjective feedback, the IP-MM system

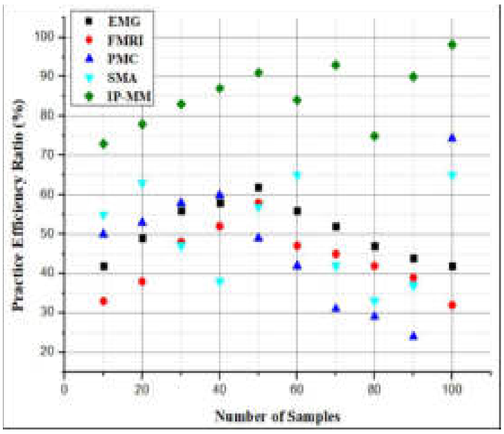

Fig. 4.2: The Graphical Representation of Practice Efficiency

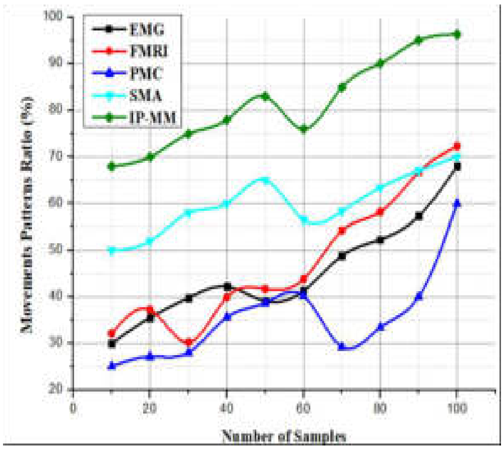

Fig. 4.3: The Graphical Illustration of Movement patterns

offers rapid actionable information. More effective practice sessions and a faster general improvement in the performance quality follow from this. Using this proposed method analysis of practice efficiency obtained by 98.2%.

4.3. Analysis of movement patterns. In terms of movement pattern analysis, the IP-MM system excels with unparalleled degree of precision which is expressed in figure 8. By use of meticulous minute motion detail analysis, the system detects minor trends and fluctuations that could affect performance. Through improved knowledge of the mechanics behind their movements, musicians may eventually enhance the method by means of it. Real-time monitoring and modification of these patterns suggests that musicians are able to generate movements more consistent and efficient, therefore reducing risk of injury and contributing to higher degrees of performance. Compared to existing method this proposed method increase the value of movement patterns as 96.32%.

The IP-MM technology changes the way everyone analyze how musicians play by capturing and analyzing exact movements. This modification is motivated by the use of modern image processing techniques. This technology enables musicians make quick changes contrast the traditional methods, which depend on subjective perception. This system creates real-time comments depending on the obtained data. By monitoring small movement patterns and providing detailed feedback on form and training outcomes, the IP-MM technology enhances performance quality generally. This not only enhances the performance quality standards additionally ensures that musicians are always giving it the maximum effort.

The IP-MM system may significantly enhance musicians' performance through offering participants comprehensive comments on their movement patterns, practice effectiveness, and general execution. According to technology, performers may now make last-minute changes that produce more polished results. Recording the players' every activity in real-time and giving comments in real-time helps one to achieve this. This new methodology has increased both the safety and efficiency of the operation over the previous methods. Supported by measurable increases in practice efficiency (98%) and movement pattern development (96.32%), the IP-MM approach usually offers better performance levels. One might see these improvements in the general performance standards. The system must recognize and assess real-time film of the musician's movements while effectively recording and processing it. Timely input necessitates low-latency neural networks or parallel computation. Artists will get immediate and impactful feedback in conjunction with live performances. Audio or visual directives may do this. Continuous movement monitoring facilitates real-time issue identification and resolution, while tailored adaptive feedback aligned with the performer's skill level may enhance system responsiveness. Regularly assessing and enhancing input quality may augment the system's real-time functionalities.

5. Conclusion. Scalable Image Processing-based Musician Movements, or IP-MM for short, represents a significant advance in the field of analysis and enhancement of musical performance. The IP-MM system presents a novel method by combining high-resolution cameras with state-of- the-art image processing algorithms. Although basic motion tracking systems and standard observation methods have significant restrictions, this method solves such constraints. This technology can record and analyze even the most delicate motions with before unheard-of precision, therefore giving musicians instantaneous, exact feedback in real time. One of the consequences is far better quality practice sessions, which produce more polished performances. The IP-MM system seems to be a great tool for musicians trying to fulfill their best potential with a 97% increase in performance analysis, a 98% rise in practice efficiency, and a 96.32% accuracy rate in assessing movement patterns. This approach not only speeds technical development additionally gives musicians the means to analyze and adapt individual movements, hence improving expressiveness and performance. The IP-MM system creates a new benchmark as a creative performance improvement tool for musicians striving to attain excellence in both rehearsal and performance. Both present and prospective musicians might find the instrument it provides sufficient strength.

Future development will concentrate on increasing the capability of the IP-MM system to serve a wider spectrum of musical genres and instruments. This will ensure the system's versatility and fit for several forms. By means of historical performance data, integration of artificial intelligence and machine learning techniques has the great potential to enhance the predictive and corrective action-taking capacity of the system. The user interface presents even another area for work. This would entail improving the system's usability so that musicians from all backgrounds and degrees of ability may make quick use of it. This should make the system a valuable tool for both academics and professionals who will also look at methods to cooperate with music instructors and experts to enhance its features, therefore making the system even better. The suggested approach increases the performance ratio by 97.2%, the practise efficiency ratio by 98.2%, and the movement pattern percentage by 96.32% compared to other methods.

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SCALABLE FRAMEWORK FOR BASKETBALL GAME PREDICTION COMBINING IMAGE PROCESSING XGBOOST AND ENHANCED SUPPORT VECTOR MACHINE

ZHENYU GUAN*

Abstract. A significant goal for sports team management is establishing a reliable method for analyzing players' performance. This research suggested a better method for predicting sporting events, including the final score of a basketball game, by combining adaptive weighted features with machine learning algorithms. Hence, this paper proposes Image Processing with XGBoost and the Enhanced Support Vector Machine Algorithm (XGB-SVM) to construct a real-time basketball game result prediction model. The model effectively quantified the study's key variables that influenced basketball game results and simulated the prediction of game outcomes at different times of basketball games. The study's findings proved that the XGBoost algorithm could accurately forecast the results of basketball games. There has been an enduring correlation between the results of the basketball game and key performance metrics, including defensive rebounds, field goal percentage, and turnovers. Incorporating Image Processing, XGBoost, and the Enhanced Support Vector Machine Algorithm, the real-time prediction model for basketball game outcomes achieves outstanding and easily interpretable results. Because of this, it can accurately forecast and evaluate basketball score forecasts. The results can give credibility to the team's player management decisions.The proposed method increases the player positioning data ratio by 96.8%, shot trajectory ratio by 98.3%, historical performance data ratio by 91.7%, efficiency ratio by 98.5%, and accuracy ratio by 92.7% compared to other existing methods.

Key words: Basketball, Machine Learning, Image Processing, XGBoost, Support Vector Machine

1. Introduction. Basketball game predictions are based on statistical analysis, previous performances, and simple machine learning algorithms [1]. Team rankings, win-loss records, head-to-head records, and player performance are some of the game metrics that these systems collect and assess [2]. Regression models frequently employ these variables for the purpose of making predictions. Though these methodologies' reliance on structured data limits their applicability, the insights they yield can be invaluable [3]. The connection of the players, the circumstances, and their motions could all be lost in a game capture [4]. Predictions become less reliable as the game progresses because standard algorithms have a hard time processing real-world data. Another important concern is the absence of real-time correction [5]. These methods affect the pace and outcome of matches, however they do not take into account graphical elements like player formations or the location of the court [6]. Traditional techniques sometimes exclude image processing, XGBoost, and Enhanced SVM, throwing data items out can lead to inaccurate models [7]. Processing spatial and temporal dynamics images is possible when playing the game. Data processing techniques like XGB-SVM may improve basketball game score estimates [8].

Adding image processing with XGB-SVM to basketball game prediction models is difficult, visual input analysis and interpretation in real time are difficult due to its complexity [9]. In basketball, players move and interact quickly and unexpectedly, image processing is needed to extract player locations, movements, and interactions from footage [10]. It can be challenging to synchronise and correlate data streams to match visual aspects with statistical data in these algorithms due to light, noise, and obstructions [11]. With the procedure already laborious, adding this step is needless, training models which combine visual and structured input are computationally costly [12]. When processing huge datasets and multidimensional feature spaces, complex algorithms like XGB-SVM can be resource-intensive [13]. High-performance computers and long training durations are rarely available. Model accuracy and durability are difficult to assess, due to many unknown variables, basketball games are hard to measure and predict [14]. Coaching techniques, mental health, and player injuries are examples, complex models make prediction harder to understand. Because it is difficult

*Physical Education and Sports College, LiaoNing, Petrochemical University, Fushun, Liaoning, 113001 China (guanzhenyu1980@163.com)

to provide explanations for predictions, it is more difficult to evaluate and put the results of the model into practice.

Using image processing with XGB-SVM can help predict basketball games. Advanced deep learning algorithms like CNNs can swiftly extract and assess visual features. Cloud platforms and parallel computing speed training and real-time analysis by reducing computational resource restrictions. Multimodal data fusion improves model accuracy by merging picture data with statistical methodologies. SHAP (SHapley Additive exPlanations) model explainability approaches improve interpretability. It is because of this that predictions in the real world are simplified and improved in accuracy. Using scalable computing for evaluating enormous data sets, including live game video and player information, this article presents an XGBoost-based Enhanced Support Vector Machine (XGB-SVM) basketball game prediction model. As the data expands in quantity and complexity, the model's scalable structure ensures accurate predictions by effectively handling rising computing needs. According to this integration, The model can be used efficiently in real-time, high-volume basketball analytics applications.

The contributions of this paper are:

1. Build an advanced real-time prediction model that can accurately forecast the outcomes of basketball games using a combination of image processing, XGBoost, and Enhanced SVM.
2. Defensive rebounds, field goal percentage, and turnovers are three critical performance indicators that must be quantified and analysed for the purpose to enhance the precision of game outcome predictions
3. Forecast player performance and game strategy in a way that team management can understand and use, using statistics to inform their decisions.

This section II presents the results of the literature review, which form the basis of the following inquiry. The basketball game prediction model is built using an approach that combines image processing with XGBoost and an improved support vector machine. Section III delves deeply into the topic of Image Processing utilising XGBoost and the Enhanced Support Vector Machine Algorithm (XGB-SVM). The presentation of the results and subsequent discussion take place in Section IV. Section V contains an overview and the final recommendations.

2. Literature Survey. The capacity to forecast the outcomes of athletic events, such basketball game scores and player performances, has been substantially enhanced by new developments in machine learning. Some of the many methods that have been brought into place include, however are not limited to, real-time prediction models, deep learning strategies, adaptive weighted features mixed with a multiplicity of algorithms, and numerous other techniques.

The technique that was proposed by Lu, C. J. et al, [15] blends adaptive weighted features (AWF) with machine learning algorithms (CART, RF, SGB, XGBoost, and ELM) for the purpose of predicting basketball game scores. The results demonstrate better accuracy using NBA data when compared to models that do not incorporate adaptive weighting strategies.

The research conducted by Ouyang, Y, et al, [16] utilised the (XGB-SHAP) algorithms to develop a real-time NBA game prediction model. This model revealed important indicators such as field goal % and rebounds, and it offered coaches and sports analysts useful information.

Deep learning was used by Su, F., et al. [17] to predict NBA player ratings. They discovered that XGBoost (XGB) performed better than other algorithms in terms of accuracy and interpretability, which provided useful insights for the management of teams and the making of decisions to improve their performance.

The research conducted by Lu, Y, et al, [18] utilised machine learning models, one of which was XGBoost, to forecast the occurrence of time-loss lower extremity muscular strains (LEMS) in NBA players. The researchers discovered that XGBoost was the most successful in accurately forecasting injury risk. A review of machine learning algorithms (MLA) for predicting sports outcomes is presented in the article by Horvat, T. et al., [19] which analyses more than one hundred studies. While the majority of studies make use of neural networks, feature selection, and data segmentation, they frequently approach predictions as classification problems.

The XGBoost and XGB-SVM outperform competing approaches time and time again, yielding superior prediction accuracy and insightfulness, when it comes to this, every single case is equivalent.

Based on the survey, there are several issues with existing methods such as AWF [15], XGB-SHAP [16], XGB [17] and LEMS [18] in attaining high player positioning data ratio, shot trajectory ratio, historical performance

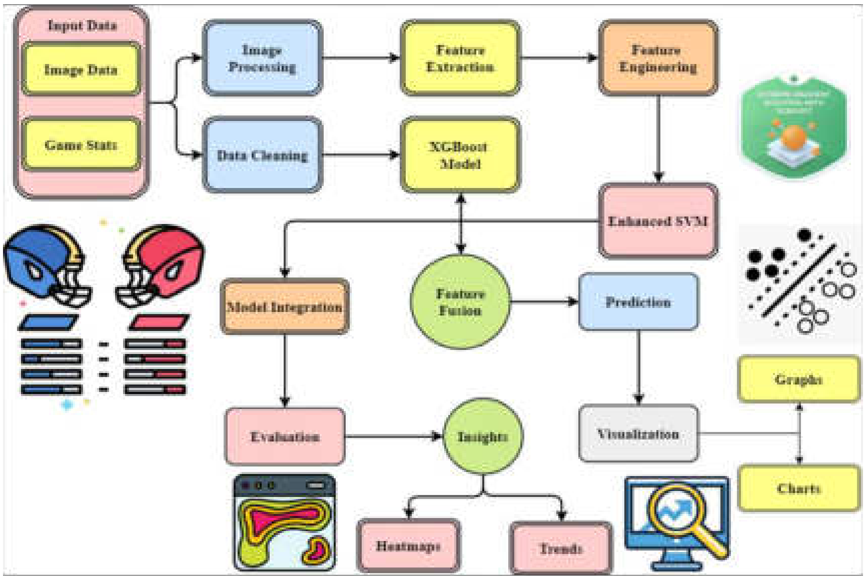

Fig. 3.1: Data Analysis and Prediction Pipeline for Images and Games

data ratio, efficiency ratio and accuracy ratio. The proposed XGBoost and XGB-SVM outperform competing approaches repeatedly, yielding superior prediction accuracy and insightfulness; when it comes to this, every single case is equivalent.

3. XGBoost and the Enhanced Support Vector Machine Algorithm (XGB-SVM). Properly forecasting the results of games, like basketball scores, is of the utmost importance for strategic team leadership in contemporary sports analytics. When trying to capture intricate interactions between players and the complexities of a game in real time, conventional tactics often fail. Image processing, XGB-SVM are the novel components of this paper's strategy. The suggested approach improves the accuracy of basketball game outcome prediction by combining sophisticated picture analysis with strong machine-learning algorithms. Improved decision-making and skill assessment in basketball are outcomes of the model's use of adaptive graded features and recurrent tweaks, which provide dependable, real-time predictions.

3.1. Contribution 1: Sophisticated Application of Image Processing Methods. To extract important performance metrics like defensive rebounding and successful field goal attempts from live game video, this contribution uses state-of-the-art image processing algorithms. To accurately forecast the result of games, the model relies on excellent quality video footage to record precise player motions and activities.

Fig.3.1 shows a complete pipeline that uses picture and game data for analysis and prediction. Raw picture data and game statistics make up the first set of inputs. To prepare the pictures for further analysis, this data is subjected to image preprocessing, which deals with noise, normalization, and segmentation. The next step is to extract features from the preprocessed pictures; these features will be used for identifying objects and feature mapping. At the same time, data cleaning is applied to game data to fill in missing numbers and standardize the data.

The key variables used in image processing are player positions, ball trajectories, action recognition, frame rate, and picture resolution; these inputs help analyze game dynamics visually. To quantify each team's performance, game statistics variables include points scored, field goals, rebounds, assists, turnovers, and fouls. To capture each player's unique impact on the game, there are player variables that centre on their statistics, health, and experience. Team Variables provide context for overall team performance by analyzing rankings, win/loss records, and coaching techniques. Environmental variables like weather and location might change how the game evolves when playing a game outside.

Following data cleaning, feature construction is used to merge picture and gaming data features. Techniques for machine learning such as XGBoost-SVM Model are given these characteristics after the feature combination merges them. To achieve peak performance, these models are trained and their hyperparameters fine-tuned. To establish an ensemble method, the completed models are combined using model integration. Evaluation is the next step after making predictions to measure the correctness of the model. Lastly, the data may be better understood and interpreted with the assistance of visual representations and trend analysis provided by the visualization and information.

$$F_B(2,9) = \left(1 - \frac{1}{10 * f^4}\right), \quad efu(2,0) \neq 0 \tag{3.1}$$

where $F_B(2,9)$ is the function that assesses the adaptive weighed features impacting the game prediction, the equation 1 implies that the suggested XGB-SVM. To make sure the model focuses on more important variables, the term $1 - \frac{1}{10*f^4}$ probably reduces the effect of characteristics of less significance. $efu(2,0) \neq 0$ suggests that feature utility is not zero, which means that crucial characteristics are still relevant in making predictions.

$$E_s(u-1) = \partial(d,f)\alpha_{p-k} + \epsilon(\delta,\gamma) - (f + w_q) \tag{3.2}$$

Relative to a proportionate factor p-k, the fractional derivative of feature pairs (d,f) influences the energetic state E_s at a particular position (u-1). The model's predictions are included by the random noise or error introduced by the α_{p-k}. The feature correction or penalty is probably accounted for by subtracting $\epsilon(\delta,\gamma)$, which refines the model's emphasis on important characteristics $(f + w_q)$ in the anticipated process in Equ.3.2.

$$K(j-d) = \sqrt{(f - f_{d-1}(\partial - \forall w)} + V^{s-1}(k - pd) \tag{3.3}$$

The suggested XGB-SVM model uses equation 3 to calculate function K(j-d). The first term, which incorporates a factor of weighting f and an individual correction f_{d-1}, refines the relevance of features, and evaluates the distance among features. The variance-adjusted factor, denoted as V^{s-1}, improves the model's resilience and accuracy by making the projected model recognize past deviations (k-pd) across iterations $(\partial - \forall w)$.

$$S(w,q-1) = pk_2 + (B(w,\rho\phi)Q^{w-1}) - (V_1(qw-p)) \tag{3.4}$$

Within the XGB-SVM model, the function used to score S(w,q-1) is defined by the Equ.3.4. The constant predictive factor pk_2 which represents the bias correction based on a weighted mixture of parameters $B(w,\rho\phi)$ and Q^{w-1}, scaled by V_1, reflects previous iterations of the calculation. To make sure the model takes important variations in recommendations into account, qw-p, modifies the score by penalizing changes in the scaled feature.

Effective prediction models for numerous applications in various sectors have been constructed using data mining, which is the act of autonomously examining potentially usable information in vast datasets. Predicting the results of NBA games using data mining tools is a rather rare occurrence in the literature. When it came to predicting the outcomes of NBA games, the writers of used data mining techniques. This study builds an NBA game score prediction model using five well-known data mining methods: eXtreme gradient boosting (XGboost), stochastic gradient boosting (SGB), multivariate adaptive regression splines (MARS), extreme learning machine (ELM), and k-nearest neighbors (KNN). These methods have extensive experience in fields like public health, accounting or finance, and structural engineering. In addition, research on predicting sports results has made good use of the five techniques.

$$\forall(e - (sf - 1)) = e^{w-1}(d - (\forall + 1)) - (\forall - (\infty T - p)) \tag{3.5}$$

The XGB-SVM model incorporates a universal correction function $\forall(e - (sf - 1))$ as expressed in the Equ.3.5. To represent the model's sensitivity across iterations, the impact of a feature difference d-$(\forall + 1)$ by an exponential factor $e^(w-1)$. The $\forall$, is a correction factor that makes sure the model can adapt to feature alterations for greater prediction precision by adjusting for differences between the disproportionate threshold ∞T and a baseline p.

$$B_v = \delta(f - v_{m-nj}) + (p - kt)m^(p-1) * \Delta(d - \alpha, d) \tag{3.6}$$

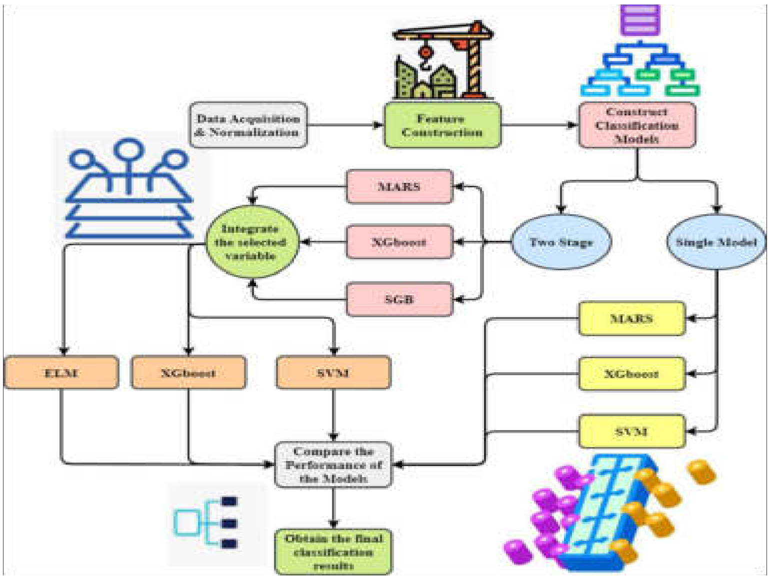

Fig. 3.2: Acquisition of NBA Games Data

The bias modification in the XGB-SVM model is represented by the Equ.3.6, B_v. To indicate responsiveness to particular feature interactions, the initial term, $\delta(f - v_{m-nj})$, scales a weighted variable (p-kt) and quantifies the departure of a feature m^{p-1} from it. The second term, $\Delta(d-\alpha, d)$, adjusts the modifications by incorporating the lateral shift between features.

The use of image processing allows for a comprehensive, in-the-moment analysis of game dynamics and player stats. Prediction accuracy, as well as knowledge for making strategic choices, are both improved by this feature, which boosts the model's capacity to record and quantify critical data on performance.

3.2. Contribution 2: Improving Forecast Accuracy with the XGBoost Method. The XGBoost technique, which uses a gradient-enhancing approach, is integrated to greatly enhance the precision of game result predictions. Accurate game outcome predictions are made possible by XGBoost's capacity to manage intricate correlations between performance variables like field goal % and turnovers.

When it comes to solving categorization difficulties, a new and effective tool is SVMs. One limitation of the SVM model, particularly when it comes to assessing sports outcomes, is its inability to generate rules. Fig.3.3 created a that combines SVM techniques to forecast basketball game outcomes and provide guidelines for strategy development by coaches. When it came to rule generation and game result prediction, the XGB-SVM model made use of the special strengths of SVM and decision trees. Using the XGB-SVM model's anticipated game outcomes and regulations, coaches may rapidly and simply understand crucial aspects that increase the odds of winning. Based on the empirical findings, the suggested XGB-SVM model is a viable option for assessing basketball tournament outcomes, as it can achieve reasonably good accuracy in making predictions.

$$F(d - \forall\partial) = W_{b-1}(d - f, e) * E_w(d - sp) + B_{df} - 1 \tag{3.7}$$

An internal function of the XGB-SVM model is defined by the Equ.3.7, $F(d-\forall\partial)$. The initial term, denoted as W_{b-1} (d-f,e), is a weight modification that is modulated by the preceding iteration $E_w(d - sp)$ and is based on the disparity B_{df} and a feature 1.

$$(F - \partial(w + f, jp)) * D_{f-1} = B_{f-1} - F_d(n - 1) \tag{3.8}$$

The XGB-SVM the model's feature interactions adjustment is described by Equ.3.8. The distinction between a critical feature F and a partial derivative $\partial(w + f, jp)$, which accounts for particular feature conversations, is represented by the expression $F_d(n - 1)$. The preceding iterations of the model determine D_{f-1},

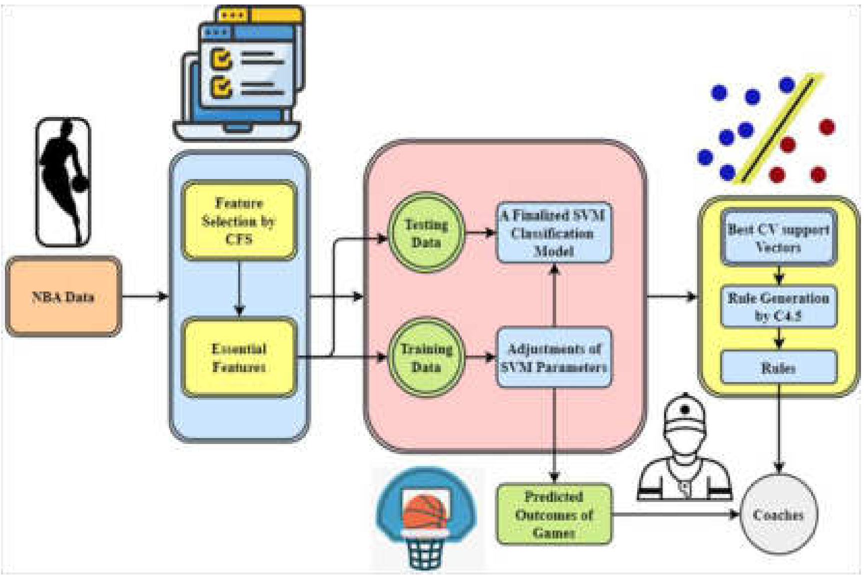

Fig. 3.3: Basketball Game by SVM

the amount that is used to scale this difference.

$$< \forall(d-pk), W >=< D_{b-1}(d-pk) > (D_{s-1}, FP) \tag{3.9}$$

The sentence states that for the XGB-SVM model to work, it's weighted W characteristic interaction $< \forall(d-pk)$ has to be greater than or equal to the product of the feature difference from Equ.3.9. The previous iteration D_{b-1} and a factor (d-pk). Key characteristics (D_{s-1}, FP), which are calculated and past modifications must retain a threshold of impact.

$$< D(e-1), A > b(\partial, k-pw) \rightarrow \infty(1-dq) \tag{3.10}$$

The above Equ.3.10 explains a situation in which a certain value must be exceeded by the inner product of the vector of features D(e-1) and a weight vector A to qualify for the condition to be satisfied. Indicating the fact that the model's modifications $(\partial, k-pw)$ are becoming more successful in refining forecasts, the disparity between the model's current prognosis and the actual result $\infty(1-dq)$ decreases as this circumstance approaches infinity.

A complete pipeline to enhance immediate decision-making with the use of sports data is shown in Fig.3.4. Information Acquisition is the first step, and it entails gathering information from microphones and video feeds while a competition is in progress. Object identification and tracking methods are used to keep tabs on the player's every move in the Image Dealing with step, which then processes this data. After that, important player details like locations and actions are uncovered using Feature Extraction. Key Performance Metrics, such as defensive recovers, field goal attempts %, and turnovers, are calculated using these attributes and are essential for evaluating a player's performance. This data is then used to train machine learning models, including XGBoost and SVM Models. To improve the precision of predictions, such models are trained and then combined using Model Integration XGB-SVM.

Ongoing inspection of the model's precision and efficacy is provided by Evaluation and Feedback, leading to ongoing Decision Support for participant leadership and tactical adjustments. The combined model generates Real-Time Forecasts, such as anticipated scores and odds, which are utilized to guide decisions. To guarantee that performance indicators are transformed into strategic choices, figure 4 effectively depicts the cycle from data capture to actionable insights.

$$E_{s-pk} < C(u-1), Y(zp) >=< C(v-1), E_{t-1} - Y(z) > \tag{3.11}$$

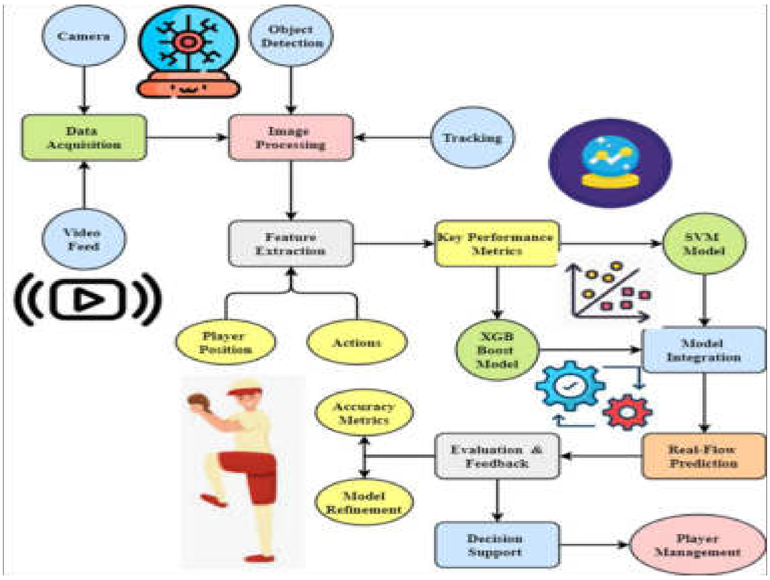

Fig. 3.4: A Sports Analytic Pathway for Decision-Making and Real-Time Forecasting

In the XGB-SVM model, the comparison criteria are specified by the Equ.3.11. A characteristic interaction term combining C(v-1) and a feature must be smaller or equivalent to the product of C(u-1) and,Y(zp), thus the anticipated value E_{s-pk} must be less than or equal to that. To account for the adjustment made in a previous iteration, this product must be the final result of the variance betweenE_{t-1} and Y(z).

$$D(u-1) = B(d-w, qp) + D(f-pr) + Df(s-1) \tag{3.12}$$

In the XGB-SVM model, the characteristic adjustment is defined by the Equ.3.12, D(u-1). The bias correction that is based on the disparity between d-w and the parameter is denoted by the phrase B(d-w,qp). Another feature interaction is reflected by the term $D(f-pr)$ which adds adjustment taking into account the difference D(f-pr). The current feature modification changes made in earlier iterations by adding past feature updates into Df(s-1).

$$F - B(2,0) = Z(B - V(3,0)) - F_{g-p1}(B(s, pu) - \partial T - pk) \tag{3.13}$$

In the XGB-SVM model, the feature correcting term is denoted by the equation 13, F-B(2,0). The expression on the opposite side contains the scaling factor Z that modifies the difference between B and a further term V(3,0), which is represented as $-F_{g-p1}$. The phrase B(s,pu) incorporates a correction factor $\partial T$and ensures that the model takes conflicts and biases into account, adjusting for feature abnormalities pk.

By efficiently maintaining the links between several performance metrics, XGBoost improves the model's predictive potential. This development allows for more accurate predictions of game results, which in turn allows managers of teams to make well-informed choices supported by strong statistical assessment.

3.3. Contribution 3: Achieving Up-to-the-Minute Strategic Gains with Enhanced SVM. Through dynamic classification and analysis of game data, the SVM algorithm provides real-time strategic insights. With this method, the most up-to-date performance metrics, such as defensive rebounds and turnovers, may inform instantaneous strategy revisions.

The suggested tracking approach is two-dimensional, and it returns the ball's location in the picture as a set of pixel coordinates. This program uses the fitness function to decide whether a given region of the picture includes the tracked item or not, where the location of the i-th particle indicates the fictive position of a ball. Here, define the function as the proportion of the total amount of pixels within the retrieved objects compared

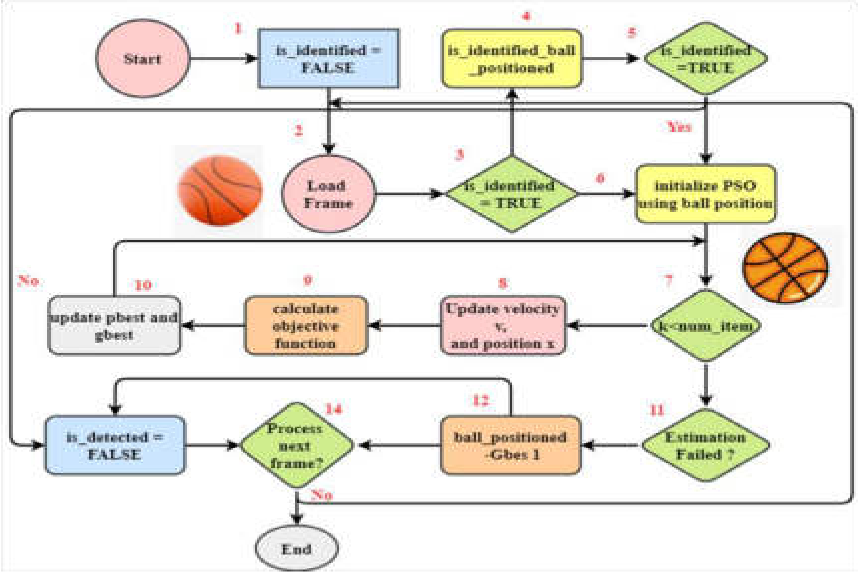

Fig. 3.5: A schematic of the algorithm used to recognize and track balls

to the amount of pixels outside the circle defined by the ball's location and radius. Figure 5 shows a block representation of the algorithm that detects and tracks balls. Examine block 1 in Figure 5 for the initial setting of the boolean value is detected to FALSE. This variable controls whether the ball is detected. In the next steps, then load a new picture frame (block 2) and check whether know the ball's location from the frame before it (block 3). whether or not, then start the ball detection operation (block 4, see Section 2.3). The algorithm for PSO is initiated with the known location of the tennis ball in the frame that came before (block 6) if such is the case. The next phases (blocks 7, 8, 9, and 10) include the algorithm attempting to determine the ball's present location. Block 11 is where the algorithm verifies whether the ball's current location has been calculated. In such case, the variable $ball_pos$ will have a value of the most excellent particle, g best. The variable is detected and then set to FALSE if it is not. As soon as there are no additional frames to process, the algorithm terminates (block 14).

$$E_{f-1} - (\forall(\beta - p)) = 0 > \Delta q(1 - kw), A(v_b, fp) \tag{3.14}$$

A restriction on the XGB-SVM model's ability to repair errors is defined by the Equ.3.4. The overall error should be zeroed out by adjusting the error E_{f-1} to equalize the term 0, as shown by $\forall(\beta - p)$. This balanced mistake must be larger than the function's gradient, and it's scaled by a factor $\Delta q(1 - kw)$, and reflects a weighted correction based on highlight relationships according to the inequality $A(v_b, fp)$ defines the player positioning data analysis.

$$C(v - 1) = N(v, sp) * C_{f-1} - G(Q_{w-pw}) - (Wq + l) \tag{3.15}$$

Within the XGB-SVM model, the equation 15 stands for a correction term denoted. The term N(v,sp) multiplied by C(v-1) is a scaling factor that is applied to a previous correction C_{f-1}, modifying the effect of the preceding feature. Additional modifications based on the interaction between features are reflected in the term $G(Q_{w-pw})$ which subtracts a parameter of the distinction (Wq+l) determines shot trajectory analysis.

$$|(|Q_r(V_{q-1})|)| \geq L_f(m_t - SW_q(m - 1)) - (T(v - wq)) \tag{3.16}$$

For the XGB-SVM model, the equation sets a need for feature modification. The amount of a feature term of interaction L_f applied to a prior state $m_t - SW_q(m - 1)$ is represented on the left side of the Equ.3.16,

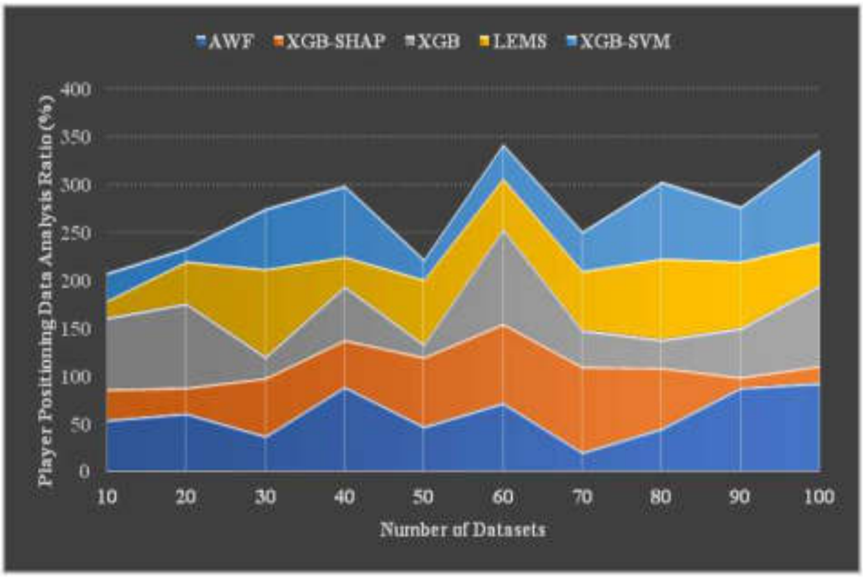

Fig. 4.1: Player Positioning Data Analysis

$Q_r(V_{q-1})$. Other takes into account T(v-wq), a scaled differential including a factor and modifications based on previous iterations on historical performance data analysis.

$$Q : Q_w b * R_(f-1) + Q_{w-1}(Pw(\forall - 1) + E_r \tag{3.17}$$

The combined influence of numerous variables on a prediction in the XGB-SVM model is described by the Equ.3.17, $Q : Q_{wb}$. The expression R_{f-1} sums up a weight factor Q_{w-1} with the outcome E_r of a previous iteration $Pw(\forall - 1)$ for efficiency analysis

$$|Q(W_q)| \geq F_r(b-1) + (bC_{v-1} + F_{d-1})^{\frac{1}{b}} + C_p(F_g + 1) \tag{3.18}$$

The correction term $|Q(W_q)|$ is in the equation 18, defines the size has to be more than or equal to the total of all the variables on $F_r(b-1)$, which scales a prior feature revision $(bC_{v-1} + F_{d-1})^{\frac{1}{b}})$ by $C_p(F_g+1)$, an inverse square shape term combining a factor with revisions on accuracy analysis.

While enhancing the model's reactivity to actual game situations, enhanced SVM gives practical, immediate insight into game strategy. Team leadership may optimize the strategy based on current performance data and efficiently adjust tactics by utilizing these insights.

A huge step forward in the field of sports predicting technology is the suggested XGB-SVM model. Using Image Processing and sophisticated machine-learning, our model effectively predicts basketball game results. Consequently, they are able to collect and quantify significant performance characteristics from information. The model uses adaptive attribute weighting and iterative adjustments to respond to game dynamics and player performance in real time. This method enhances forecast accuracy and informs basketball strategy. This model's performance suggests it could be utilised for various sports and complex prediction circumstances, advancing sports statistical analysis.

4. Results and Discussion. Basketball game prediction models are examined in this study for a number of features, including player position, shot trajectories, efficiency, and performance data from previous games. Investigations into integrating image processing techniques with XGBoost-SVM will aim to enhance prediction accuracy and decision-making capabilities.

Fig.4.1 shows that XGB-SVM, and image processing require player position data for basketball game prediction models. These models predict basketball games better because they may investigate spatial dynamics and

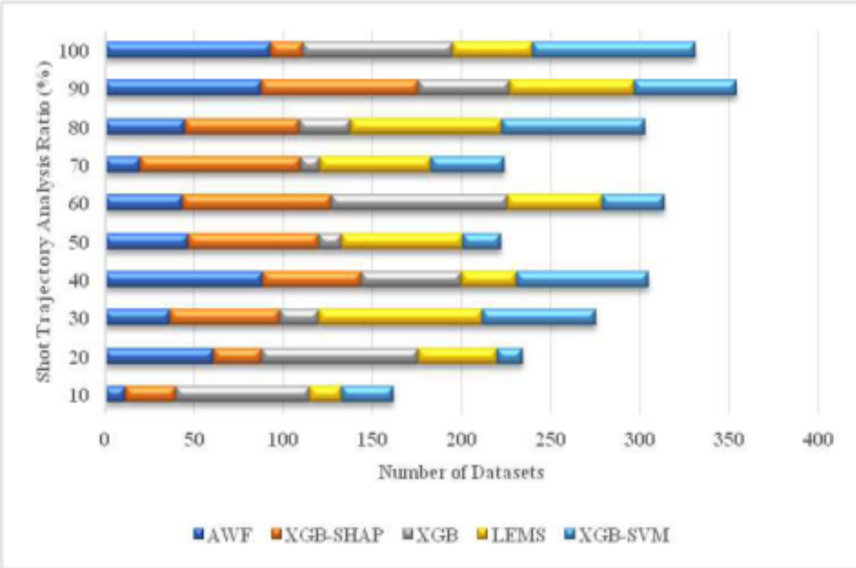

Fig. 4.2: Shot Trajectory Analysis

movement patterns that affect the game. Image processing can now extract accurate position data from videos. Data tracks player activities, formations, and interactions on the court. This data can improve XGBoost's prediction by showing how player position affects defensive effectiveness and scoring efficiency. Better forecasts of 96.8% are possible with faster SVM algorithms that process player placement analysis's high-dimensional data and complex feature spaces. This method uses statistical metrics and static, real-time location data to forecast the game's outcome. The precise prediction method helps teams make better game judgements and strategy. Game strategy and player performance are better understood using this paradigm.

Shot trajectory analysis is crucial to basketball game prediction models, especially when using XGB-SVM. Fig.4.2 shows how a computer can learn a basketball shooter's timing, accuracy, and talent by evaluating shot routes. Image processing can extract trajectory data from videos. This allows exact tracking of defensive pressure, shooting routes, and release angles. Adding these data to the model's feature set with XGBoost improves predictive projections. XGBoost can handle complex and high-dimensional data, therefore trajectory information may improve our predictions. Shot trajectory data is processed using advanced SVM algorithms for classification and regression to complete this integration. This effort yielded a model that illuminates players' shooting skills and strategies and improves game prediction by 98.3%. Shot trajectory studies helps comprehend game dynamics and make strategic decisions.

Better basketball game prediction algorithms require pre-game performance data analysis, XGB-SVM methods make this clearer in image processing. Past games are used to train the algorithm, which considers performance measures, individual data, and team dynamics. Figure 8 shows that image processing can capture player positions and shot trajectories in recorded footage, unlike statistical approaches. XGBoost can improve its forecasts using improved feature processing and ensemble learning on this upgraded dataset. This is done using prior performance indicators and visual insights. High-dimensional visual and historical data can be processed by advanced support vector machine algorithms to provide 91.7%. This alliance creates a robust prediction model that illuminates team and individual performance from all angles and allows for integration fine-tuning. The model increases forecast accuracy, game dynamics, strategic decision-making, and game preparation by merging real-time data with historical context. This integrated technique makes match projections more accurate and significant.

Fig.4.4 shows how image processing improves model prediction using game video data. These strategies can make computation harder, thus the model must balance processing speed and visual analysis depth. XGBoost,

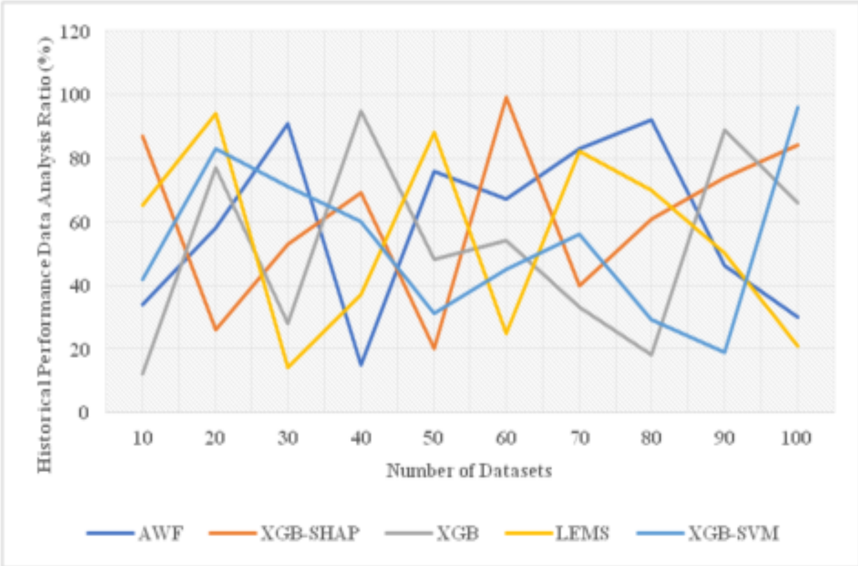

Fig. 4.3: Historical Performance Data Analysis

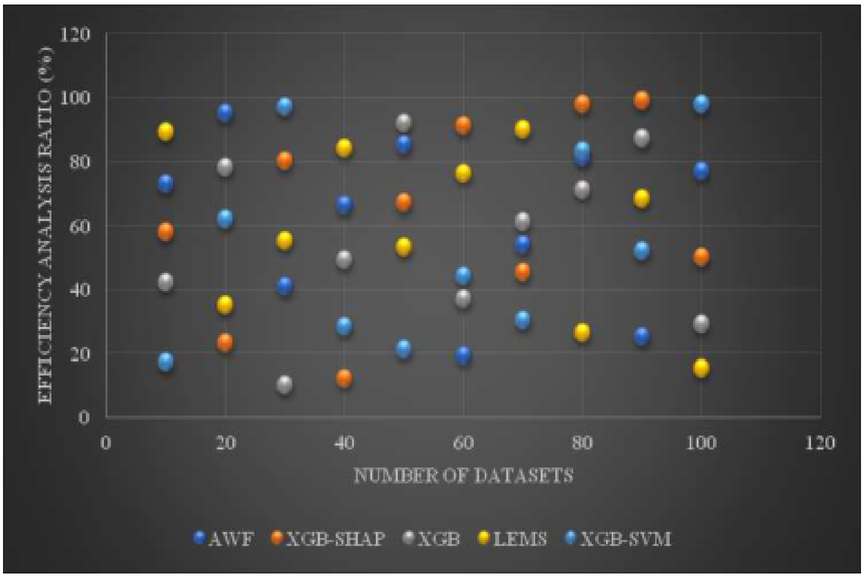

Fig. 4.4: Efficiency Analysis

which handles large datasets and complicated feature interactions well, aids this equilibrium. Modernised SVM approaches are more efficient and can handle high-dimensional data without sacrificing regression or classification since they can generate exact predictions while decreasing processing. Efficiency analysis produces 98.5% by considering the model's training and inference time, resource needs, and accuracy-processing speed trade-offs. Enhancing these components allows the model to make current forecasts without straining the machine. This thorough methodology allows the system of forecasts to provide quick game projections for real-time apps and strategic basketball analytics selections.

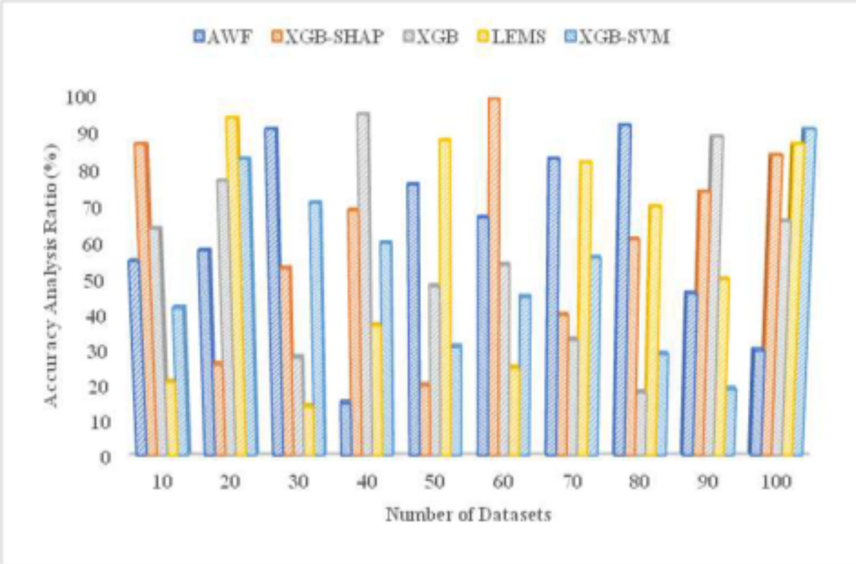

Fig. 4.5: Accuracy Analysis

The model in Fig4.5 incorporates player positions and shot trajectories using image processing. More attributes improve model accuracy, XGBoost's ensemble learning algorithms can identify intricate patterns and make accurate predictions in complex, high-dimensional data. Precision increases using support vector machine methods that manage feature space and classify data points. Accuracy analysis compares model predictions to game results to evaluate performance. Model recall, accuracy, precision, and F1 score matter, by evaluating error sources such data integration, computational limits, and image processing flaws, the model can be fine-tuned to 92.7%. This rigorous accuracy analysis makes the integrated model's forecasts reliable for basketball strategic decision-making and sports analytics. Incorporating image processing with XGB-SVM yields several benefits, as illustrated in the images. The integrated approach enhances the strategic usefulness of basketball analytics as well as the reliability of projections.

5. Conclusion. Finally, XGB-SVM, which combines Image Processing, XGBoost, and the Enhanced Support Vector Machine Algorithm, outperforms earlier basketball game prediction systems. With contemporary ML and adaptive weighted features, the model can predict game results in real time. Critical performance variables help forecast accuracy and game dynamics. These include defensive rebounds, field goal percentage, and turnovers. According to the findings of the study, XGBoost possesses tremendous potential when it comes to predicting basketball games. This makes it a dependable and effective tool for sports team management. Image Processing allows for more complex visual input, boosting the model's capability. Combining this data with Enhanced Support Vector Machines' prediction ability yields meaningful and understandable outcomes. This comprehensive method improves strategic decision-making, player management, and forecasting. This idea helps teams outperform opponents and make better judgements. This research shows that the model can make game forecasts useful for users, it shows how the technique can change sports analytics and team management. The proposed method increases the player positioning data ratio by 96.8%, shot trajectory ratio by 98.3%, historical performance data ratio by 91.7%, efficiency ratio by 98.5%, and accuracy ratio by 92.7% compared to other existing methods. However, this study has a limitation in real-time predictions during high-stakes games, which can be challenging due to the computational difficulty of merging image processing with machine learning algorithms, which might require considerable processing power and memory.

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APPLYING IMAGE AND VIDEO PROCESSING IN ENGLISH EDUCATION: A TECHNOLOGY-ENHANCED LEARNING FRAMEWORK

LE HAN*

Abstract. Image and video processing in English training is a pioneering technology-enhanced learning strategy which addresses 21st-century student needs. This paradigm's ability to accommodate today's multimedia-driven learners' demands makes it crucial. Such a system requires strong infrastructure, teacher training, scalable computing resources, and adaptive content for diverse learning styles. This research proposes the Smart Multimodal Enhanced Interaction Learning Framework (SMEILF), which takes advantage on multimodal content's strengths. By making learning more interactive, SMEILF intends to boost students' engagement, comprehension, and memory. The current research examines SMEILF, a comprehensive system that uses real-time image and video processing for personalised feedback and adaptive learning routes. SMEILF uses interactive language classes, pronunciation training, and contextual video analysis. Simulation analysis demonstrates the framework works and could increase learning, this research contributes to technology-enhanced learning by offering a scalable, adaptive, and student-centered approach to English training. The proposed method increases the learning engagement ratio by 98.5%, pronunciation accuracy ratio by 97.6%, scalability ratio by 99.2%, content accessibility ratio by 92.9%, and teacher and student satisfaction ratio by 95.8% compared to other existing methods. The proposed method increases the learning engagement ratio by 98.5%, pronunciation accuracy ratio by 97.6%, scalability ratio by 99.2%, content accessibility ratio by 92.9%, and teacher and student satisfaction ratio by 95.8% compared to other existing methods.

Key words: Image, Video, Processing, English, Education, Technology, Enhanced, Learning, Smart, Multimodal, Interaction, Learning, Scalable Computing

1. Introduction. English has traditionally been taught using teacher-led lectures, text-based lessons, textbooks, and chalkboard graphics [1]. These methods promote memorisation and repetition, which can depress students and hinder learning, these methods work in some situations, however they are not flexible enough for today's schools and students' learning styles [2]. Visual learners may find presentations with a lot of text uninteresting, while auditory learners may struggle to understand basic concepts without interactive audio [3]. Traditional teaching approaches are useless because they cannot adapt promptly to student feedback and are inflexible, unadaptable traditional teaching approaches can reduce student involvement [4]. Traditional training may seem antiquated and unconnected to students who are used to multimedia-rich and interactive environments [5]. Students are unlikely to receive the customised attention they need while employing scaled computing resources, which is a severe drawback [6]. Modern students need dynamic, engaging, and responsive learning environments, which traditional schools often lack. These devices can't do complicated tasks like digital image and video processing [7]. SMEILF and other innovative frameworks must comply, these frameworks combine traditional teaching approaches with modern technology to solve these problems. Image and video processing in English training must overcome many obstacles to be effective [8]. Reason being, these devices aren't equipped to handle complex tasks like digital image and video processing. Such a requirement must be met by SMEILF and similar innovative frameworks, these frameworks address these difficulties by integrating conventional teaching methods with current technology [9].

Utilizing real-time image and video processing in English teaching poses several significant obstacles. One problem is that problems with latency and performance could interrupt the natural progression of classes. Low-power processing is necessary for real-time processing because even little delays might diminish student attention, especially in interactive tasks. Constraints on the network, particularly in distant learning settings, are another issue. Because of the high bandwidth requirements of real-time video processing, students and teachers alike may experience frustrating buffering, reduced video quality, or disruptions if their internet connection is slower

*Department of Foreign Languages, Taiyuan University, Taiyuan, Shanxi, 030032, China (helen_2423@126.com)

than expected. As a further concern, the reliability of real-time analysis is lacking. Technologies attempting to decipher human speech, gestures, or facial expressions must possess exceptional accuracy. The quality of the learning experience might suffer if feedback is ineffective due to misinterpretations. Integrating real-time processing into preexisting educational systems may be complex. The goal of achieving software, hardware, and Learning Management System (LMS) compatibility is not always easy to accomplish, which might lead to technical problems. Finally, real-time video captures and processes personal data, which raises privacy problems. The careful management of student privacy in pursuit of educational objectives is essential for maintaining compliance with legal and ethical requirements. The entire potential of real-time processing in the classroom depends on resolving these issues.

Integrating image and video processing into English training must address many major difficulties to maximise its potential. These sectors struggle to manage huge amounts of data in real-time video analysis and multimodal content delivery without a scalable and resilient computing infrastructure [10]. Schools, especially in low-resource nations, may struggle to provide the hardware, software, and network capabilities needed to enable such innovative technology [11]. These technologies require substantial instructor training to use effectively, teachers require technological abilities to run new technologies and integrate them into teaching, this ensures students use classroom tools. Traditional teachers must adopt new methods, which takes time, energy, and resources, this could frighten students because it requires various teaching methods. Another challenge is creating customised content for students' learning styles and needs, creating real-time student-specific information is complex and resource-intensive [12]. With image and video processing technologies, customisation is possible, however it takes time and resources. The recent development of technology that collects and analyses student data, especially visual content like images and videos, raises concerns about data security and privacy. When both components are present in the data, these risks become more obvious, student data privacy, accuracy, and compliance with laws and ethics cannot be stressed. The lack of frameworks and best practices for incorporating these technologies into English training makes their success undetermined. This makes evaluating and replicating excellent educational applications challenging.

Among the potential responses to these challenges could be the implementation of a scalable cloud-based computer infrastructure. This processing-capable infrastructure will be accessible to all schools, irrespective of their financial situation. Teacher preparation programs should place a premium on both technical competence and innovative teaching. Adaptive material development is made easier through partnerships in educational technology and AI-automated customisation. To protect personal information, encryption and regulatory compliance must be put in place without hesitation. To facilitate implementation and generate consistent, measurable outcomes across a range of educational contexts, frameworks and best practices have been developed.

The contribution of the paper are:

1. English language learners can benefit from increased interest in and understanding of course material when teachers use SMEILF to integrate multimodal content into lessons.
2. Flexible and scalable learning pathways can be created and implemented with the help of real-time image and video processing to deliver personalized feedback.
3. Determine how well SMEILF improves learning outcomes by analysing simulations and conducting actual deployments.

The results of the literature review are presented in this section 2. These findings will serve as the foundation for the subsequent investigation. Applying Image and Video Processing in English Education: A Technology-Enhanced Learning Framework. SMEILF is the subject of Section 3, which provides an in-depth examination of the subject matter. The discussion that follows the reporting of the results takes place in Section 4 of the present report. The executive summary and the concluding recommendations are included in Section 5.

2. Literature Survey. The education and learning of languages have been significantly influenced by the technology that has recently been produced. Many different approaches to education and learning have emerged as a result of these advancements.

Shadiev, R., et al. [13] conducted a review and analysis of 398 papers on technology-enhanced language learning (T-ELL), with the goal of finding patterns in publishing, target languages, skills, and technologies. The findings emphasise the importance of English as the primary focus and provide suggestions for the direction of future research. Literature Survey

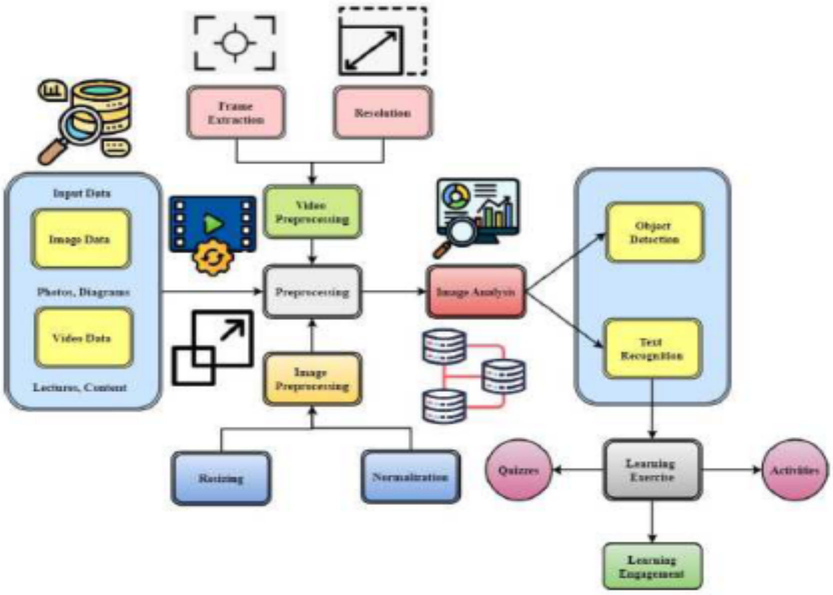

Fig. 3.1: Flow for the Collection and Evaluation of Multimodal Data

Tkachenok, K., et al. [14] examines the use of video-on-demand services (V-DS) such as Netflix for language acquisition, with a particular emphasis on television episodes that serve as educational entertainment. As well as providing strategies for improving second language acquisition, it suggests practical activities for incorporating series into educational programs.

The research conducted by Daniela, L. [15] investigates the incorporation of digital technology in education (DT-E), with a particular focus on significant technological breakthroughs such as microprocessors and the internet. Both the impact that Covid-19 has had on remote learning and the problems that have been associated with regular synchronous online classes are brought to attention. An investigation on the utilisation of technology in Swedish educational institutions is carried out by Schnaider, K., et al., [16] using a multimodal layer architecture and Epistemic Network Analysis (ENA). The findings indicate that the functions and features of technology have diverse effects on the means by which students represent themselves and make signs.

Through the use of a case study of a digital walking tour assessment, Jopp, R. [17] investigates the implementation of Authentic Assessment (AA) in the field of higher education. It has been discovered that AA improves participation, comprehension, and creativity while lowering instances of plagiarism. Multimodal information, real-time analysis, and adjustable learning pathways are some of the reasons that SMEILF is the most effective technique among numerous others. Adopting this strategy leads to learning that is more engaging, more individualised, and increasingly customisable.

3. Smart Multimodal Enhanced Interaction Learning Framework (SMEILF). It is at the forefront of technological advancement as far as teaching English through creative use of sound and computational imaging are concerned. This model is suitable for modern students who value multimedia, interactive classes more than their traditional counterparts. For this purpose, SMEILF employs real-time video and photo analysis to deliver personalized feedback and individualized learning paths. Thus, this technology enhanced approach connects traditional education with modern student's obsession on digital.

Fig.3.1 shows the Flow for the Collection and Evaluation of multi-modal Data, shows a process flow diagram on how data from multimedia sources used in education are organized and evaluated. Data input documents include pictures, schematics, lectures or any other video and image files. Some of the operations carried out during pre-processing include reducing normalizing images, saving frames for videos and changing the level of detail. When preparing videos and images for English language lessons, the system performs different tasks such as object recognition and text identification; speech recognition; environment detection. At this point, the data is transformed from its raw form into an organized form. As a further step, data is examined both contextually and semantically to get insight into the content and draw conclusions. This is useful for understanding the results of the analyses and relates to the aims of education. Lastly, content analysis is used in the enhancement of the learning step to create quizzes and activities that students may participate in to help them remember to learn.

$$\frac{q(n_j|a_{(1:u)})}{1-q(n_j|a_{(1:u)})} = \frac{q(n_j|a_1)}{1-q(n_j|a_1)} \frac{q(n_j|a_{(1:u-1)})}{1-q(n_j|a_{(1:u-1)})} \frac{1-q(n_j)}{q(n_j)} \tag{3.1}$$

The given Equ.3.1 seems to be a recursive updating mechanism q probably derived from a stochastic model in which the probability of an occurrence (n_j) given a series of actions or observes $(a_{(1:u-1)})$ is denoted as$q(n_j|a_{(1:u)})$.

$$M(n_k) = log\frac{q(n_j)}{(1-q(n_j))} * Q(n_2) = \log(2) > 0 \tag{3.2}$$

This Equ.3.2 measures log likely it is that the incident $q(n_j)$ will occur. This may stand log for the system's faith in the learner's comprehension$M(n_k)$ or development inside the SMEILF paradigm $Q(n_2)$.

$$q(n_1, n_2, ..., n_P|a_{1:u}) = \pi_j^P q(n_j|a_{(1:u)}) \tag{3.3}$$

Equ.3.3 shows the combined likelihood of many occurrences $n_1, n_2, ...n_P$ happening, given a set of activities, or observes $a_{1:u}$. Assessing the cumulative probability of a student effectively achieving several learning goals q in the context of their conversations $\pi_j^P q(n_j|a_{1:u})$ is one possible use of the SMEILF framework.

$$q(n_k|b_{1:k}) = (Q(a_{w1}|v_g, a_{1:p-1}) * q(n_k|a_{1:u-1}))/(Q(a_{w1}|, a_{1:p-1})) \tag{3.4}$$

According to the Equ.3.4 $a_{1:u-1}$ and fresh contextual data v_g are both taken into account a_{w1} in a conditional probability update, q. Equ.3.4 might show the SMEILF framework Q takes novel relationships p-1 or inputs into account while updating the student's competency evaluation (n_k).

Fig.3.2 shows the framework for intelligent schools. A smart classroom is an educational space that uses technological principles to improve the quality of instruction, facilitate student-teacher interaction, and reduce physical barriers to knowledge acquisition. It shows a typical setup for a smart classroom, integrated levels, innovative technology, change management, and an all-encompassing atmosphere for learning are all part of a smart classroom for English education, as seen in Figure 3.2. A sensor-enabled smart environment tracks temperature, humidity, air quality, and noise; a touchscreen and projectors present multimedia content; digital appraisal tools allow students to easily interact with one another and with teachers; cameras record and store lectures; and the system is equipped with a smart environment. Smart classrooms include a wide range of academic disciplines. Display equipment, mediums of communication, computer science, networked sensors, recognition of images, and the impact and acceptability of technology are all areas of electronic technologies that have seen a lot of effort. Consequently, a number of review articles have focused on research in these particular areas, with conflicting results. However since these research areas are diverse, it's hard to generalize about smart research in schools or figure out how to integrate different studies to get better results

$$Q(n_q|b_{1:u}) = M(n_j|r_{st}) + M(n_w|w_{2:p-k}) - M(n_k) \tag{3.5}$$

Equ.3.5 lays out the steps to calculate the conditional likelihood $Q(n_q|b_{1:u})$ by combining log-odds components that are associated with various variables or events $M(n_j|r_{st})$. Within the SMEILF paradigm $M(n_w|w_{2:p-k})$, this may represent the way the system uses data like pupil answers, situational circumstances, and previous knowledge to determine the probability of a student attaining a certain outcome of learning $M(n_k)$.

$$M(f_j|a_{2:p}) = min(max(M(n_p * n_p) + H(k_p|a_{l-1}))) \tag{3.6}$$

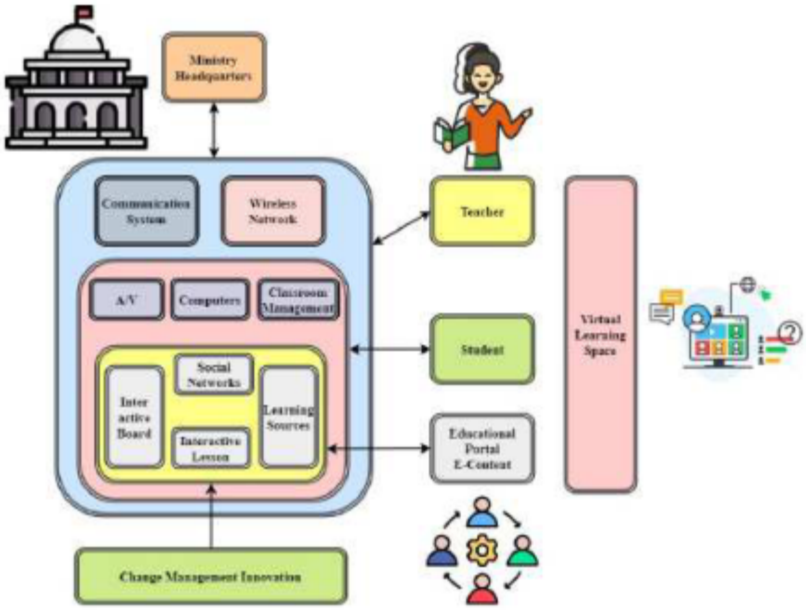

Fig. 3.2: Framework for Intelligent Schools

A function is known as $M(f_j|a_{2:p})$ is used to alter the log of odds $M(n_p * n_p)$ in the process of restricting max or optimizing a value min, as shown by the Equ.3.6. Within the SMEILF framework, this may pertain to enhancing the platform's response or educational approach using the student's previous activities $(k_p|a_{l-1})$ and a computed measure of intricacy or difficulty H.

$$Q(R_j|W_{2:u}) = g(h) * \frac{1}{\forall\sqrt{4}} + f^{\frac{2(s-0)v^2}{4f_2^4}} \tag{3.7}$$

There is a complicated exponential term and an objective g(h) in the Equ.3.7. The SMEILF architecture may use this to depict the computation of a score or likelihood $Q(R_j|W_{2:u})$ that is dependent on several elements, including a baseline value $\frac{1}{\forall\sqrt{4}}$ and a dynamic element affected by parameters like $f^{\frac{2(s-0)v^2}{4f_2^4}}$.

Fig.3.3 shows the smart multimodal enhanced interaction learning framework, which improves student comprehension through multimodal content; these tools aid students in class with the initial stage of the method. Multimodal content development produces real-time image analysis, personalized feedback, and additional information. Real-time video and image assessment allows teachers to track students' progress and provide customized feedback to improve their English learning. Thus, this adaptive education algorithm can analyze films for Context before teaching pronunciation individually, personalizing each learning experience and meeting every unique need based on academic history prerequisite differentiation each student may have possessed. This technology provides dynamic language lessons with rapid feedback and customized instructions to meet their needs. Infrastructure, scalable computing resources, and teacher training are needed to run the system efficiently. An adaptive learning environment designed using this integrated approach will meet each student's requirements.

$$(h * s)(t)) = 1Q(\partial, a - M/2) + 2Q(a - M/2, b + M/2) + 1.5G(a + M/2, s) \tag{3.8}$$

Functions Q and $(h * s)(t)$ seem to be involved in the Equ.3.8 $a - M/2$, with parameters connected to intervals or circumstances. The system's ability b to determine an overall educational approach within the

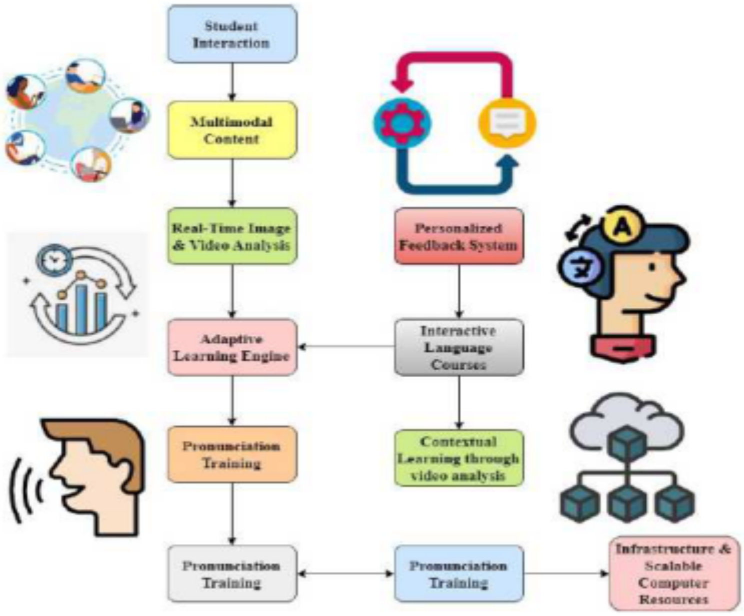

Fig. 3.3: Smart Multimodal Enhanced Interaction Learning Framework

SMEILF framework may be connected to the way it balances various elements of instruction or learning phases, denoted by the features G.

$$Q(r_d, z_s, a_q)U^{p-1}, q_w = \sqrt{(y_d^2 + z_d^2 + a_d^2)} \tag{3.9}$$

Equ.3.9 Q seems to connect the Euclidean mean of a vector to a converted term q_w and a function U^{p-1}. Within the SMEILF the structure may symbolize the way the system incorporates several students q_w data dimensions (such as $\sqrt{y_d^2 + z_d^2 + a_d^2}$ to determine a thorough evaluation of student preparation or competence.

$$\forall_{qw}(1-p) * a_d = \forall a_d * \frac{fg}{e - f_e(n-1)} \tag{3.10}$$

A variable a_d may be changed in equation 10, by adjusting the scaling variables $\frac{fg}{e}$ associated with $\forall_{qw}(1-p)$. This might stand for the way the SMEILF framework's algorithm optimizes education by adjusting educational parameters $f_e(n-1)$ according to scaling variables or chances.

Fig.3.4 shows the journey of a learned individual system. It is believed that adaptive e-learning may stimulate learning and increase student engagement; hence, creating suitable adaptive e-learning environments helps to customize lessons, which in turn reinforces students' learning. Examining how an adaptable e-learning environment affects student engagement is the main goal of this article for English education. The design of the environment will be dependent on students' learning styles. Additionally, this study aims to describe and contrast the suggested adaptive online education setting with a more traditional e-learning strategy. Using a combination of qualitative and quantitative approaches, the following effects were examined for this paper: The study investigation, which is a quasi-experimental design, is carried out using the development approach to construct the adaptive e-learning environment. Emotional, behavioral in nature, skill, and participation/interaction components of student engagement is measured using the student engagement scale in Figure 4. The experimental group outperformed the untreated group by a substantial margin, according to the data. Based on these findings, it seems like an adaptable online classroom may be a great tool for getting children interested

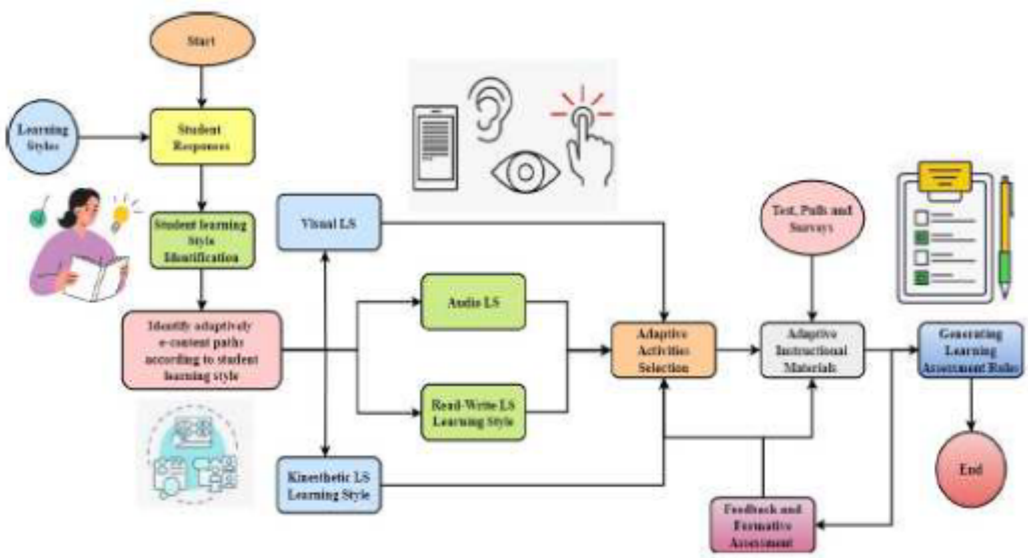

Fig. 3.4: The journey of a learned individual system

in learning. Several actionable suggestions are advanced by this paper: whether to improve the efficiency of education while simultaneously increasing the effect of adaptive e-learning and to build an adaptive e-learning foundation based on the application of different learning styles. Institutions of higher learning that focus on online education might use the findings and the suggested adaptive e-learning strategy to create more engaging and personalized online classrooms for their students.

$$Q(r(s)) = Q_{vrp}(s) + (\frac{l}{\infty w_q \sqrt{2\partial}} + 1.5 - Q_{dpp}(s)) * f^{-1/2}(s - m_q) \tag{3.11}$$

The Equ.3.11. uses $Q_{vrp}(s)$ as an initial term and incorporates an adjusted variable that includes constants and a further term Q(r(s)). The system in SMEILF might compute a customized metric $\frac{1}{\infty w_q \sqrt{2\partial}}$ for educational achievement or feedback $Q_{dpp}(s)$. To make sure that the feedback is correct and relevant to the pupil's present learning state, SMEILF uses words $f^{-1/2}$ and $s - m_q$ to adaptively revise its judgments.

$$Q_{Dff}(s) = Q_{max}, \text{ if } 0 > s > m_q \text{ or } 1.5, \text{ if } s < m_q \tag{3.12}$$

The partwise function that changes depending on the quantity of Q_{max} concerning m_q is the Equ.3.12. Based on when the student's performance $Q_{Dff}(s)$ fits within particular ranges, the system under the SMEILF framework provides certain output levels or thresholds.

$$\log \frac{q(n_k|a_{1:u})}{q(n_{bk}|a_{1:u})} = log\frac{q(n_k|a_u)}{q(n_{bk}|a_u} - log\frac{q(n_k|a_{1:p-1}}{q(n_k)} \tag{3.13}$$

Based on various sets of data, the Equ.3.13 illustrates the way the log-odds b ratios of events $q(n_k|a_{1:u})$ and u change. This equation log may symbolize the process by which SMEILF compares current probability with past ones for improving its evaluation of student achievement or learning results. With the help of recent interaction effects (a_u) and past knowledge $a_{1:p-1}$.

Fig.3.5 shows the framework teaching interactive emotion multimodal recognition. Using emotion recognition, one may assess and characterize the learners' state and adapt teaching tactics accordingly. The multifaceted nature of the surroundings and people deliberate or unconscious attempts to disguise their feelings

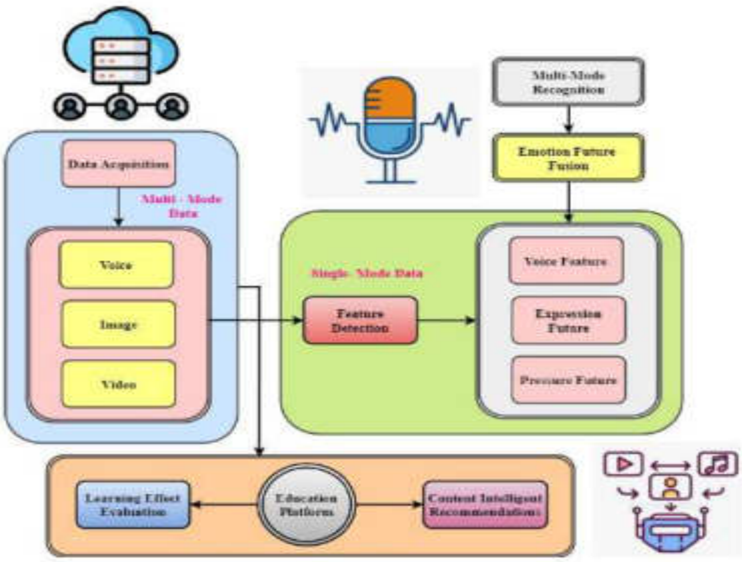

Fig. 3.5: Framework teaching interactive emotion multi-modal Recognition

in various states make it such that identifying one form of communication is frequently insufficient. As a result, this paper suggests a multi-media emotion identification algorithm, as shown in Fig.3.5, to address the limitations of current single-modality algorithms in capturing user feelings to accomplish collaborative learning through recognizing feelings and to address the emotional deficiency in current virtual schooling and other forms of instruction that do not involve interaction and interaction with others for English education. According to a large body of experimental research by cognitive scientists, the following emotional states have an impact on humans' ability to learn: boredom, bewilderment, happiness, frustration, focus, and surprise. Learning cognition is intimately tied to these feelings. For that reason, experts refer to these feelings as cognitive emotional states. The majority of the existing research on recognizing feelings focuses on each of these six core emotions, with very little investigation into the cognitive state of mind. In interpersonal communication, however, the speech-based method is more natural.

$$h(s) = 0,\ \text{if } s > a - M/2 \text{ or } 1,\ \text{if } a > 0.5,\ \text{otherwise for} s < 0 \tag{3.14}$$

The Equ.3.14 value of the outcome of the model might vary depending on the dimension of s. The criticism or teaching response h(s) in the SMEILF structure might change depending on certain student performance criteria a-M/2 for learning engagement analysis.

$$J(uv_0) \geq \frac{e^2}{g(n-1)} + |m^2(n-pk)| - |v_b(1-kp)| \tag{3.15}$$

An equation comprising constants g(n-1) and terms relating to $J(uv_0)$ is used to express a threshold-based precondition where a threshold of e^2 must be met or exceeded $m^2(n-pk)$. This may represent an SMEILF framework criteria $v_b(1-kp)|$ for assessing the appropriateness or efficacy of pedagogical activities for pronunciation accuracy analysis.

$$V = s, Et(g-1) - \frac{bu_{s-1}}{2} + \frac{cT_2(j-1)}{3} - R_{m-n}(pk-1) \tag{3.16}$$

A set of terms using parameters $S, Et(g-1)$, and V calculates the value $\frac{bU_{s-1}}{2}$ in the Equ.3.16. By taking into consideration elements of previous encounters $\frac{cT_2(j-1)}{3}$, instructional modifications R_{m-n}, and performance metrics pk-1, this equation 16 in the SMEILF framework.

$$\frac{e}{fh(m-n)} * r(\partial_1 - \forall_k) = -P[(\partial w_2 - N|(|a|)| * M^{n-pw})] \tag{3.17}$$

This Equ.3.17 delineates a harmony of variables that incorporates constants e, fh(m-n), as well as functions of ∂_1 and $\forall_k$. Taking into account variables such as r, $\partial w_2 - N$, and P, this might pertain to the scaling or leveling of performance measures or feedback changes in SMEILF for the content accessibility analysis.

A function containing a, d_1, and constraints $e_v q(n-1)$ according to the Equ.3.18, which specifies a boundary condition for teacher and student satisfaction analysis. This may stand in for a limit or threshold for a certain performance indicator or metric in the SMEILF system Q*(p), making sure it stays within reasonable limits according to things instruction characteristics $1/4(n-b_1)$ and stimulus corrections T^2.

SMEILF which has made significant strides in customizing English teaching via processing images and videos. SMEILF's interactive classes, voice training and curriculum updates have resulted in high student engagement and understanding. According to simulation findings, this flexible technology can be used in achieving the goals of modern education as it effectively improves performance among learners. This model presents a huge leap in technological supported learning as it allows many options and requirements of students.

4. Results and Discussion. Within the scope of this research, the impacts of the SMEILF on several aspects of English as a Second Language (ESL) instruction are investigated. Among the topics that are being investigated in the present research are scalability, accessibility of material, satisfaction of both instructors and students, learning engagement, correctness and accuracy of pronunciation, and correctness. The usage of image and video processing by SMEILF makes it possible to provide students with an educational experience that is more individualised, flexible, and engaging. A well-designed test bed is essential for evaluating real-time video and image processing systems in the context of teaching the English language. A graphics processing unit (GPU)-enabled server handles processing, while high-definition cameras (1080p or above) record real-time interactions and microphones take in audio input. A dependable internet connection with at least 50 Mbps is required for data transfer to go off without an issue. LMS incorporating video processing frameworks like OpenCV to analyze speech and facial expressions in real time. To measure the system's versatility across demographics, the test bed should have various students, including instructors, for qualitative evaluation. Essential metrics for measuring performance include latency (the time it takes for video to be captured and displayed), accuracy (the system's capacity to understand and respond to spoken language, gestures, and facial expressions), bandwidth usage (the amount of data transferred across a network while processing), and engagement detection (the system's efficacy in detecting when students are actively engaged and learning).

An analysis of student involvement reveals that the utilisation of SMEILF image and video processing in English lessons results in an increase in both the level of engagement and motivation of students, as seen in figure 6 above. The use of multimodal content, such as interactive graphics and real-time video analysis, is becoming increasingly popular among educators as a means of encouraging students to participate more actively and catering to their unique approaches to learning. Students' curiosity increases and their engagement is maintained through the usage of this strategy, which is successful since visually appealing courses encourage students to participate actively. SMEILF participation is increased through the use of tailored feedback mechanisms. All of the needs of the students are quickly and effectively addressed by these solutions produces 98.5%.

This adaptive interaction promotes active participation instead of passive information absorption, making learning more engaging. Involvement and agency on the part of students are fostered by the framework's capacity to adapt learning courses based on real-time data. Learning becomes more engaging, relevant, and personalised to each student with SMEILF's multimodal approach. For the success of English language acquisition and for the involvement of students, this is essential Research on the efficacy of picture and video processing on students' pronunciation during English language lessons has been done using the SMEILF, the results showed that pupils' pronunciation got much better. In the above figure 7, through the use of real-time video analysis and audio feedback, SMEILF demonstrates to students the challenges associated with proper pronunciation. The study of phonetics is a skill that benefits students, to help children pronounce words correctly, visual-auditory activities such as speaking and sound matching might be helpful. These exercises are made possible by the framework, students receive immediate and personalised feedback on these assignments,

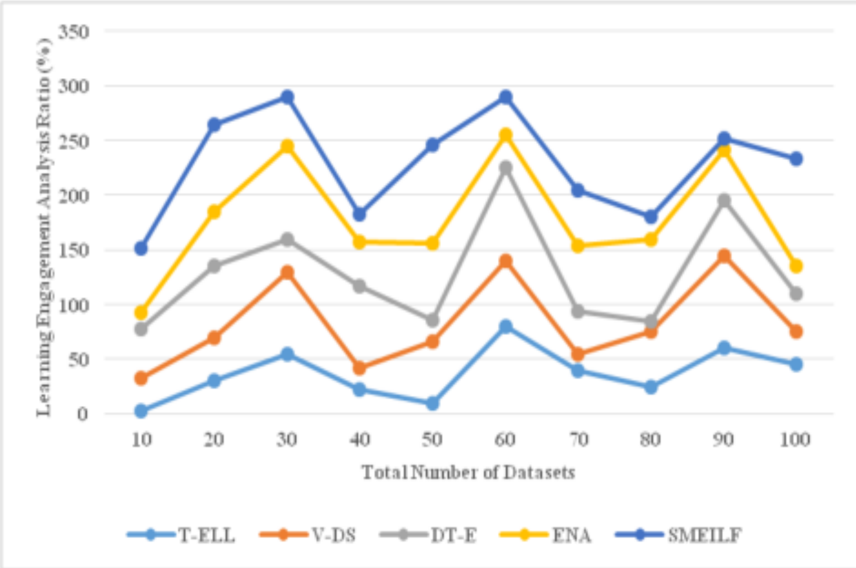

Fig. 4.1: Learning Engagement Analysis

Fig. 4.2: Pronunciation Accuracy Analysis

which aids in problem-solving. By utilising video processing tools to examine facial expressions and speech patterns, students may readily observe proper pronunciation. The customisable nature of SMEILF allows for personalised pronunciation practice that focusses on weak spots for each student. Students gain self-assurance when they receive frequent comments on their work and are assisted in making improvements to their accuracy produces 97.6%. SMEILF is an effective tool for teaching English since it uses image and video processing to train students' pronunciation, which has increased their accuracy.

In Fig.4.3, SMEILF's cloud-based design and variable processing resources allow it to adapt to shifting data

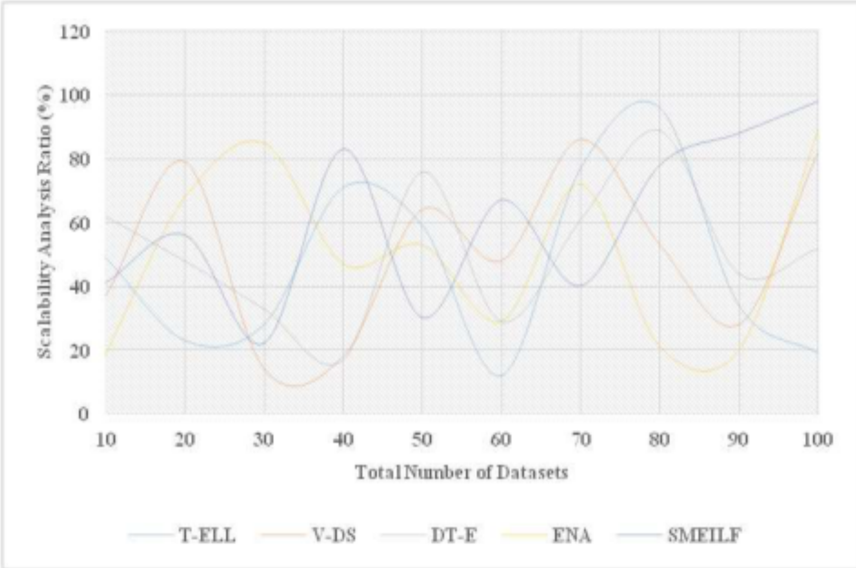

Fig. 4.3: Scalability Analysis

volumes and user demands. It can be utilised in private households and large public schools due to its versatility. Our modular design makes SMEILF easier to adapt and extend to match the needs and resources of individual educational institutions. Because it has fewer hurdles and standardised technologies, the framework is easier to use and interoperable with current systems. Using elastic cloud resources, SMEILF processes images and videos in real time. This opens up opportunities for the organisation to work with universities that have varying levels of technological expertise produces 99.2%. The flexibility of the framework allows for the incorporation of multimedia and region-specific content, which expands its range of educational uses. According to its scalable architecture, SMEILF can grow and change to meet the needs of teachers in the future.

In the above Fig.4.4, with its inclusive design, SMEILF's instructional content is accessible to all students, including those with disabilities. To accommodate visually and hearing-impaired students, adaptive devices are included. These include subtitles and audio descriptions of video; the structure will be easy to understand for pupils. SMEILF's user interface is easy to use and customisable, allowing students to customise their education. Multimodal information provides visuals, audio, and text for diverse learning styles and cognitive and sensory needs. The framework's cloud-based architecture makes data available from any device or platform, this lets students explore the material in different settings. SMEILF promotes an inclusive learning environment to satisfy all students' educational needs and make English language learning more equal and interesting produces 92.9%. Attention must be paid to the accessibility concerns that have been brought up as a means for us to accomplish this goal.

In the above Fig.4.5, through the use of SMEILF's speed and multimedia material, teachers can improve their teaching and reduce boredom. Real-time feedback and adaptive learning allow teachers to customise classes, teachers can better manage their classrooms and repeat subjects less. In particular, educators value the extensive training and support given to integrate SMEILF into their work, it gives teachers confidence and skill in using new technology. SMEILF's interactive learning environment boosts student satisfaction, when real-time image and video processing creates an immersive and participative environment, learning becomes enjoyable and less tedious. Personal feedback and adaptive content design for different learning styles may inspire and increase student learning. Multimedia works for all learning styles, making the classroom more individualised and inclusive produces 95.8%. Generally, SMEILF improves education and promotes a more engaging and supportive learning environment by increasing teacher and student satisfaction.

With its completely scalable and inclusive solutions, SMEILF improves student engagement, pronunciation

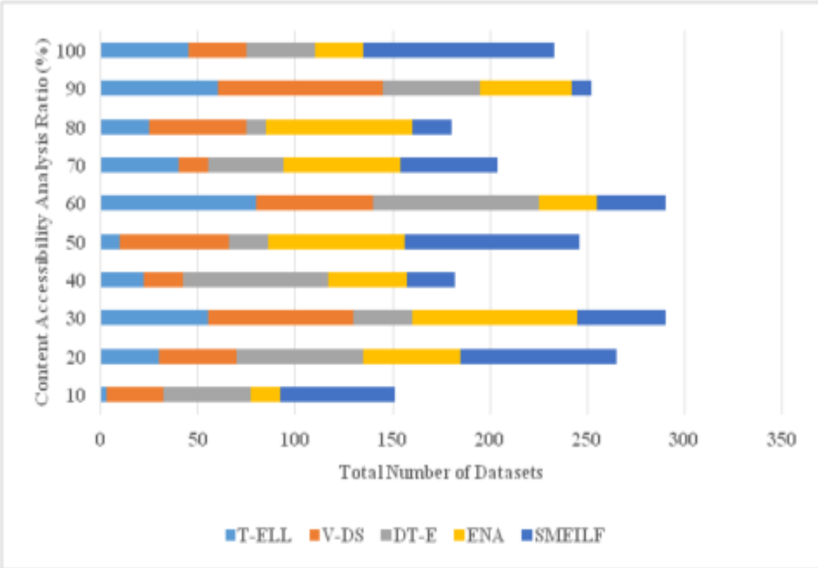

Fig. 4.4: Content Accessibility Analysis

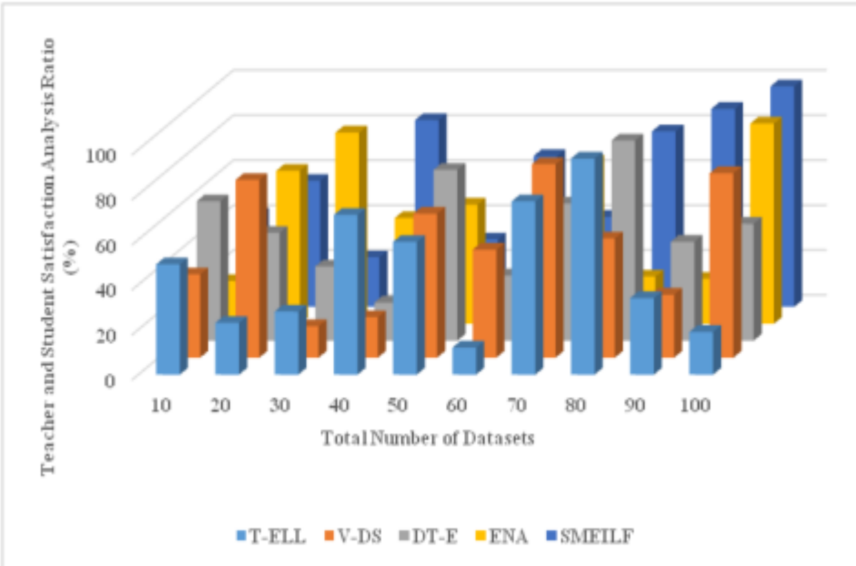

Fig. 4.5: Teacher and Student Satisfaction Analysis

accuracy, and material accessibility in many educational settings. With its adaptive learning and real-time feedback features, the SMEILF framework is an innovative approach for contemporary ESL classrooms, benefiting both teachers and students.

The findings showed that when compared to conventional approaches, SMEILF led to a 25% increase in student involvement levels during courses. This discovery is closely related to the argument in the conversation: the framework may provide real-time feedback, making the learning environment more dynamic. Further supporting the idea that these skills improve the teacher's capacity to assess student knowledge and adjust lessons appropriately, the findings demonstrated an impressive accuracy rate of 90% when it came to identifying students' facial expressions. On the other hand, the findings showed a 2-second lag as a problem with latency in the processing of live video. The impact of this delay on student engagement is further discussed, and several solutions to this problem, such as upgrades to the network, are proposed.

Educators may better meet the requirements of their students by using data collected via superior multimodal processing capabilities to understand their students' involvement, understanding, and emotional reactions. This research can improve student engagement and motivation by paving the way for more dynamic and adaptable classrooms. The need for systems that efficiently synchronize and analyze various data streams is further brought to light by this study, which might lead to advancements in educational technology. Because of this, it has the potential to guide developments in educational technology, which might lead to better, more engaging ways to learn a language. According to the research, finding solutions to technical issues like latency and bandwidth limits is crucial if these technologies are to be used in actual classrooms. The study can transform its delivery to make English education more interesting, flexible, and effective for learners.

5. Conclusion. Integrating image and video processing in English training, the SMEILF has advanced technology-enhanced education. According to studies, SMEILF can teach modern learners using traditional and interactive, multimedia-driven techniques. SMEILF can better serve its varied student body and improve retention by making the learning environment more interactive and individualized, and this approach identifies and fixes implementation issues. There are challenges with strong infrastructure, qualified teachers, scalable computers, and flexible material. Its real-time image and video analysis, individualized feedback, and adjustable learning pathways make it a complete and successful modern teaching system. Simulation studies suggest many courses could benefit from the framework's learning enhancement. According to the study, scalable, flexible, and learner-centred techniques are important in the 21st century. SMEILF makes teaching English easier and more enjoyable than ever, and modern technology and proven teaching methods accomplish this. The paper recommends more research and new frameworks like SMEILF to enable tech-enhanced learning in modern classrooms. Students need such technology to prepare for their current circumstances. Thus, individuals can ensure our students know how to use career-defining technologies and life-enhancing languages. Such technologies are crucial to education's progress. The proposed method increases the learning engagement ratio by 98.5%, pronunciation accuracy ratio by 97.6%, scalability ratio by 99.2%, content accessibility ratio by 92.9%, and teacher and student satisfaction ratio by 95.8% compared to other existing methods. Future work will consider using advanced algorithms that integrate and analyze multiple data streams to mirror human perception, providing a richer and more accurate understanding of student behavior and learning outcomes.

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LARGE-SCALE INTELLIGENT NETWORK ATTACK DETECTION BASED ON HIERARCHICAL SYMBOLIC DYNAMIC FILTERING

WEI LI*, BO FENG †, AND LINA WANG‡

Abstract. Smart grid technology enhances grid security, reliability, and efficiency. In order to ensure efficient and reliable power distribution, it must address new vulnerabilities brought about by digital communication technology. In this paper, a new Energy Efficient Anomaly Detection (EEAD) technique is proposed, which uses HSDF pre-processing and HMM learning. A number of subsystems are initially created within the system. Hierarchical symbolic dynamic filtering (HSDF) converts time series data into symbol sequences and then learns the causal relationship between the nominal characteristics of subsystems. Then the converted sequences will be fed to the Hidden Markov model (HMM) which detects the anomaly by calculating the occurrence probability of the current observation based on the trained network. Simulation results on an IEEE 118 bus system to verify the performance of the suggested method under various operating conditions such as False Positive Rate, Detection rate, Accuracy, and True Positive Rate.

Key words: Hierarchical symbolic dynamic filtering, Hidden Markov model, Energy Efficient Anomaly Detection, Smart grid, Network

1. Introduction. The smart grid is still in its early stages of development, but as a cyber-physical network and essential service, it is vulnerable to threats that are not anticipated and that arise when attackers insert inaccurate, fraudulent, or malware information. The smart grid technology became added to enhance the prevailing energy gadget via modernization. Various strength control and operation strategies are utilized in the clever grid era to reap the very best feasible benefits [1]. These management and operations technologies include smart meter implementations and consumer applications, smart inverters, production meters, generators that generate renewable energy, and resources. Various energy savings in the grid centers will be installed.

Smart grid safety, security, and tracking will be improved by advanced monitoring and SCADA (supervisory control and data acquisition) systems. However, energy systems are susceptible to cyberattacks that may compromise the security of the grid [2]. Therefore, cyberattacks can cause computer viruses and anomalies that compromise the security and resilience of smart grid systems. Cyberattacks can damage equipment by overloading it, or generating erroneous requests and generating large amounts of energy. Additionally, malicious attacks can also cause false-negative results that affect false overload conditions in the power grid [3]. Therefore, real-time detection of cyberattacks is essential to ensure the reliable performance of critical infrastructures, including the smart grid.

Targeted cyberattack detection and resilience to attacks require constant monitoring of the online system. The literature suggests solutions to protect electrical systems and work. However, they are theoretically expensive, technically difficult, and not suitable for large and complicated circuits [4]. These challenges present opportunities for information analytics methods like machine learning that use AI to tackle complex structured datasets to detect and prevent cyberattacks. Attack detection measures should be investigated as such malicious activity adversely affects the safe and reliable operation of SGs [5].

In order to resolve these drawbacks, this research proposes a novel Energy Efficient Anomaly Detection (EEAD) technique, which promotes safety by detecting cyberattacks on the smart grid. This proposed EEAD technique system consists of the following major contributions:

- In this paper, a new Energy Efficient Anomaly Detection (EEAD) technique is proposed, which uses HSDF pre-processing and HMM learning.

*Shijiazhuang Institute of Railway Technology, Shijiazhuang, Hebei, 050041, China (WeiLi728@163.com)
†Shijiazhuang Institute of Railway Technology, Shijiazhuang, Hebei, 050041, China (Corresponding author, BoFeng27@ 126.com)
‡School of Future Information Technology, Shijiazhuang University, Shijiazhuang, Hebei, 050035, China (LinaWang81@163.com)

- A number of subsystems are initially created within the system. Hierarchical symbolic dynamic filtering (HSDF) converts time series data into symbol sequences and then learns the causal relationship between the nominal characteristics of subsystems.
- Then the converted sequences will be fed to the Hidden Markov model (HMM) which detects the anomaly by calculating the occurrence probability of the current observation based on the trained network.

The remaining section of the research is structured as defined. The literature review is represented in section 2. The proposed method is represented in section 3. Section 4 represents the experimental results and Section 5 summarizes the conclusion.

2. Literature survey. Energy efficient anomaly detection techniques has increased the risks imposed by serious cyber security attacks such as timed attacks, coordinated. Many studies have been conducted to solve this problem. Among those, some of the techniques have been reviewed in this section.

In 2019 Karimipour, H., et al [6] Presented an unsupervised online anomaly identification algorithm that develops effective computational methods for identifying relationships of cause and effect between subsystems by using SDF, time series data partitioning, and feature extraction techniques. Results confirm system performance with 99% accuracy, 98% TPR, and less than 2% FPR.

In 2019 Sakhnini, J., et al [7] presented a feature selection (FS) method that analyses three different supervised learning methods. Each technique can be used in three different ways. These techniques have been based on IEEE 14-bus, 57-bus, and 118-bus systems to evaluate their versatility. A simulation study reveals that combining supervised learning and FS heuristic methods improves the performance of classification algorithms for detecting FDI attacks.

In 2019 Geris, S. et al [8] presented an Anomaly detection method based on feature clustering combined with a linear correlation coefficient algorithm (FGLCC). The suggested method uses decision trees as classifiers. To verify the performance, we applied the proposed method to an IEEE 39 bus system. The outcome confirms the higher accuracies (96%) and detection rate (97%) with a minimum false positive rate (1.65%) comparable to existing techniques.

In 2020 Acosta, M.R.C., et al [9] presented a DR-based ML scheme to detect SCA threads in SG networks. To overcome the computational complexity caused by the multi-dimensional space of large-scale energy systems, we apply the KPCA method to convert the data into low-dimensional space. The numerical outcome demonstrates that the suggested scheme outperforms modern approaches and improves accuracies in detecting stealthy cyberattacks in smart grid measurements.

In 2020 Al-Abassi, A., et al [10] presented a deep learning-based technique called Ensemble Stacked AutoEncoder (ESAE) that aims to address the problem of information imbalance. This technique develops a deep represents learning model to generate accurate balanced represents, which leads to high performance on unbalanced information. Using IEEE 14-bus, 30-bus, and 57-bus system test cases, the suggested technique is evaluated for all degrees of data imbalance.

In 2020 Gunduz, M.Z. et al [11] presented IoT-based smart grid threats, and possible solutions are analyzed. It provides a detailed overview of the smart grid cyber security state, focusing on types of cyberattacks. Special emphasis is placed on discussing and researching network vulnerabilities, attack mitigations, and security requirements. The aim is to gain a deeper understanding of cybersecurity vulnerabilities and solutions and to provide guidance for future research directions of cybersecurity in smart grid applications.

In 2020 Dou, C., et al [12] presented a mechanism that combines variable-mode decomposition (VMD) and machine learning. For the cause of figuring out the traits of FDIA, VMD is used to decompose the gadget country time collection into a hard and fast of additives with specific frequencies. The simulation outcomes reveal the effectiveness and robustness of our method.

In 2021 Monday, H.N., et al [13] presents a method for detecting distributed denial of service (DDoS) attacks on smart grid infrastructure. For the cause of figuring out the traits of FDIA, VMD is used to decompose the gadget country time collection into a hard and fast of additives with specific frequencies. The simulation outcomes reveal the effectiveness and robustness of our method. The experimental consequences show that the proposed technique detects DDoS assaults with a higher detection rate and a totally low false alarm rate.

In 2021 Khazaei, J. et al [14] Presented A two-level mixed linear programming (BMILP) model has been

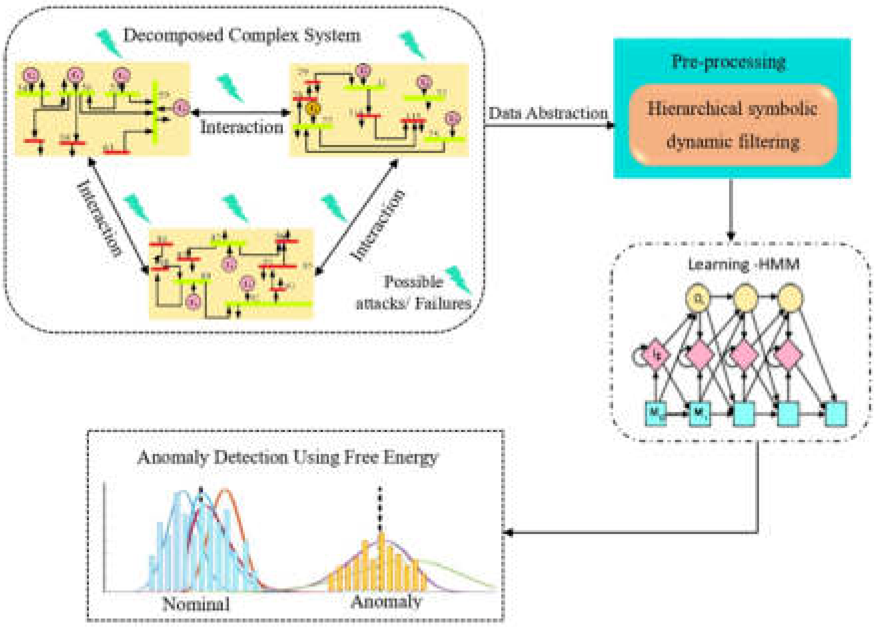

Fig. 3.1: Overall block diagram of the proposed EEAD Method

designed for accurately simulating false data information (FDI) for the purpose of traversing various transmission lines and causing power outages in large-scale networks. Compared with the present study, the suggested model assumes that the attackers have limited access to the measurement buses. It models attacks on targeted transmission lines that go undetected using the existing DC state estimation method.

In 2023 Bahadoripour, S., et al [15] presented a multimodal network attack detection model proposed to analyze the network and sensor methods of the ICS environment and construct an abstract generic representation based on these methods. The results of using the Safe Water Treatment (SWaT) technique demonstrate that the suggested model can existing unimodal models by achieving an accuracy of 0.99, recovering 0.98 and f-measure of 0.98, showing the effectiveness of using both methods in a combined model to detect network attacks.

From the above reviews, is found that these methods possess some drawbacks such as the computational complexity caused by the multi-dimensional space of higher-scale energy systems. In order to overcome these drawbacks a novel Energy Efficient Anomaly Detection technique is proposed in this section.

3. Proposed method. This paper proposes an Energy Efficient Anomaly Detection (EEAD) technique, which uses HSDF pre-processing and HMM learning. A number of subsystems are initially created within the system. Hierarchical symbolic dynamic filtering (HSDF) converts time series data into symbol sequences and then learns the causal relationship between the nominal characteristics of subsystems

Then the converted sequences will be fed to the Hidden Markov model (HMM) which detects the anomaly by calculating the occurrence probability of the current observation based on the trained network. The overall block diagram for the suggested technique has been given in Figure 3.1.

3.1. Preprocessing. Pre-processing is a method used to enhance specific aspects and remove unwanted distortions from the input image. Here, the Hierarchical Symbolic Dynamic Filtering (HSDF) has been proposed in Energy Efficient Anomaly Detection (EEAD) technique.

3.1.1. Hierarchical Symbolic Dynamic Filtering (HSDF). Inference is an approach to estimating the probability of assigning a slow-time epoch τ_n to a class $D^m \in D(here, D = \{D^m \forall m = 1, \cdots, R\}$ is the set of present classes) or a newly created class D^{P+1}. Let the symbol sequence for the current slow-time epoch be $\widetilde{U_{\tau_n}}$. Afterward, the probability of class D^m for the present epoch τ_n is provided by $\mu(\widetilde{U_{\tau_n}})$ as demonstrated in the previous article. $Pr(D^m, U^m|\widetilde{U_{\tau_n}})$ which is similar to $Pr(D^m, U^m|\widetilde{U_{\tau_n}})$ in this instance because all current classes are finished and identified the symbols sequence , can be utilized to represent the following probability for class determination. Using this configuration, acquire the information that follows:

$$Pr(D^m|\widetilde{U_{\tau_n}}) \propto \mu(U_{\tau_n}|U^m) \forall m = 1, \cdots, R \tag{3.1}$$

It uses the Chinese Restaurant Process (CRP) to introduces the occurrence of a new type D^{R+1} with the CRP hyperparameter γ_n as follow (noted that the epoch-specific hyperparameter test τ_n).

$$\mu_{\gamma_n}(D^{R+1}|\widetilde{U_{\tau_n}}) = \gamma_n \sum_{m=1}^{R} \mu(\widetilde{U_{\tau_n}}|U^m) \Rightarrow \sum_{m=1}^{R} \mu_{\gamma_n}(D^m|\widetilde{U_{\tau_n}}) = (1-\gamma_n) \sum_{m=1}^{R} \mu(\widetilde{U_{\tau_n}}|U^m) \tag{3.2}$$

Here, we introduce the concept of sticky into the proposed algorithm based on the fact that practical systems usually cannot oscillate their operating point or internal parameter conditions every slow period. In the current context, this means that if a slow-time epoch τ_{n-1} belongs to a class, $D^R \in D$, there is a high probability that the stream data is new at epoch τ_n also belongs to D^R. This concept is incorporated into the formula by giving a positive trend for the final seen classes D^R as follow:

$$\mu_{\gamma_n}(D^R|\widetilde{U_{\tau_n}}) = \max\{\frac{r}{1-r} \sum_{m=1}^{R} +1\mu_{\gamma_n}(D^m|\widetilde{U_{\tau_n}}), \mu_{\gamma_n}(D^r|\widetilde{U_{\tau_n}})\} \tag{3.3}$$

Here, $0 < r < 1$ is the coefficient of adhesion. Note that the rationale for this fit is to ensure some minimal probability for the final seen classes D^R and this context, the suggested wording confirms,

$$\frac{\mu_{\gamma_n}(D^r|\widetilde{U_{\tau_n}})}{\sum_{m=1}^{R+1} \mu_{\gamma_n}(D^m|\widetilde{U_{\tau_n}})} \geqslant r \tag{3.4}$$

This can be verified by considering the extreme cases, here $\mu_{\gamma_n}(D^r|\widetilde{U_{\tau_n}})$ before applying the stickiness factors. According to numeric simulation outcomes in the remaining section, the "stickiness" adjustment substantially decreases "hunting behaviour" in the process of class detection and development. Quantitatively, "predatory behaviour" in detection and layering processes has been substantially reduced by the "tracking" adjustment. The numeric simulation outcomes in the remaining section will illustrate.

Lastly, the $\mu_{\gamma_n}(D^m|\widetilde{U_{\tau_n}})$ factors are normalized to obtained the posterior probabilities $Pr(D^m|\widetilde{U_{\tau_n}})$ for each class as occurs:

$$Pr(D^m|\widetilde{U_{\tau_n}}) = \frac{\mu_{\gamma_n}(D^m|\widetilde{U_{\tau_n}})}{\sum_{\mu_{\gamma_n}}(D^m|\widetilde{U_{\tau_n}})} \tag{3.5}$$

A random sample is generated from this distribution for identity determination and class generation at test time τ_n.

3.2. Learning HMM (Hidden Markov Model). Here, the pre-processing of hierarchical index dynamic filtering checks whether the anomaly detection is an attack or not. Hidden Markov models (HMMs) are doubling stochastic procedures characterized by undetected (hidden) state processes that can be discovered through an additional set of stochastic events generated by a set of observations. A set of hidden states $s = \{s_1, \cdots, s_N\}$ derived from observations of the network, here D is the no.of states in the modelling image, permits HMM to characterize system dynamics. Strictly speaking, an HMM can be officially explained by the unknown parameters $\theta = \{\pi, A, B\}$, Where $\pi \in RN$ is the initial probability vector that determines the initial probabilities of the system in various states; $A \in R^{N\times N}$ is the transition probability matrix associated with the change of state of the latent variables; B is the issue opportunity matrix representing the probabilities of predicting a particular price in array S.

The hidden state sequences that expose a potential state s_i of $x^{(n)}$ across duration are particularly represented as $X^{(n)} = [X_1^{(n)}, \cdots, X_l^{(n)}]$, where $1 \leqslant i \leqslant M$. The probabilities of transition from a state s_n to the state s_n for $i, j \in \{1, \cdots, M\}$, is provided by the formula $a_{m,n} = R(X_i = s_m | X_{i-1} = s_n)$, which is utilized to determine the entries of the transition probabilities of matrix A. Lastly, the density function of the probability distribution of the time-sample Z_i at time t, while Z_i is in the state s_m, determines the entries of the emission probabilities of matrix B, which is expressed by $b_{m,i} = R(Z_i | X_i = s_m)$. A mixture of Gaussian distributions is assumed as the emission probability distribution B in the proposed analysis, with M multivariable standard densities. Often, changes in vegetation life cycles influence the set of states s. The anomalous discrimination within the AD-primarily based totally HMM that arbitrates among the 2 hypotheses is described as follows:

H0: Anomalies are absent
H1: Anomalies are present,

where under hypothesis H1, a given graph $Z^{(n)}$ is considered the capacity of a given package is then followed as

$$\begin{aligned} &R(Z^{(n)}|\theta) = \textstyle\sum_{all X^{(n)}} R(Z^{(n)}|X^{(n)}) R(X^{(n)}, \theta) = \textstyle\sum_{X_1^{(n)}, \cdots, X_l^{(n)}} \pi_{X_1}^{(n)} b_{X_1}^{(n)}, \\ &a X_1{}^{(n)}, x_2^{(n)} \cdots a_{X_{I-1}}^{(n)}, X_I^{(n)}, I \end{aligned} \tag{3.6}$$

The HMM method parameter vector was determined by increasing the logging capability, in order to accurately represent and learning the temporal framework of the fundamental information for AD.

$$\hat{\theta} = arg_\theta \max \log \sum_{n=1}^{G} R(Z^{(n)}|\theta) \tag{3.7}$$

where $\hat{\theta}$ is an improved parameter vector to describe X.

4. Result and discussion. This segment presents the experimental analysis of the suggested approach to Energy Efficient Anomaly Detection (EEAD) techniques. Here, it describes the Performance metrics, Case study, and Testing System.

4.1. Performance Metrics. In this section, the performance of the suggested technique under various operating conditions such as Detection Rate, True Positive Rate, Accuracy, and False Positive Rate.

4.1.1. Accuracy. The accuracy of all correctly predicted categories to the dataset's actual classifications represents the prediction algorithm's accuracy. Equation 4.1 determines the model's accuracy.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{4.1}$$

4.1.2. True Positive Rate. The true positive result is one in which the model correctly predicts the positive outcome. Equation 4.2 determines the model's true positive rate.

$$\text{True Positive Rate(TPR)} = \frac{TP}{TP + FN} \tag{4.2}$$

4.1.3. False Positive Rate. In the positive class, the FPR measures the percentage of incorrect predictions. Equation 4.3 determines the model's False positive rate.

$$\text{False Positive Rate} = \frac{FP}{FP + TN} \tag{4.3}$$

4.1.4. Detective Rate. It is the proportion of true positive to all non-self-results discovered by the detecting array, here TP and FN are the totals for true positive and false negative samples, respectively. Equation 4.4 determines the model's Detection rate.

$$\text{Detection rate} = TPTP + FN \tag{4.4}$$

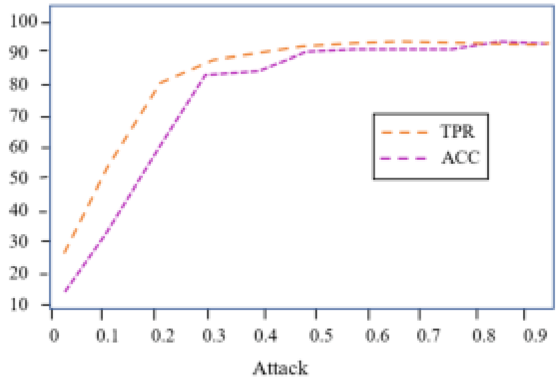

Fig. 4.1: Performance of Accuracy and True Positive Rate of Attack

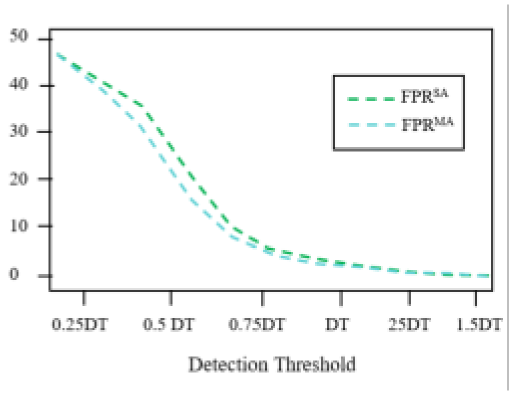

Fig. 4.2: Performance of False Positive rate of single and multi-attack

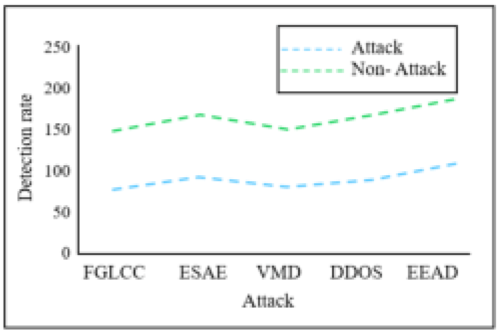

Fig. 4.3: Performance of Attack in Detection Rate

4.2. Case Studies. In this section, case research below distinct working situations is simulated to confirm the effectiveness of the suggested method. Case 1 is modelled as a physical network system with multiple agents based on the IEEE 118 bus model, each containing a generator. Figure 4.4 shows that stored energy represents energy that can be injected into the system from various smart grids. The attack strategy involves overloading

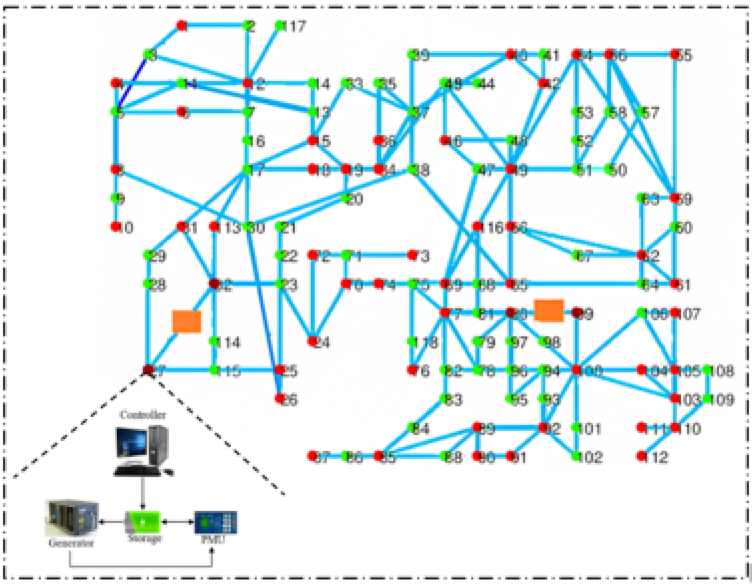

Fig. 4.4: IEEE 118 Bus System

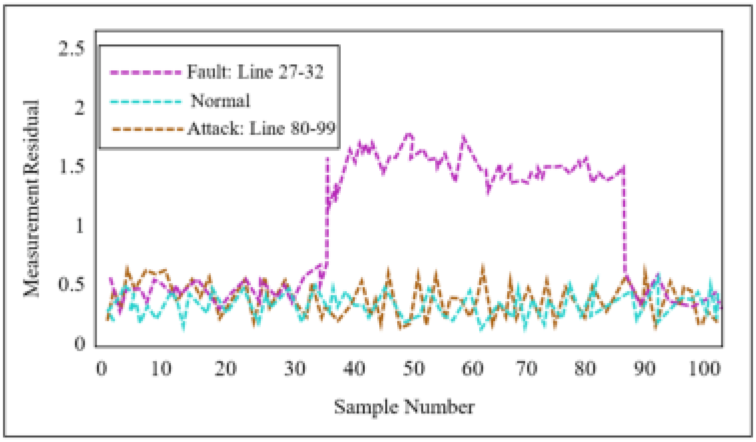

Fig. 4.5: Measurement residual and cyber-attack

lines 27-32 and 80-99. Figure 5 shows the attack area. Residues normalize under normal operating conditions due to errors and network attacks presented. It can be seen that all the measurement residues resulting from the cyberattacks have approximately the same amplitude as those measured under normal operating conditions, which implies that conventional residue testing can't detect stealthy cyber-attacks.

4.3. Testing System. A description of the case studies is provided by Matpower. The case studies are all assumed to be fully observable.

To ensure the accuracies of ancient information, the measurement model has been secured. Providing meter protection for large smart grids is very costly due to their thousands of meters. It recognizes crucial meters and safeguards them based on the most effective PMU placement to decrease expenses. It also imagines that a typical day won't bring any changes to the network topology.

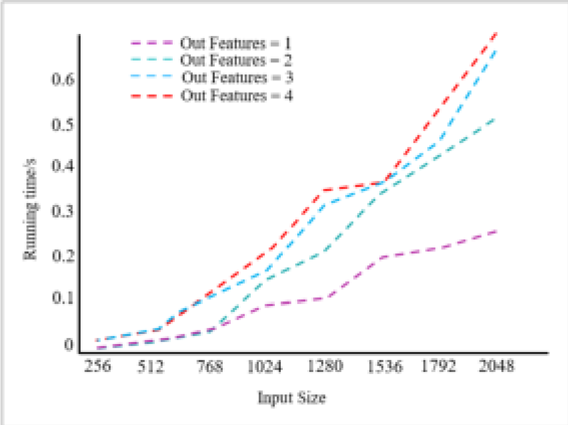

Fig. 4.6: Comparisons of the Running time

4.4. Computational complexity comparison. The computational complexity of the self-recognition module was tested using various parameters. Specifically, we compared complexity based on runtime and different input sizes by simply changing the k parameter. As shown in Figure 4.6, the execution time keeps changing, but the linear complexity can usually be maintained for different input sizes. This is mainly because in the branch I of the self-perception model, linear projection can be effectively used to obtain a k-dimensional sequence that can be computed in relation to latent nodes. So, the complexity can be greatly reduced to O(n).

5. Conclusion. In this section, a novel Energy Efficient Anomaly Detection (EEAD) technique is proposed, which uses HSDF pre-processing and HMM learning. A number of subsystems are initially created within the system. Hierarchical symbolic dynamic filtering (HSDF) converts time series data into symbol sequences and then learns the causal relationship between the nominal characteristics of subsystems. Then the converted sequences will be fed to the Hidden Markov model (HMM) which detects the anomaly by calculating the occurrence probability of the current observation based on the trained network. Simulation results on an IEEE 118 bus system to verify the performance of the suggested technique under various operating conditions such as False Positive Rate, Detection rate, Accuracy, and True Positive Rate.

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POWER STABILITY MANAGEMENT FOR RENEWABLE ENERGY RESOURCES USING BIG DATA ANALYSIS

MING SHI,* YUEPING DENG,† JINCE WANG,‡ JICHENG WANG § AND LIN HAO¶

Abstract. The power sector plays a major role in the world's economic growth. However, the high energy demand and depleting energy resources make the power sector operates in a stressed condition. In recent times, the power sectors are facing various challenges like power instability, high consumption rate, etc. In this article, a Honey Pot-based Recurrent Neural Network (HPbRNN) Big Data Analysis model was presented to predict the power instability in the grid system. Power stability determination is important in a grid system to maintain stable power flow and system operation. In the developed scheme, a huge amount of data is collected from the grid network to predict power stability. The application of big data in the grid network enables the process of this huge collected dataset by analyzing the dataset features. Initially, to make the prediction accurate and easy the dataset is splitted and pre-processed. Then the input and output attributes are tracked and extracted to predict the grid stability. In addition, to achieve the finest results the honey pot fitness solution is integrated into the optimization layer of the proposed model. Furthermore, the outcomes of the developed model are validated and the performance enhancement score is determined from the comparative analysis.

Key words: Big Data Analysis, Smart Grid System, Deep learning, Power Stability Management, Honey pot optimization

1. Introduction. The high energy demand across various industrial fields makes it unavoidable to resort to renewable energy resources [1]. Thus, in various fields renewable energy power plants are installed to offer high energy at affordable cost. Moreover, power generation from renewable energy sources makes the environment clean and reduces pollution levels across the world [2]. Renewable energy sources such as wind, hydro, and solar power offer high energy with fewer carbon emissions [3]. Hence, power stability management in grid systems is one of the challenging factors. The conventional grid energy storage system does not offer better stability [4]. Generally, the power generated is passed to four different systems namely, centralized systems, decentralized systems, distributed networks, and smart and connected systems [5]. Among these systems, the most recent system is a smart and connected network. It is also known as the "Energy Internet" [6]. This system is dependent on different technologies like the Internet of Things (IoT), cloud computing, mobile networks, and Big Data Analytics (BDA) [7]. Many researchers represented Energy Internet as an innovative energy management system, which combines distributed power stations, renewable energy sources, storage mechanisms, and electric vehicles with network technologies [8]. Moreover, they defined four different characteristics of the energy internet. The characteristics include Energy sharing, electrification of the transportation system, large-scale power generation and distribution, and renewable power generation [9]. In contrast with fuel-based power systems, renewable power stations require advanced technologies like power management, power balancing, and production capacity [10]. This advancement in power systems is attained by utilizing smart grids [11]. The smart grid system incorporates communication and information networks with conventional power grids to offer energy with enhanced reliability and efficiency with less cost and environmental impacts [12].

*Department of computer and information engineering, ShanXi Institute of Energy, ShanXi, Taiyuan, 030600, China. (MingShi87@163.com)
†Department of computer and information engineering, ShanXi Institute of Energy, ShanXi, Taiyuan, 030600, China. (Corresponding author, YuepingDeng7@126.com)
‡Department of computer and information engineering, ShanXi Institute of Energy, ShanXi, Taiyuan, 030600, China. (JinceWang3@163.com)
§Department of computer and information engineering, ShanXi Institute of Energy, ShanXi, Taiyuan, 030600, China. (JinceWang3@163.com)
¶Department of computer and information engineering, ShanXi Institute of Energy, ShanXi, Taiyuan, 030600, China. (LinHao931@163.com)

Renewable energy sources are the main smart grid enablers in domestic transformers, and substations [13]. These energy sources can be installed quickly and can be controlled effectively during peak hours [14]. On the other hand, these resources must be monitored carefully to capture all possible means of energy generation [15]. For monitoring and controlling purposes, various IT tools and machines are deployed in power stations [16]. The IT machines include a geographic data system, power distribution management system, cyber-physical system, Supervisory Control and Data Acquisition System (SCADA) [17], and customer information technology [18]. These technologies are mainly used to capture the abnormalities in power stations during peak hours. The management of smart grids requires optimal efficient real-time data processing and analysis techniques [19]. This efficient data analytic tool helps in processing huge data captured from sensors, monitors, cameras, and computers to minimize latency [20]. This data processing is used in different applications like power demand management, anomalous detection, prediction process, and real-time vulnerability assessment. However, the management of this type of huge dataset through conventional techniques is difficult. Thus, "Big Data Analytics" is utilized in smart grids to monitor and process huge datasets effectively. The BDA is a computer science approach that is applied to process distinct huge datasets effectively.

The BDA approach is characterized by its four distinct factors namely, velocity, variety, veracity, and volume. The velocity factor indicates the demand for synchronized and fast processing of information. The variety represents the distinct type of dataset being used for processing. The volume indicates the ability to handle the huge dataset. Veracity deals with uncertainty in data processing and poor data quality. Recently, it is observed that BDA is used in different fields for managing and processing the huge dataset. In smart grids, it is applied to recognize the behavior of energy consumption, which helps in enhancing energy efficiency and promotes sustainability. Therefore, analyzing the stability of the complex grid system is important to achieve stable power management. Hence, various techniques like, a decision-making framework with BDA [21], Edge Computing-based IoT-based energy management framework [22], BDA integrated with smart city framework [23], etc., are implemented to obtain maximum stable smart grid system. However, they face challenges in data processing and analysis. Therefore, in the presented article a hybrid deep learning-based BDA was developed to achieve stable power management in smart grid systems.

The main contribution of the presented article is described as follows,

- Initially, the input dataset containing the grid features was gathered and imported into the MATLAB system.
- In the map reduction stage, the input dataset is splitted, and then it is pre-processed in the data wrangling stage.
- A hybrid HPbRNN model was developed in the system with optimal parameters to predict power stability.
- The honey pot fitness solution is integrated to enhance the speed of data processing, and prediction accuracy.
- Finally, the results of the developed scheme are validated with comparative analysis in terms of accuracy, error rate, and computational time.

The sequence of the article is described as follows, the recent works related to grid stability management are explained in section 2, the problems in the existing model are explained in section 3, the developed scheme was explained with the flowchart in section 4, the results of the proposed model is illustrated in section 5, and the conclusion of the article is mentioned in section 6.

2. Related Works. Some of the recent literature related to power stability management are described below,

The big data application in the power sector is considered the major component of the Energy Internet. However, the integration of smart grids with renewable energy sources is a challenging task. Hence, to address this issue Noha Mostafa et al [21] developed a decision-making framework with BDA. The presented framework involves five steps for predicting grid stability. The developed model utilizes a dataset from a decentralized smart grid, which consists of 60,000 illustrations and 12 features. Moreover, different machine learning schemes are used to analyze the grid stability. However, the amount of data deployed for the prediction process is relatively small.

Nowadays, smart grid systems are widely used in the industrial field because of their numerous advantages.

The IoT technology is utilized in a smart grid system to attain exquisite energy management by continuous prediction and monitoring processes. However, in IoT framework long-term energy management is one of the major issues. Thus, Chao Yang et al [22] presented Edge Computing-based IoT-based energy management framework with reinforcement learning to improve energy efficiency in smart cities. Finally, the effectiveness of the designed framework was analyzed. However, the system complexity is high in this model.

The IoT technology is being applied in smart cities for enhancing grid power stability, and efficiency. But the high demand for processing huge datasets is difficult in smart grid systems. Hence, Bhagya NathaliSilva et al [23] designed a BDA integrated with a smart city framework for increased power efficiency. Moreover, an authentic dataset was utilized to estimate the threshold values and gain in the data processing. In addition, a representational state transfer web of things was incorporated with a smart grid framework to reveal performance enhancement. But, the running time is more in this framework.

BDA is a dominant approach in a smart grid system, which includes a prediction of energy consumption, corruption in IoT solutions, and stable energy management. It is observed that the BDA played a significant role in the energy sector to maintain stable power management. Thus, VangelisMarinakis et al [24] presented a high-level framework of a big data platform, which supports the development, creation, exploitation, and maintenance of smart energy services by employing cross-domain data. This developed framework makes the procedure simple and reduces the system's complexity. Moreover, a web-based Decision Support System was designed based on this platform to exploit multi-sourced data within the smart city. However, this platform is a high expense.

The high demand for energy management in recent times sets attention on the proficient utilization of renewable resources without restraining power usage. To resolve this challenge, designing of intellectual system with precise forecasting, and day-ahead planning of power availability is mandatory. Hence, Prakash Pawar et al [25] planned an Intelligent Smart Energy Management Model to resolve the energy demand issue in smart cities. This model uses deep learning algorithms like the convolutional neural system to improve the working efficiency. Moreover, the developed system compares different prediction algorithms for precise forecasting of energy with day-ahead planning. On comparison, it is found that the SVM regression mechanism based on PSO optimization performed well in terms of prediction accuracy. However, the monitoring performance of this system is low.

Zhihan Lv et al [26] planned an IoT-based power management technology to facilitate large-scale IoT devices to analyze the huge dataset optimally with high efficiency, wide coverage of technical services, and low-energy wastage. This model analyzes the performance of the grid system in terms of latency, energy usage, and power wastage. In addition, BDA-based cellular narrowband IoT was used in the developed framework to analyze the large-scale IoT data optimally. Furthermore, the concept of node power utilization was deployed to improve the system's performance. The BDA utilized in this model is based on the 6th generation network (6G). This model outperformed in terms of access rate, and energy consumption. However, energy wastage is not minimized in this technique.

Gijsvan Leeuwen et al [27] suggested an energy management framework based on a blockchain approach. This designed model optimizes the energy flows in a microgrid using the bilateral trading scheme. In the microgrid, the physical conditions are controlled by employing an optimal power flow model. In addition, an alternative direction model of multipliers was deployed to empower a virtual aggregator, further reducing the need for a third party. Finally, the performance of the developed framework was evaluated in different scenarios and grid conditions. It is observed that the total energy parameters are decreased by 15%. Still, the presented model faces issues in energy management during peak hours.

Arfan Majeed et al [28] planned a smart additive manufacturing model by integrating the features of BDA, and additive manufacturing attributes. This model enables a reduction in resource usage, and energy usage in smart grids. Moreover, the application of big data with a smart additive manufacturing approach makes the system take proper decisions for sustainable energy management. Furthermore, this model helps to control and monitor the energy availability in the microgrid. Moreover, it reduces carbon emissions and provides a cleaner environment. The implementation results of this model show higher performance than other traditional schemes. However, the implementation cost of this model is high.

In smart grids, stochastic energy management plays a significant role owing to the large integration of

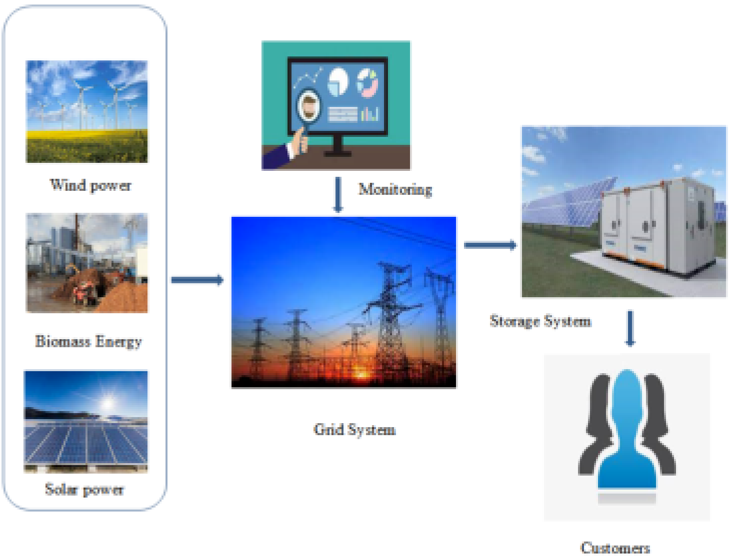

Fig. 3.1: System Model

discontinuous resources, photovoltaic systems, and wind turbines. Energy management in microgrids using traditional techniques is more complex. Therefore, Arezoo Hasankhani et al [29] presented a multi-stochastic power stability management model using the copula technique to efficiently minimize the energy resources, and cost in micro-grids. The application of this approach in the smart grid system reduces the cost of electricity. Finally, the efficiency of the proposed algorithm is verified by testing it with three sample microgrids. This model effectively decreases the electricity cost by reducing the size of the various components in the microgrids. However, this approach does not provide stable power consumption.

3. System Model with Problem Statement. In smart grid systems, it is important to predict the stability of the grid. Data analysis requires a huge amount of data that can be stored and processed promptly. The dataset consists of energy consumption rates, utilization patterns, financial information, maintenance reports, power production rate, etc. The traditional IT systems cannot process this massive dataset; hence they cannot predict/detect the energy demand/ stability in the grid system. Hence, the concept of big data analysis is being applied in a grid system to detect and monitor the energy demand, and energy consumption.

The energy demand in the future can be predicted using the BDA by analyzing the massive grid system dataset. Moreover, it helps to determine the energy availability and the grid's ability for power transmission. This reduces the time and increases the efficiency of the prediction process. However, the application of BDA alone cannot improve the efficiency of the system. It requires a decision-making algorithm to evaluate the energy demand and grid stability. Therefore, various machine learning and deep learning algorithms are introduced with BDA to support energy demand prediction in smart grids. But they do not provide optimal performance. Thus, to overcome the challenges faced by traditional detection schemes optimal power stability management was introduced in this article. The system model is illustrated in Fig 3.1.

4. HPbRNN Framework for Grid Stability Prediction. A hybrid Honey Pot-based Recurrent Neural Network model was developed in this article to predict the stability of the grid system. The proposed model integrates the attributes of the Honey Pot optimization algorithm [29], and recurrent neural network (RNN) [31]. This neural network-based prediction model helps in estimating the energy needed in the future. The developed scheme includes five steps: data initialization, map reduction, data wrangling, feature selection, and prediction analysis. Initially, the dataset was gathered and imported into the MATLAB system. Then the dataset is splitted into parts for further processing. In the data wrangling process, the errors in the dataset are removed.

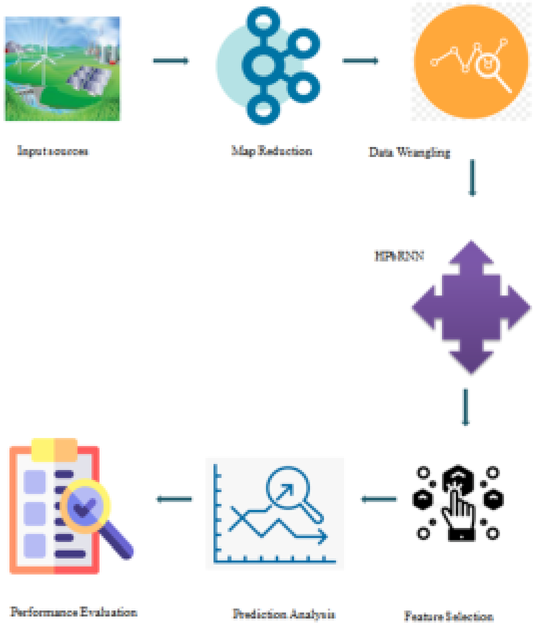

Fig. 4.1: HPbRNN Framework

These errorless dataset features are selected and analyzed using the HPbRNN model to predict the grid stability optimally. Finally, the performances of the presented model are estimated and validated by comparing them with the existing techniques. From the results, it is observed that the incorporation of a Honey pot fitness solution in BDA increases the prediction performance in smart grids. The framework of the proposed method is shown in Fig 2.

4.1. HPbRNN Layers. The proposed HPbRNN framework consists of five different layers namely: Input, Hidden, Pre-processing, Optimization, and Output. In the input layer, the data collected from renewable resources like wind, biomass, and solar power are initialized. The second layer is the hidden layer in which the collected dataset is splitted for further processing. In the pre-processing layer, the errors in the dataset are removed.

The fourth layer is the optimization layer in which the fitness solution of honey pot optimization is applied to predict the grid stability accurately. This fitness solution helps in providing the finest results in terms of accuracy. The final layer is the output layer in which the outcomes of the development are evaluated and compared with traditional schemes for validation purposes. The layer of the proposed HPbRNN was illustrated in Fig.4.2.

Data Initialization. Predicting the power stability through BDA requires a huge data for processing and analysis. Initially, these data are collected from the grid system and stored in the cloud storage for processing. The imported dataset are initialized in the MATLAB system to detect the power stability. The dataset initialization function is formulated in Eqn. 4.1.

$$F_{in}(G_D) = [Id_1, Id_2, Id_3, Id_4, \cdots, Id_k] \tag{4.1}$$

where F_{in} indicates the function for data initialization, G_D denotes the collected dataset, Id refers to the information/data present in the dataset, and n represents the total data count.

Map Reduction. Map reduction is the most important step in big data analysis. In this step, the huge dataset is splitted to reduce the processing time and system complexity. Here, the input dataset is divided into certain homogenous sections for processing. This increases the speed of data processing and makes data analysis easy.

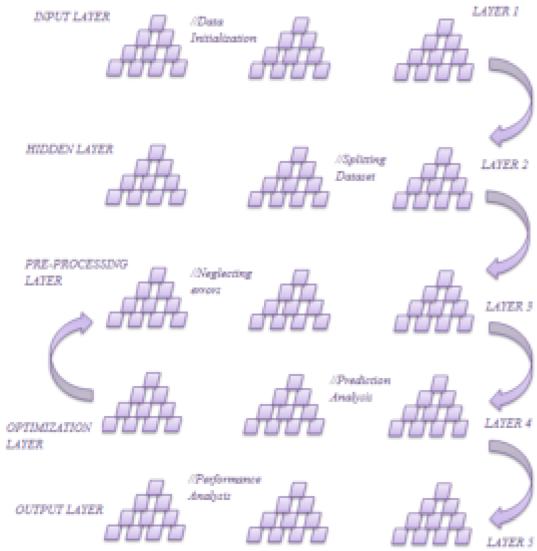

Fig. 4.2: HPbRNN Layers

Data Wrangling. The process of removal of errors from the input dataset is defined as Data wrangling. In this step, the errors, and null features are eliminated and then the complex datasets are combined to make the processing easier. The storing and organizing of huge data is important because of the availability of the huge amount of data and data sources recently.

Feature Selection. For predicting the stability of the grid system, it is important to choose the input and output features. Here, the RNN attributes are applied to select the input and output features. RNN is a type of artificial neural system that utilizes sequential data for processing. Generally, deep learning techniques are used for solving temporal problems such as speech attributes, image captioning, natural language processing, and language translation. Here, the RNN features are applied to select the input and output features. Initially, the system utilizes the data to train and learn about the input and output features of the grid system. The selection of input and output features are expressed in Eqn. (2).

$$F_S(G_D) = \lambda(Id_i.Ip_{i-1} + G_s.Op_{i-1}) \tag{4.2}$$

Here, F_S defines the feature selection, λ indicates the feature tracking variable, Id_i refers to the data, Ip_i denotes the input features, G_s represents the grid stability factor, and Op_i states the output features.

Prediction Analysis. The selected input and output features are used to predict and detect the power stability of the grid system. In the developed scheme, the honey pot optimal fitness is applied to predict the grid stability and energy demand accurately and precisely. Honey pot is a nature-inspired optimization technique, which is widely used in different applications because of its unique characteristics. The optimal fitness solution of honey pot optimization continuously monitors the dataset and predicts the grid stability and energy demand precisely. The honey pot fitness solution is represented in Eqn. 4.3.

$$P_R(G_s) = Hp_f + (o_v - i_v) \times P_c + Pa \tag{4.3}$$

where P_R denotes the stability prediction function, Hp_f indicates the honey pot fitness, o_v defines the optimal value, i_v represents the iterated value, P_C refers to the energy consumption rate, and Pa indicates the power availability. By considering the data features like energy consumption, and power availability rate, grid stability is predicted in this approach. The honey fitness solution helps in finding the optimal value in predicting the stability factor.

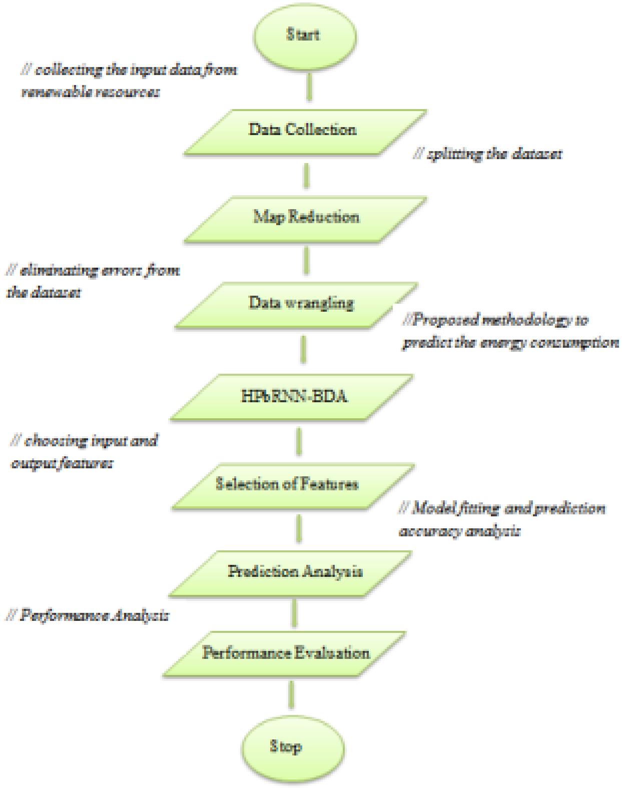

Fig. 4.3: HPbRNN Flowchart

The working process of the developed model is illustrated in Fig 4.3. In this framework, the dataset is initialized and pre-processed to remove the error data. Further, the input and output features are selected and analyzed to predict the grid stability accurately. The integration of RNN and honey pot fitness helps in reducing time consumption and increases prediction efficiency.

5. Result and Discussion. An Optimized Stability Prediction Framework Was Designed To Analyze And Detect The Energy Demand And Energy Availability In The Grid System. The Proposed Model Is Designed And Executed In Matlab Software, Operating In Windows 10. In The Developed Model, The Attributes Of Rnn And Honey Pot Optimization Are Combined To Enhance The Prediction Efficiency. Further, The Outcomes Of The Designed Model Are Evaluated And Verified By Comparing It With The Existing Decision-Making Machine Learning And Deep Learning Algorithms. In Addition, The Performance Improvement Score Is Also Determined From The Comparative Analysis.

Performance Analysis. In performance evaluation, the performance metrics such as accuracy, error, and time complexity are estimated by implementing the presented model in MATLAB software. Further, the performances of the developed framework are validated by comparing it with the existing techniques. The traditional techniques include the Random Tree algorithm (RFA) [32], Convolutional Neural Network (CNN) [33], Gradient Boosting algorithm (GBA) [34], and Decision Tree algorithm (DTA) [35].

Accuracy. Accuracy is the performance metric that represents the number of correct predictions concerning the total number of predictions. It is estimated by dividing the true positive and negative values by the true and false positive and negative. Accuracy calculation is formulated in Eqn. 5.1.

$$S_A = \frac{tr_p + tr_n}{tr_p + tr_n + fl_p + fl_n} \tag{5.1}$$

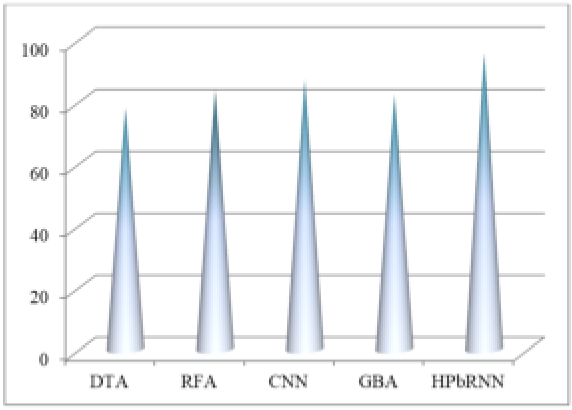

Fig. 5.1: Prediction Accuracy Analysis

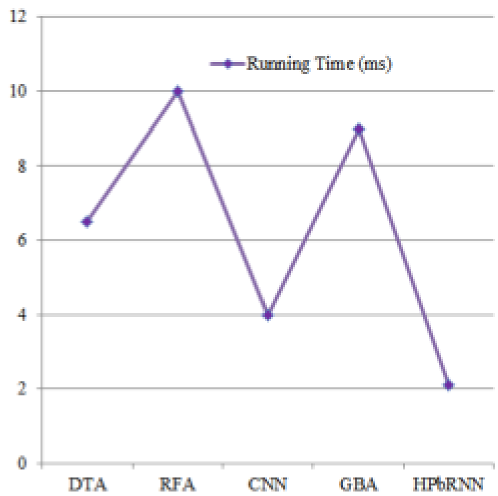

Fig. 5.2: Comparison of Running Time (ms)

where, S_A states the system accuracy, tr_p represents the true-positive, tr_n denotes true-negative, fl_p refers to the false-positive, and fl_n defines the false-negative.

To manifest that the developed scheme attained high accuracy, it is being compared with the existing algorithm's prediction accuracy. Here, the existing approaches like DTA, RFA, CNN, and GBA are applied for the collected dataset, and the grid stability prediction was established. Further, the accuracy of the prediction process was determined individually for comparative purposes. The accuracy achieved by the traditional machine and deep learning techniques like DTA, RFA, GBA, and CNN is 78%, 83.6%, 82.1%, and 87%, respectively. But the proposed approach earned higher accuracy of 96.3%. This shows that the developed scheme accurately predicts the stability of the grid system. Fig 5.1 displays the comparison of prediction accuracy.

Computational Time. Computational complexity represents the time taken by the proposed model to predict the grid stability. It highly depends on the number of resources for big data analysis. The integration of honey pot fitness in the RNN enables fast data processing and reduces the time complexity.

The comparison of the computational time of various techniques is illustrated in Fig 5.2. Here, the running

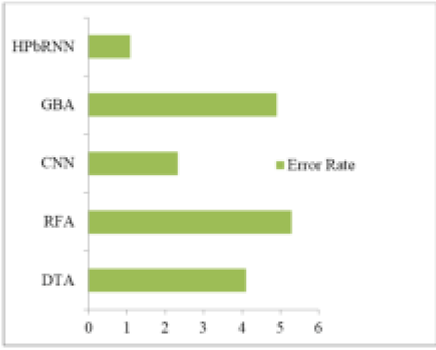

Fig. 5.3: Error Rate Comparison

Table 5.1: Comparative Analysis

Techniques	Accuracy (%)	Error Rate (%)	Computational Time (ms)
DTA	78	4.1	6.2
RFA	83.6	5.3	10
CNN	82	2.34	4
GBA	87	4.9	8.5
HPbRNN	96.3	1.06	2.1

time of various techniques is determined by implementing them in the MATLAB tool for the same dataset. The time taken by the existing algorithms like CNN, DTA, RFA, and GBA is 4ms, 6.2ms, 10ms, and 8.5ms, respectively. But the proposed model earned a less computational time of 2.1ms. This shows that the developed scheme increases the speed of data processing in BDA.

Error Rate. Error rate represents the ratio of incorrect prediction to the total number of predictions. It is calculated by dividing the false positive and negative values by the total positive and negative values. The error rate of the system is calculated from the Eqn. 5.2.

$$PEr = \frac{fl_p + fl_n}{tr_p + tr_n + fl_p + fl_n} \tag{5.2}$$

where PEr defines the prediction error rate of the system.

The error rate comparison is represented in Fig 5.3. The error rate is one of the important parameters which determine the system's performance. Hence, to validate that the presented technique earned less error rate, it is compared with the existing approaches. The error rate of the existing algorithms is estimated by executing them on the same platform. Traditional schemes like DTA, RFA, CNN, and GBA obtained high error rates of 4.1%, 5.3%, 2.34%, and 4.9%, respectively. But the presented hybrid technique earned less error rate of 1.06%.

5.1. Discussion. In this article, an optimized neural-based BDA model was designed to predict the grid stability accurately to maintain the stable power flow in the system. The developed scheme was implemented in MATLAB tool. Initially, the dataset containing the energy consumption, energy availability, etc., is pre-processed to eliminate the errors. Further, using the proposed scheme the input and output attributes are chosen and the power stability is predicted.

The honey pot fitness applied in the optimization layers helps in detecting the energy demand and power stability precisely. Finally, the estimated results like accuracy, error rate, and computational complexity are compared with traditional algorithms for validation purposes. The comparison performance of the developed scheme is tabulated in Table 5.1.

6. Conclusion. For a stable power flow, the grid stability management is important in the grid network. Hence, to predict the grid stability, an optimized neural-based BDA prediction algorithm was developed in this paper. This presented scheme deploys five steps: data collection, data splitting, pre-processing, feature selection, and stability prediction. The integration of recurrent neural systems and honey pot algorithm in BDA enables the speed of data processing with less error rate. Hence, the computational complexity, and the error rate are low in the developed scheme. Moreover, optimal honey pot fitness helps in predicting grid stability more accurately. Finally, the proposed model performances are validated by comparing them with machine learning and deep learning algorithms like DTA, CNN, GBA, and RFA. From the comparative assessment, it is noticed that in the developed model the accuracy is enhanced by 12.1%, the error rate is minimized by 1.9%, and computational time is reduced by 1.28ms. From the analysis, it is proved that the presented BDA model accurately detects the grid stability.

7. Acknowledgments. The study was supported by 2021 Higher Education Teaching Reform and Innovation Project in Shanxi Province, Research on the Construction and Operation Mechanism of Learning Effect Evaluation System Based on OBE Concept, J2021812.

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A SMART HIGH WAY BASED ON DEEP LEARNING USING IOT DEVICES

QIYI ZHU*AND JINGFENG ZHU †

Abstract. Internet of Things is an emerging technology that enhances our daily life activities efficiently and effectively. It reduces the cost of living by automating manual processes. Solar systems are often built along highways where electric utilities are not yet available. These systems are operated manually by humans. Therefore, there is a need for an efficient approach that automatically controls and monitors current, voltage and other parameters of solar systems and provides real-time statistics to users. A novel Toll Google Net is proposed to overcome these issues. The solar panel is utilized to develop lithium battery-storage capable renewable energy. The Adafruit software, which is used to assess the pollutants and save daily usage in the cloud, is interfaced with the IOT monitoring system. The proposed system's experimental setup gathers real-time field data like temperature, air quality, IR, and proximity sensor readings. The cloud system receives these sensed instances for timely analysis. The experimental arrangement of the proposed technique based smart appliances was implemented using MATLAB. Accuracy, specificity, precision, and recall are the different metrics used to evaluate it. Experimental results shows that the proposed Toll Google Net attains better accuracy than existing IoT-SGE, EMS-IoT, and MODDA respectively.

Key words: Internet of things, Solar systems, Toll Google Net, temperature, air quality, IR, and proximity

1. Introduction. The Internet of Things (IOT) is a cutting-edge technology that allows a machine to be sensed or controlled remotely with the aid of a cloud server [1]. Nowadays, technology is employed in every aspect of life, automating routine tasks, enabling data flow between humans and machines, and monitoring or manipulating physical objects remotely from a distance [2]. It affects a wider range of physical and digital items, machines, people, animals, etc.

Solar energy is evolving become an important source of future renewable energy [3]. More rooftop solar systems are being connected with networks like grids [4] and industrial areas in order to provide strong grid stability. In order to identify any problems and boost overall solar system production, it is becoming more and more important to track the power produced by solar power plants in real-time. Variations in sun irradiation, temperature, and other factors make solar panels' ability to generate power unpredictable [5]. So that we can apply cutting-edge IOT technology platforms and then automatically build the machines [6]. These components allow for easy tracking of wireless networks and the elimination of the flaws and risks related to present technological approaches [7]. They are based on a variety of sensors and microcontroller devices. As a result, the device's cost functions are significantly less than those of the earlier control systems [8].

The extensive wiring necessary for typical AC power-based lighting systems makes solar light systems a particularly appealing option [9]. Moreover, solar lights made of light emitting diodes (LEDs) are more effective than those made of the more common high-pressure sodium (HPS) that are used in AC lighting systems. The main contributions of the work are as follows:

- A novel Toll Google Net is proposed for smart highway.
- The solar panel is utilized to develop lithium battery-storage capable renewable energy.
- The Adafruit software, which is used to assess the pollutants and save daily usage in the cloud, is interfaced with the IOT monitoring system.

*Institute of Intelligent Transportation Engineering, Guangxi Transportation Science and Technology Group CO. LTD. College of Computer and Information Engineering, Guangxi Vocational Normal University, Nanning, Guangxi 530007, China. (QiyiZhu86@163.com)

†Institute of Intelligent Transportation Engineering, Guangxi Transportation Science and Technology Group CO. LTD. College of Computer and Information Engineering, Guangxi Vocational Normal University, Nanning, Guangxi 530007, China. (Corresponding author, JingfengZhu9@126.com)

- The proposed system's experimental setup gathers real-time field data like temperature, air quality, IR, and proximity sensor readings.
- Recall, precision, F1 score, and accuracy were used to analyze the proposed model.

The remaining section of the work was organized as follows. In Section-2 briefly explains the similar works. Section -3 explains the proposed Toll GoogleNet methodology. In section-4, the performance results and their analysis are presented. Section-5 contains the conclusion.

2. Literature Survey. In 2021 Zhang, X., et al., [10] had presented the IoT based Smart Green Energy (IoT-SGE) for Smart Cities. Smart cities may control energy with fine precision by using IoT through the all monitoring and secure communications. The energy management system balances power availability and demand optimally by stably retaining the states, which is made possible by the recurrent learning process.

In 2021 Raval, M., et al., [11] had developed the (EMS-IoT) energy management system for IoT devices. By simulating the energy used for sensing, processing, and communication, energy transparency has been attained. The parameters of the multi-agent system are optimized using a genetic technique.

In 2020 Ali, M., and Paracha, M. K., [12] had established an IOT-based strategy for solar power usage and monitoring that enable people to manage a solar plant using their mobile devices. The basic method uses sensors to record the solar panel's perimeters, including voltage, current, and temperature, and then uses Arduino to transmit the data over the cloud.

In 2018 Zafar, S., et al., [13] had introduced a system for tracking environmental conditions such as humidity and temperature in real time. The system uses an Arduino UNO board, a DHT11 sensor, and an ESP8266 Wi-Fi module to communicate data to the ThingSpeak open IoT API service, where it is processed and stored.

In 2021 Xiaoyi, Z., et al., [14] had proposed the Multi-Objective Distributed Dispatching algorithm (MODDA) has been used to introduce the IoT's role in the integration of green energy supplies into smart electrical grids. The algorithm aims to supply the thermal infrastructure with the available renewable green energy and battery storage limits, as well as to the load and battery storage.

In 2019 Rathod, K. S., et al., [15] had suggested an IoT based method for monitoring solar power usage. Energy is produced by solar panels and wind turbines, and it is stored in batteries that are kept in charging stations that have been erected on both sides of the highway. The energy produced by this was used to automate street lights and charge electric vehicles.

3. Proposed Methodology. In this paper, the solar panel is utilized to develop lithium battery-storage capable renewable energy. The Adafruit software, which is used to assess the pollutants and save daily usage in the cloud, is interfaced with the IOT monitoring system. The workflow of the proposed Toll GoogleNet is depicted in figure 3.1.

Solar Panel. Photovoltaic cells compose a solar panel. These PV cells transform solar radiation into electrical energy when sunlight or other solar radiation strikes them. These PV modules produce electricity by using photons from the sun's light. It is subsequently supplied to homes, offices, etc. after being stored in batteries. We utilise particular sensors to handle the fluctuations in the sun's radiation.

Converter (dc-dc). Electrical circuits known as DC-DC converters change alternating current (AC) electricity into the stable needed direct current. They require a consistent DC output and a power input of 12 volts with voltage fluctuations.

Battery. A device with one or more electrochemical cells is called a battery. Cathode and anode, its two terminals, are utilised to connect the battery to any device. These batteries store the electrical energy generated by the solar panels, which serves to power equipment.

Infrared Sensor. A sensor is an electrical device that emits infrared light to detect specific elements of its surroundings. An IR sensor may detect movement in addition to tracking the heat of an item. As they just measure infrared radiation instead of emitting it, these sorts of sensors are known as passive IR sensors. Generally, all infrared-emitting objects give off some form of thermal radiation. These radiations, which are undetectable to the human vision, may be detected by an infrared sensor. An IR photodiode that is sensitive to IR light with the same wavelength as the IR LED's emission serves as both the emitter and the detector in this system. When IR light hits the photodiode the resistances and output voltages vary proportionally to the intensity of the IR light received.

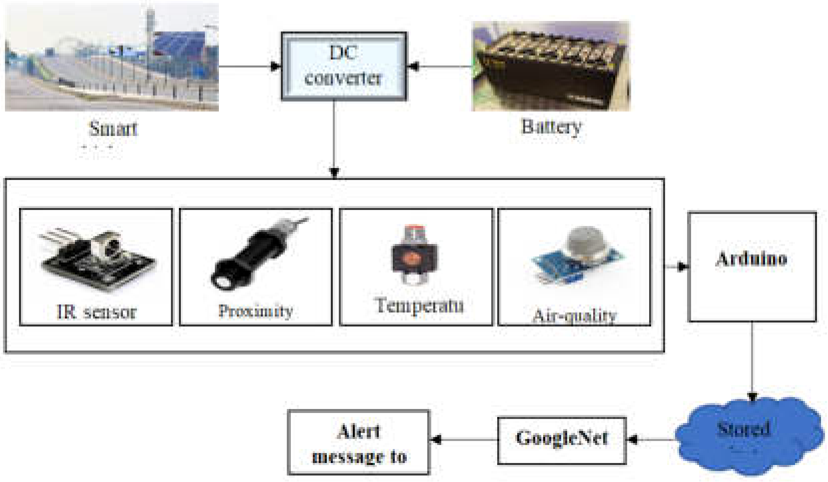

Fig. 3.1: The Workflow of the proposed Toll Google Net

Proximity Sensors. Using a proximity sensor, any adjacent object may be easily located without making direct physical touch. It detects the existence of an object by simply looking for any fluctuation in the return signal after emitting electromagnetic radiation, such as infrared. Many proximity sensor types exist, including inductive, capacitive, ultrasonic, photoelectric, magnetic, and others. This specific sort of sensor is frequently utilised in applications that demand efficiency and security. This sort of sensor has several applications, including object detection, item counting, rotation measurement, object positioning, material detection, movement direction measurement, parking sensors, and others. The finest applications for proximity sensors span a wide range of sectors.

Temperature sensors. By sensing heat energy, temperature sensors are useful for identifying physical changes in the highway. For the purpose of monitoring the local environment, authors employed temperature sensors. The acquired data is subsequently transmitted via Wi-Fi to the cloud for processing. All of this is done using an Android smartphone.

Air quality sensor. The monitoring and regulation of poisonous and dangerous gas emissions from companies and automobiles can be done with the help of sensors. If handled quickly, this can greatly safeguard the environment.

Arduino Uno. A microcontroller board featuring an open-source ATmega328 chip is called the Arduino Uno R3. The table has a USB connector, an on-board DC power connection, an ICSP header, a 16 MHz ceramic resonator, 6 analogue input pins, an ICSP header, and the reset button for microcontrollers. The microcontroller can support whatever it needs. The board is quite easy to use; just attach it to a computer.

Proposed Toll Google Net. The proposed Toll Google Net method extracts the data from the cloud and send alert message to tollgate using Google Net. The figure 2 illustrates the architecture diagram of Google Net.

For speed control test, alternative feature extraction strategies, were employed. The loss function was built from the cross-entropy loss that was observed through the training phase. In the case of conventional feature extraction, the cross-entropy loss converges to 0 after about 200 iterations. When Google Net is used, however, it quickly converges to zero after only about 100 iterations. This suggests that the model built using Google Net is more responsive to the extracts the data from the cloud and send alert message to tollgate. The contrastive loss function-based features are described in

$$S = \frac{1}{2}[(1 - z_q)(d(y_q^1, y_q^2))^2 + z_q\{max(0, \lambda - (d(y_q^1, y_q^2)))^2\}] \tag{3.1}$$

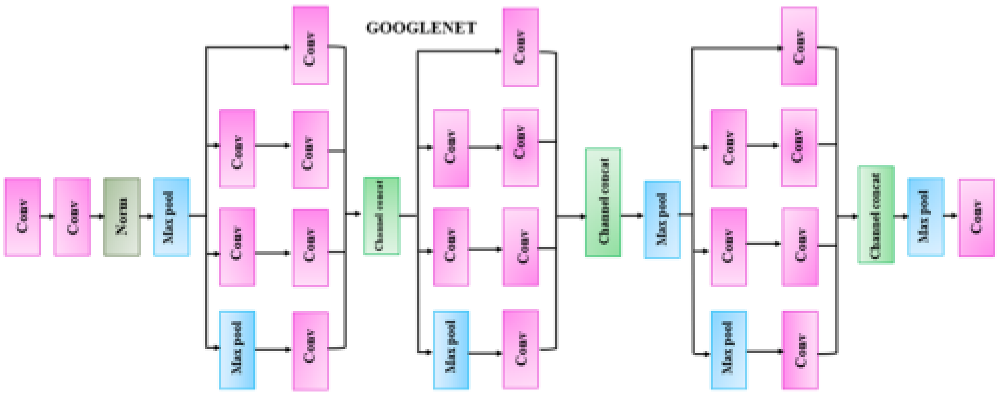

Fig. 3.2: Architecture diagram of GoogleNet

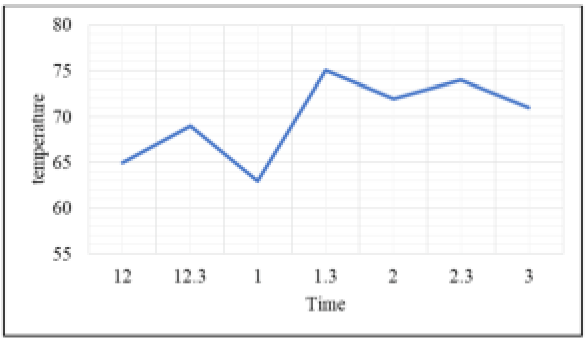

Fig. 4.1: Graph of a temperature sensor

where λ is a hyperparameter that stands for the margin and $d(y_q^1, y_q^2)$ represents Euclidean distance between y_q^1 and y_q^2. When y_q^1 and y_q^2 are members of the same class, the loss function is modest. When they are members of different classes, it is greater. Further, The margin (λ) makes sure that different image pairs are separated. The SNN encodes the features of the input H(y_k) into $G(y_k) \in R^2$.

4. Result and Discussion. The proposed system's experimental setup gathers real-time field data like temperature, air quality, IR, and proximity sensor readings. The cloud system receives these sensed instances for timely analysis. The experimental arrangement of the proposed technique based smart appliances was implemented using MATLAB. Accuracy, specificity, precision, and recall are the different metrics used to evaluate it. A comparison of the proposed technique Performance with IoT-SGE, EMS-IoT, and MODDA is made.

Figure 4.1 depicts how the temperature changes over time. There is just one temperature sensor employed, and the graph illustrates an increase in temperature value that has an impact on temperature value.

4.1. Performance Metrics. The performance analysis was calculated based on recall, specificity, precision and accuracy in this study. The region below the accuracy and recall curve for recognition is known as the Average Precision (AP). The following is the formula for accuracy and AP:

$$Accuracy = \frac{\text{True positive+True negative}}{\text{True positive+False positive+True negative+False negative}} \tag{4.1}$$

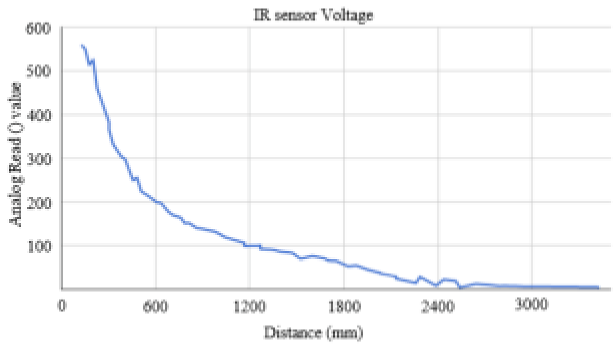

Fig. 4.2: Sensor in real distance

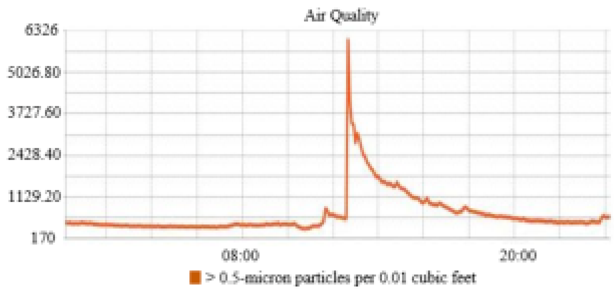

Fig. 4.3: Air quality

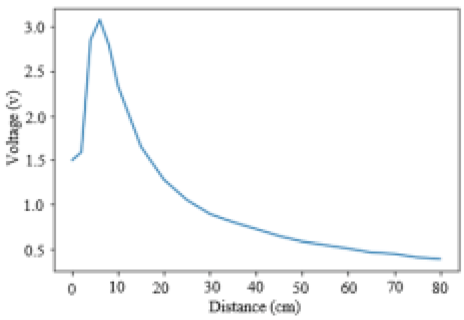

Fig. 4.4: Graphical representation of the proposed method

$$Specificity = \frac{\text{True negative}}{\text{True negative+False positive}} \tag{4.2}$$

$$Precision = \frac{\text{True positive}}{\text{True positive+False positive}} \tag{4.3}$$

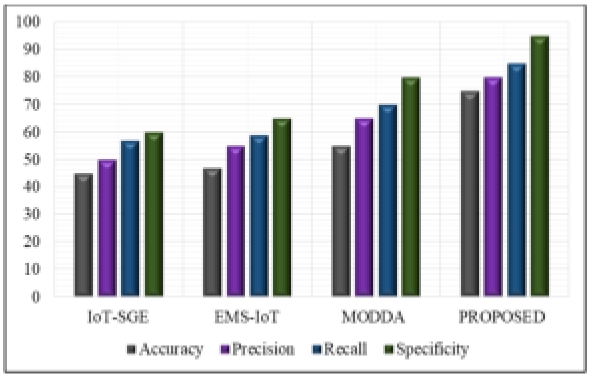

Fig. 4.5: Comparison of traditional and proposed method

$$Recall = \frac{\text{True positive}}{\text{True positive+False negative}} \tag{4.4}$$

The percentage of correctly identified labels is determined by precision, and a positive extraction of pertinent labels depends on recall. The weighted average of recall and precision is known as the F1-score. To evaluate the model's overall accuracy, it considers both false negatives and false positives. figure.4.5 shows the performance assessment of the proposed and the existing method.

As shown in fig.4.5, the accuracy of IoT-SGE, EMS-IoT and MODDA is very low. As compared to existing models, proposed provides a higher accuracy rate. Therefore, the proposed performs better than other techniques.

5. Conclusion. In this research, a novel Toll GoogleNet is proposed for smart highway. The solar panel is utilized to develop lithium battery-storage capable renewable energy. The Adafruit software, which is used to assess the pollutants and save daily usage in the cloud, is interfaced with the IOT monitoring system. The proposed system's experimental setup gathers real-time field data like temperature, air quality, IR, and proximity sensor readings. The cloud system receives these sensed instances for timely analysis. The experimental arrangement of the proposed technique based smart appliances was implemented using MATLAB. Accuracy, specificity, precision, and recall are the different metrics used to evaluate it. Experimental results shows that the proposed Toll GoogleNet attains better accuracy than existing IoT-SGE, EMS-IoT, and MODDA respectively.

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SOLAR PANEL LIFETIME DETECTION USING DEEP LEARNING NETWORK BASED ON TEMPERATURE AND HUMIDITY SENSORS

YINGHUA ZHENG* AND YUANYUAN ZHENG †

Abstract. Solar photovoltaic (PV) performance is reduced due to the increase in panel temperature. Solar PV panels must be kept at an ideal temperature to work at their peak and have the longest useful life possible. The current generation of temperature sensors has a slow response time, poor resolution, and poor accuracy. More precision, a larger dynamic range, and very high sample rates are all provided by fiber-optic sensors. This study develops a revolutionary deep learning-based method for predicting the lifespan of solar panels in order to maintain efficiency and maximise their usefulness. At first, the temperature was and humidity (TH) data are collected from the solar photovoltaic panel using the fibre-optic sensor and Sensirion SHT15 sensor. The primary device of the solar PV panel lifetime detection system is Raspberry Pi which is used to store the data collected by different sensors. These data are transferred to cloud server using Raspberry Pi. Based on the gathered data the deep learning-based Bi-LSTM network is used to detect the panel lifetime using the threshold value. Furthermore, the GSM module will notify consumers if any alterations are made to the solar panel. The efficacy of the proposed model was assessed utilising the precise criteria, such as sensitivity, accuracy, and specificity. The proposed method's accuracy of 95.2% is higher than that of conventional DL networks. By using certain measures like specificity, sensitivity, and accuracy, the suggested Bi-LSTM improves on classic CNN and LSTM by 1.78% and expands the accuracy rate range by 4.20%. The proposed method's accuracy of 95.2% is higher than that of conventional DL networks. Compared to conventional CNN and LSTM, the suggested Bi-LSTM improves overall overall trend by 4.20% and 1.78%. respectively.

Key words: Solar photovoltaic panel, Deep learning, Lifetime detection, Fibre-optic sensor, Sensirion SHT15 sensor

1. Introduction. Solar energy is among the most widely used renewable energy sources and methods of selectively capturing solar energy can be used in residential settings. Due to technological advancements in this area and its environmental friendliness, solar energy has a promising future [1]. In addition to its year-round unavailability, solar energy is also extremely expensive and it is difficult to source PV cell components. These problems can be solved by developing an efficient system to store energy and manufacturing Solar pv cells that are inexpensive, efficient, and abundant. The relatively low quality at increased panel temperatures is one of the most major disadvantages of residential solar cells [2]. Monitor heat, radiation from the sun, shadows, panel propensity, orientation, dust, and maintenance are examples of external factors that have a negative impact on the efficiency of solar panels. Monocrystalline silicon solar cells can lose up to 0.045% efficiency when temperature rises by one degree between 15 and 60 [3,4]

Thermocouples, Resistance Temperature Detector (RTD) sensors, and thermal imaging cameras are commonly used to monitor the temperature of solar PV modules. In addition to these flaws, traditional approaches are also prone to self-heating, poor resolution, nonlinear response, and slow response times [5]. Due to their Due to their resistance to electromagnetic interference, fiber-optic sensors, which have high susceptibility, wide range, and high multiplexer capability, offer a possible alternative solution. Numerous investigations have focused on the functional abnormalities associated with solar panel [6]. In recent days several frameworks were introduced by the researchers primarily to increase the lifetime of solar panel with different sensor and various artificial intelligence approaches, some of those frameworks are studied briefly in this research.

In 2019, Chaibi et al. [7] examined the current-voltage (I-V) characteristics of Si-crystalline PV modules under non-standard irradiation and temperature conditions. Each equivalent circuit model's parameters were calculated using this procedure. Then, at various levels of temperature and irradiance, the I-V curves supplied by the manufacturers and the computed I-V characteristics are compared. It is possible to achieve error reductions

*Xinxiang Vocational and Technical College, Xinxiang, Henan, 453006, China (Corresponding author, YinghuaZheng6@126.com)
†Yongji Senior Technical School of Electric Machinery, Yongji, Shanxi, 044500, China. (YuanyuanZheng7@163.com)

of 53.93% and 21.04%, respectively. In 2019 Zaimi., et al., [8] presented two methods for calculating model-physical solar panel parameters using photovoltaic metrics. The first approach establishes a critical connection between series resistance, quality factor, and photovoltaic metrics, resulting in a transcendental equation. The second way of expressing series resistance is to create an analytical expression that is based on the quality factor and key point coordinates of the series. For both approaches, To represent parallel conductance, image current, and leakage current, q - factor and all other PV characteristics must be used. An outfit deep convolutional neural network (DNN) model for the automated detection of visual flaws such as glass breaking, burn marks, snail trails, and discolouration, failure mode on various PV modules was created by Venkatesh et al. in 2022 [9].

The existing methods used to monitor the temperature of PV modules are thermocouples, Resistance Temperature Detector (RTD) sensors, and thermal imaging cameras. There are several flaws to these traditional approaches, including poor precision, nonlinear response, poor resolution, slow response time, and self-heating [10, 11]. Due to their high sensitivity, wide range, and potential for multiplexing, fiber-optic sensors offer a promising substitute strategy. FBG sensors are widely used to measure temperature and strain in distributed environments [12]. The precision of the peak detection algorithms that enable the conversion of a registered signal into temperature/strain values heavily influences the performance of FBG-based sensors [13,14]. To prevent mutual interference between nearby FBGs, an array of FBGs is frequently sparsely inscribed on a length of fibre in the spatial and spectral domains. Thus, several processing techniques can be used because it is relatively easy to discern the locations and shapes of the peaks [15]. The main contributions of the research work are summarized as follows:

- The primary purpose of this research is to designed a novel Deep learning-based solar panel lifetime prediction for sustaining performance and maximizing the productive life of solar panels.
- Initially, two different sensors such as temperature sensor and humidity sensor have been used for collecting TH data of essential parameters continuously.
- These data are transferred to cloud server using Raspberry Pi. The deep learning-based Bi-LSTM network is used to detect the panel lifetime based on the obtain threshold value the alert message is send to the user.
- The efficacy of the proposed model was assessed using the specific metrics like specificity, sensitivity and accuracy.

The rest of this work is pre-arranged as follows: section-2 describes the literature survey on neonatal cry signal, section-3 enlightens the inclusive work of the proposed methodology, section-4 narrates the experimental fallouts and discussion and section-5 encloses with the conclusion.

2. Proposed Methodology. In this section, a novel Deep learning-based solar panel lifetime prediction for sustaining performance and maximizing the productive life of solar panels.

Initially, the temperature and humidity data are collected from the solar photovoltaic panel using the fibre-optic sensor and Sensirion SHT15 sensor. These data are transferred to cloud server using Raspberry Pi. Based on the gathered data the deep learning-based Bi-LSTM network is used to detect the panel lifetime using the threshold value. The schematic representation of the proposed methodology is shown in figure.2.1.

2.1. Sensors deployed. The temperature and humidity (TH) data are gathered from two sensors namely FBG and SHT15 sensors. In optical fibers, fibre Bragg gratings (FBGs) cause periodic fluctuations in refractive index. FBG sensors are precise and adaptable thermometers. There is a microstructure within an optical fiber's core called FBG that periodically modifies the refractive index of the underlying glass material. It is possible to create fibre Bragg gratings by exposing a single-mode core of fiber that is laterally to recurring patterns of sunlight. Exposure causes the refractive index of fiber to rise permanently, causing a fixed index modulation following the exposure pattern. By examining the quick changes in panel temperature over time for both indoor and outdoor environments, the special powers of fiber-optic sensors are put on display. On-panel temperature effects of incident radiation flux and inclination angle are examined.

Figure.2.2 show that positions of FBG sensor on the solar panel where temperatures are measured. The chosen PV panels have dimensions of 480*720 mm and 240*360 mm, respectively. On both panels, the temperature is monitored at the three specified places O, A, and B. The next section presents the important findings

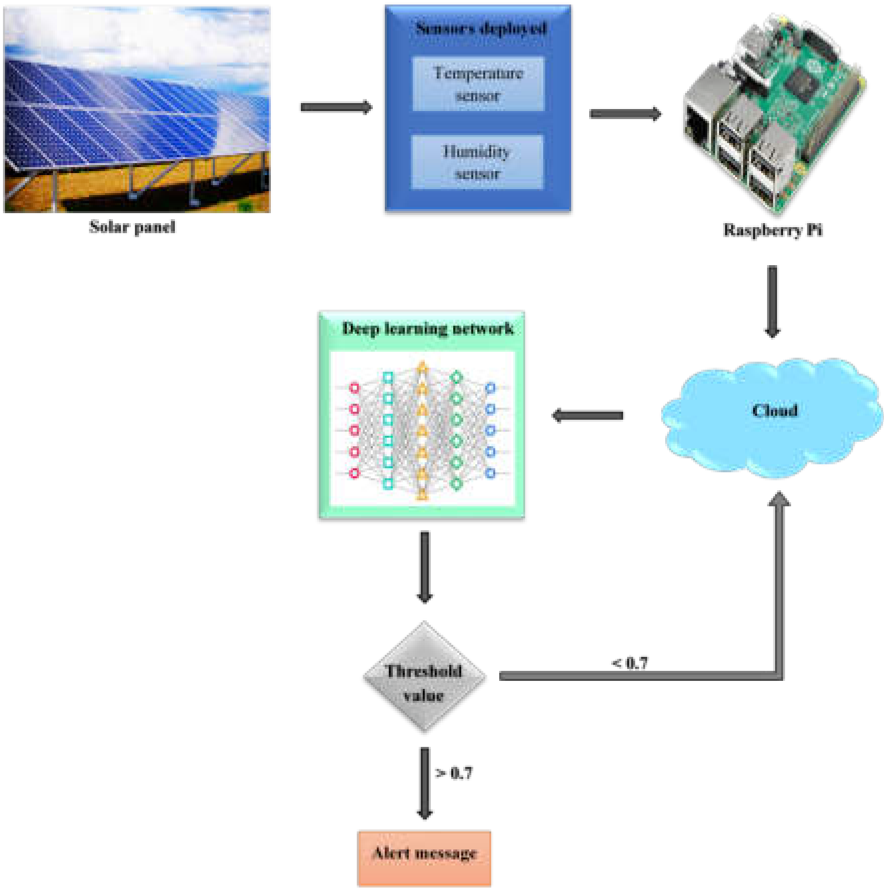

Fig. 2.1: The overall workflow of the proposed methodology

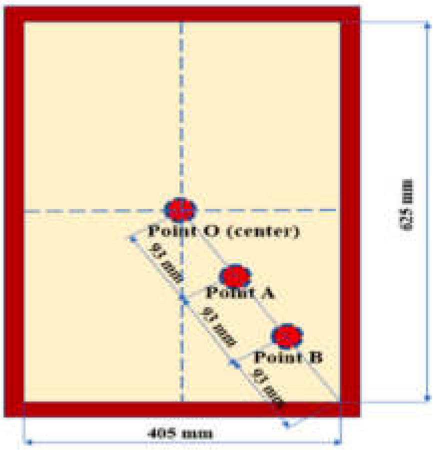

Fig. 2.2: Positions of FBG sensor on the solar panel Temperature measurements are conducted at various locations on the solar panel

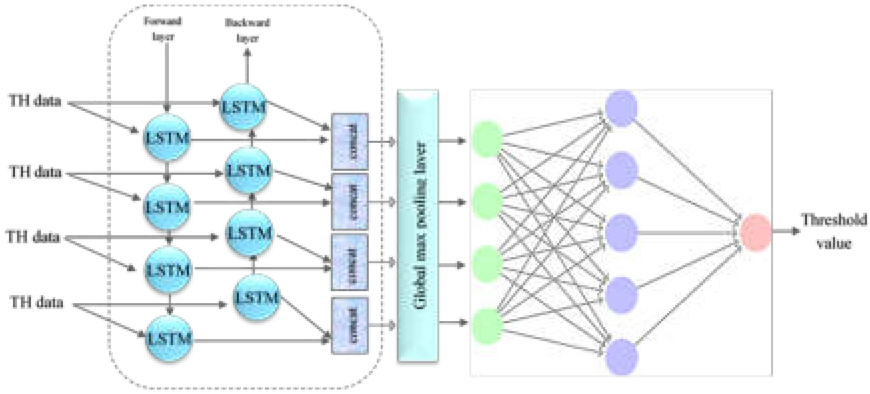

Fig. 2.3: Architecture of Bi-LSTM

from both tests. The equation states that the electrical efficiency of the PV system declines with temperature,

$$E_{eff} = E_{ref}[1 - \alpha(temp - \beta)] \tag{2.1}$$

where E_{eff} is the electrical efficiency at temperature temp, E_{ref} is the efficiency at reference temperature α and β is the temperature coefficient. The variations in temperature result in considerable losses in the amount of solar power produced over the long period. Additionally, running at high temperatures lowers the efficiency of solar panels and shortens their lifetime.

The Sensirion SHT15 sensor measures relative humidity with an accuracy of 2% in humidity and $0.3°C$. The sensor must be exposed to innately aspirated air flow in order to effectively measure humidity. To measure temperature accurately, the detector must be coloured and isolated from large temperature masses and self-heating sources. This requirement was met by encasing the SHT15 in a 2-inch PV and suspending it from the underside of the node. An electrical fault was prevented by sealing the PV interface wire hole and coating it with conformal coating.

2.2. Raspberry Pi. Raspberry Pi are used as microcontrollers in this setup. A notable feature of the Raspberry Pi is its general-purpose input-output (GPIO) interface. I/O pins are used to input and output signals. This device includes an SD card slot, a Hdmi, a composite video output, a 3.5-millimeter audio outcome, a pair of USB ports, and a Wired jack. It also includes a 700 MHz ARM BCM2835 processor. The Raspberry Pi has 26 pins, 17 of which are for GPIO (general purpose input and output). Software can be used to configure these pins for starting and stopping devices. The voltage that GPIOs can deliver is only 0V or 3.3V (low or high). The sensor data readings are stored in the cloud server via raspberry pi module.

2.3. Deep learning network. In this phase, the Bi-LSTM model was trained to detect the Solar PV panel lifetime based on the gathered TH data from the deployed sensors. LSTM is one of the RNN model capable of constructing a large-scale neural network structure. As opposed to RNN, the gradient problems are avoided by LSTM by using memory efficiently. However, in bi-directional LSTM, has input flowing in both directions, either backwards or forward differentiating it from a regular LSTM. As information propagates forward, the state of the LSTM model can only be determined based on previously processed input. On the other hand, Bi-LSTM takes both past and future data into account, allowing it to handle contextual data efficiently.

There are four main parts to the LSTM classifier: memory cell, input gate, forget gate and output gate as shown in fig.3. The input data is kept in the memory cell for a short period of time or for a long period. The Input Gate controls the amount of data, whereas the Forget Gate controls information retention in the LSTM cell. By controlling the information in the LSTM layer cell, output activation for the gate can be computed and formatted. The relationship between input, hidden states, and different gates can be derived from equations (1 to 5).

$$i_t = \sigma(weight_i * [h_{t-1}, z'_t] + bias_i) \tag{2.2}$$

$$f_t = \sigma(weight_f * [h_{t-1}, z'_t] + bias_f) \tag{2.3}$$

$$i'_t = \sigma(weight_{i'} * [h_{t-1}, z'_t] + bias_{i'}) \tag{2.4}$$

$$c_t = f_t * c_{t-1} + i_t * tanh(weight_c * [h_{t-1}, z'_t] + bias_c) \tag{2.5}$$

$$h_t = i'_t * tanh(c_t) \tag{2.6}$$

where i_t, i'_t, f_t and c_t represents the input gate, output gate, forget gate, and the cell at time t; h_t and z'_t represents the hidden vectors and input vectors at time t. At the t-th time, the input z_t from the opposite is handled by the pair of parallel LSTM layers in forward and reverse directions, and the concatenate the output. LSTMs with two parallel layers operate similarly to traditional LSTM neural networks, storing information in both directions. By employing two modes of direction, Bi-LSTM retains input data from both previous and later sequences. The output series of the first LSTM is given as an input of the second LSTM, and the output series of the second LSTM layer is the concatenated to the last units of the forward and backward layers as,

$$H_{output} = \{H_{forward}, H_{backward}\} \tag{2.7}$$

The primary function of the global max pooling layer is to extract as many features as possible from the given temporal data. A Flatten layer is typically used to transform the final feature maps into a one-dimensional array. The one-dimensional array is then used as the input of the fully connected layer. The FC layer is the feed-forward neural network, and all the neurons between layers are interconnected. By multiplying the inputs by the weight matrices and adding the bias vectors, the output of the FC layer is determined as,

$$O(z) = softmax(weight * z + bias) \tag{2.8}$$

where z denotes the input of fully connected and O(z) denotes the output of the network. The softmax layer translates the values into prospects, and the prediction layer gives the threshold value based the TH data. The primary device of the solar PV panel lifetime detection system is Raspberry Pi which is used to store the data collected by different sensors. These data are transferred to cloud server using Raspberry Pi. Based on the gathered data the deep learning-based Bi-LSTM network is used to detect the panel lifetime using the threshold value. Besides, if there are any changes inside the solar panel then users will be notified by SMS which is done by GSM module.

3. Results and discussions. In this section, the proposed approach is Based on the TH information from the deployed sensors, various measures such as accuracy, specificity, and sensitivity were calculated. The benchmark comprises the overall accuracy rate, which is explicitly specified and evaluated, as well as the proposed approach's performance. The proposed model's efficiency can be measured using the evaluation metrics specificity, sensitivity, and accuracy.

$$Specificity = \frac{TN}{TN + FP} \tag{3.1}$$

$$Sensitivity = \frac{TP}{TP + FN} \tag{3.2}$$

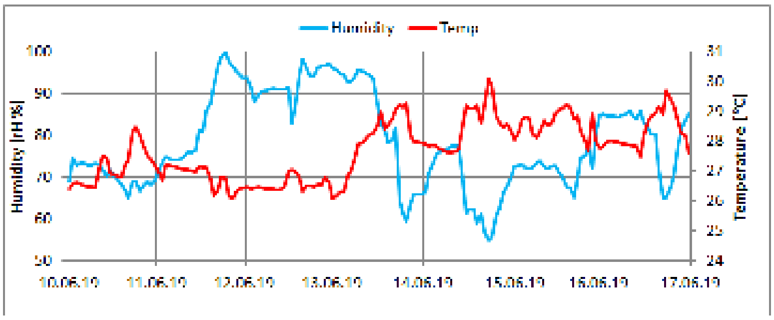

Fig. 3.1: Graphically depiction of Monthly Temperature-Humidity variation

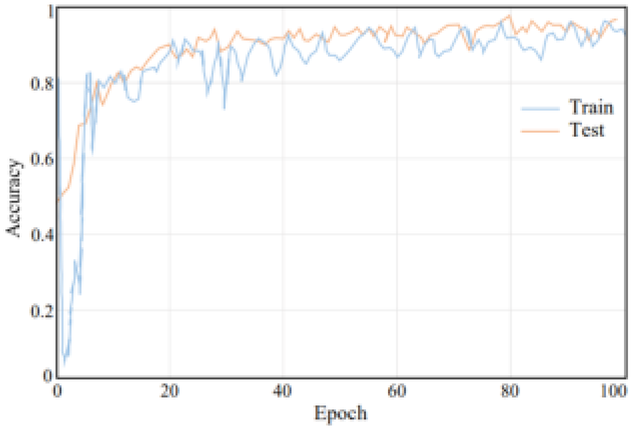

Fig. 3.2: Accuracy curve of Bi-LSTM

$$Accuracy = \frac{TP + TN}{TN + TP + FN + FP} \tag{3.3}$$

Figure 3.1 shows the monthly variation of the outdoor climatic factors. Over a one-week period, temperatures and humidity range from 25.9 to 30.2 C and 56.2 to 95.4%, respectively. The graph shows the dramatic drop in interior CO, CO2 and NO2 concentrations caused by Natural ventilation is achieved by opening doors and windows first thing in the morning. On 14.06.2021, CO concentration reduced from 5.24 mg.m-3 to 1.35 mg.m-3, Nitrogen oxides accumulation decreased from 61 g.m-3.51 to 15 g.m-3.1, and CO2 concentration decreased from 420 g.m-3.1 to 301 g.m-3.1. Increased gas concentration levels in a closed and poorly ventilated environment for an extended period of time resulted in a 75% reduction in CO, 74% reduction in NO2, and 27% reduction in CO2 as a consequence of natural ventilation. The results reveal that household activities have a significant impact on indoor air quality. Although natural ventilation has been encouraged by the system, the outside air quality has been significantly improved by its warnings.

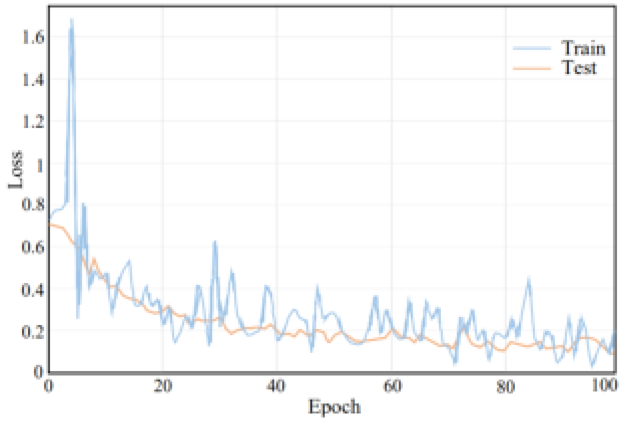

Fig. 3.3: Loss curve of Bi-LSTM

Table 3.1: Comparison between traditional networks and DRC Net

Networks	Specificity	Sensitivity	Accuracy
CNN	86.2	84.5	91.2
LSTM	85.7	84.2	93.5
Bi-LSTM	89.6	88.0	95.2

In Figure 3.2, the accuracy curve can be seen as the number of epochs on the horizontal axis and the range of accuracy on the vertical axis. As the number of epochs increases, the accuracy of the DRC net improves. Figure. displays the epoch and loss range, which shows that The disadvantage of the Bi-LSTM decreases as the epochs are increased. The proposed Bi-LSTM has a highly accurate range for identifying different cry signal classes. This study began by calculating the size of training epochs required to achieve the highest level of checking accuracy. The classification performance of Bi-LSTM was accomplished at 100 training examples by achieving the testing accuracy, according to the results of 95.2% with low error rate.

The efficiency of each Deep learning networks was estimated to show that the proposed Bi-LSTM attains high precision. A examination of the suggested Bi-LSTM with classification models like as CNN and LSTM was performed. The performance of each network was evaluated using various metrics such as specificity, sensitivity, and accuracy, as shown in table.3.1.

From table.3.1, the comparison has been performed between different approaches on basis of the specific performance parameters by attaining the best accuracy range. Moreover, the traditional networks are not achieved high accuracy compared to the Bi-LSTM. The accuracy attained by proposed method is 95.2%, which was higher than the traditional DL networks. The proposed Bi-LSTM increases the overall accuracy range by 4.20% and 1.78% better than CNN and LSTM respectively. As can be shown in Table.1, our technique is clearly superior than other methods. So, the predicted outcomes of the proposed Bi-LSTM are extremely reliable for recognizing the lifetime of the solar PV panel.

4. Conclusion. This paper focuses on introducing a Deep learning model to predict the lifetime of solar PV panel for sustaining performance and maximizing the productive life of solar panels. Initially, the temperature and humidity (TH) data are collected from the solar photovoltaic panel using the fibre-optic sensor and Sensirion SHT15 sensor. The primary device of the solar PV panel lifetime detection system is Raspberry Pi which is used to store the data collected by different sensors. These data are transferred to cloud server using Raspberry Pi. Based on the gathered data the deep learning-based Bi-LSTM network is used to detect the panel lifetime using the threshold value. Besides, if there are any changes inside the solar panel then users will be notified by SMS which is done by GSM module. The performance of the Bi-LSTM was evaluated using the specific parameters like specificity, sensitivity and accuracy. The experimental findings reveal that the proposed approach attains a better accuracy of 95.2% for detecting the life of the solar panel. The proposed Bi-LSTM increases the overall accuracy range by 4.20% and 1.78% better than CNN and LSTM respectively. In future, the advanced transfer learning networks can be used to improve the performance in lifetime detection of the solar PV panel.

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MECHANISM FOR DETECTING DOMAIN NAME SYSTEM BASED DENIAL OF SERVICE ATTACKS

SHUWEN LI*

Abstract. The Domain Name System (DNS) is a critical component of the internet infrastructure, responsible for translating human-readable domain names into IP addresses. However, the DNS is vulnerable various attacks like DNS cache poisoning, DNS tunneling, denial of service (DoS), etc. Thus, an effective attack detection mechanism is required to prevent the malicious entry in the DNS. In this article, an Elman Neural Network-based attack detection mechanism was proposed to predict the normal and malicious traffic in DNS system. The proposed model utilizes Recursive Feature Elimination (RFE) approach to extract and select most relevant features to train the ENN model. The proposed work predicts the incoming network traffic as normal or malicious based on the trained feature set. Furthermore, an alert notification module was designed to notify the administrator about the entry of attack. The proposed model was trained, tested and validated with the ICS DNS dataset and the outcomes are estimated. The developed model earned greater performances of 99.89% accuracy, 99.76% precision, 99.59% recall, and 99.68% f-measure. Furthermore, the estimated outcomes are compared with some recent optimization and deep learning-based attack detection techniques. From the comparative assessment, it is observed that the performances are improved in the proposed technique compared to existing algorithms.

Key words: Domain Name System, Denial of Service attack, Optimization, Machine Learning, Neural Network

1. Introduction. The Domain Name System (DNS) is a critical component of the internet infrastructure, responsible for translating human-readable domain names into IP addresses that can be used by computers to communicate with each other [1]. However, DNS is vulnerable to various attacks, including DNS cache poisoning, DNS amplification, DNS tunneling, and DNS hijacking [2-5]. These attacks can lead to the disruption of internet services, data theft, and other cyber-security risks [6]. To address these challenges, a DNS attack detection system can be developed using intelligent techniques. The development of a DNS attack detection system is not without its challenges [7]. One of the significant challenges is the complexity of the DNS protocol, which makes it difficult to identify malicious activity from legitimate DNS traffic [8]. Additionally, attackers use a variety of techniques to obfuscate their activity, such as DNS tunneling, which can be difficult to detect using traditional techniques [9]. Another challenge is the sheer volume of DNS traffic on the internet, making it challenging to identify anomalies and potential attacks [10]. Moreover, there is a need to ensure that the detection system does not generate false positives or negatives, which can lead to unnecessary disruption or a lack of protection [11].

Several DNS attack detection systems exist today, which employ various techniques to identify malicious activity [12]. One such system is the DNS Intrusion Detection System (DNSIDS), which uses rule-based algorithms to identify known DNS attacks [13]. Another system is the Passive DNS Replication and Analysis (PDNS), which uses a passive DNS replication technique to detect and analyze DNS traffic for anomalies [14]. Additionally, machine-learning algorithms have been employed in DNS attack detection systems, such as the DNS-Based Malware Detection (DBMD) system, which uses machine learning to identify malware communication channels in DNS traffic [15]. Moreover, the DNS-Entropy system uses entropy analysis to detect DNS tunneling activity. This approach helps to identify emerging threats more quickly and improve the overall effectiveness of DNS attack detection systems [16]. Further, a collaborative DNS attack detection framework was designed to and identify complex patterns of behavior indicative of DNS attacks [17].

Recently, the Machine Learning (ML) algorithms are used in DNS attack detection to quickly predict the malicious traffic. These ML-based techniques utilizes large amount of network traffic data to analyze the patterns of DNS attacks. This high accuracy earned by the ML-based techniques enables to share information

*Shanxi Engineering Vocational College, Taiyuan, Shanxi, China. (Corresponding author, ShuwenLi6@126.com)

across different networks securely. However, these techniques consume more time to train the system and increase the computational complexity. Although various approaches are developed to predict the DNS attacks, they face challenges like high false-positive rates, low detection probability, and increased complexity. To resolve these issues, an intelligent DNS attack detection framework was proposed in this article.

The key contributions of the research is listed below,

- An intelligent attack detection framework was developed using the Elman Neural Network to detect the DNS-DoS attack. This model utilizes the publically available ISC DNS dataset (network traffic data) for the identification of attacks.
- A Recursive Feature Elimination (RFE) technique was applied to extract and select most relevant features from the dataset. The selected feature set if fed into the ENN model for model training.
- The ENN model uses the select relevant feature set to analyze the pattern of DNS-DoS attack. Thus, the ENN classifier detects the incoming network traffic data as normal or malicious. An alert notification module was created to notify the identification of attack to the network administrator.
- The proposed technique was implemented in MATLAB tool and the results are evaluated in terms of accuracy, precision, recall, and f-measure.

The arrangement of the presented research article is described as, the recent research works related to the DNS attack detection are reviewed in section 2, the system model of the attack detection is detailed in section 3, the proposed methodology is explained in section 4, the outcomes of the proposed technique are analyzed in section 5, and the conclusion of the research is described in section 6.

2. Related works. Few recent works related to the proposed work is described below,

Ömer KASIM et al [18] proposed a novel Deep Learning (DL)-based framework for the detection of DNS flood attacks. This framework utilizes the convolutional neural network (CNN) and long short-term memory (LSTM) to provide solution for direct identification of DNS flood attacks. This model was evaluated with CICIDS dataset derived from real world data. The DL structure with LSTM achieved less low false-positive rate compared to other techniques. However, the developed model is computationally intensive and is prone to over fitting.

Minzhao Lyu et al [19] designed Machine Learning (ML)-based algorithm to identify distributed DNS attacks. This proposed model examines the DNS traffic data and highlights the incoming DNS queries, and malicious entities query scans. Further, hierarchical graph architecture is deployed to monitor DNS activity. The proposed technique provides greater performances in real-time. However, the noisy features in the traffic data affect the performance of the ML algorithm.

Naotake Ishikura et al [20] presented DNS tunneling identification approach based on the cache-property-aware features. The proposed technique utilizes the LSTM-based filter and rule-based filter to extract the tunneling features. The integration of rule-based filter attains a higher rate of attack detection. In addition, it lowers the misdetection rate and quickly identifies the DNS tunneling attack. However, it cannot detect all different types of DNS tunneling attacks.

Tahmina Zebin et al [21] Artificial Intelligence (AI)-based Intrusion Detection System (IDS) for DNS over HTTPS attack detection. The proposed model utilizes the Random Forest (RF) classifier to categorize the network traffic as malware or normal. Further, a publically available CIRA-CIC- DoHBrw-2020 dataset was utilized to predict and classify the DNS over HTTPS attacks. However, the AI-based IDS produce false positives, which refer to the detection of a threat or attack when there is none.

Randhir Kumar et al [22] presented an IDS scheme using the fog computing technology to predict the Denial-of-service (DoS) attacks in DNS system. The performance of the developed model is determined by training the RF and optimized gradient boosting system. The robustness of the proposed technique is analyzed using an IoT dataset named BoT-IoT. The utilization of RF approach in fog computing reduces the testing and training time. However, this approach is not suitable for large-scale network.

Vinayakumar Ravi et al [23] proposed automatic attack detection strategy to identify the randomly generated domain names and DNS homograph attacks with high detection rate. The effectiveness of the developed scheme was analyzed against three different adversarial attacks: DeepDGA, CharBot, and MaskDGA. The results of the developed mode are compared with most popular DL algorithms. This model attained greater detection rate of 97.16%. However, it is vulnerable to adversarial attacks.

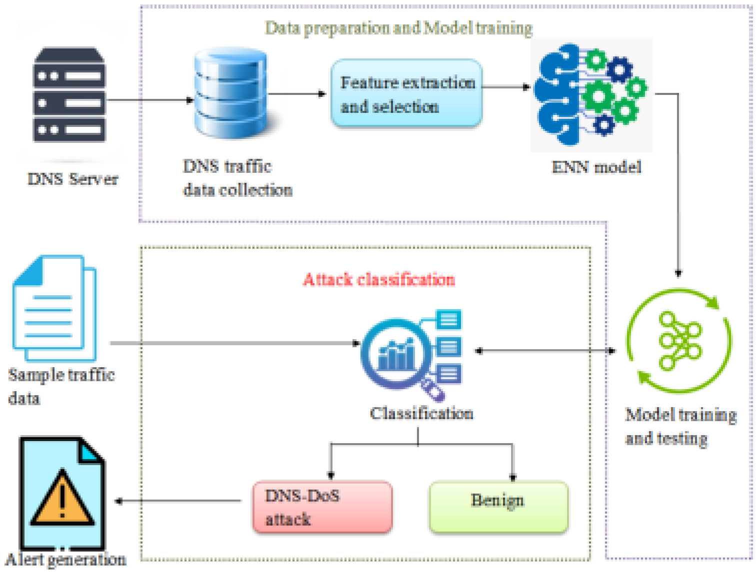


Fig. 4.1: Proposed Methodology

3. System model. The system model for DNS-DoS attack detection comprises a network of DNS servers, clients, and IDS placed in the network. The IDS monitors the DNS traffic and analyses the packets to identify any DNS-DoS attacks. The objective of the DNS-DoS attack detection system is to identify and block any DNS-DoS attacks in the network. Given a set of DNS packets, the system needs to classify each packet as either normal or anomalous. The IDS framework extracts relevant features from the DNS packets, such as DNS query rate, packet size, source IP address, destination IP address, and time of day. Then, it detects any anomalous patterns in the DNS traffic using anomaly detection algorithms such as clustering, statistical analysis, or machine learning. If an anomaly is detected, the system classifies it as a DNS-DoS attack based on a pre-defined set of rules or machine learning algorithms. Once a DNS-DoS attack is identified, the system needs to block the traffic from the identified source IP address using firewall rules or other network security measures. The system needs to send alerts to the network administrator or security team to notify them of the attack and the action taken.

4. Proposed ENN model for DNS-DoS attack detection. A novel intelligent attack detection technique was proposed using the Deep Learning (DL) algorithm. This technique utilizes the Elman neural network (ENN) to classify the DNS-DoS attacks. The presented model involves four phases namely: data collection, feature extraction and selection, ENN model training and attack classification. Initially, the network traffic data was gathered from the DNS server and fed into the system. The recursive feature elimination (RFE) approach was utilized to extract and select most relevant features from the DNS traffic dataset. Further, the ENN model was trained using the selected features for attack detection. In the classification phase, the system matches the trained attack pattern and detects the normal and DNS-DoS attack. Furthermore, the proposed model alerts the administrator to mitigate the attack. The proposed attack detection framework is demonstrated in Fig 4.1.

4.1. Data collection. The DNS-DoS attack detection mechanism begins with the data collection. In data collection phase, the network traffic data was collected from the DNS server. Capturing the network traffic data from the DNS server involves intercepting and analyzing the packets of data, which is transmitted over the network. The traffic data includes information such as source IP address, destination IP address, packet size, DNS queries, port numbers, etc. The dataset initialization is formulated in Eqn. 4.1.

$$N_{TA} = [d_{t1}, d_{t2}, d_{t3}, \cdots, d_{tk}] \tag{4.1}$$

where N_{TA} denotes the collected DNS traffic dataset, indicates the information present in the dataset, and denotes the total number of data present in the dataset.

4.2. Feature extraction and selection. Feature extraction is the process of selecting and converting the raw dataset into a sequence of meaningful features, which is utilized by the DL algorithm for attack detection. In the proposed work, the Recursive Feature Elimination (RFE) was utilized to extract and select the most relevant features. This algorithm works by recursively eliminating the least important features from the input dataset. Initially, the raw dataset was pre-processed to remove the duplicate and irrelevant information. The RFE model defines the filtered dataset as feature set to extract the meaningful features. Further, the features in the set are ranked and the feature with the lowest importance score was removed from the set. The feature extraction function is formulated in Eqn. 4.2.

$$R_{FE}(N_{TA}[d_t]) = \sum_{i=1}^{N} ||d_t(x) = d_t(\hat{x})||^2 \tag{4.2}$$

where R_{FE} denotes the RFE feature extraction function, and refers to the most relevant and least important feature present in the dataset. In this process, the most relevant DNS network traffic features like source IP address, destination IP address, protocol, request size, number of requests per second, response time, packet size, etc., are extracted. This process continues until all desired features are extracted from the dataset. The final set of features is selected for model training and testing purpose.

4.3. Elman Neural Network. The Elman neural network is a type of recurrent neural network (RNN), which is utilized in numerous applications like attack detection, time-series prediction, etc. Unlike other feed-forward neural network, which only connects the flow in one direction (input to output layer), RNN have feedback connections that permits them to utilize previous outcomes as input to the current iteration. Typically, the ENN model consists of three layers namely, an input layer, a hidden layer, and an output layer. The input layer receives the inputs to the network and the output layer provides the outcomes. The hidden layer is the main distinguishing attribute of the ENN. It consists of feedback connection from its own output to its input, enabling it to store the information from previous iterations and utilize it as context for the current iteration. The feedback connection is also termed as context layer. During training process, the input and output pairs are presented to the network and the networks output is compared to the desired output. In DNS-DoS attack detection, the ENN model was trained using the extracted relevant features of the network traffic dataset. The features like source IP address, destination IP address, protocol, request size, number of requests per second, DNS query, DNS response, etc., are fed into the input layer. To detect a DNS-DoS attack using the Elman neural network, the network takes in a sequence of feature vectors representing the network traffic over a period. The feature set fed into input layer of the ENN is expressed in Eqn. 4.3.

$$I(t) = \{f_1, f_2, f_3, \cdots, f_n\} \tag{4.3}$$

where $I(t)$ denotes the input feature set at time, indicates the extracted features, and refers to the total number of features present in the set. The network processes each feature vector and updates the hidden layer state based on the previous hidden layer state and the current input. The hidden layer of the ENN is represented in Eqn. 4.4.

$$H_i(t) = A_n(U * I(t) + W * H(t-1)) \tag{4.4}$$

where $H_i(t)$ indicates the hidden layer at time, A_n denotes the activation function, U defines the weight matrix between the input and hidden layer, and W refers to the weight matrix between the hidden layer and itself. The output layer of the ENN is expressed in Eqn. 4.5.

$$O_p(t) = R_n(V * H(t)) \tag{4.5}$$

where O_p denotes the output at time, R_n indicates the activation function, and V refers to the weight matrix between the hidden and the output layer. The training of the Elman neural network involves adjusting the

Table 5.1: Sample dataset features and its description

Feature Name	Description
query_datetime	Date and time of the DNS query
server_ip	IP address of the DNS server
client_ip	IP address of the client making the DNS query
query_name	The domain name being queried
query_type	The type of DNS query
query_class	The class of DNS query
response_code	The DNS response code
response_datetime	Date and time of the DNS response
response_ttl	The time-to-live value of the DNS response
response_address	The IP address returned in the DNS response

weight matrices U, W, and V to minimize the error between the predicted output and the actual output. The error is calculated using a cost function, such as mean squared error (MSE), and is back propagated through the network to update the weights. Thus, the system trains the model to identify the attack patterns. The classification of new incoming network traffic data is analyzed by comparing the trained attack pattern and incoming data pattern.

$$A_{CI} = \begin{cases} if(I_{dp} = T_{ap}); DNS - DoSAttack \\ else; Benign \end{cases} \tag{4.6}$$

where A_{CI} indicates the attack classification function, I_{dp} denotes the incoming network traffic data, and T_{ap} refers to the trained attack pattern. If the incoming network traffic data features match with the trained attack pattern, it is detected as attack. If the both features are not matched, it predicted as benign. Finally, an alert notification was designed alert network administrators or security personnel in real-time when an attack is detected, allowing them to take appropriate action to mitigate the attack and prevent further damage.

5. Results and discussion. A novel ENN-based attack detection framework was designed to predict the DNS-DoS attack effectively. This model utilizes the RFE approach to extract most relevant feature from the DNS traffic dataset. The ENN model was trained using the selected features to classify the traffic as normal or malicious. In addition, an alert notification module was developed to mitigate the attacks. The developed model was trained and tested with the ICS DNS dataset. The developed model was executed in MATLAB tool, version R2020a. Finally, the performances of the proposed work were analyzed and validated with a comparative analysis.

5.1. Dataset description. The ISC DNS Dataset is a publicly available dataset, which contains DNS traffic traces collected from a large number of DNS servers, including both authoritative and recursive servers. The dataset includes features like source IP, destination IP, query data time, client IP, response time, etc. The dataset was collected by the Internet Systems Consortium (ISC), a non-profit organization that supports the development of open-source software for the Internet infrastructure. The raw packet captures were collected using tcpdump and include both inbound and outbound DNS traffic. The dataset covers a period of several months and includes traffic from a variety of sources, including home networks, small and medium-sized businesses, and large enterprises. Table 5.1 tabulates sample dataset features and its description.

5.2. Comparative analysis. In comparative analysis section, the outcomes of the proposed work was compared with existing techniques like Grey wolf optimization (GWO) [24], Genetic Algorithm with Grey wolf optimization (GA_GWO) [25], Deep Belief Neural system (DBN) [26], One-Class Support Vector Machine Algorithm (OCSVM) [27], and Grasshopper Optimization (GOA) [28].

1. Accuracy. Accuracy defines the proportion of exact predictions made by the system over the total number of predictions. It measures the system capability to differentiate the normal and malicious DNS traffic accurately. The formula for accuracy is expressed in Eqn. 5.1.

$$A'_{cq} = \frac{T'_p + T'_n}{T'_p + T'_n + F'_p + F'_n} \tag{5.1}$$

where A'_{cq} defines the system accuracy, T'_p, T'_n, F'_p, and F'_n andrefers to the true-positive, true-negative, false-positive, and false-negative, respectively.

2. Precision. Precision defines the proportion of the true positive detections made by the proposed system over the total number of positive predictions made by the system. It measures the system ability to identify the malicious DNS traffic accurately. The formula for precision calculation is represented in Eqn. 5.2

$$P'_{sc} = \frac{T'_p}{T'_p + F'_p} \tag{5.2}$$

where R'_{CL} denotes the precision.

3. Recall. Recall measures the proportion of true positive predictions over the total number of actual positive instances in the data. It is a measure system capacity to detect malicious DNS traffic. The formula for recall is expressed in Eqn. 5.3.

$$R'_{CL} = \frac{T'_p}{T'_p + F'_n} \tag{5.3}$$

where R'_{CL} denotes the recall.

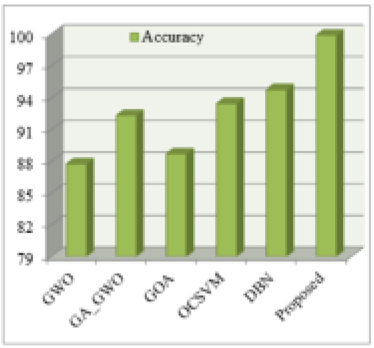
4. F-measure. F-measure represents the harmonic mean of precision and recall. It is a measure of the overall effectiveness of the system. The formula for F-measure is represented in Eqn. 5.4.

$$F_{me} = 2 \times \left(\frac{P'_{SC} + \times R'_{CL}}{P'_{SC} + R'_{CL}} \right) \tag{5.4}$$

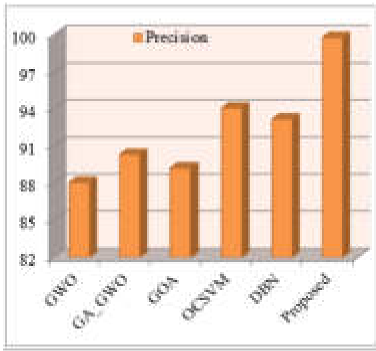
where F_{me} refers to the F-measure.

The comparative analysis is illustrated in Fig 5.1. Here, the outcomes of the proposed technique were compared with existing techniques like GWO, GA_GWO, GOA, OCSVM, and DBN. The existing techniques outcomes are estimated by implementing it in the MATLAB tool for the same ICS DNS dataset. The comparative analysis proves that the proposed model attained greater results than the existing techniques. In addition, the performance enhancement score is determined from the comparative analysis.

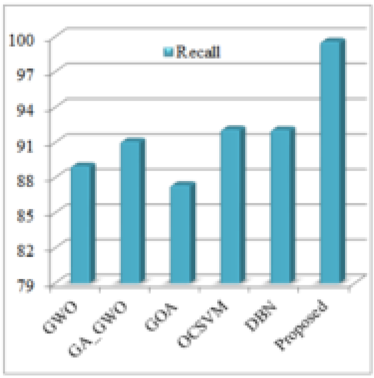
6. Conclusion. This paper presents an intelligent attack classification framework to predict the DNS-DoS attack by analyzing the network traffic data. This model utilizes the ENN algorithm to classify the normal and malicious traffic. The developed model was tested and validated with the ISC DNS dataset containing network traffic information. Further, a RFE approach was applied to extract and select most relevant features from the input dataset. In the classification phase, the ENN was trained using the selected feature set to classify the malicious traffic. In addition, an alert notification module was designed to notify the detection the attack. The developed model was executed in the MATLAB tool and the outcomes are estimated. The comparative analysis demonstrates that in the proposed technique the performances like accuracy, precision, recall, and f-measure are improved by 5.13%, 5.68%, 7.46%, and 6.39%, respectively compared to the existing techniques like GWO, GA_GWO, GOA, OCSVM, and DBN.



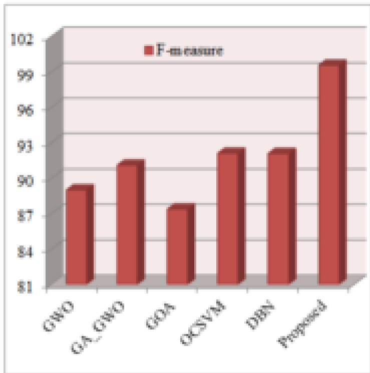
(a) Accuracy



(b) Precision



(c) Recall



(d) F-measure

Fig. 5.1: Comparative Power Generation based on Solar Forecasting Power Generation based on Solar Forecasting analysis: (a) Accuracy, (b) Precision, (c) Recall (d) F-measure

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EXPLORING THE PATH OF CULTIVATING HIGH-QUALITY APPLIED TALENTS IN THE CONTEXT OF NEW ENGINEERING BASED ON INTELLIGENT COMPUTING AND MACHINE LEARNING ASSISTANCE

YUSHENG LIN *AND CHONG CHENG †

Abstract. Since the development of domestic research on applied talent cultivation model is slow and the related theories are not perfect, further exploration and research are needed.Therefore, this paper uses machine learning and data mining technology to establish a high-quality applied talents training path generation model, and it mainly analyzes the shortcomings of current universities in training talents and the differences between applied talents and other types of talents through data mining, and finally uses the training path generation model to establish the "one three-body Finally, the training path generation model is used to establish the "one three bodies" applied talents training model.

Key words: Machine learning; Applied talents; Cultivation path

1. Introduction. In 2010, the National Medium and Long-term Education Reform and Development Plan proposed that by 2020, China's education has basically achieved modernization, basically built a learning society, and stepped into the ranks of a strong talent country. This means that the number of higher education in China will continue to grow and higher education will flourish [1]. However, with the continuous development of China's economy, the contradiction between China's talent resources and social needs has become increasingly prominent, and the structure of talents is not compatible with social development, therefore, China should vigorously promote the cultivation of application-oriented talents [2, 3].

In a word, the new engineering is a major idea of China's economic and social development, and its fundamental goal is to adapt to the requirements of industrial development. To realize the continuous optimization of industry, it is necessary to continuously optimize the disciplines, expand their contents and coverage, accelerate the construction of new engineering in China, and create favorable conditions for cultivating high-quality application-oriented talents. The development of new engineering disciplines has promoted the process of China's education reform and opened up a new situation of education reform.

2. Introduction of related theories.

2.1. Significance of New Engineering Construction. At the time when the concept of "New Engineering" emerged, the relevant education departments conducted in-depth discussions and formulated three major focuses: "Fudan Consensus", "Tianda Action", and "Beijing Guide". "Beijing Guide", and a series of initiatives have been developed to adapt to China's own characteristics and needs, to establish an education system with Chinese characteristics, and to promote the rapid development of China's education [4, 5]. The "new engineering" is a discipline with a wide range of significance, and its implementation responds to the new requirements of education development, is an important beginning of education reform, promotes the strategic development of national education, and promotes the effective transformation of industry and economic development [6, 7].

2.2. Application-oriented talent concept. The concept of "application-oriented" is a relative concept, and its relativity has two meanings: firstly, it is compared with theory and technology; secondly, the relativity of application types at different education levels and different historical stages has different connotations. Applied

*School of Electrical Engineering, Guangzhou Railway Polytechnic, GuangZhou 511300, China.
†Engineering Technology Practical Training Center, Nanjing Vocational University of Industry Technology, Nanjing 210000, China (2024101498@niit.edu.cn).

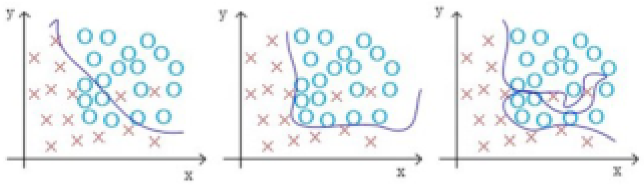

Fig. 3.1: Pre-processing simulation diagram.

talent refers to the application of the basic principles of science to create the most direct benefits for society. From the viewpoint of knowledge structure, applied talents are dominated by applied science. Theoretically speaking, applied science is a discipline corresponding to basic or theoretical science, which is closely related to people's production and life [8].

2.3. Principle of machine learning. In modern intelligence technology, data-based machine learning is an important research direction after expert system [9], which mainly studies to find out the rules that cannot be obtained by parsing method at present from a large number of observations, and use them to predict and analyze the future information. Currently, machine learning research focuses on task-oriented, cognitive models and theoretical analysis. Machine learning can be viewed as obtaining a certain output y for a given input x. Currently, many alternative machine learning algorithms are available. The first thing to do is to train the learning algorithm, that is, to learn how to classify it. In order to test the effectiveness of a machine learning algorithm, two training sets are generally needed: a training set and a test set [10, 11]. A set of training samples is used as input when the machine learning algorithm starts running, and then that sample is input again at the end of training. When the test samples are input, no classification of the samples is given and the program performs the identification.

3. Application method design.

3.1. Culture path data pre-processing. Data pre-processing is required before mining the cultivation path generation dataset, and its pre-processing simulation diagram is shown in Figure 3.1, which mainly includes the following parts.

1. Data collection: Data collection is the first link of data mining.
2. Data cleaning: It is mainly responsible for data vacancies, errors, data inconsistencies, etc.
3. Data conversion: Its main work is to convert continuous numerical attributes into discrete values.
4. Data selection: The research goal of this paper is to reduce the number of variables to be considered in the data mining process by minimizing the amount of data in data mining and finding useful feature attributes from it.

3.2. Cultivation path data mining. Once the pre-processing of the data set is completed, data mining can be performed. In order to combine the objectives and methods of the later research path exploration [12], the excavation process also addresses the current problems of our universities in the cultivation of applied talents and the differences with other types of talents. The architecture diagram of this training path data mining is shown in Figure 3.2, and the functions of the main modules are explained as follows.

1. Data collection: The correctness and validity of information collection are directly related to the determination of the cultivation program [13], the construction of indicators, and the determination of weights, which in turn affect the effectiveness of the assessment.
2. Data integration: Data from multiple files or multiple database run environments are combined and processed.
3. Data selection: The main purpose of data selection is to determine the data set to be performed and narrow down the scope of data processing so as to improve the quality of data mining.
4. Data cleaning: It solves the problems of semantic ambiguity, data loss, unclean cleaning, etc.

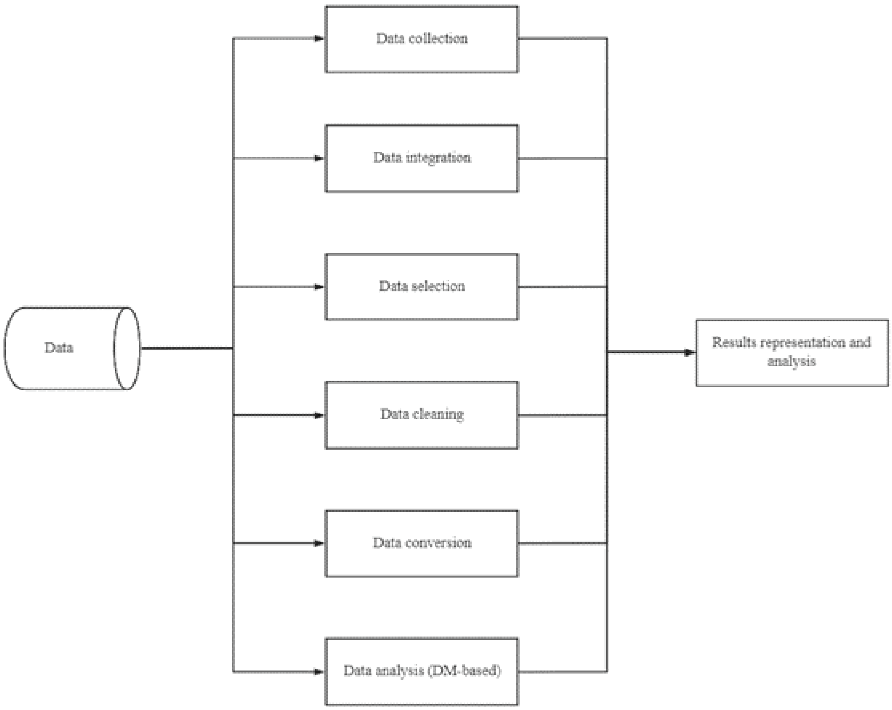

Fig. 3.2: Architecture diagram of culture path data mining.

5. Data conversion: In data coding, converting data types with different values in the database to digital format will help retrieval.
6. Data analysis: In the data analysis module, techniques and tools such as fuzzy sets, rough sets and genetic algorithms are combined to extract useful models or knowledge from the database.
7. Result Representation and Analysis: The extracted information is analyzed according to the end-user's decision making purpose and the extracted useful data is classified for the decision maker's reference.

3.3. Cultivate route generation model. The model for this road analysis includes data mining, data processing, data computation, analysis, and path analysis [14]. The core idea of the method is to use supervised learning in machine learning to achieve optimization of the model, while a hierarchical clustering method is used, which can improve the efficiency and accuracy of data mining.

1. Using supervised learning models. This time the machine learning method uses a method called supervised learning, which uses a set of labeled samples for training to obtain the best model, and then new samples are input to the model, which judges and classifies the input data, and finally the new data type is used as the basis for classification, so that the model can classify the unknown data. That is, supervised learning trains the input samples to obtain the best model results, and the model is used to analyze the test data.

2. Cultivating path generation models. In the supervised case, when the model loop is at its best, path analysis can be performed. Firstly, the original data is obtained through data mining, and based on this, the data is pre-processed and the hierarchical clustering method is used to classify the data hierarchically, and finally the best training path is obtained.

4. Application experimental analysis.

4.1. Experimental data. The data for this experiment comes from the data crawler, and data preprocessing is performed on three initial talent data sources, of which Data Source A has 5000 data, Data Source B has 3652 data, and Data Source C has 10256, whose data set source table is shown in Table 4.1.

Table 4.1: Table of data set sources.

Data Source	Time Period	Event	Number
A	2021.6-2022.6	Employment information	5000
B	2021.6-2022.6	Employment information	3652
C	2021.6-2022.6	Employment information	10256

Table 4.2: Experimental results.

Predictive Models	Classification Accuracy	Generation speed
Machine learning based culture path generation model	97.3%	500ms
BP neural network based culture path generation model	93.6%	785ms
SVM-based culture path generation model	95.5%	1500ms

4.2. Model application is experimented. After pre-processing the experimental data, we can conduct experiments to compare the analytical accuracy of the model and its analytical accuracy with that obtained by the currently used BP neural network algorithm and support vector machine (SVM) classifier model, and the results obtained from the experiments are shown in Table 4.2 below.

From the above results, it can be seen that the machine learning-based training path generation model is better than the other two models because the model uses data mining techniques to filter and classify the data before generation [15], resulting in a significant improvement in the accuracy and performance of the model.

4.3. Analysis of data mining results. After testing the generated model, data mining operation can be performed on the data set, which mainly analyzes the shortcomings of the current universities in cultivating talents and the difference between applied talents and other types of talents as reflected by the data set.

1. Problems in the cultivation of talents in China's universities. At present, China's universities are still stuck in the traditional cultivation mode, and many universities' education methods and education concepts are still in the primary stage of education. Some schools have some misunderstandings in the understanding of talents, thinking that cultivating talents is only to meet the basic needs of the society [16], while neglecting the combination of theory and practice, and Most of the traditional teaching in universities focus on theoretical teaching, thus neglecting the practical application and practical operation ability of students.

2. The difference between applied talents and other types of talents.

(1). The difference between applied talents and academic talents (as in Table 4.3).

(2). The difference between application-oriented talents and skilled talents (as in Table 4.4).

4.4. Application-oriented talent cultivation path generation. After data pre-processing and data mining, the final data set can be used for high-quality applied talent cultivation path generation operation, and finally a three-body applied talent cultivation model is generated through the model, whose structure diagram is shown in Figure 4.1.

The "One Body, Three Bodies" applied talent cultivation model mainly uses big data technology to strengthen the information exchange and collaboration among government, enterprises and universities to cultivate applied talents.

Under the "One Body, Three Bodies" applied talent cultivation model, the latest policies and information can be announced to the society through the big data platform, providing a reliable decision basis for the education and teaching work of the school. At the same time, the government can also use the big data platform to grasp the information about the training of applied talents announced by universities and enterprises, so as to better grasp the training process of practical talents, provide strong policy support for the development of applied talents in China, and promote the development of applied talents in China.

Under the "one body, three bodies" mode of training applied talents, the big data platform can maximize the information exchange between enterprises and schools, and achieve the common purpose through good communication, so that students can better apply and teachers can train. At the same time, through the big

Table 4.3: Difference between applied talents and academic talents.

Distinction Application-oriented talents	Academic	Talent
Main Tasks	Apply scientific principles or newly discovered knowledge directly to social practical fields closely related to social production life.	Dedicated to translating objective laws in the fields of natural and social sciences into scientific principles.
Knowledge Components	Consists of the knowledge system of applied science.	It mainly consists of the body of knowledge of basic sciences, such as mathematics, physics, chemistry, biology, linguistics, etc.
Job Functions	Use discovered scientific principles to serve social practice, engage in work closely related to specific social production labor and life, and create direct economic benefits and material wealth for society.	In order to explore the nature and laws of things, it is not directly related to specific social practices.

Table 4.4: Difference between application-oriented talents and skilled talents.

Distinction	Application-oriented talents	Skill-based talents
Training Objectives	Cultivating competent applied talents with innovative potential in technology and technology development is the main focus, which is reflected in technically applied talents based on general knowledge.	Cultivate practical talents who master the basic knowledge and specialized skills required by the occupation and have the comprehensive quality and professional ability to engage in a specific occupation.
Knowledge Structure	The requirement of mastering basic knowledge is high, emphasizing the comprehensiveness,systematization and scientificity of the knowledge system, requiring students to master profound professional theoretical knowledge, while also improving their scientific creativity.	The students should master the vocational skills and specialized business knowledge, and also pay attention to the improvement of their technical ability.
Competence development	The emphasis is on the cultivation of the application ability of knowledge and technology, and at the same time, the ability to apply knowledge for technological innovation and secondary development of technology should be constructed for students.	Based on mature technologies and specifications, students are trained to be competent in certain occupational positions with professional skills, techniques and application abilities, emphasizing the cultivation of students' professional abilities and professional qualities.

data platform, enterprises can be better integrated into the whole process of application-oriented talents and further deepen the cooperation of application-oriented talents, so as to achieve a seamless integration between on-campus and off-campus internship, thus improving the practicality and practicability of practical talents.

4.5. Characteristics of high-quality applied talent cultivation model. The analysis of the characteristics of the high-quality applied talents cultivation model was carried out by using the data tables fed by the data mining and generative model, and the following five aspects were derived to elaborate the characteristics of the high-quality applied talents cultivation model.

Using the information from the data mining and generative model, the characteristics of the cultivation model of high-quality applied talents are analyzed and the characteristics of high-quality applied talents are discussed in six aspects.

(1). Cultivation objectives highlighting application characteristics. Application-oriented talents with high social demands become the optimal and most necessary choice for our Applied University. Therefore, how to

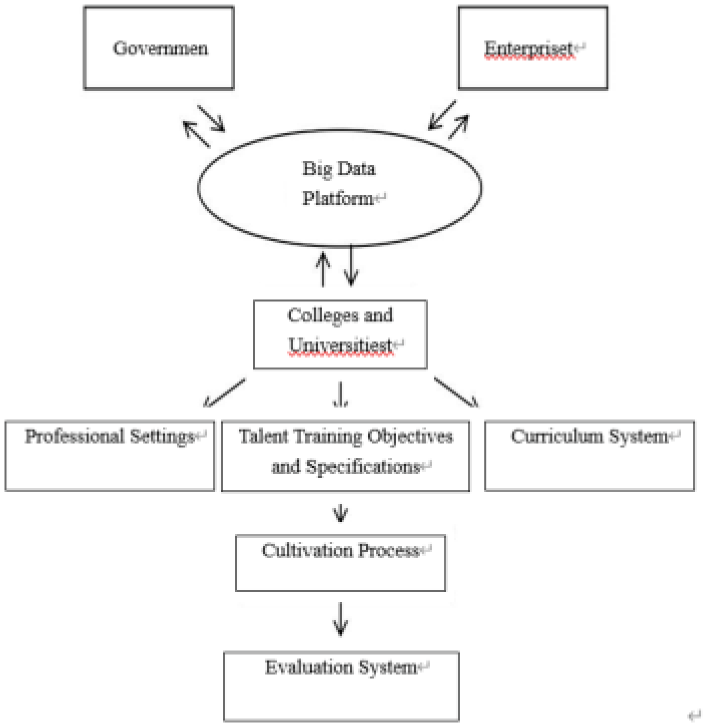

Fig. 4.1: Structure of One-Table-Three-Body Application-oriented Talent Cultivation Model.

build the cultivation mode of high quality practical talents? From the connotation of applied talents, the most fundamental characteristic of applied talents is application-oriented talents. Application is the basic feature that distinguishes applied talents from research-oriented, theoretical and technical talents. Therefore, no matter how to refine and expand the cultivation goals and standards of applied talents, the cultivation goals of applied talents should always reflect the characteristics of applied talents.

(2). Professional and curriculum settings are aligned with industry needs. The major and curriculum system is an important means to achieve the goal of talent training. Therefore, local undergraduate colleges and universities should not blindly make adequate preparation when setting up the major and curriculum system, but should fully consider the current social and economic situation, especially the development of various aspects involving the employment of talents. Local undergraduate colleges and universities should study the internal structure, demands and future development trends of different industries, and develop corresponding majors and curriculum systems according to their own schooling situation.

(3). The cultivation process highlights the theme of practice. The most fundamental characteristic of applied talents is to adapt to the needs of social and economic development. Therefore, in the whole process of implementing applied talents in local undergraduate institutions, internship is a compelling topic. Through internship, students' hands-on ability can be better cultivated, and the combination of theoretical knowledge and practical experience can be strengthened, so that they can flexibly apply theoretical knowledge to work and solve practical problems, thus reflecting the characteristics of applied talents distinct from scientific research and technology.

(4). The evaluation system presents diversification. From several aspects such as cultivation objectives, specialties, courses and cultivation procedures, the characteristics of cultivation of high-quality applied talents make its evaluation system present diversified characteristics. It includes diversification of assessment objects, diversification of assessment contents, diversification of assessment methods, etc.

(5). Dual-Teacher Teacher Team. The teacher team is an important guarantee of university education, and the cultivation of different professionals requires different requirements of knowledge, skills and experience. For example, teachers engaged in scientific research must have rich theoretical knowledge and abundant research experience, while those who are compatible with the cultivation of technical talents must have certain technical skills and abundant practical experience.

To comprehensively promote the construction of curriculum thinking and politics is a strategic measure to implement the fundamental task of establishing moral education. The construction of curriculum thinking and politics integrates value shaping, knowledge imparting and ability cultivation, integrates value guidance in knowledge imparting and ability cultivation, and helps students to shape correct world view, life view and value, which is an important task to comprehensively improve the quality of training applied talents.

5. Conclusion. With the development of society, the development of education has become necessary for a country to cultivate talents, while the new engineering has great advantages over the traditional engineering, which pays more attention to the innovation and practical ability of talents. Therefore, this paper constructs a research model of training pathways for applied talents based on artificial intelligence and machine learning. This paper introduces data mining and machine learning technology into the path analysis, so that the data talent information can be transparent, and uses the cultivation path generation model to build "one three-body" applied talent cultivation model, and analyzes the characteristics of high-quality applied talent cultivation model through the data feedback from data mining technology. In conclusion, the development of new engineering has injected new vitality and vigor to the rapid development of China, and high-quality applied talents are the key to economic development.

Data Availability. The experimental data used to support the findings of this study are available from the corresponding author upon request.

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THE APPLICATION OF COMPOSITION TECHNOLOGY THEORY IN COLLEGE MUSIC TEACHING BASED ON EDGE COMPUTING UNDER DIGITAL PLATFORM

XIN FENG *

Abstract. This essay examines how music theory is used in college and university music education to help students become more adept at analyzing and understanding a wide range of acoustic activities. In this research, we leverage the benefits of edge computing and digital platforms to create a compositional network structure for diatonic composition using the Markov model, two-way gated recurrent neural network, and curve fitting. This paper's network architecture initially creates a Markov model to generate motivic melody for creating compositional knowledge rules. This model offers broad starting conditions for creating subsequent algorithmic compositions. Next, the style of the automatically gathered MIDI composition dataset is learned using a two-way gated recurrent neural network that can extract contextual note sequence information in order to create a prediction model. The test set achieves an accuracy of 88% on the proposed model by comparison experiments. The prediction model combines the input motivic melody to generate a one-part composition melody. At the same time, on the basis of the one-part composition melody, the relationship between the melodies of the two composing voices is studied, and a curve fitting method is used to model the two-part melody.

Key words: Digital platform; Edge computing; University music teaching; Technical theory of composition

1. Introduction. As music education in colleges and universities advances, interest in music composition has grown. Learners and composers are now focused not just on performing pieces but also on understanding and processing music at a deeper level [1, 2]. For music learners, it is essential to analyze and accurately master a work before performing it according to its stylistic requirements. Meanwhile, college music teachers need to continuously improve their theoretical knowledge to adapt to the increasingly diverse educational concepts of today [3, 4].

In the digital age, theoretical research on composition techniques in university music teaching must leverage digital platforms and technologies like edge computing [5]. While automatic computer composition has been explored using various machine learning methods, challenges remain. Although computer-generated music can sometimes mimic human compositions, over time, its machine-like features become apparent, diminishing the human-like qualities [6, 7]. This issue arises mainly due to the loss of musical structure and sequences that conflict with human auditory perception. To address this, automatic composition models should incorporate music's inherent structural rules, repetition, and emotional nuances, rather than just focusing on note sequences [8].

Algorithmic composition can be classified into two main categories: rule-based composition, which relies on specific musical knowledge, and machine learning-based composition, which learns composition rules through algorithms [9]. Initially, most researchers favored the rule-based approach, as it offered logical organization and clear explanations for musical behavior [10]. However, this method has limitations: music is subjective, making rule formulation challenging, and models trained this way are often genre-specific, limiting their versatility [11, 12]. For instance, the expert system CHORAL, constrained by over 350 rules, can only emulate the style of Johann Sebastian Bach.

Machine learning and deep learning methods offer greater adaptability and versatility, as they do not require extensive musical rule formulation, lowering the barrier to composition [13]. This paper focuses on the second approach, which simplifies the composition process and reduces the need for deep theoretical knowledge [14].

However, while edge computing-based methods ensure musical structure by following predefined rules, the need to manually develop numerous rules for different styles increases labor costs and contradicts the goal of

*Tianjin Conservatory of Music, Tianjin, 300000 China (fengxin1018@outlook.com).

achieving simplicity and efficiency in computer composition.

Thus, this study aims to explore a more straightforward and effective composition model and algorithm optimization path for applying composition technology theory in university music teaching under a digital platform.

2. Theoretical Model of Composition Technology Supported by Edge Computing. The musicVAE model is designed to simulate the music composition process by encoding and decoding musical sequences through a variational autoencoder architecture. This section details the specific parameters, training process, and hyperparameter adjustments used to optimize the model.

Model Architecture and Parameter Settings.

Encoder: The musicVAE model utilizes a two-layer bidirectional LSTM (Long Short-Term Memory) network as the encoder. Each LSTM layer contains 512 hidden units. The bidirectional nature of the encoder allows it to capture contextual information from both the forward and reverse directions of the musical sequence.

Latent Space: The latent space, also known as the "implicit code," is represented by a vector of 128 dimensions. This size was chosen to balance the trade-off between capturing sufficient information and maintaining computational efficiency.

Decoder: The decoder is a hierarchical LSTM network with a similar structure to the encoder. It consists of two layers, each with 512 hidden units. The hierarchical design ensures that the latent code information is consistently utilized during the decoding process, enabling the generation of coherent and contextually relevant musical sequences.

Training Process:

- Dataset: The model was trained on a large dataset of MIDI files representing various genres and styles of music. The dataset was preprocessed to normalize the length and structure of the sequences, ensuring uniformity in the training samples.
- Loss Function: The training process employed a combination of the reconstruction loss and the KL-divergence loss. The reconstruction loss measures the difference between the original and reconstructed musical sequences, while the KL-divergence loss ensures that the latent space distribution remains close to a standard normal distribution.
- Optimization: The model was trained using the Adam optimizer with a learning rate of 0.001. The learning rate was selected after several experiments, showing the best balance between convergence speed and model stability.

Hyperparameter Tuning:

- Batch Size: The batch size was initially set to 64 and later adjusted to 128 to improve training efficiency and stabilize the gradient updates.
- Latent Dimension Size: Several experiments were conducted with different latent space dimensions (e.g., 64, 128, 256). A dimension size of 128 was chosen as it provided the best balance between model performance and computational requirements.

Dropout Rate: A dropout rate of 0.3 was applied to prevent overfitting. This rate was determined after experimenting with values ranging from 0.2 to 0.5, where 0.3 showed optimal regularization without compromising model capacity.

Evaluation and Fine-Tuning: The model's performance was evaluated using metrics such as reconstruction accuracy and musicality scores, which assess the coherence and creativity of the generated compositions. Based on the evaluation results, fine-tuning was conducted by adjusting the learning rate, latent space dimensions, and dropout rates. The model underwent multiple iterations of training and evaluation to achieve the desired level of performance.

Composing music is a creative and complex art activity for human beings, and it requires knowledge of basic music theory, harmony, polyphony, orchestration and composition structure, etc. How to use computers to simulate the composer's creation process and make the computer-generated compositions closer to the musician's real creation is a problem worth exploring. musicVAE is based on variational self-encoder, and the specific The structure is shown in Figure 2.1. Firstly, two layers of bidirectional encoder are used to encode music, then the implicit layer states in two directions of forward and reverse order are connected to get the implicit code", and

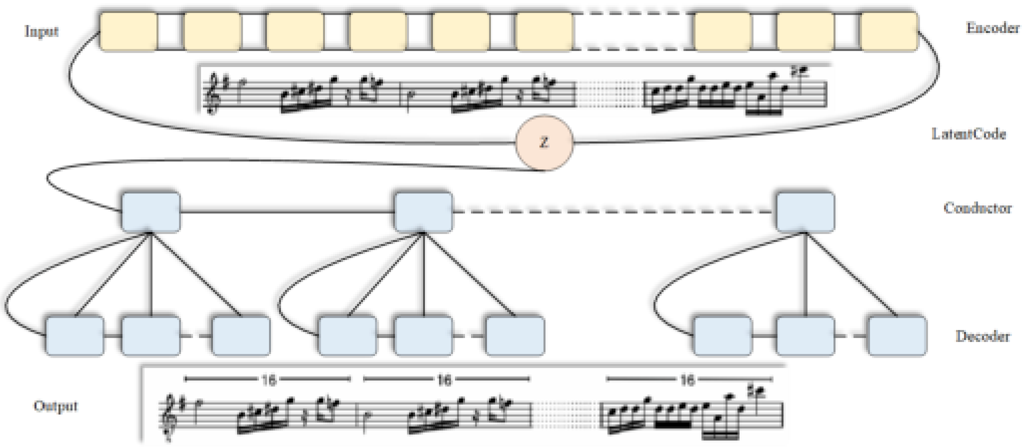

Fig. 2.1: MusicVAE architecture design.

finally a decoder is used to decode the implicit code" into music. To ensure that the information of the hidden code is always utilized in the decoding process, the decoder adopts a hierarchical design.

In the mathematical model of this study, we need to resort to the Markov model of compositional architecture, which is a relatively common mathematical statistical probability model used for sequence prediction. It is widely used in speech detection and recognition, text generation, personalized recommendation, user behavior analysis, image processing, etc. It is one of the important choices for many sequence generation problems due to its simple design and high computational efficiency [15]. The probabilities associated with different state changes in Markov models are called transfer probabilities. Suppose the sequence of states at time is j and the sequence of states at timets is j . From the definition of Markov model, it is known that the state at time is only related to the state i at time t1x, and the transfer probability is described by the mathematical formula as:

$$p_{ij} = p(i \rightarrow j) = p\left(x_t = j \mid x_{t-1} = i\right) \tag{2.1}$$

$$P = \left[p_{ij}\right]_{k \times k} = \left[\begin{array}{cccc} p_{11} & p_{12} & \cdots & p_{1k} \\ p_{21} & p_{22} & \cdots & p_{2k} \\ \vdots & \vdots & & \vdots \\ p_{k1} & p_{k2} & \cdots & p_{kk} \end{array}\right] \tag{2.2}$$

1. Matrix P:This is a k × k square matrix, representing a matrix with k rows and columns.
2. The element y in the p-matrix P is located in the jth column of the row, where the values of i and j range from $1 < i$ and$j < k$.
3. The first row of the matrix structure is composed of elements p_{11}, p_{12} ,p_{1k} . The second row is composed of elements p_{21}, p_{22}, p_{2k}, and so on, until the kth row is composed of elements p_{k1}, p_{k2}, p_{kk} .

This matrix P can be used in many fields, e.g: Linear transformations in linear algebra; Covariance matrices in statistics; Tensor representations in physics; The adjacency matrix in graph theory. The exact meaning depends on the context in which the matrix P is defined.

In the above equation, k denotes the total number of states and $P_{ij}\,(i, j = 1, 2, 3..., k)$ denotes the probability that the transition from the current state i to the next state j should satisfy.

$$0 < p_{ij} < 1 \tag{2.3}$$

$$\sum_{j}^{k} p_{ij} = 1 \tag{2.4}$$

Table 2.1: Theoretical scale structure of composition technology in college music teaching of different modes.

Mode	Scale structure
Uterine mode	2 2 3 2 3
Commercial mode	2 3 2 3 2
Mi-sol-la-do-re	3 2 3 2 2
Overtone	2 3 2 2 3
Feather mode	3 2 2 3 2

Table 2.2: Spin method of pentatonic mode.

Phonetic column name	Interval relation	Phonemic combination
B tone array	Large second degree+small third degree	Re,Mi,Sol,So,La,Do
C-tone array	Minor third degree+major second degree	Mi,Sol,La,La,Do,Re

According to the Markov process with no posteriority and the Bayesian conditional probability formula, the underlying logic of the compositional model is:

$$\pi(k) = \pi(k-1)P \tag{2.5}$$

This study will use this mathematical model as a foundation for applying compositional tone set theory concepts to the construction of motivic melodies through the fusion of folk musical elements. Through the collection and analysis of many folk song genres, we have discovered that one of the primary elements composing the melodic style of folk songs is certain sets of pentatonic triads. These triads run continuously through the piece's melody, and as the melody moves forward, various combinations of triads—which together constitute various thematic colors—make the melody present a variety of stylistic elements, much like how Western music modulates the musical structure. It contributes coherence to the music's structure. The pentatonic modes can be divided into five modes: Gong, Shang, Horn, Zheng, and Fe, each of which is composed of different triads. The scale structure of the different modes is shown in Table 2.1.

From the standpoint of interval analysis, "2" denotes the relationship between adjacent levels in the relationship between the five pentatonic scales. There are differences in the internal structure of the five scales with different pitches of the dominant tones: Gong, Shang, Horn, Zheng, and Fe. These correspond to the five pitches arranged in the numerical notation of the simple score as "1", "2", "3 ", "5", and "6". "Gong" and "Shang," "Shang" and "Jiao," "Zheng" and "Zheng," and "Zheng" and "Fe" have the main diatonic relationships. A small third relationship between adjacent levels is indicated by the letter "3". This relationship primarily exists between "horn" and "sign", as well as "feather" and "palace" and "Gong". The intervals that can occur between the intervals are three major seconds, one major third, two minor thirds, four pure fifths, and major second and minor third relationships. These interval relationships form the tritone row that is the basis for the melodic progression of the pentatonic mode.This pentatonic rotation we can divide into the following categories, as shown in Table 2.2.

The template of the above tonal column will appear frequently in the melodies of traditional Chinese folk music, constituting different melodic colors. The internal structure of the various modes in the technical theory model of composition we created for teaching music in colleges and universities is different. While the folk tuning will avoid the tonic fa and si and commonly use the tone-column melody, with fa and si rarely appearing in the strong tones, the Western tuning of Western music will follow the scale, not avoiding the tonic fa and si and frequently using the scale melody, which will bring in the tonic fa and si naturally. In Western tuning, the harmonic function is obvious, and the chord structure is emphasized more in the melody, while in traditional Chinese folk music, more emphasis is placed on the tone series, and there are some surrounding tones in the melody, often perceptually a piece will have a "national flavor", and this national flavor rationally means that the tone series will be used frequently, as shown in Table 2.3.

Table 2.3: Division structure of pentatonic modes.

Mode name	Structure
Uterine mode	A+B structure
Commercial mode	B+C structure
mi-sol-la-do-re	C+A structure
Overtone	B+B structure
Feather mode	C+C structure

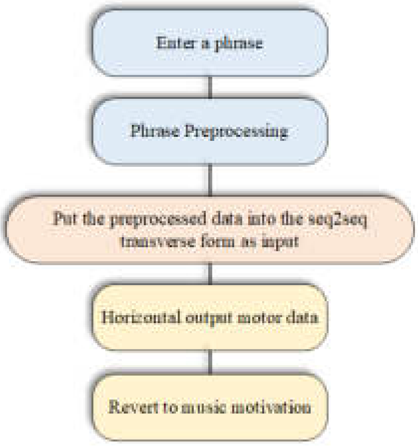

Fig. 2.2: Theoretical Model of Automatic Extraction of Music Motivation by Composing Technology in College Music Teaching.

The basis for conducting a structured generation of melodies from theoretical models of composition techniques in university music teaching is the need for a large number of musical motivation datasets as a basis for generating melodies. Since there is no previous research in this direction, there is a lack of musical motivation data sets. In order to accomplish this task of melody generation, it is necessary to rely on computers to extract a large number of musical motives from the currently available musical datasets. so a model for automatic extraction of musical motives is constructed in this paper. The flow is shown in Figure 2.2.

As shown in the flowchart, for the phrase sequence that needs to extract the motive, the first pre-processing is done to convert the phrase sequence into one-hot encoding, and then the encoding is put into the trained SEQ2 model, and the model predicts the current sequence encoding to get the musical motive encoding, and finally the encoding is reduced to the musical motive to achieve the final output effect of the composition technology model in college music teaching.

3. Methods.

3.1. Dataset and Model Runs. The dataset used in this paper comes from the Bach four-part choral corpus provided by the Python open source library. Bach, a great musician and composer of the Baroque period, wrote many four-part choral cantatas in counterpoint, each of which has a strict four-part structure with the main melody in the upper voice. Fig. 3.1 shows a fragment of the Bach Chorale BWV 334. There are 352 works in the JSB Chorale, and we expanded the dataset by transposing all works in a predefined range, resulting in 2503 cantatas. And the relationship between training set and test set will be divided by 8:2 ratio.

From a deep learning and edge computing perspective, for an input sequence of notes $(\omega_1, \omega_2, ..., \omega_n)$, the language model is modeling the probability distributionof the sequence, $P\omega$ indicating the probability of the existence of this sequence. Denote the deep learning model with parameters as $P_\theta\omega$. To make $P_\theta\omega$ approximate $P\omega$, a common approach is to maximize the objective function using stochastic gradient descent $\sum_i logP_\theta\left(\omega^I\right)$

Fig. 3.1: Bach's Praise BWV334.

Table 3.1: Discretization result of four part banknote sequence.

70	70	70	70	69	69	69	69	67	67	67	67	67	67	67	67
62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
54	54	55	55	55	55	54	54	58	58	58	58	58	58	58	58
50	50	50	50	50	50	50	50	43	43	43	43	55	55	55	55

. However, modeling the joint probability distribution of variables is usually difficult, so the model $P_\theta \omega$ needs to be transformed into an easily solvable form, which can be obtained by the chain rule as:

$$P\left(\omega_1\right) P\left(\omega_2 \mid \omega_1\right) \ldots P\left(\omega_n \mid \omega_1, \ldots, \omega_{n-1}\right) \tag{3.1}$$

The above formula can be used as a preprocessing of the data set, and the one-way language model deals with the prediction problem, where the first n-1 words are used to predict the nth word. On this basis, the technical theory of composition in college music teaching relies heavily on cyclic repetition to build structure, and such autocorrelation is evident on multiple time scales. Therefore, in order to generate longer music fragments, melodic repetition, i.e., information extraction at different time scales, needs to be considered. The pooled attention mechanism proposed in subsection III is the core of the multi-scale Transformer automatic composition model proposed in this paper. The multi-scale Transformer model is constructed by applying pooled attention instead of self-attention to capture the autocorrelation of music at different time scales, as shown in Fig. 3.2.

The elements of the matrix are integers that represent the MIDI pitch value of the note being played, and the number of consecutive repetitions of the same number indicates the note length. Since the note with the smallest temporal value in the data set is the sixteenth note, the temporal resolution is chosen to be the sixteenth note, i.e., the quarter note (one beat) is discretized into four identical sixteenth notes. Table 3.1 shows the discretized four-voice choral music.

The selected dataset has a set of metadata corresponding to each note sequence of each voice part, including four types: sustain note, beat, key number and voice part number. Table 3.2 shows the metadata corresponding to the first note sequence. The first row indicates the presence or absence of sustain in the note at the corresponding position, marked with a Boolean value; the second row refers to the discrete notes corresponding to the sixteenth notes of a quarter note, marked with 0, 1, 2, 3 cycles; the third row specifies the key number; the fourth row indicates the serial number of the voice part to which the metadata belongs, marked with 0, 1, 2, 3 for each of the four voices The fourth line indicates the part to which the metadata belongs, and the four parts are marked with 0, 1, 2, 3 respectively.

3.2. Optimization algorithm to capture relative information. In this paper, we use a modified Transformer decoder unit, as shown in Fig. 3.3. The Transformer unit contains only two sub-layers. The use

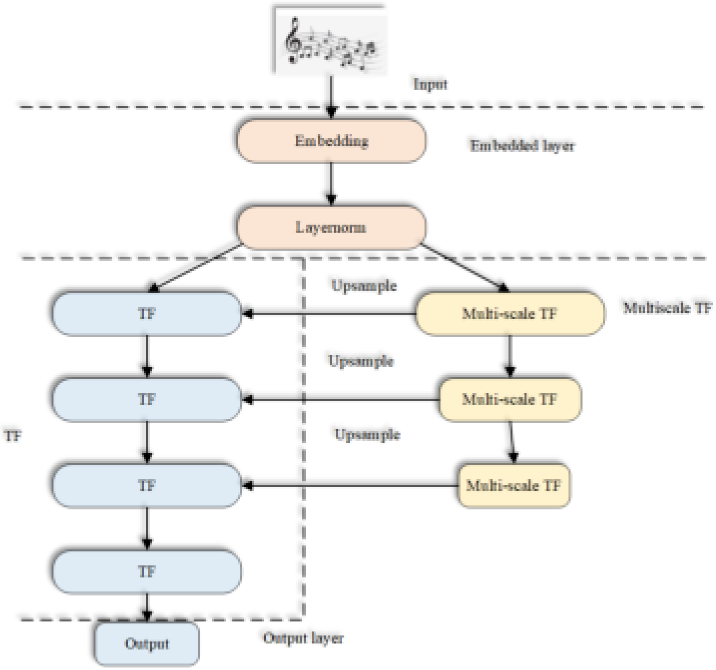

Fig. 3.2: Multi scale based automatic composition model for music teaching in colleges and universities.

Table 3.2: Metadata discretization result.

0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0
0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

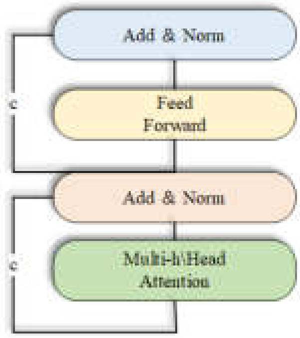

Fig. 3.3: Translated decoder unit.

of masked attention allows masking future information so that the Transformer only focuses on information from the current and previous moments. When applied to the automatic composition task, the relative position information between notes is also taken into account, so the attention mechanism used in the Transformer part adds a relative position representation.

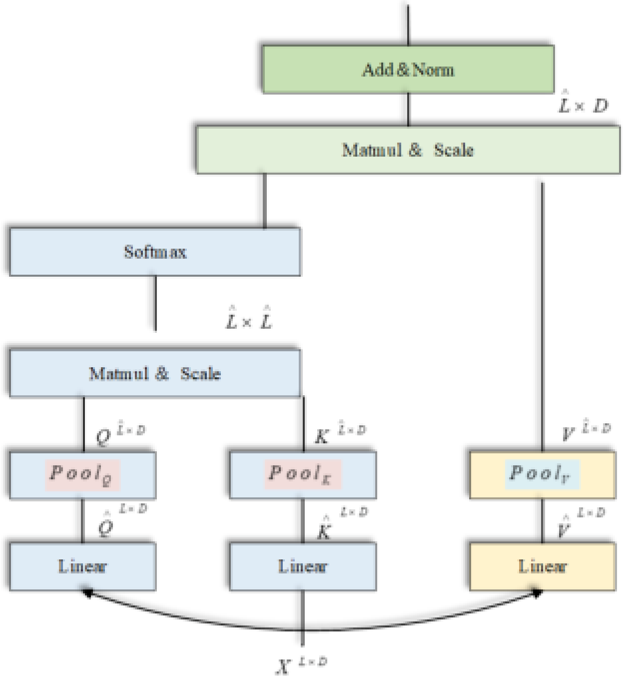

Fig. 3.4: Operation Model of Pool Attention Mechanism of Composing Technology in College Music Teaching.

To capture more relevant information, this section captures relative information in the metadata by extending the relative position representation. Since music has multiple attributes, such as time, pitch, instrument, etc. Therefore, in the model, the relative embedding of time and pitch is represented by R_t and R_p, where R_t indicates how many different sixteenth notes are between two positions and R_p indicates the difference in pitch values between notes at two positions. Therefore, the matrix representing the relative distance between any two vectors is rewritten as $S_{rel} = Q\left(R^{\top} + R_t + R_p\right)$.

The core of the multi-scale Transformer proposed in this paper is the multi-head pooling attention (MHPA) mechanism, which is a self-attentive operation mechanism that allows the Transformer unit to flexibly vary the resolution after replacing the MHA in the Transformer with MHPA. MHPA reduces the length of the sequence to be processed by pooling the input sequence. Fig. 3.4 illustrates the operational flow of the pooled attention mechanism.

In summary, the pooling attention is calculated as shown in (8) and (9). The experiments are taken,The optimization equation is obtained as:

$$Q = \left(\hat{Q}; \Theta_Q\right), K = \left(\hat{K}; \Theta_K\right), V = p\left(\hat{V}; \Theta_V\right) \tag{3.2}$$

$$PA(Q, K, V) = Soft\max\left(\frac{QK^{\top}}{\sqrt{d_k}}\right) V \tag{3.3}$$

The final output of multi-head pooled attention is obtained by considering h heads computed in parallel, each head computing pooled attention on a non-overlapping subspace of dimension D/h , and then concatenating the output results and performing one more linear transformation.

As shown in Fig. 3.5. In the training phase, G_i was trained jointly with D_i , and G_i was updated once after each K training sessions D_i , as described in the previous subsection. $K = 1$ was taken in the experiment.

The idea of GAN is also introduced after training to improve music by means of adversarial learning. Generative and discriminative models are constructed separately for each voice, with the same model structure

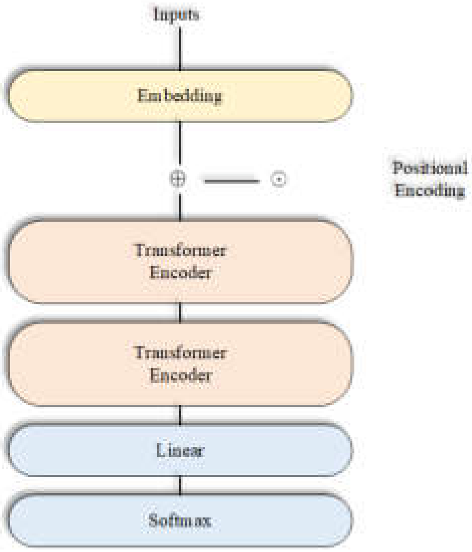

Fig. 3.5: Distinguishing Network Structure.

Table 3.3: Pseudocode for optimization of composition technology model in music teaching in colleges and universities.

Algorithm 3:	Generation algorithm 2 when training GAN
Input:	Four part note sequence V^i with length T, metadata M^i , probability distribution $p_\theta^i, i = 1, ..., I$ iteration number M
Output:	I-part note sequence V^i
1	Random initialization with uniform distribution V^i
2	For m from 1 to m do
3	Randomly select time point $t, t \in \{1, ...T\}$
4	Generate new value of V_t^i from $p_\theta^i \left(V_t^i \mathrm{I} V_{/i,t}, M^i\right)$
5	End fol
6	Return V^i

but no shared parameters. The generative model is a modified DeepBach, and the discriminative model. The pseudo-code of the generative algorithm using GAN to train the model corresponding to one voice part, using real data for the other three voices, and using G_i generation V^i is shown in Table 3.3.

The composition model studied in this paper is output in the form of probability distribution, so it is necessary to explain the sampling algorithm. V_t^i A more straightforward approach is to select the one with the highest probability, but in practical tests it has been found that this sampling approach leads to a lack of variation in the music. Therefore, this paper uses a combination of temperature sampling and top-p sampling. Fig. 3.6 shows the flow from the model output probability distribution to the sampling to get the notes.

In fact, two baseline models are trained in this section to compare with the model proposed in this paper in terms of objective metrics, as well as to compare the improved DeepBach model with DeepBach, in order to compare the multiscale design and the efficacy of relative time and relative pitch information addition. Subjective voting is used to assess the many models created by subjective experiments, which remain the best option for evaluating the generated models. Subjective voting is used to compare the musical compositions produced by various models in terms of quality.

Each model is trained separately for each of the four voices and abbreviated as S, A, T, B. Following the

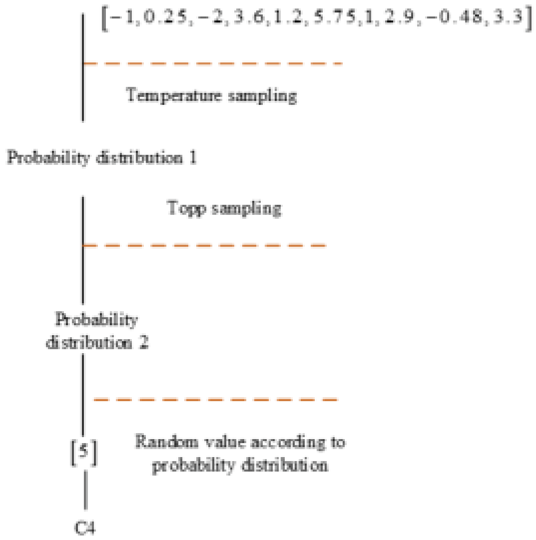

Fig. 3.6: Sampling Process of Composing Technology Model Dataset in College Music Teaching.

Table 4.1: Results of Experiment 1.

TF	0.51/0.56/0.47/0.65	0.5475
TF_REL	0.50/0.53/0.42/0.57	0.505
MTF_FT	0.44/0.50/0.39/0.57	0.475
MTF_GAN	0.42/0.50/0.35/0.55	0.455

parameter notation of section 3, the input sequence length of the model is $T = 128$, and the word embedding dimension $emb\_\dim$ =16 during the training phase. In order to judge the quality of the music generated by the model designed, the following four experiments were designed.

4. Case study. Four experiments are conducted in this paper, the first one is to compare the NLL of each model, and Table 4.1 shows the final experimental results.

Observing Table 4.1, we can know that the experimental results of the four vocal counterpart models of MTF_GAN are better than the other three, and the second vocal model of MTF_FT also reaches the optimum. The experimental results can basically illustrate the effectiveness of the multi-scale Transformer automatic composition model combined with GAN training approach proposed. In addition, comparing the results of TF and TF_REL can also illustrate the effectiveness of adding relative time and relative pitch to the Transformer.

The second one is a manual evaluation experiment. Fig. 4.1 shows the results of each model and the original Bach compositions voted as conforming to Bach's compositional style.

In Experiment 3, we built a hidden 6-layer network connection layer in the running mode of the optimization algorithm, and output the position of GRC in the first layer, then adjust the compression vector value to the interval (0, 1), and calculate the possible probability of each note output. After 12 tests, take the average value to get the test results as shown in Table 4.2 and Table 4.3.

In Experiment 4, the prediction model trained during the composition process generates a pitch for each prediction based on the input initial sequence, as shown in Fig. 4.2.

Combining the above one-part melody, the diatonic melody generated by the diatonic melody composition method designed in this paper is shown in Fig. 4.3.

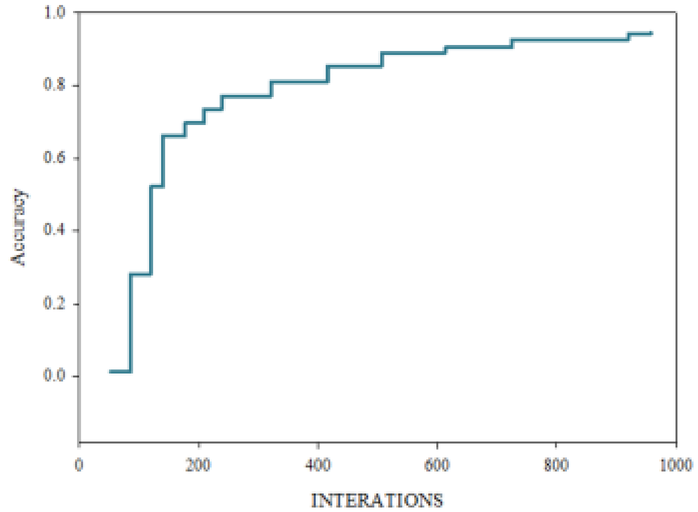

Fig. 4.1: The influence of the number of evaluation iterations on the training effect in Experiment 2.

Table 4.2: Effect of different number of neurons on accuracy in experiment 3: single layer hidden layer.

Number of neurons	128	256	512
Training set accuracy	82.39%	86.99%	97.23%
Test set accuracy	80.32%	81.39%	85.77%

Table 4.3: Effect of different number of neurons on accuracy in experiment 3 and 2 hidden layers.

Number of neurons	128	256	512
Training set accuracy	96.11%	97.47%	98.99%
Test set accuracy	84.31%	85.29%	86.53%

In this experiment, we need to further verify the accuracy and fit of the algorithm, so we will compare the composition structure optimized by this model with the relevant experiments in Google Lab, as shown in Table 4.4.

From the experimental results that, compared with other models, the algorithm model of composition technology for college music teaching designed in this paper is relatively high in F1 value, accuracy and fit, and relatively low in loss rate. Therefore, the previous experimental results can prove the excellence of our model. In addition, we also need to consider the chromatogram fitting degree to judge whether the music fitting conforms to the expected assumptions. We can get the optimized mathematical model and simplify it as:

$$V_{tr} = \sum_{i=1}^{k} V_i / \sum_{i=1}^{12} V_i, V_1 > V_2 > ...V_{12} \tag{4.1}$$

Then, based on this mathematical formula, we can judge the significant differences between different pieces of music generated in the whole model. This distribution difference shows a positive correlation with the chromatographic vector distribution. We name the scales C, D, E, G and A, and then judge the pitch contrast and energy distribution. It can be found that the C major scale occupies the largest weight, as shown in Table 4.5, which means that the model receives timbre, pitch Melodic beat and other influences.

As shown in Table **??** and Fig. 4.4, the calculation of composition technology model in college music

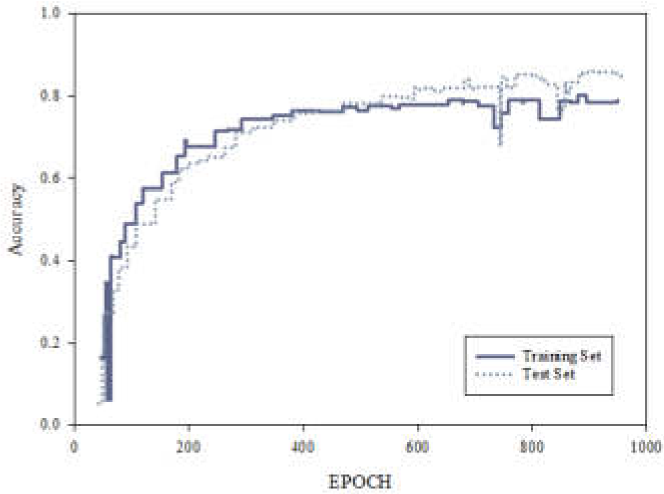

Fig. 4.2: Accuracy change process of training set and test set in Experiment 4.

Fig. 4.3: Two part Melody Created by Composing Technology Model in College Music Teaching.

teaching shows that when K=5, the contrast generated by this model is relatively high, which means that this model is more suitable for folk music teaching. For other types of music teaching and music output, more training sample sets are needed to arrange the internal structural relationships.

5. Conclusion. At the same time musical composition has existed since its emergence as a strong profession. In order to further expand the breadth and depth of music teaching in colleges and universities, and fully combine the forms of human-computer interaction, intelligent platform and edge computing with the art of music, this paper proposes a new network model for computer composition based on the LSTM model for improvement, which is proposed mainly to solve the chord repetition rate in generating chord music and the style problem of generating chord music, after the experimental results The accuracy of the test set on the proposed model reached 88%, and the music teaching and composition technology model designed in this paper is more suitable for fitting national style music.

Table 4.4: Comparison of accuracy and loss rate of algorithm model.

Network model name	Accuracy	Loss rate
Basic_ rnn	96%	0.07
Mono_ rnn	84%	0.36
Attention_ rnn	81%	0.46
Composing Model	99%	0.75

Table 4.5: Chromatographic Contrast Calculation Results of Composing Technology Model in College Music Teaching.

Song Name	Chromatographic contrast V_{tr}
Only folk songs for relatives	0.99
Basic_ Rnn Generate Songs	0.95

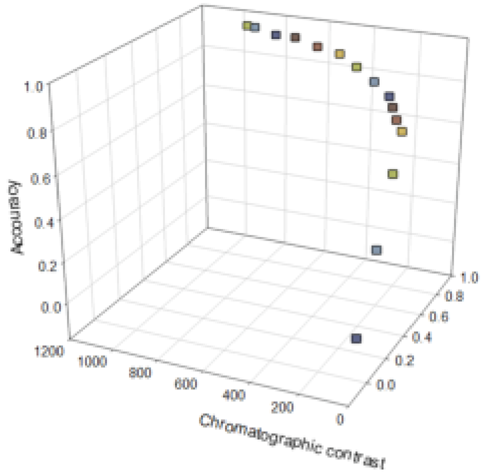

Fig. 4.4: Chromatographic contrast thermogram of composition technology model in college music teaching.

Data Availability. The experimental data used to support the findings of this study are available from the corresponding author upon request.

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APPLICATION OF INTELLIGENT ALGORITHMS AND BIM TECHNOLOGY IN THE INTEGRATED DESIGN OF INTELLIGENT MECHANICAL AND ELECTRICAL SYSTEMS IN PUBLIC BUILDINGS

FENG PENG*

Abstract. The author conducts research on the application of BIM technology in the mechanical and electrical installation process of large public buildings. Emphasis is placed on the specific application measures of BIM technology in key construction stages. In response to the current problems in application, the author proposes corresponding solutions. Finally, based on a practical case study, a complete three-dimensional information model was constructed through the application of BIM technology during the electromechanical installation process at a certain airport, this model not only guides on-site construction and project management, but also provides accurate engineering data for later operations. During the on-site construction process, the application of BIM technology has achieved the creation, management, sharing, and non-destructive transmission of engineering information, reducing 50-70% of information requests and 20-25% of professional coordination time. By simulating construction progress and optimizing pipelines to guide refined construction, the construction period is shortened, engineering costs are saved, good economic benefits are generated, and management level and efficiency are also improved.

Key words: BIM technology, Public buildings, Integration of intelligent electromechanical systems, application

1. Introduction. Today, with the flourishing development of information technology, BIM technology is leading the rapid transformation in the construction field, and the traditional construction project information management model is gradually unable to catch up with the development situation of the construction industry. BIM technology is an information technology that conforms to the development of the construction industry and can be applied in various stages such as engineering design, construction, and operation, by integrating information through parameter models for information sharing and transmission, applications such as collaborative work and pipeline integration can be achieved, through the association of "BIM+" and extended analysis software such as Energy Plus, research on scheme demonstration and performance analysis can be realized, and the combination of Internet, cloud computing, Big data, VR/AR and other technologies can create an intelligent management platform, it plays an important role in improving project quality, saving costs, improving work efficiency, shortening project duration, reducing rework, increasing publicity effectiveness, and resource waste [1].

With the development of society, mechanical and electrical installation engineering involves various aspects of production and life, building mechanical and electrical installation engineering also involves multiple professions and various types of equipment and materials with the improvement of functional requirements of buildings, it has the characteristics of high integration, high complexity, and high technicality.

Due to the connections between various professions and civil engineering, communication and collaboration among professions all affect the design, construction, and operation quality of buildings. Engineering changes, increments, rework, and other phenomena occur frequently, resulting in difficulties in communication, cooperation, and coordination [2-3]. In the design stage, the traditional design mode is to judge whether the design scheme is reasonable and feasible based on experience, if problems are found after construction and use, it is difficult to take measures to make up for and save them; Each profession operates independently, resulting in low efficiency and personnel waste due to repetitive work, the problem of errors, omissions, collisions, and deficiencies between different professions is serious, requiring design changes and additions, affecting initial investment and project schedule, it is difficult to complete collaborative design of large-scale projects, analysis

*Gardens and Architecture College, Jiangxi Environmental Engineering Vocational College, Ganzhou, Jiangxi 341000, China (FengPeng61@163.com)

of buildings with complex shapes and green buildings, and other work.

Due to the sharing of BIM model data, BIM technology has coordination and can achieve multidisciplinary collaborative design and pipeline integration, detect and solve problems such as collisions and omissions before construction, and improve work efficiency and design quality. At the same time, the advantages of BIM models in engineering quantity statistics and cost calculation can be utilized to conduct economic analysis of design schemes and control project investment [4]; Through simulation demonstration, qualitative and quantitative analysis of the design scheme, predict whether the design scheme can meet the requirements of safety, function, energy conservation and Thermal comfort. Combining Fluent software to simulate and analyze the airflow organization of the design scheme, it is used to guide the comparison and optimization of the design scheme, and to verify the reasonable feasibility of the design scheme. However, due to the characteristics of mechanical and electrical installation engineering and the limitations of design time, as well as the high cost of hardware, software, manpower, time, training, etc. Required by BIM, the design workload will increase exponentially, resulting in the design of mechanical and electrical systems still being mainly based on two-dimensional design, the application of BIM in the design of electromechanical systems is often limited to establishing a local model of the computer room for pipeline synthesis and collision inspection, as a bonus item in bidding, it fails to truly leverage the advantages of BIM and reduce the number of changes and additions.

In the bidding and construction stages, the traditional construction mode is for each profession to set their own entry time, schedule, pipeline layout, and other arrangements, operate according to the drawings and construction specifications, and only discuss countermeasures with relevant professionals when encountering problems that were not found in the joint review of drawings, discrepancies between on-site conditions and drawings, and delays in equipment entry time, which may delay the construction period, cause rework, increase investment, etc. The disbursement of progress payments is prone to underpayment and overpayment due to inaccurate accounting and delayed handling of change procedures, leading to dissatisfaction [5]. When dividing the scope of the project in the bidding process, there may be omissions in the project and non professional construction, resulting in rework delays and failure to meet design requirements. For example, the fire linkage control module has not been installed, and the air conditioning supply outlet has been reduced in size and displacement when installed by the decoration unit, increasing resistance, resulting in air flow short circuits and reduced air flow. Visualization using BIM technology can reduce the difficulty of map recognition, avoid map recognition errors, identify issues that require communication, coordination, and change early, and transform post processing into pre control [6,7].

By utilizing the coordination of BIM technology, unified arrangements can be made for the cooperation, processes, progress, technical disclosure, etc. of various disciplines, improving work efficiency, ensuring construction quality, controlling investment, and shortening the construction period. BIM technology can perform 4D and 5D simulations, and in the design phase, based on the simulated construction process of the construction organization, determine a reasonable construction plan to guide construction, measure and allocate progress payments, and achieve cost control, quality control, safety control, and progress control; The optimization of BIM technology can be utilized for pipeline deepening and optimization, collision detection and processing, and guidance for cutting and processing. Due to the high demand for BIM application from construction units, and the efficient BIM technology being able to effectively control construction costs and ensure project schedule, therefore, the current construction stage is the main stage for the application of BIM technology in mechanical and electrical installation engineering, and the main force of application is the construction unit. However, due to the fact that the designed drawings are two-dimensional, the construction unit needs to use CAD drawings to establish a complete electromechanical BIM model, and then use the BIM model for pre embedding and reservation, comprehensive support and hanger, prefabrication processing, deepening design, pipeline comprehensive design, collision inspection, scheme optimization, engineering quantity statistics, construction management, etc.

The construction unit bears some of the workload that should have been completed by the design unit [8]. With the rapid development of the economic market, the process of infrastructure construction and urbanization throughout the country has been accelerating, under the guidance of the "the Belt and Road Initiative", foreign contracted projects have grown steadily, the construction industry has become one of China's important pillar industries, with GDP accounting for about 1/7 of the total. In 2019, the total output value of China's construction industry has exceeded 24.8 trillion yuan. The traditional project management model of the con-

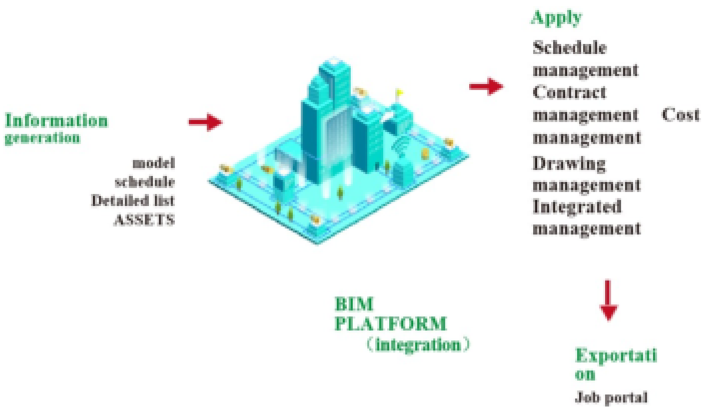

Fig. 1.1: BIM System Framework

struction industry can no longer meet the needs of more and more complex construction projects, the project management model is transforming from a single extensive model to informatization and Digital transformation [9,10].

In the 2016 development outline, the Ministry of Housing and Urban Rural Development clearly proposed to focus on enhancing the ability to integrate and apply information technology such as BIM, and emphasized in the 2020 key work points the need to promote the integrated application of BIM throughout the entire construction process. Through research, it was found that although BIM technology has been applied in the construction field for more than ten years, there are obstacles, limitations, and formalization in the application of BIM in building mechanical and electrical installation engineering, and it has not truly played its role and depth [11] (as shown in Figure 1.1).

2. Methods. In order to solve the problems in the mechanical and electrical installation engineering of large public buildings, the author introduced the application of BIM technology during the construction process. The construction unit will build a BIM application platform, form a team, configure the required software and hardware, then prepare a work plan, develop modeling standards, establish models by discipline, and integrate the models after verification, the key parts such as various systems and computer rooms will be further designed to solve pipeline collisions, and comprehensive support and hanger designs will be carried out. Subsequently, organize various units to review and deepen the design results, and after confirmation by the design party, export the drawings or directly use the models to guide construction. During the installation process, simulate the construction based on the model, determine the installation sequence of pipelines and equipment, and manage the construction site. After the project acceptance is qualified, the BIM model and data information will be handed over to the owner together [12].

2.1. Building a BIM application platform.

(1) Establishment of organizational structure. A well coordinated team is a key factor for project success, and the organizational structure of the BIM team is shown in Figure 2.1.

The BIM manager is responsible for the overall implementation and coordination of the project, team building and management, clarifying the responsibilities and job responsibilities of members, and directly responsible for the quality of BIM deliverables. The position requires familiarity with various professional knowledge on the construction site and a certain understanding of the application process of BIM [13].

The BIM supervisor is responsible for managing the BIM model, supervising the designer to complete the BIM model establishment, performance analysis, drawing, and other work, reporting to the BM manager, and reviewing the model to ensure data quality and compliance with relevant standards for all BIM work. The technical supervisor is responsible for coordinating data and application work. Each professional leader leads the team members to complete the design tasks of their respective profession, conduct 3D design and model modification, extract data from the model, calculate engineering quantities, generate detailed tables, and

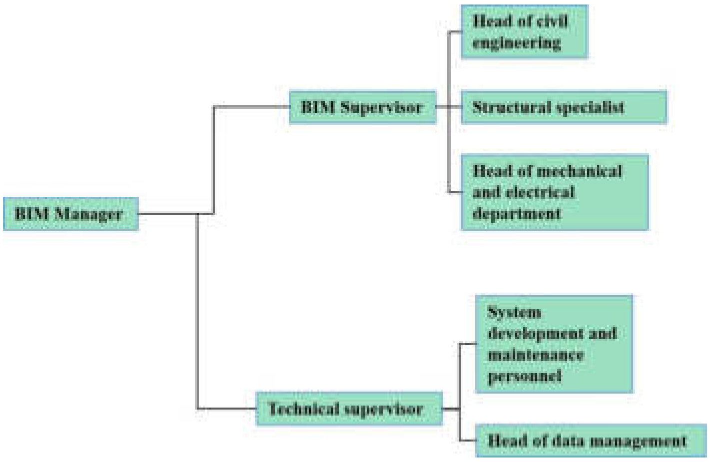

Fig. 2.1: BIM Team Organizational Structure

cooperate with each other to complete the optimization design work. System development and maintenance personnel are responsible for hardware maintenance and system development, providing technical support for software applications. The data management personnel are responsible for collecting information on the construction site and processing the data information of the model, they regularly upload the on-site information to the management system in the form of documents, images, videos, etc., and archive the data and files during the design and construction process [14,15].

(2) Infrastructure requirements. Infrastructure includes software and hardware. The application of BIM technology is achieved through software, there are many factors to consider when selecting software that is suitable for one's own development based on the characteristics of the enterprise. From the perspective of the software itself, it is necessary to consider its popularity, user-friendly interface, and price. In addition, it is also necessary to consider the reputation of the software manufacturer, user reputation, as well as the technical support and user training they can provide. Enterprises need to choose appropriate software based on their own application needs [16].

The commonly used BIM software in the process of mechanical and electrical installation includes the following categories: In the modeling software, Autodesk Revit has complete functions, easy operation, and a wide range of applications. ArchiCAD has powerful functions in the design of mechanical and electrical systems; Collision detection and construction simulation are commonly implemented using Navisworks software, which can interface well with Revit; The display of 3D effects relies on 3D Max, Lumion, and others; Guanglianda has a wide range of applications for engineering quantity calculation and cost software; In terms of construction process management, various enterprises often conduct secondary development on the Revit platform to achieve the management of model versions and project data during the design and construction process [17].

The application of software is closely related to the hardware environment. For BIM applications, the hardware environment mainly includes the following three aspects:

Network environment: In BIM applications, in order to maintain collaborative work, models and related data are generally stored centrally on a central server, members build models and input data on their respective computers, and synchronize with the central file on a regular basis. For large projects, the model contains a large amount of data, and in order to ensure smooth operation, a fast network transmission speed is required. In order to meet project requirements, it is best to connect to a network of over gigabit.

The central server is mainly used to store BIM models and related data information, and has high requirements for computer storage performance. The most important thing is data security. Due to not directly performing calculations, the requirements for processors and graphics cards are not high.

Terminal computer: Team members directly use terminal computers, and model building, information input,

Table 2.1: BIM Model Depth

grade	stage	Model depth
LOD 100	Conceptual design phase can be used for analysis	Basic shape, location, rough size, building volume,of lighting, wind environment, etc
LOD 200	Preliminary design stage	Accurate component information (geometric information such as size, shape, position, direction, and quantity, as well as material and properties): A detailed model of the electromechanical system, including approximate equipment models, which can be used for systematic analysis
LOD 300	Construction drawing design stage	A detailed construction model can produce complete construction drawings for various specialties, enerate engineering quantities and costs, calculate and analyze engineering quantities, and analyze detailed elements and systems through analysis and simulation
LOD 400	Completion stage	Including changes during the construction phase, able to accurately issue final settlement reports and analysis reports on changes in various disciplines
LOD 500	Operation management stage	Regular (short cycle) updated data management model that can be maintained and updated by various disciplines

and data calculation are all completed on terminal devices, therefore, there are high requirements for computer configuration. Generally speaking, computers require an i7 or higher processor, an 8GB or higher installed memory, a 1T hard drive, and a 2G independent graphics card to maintain smooth operation. For the project team, at least one file server, several desktops, one laptop, and one tablet are required to support BIM applications for the entire project (or part of the project) in a collaborative environment.

2.2. Model Establishment. Before establishing the model, it is necessary to configure software and hardware facilities based on project requirements, develop modeling rules, and determine the depth of the model. The American Institute of Architects divides the depth of BIM modeling into the following five levels. As shown in Table 2.1.

When modeling, construction needs need to be considered, and structural beams, floors, columns, etc. should be split according to the construction section to facilitate later construction simulation. At the same time, it should be ensured that the deduction relationship between components is correct and does not affect the calculation of engineering quantities. Under the condition of reaching the specified model depth, improve the model information, such as beam column number, concrete grade, pipeline material, etc. Consider the subsequent model processing requirements in advance and plan the organization of the model. According to the profession, the BIM model is divided into three major parts: architecture, structure, and electromechanical equipment, the electromechanical system is further divided according to needs, and then each subsystem of the electromechanical profession is named and colored according to rules to make it easier to distinguish. In the construction phase, it is necessary to supplement the following content on the basis of the design model: Temporary building houses, temporary water and electricity layout, construction machinery, material stacking planning, safety maintenance components, and other construction models [18].

2.3. Deepening Design.

(1) Collision detection. In the traditional era of two-dimensional drawings, conducting collision detection requires reviewing a large number of drawings and requiring relevant professional engineers to jointly inspect and discuss the collision situation. This collision detection speed is slow, prone to errors and omissions, and the expression is too abstract, making it difficult to fully and accurately record the detection results.

For large public buildings, it is necessary to use BIM software for collision detection in order to ensure the smooth progress of equipment installation engineering. Representing all professional pipelines in the same model according to their true dimensions can reflect some deep-seated issues in traditional drawings. Apply BIM related software, such as Revit Navisworks and others can perform collision detection to detect all pipeline conflicts in the design drawing. Based on the detection results, pipeline optimization can theoretically eliminate all collisions.

The collision detection function of Revit requires high hardware configuration requirements, and for large projects, the computational complexity is high, making it difficult to ensure smooth operation. Therefore, Navisworks is often used in engineering for collision detection. Import Revit models into Navisworks software in different disciplines, select detection conditions based on project requirements, and perform collision detection between different disciplines and between pipeline systems and building structures. The detection results can be saved in various formats such as viewpoint and text, and output as detection reports.

(2) Pipeline integration. Pipeline synthesis is the process of coordinating and arranging the location of pipelines based on the mechanical and electrical system construction drawings completed during the design phase, according to the system, nature, function, and construction requirements of the pipelines. The purpose of pipeline integration is to meet the net height requirements of building space; The second is to meet the installation and maintenance space of pipelines and equipment; Three needs to meet the installation requirements of supports and hangers; Four needs to ensure the accuracy of hole reservation and casing embedding. The mechanical and electrical installation engineering of large public buildings involves multiple specialties, complex pipeline systems, high difficulty in construction organization, and high requirements for installation quality. The comprehensive quality of pipelines directly affects the completion effect. The traditional pipeline synthesis involves overlaying the two-dimensional layout plans of various specialties, which has certain drawbacks. Multiple professional pipelines are stacked together, resulting in messy graphic content. Additionally, the relative positions and elevations of various systems are not expressed clearly and accurately for the parts with a large number of pipelines. Spatial relationships require imagination and rely on two-dimensional drawings, making it difficult to detect all pipeline collisions. The handling of collisions requires local adjustments and cannot achieve global grasp, due to the complexity of spatial and structural systems, although pipeline layout is carried out according to the process requirements of various professions, it often cannot fully meet the design principles and construction requirements. For large public buildings, using BIM technology for pipeline integration of electromechanical systems has obvious advantages. The BIM modeling process is equivalent to a comprehensive drawing review, the model is built according to the actual size and can fully demonstrate the effect after construction, for parts omitted in traditional expressions (such as valve size, pipeline insulation layer, etc.), they can be displayed in the 3D model. Thus, some problems that cannot be seen on the two-dimensional construction drawings but exist in the actual construction process are exposed.

During the installation process of the electromechanical system, due to the deepening design and route adjustment of the pipeline, the length of the pipeline and the number of pipe fittings may change accordingly, which may lead to the system not meeting the original design parameters. After adopting BIM technology, intelligent simulation of system parameters such as energy consumption and flow can be carried out based on the BIM model, providing reference for the selection of equipment parameters. In the initial stage of pipeline integration, the goal is to meet the spatial requirements of the main pipeline, the mechanical and electrical professional model includes the main pipeline, and there are no requirements for the air conditioning terminal branch pipes, water supply and drainage, and fire water pipe branches that enter the room, the air conditioning terminal air supply devices, nozzles, accessories, etc. are left to be further deepened. For the coordination of structures and related specialties, such as the parts where pipelines pass through beams and walls, it is necessary to do well in the design of hole reservation and sleeve embedding [19].

In the mid-term, it is necessary to further improve the model, improve accuracy, determine the elevation and horizontal position of the pipeline, optimize the pipeline layout, and meet the net height requirements. In the initial BIM model, the equipment in the computer room was usually not arranged, or symbolically only large electromechanical equipment was arranged. At this stage, it is necessary to deepen the design of the equipment room, lay out detailed equipment models, determine equipment parameters, and deepen the design of the pipelines inside the equipment room. In the final stage, the BIM team refined the equipment room according to the owner's requirements based on their own construction experience, and constructed a BIM model that was identical in size and appearance to the actual equipment. Improve the details of each system, coordinate all pipeline collisions, and design and arrange supports and hangers. The comprehensive results of pipelines can be directly used in the form of models through mobile terminals (iPads) to guide construction, and two-dimensional drawings can also be exported. The detailed design drawings of each discipline should include a comprehensive pipeline plan, legend, construction instructions, pipeline system diagram, plan, section, equipment room details (including equipment location, installation method, and pipeline layout), reserved and embedded drawings (including the position, precise elevation, and bending radius of openings or embedded parts), and support and hanger layout.

3. Results and Analysis.

3.1. Project Introduction.

(1) Project Overview. This project is the second phase expansion project of an airport, mainly including T2 terminal, transfer center, power center, and information center, with a designed annual passenger throughput of 29 million people. The T2 terminal has a building area of approximately 480000 square meters and a main building height of 38.7 meters. The transfer center has a building area of approximately 270000 square meters and a height of 14.63 meters. It has four underground floors and two above ground floors. The power center has a building area of 8075 square meters and a building height of 6.85 meters, with one floor above ground and one floor below ground. The information center has a building area of 9050 square meters, a building height of 38.3 meters, and eight floors above ground. The mechanical and electrical installation engineering of the airport includes conventional water supply and drainage system, siphon rainwater system, fire water system, ventilation and air conditioning system, power and lighting distribution system, fire power distribution system, automatic control and intelligence system, vertical and escalator system, security system, as well as airport specific flight information display system, broadcasting system, advertising identification system, luggage sorting system, automatic walkway system, etc.

(2) Project difficulties. The airport, as a gateway to the city, places greater emphasis on the design of roofs and exterior design than general public buildings due to its large engineering volume and high installation difficulty, it has high requirements for overall effect and spatial design, resulting in complex structural forms. On the basis of meeting the functional requirements, the electromechanical system also pays attention to aesthetics, greatly increasing the difficulty of design and construction. The installation area of the project is large, and the construction period is tight. It is necessary to ensure construction quality and reduce rework and changes.

This project includes a large number of systems, a large number of various pipelines, complex spatial relationships, and numerous mechanical equipment in power centers, air conditioning rooms, and other parts. There are significant difficulties in reviewing two-dimensional drawings, as well as frequent design changes and multiple versions of construction drawings. In order to ensure construction quality and progress, it is necessary to use three-dimensional models to optimize the layout of pipelines. Mechanical and electrical installation engineering requires consideration of many details, and the layout of pipelines can directly affect the construction sequence. Therefore, it is necessary to communicate and communicate with various units at any time during the construction period. However, there are many subcontracting units in this project, making it difficult to coordinate the relationships between all parties.

(3) Application Objectives. Based on the characteristics of the above project, in order to ensure construction quality, save costs, and shorten the construction period, the construction party requires the use of BIM technology to deepen the design of the electromechanical system, and has formulated the following application goals: Utilize 3D models to complete construction drawing review, strengthen coordination between design and construction parties, and reduce collisions and conflicts during construction; Optimize the design plan to achieve a simple pipeline and balanced system, ensuring that the equipment is in the overall optimal operating condition; Conduct construction process and schedule simulation to optimize construction organization; Conduct material statistics to effectively control costs; Combining digital production mode to achieve batch processing of prefabricated components; Combining mobile terminals to achieve construction site management; Realize digital handover and provide complete and accurate engineering information for production and operation.

3.2. Analysis of application conditions.

(1) Application Plan. Develop a project application plan based on the actual situation of the project and the B M application goals. As shown in Table 3.1.

(2) Team composition. Based on the construction site situation and application objectives, a BIM team was jointly established by the general contractor and the design institute that provides BIM services. The team consists of over 40 people, as follows: One BIM general manager, appointed by the project manager,

Table 3.1: BIM Application Scheme

Serial Number	Application content	Completion time and results
1	Team building	Build a BIM team after the project starts
2	Standard development	Refer to internal enterprise modeling and delivery standards
3	Determine the application process	The owner, design institute, construction party, and supervision unit jointly agree on the application depth and approval process
4	Develop a work plan	Within two weeks after the team is formed, divide the work stages and develop a detailed work plan
5	Check drawings	Before establishing the model, check if the design drawings are complete and if there are any omissions. Complete the initial model one month before the start of the electromechanical installation project
6	Model creation and maintenance	One week before the installation starts in a certain area, complete the detailed design of the area and solve the collision detection problem. Complete the model modification within 5 days after receiving the change notice
7	Comprehensive delivery	Complete model integration before acceptance, form a completed model, and hand it over to the general contracting unit

Table 3.2: Software Configuration

Software Name	Software Role
Revit	Modeling for Architecture, Structure, and Mechanical and Electrical Majors
Navisworks	Collision detection, 3D roaming, construction simulation
PKPM	Structural calculation and material statistics
3ds Max Design	Animation production and effect rendering
Showcase	Effect friendly dyeing and design scheme demonstration
Project	Preparation of construction schedule

with 10 years of project management experience, fully responsible for the overall progress of the project; Three BIM coordinators, appointed by the Deputy Project Manager, with over 8 years of project management experience, responsible for personnel management and work progress in each group; More than 30 BIM engineers are responsible for the establishment of architectural, structural, and electromechanical professional models, optimization design of pipelines, integration of various engineering information, and other specific tasks. They also include program developers to provide technical support for software applications.

(3) Software Selection. The software used in this project is shown in Table 3.2. In addition to professional software, this project also applies some plugins developed by a certain design institute, such as Revit based support and hanger generation plugins, material equipment coding plugins, material statistics plugins, and visual comprehensive management platforms.

(4) Hardware configuration. The software used in the project has high requirements for computer configuration. In this project, 25 laptops and 15 desktop computers are used, and the specific parameters as shown in Table 3.3.

3.3. Application Content. The application of this project is divided into three levels, the basic application is implemented using conventional software functions, the deepening application is combined with project characteristics, and the advantages of B M are fully demonstrated using plugins, finally, combined with the engineering data platform, a digital overall handover for the owner is achieved.

(1) Basic Applications. Based on the two-dimensional design drawings, apply Revit software to establish the initial model of the entire project by profession, and input component information. Due to the large volume of this project, in order to ensure smooth software operation, the drawings are divided into several areas and

Table 3.3: Hardware Configuration

Parts	Desktop parameters	Notebook parameters
motherboard	Ivytown DM2 - Intel X79 PCH	EnazerY50-70
processor	Inte1Xeon E5-2620v2 @2.10GHz Six core	Intel Core i7-4710HQ @2 5GHz GHz
Memory	32GB (DDR3 1333MHz)	8GB (DDR3L 1600MHz)
Graphics card	AMD FirePro V 4900	NVIDIA GeForceGTX860M
display	DELDOSA DELLS2340M (23.1 inch)	15.6 inch

modeled separately. Based on the same elevation and grid, the accuracy of the relative position of the model can be guaranteed. Verify whether the spatial relationship of the original design is reasonable and whether there are any errors or omissions in the pipeline through the integrated 3D model. Intuitive forms of expression are also conducive to coordination and communication between the design and construction parties.

After the model is built, collision detection is performed using Navisworks software. Collisions can be divided into two categories: hard collision and gap collision. The former refers to the cross collision between entities, while the latter refers to the non cross collision between entities, but the spacing does not meet the construction and installation requirements. Combine the disciplines of building structure, water supply and drainage, HVAC, electrical, intelligence, and information technology to conduct hard collision and gap collision detection, and generate detection reports. Classify and analyze the test results, propose modification suggestions, provide feedback to various professional designers, and coordinate the modifications together.

Based on the results of collision detection, the system pipeline must be optimized while meeting the requirements of construction and maintenance space. The optimization model must meet the requirements of design specifications and construction acceptance specifications. A comprehensive pipeline system developed based on the Revit platform can complete layout scheme comparison, installation space detection, and pipeline position and elevation adjustment in the same graphical interface. In the project, the first step is to deepen the design of key areas with a large number of pipelines and equipment. There are many pipelines in the corridor of the terminal building, and there are local automatic walkways with lowering boards. The design heights of suspended ceilings in different areas are different, and installation space and net height requirements need to be considered when arranging pipelines. In the design, conflicts are eliminated by changing the size of air ducts and cable trays or moving pipeline positions reasonably to meet spatial requirements.

The process in the baggage sorting area is complex, and the steel platforms and brackets supporting the baggage equipment are relatively dense. The suspension rods are long, and the suspension rod brackets have a lot of diagonal tension. Each suspension rod has been calculated, and the embedded parts that have taken root have been completed. The position cannot be changed, and there are many cross collisions between pipelines, steel platforms, and suspension rods. Through mold assembly, optimization and adjustment of mechanical and electrical pipelines, as well as simulation, a plan for segmented positioning and installation of mechanical and electrical pipelines, with local reserved coordination space, has been developed to achieve coordination between installation accuracy and on-site variables. The air conditioning room and power center have a high floor height, a large number of equipment, dense and large-sized pipelines, and complex pipeline support arrangements, which affect the layout of other pipelines and cause frequent cross collisions. When installing, it is necessary to consider the form of supports and hangers for pipelines and equipment, leaving sufficient space for equipment inspection. Import the Revit support model into PKPM for calculation and analysis, determine the support form and steel type, adjust the pipeline position and elevation based on the support and hanger form, reduce construction difficulty, and enhance stability.

In this project, a Revit platform based plugin developed by a certain design institute has been applied, which can identify the parts of the pipeline that pass through the wall in the model and automatically generate openings. This ensures that the position, quantity, and size of reserved openings meet the design standards and later construction requirements, and there are no omissions or errors. According to the model and construction drawings, it is possible to do a good job of opening reservation and casing embedding during the main construction. Due to the high accuracy of the models provided in the basic application stage of BIM, the accuracy of pre embedding and reservation in engineering has been significantly improved, reducing secondary excavation and improving construction efficiency. In traditional two-dimensional design, there is often a problem where the spatial positions represented by the plan and profile do not correspond, resulting in engineering change visas caused by modifying the drawings, which affects the construction progress. By applying BIM technology, drawings from all angles are generated by 3D models, fundamentally solving this problem and making up for the shortcomings of 2D design space representation. After pipeline optimization, generation of reserved openings, support and hanger design, and process simulation, the quality of the designed products has been greatly improved, and the drawings can be directly used to guide construction.

(2) Deepen application.

Support and hanger design: Utilize plugins developed based on the Revit platform for comprehensive support and hanger design. After specifying constraint relationships, the software can automatically extract pipeline loads for structural stress calculation, determine the type and size of steel profiles, generate support and hanger calculation instructions, and generate parameterized support and hanger model diagrams in the project. Pipeline prefabrication processing: Based on the comprehensive pipeline model, intelligently segment the pipeline system, by using a detailed list to calculate the length of pipe sections and the number of pipe fittings, complex pipe fittings can be digitally processed by generating part cutting diagrams in the model in advance. The air conditioning system of this project has a large amount of air ducts and a large number of pipe fittings. Based on BIM model data, a brand new plasma cutting machine is used for digital batch production, saving a lot of manpower and time, and improving production efficiency.

Construction simulation: Import the progress plan into Navisworks for simulation, and the intuitive and visual animation effect is conducive to coordination and communication among all parties, determining the production plan, and effectively reducing the loss of construction period caused by overlapping construction periods. For areas with complex pipelines and multiple disciplines involved, simulate the construction process for the installation of various professional pipelines, select the optimal construction plan, determine the construction sequence, and avoid rework problems caused by rush work between construction teams.

On site management: Strictly follow the comprehensively optimized drawings for construction on site, ensure project quality, and track project progress in real time. Compare with the progress plan and analyze the reasons for early or delayed construction period. For parts that require special recording, such as key nodes and concealed projects, on-site personnel record the information through mobile devices in the form of documents, photos, etc., and associate it with the model through the network, enabling engineering management personnel to have a deep understanding of the on-site situation.

3.4. Application effect. BIM technology has achieved good application results in this project. Compared to traditional two-dimensional comprehensive pipeline layout, the accuracy of the deepening design is improved by about 20%, and the deepening design time is reduced by 10%.

Relevant software is used for three-dimensional comprehensive pipeline layout, and areas with multiple pipeline intersections and narrow ceiling space are reasonably arranged to meet the design height of the ceiling. Integrating luggage sorting models, optimizing mechanical and electrical pipelines, ensuring process functionality, detecting and resolving over 200000 professional collisions in advance, avoiding extensive dismantling and modification in the later stage; The accuracy of hole reservation is significantly improved to avoid secondary excavation in the later stage. The mechanical and electrical installation is strictly carried out in accordance with the BIM comprehensive pipeline design drawings and models, reducing complexity to simplicity, enabling the project to be quickly and smoothly implemented, ensuring installation quality and being neat and beautiful; Unified planning, design, prefabrication, and installation of supports and hangers; Through three-dimensional construction simulation, the orderly progress of simultaneous and cross construction in various areas has been achieved, without any delay in the construction period. The construction efficiency has been improved by 15%, effectively shortening the project construction cycle. In this project, the BM application intervened after the completion of the construction drawing design and built the model according to the two-dimensional drawings. The modeling personnel were unable to fully understand the design intent and needed to communicate with the design personnel multiple times, resulting in a significant investment in manpower, material resources, and time. Directly conducting 3D design requires investing a lot of effort and funds in the early stages of the project to configure hardware facilities and train personnel. During the design process, project information needs to be added, which inevitably leads to an extension of the design cycle. But overall, 3D design does not require secondary processing. After the design is completed, it is directly applied in the form of a model, with high design quality and obvious advantages. In the domestic design industry, due to high initial investment, insufficient foreign software to fully meet design needs, and insufficient intuitive economic benefits, there is still a long way to go for the application of BIM from mold flipping to true 3D design.

During the electromechanical installation process at a certain airport, a complete three-dimensional information model was constructed through the application of BIM technology, which not only guides on-site construction and project management, but also provides accurate engineering data for later operations. During the on-site construction process, the application of BIM technology has achieved the creation, management, sharing, and non-destructive transmission of engineering information, reducing 50-70% of information requests and 20-25% of professional coordination time. By simulating construction progress and optimizing pipelines to guide refined construction, the construction period is shortened, engineering costs are saved, good economic benefits are generated, and management level and efficiency are also improved [20].

4. Conclusion. At present, there are problems in the construction and installation industry, such as outdated technology, insufficient information technology, and difficulties in communication and coordination. In order to improve construction efficiency and management level, the application of BIM technology is introduced. The author conducts research on the application of BIM technology in large-scale public building mechanical and electrical installation engineering, and verifies the application value of BIM technology in project mechanical and electrical installation engineering through case studies. By utilizing BIM technology for deepening design, the pipeline layout plan can be reasonably optimized, and through collaborative work, the deepening design time can be effectively shortened; Through collision detection, pipeline crossings and collisions can be reduced, design changes and rework can be avoided, and construction efficiency can be improved; Through construction simulation, the construction plan and schedule can be optimized, and the construction technology and on-site management level can be improved.

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CONSUMER PURCHASE BEHAVIOR PREDICTION ON E-COMMERCE PLATFORMS BASED ON MACHINE LEARNING FUSION ALGORITHM

YIBO HU*, RONG FU†, AND WENBO NIU‡

Abstract. To enhance the precision of predicting consumer purchasing behavior, the author conducts a study focused on forecasting buying patterns on e-commerce platforms through the use of machine learning fusion techniques. The research specifically integrates logistic regression and support vector machine algorithms to analyze shopping behavior data from Alibaba's e-commerce platform. The experiment revealed that, out of 1,445 test samples fed into the model, 571 were predicted to exhibit purchasing activity on the 32nd day, as indicated by a prediction outcome of "1." Compared with the samples with actual purchasing behavior on the 32nd day, their F1 score was 7.77%. The practical results show that the fused model is more accurate in prediction performance than a single algorithm model.

Key words: Machine learning, Fusion algorithm, purchasing behavior

1. Introduction. As mobile device costs and internet fees continue to decrease, a growing number of people are adopting smartphones, sparking a surge in online shopping activity. This trend has led to a significant rise in the number of individuals engaging in e-commerce. Data from the China E-commerce Research Center indicates that online retail sales in the first half of 2017 surpassed the total sales figures of 2016. With e-commerce expanding rapidly, consumers are becoming increasingly demanding, expecting higher standards from businesses in terms of brands, products, pricing, and services [1]. In addition, some giant enterprises have emerged in China's e-commerce market, such as Tmall, Taobao, and JD.com. In recent years, the government has successively introduced relevant policies to encourage young people to start businesses, and some capable entrepreneurs have also developed through this opportunity. These startups face challenges in breaking into the established e-commerce market. Recently, leading e-commerce platforms have responded by introducing innovations that focus on targeting specific consumer segments and catering to their unique needs, with platforms like Pinduoduo Shopping Mall being prime examples [2]. This platform is essentially a group buying platform, where consumers attract friends to bargain or initiate group buying to purchase goods at a low price. But at the same time, some problems have arisen, such as the inability to guarantee the quality of goods while lowering their prices, leading to consumer loss. In today's competitive e-commerce landscape, those who can accurately identify and cater to the specific needs of consumers, anticipate their preferences, and deliver superior services will be the ones to secure a strong position in the market [3].

In practical terms, with the fast-paced advancements in big data and cloud computing, effectively utilizing analytical and predictive techniques enables the prediction and understanding of consumer purchasing habits, intentions, and behavior patterns by examining both explicit and implicit feedback, such as purchase histories. This approach not only enhances the shopping experience for consumers but also allows businesses to transition from passively displaying products to actively recommending them, addressing specific consumer needs, attracting more potential buyers, and boosting conversion rates [4]. From a technological development standpoint, consumers generate vast amounts of online behavior data that is highly granular and multidimensional. Some e-commerce platforms, both domestic and international, offer anonymized data to researchers, enabling further exploration in machine learning and artificial intelligence, which holds considerable academic value. When consumers interact with e-commerce platforms and their intentions are clear, text analysis through search engines

*The School of Business, Xi'an International University, Xi'an, Shaanxi, 710077, China. (Corresponding author, YiboHu7@163.com)

†The School of Business, Xi'an International University, Xi'an, Shaanxi, 710077, China. (RongFu8@126.com)

‡The School of Business, Xi'an International University, Xi'an, Shaanxi, 710077, China. (WenboNiu9@163.com)

can effectively identify their needs. However, when consumer intentions are ambiguous and cannot be easily articulated, search engine analysis becomes less effective. At this point, using implicit feedback data generated by consumers to predict their next behavior and understand their purchasing preferences for a certain product becomes a better choice. However, due to concerns around data privacy and information protection, certain data may be encrypted and challenging to access. As a result, the challenge the author seeks to address is how to predict consumer purchasing behavior using consumer behavior data specifically by leveraging implicit feedback without needing to access detailed personal information [5].

2. Literature Review. Based on the review of previous related research, scholars' research on predicting consumer behavior in e-commerce can be divided into two categories. One is the study of recommendation systems, which mines the products that consumers are interested in by obtaining consumer behavior data from e-commerce platforms, thereby identifying the types of products that consumers are likely to be interested in and proactively presenting them with tailored product recommendations. Another approach involves utilizing various machine learning and data mining techniques to analyze consumer online behavior data and forecast purchasing patterns. For example, Pandi, V. et al. conducted sentiment analysis on Twitter to gain insights into customer purchasing behavior. E-commerce has grown significantly, especially for people who buy products on the Internet. The results prove that it is truly used to predict using the most accurate analysis model for checking customer conclusions/emotions. Analyze the accuracy of each machine learning algorithm and consider the most precise calculation as ideal [6]. Nakao, J. et al. colleagues created a production planning model that integrates customer preferences into its framework. This model generates insights into customer purchasing behavior using machine learning techniques. By clustering data based on purchase information from various customers, the model effectively segments the customer base. The findings indicate that, in contrast to models that do not incorporate customer purchase data, the proposed approach delivers improved customer satisfaction and increased profitability [7]. Prakash, R. et al. set out to explore the purchasing patterns of e-commerce customers to enhance service and product offerings. By analyzing customer data, they aim to identify product preferences based on prior transaction records. They employed a range of techniques, including logistic regression, K-nearest neighbors, support vector machines, random forests, recurrent neural networks, and long short-term memory networks. The performance of these methods was evaluated to predict which products customers are most likely to buy [8].

Based on this research, the author proposes a study on predicting consumer purchasing behavior on e-commerce platforms using machine learning fusion algorithms. By collecting and analyzing massive shopping behavior data on the Alibaba platform, these data are transformed into valuable information, providing valuable insights for e-commerce companies to optimize product recommendation systems, enhance user experience, and ultimately drive sales growth. Through this deep fusion method, the author not only demonstrates the effectiveness of machine learning fusion algorithms in the e-commerce field, but also provides new ideas and directions for future related research and practice.

3. Research Methods.

3.1. Prediction Algorithm Model.

3.1.1. Overall framework of the model. From a qualitative standpoint, consumer interest in products can be ranked as follows: click (pv) $<$ like (fav) $<$ add to cart $<$ buy. Additionally, both the sequence and timing of consumer interactions with a product influence their final purchasing decision. Furthermore, when a consumer explores multiple products within the same category, their behavior towards subsequent products is influenced by their prior interactions [9]. The author will focus on performing statistical analysis of consumer behavior sequences over time. This involves using consumer ID, product category ID, and product ID as key variables to analyze behavior chronologically and establish a sequence of actions. It should be noted that the author ignored the interspersion and selection behavior of consumers between different products, and only started with the time point when the first action was taken on a certain product to conduct behavior statistics on the operation behavior of that product, and converted the behavior time attribute to a 24-hour clock.

The author applies two machine learning methods to analyze consumer behavior sequences and other features, starting with the analysis of consumer behavior sequences arranged in chronological order. Due to the different lengths of consumer behavior, before analyzing consumer behavior, the behavior sequence is first

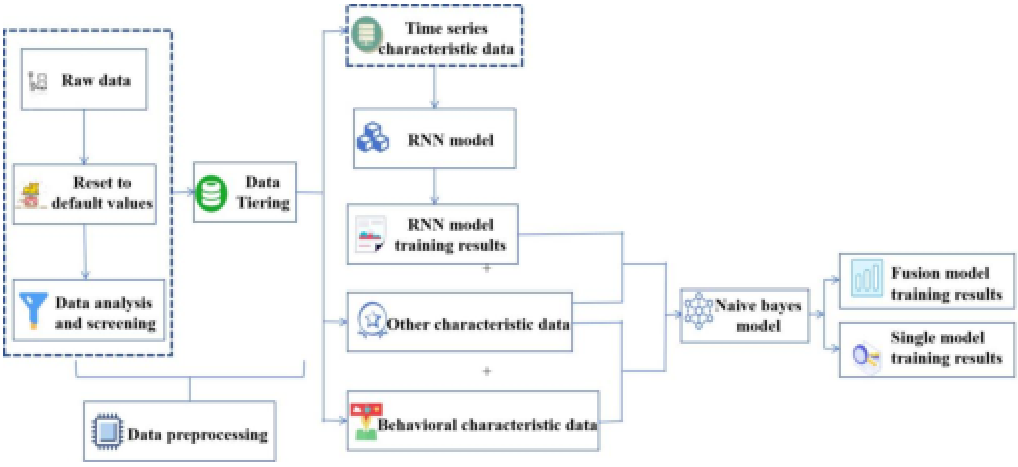

Fig. 3.1: Fusion Model Structure Diagram

stratified according to the number of behaviors. Assuming an analysis is conducted on a hierarchy with 5 behaviors, the first step is to extract the behavior sequence data from the dataset, which includes time point sequences associated with it and the true identification of whether the consumer has made a purchase, and process it into 5x24 dimensions. Behavior is divided according to the level of interest in the product, with integer values, and the time point when the behavior is empty is set to 0. Let the dataset be X and use X as the input for the RNN. RNN is an Nvs1 structure, and the input for each record in the dataset is an array of length n+1. The desired output is the probability value of whether the consumer will make a purchase, ranging from [-1,1]. The obtained probability values are added as new features to other feature sets as inputs for the Naive Bayes model [10]. The model is trained to determine the probability of whether consumers will purchase, and then the final decision result of the model is obtained, represented by 0 and 1. The fusion model structure is shown in Figure 3.1.

3.1.2. Characteristics of Online Shopping Behavior. Consumers' daily shopping behavior is generally captured through two types of feedback: explicit and implicit. Explicit feedback includes actions such as ratings, likes, and reviews, where consumers directly express their opinions about a product. In contrast, implicit feedback involves behavioral data generated during the shopping process, such as browsing, clicking, bookmarking, and adding items to the cart. Since users often do not actively rate products after purchase and may not always provide genuine feedback if they do, due to incentives like cashback or simply following requests for reviews, explicit feedback may not always accurately reflect true consumer sentiments and often suffers from data sparsity. Therefore, implicit feedback provides a more comprehensive view, addressing the limitations of explicit feedback, to some extent expressing users' true feelings, and due to the strong database support of e-commerce behavior, it can ensure data quality and accuracy. Based on the literature review above, the current research focus on conversion rates has shifted from explicit feedback data to implicit feedback data [11]. Meanwhile, due to the accumulation of massive purchasing data, research on consumer shopping behavior is no longer limited to analyzing a small amount of questionnaire data to identify influencing factors or customer segmentation and value recognition. Instead, it directly predicts consumer purchasing behavior in a more accurate way. Consequently, the author focused on user implicit feedback related to shopping behavior for the study. Utilizing a real dataset from the Alibaba e-commerce platform, the author applied big data analysis techniques to develop a model aimed at forecasting user purchasing behavior [12].

3.2. Model Algorithm.

3.2.1. Logistic Regression. Logistic regression (LR) is a probability based linear binary classification algorithm that assumes that the binary variable y of whether an event occurs follows a Bernoulli distribution, that is, the probability of event A occurring is equal to the probability of $\rho(\overline{A})$ not occurring, which is equal to

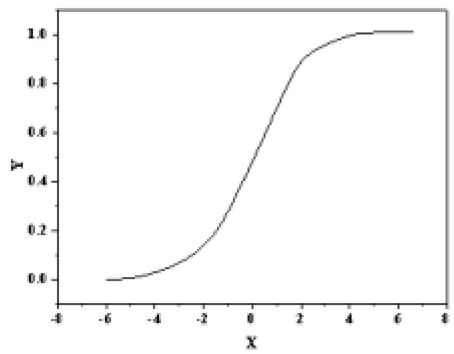

Fig. 3.2: Sigmoid function diagram

p(A). If y=1,0 is used to represent the occurrence and non occurrence of an event, the distribution function of the Bernoulli distribution is:

$$\rho(y|xl\theta) = \rho(A)^y[1 - \rho(\overline{A})]^{1-y} \tag{3.1}$$

Logistic regression uses the Sigmoid function $h(\theta)$ to describe the probability of event A occurring (A):

$$\rho(A) = \rho(y = 1|x; \theta) = h_\theta(x) \tag{3.2}$$

$$\rho(\overline{A}) = 1 - \rho(A) = \rho(y = 0|x; \theta) = 1 - h_\theta(x) \tag{3.3}$$

Among them:

$$h(\theta) = 1/(1 + e^{-(\theta^T x+b)}) \tag{3.4}$$

Logistic regression assumes that each sample in the dataset is independently and identically distributed. Using maximum likelihood estimation, the likelihood function for the parameter θ is given by:

$$L(\theta) = \rho(y|x; \theta) = \prod_{i=1}^{n} \rho(y_i|x; \theta) = \prod_{i=1}^{n} (h_\theta(x_i))^{y_i}[1 - h_\theta(x^{(i)})]^{1-y_i} \tag{3.5}$$

By taking the logarithm of the likelihood function $L(\theta)$ and then differentiating it, we can determine the parameter θ that maximizes this function. This process leads to the formulation of the Sigmoid function, as illustrated in Figure 3.2. Data points with Sigmoid function values exceeding 0.5 are classified into one category, while those with values below 0.5 are classified into a different category [13,14].

In order to avoid overfitting, it is necessary to add regularization term $r(\theta) = ||w||^2$ and penalty parameter C to the optimization equation in practical applications. The original problem becomes:

$$max_{\theta,b} ln[\rho(y|x, \theta)] + Cr(\theta) \tag{3.6}$$

Among them, C is a hyperparameter that needs to be manually set.

3.2.2. Support Vector Machine. Support Vector Machine (SVM) is a classification technique grounded in the concept of maximizing the margin between classes. The fundamental approach involves identifying a hyperplane that divides the samples with the largest possible margin. This means that the distance between

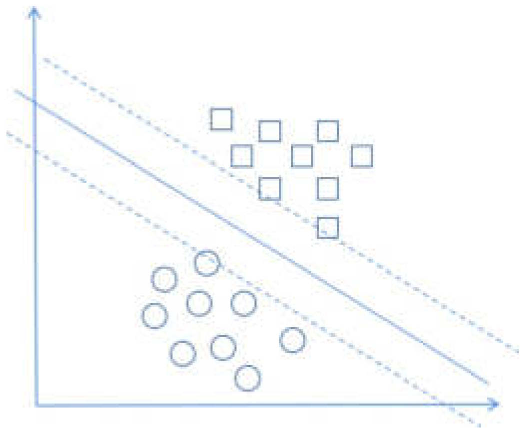

Fig. 3.3: Schematic diagram of support vector machine

the hyperplane and the nearest data points from either class is maximized. The optimal classification surface is defined by:

$$max_{w,b}\frac{2}{||w||}s.t.y_i[(w\cdot x_i)+b]-1\geqslant 0, i=1,2,\cdots,n \tag{3.7}$$

Among them, 2/|Iwl is twice the distance between the sample closest to the classification plane and the classification plane, with constraint s t. ensure correct classification for all samples. As shown in Figure 3.3, circles and crosses represent two types of samples, respectively. The circle and cross that fall on the dashed line are the samples closest to the solid line. If there is a solid line that maximizes the absolute distance between the circle and cross closest to it, then this solid line is the optimal classification surface.

In this context, 2/|Iwl represents twice the distance from the sample closest to the classification hyperplane to the hyperplane itself, while adhering to constraints that ensure all samples are classified correctly. As shown in Figure 3.3, circles and squares represent two types of samples, respectively. The circles and blocks that fall on the dashed line are the samples closest to the solid line. If there is a solid line that maximizes the absolute distance between the circles and blocks closest to it, then this solid line is the optimal classification surface [15].

Determining the optimal classification boundary can be reformulated as a convex quadratic programming problem, which involves optimizing a quadratic objective function subject to linear constraints.

$$min_{w,b}\frac{1}{||2||}||\omega||^2 s.t.y_i[(w\cdot x_i)+b]-1\geqslant 0, i=1,2,\cdots,n \tag{3.8}$$

The extent to which a sample deviates from the constraint conditions is captured by the relaxation variable ξ. Consequently, finding the optimal classification boundary is reformulated as:

$$min_{w,b,\xi}\frac{1}{||2||}||\omega||^2+C\sum_{i=1}^{n}\xi_i s.t.y_i[(w\cdot x_i)+b]\geqslant 1-\xi_i,\xi_i\geqslant, i=1,2,\cdots,n \tag{3.9}$$

Among them, C is used to ”punish” those samples that violate the constraint conditions, and the larger the C, the greater the punishment. C, like δ, is also a hyperparameter [16].

3.2.3. Fusion Algorithm. The core of machine learning involves selecting the best hypothesis from a wide range of possible hypotheses through various algorithms. Each specific learning task often requires a different algorithm suited to its particular needs. In practice, it is frequently unclear which algorithm is most appropriate for a given problem, and no single algorithm is universally effective across all domains. Algorithm fusion addresses this by combining the results from multiple individual algorithms to create a new composite model, which enhances the overall accuracy of the learning process. As computing and storage resources become more accessible, the use of ensemble methods, which integrate multiple algorithms, is gaining traction. The technique used for combining these algorithms is critical to improving the final model's performance. Common fusion methods include bagging, as seen in random forests, and boosting, used in algorithms like AdaBoost [17].

Researchers have shown that for a group of independent classification algorithms, when their accuracy in classifying a problem is greater than 0.5 (that is better than random guessing), the accuracy of using majority voting for classification will increase with the increase of the number of algorithms. Assuming di is the posterior probability of each sample classification result, and di is independent and identically distributed, E (di) is the expectation, Var (di) is the variance, if the weights of each base algorithm are set to wi=1/T (i=1,2,..., T), i.e., using the simple average method for algorithm fusion, the expected and average values of the fused algorithm are:

$$E(\overline{d_i}) = E(\sum_{i=1}^{T} \frac{1}{T} d_i) = \frac{1}{T} TE[d_i] = E(d_i) \tag{3.10}$$

$$Var(\overline{d_i}) = Var(\sum_{i=1}^{T} \frac{1}{T} d_i) = \frac{1}{T^2} TVar[d_i] = \frac{1}{T} Var(d_i) \tag{3.11}$$

From equation 3.12, it can be concluded that the expected value of the fusion algorithm remains unchanged compared to the original base algorithm, while the variance decreases as the number of base algorithms T increases [18]. As a result, a fusion algorithm typically offers higher classification accuracy compared to individual algorithms. However, in practice, increasing the number of fusion algorithms, denoted as T, does not always lead to better performance. It is essential to balance factors such as model complexity and computation time when selecting the optimal value for T. For the author's dataset, experiments indicated that using 2 to 3 fusion algorithms yields the best results. Generally, fusion algorithms tend to provide superior generalization compared to single algorithms, which can be understood through the following three intuitive perspectives:

1. From a data perspective, a single sample set might not provide enough information for a learning algorithm to identify the correct hypothesis. However, by combining multiple hypotheses that each achieve a degree of accuracy, the fusion algorithm can better approximate the true hypothesis within the hypothesis space.
2. From an algorithmic perspective, the ideal hypothesis for a given sample set might not exist within the hypothesis space of a single algorithm. By merging hypotheses from multiple algorithms, we effectively broaden the hypothesis space and get closer to the correct solution.
3. From a computational perspective, many algorithms perform localized searches within the hypothesis space, which can lead to missing the optimal solution and getting stuck in local optima. Fusion algorithms, by starting from various initial points, can collectively cover more of the hypothesis space and more accurately approach the optimal hypothesis.

The weighted average method is of particular significance for algorithm fusion, and it was popular in the 1950s. Perrone and Cooper officially used it for algorithm fusion in 1993. Algorithm fusion fundamentally involves assigning weights to each base algorithm based on learning from the sample data. In essence, different fusion techniques can be viewed as specific cases or variations of the weighted average method. For example, the simple average method is a particular instance of the weighted average approach where each algorithm is given an equal weight wi=1/T (i=1, 2..., T) being the total number of algorithms in the fusion. However, in practical scenarios, due to incomplete data and inherent noise, the weights determined from the sample data might not be entirely accurate and could potentially lead to overfitting. Research indicates that the weighted average method does not always outperform the simple average method in real-world learning tasks. For fusion algorithms to outperform the individual algorithms they comprise, it is essential that the constituent algorithms are both highly accurate and exhibit significant diversity.

Logistic regression and support vector machines are based on different principles: logistic regression uses probability-based classification, while support vector machines focus on maximizing margins between classes. Despite these differing approaches, combining them in a fusion algorithm is believed to reduce the variance of the learning outcomes and enhance overall accuracy. Empirical evidence from the author supports this view. Additionally, the simple average method for fusion has been shown to provide better prediction accuracy compared to the weighted average method. Consequently, the author employs the SoftVoting technique from the Scikit-learn library, a popular Python-based machine learning platform, to integrate logistic regression and support vector machines. The SoftVoting method determines the final classification by averaging the probabilities predicted by each model for all possible categories and selecting the category with the highest average probability. To effectively use SoftVoting, it is essential to first obtain the probability estimates from each individual model for the categories of "purchased" and "not purchased" before performing the fusion. The prediction result of logistic regression is represented as a probability value using the Sigmoid function $h(\theta) = 1/(1 + e^{-}(\theta^T x + b))$, while the support vector machine directly provides a binary output of "1" or "0" for its predictions, it is necessary to transform these binary results into corresponding probability values to integrate with the SoftVoting method. The author uses PlattScaling method to probabilistically convert the prediction results of SVM.

4. Results Analysis.

4.1. Research on Predicting Purchase Behavior on E-commerce Websites. The empirical framework of the machine learning model is shown in Figure 4.1. Firstly, after conducting certain statistical and visual analysis on the raw data, it is preprocessed to remove duplicate and default values from the data. Before filtering, the deduplicated data is first used to calculate the behavior sequence of each consumer towards a certain product, with the product as the smallest unit. Through preliminary analysis of consumer operation sequences, records that do not conform to behavioral patterns and have too few operation times are screened out, and the extraction of other feature indicators is completed. A new dataset is formed by fusion and set as D1. Perform a single naive Bayes training on the dataset and save the training results for comparing model performance. Secondly, establish the necessary environment for RNN experiments and divide the dataset obtained in the previous step into two parts: consumer behavior sequence data d1 and other feature data d2; Divide the training and testing sets based on the size of the specific behavior sequence dataset, and input them into the RNN model. The training ultimately yields the optimal behavior preference score. Then, the behavior preference score obtained by RNN is added to the D1 dataset as one of the new feature items, and a new dataset is formed as D2. Split the dataset into a training set and a testing set with a 10:1 ratio. Train the model using the training set, where the outputs are designated as 0 and 1. After training, evaluate and compare the results by calculating and visualizing the prediction outcomes from both the single Naive Bayes model and the fusion model. By comparing the two, the advantages of the fusion model are summarized, and the conditions and scenarios for the model to be established are explained.

4.2. Introduction to Empirical Data and Predictive Objectives. The dataset is derived from actual user shopping behavior on Alibaba's mobile e-commerce platform and includes five key fields: user ID, product ID, product category ID, type of user interaction with the product (e.g., click, bookmark, add to cart, purchase), and the timestamp of the behavior. It encompasses data from 19,772 users, 422,858 products, and 1,054 product categories, collected over a period from November 18, 2014, to December 18, 2014—spanning 31 days. The goal is to predict each user's purchase behavior on December 19, 2014 (the 32nd day) for all products they interacted with during the previous 31 days. Each sample is uniquely identified by a combination of user ID, product ID, and behavior timestamp, resulting in a total of 2,084,859 records.

Given the class imbalance in the prediction problem—where the number of non-purchase samples significantly outweighs the purchase samples—traditional classification algorithms may struggle with such imbalanced data. Additionally, due to constraints on computation time and memory, processing all samples is impractical. To address these issues, the author uses sampling techniques. Since purchase samples are rare but crucial for predicting future purchases, all 730 purchase samples are retained. From the 87,383 non-purchase samples, 1,500 are randomly selected to create the training set. This adjustment helps balance the sample distribution, approximating a 1:2 ratio between the two categories. For evaluating the model's performance in this imbalanced classification scenario, the author opts for the F1 score, which is a weighted harmonic mean of precision

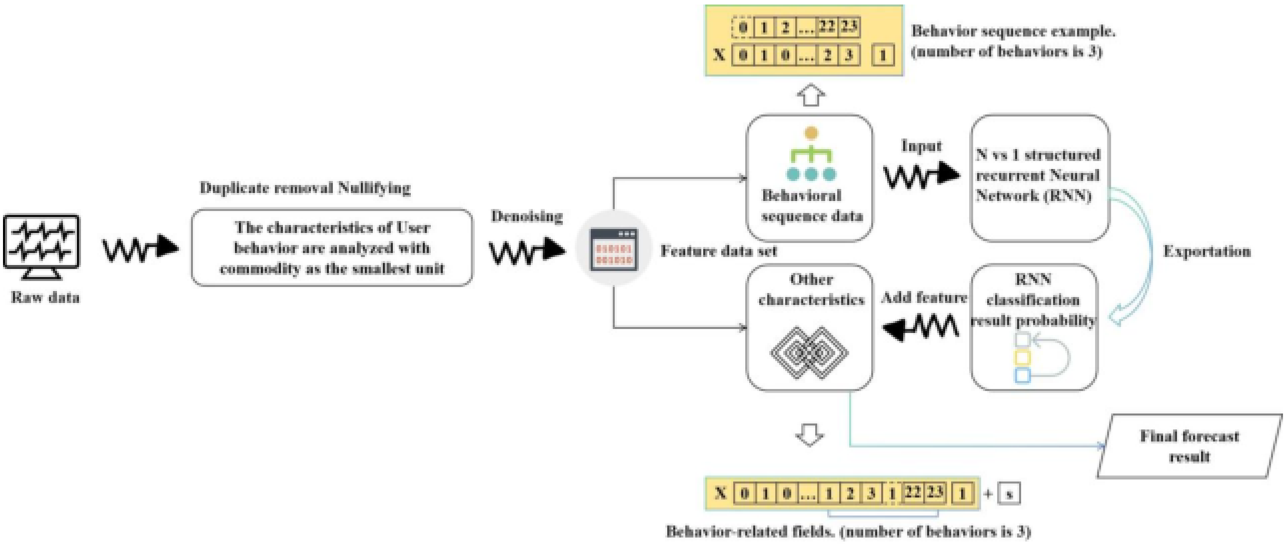

Fig. 4.1: Empirical framework of the model

and recall, rather than the traditional error rate. The formula for calculating the F1 score is:

$$F1\frac{2\times P\times R}{P+R} \tag{4.1}$$

The formulas for computing precision P and recall R are:

$$P = TP/(TP + FP) \tag{4.2}$$

$$R = TP/(TP + FN) \tag{4.3}$$

In this context, TP refers to the count of samples where the model correctly predicts the occurrence of purchasing behavior. Meanwhile, FP denotes the number of samples where the model incorrectly predicts a purchase, and FN indicates the count of samples where the model fails to detect actual purchasing behavior.

4.3. Prediction results of online purchasing behavior based on logistic regression algorithm. A training set containing 2,230 samples—comprising 730 purchase instances and 1,500 non-purchase instances—was used with the logistic regression algorithm. The hyperparameter C was explored within the range of [2,240], with 10 values selected in an exponential scale within this range. For each C value, the algorithm was subjected to 3-fold cross-validation, resulting in 30 learning iterations to identify the optimal model. The test set was then evaluated with this model, yielding 656 samples predicted to exhibit purchasing behavior on the 32nd day. The F1 score of this prediction, when compared to the actual purchases made on the 32nd day, was found to be 7.73%.

4.4. Prediction results of online purchasing behavior based on support vector machine algorithm. The "soft margin" Support Vector Machine (SVM) algorithm with an RBF kernel was utilized to build the prediction model. The process began by training the algorithm with 2,230 samples from the training set. To find the optimal hyperparameters, namely C and the Gaussian kernel bandwidth δ, a layered 3-fold cross-validation approach was employed. The ranges for C and δ were set within [2,210], and 10 values for each were chosen in an exponential scale, resulting in a total of 100 parameter combinations (10 values of C $\times$ 10 values of δ). Each combination underwent 3-fold cross-validation, leading to 300 iterations to determine the best model. Finally, the model was tested with 1,445 samples from the test set, producing 577 samples with a prediction of "1," indicating the likelihood of purchasing behavior on the 32nd day. Compared with the sample that actually made a purchase on the 32nd day, its F1 score was 7.75%.

Table 4.1: Comparison of Prediction Results of Three Models

	Sample size for predicting purchase behavior	F1 score
Logistic regression	656	7.73
Support vector machine	577	7.75
fusion algorithm	571	7.77

4.5. Logistic regression support vector machine fusion algorithm for predicting online purchasing behavior. The steps for building a model using a single algorithm are the same. Initially, a training set of 2,230 samples is utilized to train a hybrid model that combines logistic regression and support vector machine algorithms, employing the Soft Voting method for integration. Then use layered 3-fold cross validation on the hybrid algorithm to obtain the optimal fusion algorithm. Due to limitations in computing resources, the author restricts the selection range of fusion algorithm parameters. Considering the predictive performance of both the logistic regression and support vector machine algorithms across various parameter settings, the author defined the hyperparameter ranges for the support vector machine within $[2^7, 2^{10}]$. Three specific values for C and δ were chosen within this range, arranged in exponential increments; Select the range of values for the logistic regression hyperparameter C within $[2^{15}2^{20}]$, and choose 5 values within this range in exponential order as the values for C; The 3 parameters (SVM-C, 8, LR — C) have a total of 3x3x5 = 45, and the algorithm carries out 3 times cross-verification for every value, making a total of 3x45 = 135 computations. Finally, we input 1445 samples into the model and get the predicted results. A sample of "1" predicted that buying behaviour would take place on Day 32, in a total of 571 samples. Compared to those who bought it on the 32nd day, their F1 score was 7.77 percent.

4.6. Comparison of Prediction Effects of Three Models. The F1 results of 3 models built with various algorithms are presented in Table 4.1, respectively. Comparison of F1 results shows that this method has the least amount of data for forecasting buying behaviour, but it is superior to that of other individual models. Though the F1 of this method is only 0.02 percent better than that of the single-model, it is not a negligible increase since the F1 is needed for the forecast.

5. Conclusion. The rapid development of technology has also driven the continuous improvement and optimization of machine learning algorithms, but machine learning algorithms have not yet been fully utilized in practical business applications. Machine learning algorithms are simple algorithms that can perform big data analysis. Many large-scale companies are fully aware of the importance of machine learning algorithms, and the most obvious application effect is the "Double Eleven" event held by Alibaba and Tmall every year. Machine learning algorithms can be applied in a variety of ways in the process of business development. It can be a single model algorithm or a combination of two single model algorithms to form a fusion algorithm. The author mainly studies which of the two algorithms, the single model algorithm and the fusion algorithm algorithm, can achieve more accurate budget results in the business application process. The proposed method is applied to forecast the buying behaviour of consumers under on-line shopping environment and it is found that the forecast precision of this method is better than that of single-model.

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OPTIMIZATION AND IMPLEMENTATION OF MULTI SOURCE INFORMATION FUSION ALGORITHM FOR MARITIME SAFETY MANAGEMENT DRIVEN BY ARTIFICIAL INTELLIGENCE

SHUANGYI GE* AND CHENGCHENG SHAN†

Abstract. In order to ensure the relative stability of ships sailing at sea, a wave compensation platform compensation system based on artificial intelligence and information fusion is proposed. The experimental results indicate that during a motion cycle, when motion tube 1 moves downwards, motion tubes 2 and 3 will move upwards for 1/4 cycle, followed by motion tube 1 moving upwards for 1/2 cycle, and then move in the opposite direction. When cylinder 1 moves downwards from the high position, cylinders 2 and 3 move downwards. The phase difference between moving cylinder 1 and cylinders 2 and 3 is 90 degrees. In addition, the displacement phase calculated in real-time is consistent with the displacement phase of moving cylinder 1. The upward displacement of point A caused by the downward movement of the moving cylinder needs to be compensated by the downward movement, while the upward movement of points B and C needs to be compensated.

Key words: Wave compensation, Frequency domain filtering, Frequency domain integration, Data fusion

1. Introduction. The Internet of things (IOTS) connects people, things and systems, Combined with intelligent services, they can communicate with each other anytime and anywhere Communicate to meet information resource processing requirements.

In modern times, the ocean plays an important role in people's production and life. Especially in the 21st century, with the gradual decline of land resources and the worsening of living environment, people are constantly turning their attention to the ocean. The development of the ocean can not only alleviate human demand for resources, but also reduce human pollution on land and purify people's living environment. It is particularly important to increase the ocean development technology related to the development of the ocean. For example, the stable platform technology to be studied in this project is affected by wind, current and waves, so its motion form will inevitably be a complex composite movement [1]. This composite motion is composed of ship's roll motion, pitch motion, yaw motion, heave motion, heeling motion, and pitch motion, among which roll motion, pitch motion, and heave motion have the strongest impact on the performance of ships or marine equipment. The marine stabilized platform can keep the stabilized object relatively stable in the inertial coordinate system when it is disturbed. The development of marine stable platform is extremely important to give full play to helicopter offshore operation, improve the working accuracy of shipborne equipment, and ensure national defense security and economic development. Because of the advantages of parallel mechanism, such as large stiffness, stable structure, strong bearing capacity, high accuracy and small motion inertia, the parallel stable platform has attracted great attention. For the parallel stable platform, based on the complexity of the structure and the coupling of the motion, the establishment of an accurate dynamic model is the basis for the dynamic analysis, is the necessary condition for the evaluation of the dynamic characteristics of the mechanism and the dynamic optimization design, and is also the prerequisite for achieving the high-precision control of the parallel stable platform [2]. With the rapid development of Internet and cloud computing technologies, The interconnection network is connected not only to the computer, but also to the daily life The square side of the face, step by step into any time and place A point can be used to build an interconnected iot network for any device. The things network combines computer data with real and real world data. According to the industry forecast, the number is believed to be everywhere the collection of information, so that the Internet of things

*Spic Jiangsu Offshore Wind Power Co., Ltd., Yancheng, Jiangsu, 224000, China. (Corresponding author, ShuangyiGe7@163.com)

†Spic Jiangsu Offshore Wind Power Co., Ltd., Yancheng, Jiangsu, 224000, China. (ChengchengShan8@126.com)

technology can and security the question is facing a great challenge.

2. Literature Review. Through comprehensive analysis of wave compensation technology in recent years, we can find that there is a pattern in the industry: internationally, academic research on wave compensation technology is mainly focused on the lateral anti-swing of restraining load swing, while the vertical control of reducing the impact of ship motion, especially the impact of wind and waves on underwater equipment, has been very mature [3]. For example, Qiao, W. et al. discussed and investigated the cognitive differences and correlations between Safety I and Safety II in the maritime industry. To this end, they conducted questionnaires and semi-structured interviews with seafarers and maritime experts to collect raw data related to Safety I and Safety II. Then, they use empirical statistical method and fuzzy analytic hierarchy process (AHP) to further process the data from seafarers and maritime experts. The results show that the influencing factors related to personal aspects are generally considered as the leading factor of safety concept I, while organizational factors have a greater impact on safety concept II, which is crucial to the development of organizational resilience [4]. The new version of China's Maritime Traffic Safety Law 2021 (MTSL 2021) was officially implemented on September 1, 2021. MTSL2021 may significantly change the maritime traffic safety regulatory framework of waters under Chinese jurisdiction, especially the maritime safety regulatory framework of foreign ships. MTSL2021 will have an important impact on the navigation of foreign ships in waters under China's jurisdiction and China's future maritime law enforcement. However, the regulatory framework applicable to foreign ships in China's new MTSL is not without shortcomings. Some problems, including some vaguely worded clauses and provisions, the space left for discretion and the overlapping of regulatory powers between different law enforcement agencies, may bring uncertainty to the predictable, transparent and consistent results of maritime law enforcement. Zhang, H. et al. reviewed China's reform of the relevant system of maritime safety management of foreign ships, analyzed the deficiencies and problems in the new regulatory framework, and discussed its potential impact on China's maritime law enforcement [5]. Zhang, M. et al. proposed a prediction analysis method to study maritime ship traffic in more detail. This method uses Lempel-Ziv algorithm and TOPSIS based on similarity of ideal solution to manage traffic safety. Lempel-Ziv algorithm quantifies the entropy used to evaluate the irregularity and unpredictability of ship travel time series, and TOPSIS ranks the complexity. The results presented use the automatic identification system (AIS) data, which corresponds to the complex inland river traffic scene encountered in the Yangtze River. They show that the high complexity means that the time series of ship travel is neither periodic nor random, but depends on the evolution mode of traffic encounter. They analyzed the correlation between the complexity of traffic flow and the number of maritime accidents, indicating that the higher the complexity of traffic flow, the more accidents may occur. Therefore, they concluded that the proposed method can help (1) accurately distinguish the complexity of traffic flow, indicating that the higher the complexity value, the higher the irregularity and unpredictability of maritime traffic flow, and (2) provide useful reference for optimizing the traffic management within the operation life cycle of the fleet and maritime safety management in areas with high traffic flow complexity [6].

The basic framework of Internet of Things based on cloud computing: Internet of Things The network image generates a large amount of data, which travels in the cloud Reason and analysis, produce information, which can be used in things Programs should be used for the intelligence service or person in the network. Be right A large number of target data to achieve high efficiency management, need to present the strengthening of the cloud frame is on the basis of the substance the real-time service of the network is energy consumption, security and privacy And instant side lift effects are a must.

This paper introduces the processing technology of redundant data in multi-sensor measurement, and uses the weighted average method of these processing technologies to further data fusion processing of the test data processing results to obtain more useful and effective displacement compensation. The results show that redundant data fusion technology is also an effective and feasible method.

3. Research methods.

3.1. Common sensor redundancy data fusion methods. Common data processing systems run only on local computers Unlike computing, which deals with local data, cloud computing requires users to download it from the cloud the data information is processed and shared with other users in the cloud. The need for massive data generated by the Internet of Things Knowledge, collection, transmission, and ultimately the ability to tease, all of this is based on data processing The platform. Relying on cloud computing can improve the operational efficiency of the Internet of Things , Information security lays a solid foundation for the construction of the two networks.

At present, the data fusion theory and methods are mainly divided into four types of two major plates, including the estimation and statistical methods in classical processing, and the information theory and artificial intelligence methods based on modern theory. There are more specific divisions under various theoretical methods. In multi-sensor measurement system, the methods of redundant data fusion mainly include: weighted average method, least square method, Kalman filter method, Bayesian estimation method, etc.Cloud computing model types can be divided into private cloud, public cloud, community cloud and hybrid cloud four deployment, they are respectively for different use of the environment. The effective play of the advantages of cloud computing depends on scientific and reasonable security.

In this case, it is necessary and important to study security technology and strengthen encryption. In order to Ensure data security, establish information security system perfect identity authentication management body One cannot be without the other.

3.1.1. Weighted average method. To avoid arbitrary or even malicious use of data r fusion, you should first build numbers According to the security center, data security levels are divided, followed by users of different levels Set different permissions to ensure that data fusion meets requirements within a certain range Before it can be used.For multi-sensor measurement system, the purpose of position-level data fusion in real-time tracking is to judge the validity of a set of measurement data obtained, and then obtain the fusion data according to certain rules, and then send the data back to the control system for control. To make the returned data most effective, it is necessary to determine a reasonable fusion rule. It is an effective method to adjust the proportion of the measured data in the fusion results by weighting coefficients [7,8].

The weighted average method is the most simple and intuitive method, that is, the redundant information provided by multiple sensors is weighted and averaged as the fusion value. This method can process the dynamic original sensor readings in real time, but the workload of adjusting and setting the weight coefficient is large, and it has certain subjectivity. The maximum likelihood estimation method is not only applicable to any population, but also has consistency, asymptotic normality and asymptotic minimum variance under a wide range of conditions. Although the obtained statistics are not necessarily unbiased, they can often be modified into unbiased estimators. However, not all parameters to be estimated can obtain the likelihood estimator, and when using the maximum likelihood estimation method to obtain the estimator, it is often required to solve a likelihood equation [9].

The mathematical model of weighted average can be simply expressed as:

At time K, the system has n sensors at the same level. The measured value of the target is: $X_{Ki}(i = 1, 2, Ln)$, and X_{Ki} is n data that can be directly operated or transformed for operation. According to the weighted average fusion algorithm, the corresponding weight value of each sensor data is $a_{Ki}, (i = 1, 2, Ln)$, and the final data processing result is as follows 3.1:

$$X'_K = \sum_{i=1}^{n} (a^*_{Ki} X_{Ki}) \tag{3.1}$$

where a_{Ki} shall meet the following formula 3.2:

$$\sum_{i=1}^{n} a_{Ki} = 1 \tag{3.2}$$

The purpose of the algorithm is to determine the weight of each sensor at the same time, so a_{Ki}, n are the number of sensors in the system.

3.1.2. Least square method. The criterion of the least squares method is to select X to minimize the estimation performance index (sum of squares of estimation error). When the accuracy of each data measurement is different, the weighted processing shall be adopted to give greater weight to the measurement results with higher accuracy. The least square method is based on the error theory. Among the data processing methods, the error is the smallest and the accuracy is the best. In practical work, it is often necessary to process the newly acquired data in real time. Each additional data needs to recalculate all the data, and the amount of calculation is large.

The processing principle of the least squares method has been introduced in the above chapters, and will not be repeated here.

3.1.3. Kalman filtering method. Kalman filter is mainly used to fuse low-level real-time dynamic multi-sensor redundant data. This method uses the statistical characteristics of the measurement model to determine the optimal fusion and data estimation in the statistical sense. If the system has a linear dynamic model, and the error between the system and the sensor conforms to the Gaussian white noise model, the Kalman filter will provide the best estimate in the unique statistical sense for the fused data. The recursive characteristic of Kalman filter makes the system not need a lot of data storage and calculation. This method has good real-time performance and is suitable for processing dynamic, low-level and redundant data. The disadvantage is that it can only deal with linear problems, low observation degree and easy to diverge [10].

Algorithm principle of Kalman filter method. Let the system state equation be as follows 3.3:

$$x(k+1) = Ax(k) + u(k) \tag{3.3}$$

The sensor observation equation is as follows 3.4:

$$y(k) = Cx(k) + v(k) \tag{3.4}$$

where $x(k+1)$ and $x(k)$ are the state variables of the system at k+1 and k respectively; $u(k)$ is system noise; $y(k)$ is the observation variable of the system at k time; $v(k)$ is the observation noise; C is the state transition matrix of the system; A is the observation matrix of the system;$u(k)$ and $v(k)$ are white noise with zero mean value.

Based on Equation 3.3 and Equation 3.4, the one-step state vector estimation can be obtained as follows 3.5, 3.6, 3.7:

$$\hat{x}(k|k-1) = A\hat{x}(k-1|k-1) \tag{3.5}$$

$$P(k|k-1) = AP(k-1|k-1)A' + Q \tag{3.6}$$

$$\hat{y}(k|k-1) = \hat{C}(k|k-1) \tag{3.7}$$

where $\hat{x}(k|k-2)$ is the state estimation value at time k according to the estimation value at time c; $\hat{x}(k-1|k-1)$ is the k-1 moment estimate; $P(k|k-1)$ is the prediction covariance matrix; $P(k-1|k-1)$ is the error covariance matrix; $\hat{y}(k|k-1)$ is the observation value at the time of k according to the estimated value at the time of k-1, and there are:

The system noise covariance is as follows 3.8:

$$Q = E\{u(k)u'(k)\} \tag{3.8}$$

The observed noise covariance is as follows 3.9:

$$R = E\{v(k)v'(k)\} \tag{3.9}$$

Based on the observed value at the current moment and the estimated value at the previous moment, the updated value of the measurement vector of the following formula 3.10,3.11,3.12 can be obtained:

$$K(k) = P(k|k-1)C'(CP(k|k-1))C' + R)^{-1} \tag{3.10}$$

$$\hat{x}(k|k) = \hat{x}(k|k-1) + K(y(k) - Cx(k|k-1)) \tag{3.11}$$

$$P(k|k) = P(k|k-1) - KCP(k|k-1) \tag{3.12}$$

where $K(k)$ is the Kalman gain; $P(k|k)$ is the covariance matrix.

3.1.4. Bayesian estimation method. Bayesian inference is to estimate some unknown states with subjective probability under incomplete information, then modify the prior probability with Bayesian formula, and finally make the optimal decision with the modified probability.Bayesian estimation is a common method to fuse high-level information of multi-sensor in static environment. It regards each sensor as a Bayesian estimator, and synthesizes the correlation probability distribution of each target into a joint posterior distribution function. With the arrival of the observed value, the likelihood function of the assumed joint distribution is constantly updated, and the data is finally fused through the maximum or minimum of the likelihood function. Bayesian reasoning solves some problems in classical reasoning. Its difficulty is to define a priori likelihood function, which is more complex when there are multiple potential assumptions and multiple conditional independent events. It requires that some assumptions are mutually exclusive and lack general uncertainty [11,12].

Principle of Bayesian optimal estimation algorithm. Assume that the consistency measurement data set is $X = \{x_1, x_2, L, x_t\}$ in the measurement data obtained from m sensors measuring the same parameter, where $m \geqslant t$. Then the optimal result of the measured parameters is as follows 3.13:

$$P(\mu|x_1, x_2, L, x_t) = \frac{p(\mu; x_1, x_2, L, x_t)}{p(; x_1, x_2, L, x_t)} \tag{3.13}$$

If parameter μ obeys $N(\mu_N, \sigma_N^2)$, and x_k obeys $N(\mu, \sigma_k^2)$, and let $a = \frac{1}{P(x_1, x_2, L, x_t)}$, a is a constant independent of μ, so it is the following formula 3.14:

$$\begin{aligned} P(\mu|x_1, x_2, L, x_t) &= a \prod_{k=1}^{t} \frac{1}{\sqrt{2\pi}} exp\left\{ -\frac{1}{2} \left[\frac{x_k - \mu}{\sigma_k} \right]^2 \right\} \times \frac{1}{\sqrt{2\pi}\sigma_0} exp\{ -\frac{1}{2} \left[\frac{x_k - \mu}{\sigma_0} \right]^2 \} \\ &= a \cdot exp\left\{ -\frac{1}{2} \left[\frac{x_k - \mu}{\sigma_k} \right]^2 - -\frac{1}{2} \left[\frac{x_k - \mu}{\sigma_0} \right]^2 \right\} \times \prod_{k=0}^{t} \frac{1}{\sqrt{2\pi}\sigma_k} \end{aligned} \tag{3.14}$$

The exponential part of the above formula is a quadratic function of μ, so $P(\mu|x_1, x_2, L, x_t)$ is still normal distribution, assuming that it follows $N(\mu_N, \sigma_N^2)$, that is, the following formula 3.15:

$$\begin{aligned} P(\mu|x_1, x_2, L, x_t) &= \frac{1}{\sqrt{2\pi}\sigma_N} exp\left\{ -\frac{1}{2} \left[\frac{\mu - \mu_N}{\sigma_N} \right]^2 \right\} \\ \mu_N &= \left[\sum_{k=1}^{t} \frac{x_k}{\sigma_k^2} + \frac{\mu_0}{\sigma_0^2} \right] / \left[\sum_{k=1}^{t} \frac{1}{\sigma_k^2} + \frac{1}{\sigma_0^2} \right] \\ \hat{\mu} &= \int_\Omega \frac{1}{\sqrt{2\pi}\sigma_N} exp\left\{ -\frac{1}{2} \left[\frac{\mu - \mu_N}{\sigma_N} \right]^2 \right\} d\mu = \mu_N \end{aligned} \tag{3.15}$$

From the parameters of the above two formulas, the following formula 3.16 is obtained:

$$\mu_N = \left[\sum_{k=1}^{t} \frac{x_k}{\sigma_k^2} + \frac{\mu_0}{\sigma_0^2} \right] / \left[\sum_{k=1}^{t} \frac{1}{\sigma_k^2} + \frac{1}{\sigma_0^2} \right] \tag{3.16}$$

Therefore, the Bayesian estimation $\hat{\mu}$ of μ is as follows 3.17:

$$\hat{\mu} = \int_\Omega \mu \frac{1}{\sqrt{2\pi}\sigma_N} exp\left\{ -\frac{1}{2} \left[\frac{\mu - \mu_N}{\sigma_N} \right]^2 \right\} d\mu = \mu_N \tag{3.17}$$

Therefore, $\hat{\mu}$ is the optimal fusion estimation data of μ.

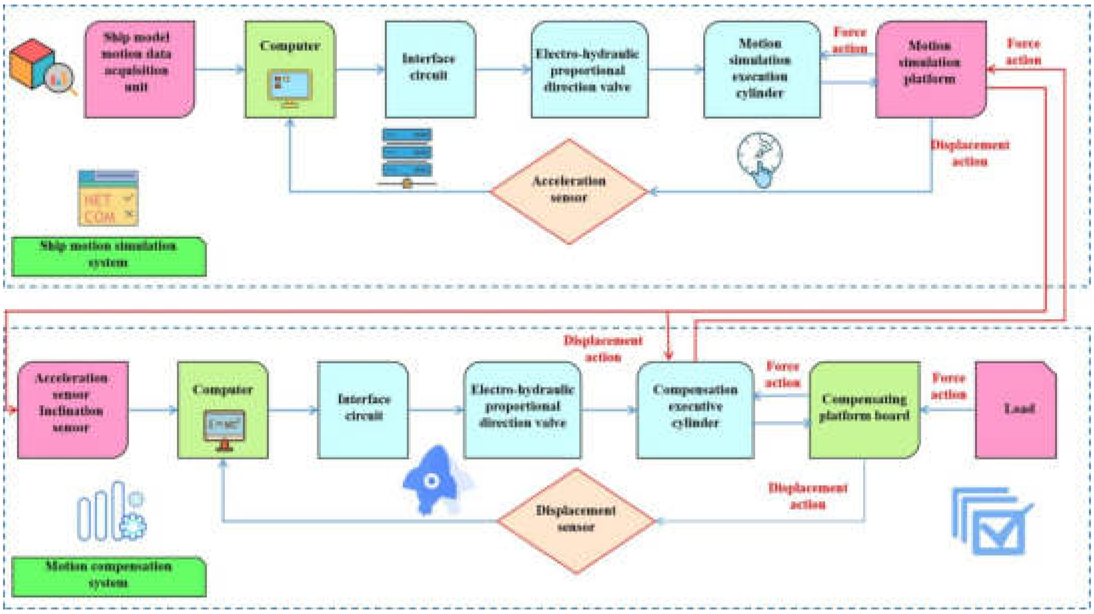

Fig. 3.1: Block diagram of motion compensation test system

3.2. Block diagram of wave compensation test system. The wave compensation test system mainly includes the ship model motion simulation system and the motion compensation system. According to the test flow, the test system block diagram shown in Figure 3.1 is obtained.

The test process is as follows: first start the ship motion simulation system to simulate the ship roll, pitch or heave motion, and then start the motion acquisition module in the motion compensation system to collect the simulation input of the instantaneous acceleration and inclination of the simulated motion in real time through the acceleration sensor and inclination sensor. After the computer compares the feedback data of the displacement sensor with the calculated displacement data, the digital analog output of the data acquisition card transmits the control signal to the electro-hydraulic proportional directional valve to drive the oil cylinder for compensation, and completes the displacement compensation of the platform [13,14].

3.3. Construction of real-time acquisition processing and compensation program system. During data processing and analysis and program writing, the acceleration signal data processing is completed by processing the collected data at one time. However, in actual compensation, the compensation signal is required to be real-time. Through real-time calculation, the collected signal is processed quickly and the latest control signal is output to the proportional direction valve to drive the executive cylinder to compensate the compensation platform plate. In addition, since previous work is based on the Visio Basic platform, it is necessary to transplant and modify the processing program written by MATLAB.

In view of the real-time nature of the frequency domain processing technology, the frequency domain processing technology, including frequency domain filtering and frequency domain integration technology, is used in the construction of the real-time processing program. Real-time collection is completed through the Timer control in Visio Basic. Every Timer.interval, a batch of new data is read in and stored in the corresponding array for subsequent program calls and processing. After transplantation, three main modules are added: frequency domain filter, FFT transform and IFFT inverse transform.

4. Result analysis. After adding the real-time processing program of acceleration signal, the compensation system can perform real-time compensation of three degrees of freedom of heave motion, pitch motion and roll motion, and can also compensate for combined motion. Since roll and pitch are similar in processing technology, the following is mainly to discuss and analyze the motion compensation of ship heave and roll [15].

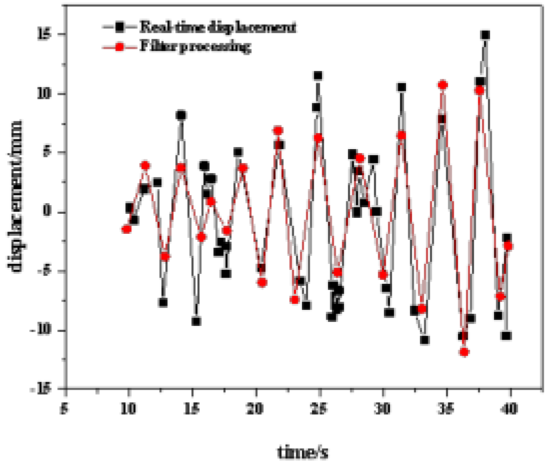

Fig. 4.1: Comparison of real-time displacement calculation and filtering results of heave motion

4.1. Heave motion compensation. The motion simulation platform simulates the heave motion of the ship, due to the inevitable impact of environmental noise, and the selected acceleration sensor has high sensitivity. Therefore, when the real-time acceleration signal is directly collected and compensated after calculation, the compensation effect is relatively poor due to the influence of high-frequency vibration, and the result of calculation is directly reflected in the compensation result. The compensation value is often large or small, which cannot meet the requirements of the assumption. Therefore, it is necessary to effectively process the high-frequency signal to avoid subsequent processing.

It can be seen from the figure that if proper processing is not added, the real-time acceleration signal will be large, basically concentrated between - 1∼+1 m/s2, and some even reach 3 m/s2 and above. The acceleration signal processed by real-time frequency domain filtering is concentrated in the range of - 0.4∼0.4m/s2, the amplitude is greatly reduced, and the overall trend is obvious. Compared with the post-processing filtering curve, we can see that due to the distortion generated in the real-time filtering process, the real-time filtering curve has many uneven points. On the one hand, it is the real vibration signal, on the other hand, it may be the error caused by the spectral leakage during the filtering process. This is a problem that needs to be solved by adding appropriate processing technology to obtain better acceleration signal [16].

The real-time calculated displacement signal and post-processed displacement signal are shown in Figure 4.1.

It can be seen from the figure that due to the high frequency influence brought in by the acceleration signal in front, some high frequency influence also appeared in the subsequent acceleration integration processing, and the displacement signal after proper filtering is relatively stable.

After the acceleration signal is integrated, the DA output signal is calculated by PID as shown in Figure 4.2.

It can be seen from the figure that the response signal of the compensation cylinder lags behind the calculated DA output signal, and the DA output control signal is not synchronized with the signal received by the compensation cylinder. After a proper phase shift of 1/4 cycle, it is found that the DA output signal is basically synchronized with the response signal of the compensation cylinder, indicating that the DA output signal is 1/4 cycle ahead of the received signal of the compensation cylinder. One of the reasons is that the program solution and signal transmission are time-consuming, and the important one is that the hydraulic control system also has certain hysteresis [17,18].

After the above processing output, what is the compensation effect of the stable platform? The most illustrative point is the comparison between the compensation amount of the compensation cylinder and the

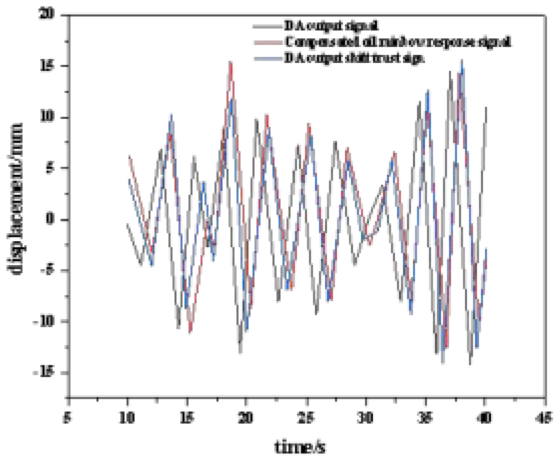

Fig. 4.2: Comparison between the heave motion DA output signal and the compensation cylinder signal

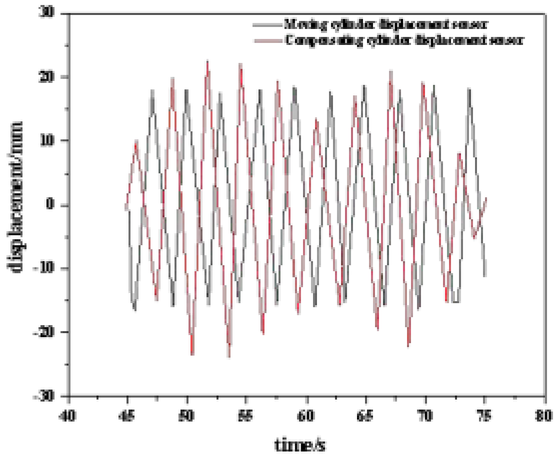

Fig. 4.3: Comparison curve between predicted ROP and actual ROP by neural network

amplitude and phase of the movement amount of the motion cylinder, as shown in Figure 4.3.

It can be seen from the figure that in the 45s∼60s interval, the compensation value of the compensation cylinder is just opposite to the movement value of the motion cylinder in phase, and the compensation value is slightly larger than the movement value in amplitude, that is, it can maintain the movement in the opposite direction with the motion cylinder to realize synchronous compensation. In the interval after 60s, the compensation value lags behind the motion value, and the compensation and motion are not synchronized. Real-time heave compensation has a certain effect, but it cannot achieve effective synchronization, mainly due to the influence of a large number of vibration signal interference, resulting in the movement of the compensation cylinder and the movement of the motion cylinder can not be synchronized, and other existing problems, which need further research and solution [19].

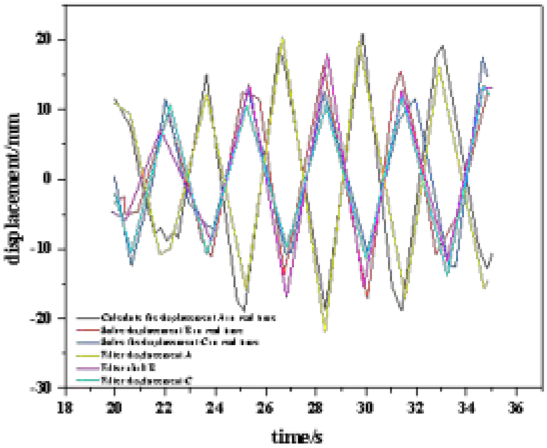

Fig. 4.4: Comparison of real-time calculated displacement and filtering results of rolling motion

4.2. Roll motion compensation. Since the mechanism of pitch motion is the same as that of roll motion in motion simulation, this paper mainly discusses the compensation of roll motion.

After filtering, the amplitude of the acceleration signal is greatly reduced, the field noise is effectively suppressed and eliminated, and the acceleration signal value is closer to the actual value. The signal obtained by real-time processing is still relatively rough and not smooth, and the phase of each accelerometer is also asynchronous, which will affect the subsequent processing. Therefore, like the heave compensation, this is an urgent problem to be solved.

The real-time result of integrating the acceleration signal obtained from real-time calculation is shown in Figure 4.4. It can be seen from the figure that although the acceleration signal calculated in real time is relatively disordered, the noise of the displacement value after the integration processing has been well suppressed, which indicates that the integration processing algorithm is relatively appropriate. One point to be explained here is the calculated displacement amplitude and phase. When simulating the motion of the platform, the compensation platform follows the motion. To realize compensation, the motion of the compensation cylinder should be opposite to the motion of the moving platform. Therefore, when the motion platform is warped, the motion cylinder 1 moves downward, and the compensation platform will move upward. To maintain the relative level of the compensation platform, the compensation cylinder A should move downward, and the compensation cylinders B and C should move upward. That is, the compensation movement of compensation cylinders B and C is opposite to that of cylinder A. Figure 4.4 and Figure 4.5 can reflect this situation.

Figure 4.5 shows that in a movement cycle, when the movement cylinder 1 moves downward, the movement cylinders 2 and 3 will move upward for 1/4 cycle, then follow the movement cylinder 1 to move upward for 1/4 cycle, and then move in the opposite direction. When cylinder 1 moves downward from the high position, cylinders 2 and 3 follow the downward movement. That is, the phase difference between the motion cylinder 1 and the cylinders 2 and 3 is 90 degrees. In addition, we can see from Figure 4.6 that the displacement phase calculated in real time is consistent with that of the motion cylinder 1. The upward displacement of point A caused by the downward movement of the motion cylinder needs to be compensated by the downward movement, while the upward displacement of point B and C should be compensated [20].

After the real-time displacement signal is obtained, the DA output signal is calculated to drive the control compensation cylinder for compensation, as shown in Figure 4.6.

From the compensation results, the action phase of the compensation cylinder and the movement cylinder can not be well matched, and the situation of lag and lead often occurs; In addition, the compensation ampli-

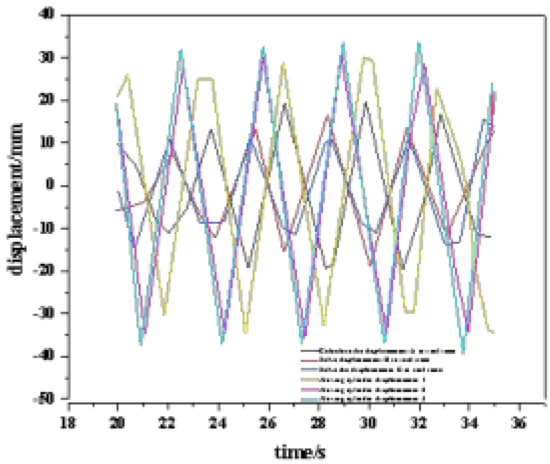

Fig. 4.5: Comparison between real-time calculated displacement of rolling motion and displacement of moving oil cylinder

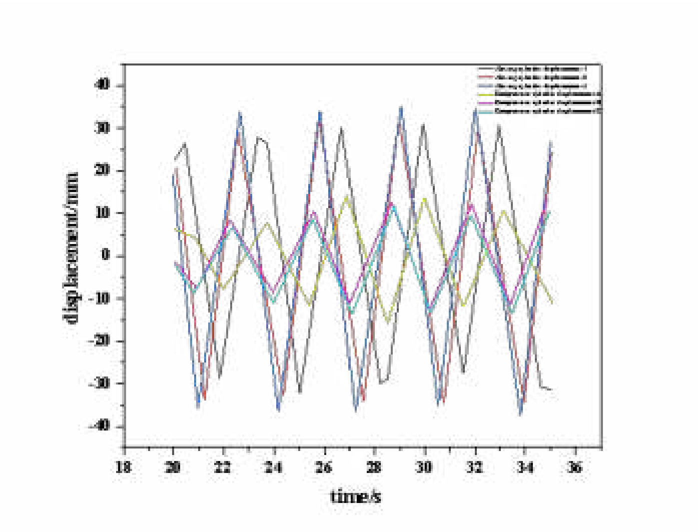

Fig. 4.6: Comparison of displacement of compensation cylinder and movement cylinder

tude is smaller than the motion amplitude, and the motion displacement cannot be completely compensated. Therefore, the compensation effect is not very ideal. There is still a distance from the expected effect, and a lot of work needs to be done. There are still many problems to be solved.

5. Conclusion. Cloud computing security system six bases This module is: management server, cloud computing resource server, data transmission, right Called encryption, asymmetric encryption, client.This paper mainly analyzes and discusses the real-time motion compensation test data of the compensation system from the ship's heave motion and roll motion. We analyze and discuss the simulation of ship motion from the start motion simulation system, input the collected data into the computer through the acquisition card, and then calculate and output the compensation control signal and compensation results by the real-time processing program. In this whole process, the treatment effect of each main joint is good. From the result, the real-time processing compensation has certain effect, but it is still far from the expected effect, and there are also many technical problems to be solved.

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INTELLIGENT PREDICTION OF CAPACITY MARGIN IN DIFFERENT TIME PERIODS BASED ON WAVELET ANALYSIS ALGORITHM

YAOHUI SUN*, CHENGUANG YANG†, XIAOJUAN CHEN‡, ZHI FANG§, AND CHUNHAI LI¶

Abstract. In order to understand the intelligent prediction of capacity margin in different time periods, the author proposes a research on intelligent prediction of capacity margin in different time periods based on wavelet analysis. The author first uses wavelet decomposition and neural networks as tools to predict electricity prices in different time periods. The changes in the electricity price sequence during different time periods are relatively single, which is conducive to the learning and training of neural networks, thereby improving prediction accuracy. Secondly, compare the predicted results of time slot capacity margin based on wavelet analysis technology with the actual values. Finally, the experimental results indicate that the average relative percentage error of short-term electricity price prediction can reach 11.40%. The intelligent Jun page measurement method for capacity margin based on wavelet analysis proposed by the author can effectively improve the prediction accuracy of power grid capacity margin, and has strong practicality and effectiveness.

Key words: Wavelet analysis, Time division, Power

1. Introduction. The intelligent prediction of time slot capacity margin based on wavelet analysis is a method that utilizes wavelet transform to analyze and predict the capacity margin of power systems. The prediction method decomposes the time series into multiple sub series, and then carries out wavelet analysis on Subsequence with different frequencies to obtain corresponding wavelet coefficients, thus realizing the prediction of capacity margin. The advantage of this method is that it can identify periodic changes at different scales, has good adaptability to the processing of nonlinear time series, has high prediction accuracy, and has certain reference value for effective management and scheduling of capacity margin in power systems. The price of electricity is the most significant factor in the electricity market that has a direct impact on both the supply and demand of electricity. It is also an essential component of the electricity market. How to accurately predict electricity prices has become an important part of electricity market reform as the market for electricity has grown. Different prediction methods can be used for different electricity markets, such as in demand side management, where electricity prices can be divided into time period electricity prices and real-time electricity prices; Under the Market clearing mechanism, the real-time price can be divided into time of use price and daily price. Due to the numerous and complex factors that affect changes in electricity prices, establishing accurate, reliable, and efficient prediction models is the key to improving the accuracy of short-term electricity price prediction. The combination of wavelet analysis and neural network is used to forecast short-term electricity price, and wavelet analysis is used to decompose and reconstruct the time series to construct a neural network forecasting model with nonlinear mapping ability, thus improving the accuracy of short-term electricity price forecasting. Short term electricity price prediction is an important link in the electricity market. It is a prediction of future short-term electricity prices, and its results can guide the operation of the electricity market. There are many factors that affect electricity prices, mainly including supply and demand relationships, seasonal factors, unit combinations, load characteristics, weather changes, etc. Due to the influence of various factors on electricity prices, there is a close relationship between price and time. Short term electricity price forecasting generally adopts linear models, which describe various price relationships in the electricity market by establishing a series of mathematical models. When predicting short-term electricity prices, it is first necessary

*State Grid BaiShan Supply Electric Power Company, JiLin, Baishan, 134300, China. (Corresponding author)
†State Grid BaiShan Supply Electric Power Company, JiLin, Baishan, 134300, China.
‡State Grid BaiShan Supply Electric Power Company, JiLin, Baishan, 134300, China.
§State Grid BaiShan Supply Electric Power Company, JiLin, Baishan, 134300, China.
¶Shijiazhuang Kelin Electric Co., Ltd., Hebei, Shijiazhuang, 050000, China.

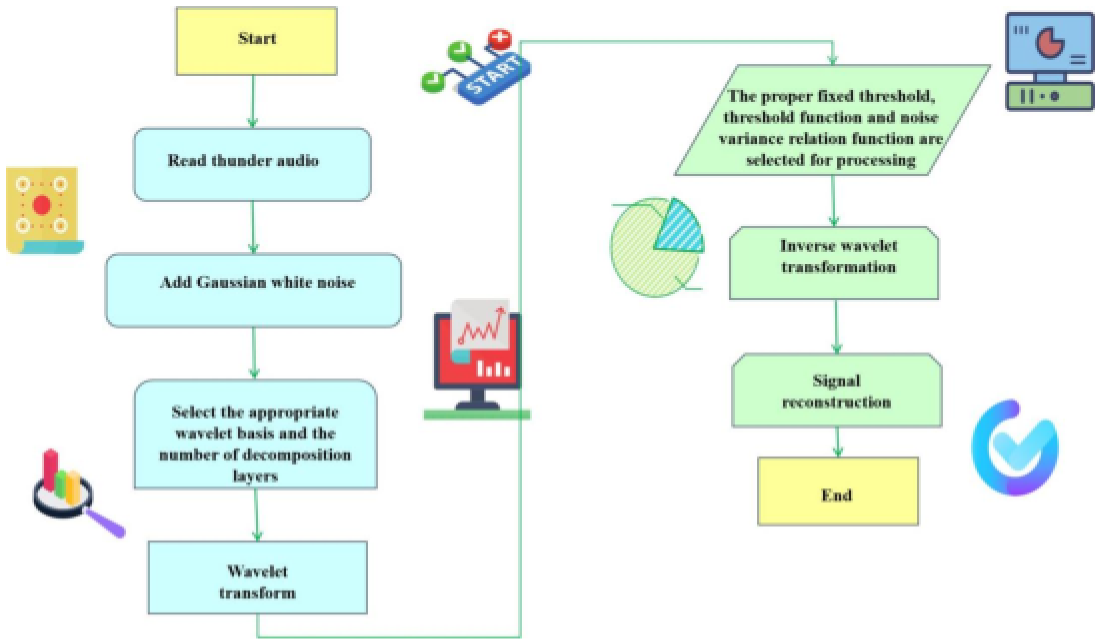

Fig. 1.1: Intelligent prediction of time slot capacity margin using wavelet analysis

to quantify and classify the factors that affect electricity price changes, and then select a suitable model for prediction based on the degree of impact of each factor on electricity price changes [1,2]. It should be noted that this method is only a prediction method for the capacity margin of the power system, and the prediction results are not absolutely accurate and are influenced by various factors, such as climate and load characteristics. Therefore, in practical applications, it is necessary to combine other methods for comprehensive evaluation and decision-making (as shown in Figure 1.1).

2. Literature Review. Wavelet analysis is an effective tool for analyzing and processing signals. It mainly decomposes and reconstructs signals to achieve nonlinear transformation and reveal the relationships between various components in the signal. The core of wavelet transform is to represent signals through the continuous and discontinuous boundaries of the scale function and time function of wavelet functions, while wavelet functions can be single scale or multi-scale wavelets. Therefore, wavelet analysis mainly studies the time series analysis between signals and noise. For a non-stationary time series, the continuous wavelet transform is a process of Discretization of the time series in the time domain. After discretization, a series of wavelet basis functions are obtained, and each wavelet basis function has a small-scale coefficient corresponding to that wavelet basis. For continuous wavelet transform, since the signal has the same frequency component at each scale, each frequency component in the signal can be represented as a weighted sum of a series of wavelet coefficients. In this way, by reconstructing the wavelet coefficients at any scale, a reconstructed sequence containing all the information of the original signal can be obtained. That is, the original time series is decomposed into multiple Subsequence at different scales through wavelet transform, and then the wavelet coefficients with different information content at different scales are obtained through reconstruction, so as to achieve multi-resolution analysis of the original time series. The original time series can be obtained by reconstructing the Subsequence obtained from each level of decomposition.

Wavelet transform is a transformation that analyzes signals in the frequency domain. It is a multi-scale analysis method aimed at identifying various frequency components in the signal, ranging from high to low frequencies. Wavelet transform has good time-frequency localization characteristics, multi resolution analysis, and tight support properties, and the singularity performance of the signal is well detected. It has a wide range of applications, including signal denoising, singularity detection, denoising, reconstruction, and data compression. Wavelet transform is an adaptive signal processing method that can improve the resolution of signals. Wavelet transform has been widely applied in the field of signal processing.

Nieves Gonzalez, A. et al. believe that fault current and voltage signals are the main factors affecting the safe and stable operation of the power system. Therefore, analyzing fault current and voltage signals can predict the safe and stable state of the power system [3]. Mohammadi, E. et al. believe that in order to ensure the safe and stable operation of the power system, it is necessary to predict accidents in advance. In actual production, it is necessary to predict the load changes of the power system and take corresponding measures before faults occur to prevent accidents [4].

The selection of parameters such as wavelet basis function, wavelet decomposition layers, threshold, and optimal scale for fault current and voltage signals. Faults in the power system can happen at any time, and accidents are also unpredictable. Accidents must be anticipated in advance in order to guarantee the power system's safe and stable operation. In actual production, it is necessary to anticipate power system load changes and take the necessary precautions before faults occur to prevent accidents. There are many methods for predicting power grid load, such as neural network prediction, fuzzy mathematics, and so on. Neural network has good nonlinear mapping ability, and can accurately reflect the nonlinear relationship between the variables in the system. However, the computational speed of neural networks is slow and cannot meet the real-time requirements of power system operation. The fuzzy mathematics method combines fuzzy mathematics with neural networks to study problems, compensating for the slow computational speed of neural networks. However, in practical applications, fuzzy mathematical methods cannot fully reflect the relationship between variables caused by changes in the operating state of the power system. Wavelet analysis has good time-frequency localization characteristics and good adaptive ability, and Time–frequency analysis of signals has good results. The author uses wavelet analysis technology to predict the capacity margin of the power system, which has good application value [5,6].

3. Research methods.

3.1. Intelligent Prediction of Time Period Capacity Electricity Price Based on Wavelet Analysis. According to the economists' study of the electricity market, there are marginal costs and marginal benefits in the electricity market. Marginal cost refers to the cost needed to produce and provide the same product or service; Marginal revenue refers to the revenue that exceeds Marginal cost when producing the same product or providing the same service under certain production technology and conditions. The main determinants of electricity price are production cost and Marginal revenue [7]. Electricity prices are influenced by many factors, such as: Load rate; Load distribution; User nature; Seasonal changes; Type of user load curve; Seasonal changes; Other factors such as taxes and fuel prices will have an impact on electricity prices.

Load rate. Refers to the ratio of electricity consumption to electricity consumption during a certain period of time, expressed as a percentage. During a certain period of time, the higher the load rate, the more electricity is consumed. The load rate can be calculated using the following equation 3.1:

$$p = q/(1+i)p = q/(1+i)p = q/(1+i) \tag{3.1}$$

where p is the load rate of the period; q is the electricity consumption during this period; i is the population during this period.

Load distribution. Refers to the changes in load within a certain area at the same time. For example, in the electricity market, the larger the electricity consumption in a certain area, the higher its proportion and the higher the electricity price [8,9], as shown in equation 3.2:

$$M_{APE} = \frac{1}{N}\sum_{i=1}^{N}\frac{|P_i - \hat{P}_i|}{\overline{P}} \tag{3.2}$$

Here, P_i represents the actual electricity price and represents the predicted electricity price, Is the average actual electricity price, where N represents the number of time periods.

User nature. Different users have varying degrees of impact on electricity and electricity prices, such as residential and agricultural users.

Seasonal variation. Refers to the variation of electricity consumption and electricity consumption during a certain period of time with the seasons. For example, electricity consumption is higher in winter than in summer; Summer consumes more electricity than winter, etc.

3.2. Wavelet Analysis and Neural Networks. Wavelet analysis is a useful tool for signal analysis that is utilized extensively in numerous fields like image analysis and signal processing. The market's supply-demand relationship determines electricity prices, but at the same time, there are various complex factors that affect electricity prices, such as unpredictable factors such as power generation games and equipment failures, which endow electricity prices with more high-frequency and detailed components, resulting in electricity prices deviating from normal values and concealing the true changing rules of electricity prices, which is not conducive to accurate prediction of electricity prices [10]. The author uses wavelet decomposition technology to extract the approximate components of the electricity price sequence, thereby eliminating the high-frequency components in the electricity price sequence, and trains the neural network using the approximate components as the historical electricity price of the neural network.

A type of feedforward network known as a radial basis function (RBF) neural network is based on function approximation theory. This kind of network's learning is like looking for the best training data surface in multiple bit space. Each hidden layer neuron transfer function of the Radial basis function neural network constitutes a basis function of the fitting surface. It is a local approximation network, that is, for each local area of the input space, only a few neurons determine the output of the network. A global approximation network is the most frequently utilized BP network. Although radial basis function networks are typically larger in scale than BP networks, they are capable of better function approximation and faster learning. The radial basis function network's structure is comparable to that of the generalized regression network (GRNN). A regularized radial basis function network is the special linear layer that serves as its output layer. The generalized regression network can accurately approximate a smoothing function when there are sufficient hidden neurons. The number of input sample vectors and the number of neurons in the hidden layer and output layer of GRNN are the same. The GRNN network is very big when there are a lot of input samples. Time phased electricity price prediction is used by the author. If historical data from the previous 28 days are used as training samples, there are only 28 sample vectors per time period—that is, there are 28 neurons in a GRNN—and the network can calculate very quickly. As a result, the author relies on the GRNN neural network to forecast electricity prices over a variety of time frames [11,12].

The electricity price prediction process is shown in Figure 3.1, where each input of the neural network is obtained from historical data and trained. The predicted prices for each time period are obtained through this process, which can form a full day predicted electricity price for the predicted day.

4. Experimental analysis. Assuming that the data on electricity load and quantity in a certain region comes from the National Bureau of Statistics. The historical data of electricity load and quantity in the region is decomposed and reconstructed using wavelet transform to obtain data for each frequency band, and grouped according to different time periods. The wavelet decomposition results of electricity load and electric satellite data for each time period are shown in Figure 4.1 and Figure 4.2. Through analysis, it can be seen that the electricity price time series is a non-stationary time series, and its maximum trend of change is to change with time. There are significant differences in electricity prices between different time periods, and the differences in electricity prices between two or more adjacent time periods are also significant. The electricity price time series mainly includes two parts of data: load and electricity quantity. Use the wavelet decomposed data of each frequency band as input signals, train and predict them using a BP neural network, and then train and predict the data of each frequency band that has not undergone wavelet decomposition. Input the trained network into the original data, and get the prediction results of each frequency band as shown in Table 4.1 [13,14].

From Table 4.1, it can be seen that the electricity consumption during periods 1, 2, 4, 6, 7, and 8 is relatively high. The electricity price for the fourth quarter of 2012 in the electricity market was predicted using a phased method. If the market is cleared once an hour, there will be 24 clearing prices per day, and each hour's electricity price will form its own electricity price sequence. For example, the 1 o'clock electricity price on each day will form a 1 o'clock electricity price sequence. After predicting the electricity prices for 24 periods, a full day forecast electricity price can be formed. Based on the segmented electricity price sequence, the predicted electricity price error using GRNN is 11.40%, while the predicted error based on the sequential electricity price

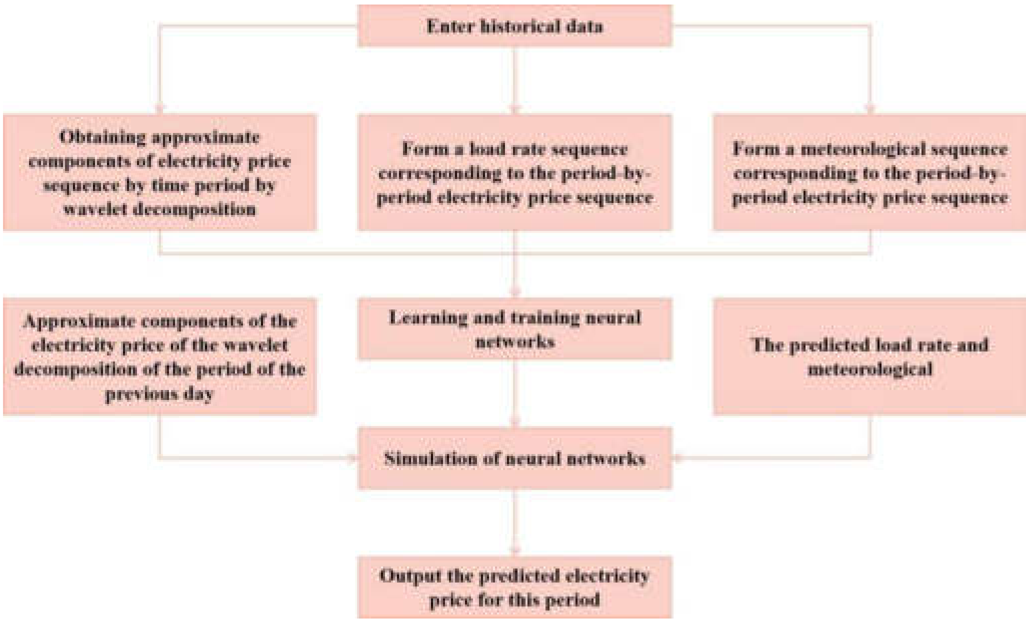

Fig. 3.1: Prediction Process of Timeslot Electricity Prices

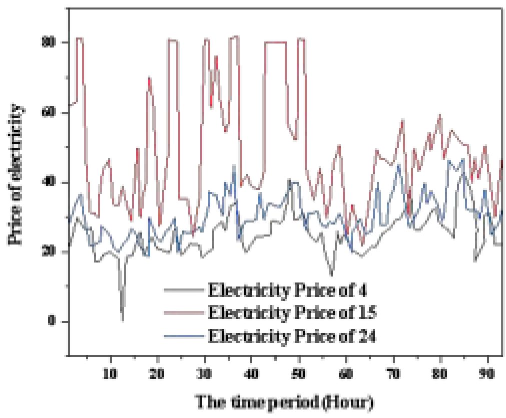

Fig. 4.1: Four point electricity price in the third quarter of the electricity market

sequence is 15.08. The prediction accuracy based on the segmented electricity price method is higher, indicating that the segmented electricity price prediction is more conducive to neural networks capturing the changes in electricity prices. The prediction errors for each time period are shown in Table 4.1. The percentage difference of Mean absolute error in each period is large. High errors mainly occur during the periods from 1:00 to 8:00, when the relative load is low and the electricity price is also low. However, the changes in electricity prices during these periods are not smooth, with more zero and negative electricity prices, which seriously affects the accuracy of electricity price prediction [15,16].

The accuracy of electricity price predictions is affected in different ways by the various input factors. In the segmented electricity price sequence, Table 4.2 depicts the effect of various input quantities and neural networks

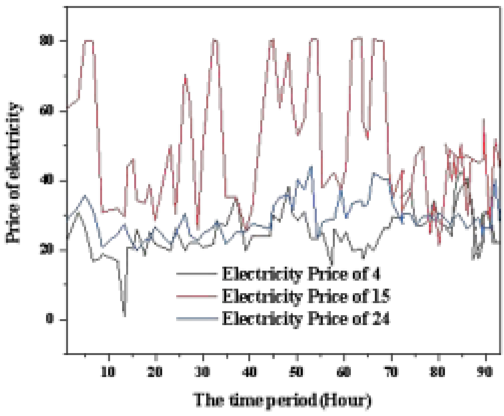

Fig. 4.2: Electricity Price of 15 in the Third Quarter of the Electricity Market

Table 4.1: Prediction Error of Each Time Period

Period of time	MAPE
1	13.485
2	14.596
3	13.245
4	14.236
5	11.362
6	15.362
7	13.256
8	15.236
9	11.352
10	11.236

Table 4.2: Impact of different input quantities and prediction methods on accuracy under segmented electricity price sequences

	Electricity price and load rate	Electricity price, load rate, and temperature
RBF	11..34	17.25
GRNN	11.36	11.40

on prediction accuracy. The prediction accuracy of the RBF network decreases when temperature factors are taken into consideration, whereas the prediction accuracy of the GRNN network slightly increases. Because the correlation coefficient between temperature factors and electricity prices is so low, it can be assumed that temperature factors have been incorporated into the load and no longer considered separately when predicting electricity prices. Compared with RBF network, GRNN network has smaller prediction error and is more suitable for electricity price prediction [17,18].

4.1. Short term electricity price prediction using BP neural network. BP neural network is a typical feedforward network, which is composed of one or more network nodes with nonlinear characteristics. There is a nonlinear mapping relationship between its input nodes and output nodes, and it can approach any complex nonlinear relationship through learning samples. Therefore, the BP neural network can be used for short-term electricity price prediction. Due to the existence of many complex influencing factors in the time series of electricity prices, using them as input signals can effectively reduce the uncertainty in the modeling process. Wavelet analysis decomposed the frequency bands of the electricity price time series and obtained good prediction results. However, the frequency band obtained after wavelet decomposition only contains less information. If you want to obtain more predictive information, you need to reconstruct the frequency band. However, there are very complex nonlinear relationships between different frequency bands, so there is a serious nonlinear relationship between the reconstructed frequency bands, and there is great uncertainty in the reconstructed data of each frequency band. These will have a significant impact on the prediction results of the BP neural network. In order to solve these problems, we use the Chaos theory to analyze the chaotic characteristics of each frequency band after reconstruction. The analysis results indicate that each frequency band has strong chaotic characteristics, which can effectively reduce the uncertainty between the reconstructed frequency bands and make the prediction results more accurate [19,20].

5. Conclusion. With the deepening of research on power system capacity margin prediction methods, in order to achieve intelligence in power system capacity margin prediction, the author proposes a time-phased capacity margin intelligent prediction method based on wavelet analysis and applies it to practical systems, effectively improving the prediction accuracy of power system capacity margin. Finally, the following conclusions are drawn: 1. Using wavelet analysis technology to decompose the operation mode of the power grid can accurately reflect the impact of changes in the operation mode on the safe and stable operation of the power grid; 2. The use of wavelet analysis technology can reduce the peak load while ensuring the safe and stable operation of the power grid, thereby improving the utilization rate of the load at various time periods; 3. Determine a time slot capacity margin prediction model based on the load growth situation of each time slot. According to this model, it is possible to predict the peak point and decrease point of load; When predicting the capacity margin in different time periods based on wavelet analysis technology, a prediction model for the capacity margin in different time periods is determined based on the load growth situation.

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COMPARATIVE STUDY OF OPTIMIZATION ALGORITHMS IN CNNS FOR BRAIN MRI IMAGE CLASSIFICATION

BILAL A.OZTURK *, HAYDER MOHAMMED QASIM †, ROA'A MOHAMMED QASEM ‡, AND FATEMEH KHAMOUSHI §

Abstract. Brain MRI often reveals long-standing diseases of the nervous system, such as multiple sclerosis, dementia, a stroke, and brain malignancies. In addition to that, the most accurate method of brain MRI, besides the diagnosis of pituitary gland diseases, is the method diagnosing the vessels of the brain and eyes and the organs of the inner ear. On the other hand, many methods of loading medical pictures have been developed with brain MRI data, often to diagnose diseases and monitor health via it. Convolutional neural networks belong to deep learning and are widely used for input from the visual domain. The most common use of CNN is in natural language processing and recommendation systems, image classification, medical imaging, and image and video recognition. This work is divided into several parts. The Msoud dataset, used in this study, consists of 7023 MRI images, which were made by the Fighshare, SARTAJ, and Br35H datasets. The MRI images are of four classes, that is, healthy brains, brains with glioma, brains with meningioma, and pituitary. In this research work, the doing of different pre-processing of the MRI input to make the images ready for the model to be trained is done. The architecture is made up of dense layers such that after each set of convolutional layers, there is a max-pooling. Eventually, batch normalization and dropouts in the training are stabilized to reduce overfitting. The proposed CNN compared with other studies and many transfer learning models found the proposed model to achieve significant accuracy of 99.00%, 98% and 97% for using Adamax, Adam and RMSprop optimizers respectively.

Key words: Convolutional Neural Network, Classification, Brain Tumour, Optimization, Deep Learning.

1. Introduction. A brain tumour, frequently referred to as BT, is a malignant expansion of brain cells that appears as a growing mass or tumour. It is made up of a component that is aberrant and not like the other cells. While tumours with cancer are consist of living, cancerous cells have a unique structure, benign brain tumours are composed of non-living cells. The two types of these malignancies are categorized as primary and recurrent. Whereas cancers that have metastatic properties spread to other parts of the body, primary tumours occur inside the brain. Brain tumours can occur in children and adults and are one of the most fatal diseases in the world. They are the third most common cancer in teenagers and young adults and the most common in older adults. For example, meningioma, pituitary, and glioma. Gliomas, which occur in the spinal cord and parts of the brain, which includes the cerebral pedicle, cause symptoms like pain, headaches, and vomiting. They are responsible for 80% of the malignant brain tumors that occur in the primary level. Lymphoma is a form of brain tumor whose incidence is rapidly increasing, resulting in an extremely high fatality rate. Meningiomas develop in their meninges which are the membrane tissues located in the areas of the brain and the spinal canal. Pituitary tumours are caused by the pituitary gland's aberrant growth. These tumours are usually not malignant [1].

Diagnosis of brain tumours Diagnostic procedures of brain tumours can be made through physical and neurological examinations besides CT and MRI. As MRI is non-invasive and non-ionizing, it is opted for rather than CT. General confirmation of its diagnoses is generally done by pathological investigation and a biopsy. A treatment plan is developed when the kind and stage of cancer have been determined. Due to the enormous number of patients, human evaluation of medical photos is complicated and error prone. Early brain tumour detection studies call for much more advanced work. The images through MRI are often exposed to noise, which needs to be removed appropriately [2]. Brain tumours bear tentacles and fluorescent characteristics, making

*Faculty of Engineering, Istanbul Aydin University, Istanbul, Turkey.(bilalabed1978@gmail.com)
†Faculty of Engineering, Istanbul Aydin University, Istanbul, Turkey.
‡Faculty of Engineering, Istanbul Aydin University, Istanbul, Turkey.
§Faculty of Engineering, Istanbul Aydin University, Istanbul, Turkey.

their separation a clumsy task. Very critical is the choosing of the best features and their extraction, and therefore determining the sample size appropriate for classification. Feature learning has been an automatic process for many and is much appreciable, although it demands huge computational resources and memory. Lately, henceforth, lightweight models have been developed that give high accuracy with minimal computation. There are recent models that address the whole of the tumour, although not focusing on some regions effectively.

To address these issues, the authors propose constructing an autonomous computer-aided diagnostic system. An automatic computer-aided diagnosis system would simplify the categorization and diagnosing process of brain MRI images for radiologists and doctors.

The key contributions of our study are the followings. We introduced a newly fine-tuned pre-trained model, EfficientNetB3, Classifying the four forms of tumours: glioma, meningioma, pituitary, we compared that approach with multiple sophisticated designs and evaluated its efficacy. We employed convolutional neural networks (CNNs), which can extract intricate patterns and fine detail in MRI data for improved diagnostic precision. The approach, based on large datasets and cutting-edge neural network architecture, is considerably better than previous approaches, reducing the number of false positives and the danger of misdiagnosis.

This research describes a thorough examination into the categorization for brain tumour MRI images utilizing DL's. The study's significant contributions are outlined below:

- Data Augmentation and Preprocessing: These strategies are vital for generalizing the model. To do this, the ImageDataGenerator function was used to preprocess pictures with a modification in the set of batch processing settings and sizes, allowing for more effective training and validation. The technique contributed to the development of a highly powerful model through extensive exposure to numerous picture alterations.
- Model Architecture and Training: The model architecture of the study was closely like the state-of-the-art CNN, EfficientNetB3, well known to its efficiency with performance. To prevent overfitting, fine-tuning was done by adding batch normalization, dense layers with regularization, and dropout layers.
- Advanced Techniques Implementation: The abovementioned advanced machine learning techniques include regularization methods, which are responsible for avoiding data overfitting and attuning the model for generalization. The hyperparameter tuning and the model optimization approach are advanced for deep learning models about training for medical image classification.
- Repeatability and practical application: This would describe a repeatable paradigm of the classification of MRI images, which will be very useful to both medical users and researchers. Implementation details with necessary steps and code will ensure the derived methodology can be easily adapted and further expanded for other similar tasks of medical image analysis. This will further foster ongoing research and development in this area of medical image analysis.

In general, this work demonstrates the application of deep learning techniques in an effective way to contribute to the challenging problem of brain tumor classification, which remains an important area in medical imaging and diagnostics.

2. Related work. Gwak et al. [3] presented a model based on deep feature and ML classifiers compared to ensemble learning models. The researchers collected information from brain MRI scans applying a deep convolutional neural network (also known as CNN) and transfer learning techniques. Various ML classifiers were then utilized to assess the retrieved deep features. A feature collection is created by combining the top three deep learning, which demonstrate strong performance in the machine learning classifier. The model's success can be considerably enhanced by the ensemble performance derived from deep features, as demonstrated by the experimental data.

Chenjie Ge et al. [4] a graph-based semi-supervised learning model for IDH mutation prediction and glioma classification is presented. Test accuracy for the model was reported at 86% on the TCGA data and 90% on the MICCAI data, based on testing it on two glioma datasets.

Das et al. [5] investigated brain tumour disorders using the CNN architecture. Their main goal has been to develop a CNN model that can identify brain tumours using T1-weighted, contrast-enhanced MRI scans. The proposed approach is divided into two basic stages: CNN is used for classification after images undergo pre-processing applying a range of methods for image processing. Pituitary adenoma, meningioma, and glioma are the three forms of brain tumours shown in the study set of 3,064 images. The test accuracy was 94% when they used the CNN model. Moreover, genetic algorithm and support vector machine were utilized by Narayana et al. [6] to categorize and segment brain MRI data. The accuracy rate of categorizing brain MRI scans either normal or abnormal was around 91%.

Kumar et al. [7] proposed approaches for a separate experiment. Three categories of machines are interconnected: support vector machine (SVM algorithm), artificial neural networks (ANN), and suggested technique involves preparation, the process of segmentation feature extraction, and classification.

First, the median filtering technique is utilized to an input MRI image to perform pre-processing procedures. Next, the FCM clustering technique is used to carry out segmentation. In the third step, the Grey Level Co-occurrence Matrix (GLCM) is applied to extract features. Ensemble classification is used to establish the automated stage of a brain tumour. The ensemble classifier is used to discriminate between photos with and without tumours. The procedure was found to be more exact, efficient, and dependable because of the experiments. The proposed approach achieved an accuracy of 91%.

Jibon et al. [8] recommended a classification system that employs CNN and log-polar transform (LPT) to distinguish between malignant and non-cancerous tumours in MRIs. While CNN integration introduced a machine learning method for classifying tumours from damaged images, LPT was utilized to retrieve rotation and scaling information from damaged photos. Because of rotation and scale invariance, the ML approach was found to be more successful in classifying individual MRI images as well as brain MRI images.

Sultan et al. [9] created a CNN-based DL system to identify three kinds of brain tumors from two publicly available datasets.

Yazdan et al. [10] proposes a multi-class classification technique for using magnetic resonance imaging (MRI) to identify instances of Glioma, Meningioma, Pituitary, and No Tract. In terms of precision and effectiveness, the results of experiments showed that the proposed multi-scale CNN model outperformed AlexNet and ResNet while requiring fewer computational resources. The approach has a 91% F1 score and an accuracy rate of 91%.

A. Asiri et al. [11] suggested a method for reducing the parameter-heavy character of CNNs by utilizing involutional neural networks (InvNets) for brain tumour classification. The InvNet architecture attained a 92% accuracy rate.

There have been other methods proposed for classifying brain tumours, which suffer from several deficits of their own. For example, none of the available approaches are good enough to classify brain tumours, which is critical in the medical field. With most of the procedures, reliance on manually outlined locations of the tumours does not support full automation. Previous efforts based on such techniques using the Convolutional Neural Networks (CNN) and their variants do not bring any significant performance improvement. Hence, other metrics than accuracy need to be referred to while evaluating the performance. Moreover, models based on CNNs perform very badly when implemented with small datasets such as medical image databases.

3. Methodology. We offer the architecture for categorizing brain tumours utilizing to three-layer CNN, with the core framework based on the EfficientNetB3. The EfficientNet models stand out for their remarkable effectiveness and speed in a wide range of machine vision algorithms, particularly medical image processing. Figure 1 depicts the flowchart for the CNN model. Figure 3.1.

3.1. Dataset Description. The collection of data was utilized for training, validation, and testing. This open due dataset includes 7023 grayscale MRIs in JPG format with different human brain types. The developed models were analysed and validated using this dataset with different CNNs. The collection of data was acquired using three distinct sources: figshare, the SARTAJ dataset, and Br35H. The dataset has four classes of brain tumours: Glioma (training images: 1321, testing images: 300), Meningioma (training images: 1339, testing images: 306), No-tumour (training images: 1595, testing images: 405), and Pituitary (training images: 1457, testing images: 300).

3.2. Data Pre-Processing. Data preparation refers to preprocessing of data in which data is cleaned, prepared, and fine-tuned. This makes the model better in its prediction. The challenge is mostly presented by MRI datasets in the sense that the brain images of the subjects are of different sizes, whereby the width, height, and overall size may differ. All images have been made into one single dimension for training.

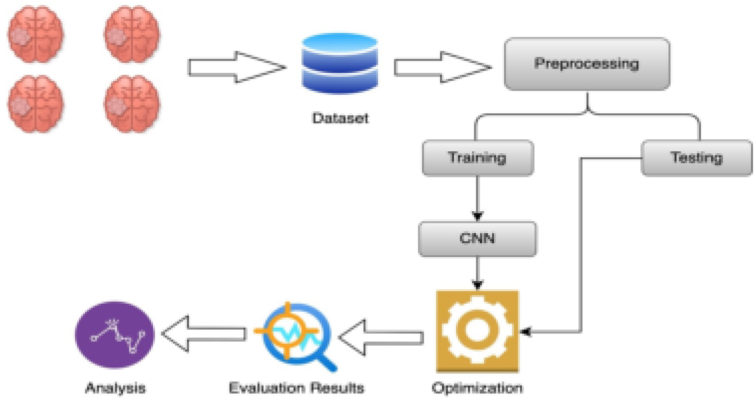

Fig. 3.1: The CNN Model Flow Chart.

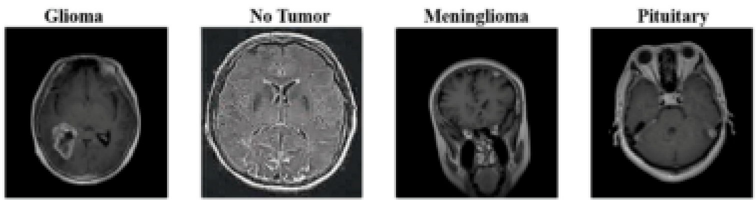

Fig. 3.2: Sample Images for Brain Tumour Dataset.

3.2.1. Data augmentation. The augmenting data is an interesting method to increase the efficiency and generalization of DNNs under normal conditions when labelled data is scarce. Data augmentation provides an excellent strategy for training DL models on seismic data because they are model-agnostic techniques and have low computational cost compared to the training process. One of such regularization techniques is data augmentation, which enhances the invariance of the dataset, injecting more invariant examples through label-preserving modifications. It is empirically demonstrated to be effective in reducing overfitting during training of CNNs for classification tasks. Data augmentation has an essential way to overcome problems like uneven distribution and data shortages. It has been implemented in several studies for brain tumour classification involving geometric transform operations like changes in brightness, zoom, or scaling and rotation. For example, common data augmentation methods are random cropping, flipping, and color adjustment techniques [12]. Together with Taylor, DeVries [13] presented Cutout, which generates enhanced pictures by systematically slicing out cube areas of input photos. Drop out also loses undetected nodes from a network at random throughout the training phase [14]. Popular methods that drop random hidden nodes in networks include Maxout [15], Continuous Drop out [16], Drop Path [17], with the stochastic depth [18], the last of which is based on the method to produce. For example, during training, stochastic depth randomly loses part of the remainder branches in a ResNet, causing the network size to decrease. Dropout now has many variant forms, and a new one is Drop Block [19], in a feature map, the nearby areas. Drops nearby regions on a feature map. Weight decay, or Tikhonov regularization, supplements a norm penalty of weight at a parameter to the loss function widely in neural networks and in linear inverse problems [20]. For example, DisturbLabel [21] augments the data by introducing noisy labels but in return suffers in performance. Recently, shake-shake-based regularization has been proposed to mix features within CNNs and obtain cutting-edge classification performance [22], [23].

3.2.2. Regularization. Regularization is a technique to prevent overfitting by changing the procedure of the model's training and its architecture. The most common regularization techniques are: L2 regularization, L1 regularization, Dropout Regularization.

The L2 regularization of regression analysis is commonly referred to as ridge regression. The technique is such that it adds the squared coefficients/weights norm, multiplied by some kind of regularizer term, to the loss or cost function.

L1 regularization is popularly referred to as lasso regression, where the absolute value of the magnitude of the coefficients or weights is added to the loss or cost function alongside a regularizer.

Previous research has demonstrated that regularization enhances categorisation performance in deep models. The implementation first employed the notion to enhance the efficiency of the conception model when processing ImageNet data. The fact remains that several released models for image classification have welcomed regularization up to this time. Although very popular since it has many characteristics such as a classification boost and speeding up the convergence method, its incorporation in HSIC is not investigated. Also, when and why it should be effective is not well understood.

3.3. Convolutional Neural Networks (CNN) Architecture. In this study uses a dataset of MRI brain scans that already has data categorized with either having a tumour or not. The data is easily separated into two primary groupings, i.e., training as well as testing. The dataset is gathered by iterating over directories of the respective categories, pulling file-paths and labels compiled into Pandas data-frames for both training and testing. CNN was used to classify patients with or without tumour in the dataset used. To begin, in pre-processing, ImageDataGenerator was utilized to handle the photos during model training, allowing the data to be processed efficiently through proper batch processing.

The CNN [24] architecture is the most common type of ANNs in practice today, and it is widely implemented in pattern recognition applications using images. Object identification, then, becomes the process of picking out some distinctive patterns from the input, which are recognized through a layer of deep, hidden layers. The first few layers of the network recognize easy patterns, such as lines and curves, and the more layers added, the more complex the patterns recognized can become, such as faces. These networks have been formed with a focus on image processing and have been motivated by the operation of the visual cortex in image processing and recognition. Convolution mainly focuses on the detection and learning of characteristic patterns that will help in the determination and categorization of objects based on their knowledge of features include curves, lines, as well as colour tones. The input/output layer, convolution layer, pooling layer, nonlinearity or function of activation layer (ReLU), and final classification layer make up the standard CNN design.

CNN have been applied largely to most applications that rely on artificial vision techniques [25]. While showing a lot of promise in such application domains, CNNs bring high computational costs, hence the need for techniques that exploit and optimize the computation cost without affecting the performance. Thus, the present paper introduces the capability of tuning CNN parameters in order to reduce computational costs and further augment recognition rates.

The CNN model architecture included a convolutional neural network. Table 3.1 demonstrates the CNN model structure. The basic model then adds a few more layers:

1. The batch normalization method is used for normalizing previous layers activations and stabilise the process of learning.
2. It has a 256-unit dense layer appended to it, where both L1 and L2 regularization are added to avoid overfitting by imposing a penalty for large weights.
3. Dropout layer in which the dropout rate is 0.4 and the units are dropped randomly during training to avoid the co-adaptation of neurons.
4. The output layer is of the dense type with a softmax activation to assign probabilities to classes.
5. It was built utilizing the Adamax optimizer, which has a rate of learning of 0.001. The loss function that was utilized was classified cross-entropy; This type of reduction function is frequently employed in multi-class occupation categorization.
6. The approach used is trained utilizing the training set of 10 sessions, and then validated using a previously produced validation dataset. Model efficiency measures, like accuracy and loss, ability to be checked regarding to both the sets of training and validation used in the learning technique and updated as needed.
7. The model is validated after training against the training, validation, and test data to check the achieved

Table 3.1: The parameters for the suggested CNN model are given below.

Parameter	Value
Input Shape	(224, 244, 3)
Pooling	Max
Batch Normalization	Momentum: 0.95, Epsilon: 0.01
First Dense Layer	Units: 256, Activation: ReLU, Regularizers: L2(0.016), L1(0.006)
Dropout	Rate: 0.4, Seed: 75
Second Dense Layer	Units: classes number, Activation: Softmax
Optimizer	Adamax, Learning Rate (lr): 0.001
Loss Function	Categorical_Crossentropy
Metrics	Accuracy
Epochs	10
Batch Size	16
Image Size	(224, 244)

generalization capabilities. Performance is measured using accuracy and loss metrics.

Visualization. Training accuracy, cross-validation, and loss plot are displayed to show changes in overfitting and underfitting. Confusion matrix of the test set predictions to get a broad understanding of the model's effectiveness across different classes. Validate the data processing by seeing example images from the training set.

Finally, it makes predictions on the test dataset and forms a full classification report, giving details on recall, f1-score, precision, and support of each category; therefore, giving detailed performance of the model. This is aimed to ensure that the CNN performance is evaluated exhaustively in classification competency for MRI images based on the presence of brain tumours, taking this into consideration with practical application and vigorous performance validation.

4. Result. The thorough analysis provided a key factor of assessment: the training and validation accuracy and the measure of the loss. The detailed analysis was based on behaviour of individual classes from a confusion matrix. The programming language implemented to design the proposed model is Python. With its simplicity, flexibility, and collection of libraries, Python is more popular in the field of neural networks and machine learning. The basic libraries applied for neural networks (NN) are TensorFlow (TF), Keras, and Matplotlib. TF is a Python library tool for deep learning developed by Google; a whole set of tools and functions are available to efficiently build and train neural networks. The CNN model performance with the brain tumour dataset is measured using a variety of evaluation criteria, including accuracy, recall, precision, and F1 score [26].

Accuracy explains how to calculate the efficiency of the classifier based on the expected accuracy ratio. It can be identified as stated in Equation (4.1).

$$Accuracy = \frac{TP + FN}{TP + TN + FP + FN} \tag{4.1}$$

Recall it is a statistic that represents the proportion of positive processes that need to be estimated. It can be identified as stated in Equation (4.2).

$$Recall = \frac{TP}{TP + FN} \tag{4.2}$$

On the other hand, precision indicates the percentage of estimated positive values that are actually positive. It can be identified as stated in Equation (4.3).

$$Precision = \frac{TP}{TP + FP} \tag{4.3}$$

The F1 Score is obtained through calculating the harmonic average of precision and recall; it employs a harmonic mean since extreme situations are not ignored, just as a simple average does. For example, if we had

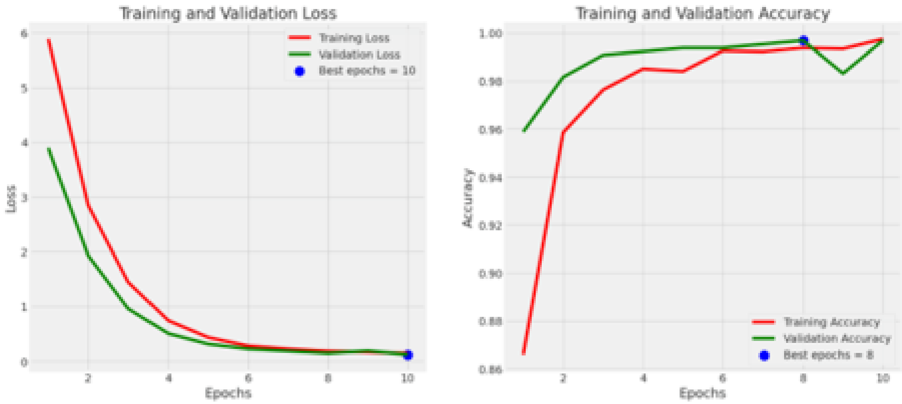

Fig. 4.1: Loss and Accuracy for training & validation.

computed using a simple average, the accuracy of a 1 and recall of 0 model would yield an F1 score of 0.5, which is extremely deceptive. F1 Score can be identified as stated in Equation (4.4).

$$F1 = \frac{2 * Precision * Recall}{Precision + Recall} \tag{4.4}$$

Figure 4.1 shows the procedure of developing and validating a classification model for this research. This graphic demonstrates that the model learned well on the initial training data and generalized well on the validation data. A quick reduction in training as well as validation losses suggests successful learning and a reduction in prediction mistakes. The relatively small gap between the training and validation lines of loss provides the appearance that the model does not overfit, however this is an overfitting instance because the accuracy of validation is high and consistent. The fact that training accuracy approaches 1.0 indicates that the model can accurately predict the training data to a great extent. In general, these graphs suggest an accurate model with strong generalization, which leads to excellent training and validation performance.

Figure 4.2 shows a confusion matrix that summarizes the DL model's performance in classifying brain tumors. The model works very precisely, which is well observed by the great diagonal presence representing a big amount of correct predictions for each class: precisely, 147 observations are right with glioma, 148 with meningioma, 208 without tumor, and 150 observations with the pituitary tumor class. There is very little confusion: precisely just 2 cases with glioma and 1 pituitary tumor were wrongly classified as meningioma. In its essence, this robustness and trust in identifying glioma, meningioma, no-tumor, and pituitary-tumor cases presents a force to be reckoned with in clinical diagnostics, thus helping medical professionals in identifying tumors accurately and promptly.

Table 4.1 shows the results using the RMSprop optimizer with CNN with brain tumor data set, where the overall accuracy reached 97% for all classes.

Table 4.2 shows the results of different evaluation metrics using the Adam optimization tool with CNN on brain tumor data set. The results showed an increase of 1% in the accuracy.

Table 4.3 shows a high result with all the evaluation metrics by using CNN with Adam optimizer where reached the accuracy, precision, recall, and F1 score to 99%.

A comparative analysis of different methods in performance metrics for different studies is shown in Table 5. Methods include Decision Tree [25], Random Forest [25], fused-based methods [26], Deep Neural Network [27], and Involution Neural Network [11]. From this table, it is evidently seen that the performance of the proposed Convolutional Neural Network was prominent with all existing methods in terms of the measures of accuracy, precision, recall, and F1-score. These depict a highly improved performance compared to the past approaches.

5. Limitation. A summary of state-of-the-art approaches to diagnosing brain cancers as meningioma, glioma, or pituitary tumors: When it comes to the key classification problem for a critical medical purpose, all

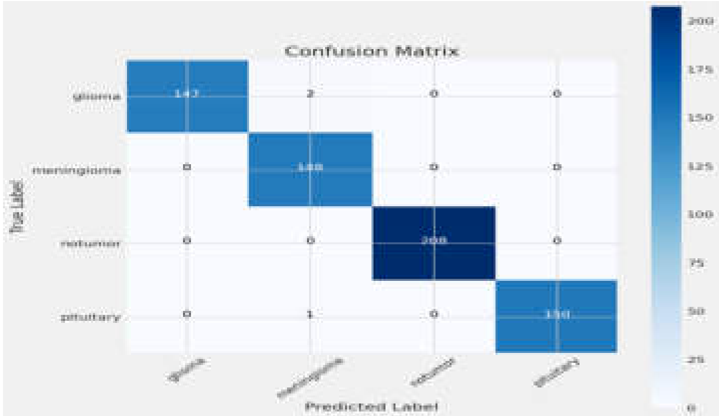

Fig. 4.2: Confusion matrix for convolution neural network.

Table 4.1: The evaluation outcomes of the proposed CNN model using the RMSprop optimizer.

	Precision	Recall	F1-score	Support
Glioma (class 0)	99%	96%	97%	151
Meningioma (class 1)	95%	95%	95%	164
Notumor (class 2)	97%	99%	99%	192
Pituitary (class 3)	99%	98%	99%	149
Accuracy			97.0%	656
macro avg	97.1%	97.2%	97.1%	656
weighted avg	97.1%	97.1%	97.2%	656

Table 4.2: The evaluation findings using the Adam optimizer for the proposed CNN model.

	Precision	Recall	F1-score	Support
Glioma (class 0)	99%	95%	97%	151
Meningioma (class 1)	98%	96%	97%	164
Notumor (class 2)	99%	99%	99%	192
Pituitary (class 3)	96%	99%	98%	149
Accuracy			98.1%	656
macro avg	98.1%	98.2%	98.1%	656
weighted avg	98.1%	98.1%	98.2%	656

cutting-edge approaches fall well short. The previous methods needed manual delineation of the tumor regions before classification and therefore never became completely automated. The automatic algorithms developed by the use of CNNs or their variants have not been able to significantly enhance the performance. Moreover, these methods were tested on an imbalanced image dataset, so evaluation through other metrics besides accuracy is needed. Finally, none of these studies related to the issue of data scarcity, which may often happen in applications. Convolutional neural networks are now a mature and standard tool for classifying images in the diagnosis of medical diseases, but developing just one single model applicable to different tasks that might be useful is in many cases neither practical nor feasible. For each problem, a different CNN model would have to be designed from scratch based on the nature of the problem, the inputs, and the expected outputs of these models.

Table 4.3: shows the evaluation results of the proposed CNN model with Adamax optimizer.

	Precision	Recall	F1-score	Support
Glioma (class 0)	99%	99%	99%	149
Meningioma (class 1)	98%	99%	99%	148
Notumor (class 2)	99%	99%	99%	208
Pituitary (class 3)	99%	99%	99%	151
Accuracy			99.0%	656
macro avg	99.1%	99.1%	99.1%	656
weighted avg	99.2%	99.1%	99.1%	656

Table 4.4: Comparative analysis with other studies

Study	Method	Accuracy	Precision	Recall	F1-score
Pandarakone et al. [27]	Decision Tree	78.75%	-	-	-
Pandarakone et al. [27]	Random Forest	80.75%	-	-	-
Amin et al [28]	Fused-based methods	Avg 86%	-	-	-
Kumar et al.[29]	Deep Neural Network	89%			
Asiri et al.[11]	Involution Neural Network	92%	92.5%	91.75%	92%
Proposed	CNN	99%	99%	99%	99%

6. Conclusion. The proposed approach is aimed at achieving the necessary optimal accuracy in the classification of images and reducing the level of error. We propose to use a custom convolutional neural network architecture to enhance the performing accuracy of the dataset. This work focuses on the use of CNNs to identify MRI images. This work tried to find out the best Deep Learning classifier for the automatic classification of tumour cases with the help of an MRI dataset. The brain tumours identified were no tumour, pituitary, meningioma, and glioma. The results from the experiments prove that the proposed model classifies brain tumours with an accuracy of 99% with the dataset disclosed earlier. It can be further validated with a wide variety of datasets. Future research studies may be based on the scale and the properties of generalization of the proposed methodology in relation to larger and more diversified datasets. Interpretability of CNN models, when researched and combined with different optimization algorithms, will help to increase the accuracy and robustness of disease detection.

Future work. Future research studies may be based on the scale and the properties of generalization of the proposed methodology in relation to larger and more diversified datasets. Interpretability of CNN models, when researched and combined with different optimization algorithms, will help to increase the accuracy and robustness of disease detection.

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MULTI MODAL TRANSPORTATION PATH SELECTION OF COAL BASED ON GENETIC ALGORITHM

JIANJUN WU*, SHUSEN ZHANG †, GONG PING ‡, AND JUNYU CHEN§

Abstract. In order to solve the problem of selecting transportation routes and transfer nodes reasonably in the process of multimodal logistics distribution, the author proposes a coal transportation multimodal transportation path selection based on genetic algorithm. Firstly, this paper establishes an object function for routing according to the features of multi-modal transport, which has the minimum transport time, the minimum transport length and the minimum transport cost. Secondly, we design appropriate GA components, and get a multiobjective route optimal model for multimodal transport by using GA. Taking into account the high transportation costs of coal as a bulk commodity, a coal transportation multimodal transport path optimization model was constructed with the total transportation cost as the objective function of the model, and the minimum economic cost as the objective. At last, this paper applies GA and MATLAB to resolve the case. Experiments showed that the starting population was 90, with a cross rate of 0.6 and a mutation rate of 0.02. After 100 iterations, it was found that the fitness change between adjacent generations was less than 0.01, indicating that the population mean of the running results had stabilized. At this point, it can be considered that the results have converged. This method validates the practicality of the established model and provides a reference for logistics enterprises to carry out multimodal transportation.

Key words: Multimodal transport, Logistics delivery, Optimize the model, genetic algorithm

1. Introduction. Coal, as the main energy source of the country, currently accounts for nearly 70% of the total energy consumption. According to the current resource composition of the country with "rich coal, poor oil, and little gas", coal as the main energy source for the people will not change significantly in the long term in the future [1]. However, the distribution of coal resources in the country is extremely uneven, with the main production and sales areas of coal separated from each other. This issue has resulted in a transportation pattern characterized by "transporting coal from the north to the south and from the west to the east". Although the country has made many efforts to increase coal transportation capacity, the shortage of transportation capacity is still difficult to fundamentally change in the near future [2,3].

The main energy source of the country is coal, and the stability of coal prices is crucial for the development of the country's industry. Although coal enterprises may increase profits due to the rise in coal prices, other enterprises such as thermal power supply, chemical industry, metallurgy, etc. will experience cost increases due to the rise in coal prices [4]. Therefore, changes in coal prices will have a significant impact on industrial development. The transportation cost of coal is one of the factors affecting coal prices. As transportation costs increase, coal prices will correspondingly rise. In the future, the national coal production will continue to increase, and the main coal mining areas will shift from east to west. The changes in coal mining areas and transportation distances have led to an increase in coal transportation costs, which in turn has driven up coal prices. Therefore, it is urgent to minimize the cost of coal transportation to the greatest extent possible. Coal is a typical bulk commodity that mainly relies on iron wheels for long-distance transportation, and its demand for road transportation is also high. The expansion and renovation of highway and railway facilities have to some extent released the transportation capacity of goods, promoting the use of the shortest path for bulk material transportation, thereby improving transportation efficiency [5]. For example, some of the indirect transportation volume undertaken by sea rail intermodal transport can be returned to direct railway or highway transport, so the optimization of coal transportation multimodal transport routes can be carried

*Chinacoal Huajin Group Co. Ltd., Hejin Shanxi, 043300, China.
†Chinacoal Tianjin Design and Engineering Co. Ltd., Tianjin, 300120, China.
‡Chinacoal Tianjin Design and Engineering Co. Ltd., Tianjin, 300120, China.
§Shenzhen Tuwei Technologies, Ltd., Shenzhen Guangdong, 518000, China.(Corresponding author, 18011958993@163.com)

out while considering the cost of coal transportation and transportation.

The above content is a discussion on the distribution, price, transportation, and other aspects of national coal. Based on this, constructing a national coal multimodal transport network model has certain research significance. But coal is a bulk commodity, and the generalized multimodal transport model will not be suitable for the multimodal transport of coal. Therefore, the author will consider the particularity of coal, construct a multimodal transportation path selection model for coal transportation, combine the characteristics of multiple transportation modes, leverage the overall benefits of multimodal transportation, optimize transportation paths, control transportation costs, improve service efficiency, and create profits for coal enterprises through scientific management methods. At the same time, the author conducted numerical verification and comparative analysis, proving the practicality and feasibility of the research method, providing a certain theoretical basis and work foundation for future related research work [6,7].

2. Literature Review. The reasonable path of multimodal transport refers to a reasonable and feasible transportation route plan that conforms to the characteristics of general cargo owners or multimodal transport operators' cargo transportation operations, including the use of transportation methods. The main body of multimodal transportation is railway, waterway, and air transportation, while road transportation plays a connecting role as the starting and ending points and transit points in the combined transportation path.

Meanwhile, among these modes of transportation with the lowest cost or shortest route, single transportation has lower costs and is more competitive than combined transportation. Therefore, within the reasonable distance range of various transportation modes, transportation companies or freight agents will choose direct transportation to reduce the cost and increase in cargo damage caused by transshipment. Ke, H. et al. developed a model with transportation carbon emissions as the primary objective and freight utility value as a secondary objective. The model adheres to constraints related to overall freight turnover rates, the economic and social benefits of freight transportation, and the ecological limitations of the freight transportation system [8]. Johar et al. analyzed and optimized two parameters of genetic algorithm, namely the generation number and population size. The results indicate that genetic algorithms are effective in maximizing the net present value of supplier payment plans [9]. Jiang et al. developed a multimodal transportation route optimization model aimed at minimizing the total transportation costs, which include transportation, transit, waiting, and carbon emission costs. To solve the model, they use a genetic algorithm incorporating retention and migration strategies. A case study has proven the model's effectiveness and can offer decision support for selecting optimal multimodal transport solutions [10,11].

In summary, existing research mostly constructs multimodal transport path selection and optimization models based on the objective functions of total transportation cost, service level, or optimal transportation time. Generally, these models are transformed into multi-objective combinatorial optimization models, shortest path models, or integer programming models for solution. Analysis shows that most scholars focus on the study of shortest path models, but they often emphasize the arc connections between two points in the network diagram, while ignoring the number of transportation mode conversions and the rationality of the conversion sequence. They mostly achieve optimal paths from a theoretical perspective, but the practical application results are not ideal and cannot achieve the expected goals [12].

3. Method.

3.1. Description of Path Problems. The multimodal transport network includes multiple modes of transportation and transfers between them. Generally, network transformations are used to reasonably represent the transfers between modes of transportation, while also following two principles. First, if there are multiple modes of transportation between two nodes, each mode of transportation corresponds to a separate connection line; Secondly, when there is a transfer operation at a certain node, the transfer of transportation modes is represented by the connecting lines between new nodes, that is, the starting and ending points of each transportation mode are separated, that is, the starting and ending points of each transportation mode are represented by a new node. At transit nodes, the endpoints of various modes of transportation are referred to as inbound nodes, and the starting points of various modes of transportation are referred to as outbound nodes.

The transformed network diagram is shown in Figure 3.1, with two connecting lines added between O-A,

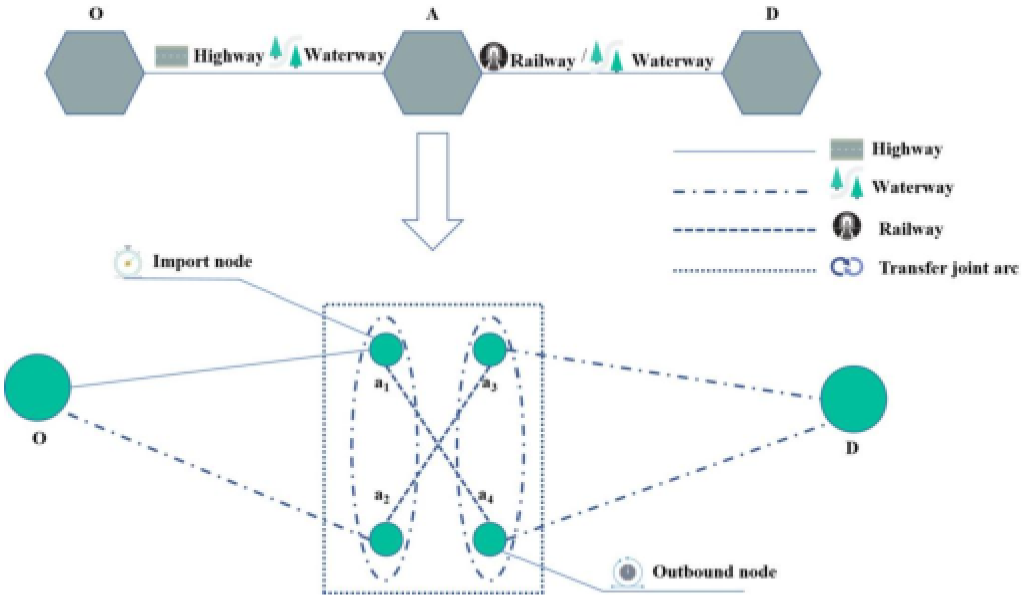

Fig. 3.1: Network Transformation Diagram

representing waterway transportation and highway transportation respectively. Similarly, add two lines between A-D, representing railway transportation and waterway transportation respectively. In addition, there may be a situation of transportation mode transfer at node A, so node A is divided into four nodes $a_1 - a_4$, with each node representing a transportation mode along the lines between O and D [13,14].

We assume the following conditions: (1) There is no increase or decrease in goods during transportation, nor is there any replenishment or reduction of goods; (2) Assuming that the freight demand between ODs is indivisible, meaning that only one mode of transportation can be chosen between two nodes.

3.2. Definition of Model Symbols. Let

E represent the set of all modes of transportation in the multimodal transport network;

N represents the set of all feasible paths;

Q represents the transportation volume of goods;

T represents the delivery time requested by the shipper for the goods, where $T \in [w, v]t$ represents the actual time consumed for the transportation of the goods.

J_t represents the penalty cost per unit time; is the final penalty cost for the goods.

l and m are weight coefficients $\in (0, 1)$ and l+m=1.

$u^e_{n,n+1}$ and $C^e_{n,n+1}$ respectively represent the e-th mode of transportation used between nodes n to n+1 during multimodal transport, as well as the unit transportation cost (yuan/hour/ton) of the e-th mode of transportation.

$b^e_{n,n+1}$ the transportation distance generated between nodes n and n+1 under the e-th mode of transportation.

$R^{eh}_n S^{eh}_n$ respectively represent the transition from the e-th mode of transportation to the h-th mode of transportation and the resulting transit costs during multimodal transport.

$t^e_{n,n+1}$ represents the transportation time for selecting the e-th mode of transportation between nodes n and n+1 during multimodal transport.

$H^e h_n$ represents the transition time from the e-th mode of transportation to the e-th mode of transportation during multimodal transport [15].

3.3. Optimization Model and Constraints. For the convenience of establishing the model, the following assumptions are made.

1. The logistics distribution network of multimodal transportation is fixed and unchanged, and all possible nodes and transportation routes throughout the entire logistics distribution process have been provided;
2. The indicators such as freight rates, transportation time, and transportation capacity of different transportation modes vary among different nodes;
3. Transfer can occur on each node, but each node can only occur once at most. Two nodes can only choose one mode of transportation for goods transportation;
4. The delivery of goods as a whole cannot be divided. During transportation, it is not possible to divide the delivery goods into multiple modes for simultaneous transportation. The transfer of goods can only occur at nodes, not during transportation;
5. Ignoring uncertain factors such as weather changes, road conditions, and human operations throughout the process;
6. The overall logistic cost consists of the transport of goods, the transport of goods, and the penalty. Overall logistic transport time consists of transport time and transport time [16].

Based on the above assumptions, the following logistics distribution path optimization model can be established:

$$\begin{aligned}&\min Z = l[(\textstyle\sum_{n\in Ne\in E}\sum_{n,n+1} u^e_{n,n+1}Q) + (\sum_{n\in Ne}\sum_{e\in E} R^{eh}_n S^{eh}_n Q) + J]+\\&m[\textstyle\sum_{n\in Ne}\sum_{eE} u^e_{n,n+1} + \sum_{n\in Ne}\sum_{e\in E} R^{eh}_n H^{eh}_n Q]\end{aligned} \tag{3.1}$$

The constraint conditions are:

$$\sum_{n\in Ne\in E}\sum_{n,n+1} u_n n + 1 t^e_{n,n+1} + \sum_{n\in N}\sum_{e\in Eh\in E}\sum_{n} R^{eh}_n H^{eh}_n = T \tag{3.2}$$

$$\sum_{n\in Ne\in E}\sum_{n} R^{eh}_n = 1 \tag{3.3}$$

$$u^e_n - 1, n, u^h_{n,n+1} = R^{eh}_n \tag{3.4}$$

$$\sum_{n\in N} u^e_{n,n+1} \leqslant 1 \tag{3.5}$$

$$u^e_{n,n+1}, R^{eh}_n \in \{0,1\} n \in N, e \in E, h \in E \tag{3.6}$$

$$J_t = \left\{ \begin{array}{cc} 0 & t \leqslant v \\ (t-v)z & t \geqslant v \end{array} \right\} \tag{3.7}$$

$$Q \leqslant Q^e_{n,n+1} \tag{3.8}$$

The objective function Z in equation 3.1 is a generalized cost, representing the minimum sum of logistics distribution cost and time cost. Logistics distribution costs are comprised of three components: transportation costs, transit costs, and penalty costs [17]. The total transportation time consists of two parts: the time taken to transport goods while in transit and the time spent at transit nodes;

Equation 3.2 indicates that the total transportation time for goods is equal to the sum of the transit time and the time spent in transit.

Equation 3.3 indicates that if the goods need to be transferred at the transportation node, the transportation mode can only be changed once.

Equation 3.4 represents the continuity of various transportation modes during transportation between two adjacent nodes.

Equation 3.5 represents that in a multimodal logistics network, the transportation mode between two transportation nodes can only be one of road, railway, waterway, and air at most.

Equation 3.6 represents that the decision variable can only take 0 or 1, with 0 indicating that it has not been selected and 1 indicating that it has been selected.

Equation 3.7 represents the penalty cost incurred if the goods cannot be delivered on time according to the time regulations.

Equation 3.8 represents that in the transportation node n to n+1 section, the cargo transportation volume cannot exceed the transportation carrying capacity of the section.

3.4. Genetic Algorithm Steps. There are two main optimization algorithms for logistics transportation and distribution: deterministic algorithms and search algorithms. When encountering some irregular optimization problems, deterministic algorithms cannot accurately search for the optimal solution. Search algorithms are crafted to tackle complex optimization problems by encoding and decoding the issues, aiming to identify the best possible solution. Genetic algorithm is an evolutionary algorithm derived from genetic phenomena in the biological world. Its main feature is that there are no restrictions such as function differentiation and function continuity, and it can process the result object with good global search for optimal solutions [18]. The specific steps of genetic algorithm are as follows.

(1) Initialization. Randomly select an initial population consisting of n chromosomes, with representing this initial population. Use this initial population as the starting point for data iteration to obtain the initial solution.

(2) Choose. Select individuals from the initial population who are more suitable for the environment to reproduce the next generation. According to the fitness calculation method: assuming $f(u_i)$ is the fitness of the selected individual, and P_{ui} is used to represent the probability of chromosome u_i being selected, then there is:

$$P_{ui} = \frac{f(u_i)}{\sum_{i=1}^{n} f(u_i)} \tag{3.9}$$

According to the expression of P_{ui}, it can be seen that the larger the $f(u_i)$ value of an individual, the larger its $f(u_i)$ value, that is, the higher the probability of being selected for inheritance to the next generation. Conversely, the smaller the P_{ui} value of an individual, the smaller its EE value, and the lower the possibility of inheritance to the next generation.

(3) Cross over. Cross operation, also known as recombination operation, selects individuals for breeding the next generation, randomly selects two individuals with the same position, and performs recombination according to the crossover probability p. This biological process represents the random exchange of individual genes, with the aim of generating new gene combinations, that is, producing new individuals. During crossover, crossover operators include single point crossover, multi-point crossover, uniform crossover, etc.

(4) Mutation. The function of mutation operation is to retrieve important genetic information missed by the selection and crossover operations mentioned above. According to the principle of genetic variation in genetics, the mutation probability pm is used to perform mutation operations on genes of individuals containing important genetic information. The emergence of new individuals cannot be achieved through crossover operations, and can only rely on mutation operations [19].

(5) Global harvest. When the $f(u_i)$ value reaches stability, the global optimal harvest is reached, and the algorithm ends. Otherwise, it returns to the selection process and performs a loop operation.

The iterative process of the algorithm concludes when the fitness of the optimal individual meets the specified threshold, or when neither the fitness of the optimal individual nor the overall fitness of the population shows further improvement. If these conditions are not met, the algorithm replaces the current generation with the new population generated through selection, crossover, and mutation, and repeats the process from step 2, continuing the selection operation in a loop.

3.5. Solving Design Based on Genetic Algorithm.

Chromosome coding design. The specific encoding process of genetic computing is as follows: the first gene on the chromosome is the starting city node O for goods, followed by the next gene Xi, which represents the random selection of other city nodes for connection through a certain transportation method from the starting

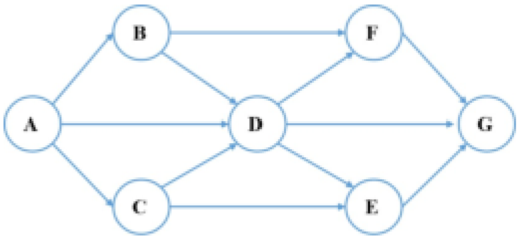

Fig. 3.2: Transportation Network Diagram

city node. The i on gene Xi represents the transportation method used for goods transportation between city node O and city node X, it is randomly selected from the existing transportation modes between these two city nodes, and then the process of random selection is repeated until reaching the destination node D, thus forming the first chromosome in the population.

Determine the initial group. Continuously repeating the above random selection process can generate the initial population required for genetic algorithm solving. The selection of the initial group should have a wide range of representativeness. Generally speaking, the group size should be between 10 and 100, which not only ensures computational efficiency but also enables the algorithm to converge to the global optimum.

Adaptation function. In genetic algorithms, fitness functions are used to indicate the superiority or inferiority of individuals and solutions. Different individuals have different fitness values, and individuals with higher fitness values have a higher probability of inheriting to the next generation. The author uses the minimum generalized transportation cost as the main evaluation criterion based on the characteristics of the problem. Therefore, for the author's multimodal transportation path optimization model, we mainly adopt the reciprocal of the total cost generated throughout the entire process of each transportation scheme as the individual fitness function.

Crossover and variation. Based on the crossover and mutation probabilities of genetic algorithms, individuals are subjected to crossover and mutation operations, and several sets of solutions are output. Chromosomes are randomly selected for partial gene exchange according to the crossover rate to achieve the process of chromosome crossover. The crossover rate is typically set between 0.25 and 0.75. The mutation rate represents the ratio of mutated genes to the total number of genes across all chromosomes, generally ranging from 0.0001 to 0.1.

Algorithm terminated. In the process of solving the optimal solution for the multimodal transportation path optimization model, after n generations of population reproduction, when the fitness function value tends to stabilize, that is, when the fitness function converges, the algorithm terminates [20].

3.6. Example Analysis. 30 tons of goods suitable for multimodal transportation will be transported from city A to city G. There are a total of five transit cities to choose from: B, C, D, E, and F. During the distribution process, there are at least one or more transportation modes to choose from, including road, railway, water, and air transportation. The transportation network diagram is shown in the following Figure 3.2.

The specific transportation options available between cities are described in Table 3.1.

4. Results and Discussion. The unit transportation costs and transportation times of various modes of transportation between cities are shown in Table 4.1. If a particular mode of transportation is unavailable in a city, its associated cost and time are treated as infinite. The unit transit costs between various transportation modes are detailed in Table 4.1, while the conversion times between different transportation modes at each node city are provided in Table 4.2.

Note: a/b/-, a represents the unit transportation cost (yuan/ton/hour), b represents the transportation time (hours), - represents the absence of a certain transportation method.

Other data includes total transportation time requirements and penalty costs incurred. The author sets the transportation time as 3 days (72 hours) and the penalty cost as 200 yuan per hour for overdue.

Table 3.1: Transportation modes between cities

	A	B	C	D	E	F	G
A	\	Public/Iron	Public/Iron	Public/Iron	\	\	\
B	Public/Iron	Public/Iron	Public/Water	Public/Iron	Public	\	
C	Public/Iron	Public/Iron	\	Public/Iron	Public/Iron	Public/Iron	\
D	Public/Iron	Public/Water	Public/Iron	\	Public/Water	Public/Iron	Public/Iron/ Water/Aviation
E	\	Public/Iron	Public/Iron	Public/Water	\	Public/Iron	Public/Water
F	\	Public	Public/Iron	Public/Iron	Public/Iron	\	Public/Iron
G	\	\	\	Public/Iron/ Water/Aviation	Public/Water	Public/Iron	\

Table 4.1: Unit transportation costs (yuan/ton/hour) and transportation time (hours) for various transportation modes between cities

	A-B	A-C	A-D	B-D	C-D	D-E	D-F	D-G	E-G	F-G
road transport	27/6	29/6	34/19	26/9	30/11	34/10	29/12	37/17	27/12	31/13
railway transportation	22/7	19/7	31/23	20/11	29/15	-	30/13	31/18	31/13	32/14
Waterway transportation	-	-	-	-	-	14/19	-	-	17/29	-
transport aviation	-	-	-	-	-	-	-	300/2	-	-

Table 4.2: Unit Transfer Costs (yuan/ton · hour)/Conversion Time (hours) between Different Transportation Modes

intercity	road transport	railway transportation	Waterway transportation	transport aviation
road transport	0/0	31/2	24/2	24/2
railway transportation	19/2	0/0	24/1	24/2
Waterway transportation	21/1	22/1	0/0	22/1
transport aviation	24/2	24/1	22/1	0/0

The network is addressed using a genetic algorithm implemented in MATLAB. The algorithm is configured with the following parameters: an initial population of 90 individuals, a crossover probability of 0.6, and a mutation probability of 0.01. After 100 iterations, it was found that the fitness change between adjacent generations was less than 0.01, indicating that the population mean of the running results had stabilized. At this point, the results can be considered converged, as shown in Figure 4.1.

The final optimized route obtained is: A $\rightarrow$ Railway $\rightarrow$ B $\rightarrow$ Highway $\rightarrow$ D $\rightarrow$ Waterway $\rightarrow$ E $\rightarrow$ Highway $\rightarrow$ G, with a total cost of 37710 yuan, transportation cost of 32340 yuan, transit cost of 5370 yuan, and a total time of 59 hours, including 8 hours of transit time and 3 transit times, without incurring any penalty costs.

If the author adopts a single transportation method, the optimal solution obtained is railway transportation: A-D-G, with a total cost of 41280 yuan and a total time of 38 hours.

5. Conclusion. The author proposes a coal transportation multimodal transport path selection based on genetic algorithm. In response to the logistics distribution problem of multimodal transport, the author constructs a multi-objective optimization model with the minimum cost of transportation mode usage cost, cargo transportation transit cost, transportation time cost of goods in transit, and cargo transit time cost, which is theoretically feasible Analyze the applicability of genetic algorithms and design a genetic algorithm for multimodal logistics distribution. The calculation results of the example show that using genetic algorithm can reliably find better solutions in logistics distribution optimization problems There are many factors that affect the logistics and distribution of multimodal transport, and this study selects the main factors that affect

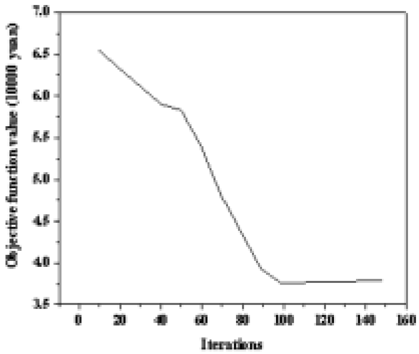

Fig. 4.1: Evolution of Optimal Solution

logistics and transportation distribution. Other factors such as driver labor costs, vehicle maintenance and upkeep costs, etc. are not fully covered; Moreover, some conditions assumed during modeling and algorithm design may differ from the actual operating environment. Therefore, how to more accurately transform the actual multimodal logistics distribution problem into an accurate model and make theoretical research more meaningful is a further direction for deepening.

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THE ARTIFICIAL INTELLIGENCE DRIVEN AUTONOMOUS NAVIGATION OPERATION PATH PLANNING SYSTEM FOR AGRICULTURAL MACHINERY

LEI WANG[*], YONG CHANG[†], AND WENBIN CHEN[‡]

Abstract. This study aims to develop an artificial intelligence-based autonomous navigation job path planning system for agricultural machinery. The core algorithm of the system combines path planning, monocular vision, visual navigation map, area detection and color calibration, etc., to realize autonomous navigation and efficient operation of agricultural machinery in complex farmland environments. The system uses the visual navigation map and area detection algorithm to identify and plan the path of the target area. The color calibration module further improves the accuracy of image information and provides higher reliability for path planning. The simulation results show that the system can accurately detect the working area in the complex farmland environment, plan the optimal path, and ensure the stability and efficiency of the mechanical operation. Accurate data analysis shows that the path planning success rate of the system is more than 90% in various farmland scenarios, effectively improving the automation level of agricultural machinery operations. This study provides a new idea and practical basis for future intelligent development of agricultural machinery.

Key words: Artificial intelligence; Agricultural machinery; Autonomous navigation; Path planning; Visual image.

1. Introduction. With the development of modern agriculture, the intelligent demand for agricultural machinery is increasing daily. How to realize the autonomous navigation of agricultural machinery in complex farmland environments has become an important research direction. Against this background, the techniques of path planning, monocular vision, visual navigation map, area detection and color calibration have been widely used and studied. The combination of these technologies not only improves the efficiency of agricultural machinery but also lays the foundation for precision agriculture.

The traditional path planning method mainly relies on GPS and inertial navigation systems, but its accuracy and reliability have significant limitations in complex terrain and occlude environments. In literature [1], A path planning method based on the A* algorithm was proposed to solve the problem that traditional path planning is not flexible in path selection in farmland operations by introducing cost function and heuristic search. However, such methods still have the challenge of insufficient navigation accuracy in the face of an unstructured farmland environment. As a low-cost and high flexibility image acquisition method, monocular vision technology has a broad application prospect in agricultural machinery navigation. Document [2] uses a monocular camera to obtain farmland images and realizes farmland boundary identification through an image processing algorithm, effectively solving the problem of inaccurate farmland boundary detection. However, due to the complexity of the farmland environment, the robustness of monocular vision under different lighting conditions needs to be further improved. The generation and application of visual navigation maps are a vital link to realizing the autonomous navigation of agricultural machinery. Literature [3] proposes a farmland map construction method based on visual SLAM technology, which solves the problem of real-time map generation and updates in the farmland environment by matching continuous image frames and location estimation. This method is effective in structured environments, but the accuracy and stability of visual navigation maps in unstructured farmland still need further study. Area detection is a critical step in path planning. Literature [4] adopted a deep learning-based region detection algorithm to solve the problem of low target region recognition rate in

[*]School of Mechanical Engineering, Gansu Animal Husbandry Engineering Vocational and Technical College, Wuwei 733006, China

[†]College of Electronic and Electrical Engineering, Lanzhou Petrochemical University of Vocational Technology, Lanzhou, 730060, China

[‡]School of Mechanical Engineering, Gansu Animal Husbandry Engineering Vocational and Technical College, Wuwei 733006, China (Corresponding author, 18993856581@163.com)

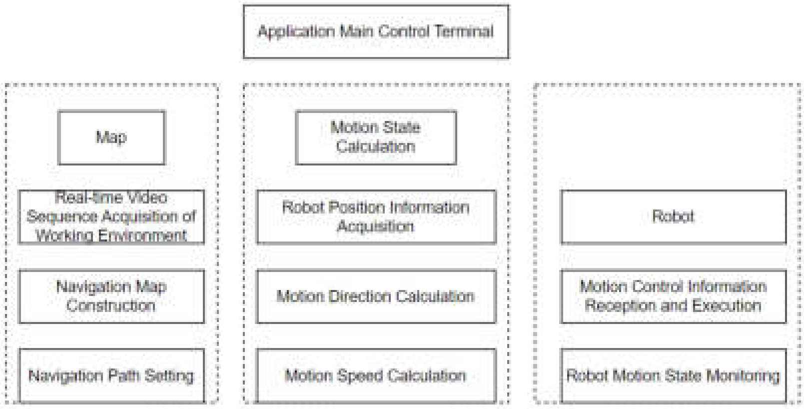

Fig. 2.1: Block diagram of the agricultural robot navigation system.

complex farmland scenes. However, due to the diversity of farmland scenes, this method lacks generalization ability. Current research focuses on improving the stability and accuracy of region detection algorithms in diverse scenarios. Color calibration plays a vital role in the visual navigation system, which can help the system maintain image recognition stability. Literature [5] proposed a calibration method based on color model conversion, which dynamically adjusts the image color space to solve the problem of image deviation caused by light changes in farmland operations. However, achieving accurate color calibration under complex lighting conditions is still a significant challenge in visual navigation systems.

In summary, the existing research has made remarkable progress in path planning, monocular vision, visual navigation maps, area detection and color calibration, but some shortcomings remain. This paper proposes an artificial intelligence-driven path planning system for agricultural machinery autonomous navigation [6]. The system combines path planning and monocular vision technology and realizes autonomous navigation in complex farmland environments through a visual navigation map and area detection algorithm. A color calibration module is also introduced to improve navigation accuracy under diverse lighting conditions. This paper will focus on the algorithm design, model simulation and experimental verification process of the system and analyze the simulation results in detail to provide a reference for the future development of intelligent agricultural machinery.

2. System structure design. The robot navigation system consists of two parts, including the main control terminal of the application system and the control terminal of the robot's lower computer. They are responsible for establishing navigation maps, planning paths, identifying robot positions, and updating the robot's motion status to ensure that the robot can follow the user's planned route [7]. The above application mainly uses the camera to collect the image of the working environment of agricultural machinery, and constructs its visual navigation diagram to locate it. Then, the data, such as the planned route and the starting point location, are used to analyze the following movement conditions. The control information of the moving condition is transmitted to the bottom controller of the robot through the network communication module [8]. Then, on the bottom controller, the robot moves according to the trajectory designed by the user. At the same time, the current working status of the slave controller is transmitted to the master controller of the application system as a data frame, which helps the master controller modify the robot arm's action in real time. The control process block diagram of the agricultural robot navigation system is shown in Figure 2.1.

3. Structural design of agricultural robot.

3.1. Agricultural robot motion model. The agricultural machine robot has a three-wheel all-round traveling mode. It is composed of three McNamm wheels, each at 120 degrees Angle, to form a walking mechanism, through the lateral speed and the corresponding relationship between the speed of the walking wheel, to realize the agricultural machinery robot [9]. It can follow the command issued by the navigation

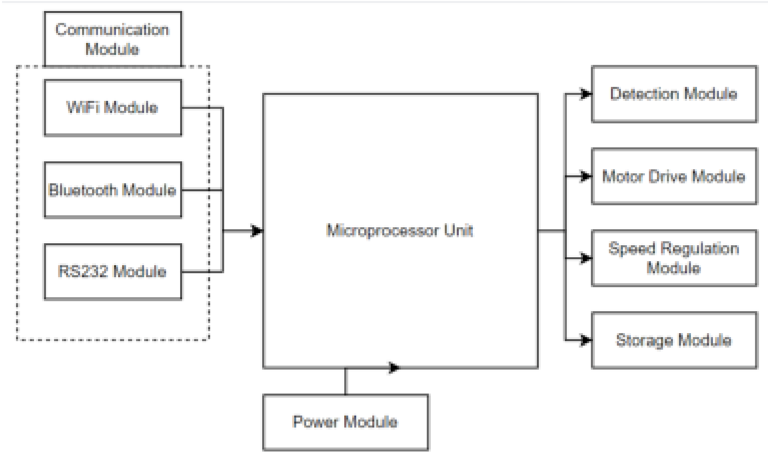

Fig. 3.1: Hardware structure block diagram.

control software and carry out the operation according to the route made by the user. The moving trajectory is a discrete point including starting and ending points. The accumulated error is reduced by updating the mobile node in real-time.

3.2. Hardware of the control terminal of the lower computer. In the control part of the slave machine, the acceptance of the control command of the host system, the guidance of the robot's motion trajectory, the adjustment of the motion difference and the detection of the state are completed [10]. It mainly includes a communication module, microprocessor module, power module, storage module, motor drive module and speed control module. The hardware configuration block diagram is shown in Figure 3.1.

The central controller of the navigation and positioning system transmits real-time positioning information, moving direction and speed calculation data to the subordinate microcontroller through the communication module [11]. Then, the speed adjustment module and the motor drive module are adjusted by the single-chip microcomputer to realize the adjustment of the motion state of the robot arm. With 32-bit STM32F103 as the slave chip, the system can receive and execute the instructions of the central controller of the application system and monitor the robot's movements. The DC motor on each moving wheel is driven by double pulse width modulation and pulse width modulation [12]. Then, the speed of each moving wheel is controlled. The power supply unit provides a continuous and stable operating voltage for the underlying controller of the robot.

4. Position and navigation of agricultural robots based on visual positioning. The system uses a single-eye camera to collect images of the job site, build a visual map of the job area, and carry out automatic navigation—real-time positioning and tracking of the robot's movement on the visual map [13]. At the same time, the user's customized route is combined to obtain the next moving direction and speed. This allows autonomous navigation from the starting point to the end.

4.1. Principle of Monocular Visual Positioning. The position accuracy is a necessary standard to measure the work efficiency when the robot moves autonomously. The 2D image of the working environment is drawn by transforming the Angle of view to achieve the transformation from world coordinates to image coordinates based on obtaining the working environment image of agricultural machinery using monocular vision [14]. In addition, the project uses the upper part as a reference plane to establish a navigation map based on vision.

4.2. Obstacle avoidance method of agricultural machinery arm in the process of moving. There are often mobile obstacles in the cooperative process of multiple agricultural machines. When encountering movement obstacles, achieving high precision, or avoiding the target is often impossible, failing multiple agricultural machinery equipment. However, the obstacle avoidance method designed by the potential field method can effectively avoid random obstacles in the movement and plan a feasible path [15]. The repulsive force between objects and the gravity between working targets overlap to make the manipulator move toward the predetermined working attitude under the push of external force. The mechanical arm is driven by the combined force of gravity F_a and repulsive force F_β to move in the direction of the purpose [16]. The role of the gravity potential field in the conventional artificial potential field method is:

$$V_a = \frac{1}{2}\lambda_b \left|R - R_{gaal}\right|^2 \tag{4.1}$$

F_α is the gravitational coefficient. Where R is the point coordinate vector required in the process of grasping the manipulator. R_{gool} is the object positioning vector.

$$F_a = -\operatorname{grad}(V_a) = \lambda_b \left|R - R_{gad}\right| \tag{4.2}$$

The repulsive force of the conventional artificial potential field method is:

$$V_\beta = \begin{cases} \frac{1}{2}\lambda_s \left(\frac{1}{\xi} - \frac{1}{\xi_0}\right)^1 & (\xi \leq \xi_0) \\ 0 & (\xi > \xi_0) \end{cases} \tag{4.3}$$

λ_s is the coefficient of repulsion. Where ξ is the distance from the central point of the obstacle to the harvesting arm. ξ_0 represents the range of action of the obstacle, which is usually a constant [17]. The negative slope of the resistance field is shown as follows:

$$F_\beta = -\operatorname{grad}(V_\beta) = \begin{cases} \lambda_s \left(\frac{1}{\xi} - \frac{1}{\xi_0}\right)^2 \frac{1}{\xi^2}\frac{\partial \xi}{\partial R} & (\xi \leq \xi_0) \\ 0 & (\xi > \xi_0) \end{cases} \tag{4.4}$$

The force acting on the robotic arm is

$$F_{\text{bowl}} = F_a + F_\beta \tag{4.5}$$

When the picking robot approaches the object, the resulting repelling effect causes the arm to deflect. Therefore, a potential method is proposed to ensure the trajectory of the acquisition manipulator [18]. In this method, the repulsion field is adjusted by changing the distance between objects to minimize the repulsion between objects. The modified function is

$$V_\beta = \begin{cases} \frac{1}{2}\lambda_s \left(\frac{1}{\xi} - \frac{1}{\xi_0}\right) 2\left(R - R_{\text{goal}}\right) 2 & (\xi \leq \xi_0) \\ 0 & (\xi > \xi_0) \end{cases} \tag{4.6}$$

Different from the general repulsion calculation method based on the artificial potential field, with the improved repulsion force, the suction force received by the robot when approaching the obstacle continues to increase, and the repulsion force will gradually decrease. As the picking robot gets closer, the repulsive force gets smaller, and gravity gets bigger. The repulsive force acting on the robotic arm is the resultant force. Its expression is as follows

$$F_\beta = F_{\beta 1} + F_{\beta 2} \tag{4.7}$$

When the object exerts $F_{\beta 1}$ repulsive force A on the robotic arm, there is also a gravitational force $F_{\beta 2}$ acting on the object.

4.3. Position and trajectory control of the agricultural mechanical arm. Agricultural machinery should avoid operation in various environments and ensure the optimal solution of the operation route. Suppose that the ant code of the agricultural robot is $\lambda(\lambda = 1, 2, \cdots, m)$, and all the nodes it passes through are marked as tabu $u_\lambda(\lambda = 1, 2, \cdots, m)$, and the forbidden search list is constructed. By optimizing the algorithm, the algorithm has the minimum search distance. Plan your following route. Suppose the interval $L_{i,j}(i, j =$

$0, 1, \cdots, n-1$) from node i to node j, then the pheromone density on the line between node ij and node j at time t is δ_{ij}. The probability of the colony moving from one place to another in each time is

$$f_{ij}^{\lambda} = \begin{cases} \frac{\delta_{ij}^{c}(t)\varphi_{ij}^{d}(t)}{\sum_{\lambda \in \text{ allowed }_{\lambda}} \delta_{ij}^{c}(t)\varphi_{ij}^{d}(t)} \\ j \in \text{ allowed }_{\lambda} \\ f_{ij}^{\lambda} = 0, \text{ other} \end{cases} \tag{4.8}$$

allowed $_{\lambda}$ provides every node that can be moved and selected. c is a motivator of information. d is the required revelatory factor. φ_{ij} is an illuminating function. At time $t+n$, information about the route (i, j) program can be adjusted to

$$\delta_{ij}(t+n) = (1-\xi) \times \delta_{ij}(t) + \Delta\delta_{ij}(t) \tag{4.9}$$

$$\Delta\delta_{ij}(t) = \sum_{i=1}^{m} \Delta\delta_{ij}^{\lambda}(t) \tag{4.10}$$

$\xi \in (0, 1)$ is the pheromone releasing factor. $\Delta\delta_{ij}^{2}(t)$ represents an increase in pheromones. The population density of ants can be divided into three categories: the ant week model, the ant number model, and the ant density model. The following formula can represent the ant cycle system pattern

$$\Delta\delta_{ij}^{2}(t) = \frac{W}{H_2} \tag{4.11}$$

The ant population model can be expressed as

$$\Delta\delta_{ij}^{2}(t) = \frac{W}{L_{ij}} \tag{4.12}$$

The ant density model can be expressed as

$$\Delta\delta_{ij}^{2}(t) = W \tag{4.13}$$

where H_2 is the sum between nodes. W is for pheromone. Combining the ant optimization and artificial potential field methods enables the agricultural robot arm to avoid arbitrary obstacles and achieve intelligent path planning. The flow of the position tracking algorithm is shown in Figure 4.1.

The rich and vast color space of RGB mode is used to better adapt to the color transformation requirements caused by environmental factors such as environment and lighting. Through the feedback adjustment of the path, the path planning is completed and determined as the shortest path, and then the path is output. Optimal processing can be performed when the minimum distance is not reached.

5. Experimental verification and analysis. A collision avoidance method based on a moving target is proposed. Its main objective is to prevent conflict between the agricultural machinery arm, the obstacle body, and the robot arm and enhance its obstacle avoidance ability. The operation scheme of multiple agricultural machines designed according to the law of moving obstacle avoidance is given. Many moving obstacle groups were established and simulated, and the following trajectory planning was obtained (Figure 5.1).

The effectiveness of this method is obtained through several experiments. Experimental results show this method can be used for trajectory planning under arbitrary obstacles. Finally, the ant colony algorithm, genetic algorithm, neural network, and fuzzy algorithm are compared, and the conclusions are shown in Table 5.1.

The simulation results show that the ant algorithm can achieve more success time, a more extensive average route and maximum operational efficiency.

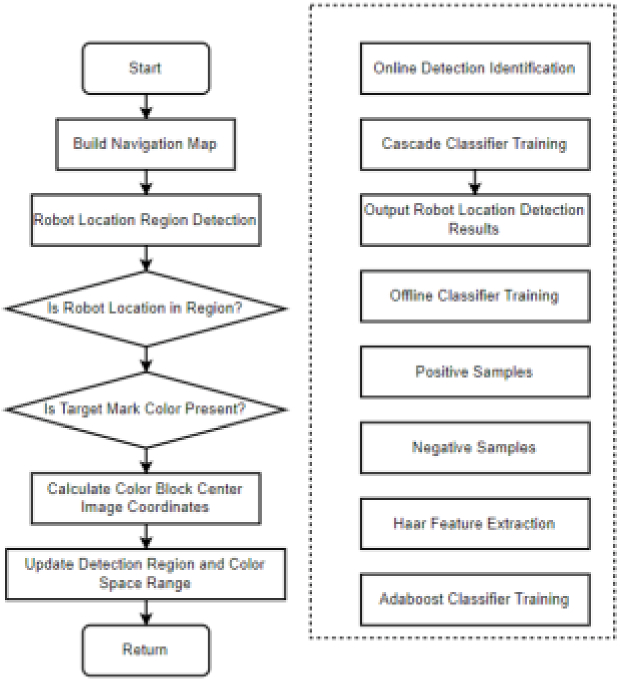

Fig. 4.1: Flow chart of the positioning tracking algorithm.

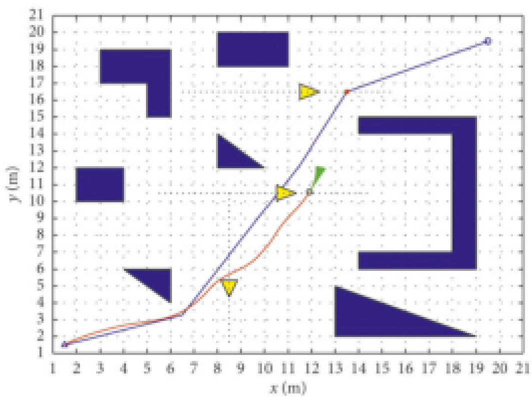

Fig. 5.1: Result of multiple dynamic path planning.

Table 5.1: Test result table for path planning.

Algorithm	Number of successes	Average path length /m	Average running time per cycle /s
Ant colony algorithm	49/50	4506	0.33
Genetic algorithm	47/50	5099	0.68
Neural network algorithm	46/50	5133	1.27
Fuzzy algorithm	45/50	4954	1.44

6. Conclusion. In this study, an artificial intelligence-based path planning system for agricultural machinery autonomous navigation was developed, which utilized monocular vision, visual navigation map, area detection and color calibration technology to achieve accurate navigation and operation in complex farmland environments. By designing a path planning algorithm, the system can effectively identify the working area, generate the optimal path to guide agricultural machinery operation and improve its automation level. The experimental and simulation results show that the system has a high degree of path planning accuracy and stability in various farmland scenarios, ensuring the continuity and efficiency of mechanical operation. By introducing a visual navigation map and color calibration module, the system can still stably detect regional boundaries under complex lighting conditions, reduce errors, and optimize navigation effects. Comprehensive evaluation shows that the path planning success rate of the system is more than 90%, which saves time and improves precision. The research results strongly support the development of intelligent agricultural machinery and provide a new idea and reference for the future intelligent path planning of agricultural machinery.

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GENETIC ANT COLONY ALGORITHM AND ITS DESIGN AND RESEARCH IN CLOUD COMPUTING PLATFORM RESOURCE SCHEDULING

DONGHUI MEI,[*] WENWEI SU,[†] YAN SHI [‡] AND YANXU JIN[§]

Abstract. In order to solve the problems of slow convergence speed and low efficiency in finding precise solutions in existing cloud computing resource scheduling algorithms, the author proposes a genetic ant colony algorithm and its design and research in cloud computing platform resource scheduling. The author introduces a hybrid algorithm that integrates genetic algorithms with ant colony optimization. This approach begins by encoding parameters and seeks the best combination through evolutionary processes. It effectively merges the ant colony algorithm's feedback mechanism with the genetic algorithm's global search capabilities and rapid convergence. Then, multi-dimensional QoS constraints are proposed according to the needs of different users to perform local and global updates of pheromones. Finally, comparative simulation experiments were conducted on the cloud simulation platform CloudSim with simulated annealing algorithm (SA) and basic ant colony algorithm (ACO). The experimental results show that GAACO has a better time cost than ACO, but the time cost is longer than SA, and as the number of tasks increases, the time gap becomes larger. Compared with ACO, the time is reduced by 50.8%, and compared with SA, the time difference is 4%. Therefore, in terms of time cost, this algorithm is better than ACO. The algorithm proposed by the author effectively shortens the completion time of task scheduling, reduces operating costs, and has superior comprehensive performance.

Key words: Cloud computing, Resource scheduling, Genetic algorithm, Ant colony Pheromone

1. Introduction. Cloud computing, as a new type of business service model, has received widespread attention from both industry and academia since its proposal [1]. As research and applications in cloud computing advance, cloud systems are expanding in scale and growing increasingly complex in their topology. Moreover, the diverse nature of resources presents significant challenges in efficiently scheduling cloud computing tasks, making it a critical area of focus in cloud computing research [2].

In recent years, cloud computing task scheduling and optimization algorithms have developed rapidly. Usually, the first step is to use Map/Reduce to process cloud computing tasks, dividing large-scale tasks into multiple subtasks, and then scheduling each subtask through Map and Reduce stages [3]. Studies indicate that scheduling tasks in cloud computing is classified as an NP problem. To address this, heuristic algorithms are predominantly employed, including optimization algorithms based on genetic algorithms (GA), particle swarm optimization, and ant colony optimization (ACO). These methods aim to minimize task completion times and ensure effective load balancing across node resources to better meet users' practical application requirements. Each of these algorithms has its own distinct strengths and weaknesses. For instance, genetic algorithms excel in global search but often require numerous parameters and can be prone to finding local optima. Ant colony algorithms are strong in local search but may experience slow initial search due to the lack of initial pheromone levels [4]. Particle swarm optimization offers high efficiency early on but can suffer from slow convergence and instability later in the process. The genetic ant colony algorithm integrates the genetic algorithm's global search strengths with the ant colony algorithm's local search capabilities, thereby enhancing both the optimization efficiency and solution quality [5].

In cloud computing environments, resource scheduling problems are highly complex and dynamic, and the introduction of genetic ant colony algorithm provides a new direction for solving this problem. Through this algorithm, cloud computing platforms can allocate computing resources more intelligently, maximize resource

*Information Center of Yunnan Power Grid Co., Ltd., Kunming, Yunnan, 650032, China. (Corresponding author, lrzhoujinyu@163.com)
†Information Center of Yunnan Power Grid Co., Ltd., Kunming, Yunnan, 650032, China.
‡Information Center of Yunnan Power Grid Co., Ltd., Kunming, Yunnan, 650032, China.
§Information Center of Yunnan Power Grid Co., Ltd., Kunming, Yunnan, 650032, China.

utilization, and reduce operating costs and energy consumption while meeting user needs.

The author's goal is to design and optimize a cloud computing platform resource scheduling model based on genetic ant colony algorithm, aiming to improve the efficiency and fairness of resource scheduling [6].

2. Literature Review. With the advancement of technology, high-performance computing has been increasingly applied in fields such as climate simulation, fluid mechanics, molecular dynamics, and bioinformatics [7]. The speed of data processing and the response time to user demands cannot be effectively improved for high-performance computing under high-performance concurrency, multiple computing system models, data and cloud storage.

How to allocate resources, energy-saving scheduling and load balancing for high-performance computing system platforms is the core of enhancing performance. In order to improve the utilization rate of high-performance computing systems and reduce system load imbalance, engineering scholars have conducted many scheduling algorithm studies [8]. Abbasi, S. et al. developed an algorithm that applies genetic algorithms to manage faults and costs in resource allocation for services. The core idea is to leverage genetic algorithms to choose the most suitable resources for different services. The algorithm focuses on minimizing both processing and energy costs, with these costs serving as the objective function to drive the optimization process [9]. Malathi, K. et al. introduced a genetic algorithm-based system for scheduling independent tasks, which optimizes both time and resource usage while considering the safety requirements for task allocation.

Currently, a range of metaheuristic algorithms, including genetic algorithms, are employed to address task scheduling challenges [10]. Chu, L. et al. developed a collaborative scheduling model for managing multiple equipment resources at automated container terminals, aiming to reduce completion time and enhance loading and unloading efficiency. Their comparison of particle swarm optimization and genetic algorithms demonstrated that their proposed algorithm significantly boosts both global and local search capabilities in finding optimal solutions. Furthermore, their findings show that the collaborative scheduling approach, which takes into account mixed processes, effectively enhances the efficiency of automated container terminal operations. This research offers valuable insights for optimizing loading and unloading processes and improving coordinated scheduling at automated docks [11].

However, genetic algorithms have better search space solution capabilities and require more local parameters, making it easy to obtain locally excellent solutions; Ant colony algorithm has better ability to search for exact solutions, but due to insufficient initial pheromones, the initial search for solutions is slower. In response to the above shortcomings, the author proposes a genetic ant colony algorithm and its design and research in cloud computing platform resource scheduling. The genetic ant colony algorithm, which combines user multi-dimensional QoS (quality of service) constraints, integrates user needs into the algorithm in mathematical form, and uses genetic algorithm to encode heuristic factors, expected heuristic factors, and pheromone volatility coefficients. In the process of evolution, the optimal combination is found, which improves the convergence speed and global search ability of the ant colony algorithm, and optimizes the virtual machine resource load and user comprehensive cost.

3. Method.

3.1. Problem description of cloud computing resource scheduling. Virtualization has fundamentally transformed cloud computing compared to traditional distributed resource scheduling models. As illustrated in Figure 3.1, cloud computing resource scheduling involves breaking down each task into multiple independent subtasks [12].

Upon receiving a request, the system allocates a specific amount of virtual resources, with each subtask being assigned to a corresponding virtual resource node.

In cloud computing, resource scheduling is defined as follows: Tasks are segmented into independent subtasks and assigned to m virtual resource nodes for executio, where $m < n$.

Let $T = \{t_1, t_2, \cdots, t_n\}$ represent the set of subtasks, where $t_j (0 < j \leqslant n)$ represents the jth subtask.

Let $VM = \{vm_1, vm_2, \cdots, vm_m\}$, represent the set of virtual resource nodes, where $vm_i (0 < i \leqslant m)$ represents the i-th virtual resource node, and each t_j can only execute on one vm_i.

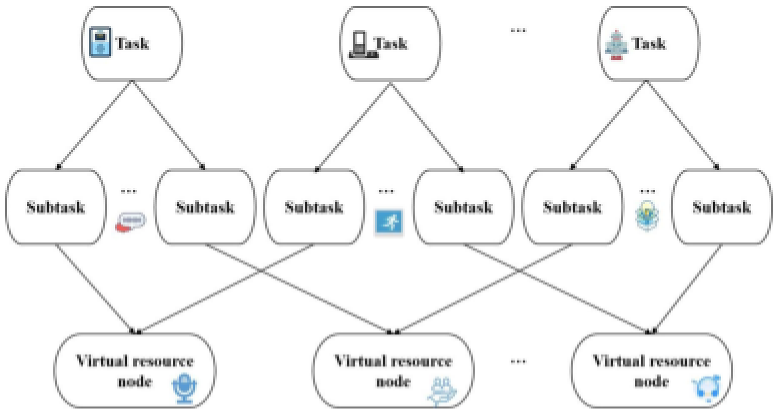

Fig. 3.1: Resource Scheduling in Cloud Computing

The correspondence between T and VM can be represented by the allocation matrix X as

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{3.1}$$

Here x_{ij} represents the correspondence between t_j and $vm_i, x_{ij} \in \{0,1\}, \sum_{i=1}^{m} x_{ij} = 1, i \in \{1,2,\cdots,m\}, j \in \{1,2,\cdots,n\}$, indicating that if t_j is executed on $vm_i, x_{ij} = 1$, otherwise, x_{ij}. The expected time for t_j to complete on vm_i is represented by ET_{ij}, which corresponds to the allocation relationship matrix X [13,14]. The ET matrix is

$$ET = \begin{bmatrix} ET_{11} & ET_{12} & \cdots & ET_{1n} \\ ET_{21} & ET_{22} & \cdots & ET_{2n} \\ \vdots & \vdots & & \vdots \\ ET_{m1} & ET_{m2} & \cdots & ET_{mn} \end{bmatrix} \tag{3.2}$$

If the starting time of vm_i is c_i, then the expected completion time of vm_i's processing task is $CT_i = c_i + \sum_{j=1}^{n} ET_{ij} \times x_{ij}$, where $i \in \{1,2,\cdots,m\}$ and $j \in \{1,2,\cdots,n\}$. Define $CT_{max} = max\{CT_i\}, CT_{min} = min\{CT_i\}$. Therefore, the expected time to complete the total task is CT_{max}, and the fitness function of the total task completion time is

$$f_{CT} = \frac{CT_{max} - CT_{min}}{\sum_{j=1}^{m}(CT_i - CT_{min})} \tag{3.3}$$

Similarly, the total cost completed by t_i on vm_j is represented by EC_{ij}. Let A_{ij} represent the resources occupied by t_i on vm_j, then EC_{ij} is positively correlated with the time consumed ET_{ij} and the resources occupied A_{ij}. Let its correlation coefficient be ξ, then

$$EC_{ij} = \xi \times ET_{ij} \times A_{ij} \tag{3.4}$$

Corresponding to the allocation relationship matrix X, the EC matrix is

$$EC = \begin{bmatrix} EC_{11} & EC_{12} & \cdots & EC_{1n} \\ EC_{21} & EC_{22} & \cdots & EC_{2n} \\ \vdots & \vdots & & \vdots \\ EC_{m1} & EC_{m2} & \cdots & EC_{mn} \end{bmatrix} \tag{3.5}$$

Let EC_i be the cost of processing task vm_i, where $i \in \{1, 2, \cdots, m\}$ is $EC_i = \sum_{j=1}^{n} EC_{ij} \times x_{ij}$. So, the fitness function of the total cost of task expenses is

$$f_{EC} = \frac{\sum_{i=1}^{m} EC_i}{\sum_{i=1}^{m} \sum_{j=1}^{n} EC_{ij}} \tag{3.6}$$

The resource scheduling adaptation function of the optimization algorithm is

$$F_{fitness} = a \times f_{cr} + b \times f_{EC} \tag{3.7}$$

In the formula: $a + b = 1, 0 \leqslant a, b \leqslant 1$. The goal of the algorithm is to find a suitable matrix X that minimizes the value of F_{fitues}.

3.2. Genetic Ant Colony Algorithm for Solving Cloud Computing Task Scheduling. The foundational model of the ant colony algorithm was developed by Italian researcher DIRIGO, drawing inspiration from the natural foraging behavior of ants. This behavior demonstrates self-organization and is effectively a solution to the shortest path problem, making it applicable to classic NP problems like the Traveling Salesman Problem (TSP) [15]. On the other hand, the genetic algorithm (GA) emulates Darwinian natural selection and genetic principles to search for optimal solutions through simulated evolution. By integrating genetic algorithms with ant colony algorithms, it is possible to enhance the global search capabilities and convergence speed of the ant colony approach.

The general process of using genetic ant colony algorithm to solve cloud computing task scheduling problems is as follows. Let $\alpha_q, \beta_q, \gamma_q$ be the values of the heuristic factor, expected heuristic factor, and pheromone volatilization coefficient corresponding to the q-th generation of the genetic population after encoding, crossover, mutation, and decoding, respectively. The heuristic factor signifies the influence of accumulated data as ants move, while the expected heuristic factor indicates the weight assigned to this heuristic information during the selection of virtual machines. The heuristic factor, expected heuristic factor, and pheromone volatilization coefficient are encoded in binary, with each parameter occupying 20, 20, and 40 binary bits, respectively; When selecting chromosomes, use roulette wheel to describe n virtual machines in the data center using $G(V, E)$, where V is the set of virtual machines and E is the set of virtual machine task execution time. Assuming there is an ant in the system, the ant's selection of the next task execution virtual machine is determined based on the amount of information on each virtual machine. Use taboo table to represent the virtual machines that the ant has already selected, and $allowed_k = \{V - tabu_k\}$ to represent the virtual machines that ant k can choose next, when the number of tasks exceeds the number of virtual machines, each virtual machine may be selected multiple times. The heuristic function $\eta_{is}(t) = 1/D_{ij}$ represents the expected transfer of ant k from virtual machine i to virtual machine s at time t, and $\tau_{is}(t)$ represents the residual information from virtual machine i to virtual machine s at time t. Initially, the information is the same, that is $\tau_{is}(0) = const$[16]. The probability $p_{ij}^k(t)$ of ant k transferring from virtual machine i to virtual machine j is:

$$p_{ij}^k(t) = \begin{cases} \frac{|\tau_{ij}(t)|^{\alpha_q} |\eta_{ij}(t)|^{\beta_q}}{\sum_{j \in allowed_k} |\tau_{ij}(t)|^{\alpha_q} |\eta_{ij}(t)|^{\beta_q}} & j \in allowed_k \\ 0 \quad j \neq allowed_k \end{cases} \tag{3.8}$$

When ants are in motion, in order to avoid excessive accumulation of pheromones, they need to update their pheromones after completing each scheduling, which can be done according to the following rules:

$$\tau_{ij}(t+n) = (1 - \gamma_q)\tau_{ij}(n) + \Delta\tau_{ij}(n) \tag{3.9}$$

$$\Delta\tau_{ij}(n) = Q/multiQoS_p \tag{3.10}$$

In the formula: Q is the intensity of pheromones; $multiQoS_p$ refers to multidimensional QoS constraints [17].

Considering the specifics of cloud computing task scheduling, the enhancements of the genetic ant colony algorithm over the standard ant colony algorithm are primarily evident in the following areas:

1. The heuristic factors, expected heuristic factors, and pheromone volatility coefficients have undergone cross variation in the genetic population, increasing the likelihood of understanding and improving global search capabilities.
2. In terms of pheromone updates, global and local updates have been carried out, while also incorporating the requirements for cost, time, system load, and service quality in cloud computing task scheduling, proposing multidimensional QoS constraints.

3.3. Establishment of Multidimensional QoS Constraint Function. The ordinary ant colony algorithm does not impose multidimensional QoS constraints when solving problems, but in the actual cloud computing scheduling process, there are corresponding requirements. Therefore, the author added multidimensional QoS constraints in three aspects: cost, time, and reliability, and established corresponding constraint functions. Let K_{best} be the set of tasks that allocate all current tasks to the best performing virtual machine, K_{woos} be the set of tasks that allocate all current tasks to the worst performing virtual machine, p be the number of the current ant, K be the task allocation scheme for the p ant with the number, K_j be the resource number assigned to the K_j-th task, and k be the number of current tasks to be allocated. Based on this, the author proposes the following hypotheses: Assumption 1 uses T_{min} to represent the time cost of allocating all current tasks to the best performing resources, T_{max} to represent the time cost of allocating all current tasks to the worst performing resources, T_c to represent the time cost of using genetic ant colony algorithm for task scheduling, and T_{res} to represent time constraints, which are mathematically defined as:

$$T_{min_p} = \frac{\sum_{i=1}^{k} J_i(length)}{k \cdot Vm_{best(mips)}} + \frac{\sum_{i=1}^{k} J_i(inputfileSize)}{k \cdot Vm_{best(bw)}} + \frac{\sum_{i=1}^{k} J_i(outfileSize)}{k \cdot Vm_{best(bw)}} \tag{3.11}$$

$$T_{max_p} = \frac{\sum_{i=1}^{k} J_i(length)}{k \cdot Vm_{worst(mips)}} + \frac{\sum_{i=1}^{k} J_i(inputfileSize)}{k \cdot Vm_{worst(bw)}} + \frac{\sum_{i=1}^{k} J_i(outfileSize)}{k \cdot Vm_{worst(bw)}} \tag{3.12}$$

$$T_{c_p} = \sum_{i=1}^{k} \frac{J_i(length)}{k \cdot Vm_{K_j(mips)}} + \sum_{i=1}^{k} \frac{J_i(inputfileSize)}{k \cdot Vm_{K_j(bw)}} + \sum_{i=1}^{k} \frac{J_i(outfileSize)}{k \cdot Vm_{K_j(bw)}} \tag{3.13}$$

$$T_{res_{K_j}} = \frac{T_{c_p} - T_{min_p}}{T_{max_p} - T_{min_p}} \tag{3.14}$$

Assuming that C_{min} represents the cost cost of allocating all current tasks to the best performing resources, C_{max} represents the cost of allocating all current tasks to the worst performing resources, C_c represents the cost of using genetic ant colony algorithm for task scheduling, and C_{res} represents the cost constraint, their mathematical definitions are:

$$C_{min_p} = \frac{\sum_{i=1}^{k} J_i(length)}{k \cdot Vm_{best(mips)}} \cdot perofmips + \frac{\sum_{i=1}^{k} J_i(inputfileSize)}{k \cdot Vm_{best(bw)}} \cdot perofbw + \frac{\sum_{i=1}^{k} J_i(outfileSize)}{k \cdot Vm_{best(bw)}} \cdot perofbw \tag{3.15}$$

$$C_{max_p} = \frac{\sum_{i=1}^{k} J_i(length)}{k \cdot Vm_{worst(mips)}} \cdot perofmips + \frac{\sum_{i=1}^{k} J_i(inputfileSize)}{k \cdot Vm_{worst(bw)}} \cdot perofbw + \frac{\sum_{i=1}^{k} J_i(outfileSize)}{k \cdot Vm_{worst(bw)}} \cdot perofbw \tag{3.16}$$

$$C_{c_p} = \frac{\sum_{i=1}^{k} J_i(length)}{k \cdot Vm_{K_j(mips)}} \cdot perofmips + \frac{\sum_{i=1}^{k} J_i(inputfileSize)}{k \cdot Vm_{K_j(bw)}} \cdot perofbw + \frac{\sum_{i=1}^{k} J_i(outfileSize)}{k \cdot Vm_{K_j(bw)}} \cdot perofbw \tag{3.17}$$

$$C_{res_{K_j}} = \frac{C_{c_p} - C_{min_p}}{C_{max_p} - C_{min_p}} \tag{3.18}$$

Table 3.1: Parameters of Genetic Ant Colony Algorithm

Parameter symbols	Parameter meaning	Parameter values
evolutionNum	evolutional generation	100
population	Genetic population size	10
m	Number of ants	30
P_c	crossover probability	0.34
P_m	mutation probability	0.09
$\aleph_{max}$	Maximum Inspiration Factor	1.00
β_{max}	Expected maximum inspiration factor	2.00
γ_{max}	Maximum evaporation coefficient of pheromones	0.10
Q	Pheromone intensity	50.00

In the formula, perofmips represents the cost of executing instructions per unit time; Perofbw is the cost per unit time bandwidth [18].

Assuming 3Res is the quantified reliability value when using genetic ant colony algorithm for task scheduling; ResRes is a reliability constraint, and its mathematical definitions are:

$$Res_p = \frac{1}{500}\sum_{i=1}^{k}\frac{J_i(length)}{Vm_{K_i}(mips)} \tag{3.19}$$

$$resRes_{K_j} = Res_p/antSize \tag{3.20}$$

Among them, antSize is the size of the ant population.

Assuming $4\lambda_1, \lambda_2, \lambda_3$ are weight coefficients $(\lambda_1 + \lambda_2 + \lambda_3 = 1)$ for cost, time, and reliability, which can be adjusted according to user requirements, the author selects three coefficients of 0.3, 0.4, and 0.4, respectively. The final multidimensional QoS constraint function is defined as:

$$multiQoS_p = \lambda_1 \cdot Tres_p + \lambda_2 \cdot Cres_p + \lambda_3 \cdot resRes_p \tag{3.21}$$

3.4. Simulation experiment. In order to test the performance of the algorithm proposed in this article, the CloudSim 3.0.2 cloud simulation platform from a certain university's grid laboratory was used in the experiment, and simulation comparisons and result analysis were conducted with the basic ant colony algorithm (ACO) and simulated annealing algorithm (SA). In the cloud simulation platform, first create a new MyAll ocateTest class for initial configuration of the cloud environment, including the creation of the data center, initialization of the scale parameters of cloud computing tasks, task size and input/output data file size, creation of virtual machine resources. Each virtual machine resource encompasses attributes such as CPU count, memory size, bandwidth, and instruction processing speed. CloudSim objects are instantiated to introduce cloud computing tasks, and three algorithms—GAACO, ACO, and SA—are implemented within the DatacenterBroker class [19]. The parameters pertinent to the genetic ant colony algorithm are detailed in Table 3.1.

Compare the performance of genetic ant colony algorithm from four aspects, namely average time cost, average cost, algorithm service quality, and system resource load rate. At the beginning, the task size is 10, the cloud computing resources are 10, the virtual machine storage size is 10GB, the memory size is 256MB, the number of CPUs is 1, the bandwidth is 1000MB, the unit time bandwidth cost is 0.01 yuan/s, and the unit time instruction cost is 0.01 yuan/s. The task size is tested in increments of 10. The quality of algorithm services is reflected through multiQoS. Define the resource load rate as:

$$sysuse = \frac{1}{n}\sqrt{\sum_{i=1}^{n}(use_i - use_{Avg})^2} \tag{3.22}$$

In the formula: use_i is the load of the i-th resource; use_{Avg} is the average load of the system; n is the number of resources [20].

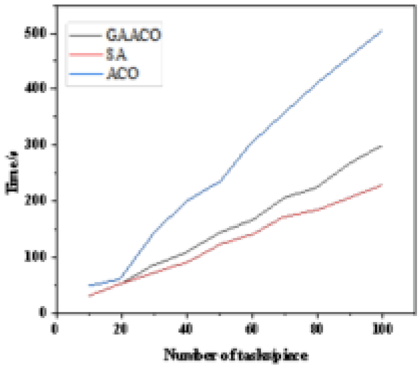

Fig. 4.1: Average time cost of each algorithm

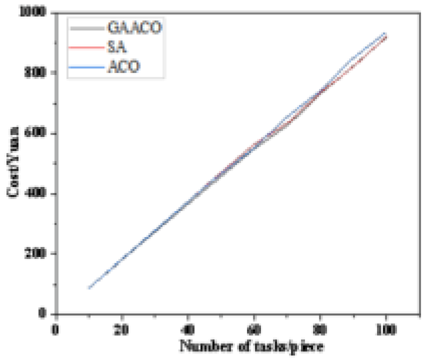

Fig. 4.2: Cost of each algorithm

4. Results and Discussion. With an increase of 10 tasks, the average time cost for each algorithm is computed, as illustrated in Figure 4.1. The results reveal that GAACO performs better in terms of time cost compared to ACO, although it still takes more time than SA. Additionally, as the task count grows, the time difference between GAACO and SA becomes more pronounced. Compared with ACO, the time is reduced by 50.8%, and compared with SA, the difference is 4%. Therefore, in terms of time cost, this algorithm is better than ACO, but not significantly different from SA.

The cost of each algorithm under different task quantities is shown in Figure 4.2. As the number of tasks increases by a multiple of 10, it can be seen that the differences between the algorithms are not significant, with an average cost difference of only about 1%.

The experimental results of the service quality of each algorithm are shown in Figure 4.3. It can be seen that the service quality of this algorithm and SA slowly increases with the increase of task quantity, while ACO shows a sharp upward trend in a straight line. Service quality is a comprehensive indicator of cost, time, and reliability. It can be seen that GAACO's overall performance is better than ACO and SA, with reductions of 14.3% and 76.7%, respectively.

The experimental results of the system load of each algorithm are shown in Figure 4.4. It can be seen that the system load of ACO has been maintained at a high level, while the system load of GAACO is higher than SA but significantly better than ACO. The average system load of GAACO is reduced by 50.1% compared to ACO. Combining Figures 4.1-4.3, it can be seen that SA is more inclined towards an average scheduling approach, where the number of tasks allocated to each virtual machine is basically the same. Therefore, the

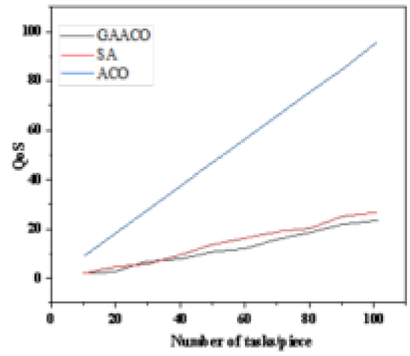

Fig. 4.3: Service Quality of Various Algorithms

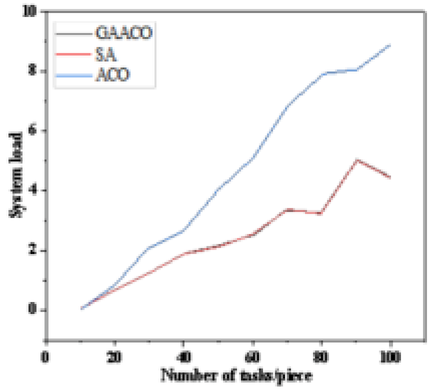

Fig. 4.4: Load of each algorithm system

load obtained using equation (3.22) is 0. However, cloud computing task scheduling often requires cost, time, and reliability to be balanced based on user requirements, which is reflected in QoS. In summary, the algorithm proposed by the author can better meet the needs of customers in the actual scheduling process.

5. Conclusion. The author introduces the genetic ant colony algorithm and explores its application in resource scheduling on cloud computing platforms. After a thorough investigation into cloud computing task scheduling, the proposed algorithm is evaluated against the basic ant colony algorithm and simulated annealing algorithm across four dimensions. The findings indicate that the new algorithm outperforms the other two, offering superior balance in terms of time cost, cost efficiency, reliability, and system load. This makes it a highly effective method for meeting the multi-dimensional QoS requirements of users.

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CORE LITERACY OF COLLEGE COUNSELORS AND STUDENT PRIVACY PROTECTION BASED ON EDGE INTELLIGENCE AND LIGHTWEIGHT COMPUTING

JING FANG*

Abstract. College counselors play a key role in promoting ideological and political education in universities, serving as sponsors, implementers, and mentors for students. Their influence extends to shaping the overall development of higher education and significantly impacts the cultivation of talent. This document aims to investigate the current state of knowledge and policy implementation regarding political and ideological education in information technology universities. It also proposes strategies to enhance the role of college counselors in this area. The study demonstrates that applying an optimized growth algorithm can improve both the educational framework and the competencies of counselors, fostering stronger core values and competitiveness within universities.

Key words: Information technology; College counselors; Ideological and political education; FP Growth algorithm

1. Introduction. "We should build a good team of counselors to ensure that this team is of high quality and high standard, and that this team is succeeded by a continuous source of people," stated General Secretary Xi Jinping at the National Conference on Ideological and Political Work in Colleges and Universities [1, 2]. The sacred mission of establishing moral education falls on counselors in colleges and universities, who also organize and carry out students' ideological and political education. Additionally, counselors' core literacy abilities have a direct impact on the caliber and extent of talent cultivation in colleges and universities. [3, 4]. The core literacy of counselors is not only beneficial to the development of counselors themselves, but also provides strong talent support for the construction of college counselor team, which eventually provides a strong guarantee for the overall development and growth of students.

The National Education Conference has made it clear time and time again that every facet of education had to be delivered flawlessly. In addition to imparting technical knowledge, information technology courses ought to foster students' information literacy. Condensing cultural heritage in value shaping and using its unique classroom teaching methods to achieve coordinated education are two benefits of integrating curriculum thinking into IT courses, in addition to facilitating knowledge dissemination, value shaping, and increasing students' identification with their majors [5]. The edge computing concept was created as a reaction to the aforementioned difficulties. With edge computing, a new concept of edge—a continuum—is introduced in contrast to the cloud computing model, which uploads all traffic to the data center. Edge Computing refers to a new computing model at the edge of the network near the IoT devices, which migrates some or all of the computing tasks of traditional cloud computing centers to the device side to provide edge services nearby, meeting the key requirements of time-sensitive connectivity, real-time business, security and privacy protection [6]. Compared with the traditional cloud computing model, edge computing refers to a small "cloud" processing center close to the physical device, i.e., computing processing and storage at the edge of the network [7]. The edge computing model has the advantages of real-time data processing and analysis, high security, high scalability, and low transmission bandwidth [8]. At the same time, edge computing provides a more convenient and scalable path to expand the computing capacity through the combination of IoT devices and edge computing platform, and adding new devices has less impact on the network bandwidth demand; the IoT devices in the access network receive information, and the IoT devices give the relevant location information and data to the edge nodes for processing according to their real-time location, and the edge computing platform discovers the location of the devices with this information, and the data collected by the IoT devices are used on the local devices for data pre-processing, computing and analysis. Pre-processing, computation and analysis [9, 10]. In

*Marxism College, Henan Polytechnic, Zhengzhou 450046, China (fangjing198102@126.com).

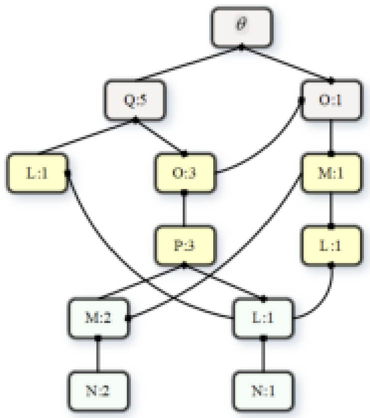

Fig. 2.1: Features of an FP tree.

the process of ideological and political education for college students, counselors in colleges and universities increasingly need to use network information media, and their core network information literacy will largely determine the effectiveness of ideological and political education.

The research and discussion on the network information core literacy of counselors can offer new theoretical perspectives and theoretical knowledge for the team construction of counselors as the main body of ideological and political education, as well as theoretical guidance and factual basis for the reform and development of Chinese ideological and political education. This is because the research is based on the characteristics of the new network media era and the fundamental purposes of the current ideological and political education in colleges and universities.

2. FP Growth algorithm optimization. An effective approach for association rule mining is the FP-growth algorithm, which creates frequent item sets from the FP tree by exploring the tree from the bottom up. In this paper, we address the drawback of having to repeatedly traverse through the laborious item list L during the construction of the FP tree by proposing an improved algorithm based on hash tables. This algorithm implements the mapping from item name keyword to storage address and then the mapping from item name keyword to its support count. When finding the support count of an item, only its name keyword is needed, and there is no need to traverse the frequent item list L from the beginning, and the time complexity is improved from 0(n) to 0(1). The experimental results show that the improved algorithm outperforms the original algorithm, saves traversal time, and improves the mining efficiency.

The connected element items can be called linked lists, as shown in Figure 2.1.

The calculation equation of conditional information entropy divided into subsets is as Eq. 2.1:

$$Info_a(D) = \sum_{j=1}^{k} \frac{d_{1j} + d_{2j} + ... + d_{mj}}{D} Info_a(D_j) \tag{2.1}$$

$Info_a(D)$ represents the dataset D's information entropy, also known as information gain, in relation to an attribute a. $\sum\limits_{j=1}^{k}$ represents the total of several categories or subcategories. The number of categories or subgroups in the dataset is denoted by j and k. $d_{1j} + d_{2j} + ... + d_{mj}$ denotes the relative frequency (or weight) of a particular set of j, where d_{ij} represents the number of class i or the i data point in the jgroup, and D is the total number of the entire dataset. $Info_a(D_j)$ signifies the group D_j information entropy.

Wherein, Eq. 2.2:

$$Info\,(D_j) = -\sum_{i=1}^{m} p_{ij}\log_2, p_{ij} = \frac{D_{ij}}{D_j} \tag{2.2}$$

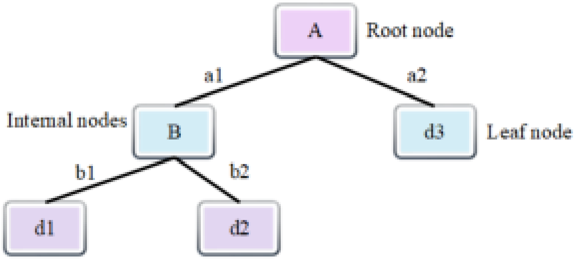

Fig. 2.2: Concept diagram of decision tree.

$Info\,(D_j)$ represents the dataset's uncertainty through the information entropy of D_j. $\sum\limits_{i=1}^{m}$ is the total of all the categories (i) in the dataset (D_j), where m is the number of categories. $-p_{ij}\log_2, p_{ij}$:represents the category I partial entropy in the dataset D_j. The reason for the negative sign is that the probability's logarithm is negative and the entropy value is non-negative. $p_{ij} = \frac{D_{ij}}{D_j}$ represents the likelihood that category i will appear in dataset D_j, where

$$D_{ij}$$

is the number of samples of category i in dataset D_j and D_j is the total number of samples in dataset D_j.

Therefore, the equation for calculating the set of candidate partition points for the feature a of continuous values containing n-1 elements is as Eq. 2.3:

$$T_a = \left\{ \frac{a^i + a^{i+1}}{2} \mid 1 < i < n - 1 \right\} \tag{2.3}$$

Secondly, the information gain of these dividing points is calculated as the discrete value, and the equation for calculating the information gain when processing the continuous value becomes as Eq. 2.4:

$$Gain(D, a) = \frac{\max}{t \in T_a} Gain(D, a, t) = \frac{\max}{t \in T_a} Info(D) \tag{2.4}$$

The equation for computing the split information entropy of feature a is shown in Eq2.5:

$$O_a(D) = -\sum_{j=1}^{s} \left(\frac{D_j}{D} \log_2\right) \tag{2.5}$$

When evaluating a multi category model, the accuracy, recall, F1- Measure and accuracy of a specific class will not be used to evaluate the model, but the overall accuracy of the model will be used to evaluate the staged performance prediction model. The calculation equation of accuracy rate is as Eq. 2.6:

$$Accuracy = \frac{correctClassification(testSet)}{total(testSet)} \tag{2.6}$$

As shown in Figure 2.2 and Eq. 2.7, the root node has only an out edge but no in edge.

$$\sum{}_{k=1}^{k} pk(1 - pk) = 1 - \sum{}_{k=1}^{k} p^2 k \tag{2.7}$$

The evaluation indicators calculated based on the confusion matrix are shown in Table 2.1:

Table 2.1: Evaluation index of confusion matrix calculation.

Index	Equation	significance
Error rate	Error rate=l-accuracy	The probability that a positive sample is wrongly classified
False alarm rate	Prate=FP/N	The probability that negatives samples are wrongly classified into positive samples

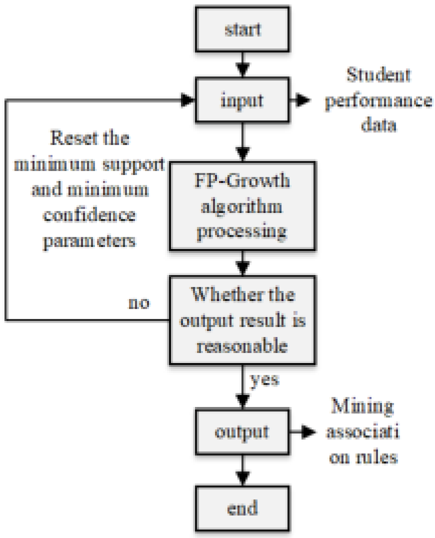

Fig. 3.1: FP Growth Algorithm Optimization.

3. Methods. The two types of scores of extracurricular training programs, the scores of scientific research practice and grade examination, and scores of dozens of subjects in the class. The key to improving the "three complete education" personality bureau [11]. The "three complete education" means to adhere to the all-round, all staff, and whole process education. The proposal of "three complete education" gives full play to the unique advantages of socialist education with Chinese characteristics and creates a pattern of education. Flow chart of improved algorithm in Fig. 3.1:

In this paper, we hope to get the association rules of specific data items, FP Growth aims to find the frequent itemset, regardless of which data item is obtained. Therefore, FP Growth is improved in two directions:

1. After improvement, frequent itemset containing specific data items can be obtained. The association rules obtained in this way are more intuitive and convenient for us to analyze the results. It is the reform and innovation of education and teaching methods. All kinds of courses tend to focus on knowledge transmission and neglect value shaping, leading to ambiguous phenomena in educational goals.
2. The curriculum are consistent in political direction, cultural direction, and values direction. Both should cultivate students' political identity and national identity in classroom teaching. Deeply mining the education data generated in the education process to obtain the corresponding knowledge system, and then using the knowledge system to continuously improve and enhance the education environment is a circular system of production, feedback, and continuous improvement. The education data mining is shown in Fig. 3.2.

4. Case study. In the experiment, we selected the Information Technology Foundation published by the Education Science Press as the teaching content to analyze one by one, explore and select the curriculum content suitable for the curriculum content [12]. Through research, it is concluded that eight contents of this textbook are suitable for carrying out ideological, as shown in Table 4.1.

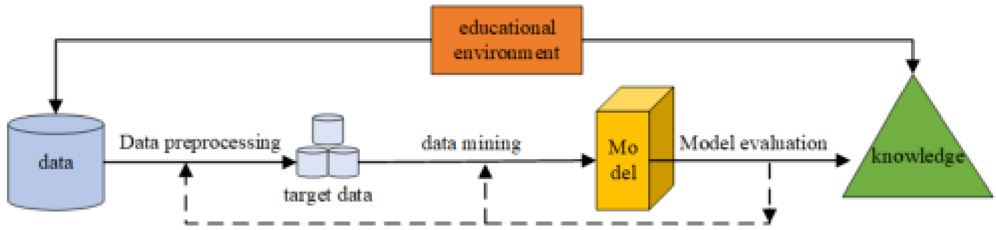

Fig. 3.2: Educational Data Mining Process.

Table 4.1: Ideological and political integration points of information technology curriculum in senior high school.

Serial No	Chapter content	Teaching method	Teaching case	Objectives of the course
1	1.2 Rapidly changing information technology		By showcasing the development process and future trends of information technology through multimedia, combined with teaching and case-based teaching methods.	Stimulate students' innovation ability
2	3.2 Programming and processing of information Lecturing method	Drill method	Show students the illegal and criminal acts of high-tech spies or hackers who steal other people's information by programming and processing	Cultivate students' technical integrity
3	3.3 Intelligent processing of information	Lecturing method Drill method	Students demonstrate the illegal and criminal behavior of high-tech spies or hackers who use programming to steal other people's information	Stimulate students' scientific interest and improve their scientific and technological ability
4	4.2 Table information processing Lecturing method	Drill method	Let students build class related data	Cultivate students' responsibility
5	5.3 Acquisition and processing of image information	Drill method and case teaching method	Make a national flag or party emblem through computer graphics software and explain the internal meaning of the national flag or party emblem	

The main model evaluation method used in this link is the tenfold cross validation method. First, divide the sample dataset into ten equal parts according to requirements, and take turns to test nine of them as training data and one as test data. Each test will yield the corresponding model accuracy. Finally, judge according to the measured accuracy of the decision tree model. The tenfold cross validation model evaluation algorithm is closely related to the setting of the number of leaves in the decision tree. The accuracy of the model varies with the number of leaves, as shown in Table 4.2. According to the table and broken line statistical graph data, when the set value of the number of leaves of the decision tree in this study is greater than 9.

The information technology course in senior high school belongs to the basic course of compulsory education. The basic courses mainly cultivate the common foundation for students' lifelong development and adaptation to the future society. It is not only an independent discipline branch, but also the basis for the development of all disciplines.

Information technology is a basic course in middle schools. If students correctly understand the knowledge points of information technology, the final evaluation should be conducted through the actual process, and guide students to learn how to use information technology to solve practical problems. The ideology and politics of education require the standardization of theory and practice. In fact, ideology can also be combined

Table 4.2: Accuracy of Decision Tree Model.

Leaf number	3	4	5	6	7	8	9	10	11	12
Accuracy	0.628	0.751	0.826	0.822	0.847	0.851	0.872	0.891	0.908	0.906
Leaf number	13	14	15	16	17	18	19	20	21	22
Accuracy	0.909	0.911	0.916	0.914	0.918	0.927	0.928	0.924	0.925	0.927
Leaf number	23	24	25	26	27	28	29	30	31	32
Accuracy	0.923	0.923	0.931	0.928	0.943	0.943	0.938	0.936	0.939	0.939
Leaf number	33	34	35	36	37	38	39	40	41	-
Accuracy	0.947	0.938	0.941	0.935	0.938	0.943	0.943	0.946	0.943	-

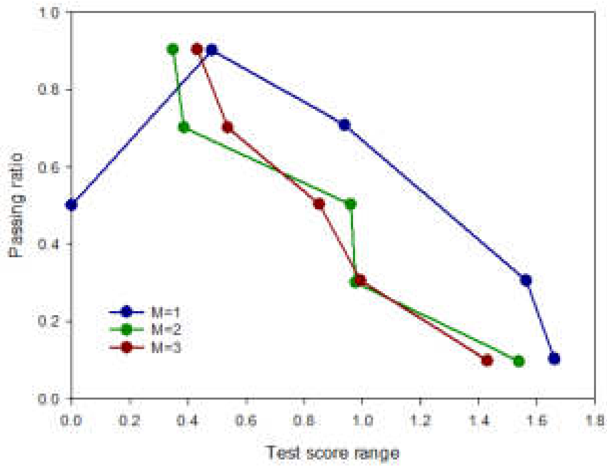

Fig. 4.1: Impact of test scores on final scores.

with politics, education and moral education [13]. Through skill learning, let students accept ideological and political education imperceptibly. When the same manuport and mi Confidence are set for the algorithm before and after improvement, the running time of the algorithm before improvement is 9 times that of the algorithm after improvement, which is quite time-consuming, and the number of association rules obtained is 3 times that of the algorithm after improvement, but most of them are redundant rules without specific items. On the contrary, the improved algorithm not only runs fast, but also obtains association rules with specific items, The results are more intuitive and easier to analyze. An eight-chapter chapter test paper is provided for the course on the Wisdom Tree online education and learning platform. The influence of test scores in each chapter on final scores is shown in Fig. 4.1.

The majority of political and ideological educators likewise primarily employ the brainwashing and spoon-feeding methods of instruction. While the ideological and political courses are less closely related to the students' reality, the practical teaching form is overly simplistic, the practical teaching link is relatively weak, and the social hotspots are subject to special education, but they are taught strictly in line with the teaching material system, with few social practical activities arranged in a way that is closely related to the students' reality and the teaching content.[14]. Alert notification industry is separated into active alert notification and passive alert notification. The active early warning notice is that the system automatically forecasts the learning state of pupils at this level every.

5. Conclusion. People's focus on education has steadily grown as society has advanced, and counselors' standing has risen along with it. The state has released pertinent policy guidelines, numerous colleges and universities have established platforms for counselor team creation, and the state and colleges and universities have increased their support for the counselor team. As a result, strengthening counselors' fundamental traits not only contributes to college students' success and well-being but also effectively boosts the efficacy of work pertaining to political and ideological education and encourages students to move toward becoming "a new man of the times who will take on the great responsibility of national rejuvenation." The strengthening of counselors' core traits will have a favorable impact on kids' progress and healthy life.

Data Availability. The experimental data used to support the findings of this study are available from the corresponding author upon request.

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HYBRID DEEP LEARNING RECOMMENDATION SYSTEM FOR ACCURATE MOVIE AND PRODUCT REVIEW PREDICTIONS

SANJEEV DHAWAN*, KULVINDER SINGH†, AND MANOJ YADAV‡

Abstract. This paper investigates the efficacy of deep learning models for sentiment analysis using two publicly available datasets: IMDb's movie review dataset and Amazon's product review dataset. The main objective was to evaluate the performance of various model architectures, particularly Long Short-Term Memory (LSTM) networks with dropout techniques, in emotion categorization under different settings. Key performance metrics, including accuracy, precision, recall, and F1 score, were used to train and validate several deep learning models: LSTM Spatial Dropout 1D, Bidirectional GRU-LSTM, Hybrid LSTM+GRU, and Bidirectional LSTM. The LSTM Spatial Dropout 1D model achieved remarkable results, with 93.00% accuracy and F1 score on the Amazon dataset, and an impressive 96.20% accuracy and 97.78% F1 score on the IMDb dataset. The Bidirectional GRU-LSTM model also performed exceptionally, achieving 98.69% accuracy, 96.16% precision, 94.62% recall, and 93.49% F1 score, outperforming many existing hybrid models in recommendation systems. By integrating forward and backward context, the Bidirectional GRU-LSTM model effectively captures complex temporal relationships, offering more accurate recommendations than traditional models that analyze data separately. This study underscores the robustness of LSTM-based architectures in sentiment analysis and highlights the potential of combining sentiment analysis with collaborative filtering to enhance precision and specificity in e-commerce recommendation systems.

Key words: Recommendation Systems, Collaborative filtering, Content-Based Filtering, Deep Learning, Bi-LSTM, Bi-LSTM-GRU.

1. Introduction. Introduction and examples. Users wanting to make wise decisions find it difficult to negotiate the enormous volume of data available online regarding service providers—such as hotels, restaurants, and merchandise. The abundant data might hinder decision-making procedures since people often struggle to sort through many possibilities to identify what really satisfies their needs. Recommendation systems (RSs) have been created to handle this problem by means of data processing simplification and tailored recommendations depending on user preferences. A restaurant recommendation system might, for instance, examine user dining behaviour and preferences to recommend nearby restaurants that fit them, therefore simplifying and accelerating the choosing process. Commonly used systems include content-based filtering (CBF), which suggests products based on their characteristics, and collaborative filtering (CF), which depends on the preferences of like users. Many recent RSs also apply hybrid approaches, combining CBF and CF to improve their recommendation accuracy. Online reviews have exploded as customer reviews progressively shape buying decisions. Many times, consumers base their decisions on the opinions and insights of others, such a review of a hotel stay or a purchase of a good or service. In this regard, sentiment analysis (SA) methods can be used to evaluate consumer perceptions of different services and products, therefore improving the quality of information retrieval by means of insightful analysis of the feedback. Using these technologies allows people to quickly obtain pertinent data and investigate hitherto unexplored fields, therefore improving the results of their decisions [22]). To solve this issue, recommendation systems have been created to sort data and give users individualized suggestions based on their preferencesBy harnessing these technologies, individuals can swiftly access information and delve into previously uncharted subjects, thereby enhancing the caliber of information retrieval services. Recommendation systems (RSs) frequently leverage collaborative filtering (CF), content-based filtering (CBF), and hybrid methodologies

*Faculty of Computer Science and Engineering, Department of Computer Science and Engineering, University Institute of Engineering and Technology (U.I.E.T), Kurukshetra University, Kurukshetra, Haryana, India (sdhawan2015@kuk.ac.in)
†Faculty of Computer Science and Engineering, Department of Computer Science and Engineering, University Institute of Engineering and Technology (U.I.E.T), Kurukshetra University, Kurukshetra, Haryana, India(ksingh2015@kuk.ac.in)
‡ PDepartment of Computer Science and Engineering, University Institute of Engineering and Technology (U.I.E.T), Kurukshetra University, Kurukshetra, Haryana, India (manoj200yadav@gmail.com)

that amalgamate both techniques to select items for recommendation [10], [2], [24]. In recent times, there has been a rise in the significance of customer reviews in the decision-making process over the use of services or purchases. Due to the fact that many buyers consider other people's opinions while making decisions, the quantity of customer evaluations that are placed online has significantly expanded. A customer's evaluation is based on their unique experiences using a certain service, such as renting a hotel, purchasing merchandise, or viewing a movie. In this situation, sentiment analysis (SA) techniques can be applied to gather information about customers' attitudes toward various concerns [19].

Sentiment Analysis seeks to identify the underlying sentiment of user-generated content about a given topic or entity [4]. To accomplish this, first determine whether overall tone of text is positive, negative, or neutral and then automatically extract relevant information about the entity being discussed. There are three tiers of data extraction at which Sentiment Analysis can be performed [26] a level, a sentence, and a whole document. The three primary strategies for addressing the SA issue are lexicon-based [28]. Machine learning-based [29] and hybrid approaches [25]. The first systems to be used for SA relied on dictionaries.

They fall into either the corpus-based or dictionary-based categories, depending on how they store and use lexicons and linguistic rules. Both classic and modern deep learning (DL) approaches are examples of Machine Learning (ML)-based techniques. Last but not least, a hybrid method integrates lexicons and machine learning tools [4]. It has been established that DL techniques applied to sentiment analysis are more effective than more traditional methods [14]. For sentiment categorization [30], can use a variety of Deep Learning models, including DNN stands for Deep Neural Network [1], [6], RNN (Recurrent Neural Network)[31], CNN (Convolutional Neural Network)[13],[5], LSTM (Long-Short Term Memory) [3], and GRU (Gated Recurrent Unit) [9]etc.

This work aims to enhance e-commerce recommendation systems by integrating collaborative filtering with sentiment analysis using deep learning. It introduces a novel Deep Learning based SA model tailored for this purpose, showing significant improvements in system efficiency and precision through empirical validation against baseline models.

2. Literature Review. Researchers are tackling data sparsity, cold start, and the gray sheep issue in collaborative filtering. Integrating sentiment analysis shows promise, with relevant studies and their contributions reviewed.

2.1. Recommendation System Based on Deep Sentiment Analysis. In [20] autoencoders and sentiment data enhance deep learning multi-criteria recommendations. LSTM and LSTM with Word2Vec excel in sentiment analysis. Their approach on the TripAdvisor dataset surpassed current methods, highlighting emotive data's crucial role.

In [9] the deep learning was employed for sentiment analysis to predict review sentiments for recommendations. LSTM and GRU models were evaluated using Amazon data, showing superior performance over traditional methods in the study.

In [22] the DSL-TR integrates CNN-BiLSTM for deep sentiment learning, incorporating review timestamps and factorization machine technique to predict ratings across Amazon datasets, outperforming alternatives.

In [21] is proposed new computer architecture enhances recommender systems with deep learning models integrating rating scores and emotional textual comments. Includes novel CFMDNN and MCNN models, showing strong performance across multilingual datasets (English and Arabic).

In [17] is presented a deep learning model-based recommendation system framework integrating textual comments and rating scores, overcoming existing limitations with models like MCNN and CFMDNN. Achieved strong performance across English and Arabic datasets.

In [32] are evaluated deep neural networks and collaborative filtering for enhanced recommendations, comparing LSTM, GRU, and a multilayer RNN to optimize system precision.

In [33] is proposed a deep learning framework that explores RNN for reviewer emotion analysis, scoring and recommending nearby locations based on social media reviews for accurate venue suggestions.

2.2. Collaborative and Content-Based Approaches. In [34] a Hybrid Neural Collaborative Filtering (HNCF) model integrates deep learning and interaction modeling, including Deep Multivariant Rating (DMR), to enhance rating matrix-based recommender systems. It outperforms Yelp2014, Yelp2013, and IMDb in accuracy and reliability of top-n product suggestions.

In [7] it is proposed a genetic-based method identifies similar user preferences, creates suggestion spaces, and improves recommendation accuracy, recall, F-Measure, and Mean Absolute Error (MAE).

In [16] a hybrid recommendation strategy suggests tourist destinations using content analysis and collaborative filtering. It combines their strengths, using Cosine similarity and Singular Value Decomposition (SVD) for performance. Weighted hybridization of results outperforms singular CB and CF methods.

In [18] it is improved a vehicle-cargo matching on the VCM platform. The enhanced content-based VCM system recommends vehicles based on cargo owners' needs. A hybrid approach combining tag-based and collaborative filtering predicts shipper-driver ratings accurately, forming the PVCM model for personalized recommendations to shippers.

In [11] is proposed a streamlined method to recommend reading material for student courses, prioritizing information analysis in the administration recommendation system for integrated and rapid network asset growth.

In [10] is implemented a content-social filtering strategy introduces a novel document comparison method, distinguishing it from prior studies. Analysis validates its efficacy and practical implementation, outperforming Pure Collaborative Filtering and Singular Value Decomposition on real-world data.

2.3. Research Gaps. The literature underscores combining sentiment analysis and deep learning to enhance recommender systems. Practical application and scalability in real-world settings are critical due to reliance on simulated data. Further exploration across sectors like e-commerce, healthcare, and education is essential. Hybrid model investigations are needed beyond collaborative filtering and deep learning. User reception of these advanced systems remains pivotal for accuracy and satisfaction assessment.

3. Objecttives, motivation and research contributions.

3.1. Objectives.

- To analyze sentiment from Amazon and IMDb reviews to extract insights for developing a recommendation engine.
- To preprocess textual data to enhance accuracy and compatibility with sentiment analysis tools.
- To conduct exploratory data analysis (EDA) to understand the characteristics and patterns of the review datasets.
- To prepare data for training by encoding text information into numerical sequences and ensuring uniform input dimensions.
- To model with hybrid architectures combining LSTM, GRU, and other layers, optimizing hyperparameters for effective sentiment classification.

3.2. Motivation. This project addresses the challenge users face when choosing from numerous online options. Recommender Systems (RSs) like CF, CBF, and hybrids mitigate issues of sparsity and unreliable recommendations. Sentiment Analysis (SA) now influences buyer decisions by analyzing user-generated content using deep learning models like LSTM, GRU, CNN, and Bidirectional networks, improving classification results.

3.3. Research Contributions. The paper introduces a novel recommendation system (RS) integrating sentiment analysis (SA) techniques driven by deep learning to enhance the precision and uniqueness of e-commerce recommendations. By combining SA with collaborative filtering through hybrid deep learning methods like LSTM, GRU, and Bi-LSTM, the study significantly improves recommendation quality using e-commerce data.

4. Methodology. Here present the proposed deep learning methods for the recommender system based on sentiment analysis. Figure 4.1 depicts a schematic of the system's layout. The architecture makes it simple to set up the modules and how they interact, letting the app be pieced together using any of the available approaches. The structure consists of six individual elements (data collection, data pre-processing, Exploratory Data Analysis (EDA), Training, Modelling, and model evaluation). The reviews' raw data was applied to conduct experiments and train hybrid DL models on sentiment analysis.

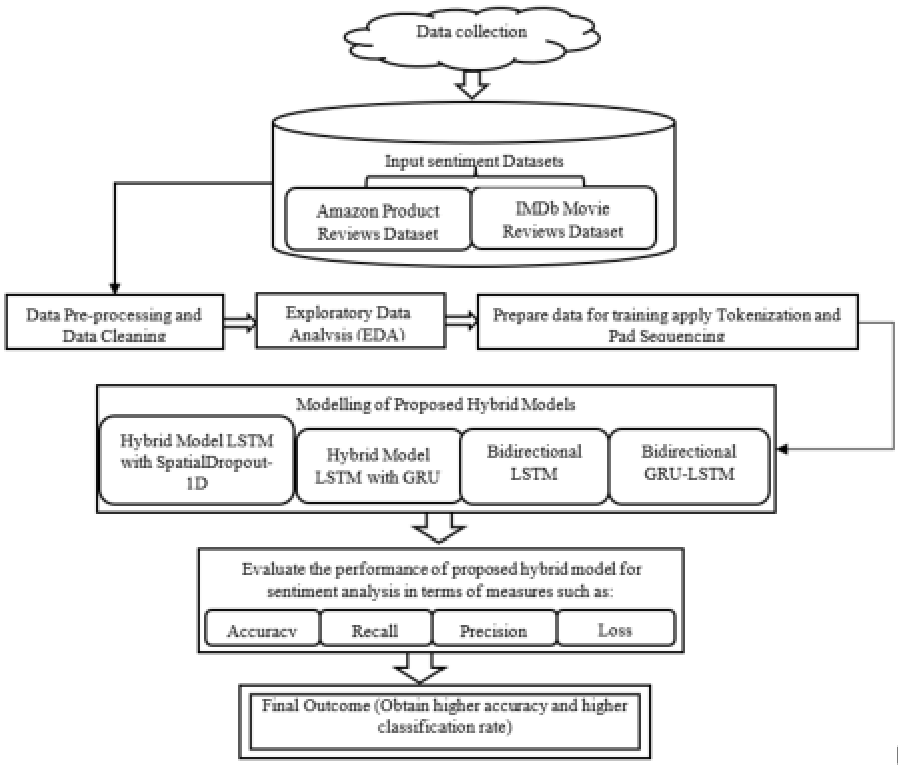

Fig. 4.1: The Proposed Methodology Architecture.

The recommended approach for the sentiment analysis-based recommendation system is depicted in Fig. 4.1. The various elements of this system, such as data collecting, data pre-processing, exploratory data analysis (EDA), classification models, and performance assessment, are elaborated upon below with thoroughness. The process is outlined in the following manner:

4.1. Data Collection. This work utilized two publicly accessible online sentiment datasets, namely Amazon's product review dataset and IMDb's movie review dataset. Together, the datasets used in this study—Amazon's product review dataset and IMDb's movie review dataset represent a great variety of samples vital for sentiment analysis. Comprising tens of thousands of evaluations, the Amazon product review dataset reflects a broad spectrum of consumer attitudes and rates from 1 to 5. This range helps to classify emotions into negative, neutral, and positive categories, so offering a whole picture of consumer satisfaction. Conversely, the IMDb movie review dataset comprises 50,000 reviews, therefore highlighting a range of viewpoints on a wide spectrum of films. Natural language processing (NLP) applications benefit especially from this dataset since it includes many genres and styles of writing, therefore strengthening the sentiment classification models' resilience. Training and validation of the hybrid models used in this research depend on the variety and volume of these datasets, which guarantees that they can generalise well across many contexts and fairly predict sentiments in both product and movie evaluations.

Amazon product review dataset. The research aims to analyze Amazon customer reviews to develop a product recommendation engine by extracting insights, including positive and negative sentiments. The process involves incorporating attribute-based reflective elements into the analysis. The dataset is a subset of Amazon.com reviews, randomly selected and numbering in the tens of thousands, with ratings from 1 to 5 indicating satisfaction levels. Ratings 1 and 2 are categorized as negative feedback, 4 and 5 as positive, and 3 as neutral

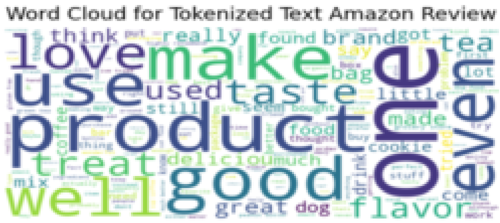

Fig. 4.2: Word cloud view of the text Amazon Movie review dataset

for sentiment classification experiments [35].

IMDb Movies Review dataset. The study applies sentiment analysis to IMDb's dataset of 50,000 movie reviews, showcasing insights from textual data. This extensive dataset offers a substantial resource for NLP and text analytics, providing a benchmark for binary sentiment classification using various methods including deep learning techniques.

4.2. Data Pre-processing and Cleaning. Data preparation involves transforming raw data into a suitable format. Initially, undesirable attributes are removed to enhance the quality of textual data through NLP text pre-processing. This includes eliminating stop words like "your," "I," and "it," which do not contribute to sentiment analysis. Emojis are cleaned by converting text to lowercase, removing carriage returns, and substituting non-UTF-8 characters. Hashtags are separated from words, and punctuation and non-alphabetic characters are filtered out from reviews. This rigorous process ensures consistency and improves the text's suitability for natural language processing applications, facilitating accurate sentiment analysis and model training.

To improve the quality of the input data, the data pretreatment processes comprised tokenising, text normalising, and stop word removal. Text normalising meant changing all text to lowercase and fixing spelling mistakes so guaranteeing consistency. Tokenising the book into separate words or phrases made analysis simpler. To cut noise and concentrate on meaningful words that support sentiment, stop words including "and," "the," and "is," were deleted. Furthermore used to rank significant features depending on their significance in the context of sentiment analysis were feature selection methods such TF-IDF (Term Frequency-Inverse Document Frequency), hence enhancing the model performance.

Methods were used to add variability in the current samples therefore improving the dataset. These methods assisted to vary the training data by synonym replacement, random insertion, and back-translation. This improved the robustness of the model so that, in sentiment analysis, it could effectively generalise and operate on unseen data.

4.3. Exploratory Data Analysis (EDA). Bar charts, histograms, and box plots are just some of the data visualization techniques that EDA uses. Create a heat map to visually represent the relationships (correlations) between different variables. See below for a summary and visual representation of both datasets.

Fig. 4.2 displays topical word clouds derived from datasets discussed in Section 4.1 word cloud visually represents text data, where the size of each word corresponds to its frequency. Common words, such as "product," "one," and "good," appear larger.

Fig. 4.3 shows a bar graph shows the top 20 most frequent words in Amazon review texts. The x-axis displays word frequency, with "like" being the most common and "time" the least, descending from left to right.

Fig. 4.4 horizontal box plot shows Amazon review lengths, with a 2000-character median, IQR, and whiskers highlighting outliers up to 7000 characters.

Fig. 4.5 shows histogram of text length for Amazon reviews, The x-axis signifies text length, and the y-axis signifies frequency. The histogram is blue in color. It has a peak at around 1000 text length. The histogram also has a long tail towards the right

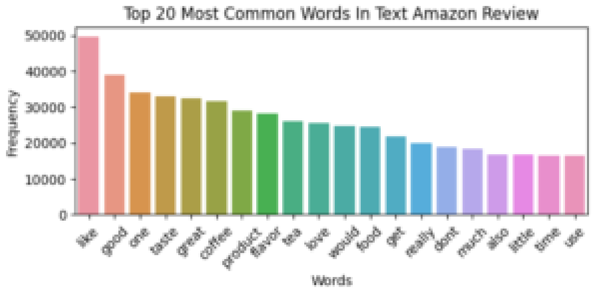

Fig. 4.3: Bar graph of top 20 most common words in text amazon review dataset.

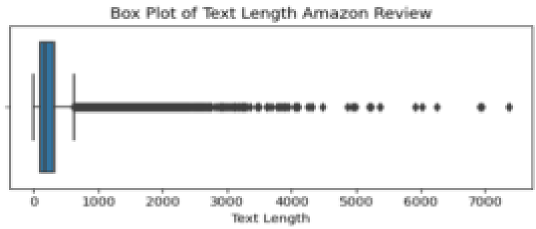

Fig. 4.4: Box Plot of text length amazon review dataset

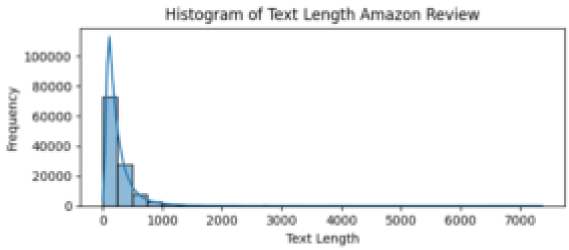

Fig. 4.5: Histogram of text length amazon review dataset.

Fig. 4.6 is a pie chart of the most frequent words in the Amazon review dataset. The chart is divided into 10 sections, each representing a different word. The words included are: “good”, “one”, “taste”, “great”, “coffee”, “product”, “flavour”, “tea”, “love”, and “like”. The largest section corresponds to the word “like” at 15.2%, followed by “good” at 11.7% and “love” at 9.6%. The smallest section represents the word “tea” at 8.01%.

Fig. 4.7 presents the IMDb movie review text dataset as a word cloud. Word cloud based on IMDb movie reviews’ most frequently used terms, including ”film,” ”movie,” ”one,” ”character,” ”scene,” ”good,” and so on. Furthermore, Fig. 4.9 presents a compilation of the top 20 words that occur most frequently within the IMDb Movie Reviews dataset.

Fig. 4.9 The Box Plot of IMDb Movie Review Text Length is displayed. The words in the dataset and their relative frequency are displayed as x and y axes, respectively, in the figure. Words associated with movies appear more often than others, such as ”make,” ”fire,” ”two,” ”character,” etc.

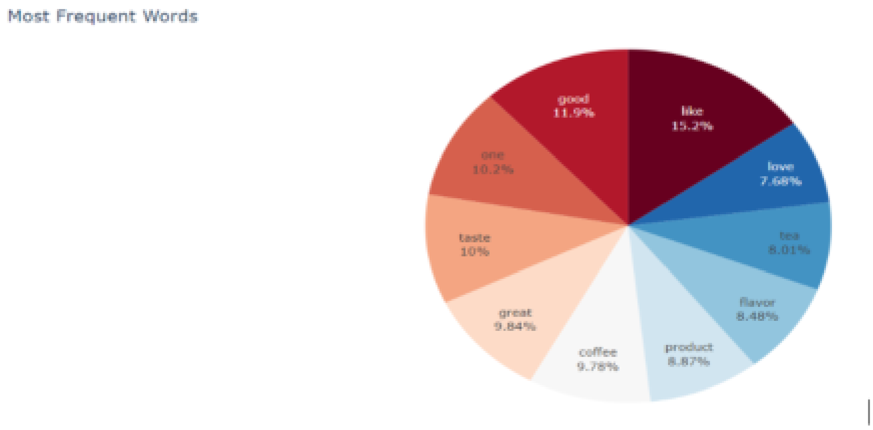

Fig. 4.6: Pie chart of most frequent words of amazon review dataset.

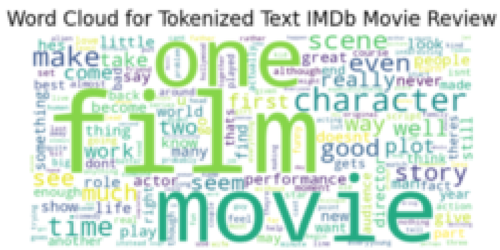

Fig. 4.7: Word cloud view of the text IMDb Movie review dataset

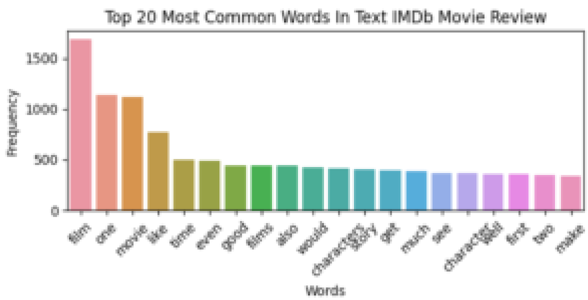

Fig. 4.8: Bar graph of top 20 most common words in text IMDb Movie review dataset.

4.4. Prepare Data for Training. Used Pad Sequencing and Tokenization on training data. The primary goal is to get text data ready for NLP work.

At first, take the text information from the DataFrame 'df' and put it into the variable 'review.' Subsequently, a tokenizer is used via the `Tokenizer` class, with a cap of 10,000 words as defined by 'num_words.' After the text is processed and a vocabulary is built, the tokenizer is "fit" on the "review" data. With the number of distinct words in the text data in mind, the variable 'vocab_size' is determined to be the length of

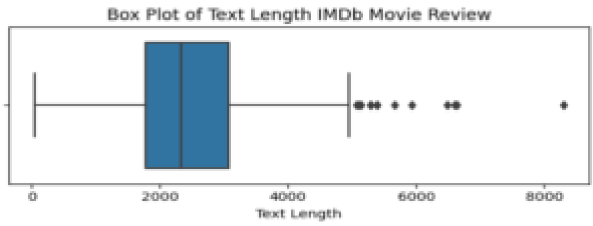

Fig. 4.9: Box Plot of text length IMDb Movie review dataset.

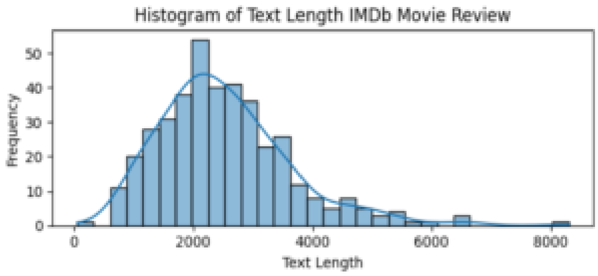

Fig. 4.10: Histogram of text length IMDb Movie review dataset.

the word index plus one.

Using the `tokenizer.texts_to_sequences` method, the text information is encoded into numerical sequences. The vocabulary is indexed according to each word in the 'review' data. The sequences have a maximum length of 200 and are padded using `pad_sequences` to guarantee uniform input dimensions for deep learning models. When dealing with sequences of varying lengths, this step is especially important because it guarantees that all data will be processed in the same way.

4.5. Modelling with Hybrid models. Hybrid Model LSTM with Spatial Dropout-1D; Hybrid Model LSTM with GRU; Hybrid Model LSTM with RNN; Hybrid Model RNN with LSTM; Hybrid Model RNN with LSTM; Hybrid-Training LSTM and Hybrid-Training GRU-LSTM. Key steps for putting into practice the models discussed below.

SpatialDropout1D. SpatialDropout1D is a specialized dropout layer used in deep neural networks for processing sequential data like time series or natural language. Unlike traditional dropout, SpatialDropout1D applies dropout independently to each feature along the time dimension (sequence length). This approach reduces the network's reliance on any single feature at a given time, fostering broader and more robust feature representations. During training, it generates a binary dropout mask based on a specified dropout rate, selectively zeroing out input features to introduce randomness and prevent overfitting. In inference, dropout is inactive, allowing the input to pass through unaltered. SpatialDropout1D effectively mitigates overfitting in models handling sequential data, particularly beneficial in tasks such as natural language processing where preserving word order is critical. Its adaptation enhances model performance by ensuring diverse feature utilization across sequences.

Hybrid Model LSTM with SpatialDropout1D. The implementation of the Hybrid model (LSTM with SpatialDropout1D) begins by initializing 'EmbeddingVectorLength' to 32, which defines the dimensionality of word embeddings used for NLP inputs. A Sequential model is then constructed, facilitating the sequential layering of neural network components. An embedding layer is added next to convert vocabulary words ('Vocab Size') into embedding vectors of specified length, with input sequences limited to 200 characters. Following this, a 0.25-dropout SpatialDropout1D layer is incorporated to randomly deactivate neurons during training, mitigating overfitting. A 50-unit LSTM layer follows, renowned for its effectiveness in processing sequential data, with

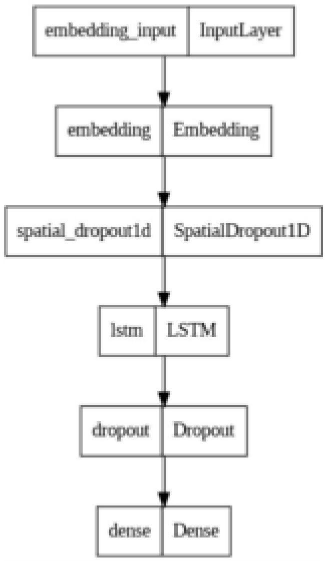

Fig. 4.11: The model architecture of hybrid model(LSTM with SpatialDropout-1D).

dropout rates set for both inputs and recurrent connections at 0.5. Lastly, a dense layer comprising a single unit with a sigmoid activation function is added for binary classification tasks, producing output probabilities ranging from 0 to 1. The model is compiled using binary cross-entropy loss, Adam optimizer, and accuracy metrics, ideal for binary classification tasks in NLP and other domains.

Fig. 4.11 architecture depicts a real-world application of a hybrid model consisting of and SpatialDropout1D. This schematic depicts how data moves through the model: Embedding the word embedding input layer is represented by the InputLayer class. The input tokens are subjected to embedding, a process that entails transforming them into dense vectors referred to as word embeddings. SpatialDropout1D is a dropout technique that eliminates complete 1D feature maps across channels, rather than individual elements. Dropout is a regularization method used to address the issue of overfitting. Densely interconnected layer. Dropping entire feature maps (along channels) instead of individual elements is what SpatialDropout1D is all about, and it makes for superior regularization of sequential data.

4.5.1. Hybrid Model LSTM with GRU. The construction of a Sequential model begins with an embedding layer that maps words to numerical vectors of specified dimensions ('EmbeddingVectorLength') and vocabulary size ('Vocab Size'). Input sequences are capped at 200 characters. A 0.25-percent-dropout SpatialDropout1D layer is added to prevent overfitting in sequence data. The model incorporates both GRU and LSTM layers, each with 25 units, to handle sequential input effectively. Dropout rates for inputs and recurrent connections are set to 0.4 to enhance model generalization. The LSTM layer also utilizes dropout regularization. Finally, an additional Dropout layer with a 0.2 dropout rate further mitigates overfitting concerns in the model. This architecture is tailored for NLP tasks requiring robust handling of sequential data.

Bidirectional GRU-LSTM models are computationally intensive yet crucial for capturing bidirectional dependencies in sequential data. They excel in sentiment analysis and recommendation systems, enhancing accuracy despite their complexity. To mitigate high variance, regularization methods like L2 regularization penalize large parameter values, preventing overfitting. Dropout further strengthens model robustness by randomly deactivating neurons during training. Ensembling techniques such as bagging or boosting combine predictions from multiple models to reduce variance. Cross-validation assesses model performance across diverse subsets, ensuring robustness. These strategies collectively enhance model generalization, enabling effective predictions on unseen data and improving overall performance in recommendation systems.

Several hybrid models are used in this work to improve the performance of sequential data processing tasks

Table 4.1: Hyperparameters Details

Parameter	**Details**
Model	Sequential
Layers	LSTM, GRU, SpatialDrop1D, Bi-LSTM, Bi-GRU-LSTM
Dropout	20%
Activation	Sigmoid
Loss	Binary Cross Entropy
Epochs	20
Validation Split	25%
Batch Size	1024

including sentiment analysis and recommendations by especially combining Long Short-Term Memory (LSTM), Gated Recurrent Units (GRU), and 1D Convolutional Neural Networks (1D CNN). Both LSTM and GRU, both variations of recurrent neural networks (RNN), shine in sequential data in capturing long-term dependencies. While GRU, a condensed form, performs quicker with less parameters, LSTM with its memory cells efficiently addresses vanishing gradient problems. Conversely, the 1D CNN is incorporated to detect local patterns in the sequence data, thereby detecting important elements before forward sending them to the recurrent layers. Usually serving as a feature extractor in the hybrid models, 1D CNN analyses input sequences to gather pertinent local information. LSTM or GRU layers then receive this output to record temporal dependencies, therefore offering a complete knowledge of both local and sequential properties. Combining 1D CNN with LSTM and GRU helps the model to leverage the strengths of both convolutional and recurrent networks, hence enhancing performance in applications like sentiment analysis, where knowledge of local features and long-term dependencies is absolutely vital. It is imperative to establish the originality of the suggested design and can be achieved by means of a comparative study with current recommendation systems. This study will show how the suggested deep learning models—such as the Bidirectional GRU-LSTM—outperform conventional approaches in terms of accuracy and efficiency, so stressing their special contributions to the discipline of e-commerce suggestions. The justifications for using particular techniques, such hybrid models including bidirectional GRU-LSTM and LSTM with Spatial Dropout. This covers talking about how these techniques guarantee correct content recommendations by efficiently tackling the difficulties of user profile and sentiment analysis. Furthermore underlined should be issues of the resilience of these models in managing various datasets, such as Amazon and IMDb. By clearly stating these decisions, you lay a strong basis for your research and show how each approach improves the general analysis and fits the aims of the study.

LSTM, GRU, and 1D CNN's hybrid technique was selected above conventional models because of its better capacity to detect intricate patterns and dependencies in sequential data, including user reviews and feelings. Long-term dependencies are handled effectively by LSTM and GRU, therefore reducing the vanishing gradient issue typical in conventional recurrent networks. Combining these with 1D CNN improves feature extraction by spotting local patterns within the data, so producing better input sequence representation. More subtle sentiment analysis made possible by this integrated architecture produces more accurate and successful suggestions in e-commerce platforms.

i. Activation function. Activation functions like sigmoid, ReLU, and softmax determine neuron activation in neural networks by processing inputs to produce output values. They control a neuron's behavior based on its input and activity state. The sigmoid function, chosen here, limits outputs to a range between 0 and 1, making it ideal for binary classification tasks. It computes the likelihood of an input belonging to a category, crucial for the final layer in such models[26]:

$$Sigmoid = \frac{1}{1+e^{-x}} \dots (1) \tag{4.1}$$

ii. Loss function. The loss function, also known as the error function, evaluates model performance by comparing predicted outputs to actual labels using training data. It's critical to choose a metric that accurately measures model effectiveness. For deep neural networks (DNNs), tailored loss functions address specific objectives, such as minimizing classification errors. In this case, binary cross-entropy was used for straightforward binary classification, producing a probability value between 0 and 1 as output. The formula for binary cross entropy is $-1 \times \log(\ textprobability)$ [36].

$$Loss = -\frac{1}{N}\sum_{i=1}^{N} y_i \cdot \log(p(y_i)) + (1 - y_i) \cdot \log(1 - p(y_i)) \tag{4.2}$$

Here, Yi is the real class and log(p(yi) is the probability that Yi belongs to that class.

- p(yi) is the probability of one
- 1-p(yi) is the probability of zero

iii. Batch size. This accounts for the training dataset that is specific to each batch. The process of iterating is dependent on the dataset, which necessitates dividing it into successive batches due to the impracticality of feeding a single epoch into the computer in its entirety.

iv. Epoch. An epoch is considered complete when all the data has been both fed into and outputted from the neural network simultaneously. The parameters of a neural network can be adjusted by an iterative process of supplying it with training data. After each iteration, the parameter is revised. Generally, extending the number of epochs results in enhanced accuracy and less loss.

4.6. Performance Evaluation Metrics. In evaluating a machine learning model's effectiveness for sentiment analysis using deep learning on Amazon product and IMDb movie review datasets, performance metrics like accuracy, precision, recall, and loss were assessed. Models were selected based on minimal validation loss and tested using a confusion matrix to compare classification results, including True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN).

Accuracy. The accuracy of a classifier is evaluated by calculating the ratio of correct classifications to the total number of predictions. In this work model gets 98% and 100% accuracy on both datasets. The formula for precision is given by the following equation:

$$Accuracy = \frac{TP + TN}{TP + TN + FN + FP} \tag{4.3}$$

Precission. Precision in classification refers to the proportion of correctly identified true positives. In this work model gets 98% and 100% precision on both datasets. The equation can be represented accurately as:

$$Precision = \frac{TP}{TP + FP} \tag{4.4}$$

Recall. Recall is calculated by dividing the number for true positives by the sum of true positives & false negatives. Precisely measuring the number of positive designations is essential in this situation. In this work model gets 94% and 100% recall on both datasets. The formula for memory is as stated:

$$Recall = \frac{TP}{TP + FN} \tag{4.5}$$

F1 score. The F1 score is a statistical measure that balances precision and recall, providing a single metric for model performance evaluation.

$$F1 = \frac{2 \cdot TP}{2 \cdot TP + FP + FN} \tag{4.6}$$

Epoch and loss curve. These curves are graphed over time and help interpret the model-training process by showing how the parameters of epoch and loss change over time. In this work model gets 0.04% and 0.012% loss on both datasets.

Table 5.1: Comparison of deep learning models on Amazon Product Review Dataset

Deep Learning Model	Accuracy	Precision	Recall	F1 Score	Loss
LSTM Spatial Dropout1D	98.01	94.00	92.04	93.00	0.05
Hybrid LSTM+GRU	98.04	93.60	92.70	91.72	0.05
Bidirectional LSTM	97.77	93.28	91.16	91.66	0.06
Bidirectional GRU-LSTM	98.69	96.16	94.62	93.49	0.04

Table 5.2: Comparison of deep learning models on IMDb Movie Review Dataset

Deep Learning Model	Accuracy	Precision	Recall	F1 Score	Loss
LSTM Spatial Dropout1D	96.20	97.31	98.26	97.78	0.012
Hybrid LSTM+GRU	93.72	81.67	72.80	76.98	0.022
Bidirectional LSTM	96.39	90.02	84.37	87.10	0.024
Bidirectional GRU-LSTM	93.47	81.02	70.80	75.57	0.012

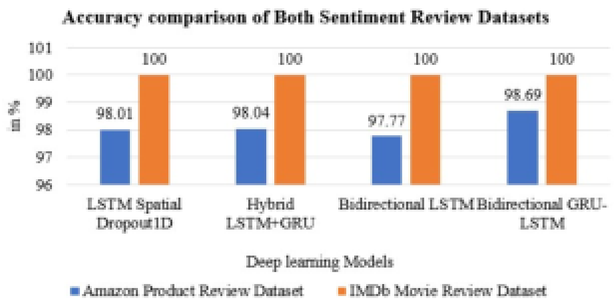

Fig. 5.1: Bar graph of Accuracy comparison between both datasets with deep learning models

5. Comparative analysis with Discussion. In this section, the empirical results used to assess the efficacy of the proposed approach for constructing recommender systems are presented. The findings of the investigation are documented in detail. Empirical data was acquired using Google Colab, leveraging Python, which is widely recognized as a leading programming language for machine learning and data analysis due to its extensive library support. For this study, Python was chosen for its accessibility and robust libraries, including NumPy, pandas, seaborn, scikit-learn, matplotlib, Keras, and TensorFlow.

The datasets used in this study included Amazon product reviews from Amazon website and movie reviews from IMDb. These datasets were partitioned into training and test sets. Sentiment data was classified and analyzed using various deep learning models, including Hybrid Model LSTM with SpatialDropout-1D, Hybrid Model LSTM with GRU, Bidirectional LSTM, and Bidirectional GRU-LSTM.

The accuracy metric, representing the percentage of correctly classified instances in the validation set, was used to evaluate the models. The experiments, summarized in tables 5.1,5.2, present the accuracy of several deep learning methods. The results demonstrate the effectiveness of the proposed models in accurately categorizing sentiment data, validating their potential for improving recommendation systems.

The evaluation will be conducted on two separate datasets. Reviews of products on Amazon or reviews of movies on IMDb. In addition, the comparison results are shown in bar graph form in Fig. 5.1,5.2,5.3,and 5.4.

The table 5.1,5.2,and bar charts depict the divergent levels of effectiveness between deep learning models that were trained on either the Amazon Product Review Dataset or the IMDb Movie Review Dataset.

The examination of deep learning models on the IMDb Movie Review Dataset and the Amazon Product Review Dataset offers interesting insights about the efficiency of several architectures for sentiment analysis

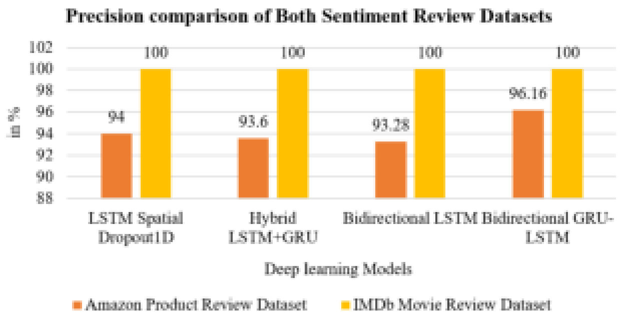

Fig. 5.2: Bar graph of Precision comparison between both datasets with deep learning models

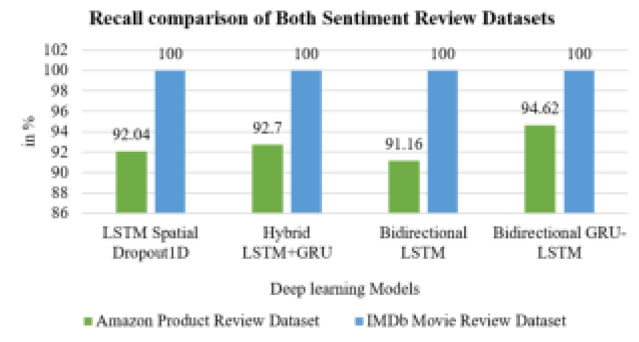

Fig. 5.3: Bar graph of Recall comparison between both datasets with deep learning models

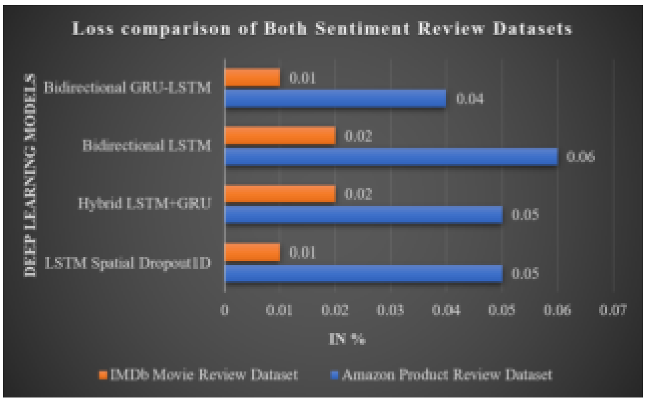

Fig. 5.4: Bar graph of Loss comparison between both datasets with deep learning models

problems. With an astounding accuracy of 93.00%, the LSTM Spatial Dropout1D model ranked first in the first table, which summarises the performance on the Amazon dataset. With a precision score of 90.73% and a recall of 95.38%, this model showed an amazing capacity to strike a balance between accuracy and recall, producing an F1 score of 93.00%. With an accuracy of 93.50% and a greater precision of 92.57%, the Bidirectional GRU-LSTM model quite faithfully followed. Its recall of 94.44% and F1 score of 93.49% show how well it reduces false positives while preserving a great capability for spotting true positive cases. Though they did not outperform the top models in general efficacy, the other models—including Hybrid LSTM+GRU and Bidirectional LSTM showed satisfactory performance. On the other hand, IMDb dataset results showed much better performance measures. Once more leading with an accuracy of 96.20%, accompanied by an amazing precision of 97.31% and recall of 98.26%, the LSTM Spatial Dropout1D model produced an F1 score of 97.78%. This shows that the model not only fairly projected the results but also performed exceptionally well in spotting genuine favourable attitudes among the evaluations. Though it showed a clear decline in precision and recall when compared to the LSTM Spatial Dropout 1D model, the Bidirectional LSTM model also performed admisitely, with an accuracy of 96.39%. The Hybrid LSTM+GRU model suffered notably, especially on the IMDb dataset, with a precision of only 81.67% and a recall of 72.80%, so highlighting its shortcomings in efficiently capturing sentiment nuances in challenging text data.

Indicating its resilience in sentiment analysis tasks, the study highlights generally the advantage of the LSTM Spatial Dropout1D model across both datasets. Its capacity to control overfitting and efficiently capture contextual information is shown by the always high performance measures over several contexts. These results imply that deep learning models—especially those using LSTM architectures with dropout techniques—are suited for sentiment analysis and future study could investigate optimisations and advanced architectures to improve performance even further in varied textual datasets.

Deep learning models on the IMDb Movie Review Dataset and the Amazon Product Review Dataset show diverse patterns and efficacy across several architectures in performance comparison. With an accuracy of 93.00%, the LSTM Spatial Dropout1D model stands out in the Amazon dataset showing a solid balance between precision (90.73%) and recall (95.38%), hence producing an F1 score of 93.00%. With an accuracy of 93.50% and underlining its capacity to reduce false positives while keeping a high true positive rate, the Bidirectional GRU-LSTM model rather closely follows. On the other hand, the IMDb dataset shows even better overall performance; the LSTM Spatial Dropout1D model once again leads at 96.20% accuracy and remarkable precision of 97.31% and recall of 98.26%, therefore producing an F1 score of 97.78%*. Though the Hybrid LSTM+GRU model underperforms greatly, especially in precision and recall, suggesting its limits in catching emotion nuances, the Bidirectional LSTM model also performs well.

Consistent performance across both datasets shows that the LSTM Spatial Dropout1D model is resilient for sentiment analysis tasks overall.

Unexpected outcomes can offer insightful analysis and point out areas of interest for more investigation in both scholarly fields and useful applications. If a model meant to improve sentiment classification, for example, shows lower-than-expected performance on a particular dataset, it could point to underlying data complexity—such as confusing language or varied contexts not sufficiently recorded. This insight implies that to improve model resilience, more complex feature extraction techniques or the inclusion of more data sources is necessary. Such results can inspire academics to look at alternate approaches such using ensemble techniques or transfer learning or challenge the limits of current methods. Practically speaking, knowing these surprising results will help companies rethink their user engagement plans or product recommendations so they better fit user attitude. Overall, acknowledging and evaluating surprising outcomes helps one to have a constant improvement attitude, so opening the path for developments in academic study as well as practical applications.

Presenting the results with confidence intervals or error bars will help to improve the dependability of the conclusions. Error bars can graphically show the variability and uncertainty in the measurements for every performance metric—accuracy, precision, recall, F1 score—that model uses. Usually, statistical techniques allow one to determine a 95% confidence interval, so clarifying the range within which the actual model performance is like to fall. This method not only helps to find statistically significant variations between models but also guarantees a more complete interpretation of the data by strengthening the general conclusions derived from the investigation.

The model integrating RoBERTa, Long Short-Term Memory (LSTM), Bidirectional LSTM (BiLSTM), and Gated Recurrent Unit (GRU), achieves an accuracy of 94.9%, with precision, recall, and F1 score of 95 each. This hybrid technique combines the strengths of its components: RoBERTa's Transformer-based architecture for enhanced context awareness, LSTM and BiLSTM's sequence modeling and long-term dependency capture, and GRU's efficiency in training while maintaining high performance in sequential tasks. However, the proposed Bidirectional GRU-LSTM model demonstrates a significant improvement, achieving 98.69% accuracy, 96.16%

Table 5.3: Comparative Analysis of Existing Model and Proposed Highest Performance Model

Model	**Accuracy**	**Precision**	**Recall**	**F1 Score**
Hybrid (RoBERTa) [37]	94.9	95	95	95
Bidirectional GRU-LSTM	98.69	96.16	94.62	93.49

precision, 94.62% recall, and an F1 score of 93.49%. By processing input bidirectionally, this model captures both forward and backward dependencies, leveraging the strengths of GRU and LSTM architectures to better handle intricate patterns and temporal linkages in data. The superior accuracy indicates the Bidirectional GRU-LSTM's ability to handle nuanced dataset subtleties, making it the best-performing model in this study. Moreover, it surpasses many existing hybrid recommendation systems, which often separately analyze user behavior, item characteristics, and sentiment data. The Bidirectional GRU-LSTM's integration of bidirectional context processing enables richer, dynamic insights, enhancing recommendation precision by accounting for complex temporal interactions.

6. Discussion. This work shows the great promise of deep learning models—especially LSTM-based architectures—in sentiment analysis over several datasets. Showcasing their resilience in precisely categorising emotions, the LSTM Spatial Dropout 1D and Bidirectional GRU-LSTM models fared quite well. Particularly the Bidirectional GRU-LSTM model improved recommendation precision by capturing both forward and backward contextual dependencies, hence outperforming conventional hybrid models applied in recommendation systems. This work also emphasises the interesting way sentiment analysis may be combined with collaborative filtering in e-commerce systems to improve the relevance and accuracy of suggestions in dynamic, real-world environments.

7. Conclusion. Through a focus towards enhancing content recommendations in streaming services including movies and merchandise, this paper discusses the difficulties of building reliable user profiles for recommendation systems. The work shows the ability of deep learning models such as LSTM with Spatial Dropout-1D, LSTM+GRU, bidirectional LSTM, and bidirectional GRU-LSTM in improving sentiment analysis and recommendation accuracy by means of their respective application in Particularly the bidirectional GRU-LSTM model shines in capturing bidirectional relationships in data, hence enhancing the quality of recommendations by considering both forward and backward temporal dependencies. Preventing overfitting and guaranteeing the resilience of the model depend on methods including regularisation and cross-valuation. Understanding complex emotions, such irony, which emphasises the need of constant model improvement, still presents difficulties, nevertheless. The results of this work highlight, especially via sentiment analysis, the possibility of including deep learning techniques into recommendation systems. With its capacity to capture intricate temporal correlations and so reflect the high performance of the bidirectional GRU-LSTM model, above conventional hybrid models it demonstrates its great advantage. Future studies might look at using feature selection methods and ensemble learning to raise accuracy and flexibility even more. Expanding sentiment analysis into other fields, such banking and healthcare, might offer insightful information impacting decision-making procedures. Incorporating multimodal data sources—such as audio and visual materials—may also improve sentiment classification sensitivity. Furthermore vital for enhancing model interpretability, fostering user confidence, and guaranteeing recommendation system transparency is investigating explainable artificial intelligence (XAI). The limits of the study, which depend on publically accessible datasets, draw attention to the possible differences in real-world user behaviour and the necessity of honing models for different cultural environments to guarantee worldwide applicability. Notwithstanding these constraints, the work provides insightful analysis on how to improve recommendation system performance by means of sophisticated deep learning methods.

Future Coverage. The results of this work open various directions for next investigations. Extending the sentiment analysis paradigm to fields like banking and healthcare, where knowledge of user sentiment can greatly influence decision-making procedures, seems to be one bright future path. Including multimodal data sources—such visuals and audio—alongside text could further improve sentiment categorisation sensitivity. Improving model interpretability and user confidence also depends on researching cutting-edge technologies such explainable artificial intelligence (XAI). At last, analysing the performance of the model in many cultural settings helps to highlight the subtleties of sentiment expression, hence guiding the creation of more flexible and successful recommendation systems.

Limitations. The fact that this study depends on publicly accessible data limits it in that it might not fairly depict actual user behaviour. Furthermore, the emphasis on sentiment analysis could cause one to ignore other elements impacting advice. The performance of the model may also change depending on the cultural setting, therefore influencing its generalisability and efficiency. Strength & weakness. Indicating strong sentiment analysis resilience, the LSTM Spatial Dropout 1D model shines in accuracy, precision, and recall over both datasets. With much lower precision and recall, the hybrid LSTM+GRU model highlights difficulties in precisely capturing emotional nuances in difficult texts.

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ENHANCED CRIMINAL SUSPECT IDENTIFICATION USING A NOVEL SMART SYSTEM WITH HYBRID ENCRYPTION AND ANN CLASSIFICATION

NAJAH KALIFAH ALMAZMOMI*

Abstract. The current advancement in the growth of crime rates and the complexity of crimes that are being committed in society call for the adoption of better methods of identifying criminal suspects. While traditional methods are somewhat useful, they are not sufficient in dealing with the intricacies and the sheer scale of today's data landscape. Machine intelligence has become popular in many fields including criminal justice because of its capability to learn from big data. This study presents a novel smart system for classifying criminal suspects using four key steps: query-based authentication (QBA), data categorization, data encryption and decryption, and artificial neural network (ANN)-based classification. QBA ensures only authorized access to sensitive data by verifying user-specific information. Data is categorized into sensitive (personal and social criminal data) and non-sensitive (classification results) categories, with sensitive data encrypted using a Two-Level hybrid ECC (Elliptic Curve Cryptography) and ECC-RSA (Rivest, Shamir, Adleman) model, optimized via the HSMEO algorithm for high security and efficiency. The ECC-RSA model outperforms traditional encryption methods (AES, DES, RSA, ECC) in security (98.53 %), trust score (4.83), throughput (77.57), and encryption/decryption times (3.459/2.994 seconds). Additionally, the HSMEO model significantly reduces key generation time to 1.97545 seconds, surpassing other optimization strategies like SMO, EO, PSO, MFO, and FFO. Graphical representations of key metrics validate the ECC-RSA model's superior performance in security, efficiency, and reliability, making it an effective method for protecting sensitive data and ensuring efficient criminal suspect classification through expert system.

Key words: Criminal Suspect Classification; Machine Learning; ECC-RSA; HSMEO; ANN.

1. Introduction. In the current digital era, the precarious task of the proliferation of criminality in online social networks is a real threat to the planning and implementation of illegal operations. The very essence of these platforms that allow automatic interaction among a wide number of people coupled with anonymity has unintentionally created a hospitable area for mischievous activities from cyberbullying to international crime [1]. Despite the magnitudes of the problem, the field of studies is severely underrepresented in terms of the amount of research carried out that focuses on identifying and categorizing perpetrators of cyberbullying. This lack of scholarly investigation, in turn, has emphasized the urgent necessity of tapping into cutting-edge technologies, such as machine intelligence, to overcome the menace of digital untruths [2].

The foregoing discussion underscored the backdrop of the current research that is set to expand the frontiers of machine intelligence by developing smart system algorithms that can be used to identify and categorize individuals involved in online criminal activities [3]. This research strategy strongly relies on the data derived from these platforms besides the skills and knowledge gained from the law enforcement databases and the ultimate goal is to create a robust expert system framework that is used in identifying possible criminals. Essentially, this research proposal calls for a change of paradigm where social networking and law enforcement are brought on the same footing to address the current growing cases of digital insecurity [4].

The rapid development of the criminal activities that are performed through online social networks has turned into a huge problem for the new generation, which is on the one hand caused by the unique opportunity that cyber-criminals are given to harmonize their actions and to implement their illegal schemes [5]. Although the weight of this matter is immense, nonetheless, the state of the research about who committed those digital misdeeds and the way they can be classified lacks depth. This research gap points out the importance of new technologies like machine intelligence that can help us identify and categorize suspects among the many social media interactions this complex network involves [6].

With the development of machine intelligence and its ability to solve a complex pattern and anomalies

*Department of MIS, College of Business, University of Jeddah, Jeddah, Kingdom of Saudi Arabia (nalmazmomi@uj.edu.sa)

in much bigger data, the present study focuses on the utilization of ANNs to meet this challenge [7]. Such a research project aims to enlist social media and law enforcement agencies' big data to develop a more smart system for mapping criminal suspects within online social networks. This venture is determined by the urgency to develop digital security and to take necessary steps against the massive dissemination of cybercrimes in cyberspace [8].

The main parts of the model being the four crucial elements that interplay one with the other ensuring the overall effectiveness and robustness are the pivotal points in its functionality. First, authentication is the initial task carried out by the query protocols, providing the tools needed to access and analyze the data streams [9]. Additionally, the data category is a significant aspect in discriminating sensitive and non-sensitive information, and consequently, the basis for the proceeding analyses [10]. Particularly, the implementation of the ECC-RSA [11] scheme— a next-generation encryption standard that combines RSA and ECC algorithms [12] — has demonstrated the integrity and confidentiality of the data as the key priorities.

Additionally, the employment of HSMEO [13] which is a new kind of method is an innovative step that is used to optimize the private keys choice within the encryption system. The proposed model, with slime mold-inspired algorithmic solutions that have inbuilt efficacy and adaptability, shows promise to increase the degree of both data security and encryption efficiency. Therefore, such solutions would strengthen the integrity of smart system. Finally, the integration of artificial neural networks (ANNs) [14] for criminal suspect classification represents the apex of the smart system and enables it to detect patterns and norm violations within the abundant social network data. This expert system approach improves the model's performance in terms of classification and prediction of criminal behaviour.

This research aims to create a useable taxonomy for the extraction of suspicious individuals from social networks with the help of machine learning algorithms and the neural network classifier (ANN) in particular. Although it is self-evident that there is no alternative to identifying cyber criminals in the social media realm, there is a gap in literature on the effective categorization methodologies. Therefore, the study is aimed to harmonize these two types of data obtained from the web and law enforcement agencies for the identification of possible suspects. This undertaking embraces a smart system that incorporates authentication, data classification, encryption, as well as expert system components like artificial intelligence neural networks to precisely and accurately distinguish and group actual criminals present in social media platforms. The scientific validation of the model is conducted through experimental trials carried out within the Matlab environment, and the model performance indicators are sought. In addition, the study intends to assess the security and efficiency level of the built encryption framework by using the ECC-RSA paradigm and HSMEO technique to generate the private keys. The major contributions of this study are as follows:

- The study presents a unique smart system methodology for classifying criminal suspects, integrating four key steps: query-based authentication (QBA), data categorization, data encryption and decryption, and artificial neural network (ANN)-based classification.
- By implementing QBA, the methodology ensures that only authorized individuals can access sensitive data, enhancing the overall security of the system.
- The approach categorizes data into sensitive and non-sensitive groups, ensuring that personal and social criminal data are securely managed while classification results are efficiently handled.
- The study introduces a Two-Level hybrid ECC and RSA (ECC-RSA) model, optimized with the HSMEO algorithm, providing superior security (98.53%), trust score (4.83), and throughput (77.57) compared to traditional encryption methods.
- The HSMEO algorithm significantly reduces key generation time to 1.97545 seconds, outperforming other optimization strategies such as SMO, EO, PSO, MFO, and FFO, enhancing the efficiency of cryptographic operations.
- Graphical representations of key metrics validate the ECC-RSA model's superior security, efficiency, and reliability performance, establishing it as an effective expert system for protecting sensitive data and efficiently classifying criminal suspects.

The paper's organization is structured as follows: Section 2 provides a comprehensive literature review, examining existing methodologies and highlighting the need for an advanced approach to criminal suspect classification. Section 3 details the material and methods used in the study, describing the novel four-step methodology which includes QBA, data categorization, a Two-Level hybrid ECC and RSA (ECC-RSA) encryption model optimized with the HSMEO algorithm, and ANN-based classification. Section 4 presents the experimental results, showcasing the proposed ECC-RSA model's performance metrics compared to traditional encryption methods, and highlighting its superior security, efficiency, and reliability. Section 5 discusses the findings in-depth, analyzing the implications of the results and how the proposed methodology enhances data protection and classification efficiency. Section 6 concludes the paper by summarizing the key contributions and potential future research directions in criminal suspect classification and data encryption.

2. Literature Review. The paper is going to dwell on the different strategies that are being used to improve the systems of collecting evidence and predicting the suspects within the criminal networks. The work of Jhee et al. [15] is the application of machine learning in criminal investigations. To be specific, the authors developed a fast inference approach for the analysis of large criminal networks. The way they experimented is representative of their precision and fast inference ability, which makes them a good choice for real-life cases. Nevertheless, the test demonstrated that with bigger datasets, the inference becomes slower and it is more complicated to identify data from criminal networks. This shows that more research needs to be done to assess the technology application across diverse crime data. Jhee et al. [16] study also brings forth the criminal network-based suspect prediction framework and the impact of the reduction in execution time while not compromising the competitive performance of the framework is highlighted. Nevertheless, a few obstacles such as the slow running of the entire processing on large datasets and the memory-intensive computations that come with it are the outstanding disadvantages that restrict it from wider adoption. Hence, the investigations of scalable solutions for wider applicability are highly encouraged.

Furthermore, Chachoo [17] puts forward the network analysis of digital crimes that the ANOS OCL method is used for identifying the key actors in criminal networks, paying attention to online social networks. While efficient in detecting criminal activities, it could not fully reflect the roles of all key actors and complex interactions in the crime community. Hence, it is evident that online criminality is more complicated than it seems. Besides that, Gupta et al. [18] provide mechanisms for identifying cybercriminals on social media using machine learning techniques and also, they highlight the difficulties associated with the text format of crime-related activities.

Florentino et al. [19] provide an approach with a novel characteristic: they do not label data anymore; they also do not relate messages to any vocabulary. However, data scarcity and the dynamic nature of social networks remain the major problems that make it imperative to do frequent model updates to be effective. Shafi et al. [20] proposed a reduced-complexity method for classifying criminal activists on social media, where the feature extraction process is simplified and the technique can be adapted to the regular changes in the strategies of criminals.

Alebouyeh and Bidgoly [21] put a spotlight on the criminality of social network users through centrality measures, giving more importance to relationships than the content that is published. Although there is no denying that strong relationships between criminals can happen, yet there is a possibility of centrality measures not being able to detect such kinds of criminals correctly. Adding up to that, ethical issues and hidden biases of centrality-based criminal apprehension should be also examined. On the other hand, Deepak and his colleagues [22] explored the knowledge-based hybridized approach for crime classification by presenting the dynamic ontology generation together with deep learning techniques. The technique shows better results on various datasets, which proves that the creation and use of modern neural networks open new perspectives on crime classification. The paper, though, does not seem to be addressed to limit specific issues, hence the need to carry out additional studies for the comprehensive evaluation of its applicability. These researches, as a whole, pave the way for the development of methods used for the detection of crime and the identification of the suspects within the networks as well as pointing out both the pros and cons of that network in real-life situations.

Florentino, Goldschmidt, and Cavalcanti [23] are offering a vocabulary-driven technique that is supposed to help the identification of people suspected of criminal activity on social networks, which is a difficult task when there is a lack of training datasets. They applied a controlled vocabulary including categorized terms to social media messages which are labeled data, so that it could be analyzed without them. Thru the study of the paedophilia domain, the experiment can be said to be hopeful in that it does not use pre-existing datasets

Table 2.1: Summary of methodologies, main findings, and limitations.

Ref.	Methodology	Main Findings	Limitations
[15]	Machine learning, Fast inference algorithm	Competitive performance, Fast inference	Slow inference with large data, Complexity of criminal network
[16]	Criminal network-based suspect prediction	Reduces execution time, Maintains competitive performance	Slow inference, Scaling challenges, Memory and time-consuming, Expensive clustering
[17]	ANOS OCL	Efficiently identifies key actors, Reveals criminal behaviors	Online networks focus, Limited offline representation, Inaccurate identification, Focus on social media
[18]	User content analysis, User network analysis, Machine learning	Effective detection in social media, Benchmark validation	Limited real-world applicability, Needs performance assessment
[19]	Suspect identification from messages, Controlled vocabulary	Promising in paedophilia	Lack of labeled data, Requires frequent updates
[20]	Feature extraction, State vector machine	Simplifies extraction, Reduces energy consumption	Challenges in traditional text classification
[21]	Centrality measures	Effective identification based on social relationships	Focuses only on social relationships, Assumes strong connections
[22]	Bi-LSTM neural network, Fuzzy c-means pre-processing	Outperforms existing methods in crime classification	Poor betweenness centrality results, Ethical implications not discussed
[23]	Controlled vocabulary	Promising in paedophilia	Lack of labeled datasets, Difficulty in supervised learning
[24]	Criminal associations, Linear association model	Effective and flexible	Ignores individual attributes, Limited comparison with one algorithm
[25]	Targeted Bayesian network	Accurate suspect identification, Anomaly detection	Limited generalizability due to specific datasets
[26]	Supervised learning, Similarity measures, K-Medoids clustering	Good results, High accuracy	Effectiveness in real-world scenarios not fully explored, Scalability and long-term performance not discussed

to identify criminal suspects. While the research considers this a disadvantage, these restrictions have been pointed out, illustrating the challenge of an accurate application of supervised machine learning in practical environments. Notwithstanding, although a controlled vocabulary method can be used to deal with the shortcomings of this approach, it still provides a viable solution to the identification of suspects on social networks. Moreover, Troncoso and Weber [24] propose a new way of uncovering associations among criminals who use social network analysis to combine individual attributes data. Their model is innovative because it brings about a new way of exposing the links within criminal organizations by highlighting its effectiveness in generating a variety of association networks. The devised model promotes the efficient momentum of investigative resources by taking the optimization of the crime planners' utility function into account. Nevertheless, the study has some drawbacks, such as the absence of an account for individual attributes, consideration of only one existing algorithm, and limited generalization since the study was conducted on only one particular dataset.

2.1. Research Gaps. Social network-based criminal suspect sensing technologies raise privacy concerns. If suitable privacy safeguards are not put in place, the collection and analysis of private data from social media networks may violate a person's right to secrecy and privacy. By ensuring the quality and consistency of the information acquired, law enforcement organizations might use this technology to access information from social media networks without endangering the privacy of people. Abuse would be prevented, the system would be easily explained and traced, and there would be sufficient numbers of controls and measures of responsibility.

Criminal Suspects Sensing is the concern of balancing between protecting people's privacy and at the same time apprehending criminals. It is possible to make certain adjustments to prevent such data collecting from being a breach of people's rights and privacy if certain gaps are closed. It is now possible to make certain that such kind of data is gathered ethically, in the right way, and in a truthful way. To address these gaps in sensing criminal suspects through social networks, it is possible to suggest the cooperation of multiple modalities. This entails establishing explicit rules and regulations, using privacy-enhancing technologies, and taking additional steps.

3. Material and Methods.

3.1. Overview of the Proposed Model. Through four main steps, this study creates a novel smart system approach for categorizing criminal suspects: ANN-based criminal suspect classification, data categorization, data encryption, and decryption phase, query-based authentication (malicious user identification), and data encryption are among the recommended approaches.

Step 1: Query-based Authentication (QBA): To ensure that only approved individuals have ownership of private data, like suspects' identities and social media profiles, QBA may be used. QBA requires users to provide specific information or answers to questions, known as queries, that only they would know. This information is compared to a pre-defined set of responses or answers associated with the user's account. The user is authenticated and granted access if the provided information matches the pre-defined answers.

Step 2: Data Categorization: User data, U^i; $i = 1, 2, \ldots, N$ is first divided into sensitive and non-sensitive categories. The data of personal and social criminal suspects are considered sensitive information S^i, as they contain information about the suspects' identity, contacts, and other private details. The instance vector q, which is a combination of personal and social data, is also considered sensitive. On the other hand, the classification result v, which indicates whether a suspect is classified as a criminal or not, is considered non-sensitive information G^i. However, its confidentiality is still important, as it should be the owner of the instance vector (police station).

Step 3: Proposed Data Encryption and Decryption Phase: The identified sensitive data S^i is encrypted using a newly introduced Two-Level hybrid ECC and RSA (ECC-RSA) Model. In the ECC-RSA model, the optimal private key $\mathrm{PK_{TC}}$ is selected via HSMEO. The encrypted data acquired from the ECC-RSA model is denoted as E^i.

Step 4: ANN-based criminal suspect classification: Criminal suspect classification can be done using ANN. A suspect's features are supplied into an ANN, classifying the suspect as either a criminal or not as an output. This integration is in consonance with the expert system approach to improve the capacity of categorizing and predicting criminal conduct.

3.2. System System. A smart system for criminal suspect sensing model has been proposed, and it is comprised of seven entities. These entities are as follows: the Key Management Centre (KMC), a Criminal Intelligence Analyst (CIA) that functions as a trusted scientific research centre, Users (suspects), a Police Station (PS), a Secure Public Server (SPS), a Social Server (SS), and a Trusted Authority (TA). The structure is divided into two different domains, namely the Preparation Domain and the Analysis Domain, each of which has a unique set of goals for the data that is being processed.

In the Preparation Domain, tasks are carried out by suspects, CIA, SS, SPS, and PS. On the other hand, in the Analysis Domain, suspects, CIA, TA, and PS (in the capacity of a query requester) are involved in complex activities. An identification method that takes into consideration both private information and social media platforms is used by the system to identify potential suspects, as shown in Figure 3.1.

KMC is a reliable organization in charge of creating keys, registering parties, and maintaining the legal parties' keys in the system. Nevertheless, the KMC is not engaged in any party or network interactions beyond this initial setup. Its only duty is to make sure the keys are managed securely and appropriately.

Users create their public and private keys and register with the Key Management Centre (KMC) in the Preparation Domain. People who are suspected or have ties to suspects are the main focus of the system. Their data is regularly sent to the Secure Public Server (SPS) via the Police Station (PS) Server. The contact information of the users—designated as c_j and c_i—is captured by their cellphones and is periodically backed up to the Social Server (SS). This information includes identification, duration, and social relationships.

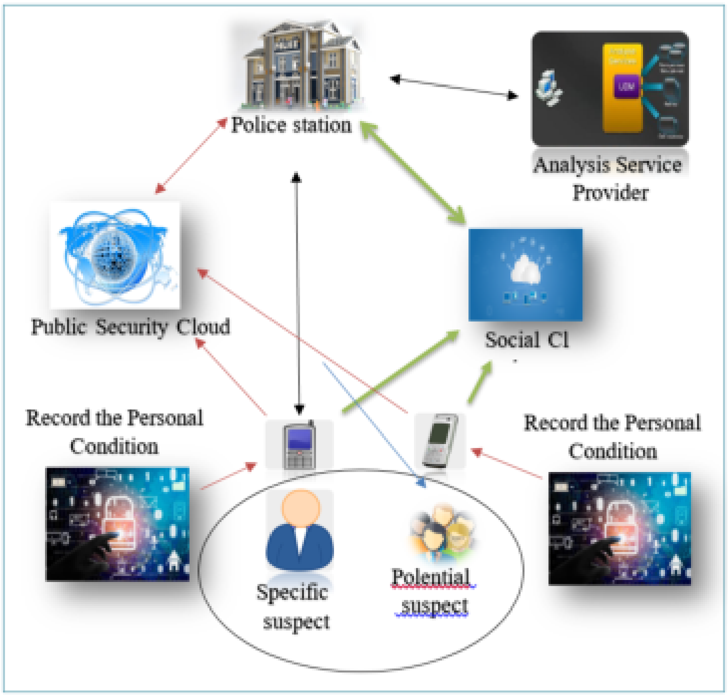

Fig. 3.1: Social Network and Personal Data – based Criminal Suspect Detection System

The entities and domains of knowledge used in the proposed expert system are described and these are used to offer a holistic and efficient means of identifying criminal suspects, with the help of conventional and digital sources for improved efficiency and security.

The PS in the Preparation Domain has designated the Criminal Intelligence Analyst (CIA) as a reliable third party. Using the training datasets, it trained the tree model and saved it in the Trusted Authority (TA) for examination of criminal suspects. While the TA does the majority of the work in the Analysis Domain, the CIA may help with the categorization process. The Secure Private Server (SPS) is a server that has a large storage capacity and is responsible for collecting and storing encrypted personal data of users. Another similar server is known as the SS and it is responsible for the acquisition and archiving of encrypted social information. This information is only sent to the PS in the Analysis Domain and it helps in identifying the right products to offer to the customers. The TA in the Analysis Domain is a semi-honest participant, which has significant computing and storage resources these capabilities, process the obtained query data from the PS through operations that, if done manually, would take a lot of time. About the current system, the PS is not the only consumer of the expert system. The use of this tool is to establish if the contacts that user cj has been interacting with are suspects or not. If the decision is made that cj is a gang-affiliated criminal suspect, the PS will then pull the social details of cj from the SS. Also, the TA and CIA will investigate the criminal suspect by inputting the personal data of cj contacts and providing the encrypted results to the PS. After decrypting the result, the PS examines to identify if the contacts listed in the cj file are criminal suspects or not. The PS then communicates the result of the analysis to the police officer who has a duty of handling criminal suspects.

The most common security model in cryptography is the semi-honest model, which means that all the participants in a communication protocol adhere to the rules of this protocol but may attempt to obtain additional information. This approach focuses on the threats that originate from outside the organisation and threats that originate from within the organisation. An external attacker is an individual who attempts to penetrate the security of the data or systems to cause harm. Semi-honest is defined herein as any external invader that is untrusted and attempts to gain unauthorized access to the communication channel. This kind of attacker is sometimes referred to as an "external eavesdropper". Such an attacker could be able to intercept certain communication requests or answers over the shared channel and use them to get private data. Conversely, an internal attacker is a semi-honest, passive entity that has authorization to enter the network beforehand. While it will apply the expert system model, there's a possibility that it may use the information obtained from the interactions to deduce confidential information from SPS, SS, PS, or TA, among other system entities. This kind of attacker poses a serious threat to the confidentiality and privacy of the data contained in the smart system; hence adequate security measures must be implemented to prevent them. For example, access restrictions, monitoring tools, and audits may be used to prevent illegal access and identify any questionable behavior inside the system.

3.3. Query-based authentication. Query-based authentication is the first stage of the proposed smart system that attempts to verify the legitimacy of the query and the query issuer. TA is presented with a random challenge from PS at this phase. After that, TA encrypts the challenge using PS's public key and returns it to PS. PS uses its private key to decode the encrypted challenge before sending it to TA. If the decrypted assignment matches the original challenge, authentication may continue via the sorting process. Before sending the instance vector q to the TA for classification, the PS encrypts it using the public key of the TA. TA uses the encrypted model M to carry out the classification after decrypting the encrypted vector. After then, PS receives the encrypted classification outcome v and uses its private key to decode it to get the plaintext result. Social data from SS and personal data from SPS are encrypted using unique keys that are only known to the relevant organizations to guarantee security and privacy. Similarly, to ensure that only authorized personnel access the data, the access pattern is also encrypted. Moreover, the instance vector q is not reachable by TA or CIA; only PS is allowed to access it. The recommended approach applies homomorphic encryption on the encrypted instance vector q for suitable classification and outcome anonymization. This approach affirms that the classification result is encrypted and only PS has access to the result hence enhancing the security of the classification result. Further, the privacy-preserving technique retains the certainty of the classification result because homomorphic encryption preserves the accuracy of the calculation. The first type is identification using a question.

Figure 3.2 shows an example of a secure query-based authentication between the PS and the TA. It begins when PS has to come up with a challenge, encrypt it with the public key of TA, and then send it to TA. To confirm that the challenge has been changed in any way, TA then decrypts the challenge with the assistance of its private key. After this, the TA encrypts the result of the authentication process with the help of the PS's public key and sends the encrypted message back to the PS. PS then uses the private key to decrypt the encrypted authentication result.

As a result, before passing the instance vector q to TA for classification, PS encrypts q with the help of TA's public key. TA also decrypts the instance vector $\mathcal{C}$ with its private key and subsequently applies the encrypted model M on the instance, and lastly encrypts the class label Y using the PS's public key. Finally, PS employs the private key to decrypt the classification outcome to get the plaintext result.

This secure process means that all the communications and the data passed through the channels are encrypted and decrypted using the right keys to ensure that the data passed through the channel is not intercepted by unauthorized individuals and that the data passed through the channel is not altered in any way during the authentication and classification processes.

The question requester is made up of three people: It also includes TA, PS, and CIA. In this case, PS could explain to the TA that they should verify some data that contain errors. The format of this question depends on the material being taught and the structure of the course. This investigation will include any information the PS may have on the suspect including the suspect's name and ID number and any other relevant information.

Furthermore, the identification authentication is done by QBA before accessing a suspect's data. This may point to the fact that there is a need to limit the type of persons who have access to private criminal data. Besides, it could be useful in warding off negative attacks and getting unauthorized access to the system. It is also possible to categorize criminal suspects using the QBA and the same tool implies that only the law enforcement bodies can use it. This is because while the system is being used, it can prompt security questions or may request the police personnel to input more identity details. This may help to guarantee that data stored in the system is protected from other people getting access to it.

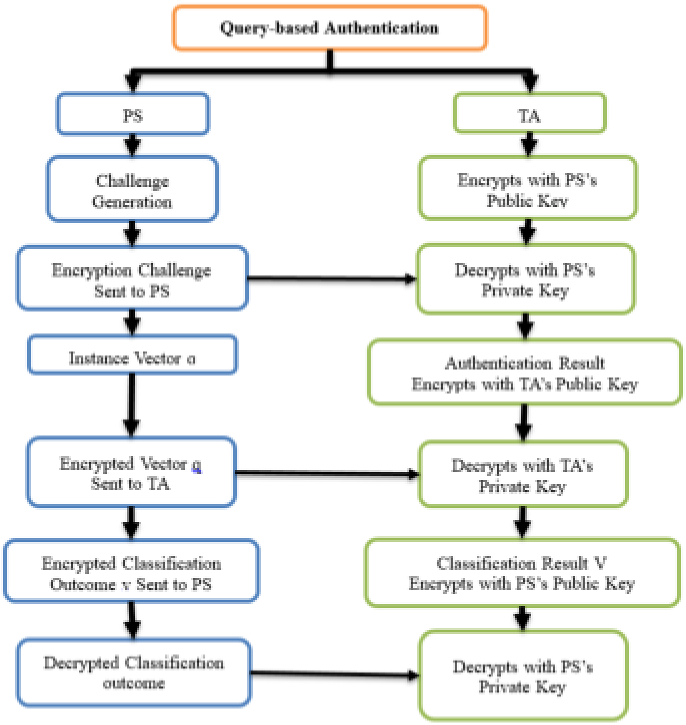

Fig. 3.2: Secure Query-based Authentication Process

The Basics of Using QBA to Mark Someone Who May Have Committed a Crime:

- *User authentication:* This requires the user to enter a username and password so that the user can operate the system and sort out criminal suspects.
- *Query submission:* Other details about a suspect may be required by the users if the system has authenticated the users.
- *Authentication:* Thus, the system confirms the identity of a user and allows for the assessment of information regarding a suspect. This may be achieved through biometric identification, identification by questions, and multi-level identification amongst others.
- *Suspect data access:* If the QBA is successful, then the system will allow the user access to information related to the suspect. Therefore, by applying the criminal suspect categorization system, QBA may provide a rapid and safe identification that will prevent all unauthorized individuals from accessing the details.
- *Procedure for Registration:* Customers subscribe to the data centre and input their information in the database. The client initially creates the user ID ($\mathrm{US}^{\mathrm{id}}$), then enters the password ($\mathrm{PW}^{\mathrm{id}}$) and all the user details.
- *Procedure for Login:* Following a successful registration, the user may download or upload data to the server. Without registration, no client may access the server or get data. We can prevent data loss using this strategy. Customers must first provide their login information, which consists of their password ($\mathrm{PW}^{\mathrm{id}}$) and user ID ($\mathrm{US}^{\mathrm{id}}$). After receiving it, the server checks to see whether the user is permitted. User data may be classified once the query request has been examined.

3.4. Data Categorization. Sort the user data according to the query's authenticity. The user transmits his data U^i to the network after registering with it. This information is divided into:

- Sensitive information (S^i)
- General information (G^i)

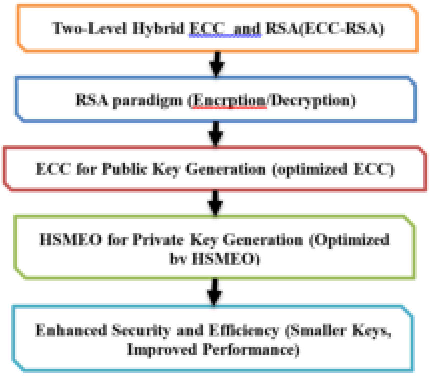

Fig. 3.3: Two-Level Hybrid ECC and RSA (ECC-RSA) Model

Social and personal data are two types of sensitive data. Information that may be used to identify an individual, such as name, address, phone number, and email, is referred to as personal data. This information is considered sensitive and must be protected from unauthorized access as it might be used to jeopardize the person's security and privacy. But social data also include information on the individual's social network, such as the individuals they engage with, how often and for how long, and other social connections. Since this information may reveal private facts about a person's behavior, hobbies, and connections, it may also be regarded as sensitive. Information that is not regarded as confidential and doesn't need extra security is referred to as non-sensitive information. It may include data that is freely available to the public and does not pose a threat to the security or privacy of an individual, for example, employment history information and demographic data. Given the input of sensitive and nonsensitive data, it is possible to predict the probability of a particular person being a criminal suspect. The private information is encrypted and decrypted and the data is taken as input. The parties performing the encryption and decryption job are PS, CIA, and TA.

3.5. Proposed Data Encryption/Data Decryption Model. The ECC-RSA model is a privacy-preserving method that relies on homomorphic encryption for the computation of data over encrypted data. It allows the PS to communicate with the TA and CIA through encrypted queries, thereby providing them with the encrypted data without ever exposing the plaintext to them. In this case, the encrypted output is passed to the PS to decrypt it and decide on the classification of the information without compromising the security of the information.

3.5.1. Hybrid ECC and RSA (ECC-RSA) Model. Figure 3.3 presents the Two-Level Hybrid ECC and RSA (ECC-RSA) Model which combines the RSA and Elliptic Curve Cryptosystems (ECC) for enhanced and improved cryptographic services. RSA is used for encryption and decryption since it has an excellent security strength whereas, the optimized ECC is used to generate the public key because of its efficiency and relatively small key size. The private key is then generated efficiently with the help of the new Hybrid Slime Mould Equilibrium Optimization Algorithm (HSMEO) that enhances the effectiveness of the suggested model. This makes the hybrid approach have a smaller key size and better performance compared to the other traditional schemes, hence suitable to be used in different cryptographic applications that require security and performance.

ECC and RSA are combined in a recently developed Two-Level Hybrid ECC and RSA (ECC-RSA) Model. In ECC-RSA, the RSA model is employed in the encryption/decryption of messages while the optimized elliptic curve cryptography is employed in the generation of the public key. When generating the private key, the ECC-RSA approach is again the most efficient, especially when using the new HSMEO. The cryptography methods used here are RSA and ECC-RSA though the former is slower than the later because of the larger key size. As for this, the ECC-RSA technique is more secure when it comes to smaller keys. Another factor that can help to decrease the size of the key and to create a system of secure keys is the small size of the keys of ECC. It is beneficial to combine RSA and ECC because doing so can enhance data security since it offers even smaller keys and higher efficiency. After identifying the key size, the ciphertext is applied in the encryption and decryption processes. In case ECC is employed to generate fewer but more reliable keys, the RSA encryption could require less storage space and still enhance data security. The steps of the ECC-RSA model are stated as follows: The steps of the ECC-RSA model are stated as follows:

1. Public Key Generation Using ECC. Public key cryptography is one of the most widely used methods for secure communication protocols. The discrete logarithm issue on an elliptic curve is very difficult to solve, which is one of the reasons ECC works so well. Two cryptographic keys—a public key and a private key—are created using ECC. Scale multiplying the random integer private key with a base point on this curve yields the public key. The value of the private key determines how many times the base point is multiplied by itself during the scalar multiplication operation. First, multiply a shared secret by the recipient's public key and encrypt the message using this ECC. First, the sender encrypts the message using a symmetric encryption technique like AES and the shared secret. With their private key, only the other person who is also upholding the shared secret and symmetric encryption technique may decipher the encrypted communication. Due to its small key size and excellent performance in constrained situations, ECC is often used in devices such as mobile phones and Internet of Things (IoT) devices. However, the security of ECC is affected by the parameters of the elliptic curve as well as the employment of cryptographic methods.

Step 1: Pick any prime value, v.

Step 2: To generate the public key, select a random number as $v(b)$.

Step 3: Wherein, $v(b) < v$, calculate C for the point on the curve.

Step 4: Where $C > v$, calculate the public key using Eq. (3.1).

$$p = v(b) \times C \tag{3.1}$$

where p points to the Public Key, and $v(b)$ represents the Private Key.

Step 5: The private key of ECC is generated by two different models, Lorenz Chaotic System (LCS) and SHA3-512. The generated random sequence using LCS is hashed using the SHA3-512 algorithm, expressed as per Eq. (3.2). The encryption system based on the novel key generation process in ECC achieves both speed and security by increasing the entropy of data information and reducing processing time.

$$v(b) = \mathrm{LCS} \times \text{SHA3-512} \tag{3.2}$$

where LCS is given by:

$$\mathrm{LCS} = \dot{x}_1 + \dot{y}_1 + \dot{z}_1 \tag{3.3}$$

and SHA3-512 indicates the hash function of SHA3-512.

Three phases, including x_1, y_1, and z_1, define the state variables and part of the LCS:

$$\begin{aligned} \dot{x}_1 &= -\sigma x_1 + \sigma y_1 \\ \dot{y}_1 &= r x_1 - y_1 - x_1 z_1 \\ \dot{z}_1 &= x_1 y_1 - b z_1 \end{aligned} \tag{3.4}$$

where σ, r, and b are real positive parameters. Depending on parameter values, the LCS can exhibit quite complex dynamics.

Step 6: Hence, the best private key is chosen from the entire generated keys using the Hybrid Slime Mould Equilibrium Optimization (HSMEO).

Step 7: Be able to output the best public key after the computations.

2. Encryption/ Decryption Using RSA. One of the most widely used public key cryptography methods, RSA is employed for protecting the content of the messages exchanged over the Internet. Two keys are generated, a public key and a private key with the help of the Random Number Generator (RSA) algorithm. These keys are created by using prime numbers and a mathematical function called modulo arithmetic. RSA is a public key cryptography algorithm that has uses in numerous fields including security of data in communication, data signatures and virtually any other use and is also used in encrypting and decrypting of data. The public key is used for the encoding of the messages while the private key is used for the decoding of the messages.

Step 1: Let us take a look at the input file.

Step 2: Now you have to add the second key, which is the public key generated through the use of the RSA algorithm, to the key pair.

Step 3: Subtract the value obtained after the RSA algorithm has been computed with the optimal value.

Step 4: This input file is then encrypted with RSA and uploaded to the server.

Step 5: After a file is uploaded, it is then downloaded from the server and decrypted from the RSA public key to get the original file.

Step 6: On the receiving end, the encrypted data is decrypted using the same public key, 'p,' to obtain the initial data.

It is proposed to employ a metaheuristic algorithm to create an optimal private key of criminals' profiles within an OSN.

3.5.2. Hybrid Slime Mould Equilibrium Optimization Algorithm (HSMEO). The HSMEO method yields the optimal private key. It is an optimizing method for challenging optimization issues that draws inspiration from nature. The motion of slime mould, a single-celled creature that looks for food sources to live, is modeled by this algorithm. Better private keys are produced by HSMEO for secure communication, ensuring the secrecy and integrity of any correspondence between two people. The other method is the HSMEO technique which is a combination of SMA and EOA. According to the HSMEO scheme, SMA is employed for search space analysis to obtain the global optimum, while EOA is employed to exploit the better settings within the region. Optimizer of equilibrium: This metaheuristic optimization tool applies the physics principle of equilibrium. The algorithm can identify the optimum response by achieving a balance between the exploration and exploitation of the search region. We employ numerous local search algorithms to identify possible geographic areas; an unordered set of moves across the solution space is investigated, and a set of potential solutions is stored in the space. This way it adapts its exploration and exploitation strategies over time based on the properties of the search space and expected solution behaviours. The parts that follow give a more detailed account of what is meant by EO's fundamental idea.

The following figure 3.4 illustrates the progressive steps of the Hybrid Slime Mould Equilibrium Optimization Algorithm (HSMEO). It starts with the general HSMEO Algorithm Phases, which describe the process of moving between different optimization phases. In Private Key Optimization, the main goal, focus is on the fact that the algorithm is based on natural processes to increase the level of protection in the process of communication. The subsequent stages describe the complex mechanisms in detail, such as the Slime Mold Motion Model, the interaction of SMA and EOA that provide a holistic optimization process, and the Equilibrium Optimizer which maintains the balance between exploration and exploitation. Local Search Algorithms enable a comprehensive search of the solution space while Continuous Strategy Modification means that the algorithm can adjust to the changes in the search space. Altogether, these phases represent the effectiveness and the high level of the HSMEO approach to address optimization problems.

Inspiration. EO starts the optimization process using the initial population. Equation (3.5) predicts that the initial quantities in the search space are produced in the following ways depending on the number of particles and the dimensions:

$$D_j^{\text{initial}} = D_{\min} + \text{rand}_j \times (D_{\max} - D_{\min}), \quad j = 1, 2, \ldots, n \tag{3.5}$$

where rand_j is a random vector in the range $[0, 1]$, D_j^{initial} defines the initial concentration vector of the i-th particle, $D_{\min}$ and $D_{\max}$ define the minimum and maximum values for the dimensions, and n is the total number of particles in the population. To classify the candidates for equilibrium, particles are sorted after being evaluated for their fitness function.

Equilibrium Pool and Candidates. For an algorithm to be more exploratory and to avoid being trapped in local optima, an equilibrium state has to be maintained during the search process. The best solutions available must be combined with new research into previously unexplored parts of the subject to maximize the effectiveness of the solutions. This strategy keeps the algorithm from becoming stuck on a less-than-ideal answer

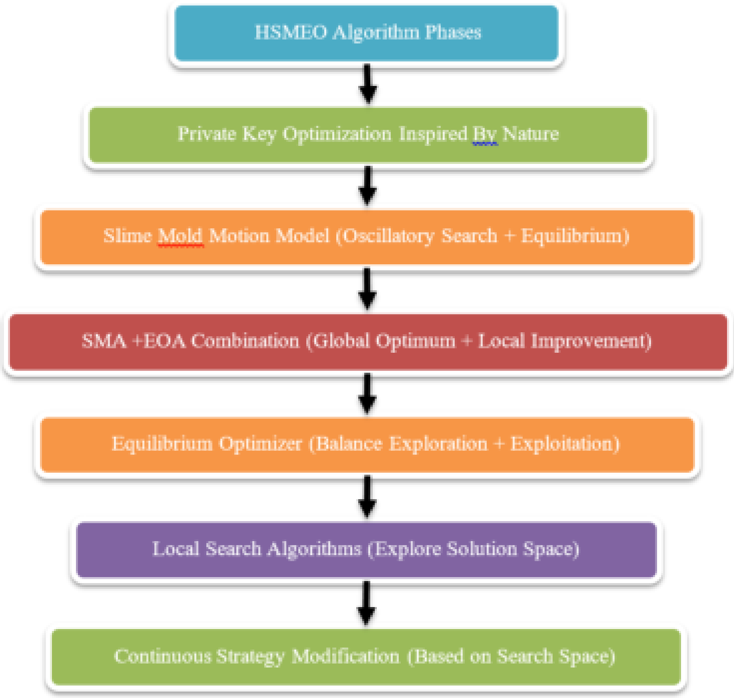

Fig. 3.4: Phases of the Hybrid Slime Mould Equilibrium Optimization Algorithm (HSMEO)

and allows it to keep looking for better ones. We identify five possible options in the context of equilibrium pool particles. Four of these contenders represent the best particles discovered throughout the whole optimization procedure. A particle representing the arithmetic mean of the preceding four particles is the fifth contender. While the four ideal particles aid in thoroughly exploring the search space, this fifth candidate particle aids in the exploitation of the solutions. The Hybrid Slime Mould Equilibrium Optimization (HSMEO) algorithm may provide optimum private key creation by combining these techniques.

The equilibrium pool's vector $\vec{D}_{\text{eq,pool}}$ is shown in Equation (3.6).

$$\vec{D}_{\text{eq,pool}} = \left\{\vec{D}_{\text{eq}(1)}, \vec{D}_{\text{eq}(2)}, \vec{D}_{\text{eq}(3)}, \vec{D}_{\text{eq}(4)}, \vec{D}_{\text{eq,ave}}\right\} \tag{3.6}$$

Each particle updates its concentration during an iteration by selecting random candidates among those selected with a similar probability.

Exponential Term. The EO algorithm's exploration and exploitation are balanced in part by the exponential term $\vec{F}$. According to Equation (3.7),

$$\vec{F} = e^{-\vec{\lambda}\times(T-T_0)} \tag{3.7}$$

Here, T is an iterative function that gets smaller as the number of iterations increases, and $\vec{\lambda}$ is a random vector between $[0,1]$. As per Equation (3.8),

$$T = \left(1 - \frac{\text{Iter}}{\text{Max\_iter}}\right)^{\frac{b_2\times\text{Iter}}{\text{Max\_iter}}} \tag{3.8}$$

where Iter and Max_iter are the current and maximum number of iterations. In Equation (3.9), T_0 is calculated as,

$$\vec{T_0} = \frac{1}{\vec{\lambda}}\ln\left[-\left(b_1 \times \text{sign}(\vec{r}-0.5) \times \left[1 - e^{-\vec{\lambda}\times T}\right]\right) + T\right] \tag{3.9}$$

Here, the constants b_1 and b_2 regulate the capacities for exploration and exploitation, respectively. The exploration capability is stronger, and the exploitation ability is weaker with a higher value of b_1. The exploitation capability is stronger, and the exploration capability is weaker with a higher value of b_2. b_1 and b_2 are equal to 2 and 1, respectively. The direction of exploration and exploitation is indicated by $\mathrm{sign}(\vec{r}-0.5)$. Equation (3.10) organizes and shows the final form of $\vec{F}$:

$$\vec{F} = b_1 \times \mathrm{sign}(\vec{r}-0.5) \times \left[e^{-\vec{\lambda}\times T} - 1\right] \tag{3.10}$$

Generation Rate. By enhancing the exploitation phase, the generation rate $\vec{g}$ enables the EO algorithm to deliver precise solutions. The first-order exponential decay process is used to define the generation rate as shown in Equation (3.11),

$$\vec{g} = \vec{g}_0 e^{-\vec{\lambda}\times(T-T_0)} \tag{3.11}$$

where $\vec{g}_0$ denotes the starting point and k denotes the decay constant ($k = \lambda$). As a result, the generation rate's final expression is shown in Equation (3.12),

$$\vec{g} = \vec{g}_0 e^{-\vec{\lambda}\times(T-T_0)} = \vec{g}_0 \times \vec{F} \tag{3.12}$$

where

$$\vec{g}_0 = (\mathrm{gcp}) \times (\vec{D}_{\mathrm{eq}} - \lambda \times \vec{D}) \tag{3.13}$$

$$\mathrm{gcp} = \begin{cases} 0.5r_1, & r_2 \geq \mathrm{gp} \\ 0, & r_2 < \mathrm{gp} \end{cases} \tag{3.14}$$

where r_1 and r_2 are random numbers between $[0,1]$, and gcp is also known as the generation rate control parameter. The likelihood of this contribution determines the number of particles that will use generation terms to update their states. GCP is found in Equation (3.14), and its purpose is to strike a balance between exploration and exploitation with GP (GP $= 0.5$). A population-based optimization technique called the equilibrium optimizer works by repeatedly updating the entire population of solutions. This may result in slow convergence, particularly for complex problems or when the algorithm becomes stuck at a local optimum. Equilibrium optimizer's drawbacks include uneven exploration and exploitation, poor exploration capability, and a tendency to easily enter local optima. The population's diversity can be increased by switching from the slime mould algorithm (SMA) default simple random search approach to an equilibrium optimizer strategy.

The proposed HSMEO updating rule is shown in Equation (3.15).

$$\vec{Y}(T+1) = \begin{cases} \vec{Y}_{\mathrm{eq}}(T) + \left(\vec{Y}(T) - \vec{Y}_{\mathrm{eq}}(T)\right) \times \vec{F} + \left(\vec{g} \times \frac{1-\vec{F}}{\lambda} \times U\right), & \mathrm{rand} < z \\ \vec{Y}_{\mathrm{eq},1}(T) + \mathrm{Levy} \times \left(\vec{X} \times \left(\vec{Y}_B(T) - \vec{Y}_A(T)\right)\right), & r < q \\ \vec{Y}(T) + \mathrm{Levy} \times \vec{Y}(T), & r \geq q \end{cases} \tag{3.15}$$

To increase local exploration, when the individuals found less information, empirical value defined as $z = 0.3$, better performance was achieved by using Levy flights instead of uniformly distributed random variables $(vb) \times \vec{vb}$, U is considered as a unit, $(\vec{Y}_{\mathrm{eq}})$ stands for a randomly chosen solution

3.6. ANN-based criminal suspect classification. Artificial neural networks are used by TA to categorize criminals in online networks. An ANN is a particular kind of machine learning algorithm that learns to predict or make judgments. The process of determining a person's probability of becoming a criminal suspect based on their age, gender, job, criminal history, and other characteristics is known as criminal suspect categorization. ANNs are very accurate in predicting if a person is likely to be a criminal suspect based on past data. A neural network is composed of layers, with neurons at the base of each layer. The categorization of a layer

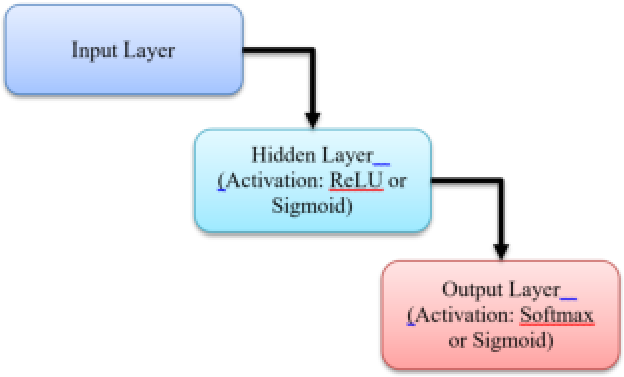

Fig. 3.5: Structure of a Neural Network Featuring a Hidden Layer.

as input, hidden, or output relies on its location inside the neural network. In a network, the input layer is the top layer and the output layer is the bottom layer. Hidden layers are those that are layered underneath the input and output layers. Depending on how the network is constructed, the number of neurons in each layer might change. The neurons in each layer are linked to the neurons in the layers above and below it. Complex changes take place in the network's hidden layers so that it can recognize patterns in the incoming data and generate accurate predictions.

The link between D2D and cellular channel gains lies at the core of the optimization challenge in mobile networks. It is advised to use an artificial neural network (ANN) to learn this connection and adjust the transmission intensity of D2D pairs appropriately, since this relationship cannot be deduced analytically. Stated differently, the ANN functions as a regulator, adjusting the transmission strength of D2D pairings based on data supplied to base stations about cellular channel gain. N D2D pairs are given a binary classification challenge: the optimization aims to adjust the transmission power of each pair to either $k_m = k_{\min}$ or $k_m = k_{\max}$. A fully connected ANN may be used to map cellular channel gains to the ideal binary transmission power setting for each m-th D2D pair, thereby overcoming this difficulty and optimizing the overall capacity of D2D pairings.

In Fig. 3.5, the proposed ANN for binary classification is shown. The ANN consists of an input layer $C = (C_1, C_2, \ldots, C_m)$, hidden layers $S = (S_1, S_2, \ldots, S_m)$, and an output layer $B = (B_1, B_2, \ldots, B_m)$. The input layer of the proposed ANN aligns the cellular channel gains from the D2D users to the base stations. The input layer has an input vector of length $X \times W$ and is denoted as $\text{Out}_{c0} = (K_{1,1}, K_{1,2}, \ldots, K_{X,W})$, which represents the cellular channel gains between base stations and D2D users.

The sigmoid function produces output values between 0 and 1, representing the probability that the transmission power for the m-th D2D pair should be set to 1. The transmission power for the m-th D2D pair is determined based on the output value of the ANN for that pair, as per Eq. (3.16):

$$k_m = \begin{cases} k_{\max}, & \text{if } \text{out}_B > 0.5 \\ k_{\min}, & \text{otherwise} \end{cases} \tag{3.16}$$

An activation function Φ is used to describe a basic model of a neuron by applying it to a linear combination of input data $C = (C_1, C_2, \ldots, C_m)$, weights $D = (D_1, D_2, \ldots, D_w)$, and a bias constant y. Consequently, the output B is such that $B = \Phi(U)$, where $U = y + \sum_{r=1}^{w} D_r C_r$. The process continues until the output layer generates the desired output by passing this output along to the subsequent layer as input data along with all of its other outputs.

The activation function Φ of the most general neuron model, the sigmoid neuron, is the sigmoid function $\Phi(U) = \frac{1}{1+e^{-\eta U}}$. The output is computed as per Eq. (3.17):

$$B = \frac{1}{1 + e^{-\eta\left(\sum_{r=1}^{w} D_r C_r - y\right)}} \tag{3.17}$$

Table 3.1: Hyperparameters Used for the Training of ANN

Parameter	**Value**
Input Layer	10
Hidden Layer	1
Hidden Neurons	10
Transfer Function	tansig
Backpropagation Network Training Function	traingdx
Epochs	100
Performance Function	MSE
Training Function	Levenberg-Marquardt Backpropagation
Output Layer	1

For a deep learning model to perform at its highest level, it is necessary to choose the appropriate hyperparameters. Some examples of the hyperparameters that influence the architecture of the model are the number of hidden layers, the number of neurons in each layer, and the learning rate. These are just a few examples. The optimal combination of hyperparameters may be discovered via the use of either a grid search or a randomized search. On the other hand, the randomized search technique chooses hyperparameters at random from a certain distribution, whilst the grid search strategy evaluates the efficacy of the model by utilizing all of the potential combinations of hyperparameters that fall within a defined range. The above result indicates that the performance of the artificial neural network (ANN) can be improved by adjusting the hyperparameters, which would improve the rate of convergence and accuracy of the model.

Table 3.1 summarizes the hyperparameters of the Levenberg-Marquardt Backpropagation-adapted hidden layer with ten neurons. Ten computational elements form the intermediate layer that uses the tansig transfer function to transform the input to an output value between -1 and 1. Regarding backpropagation training, there is only one function, and it is called Traingdx. It modifies the net weights to minimize the gap between the outcome predicted and the actual outcome by using the back propagational technique with the inclusion of the momentum factor. The output layer has one node for ten input variables and the mean squared error is used to check the actual and predicted values after 100 epochs of training. Last but not least, it would be possible to state that ANNs can contribute to the improvement of the accuracy and efficiency of the categorization of criminal suspects. The effectiveness depends on the quality and relevance of the training data, as well as the ability to analyze the data. It is quite possible that integrating human and legal approaches with ANN may help criminal justice systems to better and more logically sort suspects. The research findings will be provided to a law enforcement agency if the user does not meet the criteria of being suspicious. It will also be possible for the agency to look for such data and get the list of possible suspects who have not been arrested yet.

4. Experimental Results. The study used query-based authentication (QBA) to ensure that only authorized users with proper identification details accessed relevant information. Machine intelligence was applied to categorize data into two groups: personal and social criminal data which can be considered as sensitive data and classification results which can be considered as non-sensitive data. This paper also presented the Two-Level hybrid ECC and RSA (ECC-RSA) encryption model and compared it with other traditional methods such as AES, DES, RSA, and ECC and proved that the proposed model was more secure and efficient. The encryption/decryption time and throughput analysis of ECC-RSA were quite satisfactory. In this study, the HSMEO algorithm improved the ECC-RSA model, and it was found that the key generation time of the proposed algorithm was smaller than SMO, EO, PSO, MFO, and FFO. Graphical illustrations corroborated the viability of the ECC-RSA encryption model as a more secure and optimally performing encryption technique compared to the others. Finally, the findings of the experiment show that the smart system methodology above is effective in concealing the data from other users and in categorizing criminal suspects using an expert system approach.

4.1. Experimental Setup. This recommended solution has been implemented in the MATLAB environment. The Two-Level Hybrid ECC and RSA (ECC-RSA) Model utilizes a classifier-based artificial neural network and a hybrid slime mould optimization for suspect profiling. In this part, the model analysis is presented more graphically as can be seen below. The following are some of the existing approaches that can be compared to the proposed methodology: Among these metaheuristic algorithms, Slime Mould Optimisation (SMO) [26], Equilibrium Optimizer (EO) [27], Particle Swarm Optimisation (PSO) [28], Moth Flame Optimizer (MFO) [29], and Firefly optimizer FFO [30]. They are also compared with RSA [32], Elliptic Curve Cryptography [31], AES [33], and Information Encryption Standard (DES) [34]. That is why measures such as the time taken to generate keys, encrypt, and decrypt are used to assess the recommended approach.

4.2. Performance Metrics. A performance matrix is a set of parameters of a measurable nature that have been formulated to measure the performance, effectiveness, and quality of an encryption system. These are generation time, encryption time, decryption time, security strength, trust score, throughput, and delivery ratio. These metrics include aspects of the encryption system in terms of speed, reliability, security, and efficiency in processing and transferring encrypted data. The performance matrix is a means of comparing the performance of the system in the encryption of data to make the right decision about whether the system is efficient in protecting sensitive information or not.

4.2.1. Key Generation Time (Sec). Key generation time is the time taken to generate the keys that are used in the encryption and decryption of information. It is an important parameter as shorter key generation time reduces the time that is taken to set up secure communication and protect data to start secure transactions and communication.

The formula to estimate the KGT is described in Equation (4.1).

$$\mathrm{KGT} = f(P, A, B, G, n, h) \tag{4.1}$$

4.2.2. Encryption Time (sec). Encryption time is the time required for converting the plain text data into cypher text with the help of the encryption algorithm. This metric is very vital, especially in areas where there is a need to minimize the time taken in the transfer of data. Quicker encryption times can be used in the protection of data in a very efficient manner without much or any impact on the system. The formula to calculate the encryption time is as follows Equation 4.2.

The formula to calculate the encryption time is as follows (Equation (4.2)):

$$\mathrm{ET} = \left(\frac{\mathrm{psize}}{\mathrm{ksize}}\right)^2 \cdot \mathrm{KGT} + \mathrm{et} \cdot \mathrm{psize} \tag{4.2}$$

where ET is the time required to encrypt one byte of the plaintext message using RSA encryption in seconds; KGT is the size of the RSA key in bits; and psize is the size of the plaintext message to be encrypted in bytes.

4.2.3. Decryption Time (sec). The decryption time is the amount of time taken to decrypt the given ciphertext to plaintext using a decryption algorithm. This metric is very useful in the timely retrieval and use of encrypted information. Less decryption time implies that the secured information is processed and made available more quickly; thus, there is improvement in the processing of data and decision-making.

The formula for calculating the decryption time is represented in the following equation:

$$\mathrm{Dt} = \left(\frac{\mathrm{csize}}{\mathrm{ksize}}\right)^2 \times \mathrm{kgt} + \mathrm{dt} \times \mathrm{csize} \tag{4.3}$$

where dt is the quantity of time it takes to decode one byte of ciphertext using RSA decryption in seconds, and csize is the extent of the ciphertext message to be decrypted in bytes.

4.2.4. Security. In the context of encryption systems, security is the capacity of encryption algorithms to prevent unauthorized use of data or alteration of it. The security strength of the encryption scheme depends on the types of attacks that can be carried out on the cipher system. High security also plays a role in preventing the interception of encrypted data by individuals who are not authorized to access it, and it also protects the data from being tampered with or from loss of integrity.

It is possible to state that the level of security provided by a cryptographic approach is equal to $2^{(n-1)}$, where n is the number of bits in the key. For example, an encryption technique with a key of 128 bits would be as secure as $2^{(128-1)} = 2^{127}$, which is approximately 1.7×10^{38}. Thus, it is thought that such encryption is essentially impossible to crack with present-day techniques, even with 2^{127} different keys.

4.2.5. Trust Score. Trust score is another invented measure that tries to express the degree of trust and reliability of an encryption system. It depicts the degree of confidence that the system can protect sensitive information from any danger. A high trust score implies that the encryption system is perceived to be effective in the protection of information and that the information is secure from other individuals' interference. Equation 4.4 shows an example of a simple formula for computing the trust score. Thus, the Trust score is determined by the following equation:

$$\text{Transparency} \times 0.1 + \text{Competence} \times 0.2 + \text{Honesty} \times 0.3 + \text{Reliability} \times 0.4 \tag{4.4}$$

Each element in Eq. The weight of each factor, in this case, Equation 4.4 is determined by the overall confidence that has been set. It was seen that reliability, which can be defined as the extent to which a firm fulfils its commitment, was the most heavily weighted at 0.4 on the other hand, the level of transparency which measures the extent to which a company is willing to reveal information on the actual business processes has the least scale weight of 0.1. This is because it is possible to obtain the specific ratings of each piece by using different metrics like the effectiveness statistics, the user feedbacks and the third-party reports. These are then added to the corresponding weight to arrive at the total trust score.

4.2.6. Throughput. Throughput is defined as the ability of an encryption system to process the data or data transfer rate in a certain period. It defines the efficiency by which the system can perform data encryption and decryption tasks. This is because data can be processed and transmitted in a fast manner to ensure that it does not become a bottleneck and to ensure that the efficiency of applications and systems is not compromised. Equation 4.5 may be used to represent the throughput formula:

$$\text{Throughput} = \frac{\text{Total amount of data transmitted or processed}}{\text{Total time taken}} \tag{4.5}$$

Quite often, the answer to this equation is presented in terms of bits per second (bps), bytes per second (Bps), or another data transfer rate unit.

4.2.7. Delivery Ratio. The delivery ratio is the ratio of the number of packets of encrypted data successfully delivered to the total number of packets transmitted through the encryption system. It shows the efficiency of the system in ensuring that protected data is delivered to intended users. A high delivery ratio proves the efficiency of the system in providing secure delivery of encrypted data and guarantees effective communication and data transfer. Equation 4.6 is used to compute the packet delivery ratio.

$$\text{PDR} = \left(\frac{\text{Number of packets received at destination}}{\text{Total number of packets sent from source}}\right) \times 100\% \tag{4.6}$$

4.3. Results. Table 4.1 presents AES, DES, RSA, and ECC along with the recommended Two-Level hybrid RSA and ECC (ECC-RSA) model's security, trust score, throughput, encryption and decryption times, and delivery ratio. When compared to other methods, its security percentage of 98.53% offers the best degree of protection [35]. It is regarded as the most trustworthy algorithm overall, with the highest trust score of 4.83. The quickest encryption and decryption times for the suggested ECC-RSA approach are 3.459 and 2.994 seconds, respectively [36]. The ECC algorithm has the quickest decryption time (5.1243 seconds) and the slowest encryption time (3.7086 seconds) among the various approaches. The highest throughput of 77.57 for the suggested ECC-RSA methodology illustrates even more how much quicker it can process larger quantities of data than the other methods [37]. With the best delivery ratio of all the algorithms, 0.9884, it provides even more proof of a better chance of an efficient message transfer. The adoption of the extremely secure and efficient ECC-RSA method is recommended. The high degree of security and quick encryption and decryption operations of the proposed approach may be advantageous for classifying criminal suspects.

Table 4.1: Comparison of Overall Performance

Techniques	**Encryption Time (Sec)**	**Decryption Time (Sec)**	**Security (%)**	**Trust Score**	**Throughput**	**Delivery Ratio**
Proposed ECC-RSA	3.459	2.994	98.53	4.83	77.57	0.9884
ECC	3.7086	5.1243	92.64	4.36	69.354	0.9234
RSA	4.1348	4.793	94.54	4.11	65.45	0.9614
AES	9.6512	6.6401	85.669	3.07	39.94	0.8823
DES	6.182	11.9697	72.45	3.2	44.35	0.8534

Table 4.2: Comparison of Key Generation Time (HSMEO)

Methods	**Key Generation Time (Sec)**
Proposed HSMEO	1.97545
SMO	3.13684423
EO	2.708879857
PSO	3.891071564
MFO	4.668197068
FFO	5.41265866

Table 4.2 displays the significant production times for SMO, EO, PSO, MFO, and FFO in the developed HSMEO model. Unlike the previous models, the proposed HSMEO model produces keys in 1.97545 seconds or less. It has been shown that the generation of keys takes longer for SMO, EO, PSO, MFO, and FFO [38], with MFO and FFO taking much longer. These findings suggest that the HSMEO model generates keys faster than other methods do, according to the proposed model. The last aspect of the suggested model is that it takes more time to generate compared to other models, which is crucial when grouping criminal suspects. Because secure jobs may often be completed more quickly, the proposed model is more beneficial. The conclusions of the study are significant because applications may become safer and more effective if there are shorter key generation periods [39]. To perform the encryption and decryption functions, a key is mandatory. The improved performance of the HSMEO technique has a significant impact on the design and construction of secure cryptographic systems. Given all this, the study reveals that the HSMEO approach can be used to quickly derive safe encryption keys. In this part, the authors compare the graphical representation of the metrics with other techniques like SMO, EO, PSO, MFO, and FFO. This research also compared and contrasted various key generation efficiency strategies with some of the most commonly used encryption algorithms like RSA, DES, AES, and ECC. A comparison of these approaches was also conducted simultaneously.

In addition to the five other optimization strategies (SMO, EO, PSO, MFO, and FFO), Figure 4.1 illustrates the amount of time required to generate a key for the HSMEO strategy that is suggested. Given the statistics, the HSMEO approach that was presented is superior to other methods in terms of its effectiveness since it only takes 1.97545 seconds to produce a key. The EO, SMO, PSO, MFO, and FFO strategies, with the respective key creation times being 2.84568425 seconds, 3.13684423 seconds, 3.891071564, 4.668197068, and 5.41265866 seconds, respectively. In addition to this, it emphasizes the fact that the HSMEO technique offers superior performance in comparison to other approaches [40]. It is quite important to choose the optimization approach that is designed to be the most efficient to generate safe encryption keys. The outcomes of the investigation are supported by the graphical depiction of the comparison of the times at which the key was generated.

Figure 4.2 displays a visual depiction of the Encryption Time (in seconds) for the four widely used encryption methods (RSA, ECC, AES, and DES) as well as the proposed ECC-RSA approach. According to the graph, the quickest encryption time was 3.708 seconds for ECC, while the second-fastest encryption time was 3.459 seconds for the Proposed ECC-RSA technique. The encryption timings for RSA, DES, and AES were 4.134, 6.182, and 9.651 seconds, in that order. It is fast and simple to see how different encryption methods

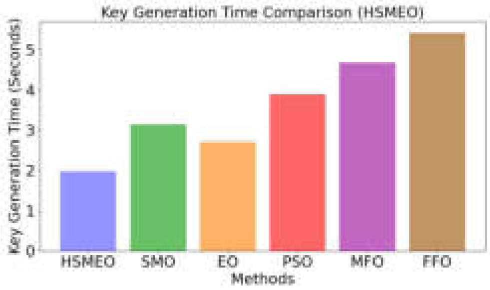

Fig. 4.1: Comparison of key generation time of the proposed method with existing techniques.

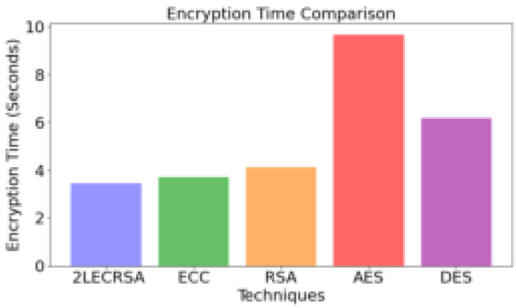

Fig. 4.2: Comparison of encryption time of the proposed method with existing techniques.

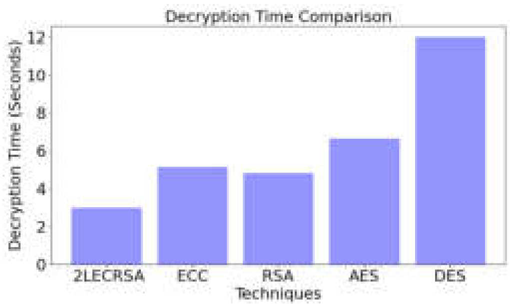

Fig. 4.3: Comparison of decryption time of the proposed method with existing techniques.

vary in terms of encryption time thanks to the graphical depiction. It emphasizes how the Proposed ECC-RSA method and ECC work comparatively well in comparison to the other encryption algorithms, especially AES, which has the slowest encryption time.

Figure 4.3 shows that, at 2.994 seconds, the Proposed ECC-RSA technique has the quickest decryption time. The next four algorithms RSA, ECC, AES, and DES have decryption times of 4.793, 5.124, 6.640, and 11.969 seconds, respectively. The suggested ECC-RSA technique highlights a large efficiency gain when compared to conventional encryption algorithms, particularly DES and AES, which have the fastest decryption times.

The comparison of the suggested ECC-RSA methodology and the four most commonly used encryption methods (RSA, AES, DES, and ECC) is depicted in Figure 4.4. The recommended ECC-RSA technique demonstrated a high level of security in preventing unauthorized access to sensitive information with the security percentage of 98%. 53%. The security percentages that ECC, RSA, and AES obtained—92.64%,

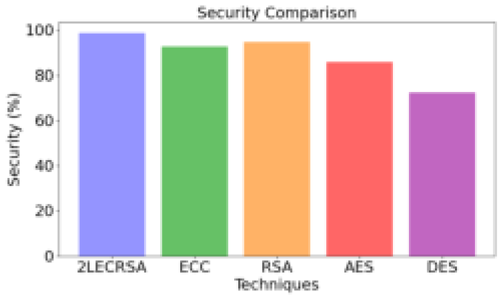

Fig. 4.4: Comparison of security of the proposed method with existing techniques.

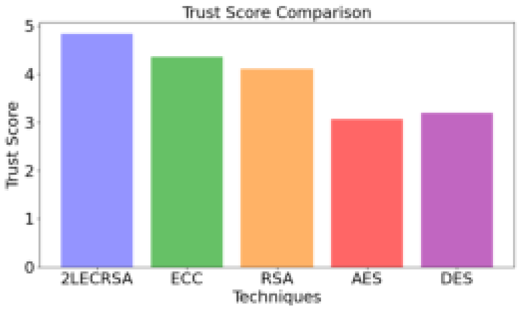

Fig. 4.5: Comparison of the trust score of the proposed method with existing techniques.

94.54%, and 85.69% also demonstrate the level of protection. On the other hand, the security percentage of the DES technique was only 72.45% which is a little less than the other methods in terms of security. As a consequence, it may be more vulnerable to invasions and unauthorized access to confidential information.

This is why the trust score is a parameter that should be taken into consideration when choosing the encryption algorithm. The trust score is an algorithm that measures the confidence that users have in the ability of the algorithm to secure their information. The ECC-RSA encryption method is proposed to be implemented as shown in figure 4.5 below as well as the graphical representation of the trust ratings of the different encryption methods. The highest trust score of 4 is achieved among all methods. Based on the foregoing analysis, the recommended ECC-RSA algorithm is a good encryption for protecting sensitive information due to its flexibility. Examples of trust-related characteristics that, depending on the specific use case, are often given different weights in trust score calculations include openness, honesty, reliability, and credibility.

A crucial metric called throughput measures how fast an encryption and decryption method can process data. A high throughput rate algorithm can process enormous volumes of data quickly and effectively. Figure 4.6 illustrates throughput graphically. With a 77.57 throughput score, the proposed ECC-RSA method proved to be capable of handling large amounts of data quickly. ECC, RSA, and AES have correspondingly quite high throughput scores of 69.35, 65.45, and 39.94. However, the DES technique came in last with a throughput score of 44.35, processing data far more slowly than the other methods. Selecting an encryption method requires careful consideration of both security and performance. Robust security is necessary to avoid issues with system performance, but it's also critical to make sure the algorithm can handle data rapidly. The security of the confidential data and the efficiency of the system can be preserved by implementing the suggested ECC-RSA approach as it exhibits high security and overall throughput performance.

The delivery ratio is a parameter that estimates the number of data packets that can be transmitted by encryption. A high delivery ratio means that the data packets are sent without errors, are dependable and are delivered often. As aforementioned, the delivery ratio was 0.9884, the ECC-RSA approach recommended herein proved to offer the highest level of dependability when it comes to the transportation of data packets

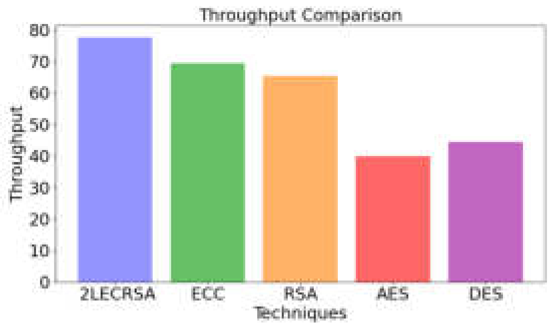

Fig. 4.6: Comparison of throughput of the proposed method with existing techniques.

Fig. 4.7: Comparison of the Delivery Ratio of the proposed method with existing techniques.

(as shown in FIgure 4.7).In this regard, the delivery ratio is a significant parameter that should be considered in the selection of an encryption scheme because it influences the reliability and speed of the data transmission. As much as the suggested ECC-RSA technique has been proven to be effective on all the parameters including delivery ratio, it can be safe and reliable for data transmission.

5. Discussion. From the results of the study, it can be concluded that the ECC-RSA model is more secure and has a higher trust score, throughput, encryption and decryption time, and delivery ratio as compared to other encryption techniques and thus, can be used in real-time applications where data security is a major concern. The key generation method HSMEO used in the ECC-RSA model also turns out to be efficient as compared to other key generation methods as it generates keys in less time than the other methods which proves that the proposed ECC-RSA model is efficient. The use of graphs for the metrics also helps enrich the study's result since it also illustrates how the proposed ECC-RSA model is more secure, efficient, and effective compared to the other encryption methods. Therefore, it can be concluded that the ECC-RSA model described in the paper, supported by the machine intelligence technique, can be recognized as a secure, efficient, and reliable tool for ensuring the confidentiality of information in such applications as Internet banking, e-commerce, and real-time data transfer. The incorporation of Smart System and Expert System in this model also improves the model's ability to address data security issues efficiently.

5.1. Practical implications. The practical relevance of HSMEO for the identification of criminal suspects through the artificial intelligence network is connected with law and security. This method is unique and well-defined to the use of machine learning algorithms in the processing of criminal and social data from the police information system, and social media among other sources. For the encryption and decryption processes, a two-level hybrid encryption method, which is ECC-RSA, is utilized. This division of the system guarantees the isolation of confidential and non-confidential data, thus increasing security and privacy. On the other hand, the inclusion of HSMEO for private key selection is a quick unique innovation in the encryption processes, to make sure that they will be efficient and secure. In addition, the ANN classifier which can be used to differentiate criminal suspects in social networks with a much higher level of accuracy and realness is another important implementation. Practically, these findings may enrich the existing toolkits of law enforcement agencies allowing them to combat cybercrimes more efficiently and realistically. The utilization of the proposed model in MATLAB's environment signifies the practicality of the real-world applications.

5.2. Limitations. The proposed hybrid Lime Mould equilibrium optimization-based artificial neural network approach for criminal suspect identification online crime has a lot of potential in solving online crimes. Nevertheless, its deficiency is significant. On the one hand, it is largely dependent on the credibility and accessibility of crime and social statistics, a condition that would lead to inaccuracies if either limited or biased. Additionally, we have the issue of using machine learning methods which can generate bias and interpretability problems, and, eventually, classify unfairly.

6. Conclusion. This research uses machine learning methods to categorize criminal suspects on social media. The proliferation of virtual social networks has increased the frequency of communication between suspects in criminal activities. On the other hand, not enough focus has been placed on how criminal suspects are categorized on social media. In an attempt to close this gap, this study proposed a novel method of identifying criminal suspects using data from social media and police information systems. The four primary phases of the suggested approach are query-based authentication, data categorization, suggested data encryption and decryption, and criminal suspect classification based on ANN. As part of the data categorization procedure, sensitive and non-sensitive data were separated into many categories. HSMEO chose the best private key by using the ECC-RSA Model, a two-level hybrid of ECC and RSA, to encrypt and decode data. The criminal suspects on the social network were categorized by an ANN. The application of the smart system approach is based on the MATLAB platform, which enables a large number of users to participate in the system testing. Our study's unique method for categorizing criminal suspects on social media will have a significant impact on law enforcement agencies. The efficacy and efficiency of the offered approach indicate that it might be highly beneficial in preventing cybercrime. The use of the expert systems and MATLAB made it possible for the researcher to conduct an efficient and fast assessment of the performance of the system. The research contrasted the ECC-RSA system under investigation's total key generation effectiveness. Based on the results, the system's high degree of security (98.53) indicates that it is resistant to potential security breaches. The system's 77.57 throughput score demonstrated that it could easily handle a large volume of data.

This research lays the foundation for further exploration in the application of machine learning for criminal suspect classification on social media. Future work could focus on expanding the dataset to include more diverse social media platforms and integrating real-time data streams for more immediate identification of suspects.

Availability of Data and Materials:. The data that support the findings of this study are available on request from the corresponding author.

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