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RESEARCH ON VISUALIZATION AND INTERACTIVITY OF VIRTUAL REALITY TECHNOLOGY AND DIGITAL MEDIA IN INTERIOR SPACE DESIGN

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Abstract. The combination of digital media and Virtual Reality (VR) technology has become a disruptive force in the interior space design industry, changing the way that design is explored and augmenting its experiential aspects. Examining the substantial effects of deep visualization and technological interaction on the conception and interaction with interior environments, this research explores the junction of these dynamic domains. This study intends to uncover the interactions that drive internal designing spaces into a new era of creativity and engagement with users through a thorough investigation of state-of-the-art VR tools and multimedia services and technologies. The research approach entails a thorough examination of popular virtual reality systems and digital media strategies used in the interior design industry. We'll carry out user feedback surveys and real-world case studies to see how well these tools work at communicating design ideas and encouraging group decision-making. Considering aspects like accessibility, visual dedication, and real-time interaction, the study aims to identify the main opportunities and obstacles associated with the combination of VR and electronic media inside interior space design. This research will lead to the proposal of a framework for the best possible use of digital media and virtual reality in interior space design. The framework is intended to serve as a guide for designers, architects, and other relevant parties as they fully utilize these technologies to improve visualization, collaboration, and user experience. Furthermore, the study will provide insightful information to the larger conversation on how emerging technologies are reshaping design disciplines.

Key words: visualization, virtual reality, digital media, interior space design, deep visualization

1. Introduction. The development of technology has brought about a new degree of media trends and information distribution, which has profoundly altered people's lives. Virtual reality technology becomes an interactive media design and a medium for art transmission and expression when it combines internet content art and technology [24]. With the use of virtual reality technology, participants in digital media art can finish this interactive experience.

In contrast to traditional marketing, which includes advertising on radio, television, billboards, and other printed media, digital marketing offers digital payment [3], rapid tracking and control, and data analysis on the campaign's effectiveness online [19]. Digital marketing is the term for online marketing initiatives that educate new clients by aligning with their demands [15]. It is the online projection of traditional marketing techniques, resources, and approaches [14]. Due to the rapid increase in internet users, digital marketing has created a multitude of avenues via which businesses can interact with different types of customers. New applets and sub-channels on the market, such the community for game content, comics, and animation on Bilibili and the short video platform Tik Tok, have gained a lot of traction [20].

Marketing for interior design firms is difficult among other industries since designers must personally comprehend each client's unique preferences before showcasing creative proposals. Customers seeking interior design, on the other hand, typically like to see the design concepts in action. Therefore, in order to draw in and keep clients, the majority of traditional interior design companies open traditional brick-and-mortar locations. Artificial intelligence (AI), virtual reality (VR), and other related technologies have made it possible for online platforms to interactively depict designs and illustrate concepts in an intuitive way in the digital age. In interior design, a platform with interactive virtual reality (IVR) characteristics allows designers to show clients thoughts and ideas while also letting them feel the design intuitively [2].

Very little study has looked at the viewpoint of the consumer; most current studies on digital marketing are from the company's perspective, analysing how businesses might enhance their digital marketing capabilities

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to draw customers [7, 27, 28, 21]. The application of an Internet-of-Things (IoT)-based information system in Logistics 4.0 was examined by Tang et al. [20]. Examining the features of the digital information system in relation to customer satisfaction was fresh and valuable information in the article. Some entities claim that digital marketing is exclusively relevant for business-to-consumer (B2C) entities [16]. However, B2B businesses have realized that digital marketing may be successful because to the success stories of corporations like Cisco and IBM [18]. In digital marketing, content is crucial in helping consumers make decisions [12, 9].

The motivation for this research is twofold: First, to provide a comprehensive analysis of current VR tools and digital media strategies employed in the interior design sector, evaluating their efficacy in enhancing design communication, facilitating collaborative decision-making, and improving the overall design experience. Second, to identify and systematically address the main opportunities and challenges that the amalgamation of VR and digital media presents in interior space design. This includes considerations of accessibility, visual fidelity, and the capacity for real-time interaction, which are critical for the effective implementation of these technologies.

The main contribution of the proposed method is given below:

1. Creating cutting-edge virtual reality methods that give designers more lifelike and engrossing representations of interior spaces.
2. Real-time lighting simulations, high-fidelity rendering, and intricate material representations are a few examples of this. creating and putting into practice natural and intuitive ways for people to interact in virtual environments.
3. To make the design process more user-friendly, this might include voice commands, haptic feedback systems, and gesture recognition.
4. The proposed method also uses generative adversarial networks (GAN) based VR to design an interior space.

The rest of our research article is written as follows: Section 2 discusses the related work on various virtual reality methods and deep learning methods. Section 3 shows the algorithm process and general working methodology of proposed work. Section 4 evaluates the implementation and results of the proposed method. Section 5 concludes the work and discusses the result evaluation.

2. Related Works. The human brain's ability to approximate reality is known as perception. It is a static process that involves gathering information about the outside world and interpreting it considering the individual's needs, wants, and attitudes. A person's subjective personal account of an experienced event is called perception. Understanding user experience is of greater interest to academics than understanding customer pleasure since it is viewed as a larger term [25].

Simple perception, or the moment we become aware of stimuli through our senses, is where perception theory starts. People react to what they see by using their judgment or intuition. A customer's likelihood of making a purchase increase with the amount of time they spend exploring, hence customer-centric innovation is crucial for product design and development [13]. Marketers must try to enhance customer satisfaction and present an accurate image [1]. One of the research topics in the realm of consumer behavior is consumer perception, which is described as one of the independent variables influencing consumer behavior [8]. Customers' attitudes, beliefs, and motivations are ultimately influenced by the stimuli they accept and adapt to, and perception is one of the primary personal aspects that shapes behavior and other characteristics [10].

The process by which a person learns about the surroundings and interprets the information considering his or her needs, requirements, and attitudes is known as customer perception.], who developed the idea of perceptual filter theory. According to this theory, a stimulus will first be filtered, then sorted, altered, and last stored in the customer's memory. Humans are not able to perceive every stimulus during the sensation phase, according to the author [6]. Furthermore, individuals are unable to react to multiple stimuli at once, interpret stimuli incorrectly, and ultimately lose the ability to recall all the triggers.

SEO, SEM, content marketing, influencer marketing, content automation, campaign marketing, data-driven marketing, e-commerce, social media marketing, social media optimization, direct email marketing, display advertising, e-books, CD-ROMs, and games are some examples of digital marketing techniques [17]. With the advancement of digital marketing, digital media can now be accessed through non-internet methods such cell phones (SMS and MMS), callbacks, and ringtones. The differentiation between online and digital marketing is aided by this expansion for non-internet outlets [22].

One new kind of art is digital media art. Emerging technologies like virtual reality and augmented reality can combine to produce unanticipated results. Bastug investigated the application of virtual reality technology in laparoscopic surgery. Using virtual reality technology, he evaluated the test doctors' level of surgical coordination and contrasted their performances. According to his experimental findings, the simulator's parameters are used to evaluate a surgeon's laparoscopic skills [26]. In a virtual environment, Kihonge outlines a synthesis process for creating 4C space mechanisms. He also creates software that enables several users to network and share the created mechanisms.

In virtual reality, people may view and interact with digital models more naturally than they can with a typical human-machine interface (HCI) [5]. Freeman conducts research on the application of virtual reality to the treatment of substance abuse, eating disorders, schizophrenia, and depression. Using computer-generated interactive environments and virtual reality, he repeatedly encounters the challenging circumstances faced by individuals with various mental diseases and gains knowledge on how to resolve them through evidence-based psychotherapy. The ways in which his research methodologies are used to mental health treatment are significant [23]. Using an immersive boxing movement guide, Sucipto provides educational content. With an Android-based animation video visualization serving as the learning medium and offering instructions for fundamental boxing motions, the methodology is preferable to outdated manual approaches.

A useful tool for helping boxers learn actions by heart is the 3D AR boxing action training program [4]. Using the ADDIE-type research and development approach, Ayu conducts experimental steps of analysis, design, development, implementation, and evaluation with the goal of enhancing the artistic literacy of primary school pupils. Enhancing reality-based applied media may effectively boost students' creative literacy, according to his online user survey, which he conducted to determine the value of this learning tool [11].

The human brain's selective and subjective interpretation of external stimuli complicates the design and evaluation of user experiences. Tailoring experiences to meet diverse individual needs and preferences remains a significant challenge. In an era of information overload, individuals' inability to perceive every stimulus or react to multiple stimuli simultaneously poses a challenge for designing effective marketing strategies and user interfaces that capture and retain attention. Ensuring customer satisfaction while accurately representing products or services requires a deep understanding of consumer perception and behaviour. Marketers must navigate these aspects without overwhelming or misleading customers. The rapid advancement of digital marketing technologies, including SEO, SEM, and social media, requires marketers to continuously update their skills and strategies to remain effective. Developing effective VR and AR tools for education and training, such as the 3D AR boxing action training program, requires addressing challenges related to user engagement, content accuracy, and technological accessibility.

3. Proposed Methodology. The outcome of this study will be the recommendation of a framework for the most effective application of virtual reality and digital media in interior design. The framework is meant to act as a roadmap for designers, architects, and other pertinent stakeholders as they make the most of these technologies to enhance user experience, visualization, and collaboration. The proposed method uses GAN-based VR interior design. In figure 3.1 shows the architecture of the proposed method. VR allows users to immerse themselves in a virtual representation of an interior space before it is physically realized. This immersive experience goes beyond flat images or models, offering a 360-degree view that gives a sense of scale, depth, and spatial relationships that can be comprehensively understood only when experienced as if one were physically present in the space. With VR, users can interact with the interior environment in real-time. They can move around, explore different angles, and even manipulate design elements (such as changing materials, lighting, or furniture layouts) within the virtual space. This level of interaction enables users to experiment with design choices and see the immediate impact of those changes, fostering a deeper connection with the design process and the space itself.

3.1. Data Collection. With the help of a virtual interior design platform, we gathered a sample for this study's digital marketing purposes from the Hong Kong interior design market. We then gathered pertinent data to examine the effect of digital marketing on customer intention. Just 40% of interior designers in Hong Kong have a website [20]. Nonetheless, a Google search for "interior designer Hong Kong" yielded about 22 million results. Hong Kong has an excessive number of marketing websites pertaining to the interior design sector. Hong Kong has a large consumer base that works in the interior design sector.

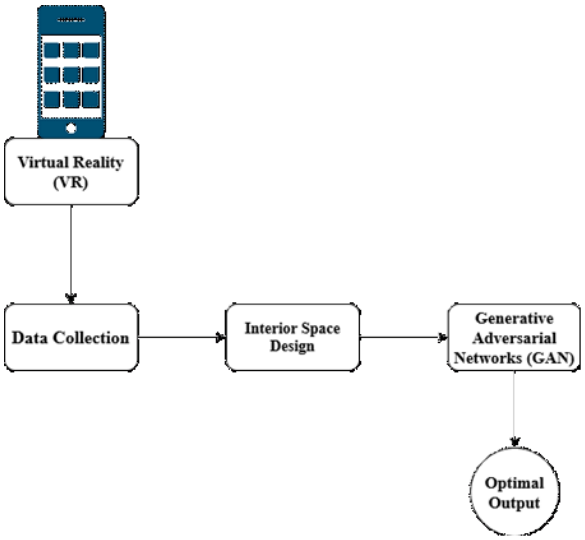

Fig. 3.1: Architecture of Proposed Method

3.2. Questionnaire Development. A questionnaire survey was employed as a research tool in this work. The questionnaire was divided into sections. Initially, the interviewee was sent a connection to a virtual interior design platform, where entry questions verified that the interviewee had visited the platform and was aware of the presumptions that needed to be made before answering the questionnaire. "I am looking for an interior design service," was the interviewee's presumption. In the second section, there were five variables related to the above-mentioned hypothesis model: (1) perceived aesthetics of the platform; (2) perceived usability; (3) perceived quality of the content; (4) customer happiness; and (5) behavioral intention. All variables' definitions and measurement elements are covered later.

Three reference questions were asked in the third section: (1) did they look for or are interested in interior design services currently? (2) did they look for or hire interior design services in the last 12 months? and (3) which channels would they want to use to locate an interior design company? The questionnaire's final section asked about demographic data.

3.3. Generative Adversarial Networks (GAN). The author created the generative adversarial network (GAN) in 2014. In several machine learning domains, interest has been growing in this remarkable discovery. Two neural networks that interact make up the GAN. It is both a discriminator (D) and a generator (G) (D). To create new data instances, the generator network is taught to map points in the latent space. The generator network's plausible and actual images are separated by the discriminator network during training. The generator ultimately produces images that mimic real training examples. Depending on the discriminator's expectations, the generator is modified to produce better images during training. Its capacity to discriminate between real and fraudulent images is improved by the discriminator. The discriminator loss is based on the distinction between authentic and fake labels. If the image is man-made or environmental, this is indicated by the label. Figure 3.2 displays the GAN's general diagram.

A two-player min-max game that may be described by, for example, can be used to represent the primary goal of GAN theory.

$$\min_{G}\max_{D} V\left(D,G\right)=\mathbb{E}_{x\sim P_{d}(x)}\left[logD\left(x\right)\right]+\mathbb{E}_{rnv\sim P_{rnv}(rnv)}[\log(1-D(G(rnv)))] \tag{3.1}$$

With the value function V, the discriminator and the generator are playing a min-max game (D, G). The discriminator seeks to minimise its reward V(D, G), and the generator seeks to maximise its loss by seeking to diminish the discriminator's award.

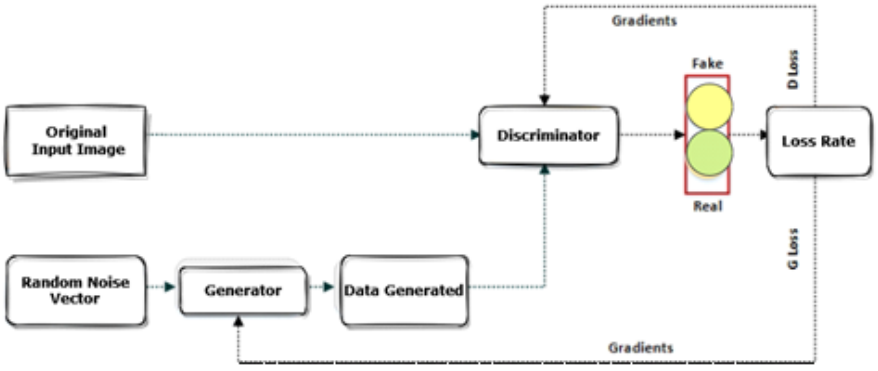

Fig. 3.2: Architecture of General Adversarial Network

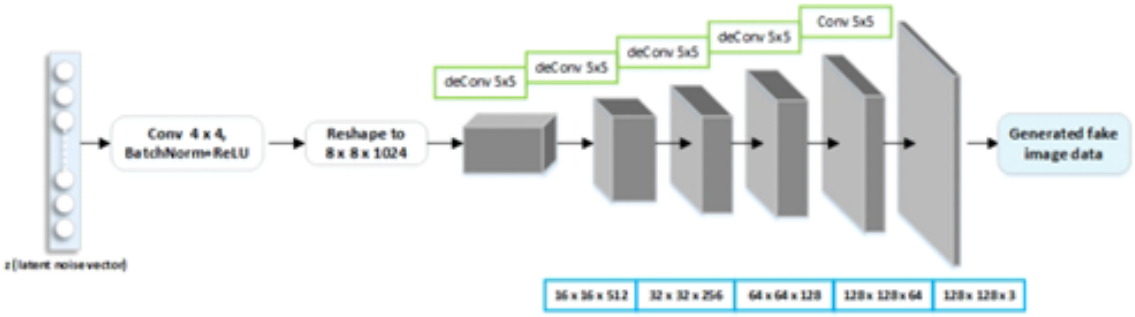

Fig. 3.3: Generator Model Architecture

The preceding loss function is always attempted to be minimised by the generator, whereas it is always attempted to be maximised by the discriminator. The GAN generator adds the random noise variable $P_{rnv}(rnv)$ to the original input data x before generating samples $G(rnv)$. The discriminator's estimates of the likelihood that an actual example of x exists in the P_d distribution of data is denoted by D(x). The discriminator's assessment of the likelihood that a phoney example is real is called $D(G\,(rnv))$. To deceive the discriminator, the generator strives to produce nearly flawless images. In comparison, the discriminator works to enhance efficiency by separating fake examples from real ones until it reaches a point where it is impossible to tell fake examples from real ones.

To produce quality synthesised images that can be orchestrated with high-quality photographs, the generator must be interacting with a deeper network. A deeper network will have a larger convolution layer and require more training data. We first supplied the original image data and downsized it to 128*128*3 to consider GPU for the training. To match the generator, the image was scaled to [1, 1] pixel values. Because it makes use of the tanh activation function, it was issued. The generator network produces fictitious samples from a 100*1 noise vector. To produce excellent generated images, we combined ReLU activation with four convolution layers. The architecture of the generator model is shown in Figure 3.3.

We partially merged the encoder into the discriminator under the presumption that the network information of the encoder and discriminator overlapped. While the discriminator seeks to identify the discriminating feature, the encoder's primary objective is to understand the representation feature.

$$\mathcal{L}_{recons}^{pix} = \mathbb{E}_{q\sim D_{encoder}(x), x\sim I_{real}}[|\,|\kappa\,(q) - \tau\,(x)|\,|] \tag{3.2}$$

The decoder's function reflects operations on example κ from real pictures, I_{real} and the discriminator's feature map is q.

3.4. Data Analysis Tool. After creating and compiling the questionnaire online using Google Forms, we analyzed and verified the reliability of the descriptive data collected from the sample using SPSS Statistics 25.0. Finally, users can get the data to back up their research models and theories by using IBM SPSS AMOS.

Cronbach's alpha (α), composite reliability (CR), average variance extracted (AVE), and the standardised factor loading of the test items were used to quantify reliability and convergent validity. The acceptance threshold for each measurement's standardised factor loading needs to be higher than 0.700. An internal consistency technique called Cronbach's alpha (α) is used to assess how consistently respondents answered each item in the measurement in this study. Valid alpha values fall between 0.7 and 0.8, whereas values greater than 0.9 indicate exceptionally high internal consistency.

Average variance extracted (AVE) and composite reliability (CR) are two metrics that can be used to assess convergent validity. The constraint in loadings would be the distinction between α and CR. Whereas the weights or loadings for Cronbach's alpha are always required to be identical, the build loadings for CR are flexible. A CR value of 0.8 or higher is regarded as satisfactory. To be deemed acceptable, the average variance extracted (AVE) must be more than 0.5.

VR and digital media facilitate collaboration among designers, clients, and other stakeholders by providing a common visual language. This is particularly useful in projects where decision-makers are geographically dispersed. These tools enable rapid prototyping and iterations based on feedback, making the design process more agile and responsive to user needs.

4. Result Analysis. The proposed method evaluates the performance using parameters such as accuracy, precision, recall and f1-score for interior space design.

Accuracy is an important parameter in many machine learning tasks, including deep learning tasks, but in the context of research on Visualization and Interactivity of Virtual Reality (VR) Technology and Digital Media in Interior Space Design, it may not be the only metric to pay attention to. Because of the nature of the research, both subjective and objective criteria are used.

Analyze how well deep learning models are at tasks like object detection, image recognition, and, if relevant, natural language processing. Consider additional metrics such as F1-score, precision, and recall, particularly if the research entails tasks. Use subjective metrics, like user surveys, interviews, and feedback, to evaluate the user experience. Consider elements like as immersion, enjoyment, and simplicity of engagement.

Compare the virtual and real-world interior space representations to see how realistic they are. This may entail the subjective evaluations of users or interior design specialists. Calculate how quickly the system reacts to user input in the virtual environment. Experiences with low latency are more immersive and participatory. In figure 4.1 shows the evaluation of accuracy.

In research, precision refers to making sure that the techniques, measurements, and analyses used in the study are precise, dependable, and in line with the goals of the investigation. Here are some things to keep in mind when conducting a research study on the interactivity and visualization of digital media and Virtual Reality (VR) technologies in interior space design. Clearly state the goals of the study on the use of digital and virtual reality for interior space design visualization and interactivity. Make sure the goals are in line with the study's overall aims. Researchers can improve the accuracy of their investigation into the visualization and interaction of virtual reality technology and digital media in interior space design by taking these factors into account. Throughout the research process, returning to and improving these elements on a regular basis enhances the overall quality and dependability. In figure 4.2 shows the evaluation of precision.

Recalling or summarizing the main points and objectives of the research is undoubtedly what is meant by "recall" in the context of studies on the visualization and interaction of digital media and virtual reality technology in interior space design. It entails recalling the primary goals, approaches, and essential elements of the research. Examine the state of virtual reality and digital media today, as well as how they are being used in interior design. Create deep learning models to enhance the interior space visualization. Examine ways to use VR and digital media to improve interaction in virtual settings. Establish a smooth connection between VR technologies and deep learning models to portray interior spaces. In figure 4.3 shows the evaluation of recall.

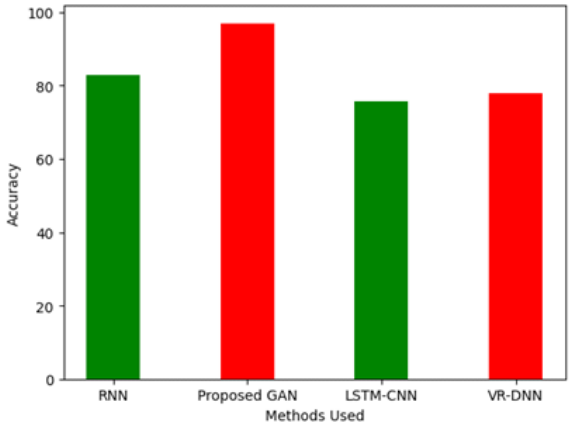

Fig. 4.1: Accuracy

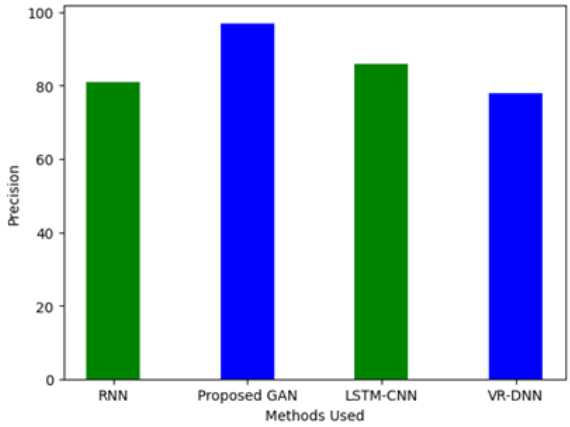

Fig. 4.2: Precision

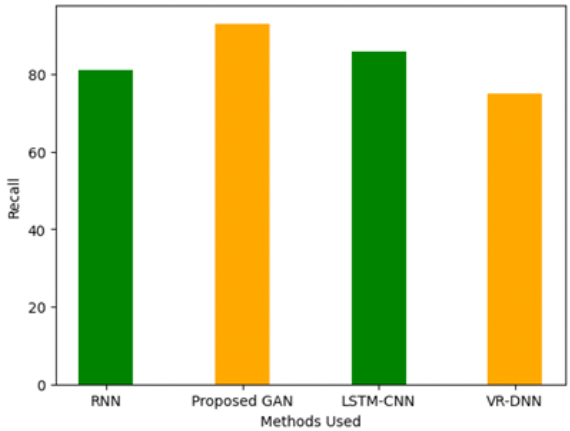

Fig. 4.3: Recall

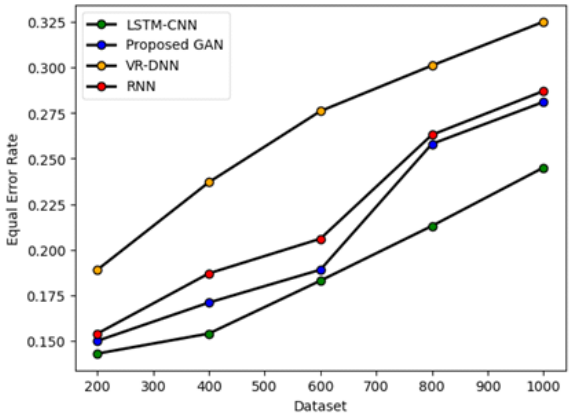

Fig. 4.4: Evaluation of Error Rate

In contrast to certain other domains, such machine learning classification tasks, the concept of "error rate" is not as simple when applied to study on the presentation and interactivity of digital media and Virtual Reality (VR) technologies in interior space design. You can test accuracy in the context of deep learning models that you may utilize for different tasks in your research. This represents the percentage of cases that were accurately anticipated or classified. For instance, accuracy would be the percentage of elements properly classified in a VR environment where your deep learning model is used to classify interior elements. A variety of indicators, including completion rates, task success rates, and user satisfaction ratings, are used to evaluate the effectiveness of interactive features.

Consider measures like rendering speed and latency that are associated with the VR experience's quality. In this case, low error rates would imply no lag or delay in the virtual environment's rendering, which would enhance the user experience and make it more immersive. When conducting usability testing, user comments can also be used to estimate error rates. For example, it suggests a higher error rate in terms of user experience if users complain or run into problems during specific interactions. Analyse the error rates according to ethical and privacy concerns. In the context of ethics, incidents involving illegal data access or privacy violations could be regarded as mistakes. In figure 4.4 shows the evaluation of Error Rate.

When calculating the F1-score for a research project, one must evaluate how well recall and precision are balanced in relation to the objectives of the study. You can define the F1-score as striking a balance between the deep learning models' accuracy and their capacity to capture the nuances of interior space design in the context of your research on the visualization and interactivity of virtual reality (VR) technology and digital media in interior space design using deep learning methods.

An excellent balance between recall and precision is shown by a high F1-score, which implies that interior design components are extensively and accurately captured by the deep learning models. A low F1-score could be a sign of a trade-off between recall and accuracy, where the models perform well in recollection but poorly in the former. Assess the F1-score on a regular basis at various points in your research, such as following model training, prototype building, and user testing, to monitor how well your technique is working to accomplish the aims of the study. Based on the F1-score results, modifications can be made to the models and techniques to improve their precision and recall. In figure 4.5 shows the evaluation of F1-score.

5. Conclusion. Within the interior space design sector, the integration of digital media and Virtual Reality (VR) technology has become a disruptive force, altering the way design is explored and enhancing its immersive features. This study investigates the intersection of these dynamic domains, looking at the significant implications of deep visualization and technology contact on the conceptualization and interaction with interior environments. Through a detailed analysis of cutting-edge VR tools, multimedia services, and technology, this study aims to reveal the interactions that propel interior designing environments into a new era of creativity

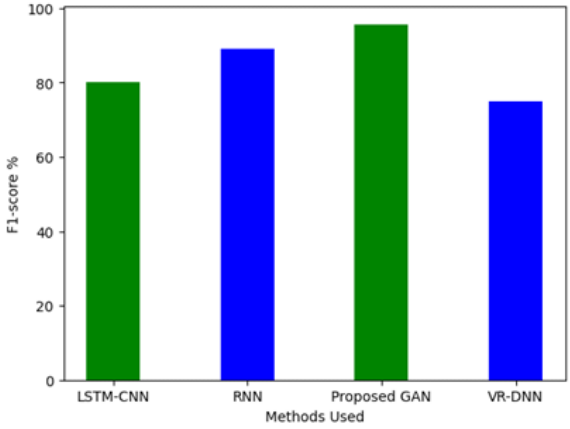

Fig. 4.5: F1-score

and user engagement. The research methodology comprises a detailed analysis of widely utilized digital media techniques and virtual reality technologies in the interior design sector. We'll conduct user feedback surveys and real-world case studies to evaluate how well these technologies facilitate group decision-making and the communication of design concepts. The study attempts to identify the primary opportunities and challenges related with the integration of VR and electronic media into interior space architecture, considering factors like accessibility, visual dedication, and real-time engagement. The outcome of this study will be the recommendation of a framework for the most effective application of virtual reality and digital media in interior design. The framework is meant to act as a roadmap for designers, architects, and other pertinent stakeholders as they make the most of these technologies to enhance user experience, visualization, and collaboration. Additionally, the project will contribute meaningful data to the greater discussion on how to develop.

Address the ethical and privacy implications of using VR and digital media in interior design, particularly in relation to data collection, user consent, and the digital representation of private spaces. Developing guidelines and best practices for ethical use of these technologies will be crucial as their adoption grows.

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