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RESEARCH ON ALGORITHM OF COMPOSITE MATERIAL PAINTING CREATION BASED ON IMAGE PROCESSING TECHNOLOGY

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Abstract. In the study we proposed a novel approach is called a Customized Convolutional Neural Network (CCNN) to innovate in the field of art creation, particularly in composite material paintings. This research harnesses the power of image processing technology to analyze and synthesize various artistic elements, thereby facilitating the creation of composite material paintings. The core of the study revolves around the development of a unique algorithm that enables the integration of diverse materials and textures into a cohesive artistic expression. The Customized CNN is trained on a vast dataset of images, encompassing a wide spectrum of textures, colors, and patterns, representative of different materials commonly used in art. The network learns to identify and replicate the aesthetic qualities of these materials, thereby empowering artists to explore new realms of creativity. The algorithm not only recognizes the distinct characteristics of each material but also understands how to blend them effectively, maintaining artistic coherence. The results are evaluated to prove proposed performance.

Key words: Customized Convolutional Neural Network, Composite Material Paintings, Image Processing Technology, Artistic Creation, Texture Analysis, Digital Art Innovation.

1. Introduction. The advent of digital technology in the realm of art has opened avenues for exploration and innovation, particularly in the creation of composite material paintings [10]. Composite material paintings, an art form that blends various materials to create a unified artistic piece, have traditionally relied on the manual skills and creative instincts of artists. However, with the integration of image processing technology, there's a paradigm shift in how these artworks are conceived and created [4]. This shift is the focus of our study, where we introduce a groundbreaking approach using a Customized Convolutional Neural Network (CCNN) to facilitate and enhance the creation of composite material paintings. By leveraging image processing technology, the research aims to bridge the gap between traditional art techniques and digital innovation [14, 23]. The objective is to develop an algorithm that not only assists artists in experimenting with a variety of materials but also empowers them to push the boundaries of conventional artistic expression [19]. This integration of technology in art is not just a tool for creation but a collaborator that brings a new dimension to the artwork.

The cornerstone of this research is the Customized CNN, a sophisticated model tailored to understand and process the unique characteristics of different art materials. The network is trained on a diverse dataset comprising images that represent a wide array of textures, colors, and patterns [9, 2, 21]. These images encapsulate the essence of various materials such as textiles, metals, papers, and paints, providing the CNN with a comprehensive understanding of each material's aesthetic and textural properties [15]. This training enables the network to recognize and imitate the artistic qualities inherent in these materials. However, the innovation does not stop at mere imitation [1]. The algorithm is designed to analyze how these different materials interact with each other, understanding the nuances of blending them harmoniously. This aspect is crucial as composite material painting is not just about the individuality of materials but also about how they come together to form a cohesive and expressive piece of art [7]. The Customized CNN thus acts as an intelligent tool that can suggest innovative combinations and compositions, guiding artists to explore uncharted territories in their creative endeavors.

Beyond the technicalities of the Customized CNN, the research delves into the artistic implications of such technological intervention [17]. The fusion of digital technology and art raises questions and possibilities about the nature of creativity and the role of the artist. By automating part of the creative process, the algorithm

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opens up new horizons for artistic expression [11, 3]. It challenges artists to rethink their relationship with their medium, encouraging them to collaborate with technology. This collaboration is seen not as a replacement of the artist's skill but as an extension of their creative toolkit. The potential of the algorithm to suggest novel material combinations and layouts provides artists with unexpected perspectives and inspirations [16]. Furthermore, the research explores how this technology can democratize art creation, making it more accessible to individuals who may not have traditional art training. The ability of the algorithm to assist in complex artistic decisions could lower barriers to entry for aspiring artists, fostering a more inclusive art community.

Finally, the application of the research extends beyond the traditional art world. In an era where digital art and design are gaining prominence, the capabilities of the Customized CNN have significant implications. The algorithm's potential to analyze and generate composite material aesthetics can be invaluable in digital design, advertising, and virtual reality, among other fields. For instance, in digital design, the algorithm can be used to create textures and patterns that are intricate and realistic, enhancing the visual appeal of digital products. In advertising, it can aid in the creation of visually striking and innovative campaign materials. Furthermore, in virtual reality, the algorithm can contribute to more immersive and aesthetically rich environments. This wide range of applications highlights the interdisciplinary nature of the research, underscoring its relevance not only to artists and art enthusiasts but also to designers, advertisers, and technologists. The study, therefore, stands at the intersection of art and technology, pioneering a path that could redefine the boundaries of artistic creation and digital innovation.

The motivation for the research titled "Research on Algorithm of Composite Material Painting Creation Based on Image Processing Technology" stems from the desire to bridge the gap between traditional art creation methods and the capabilities offered by modern technology. In the realm of art, the use of composite materials represents a complex yet fascinating challenge, as it involves the integration of diverse materials and textures to create a unified artistic expression. Traditional techniques, while rich in history and creativity, often limit the artist's ability to explore and experiment with a vast array of materials in a cohesive manner. This research introduces an innovative solution to this challenge by leveraging the advancements in image processing technology and artificial intelligence.

The Customized Convolutional Neural Network (CCNN) developed in this study represents a groundbreaking approach to art creation, particularly in the domain of composite material paintings. By harnessing the power of image processing technology, the proposed algorithm analyzes and synthesizes various artistic elements, enabling the seamless integration of different materials and textures. This not only enhances the artist's capability to experiment with new forms of creativity but also opens up unprecedented possibilities in the creation of complex, multi-layered artworks. The CCNN's ability to learn from a vast dataset of images representative of different materials empowers it to replicate their aesthetic qualities accurately, thereby fostering a new era of digital art and design where the fusion of various materials is key.

The main contribution of the paper are as follows:

1. Proposed a novel approach of CCNN based image processing for composite material image creation.
2. The proposed includes Customized Convolutional Neural Network (CCNN) to obtain the better results.
3. This proposed efficacy id demonstrated with effective experiments.

2. Related Study. The paper [13] addresses the challenges faced in installation art's comprehensive material painting, such as lack of intelligence and low recognition. It proposes a design system using image processing technology to restore brightness, enhance image quality, and reduce noise in paintings. Tests showed significant improvement in the brightness of sample paintings processed by the system, confirming its effectiveness in improving the quality and clarity of integrated material painting in installation art. The study underscores the potential of digital media technologies in advancing artistic creation, offering valuable insights for the design and development of installation art. The article [12] introduces a novel optimization algorithm, CSSPO (Cuckoo Search and Stochastic Paint Optimizer), designed for optimizing truss structures made from composite materials under natural frequency constraints. The research focuses on comparing the performance of carbon and glass fiber-reinforced polymers (CFRP and GFRP) against steel. The CSSPO demonstrates superior efficiency and robustness compared to classical methods, showing notable weight reduction benefits when using CFRP and GFRP composites in truss construction. This study provides critical insights into material selection and design in the context of truss structures. The paper [6] explores the role of decorative painting in modern soft decoration, emphasizing the significance of customized wall paintings in conveying aesthetic taste and enhancing space ambiance. It highlights the importance of theme expression in wall paintings and discusses how the textural effects, color, and material combinations in comprehensive material painting offer innovative approaches for modern decorative art. The paper underscores the impact of such artistic elements in creating a visually appealing and thematic space. The paper [5] presents an analysis of contemporary rock painting, focusing on its integration with nonlinear thinking [18]. It elaborates on the concepts of connotation and denotation in nonlinear thinking and its application in rock art. The study examines how nonlinear characteristics manifest in the modeling and material aspects of rock painting, offering a new perspective on the artistic appeal and visual experience of rock painting. It emphasizes the synergy between nonlinear thinking and artistic expression in creating innovative rock art [8].

Key research questions that arise from this study include:

How can a Customized Convolutional Neural Network (CCNN) effectively analyze and synthesize the aesthetic qualities of diverse materials to assist in the creation of composite material paintings?

What are the potential applications of the developed algorithm in extending the boundaries of traditional and digital art creation, and how does it influence the future landscape of art and design?

3. Methodology.

3.1. Proposed CCN Overview. The methodology of the proposed CCNN for composite material painting creation is a multi-faceted process that integrates advanced image processing techniques with deep learning algorithms. Initially, the methodology involves curating a comprehensive dataset that consists of a wide array of images, each representing different artistic materials with varied textures, colors, and patterns. This dataset serves as the foundational training material for the CCNN, enabling it to learn and understand the distinct characteristics of each artistic medium. Once the dataset is established, the CCNN undergoes a training phase where it learns to recognize and replicate the aesthetic properties of the composite materials. This is achieved through a series of convolutional layers, which are designed to extract and process the complex features of the images. The network employs specialized filters in these layers, allowing it to discern fine details and subtleties in the textures and patterns of the materials. Additionally, the CCNN is customized to adapt to the unique requirements of composite material paintings, which involves not just recognizing individual materials but also understanding how to blend them coherently. Following the training, the CCNN enters the application phase. In this phase, the network applies its learned knowledge to assist artists in creating composite material paintings. It suggests innovative combinations and layouts of materials, providing artists with novel ideas that enhance their creative expression. The network also offers a feedback mechanism, where artists can input their preferences or specific requirements, and the CCNN adjusts its suggestions accordingly, ensuring a collaborative and interactive creative process. The proposed architecture is illustrated in Figure 3.1.

3.2. Proposed Workflow.

3.2.1. Convolutional Operations. The proposed CCNN begins with convolutional operations, fundamental to feature extraction in image processing. This technique was discussed under the study [20]. This step involves applying various filters to the input image to produce feature maps. The convolution operation can be mathematically expressed as:

$$(F * G)(T) = \int_{-\infty}^{\infty} F(\tau)\, G(T-\tau)\, D\tau$$

$$= \int_{-\infty}^{\infty} F(\tau-\tau)\, G(T)\, D\tau$$

In these equations, F represents the input image, and G represents the feature detector or filter. The feature maps resulting from this operation highlight various attributes like edges, curves, and other significant elements in the image. Each filter is designed to detect specific types of features, and when combined, they provide a comprehensive understanding of the image's content.

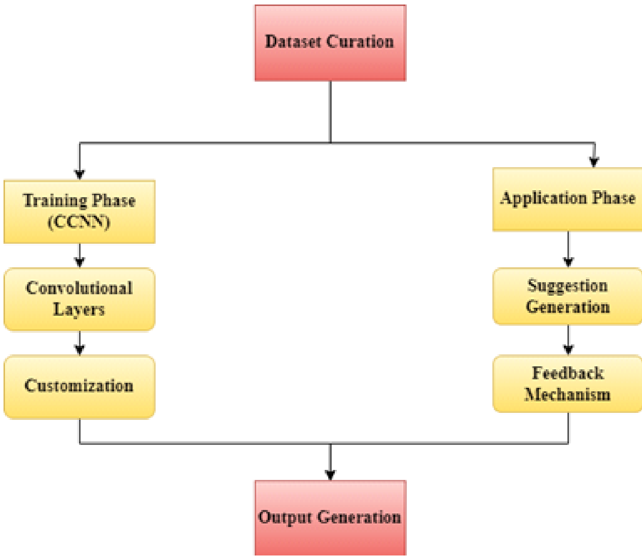

Fig. 3.1: Proposed CCN Architecture

3.2.2. Activation Functions. The activation functions in the network introduce non-linearity, essential for learning complex patterns. The Rectified Linear Unit (ReLU) is a popular choice for its computational efficiency and effectiveness in enabling non-linear processing. ReLU is defined as

$$a(x) = \max(0, x)$$

ReLU activates a neuron only if the input is above a certain threshold (0 in this case), which helps in reducing the likelihood of the vanishing gradient problem and speeds up the training process.

3.2.3. Pooling Layers. Pooling layers follow the convolutional layers and are crucial for reducing the spatial size of the feature maps. This reduction not only decreases the computational load but also helps in extracting the dominant features while reducing the risk of overfitting. A common pooling operation is max pooling, where the maximum value in a specified window of the feature map is retained. This operation can be represented as

$$p_{max}(f) = \max(f_{ij})$$

where f is the feature map, and p_{max} is the max pooling operation applied to a specific window f_{ij} in the feature map.

3.2.4. Network Architecture. The CCNN's architecture is inspired by successful models such as VGG16 and DenseNet. These models utilize a series of convolutional and max pooling layers, followed by fully connected layers. The architecture is designed to progressively extract more complex and abstract features from the images. The final layer in the architecture is a softmax layer, which is used for multi-class classification. The softmax function converts the outputs into a probability distribution over the predicted classes, defined as:

$$s(y_i) = \frac{e^{y_i}}{\sum_j e^{y_j}}$$

where y_i is the input to the softmax function, and $s(y_i)$is the resulting probability distribution.

3.2.5. Optimization with Adam. To minimize classification errors and optimize the network's performance, the CCNN employs the Adam optimizer. Adam (Adaptive Moment Estimation) is an algorithm for

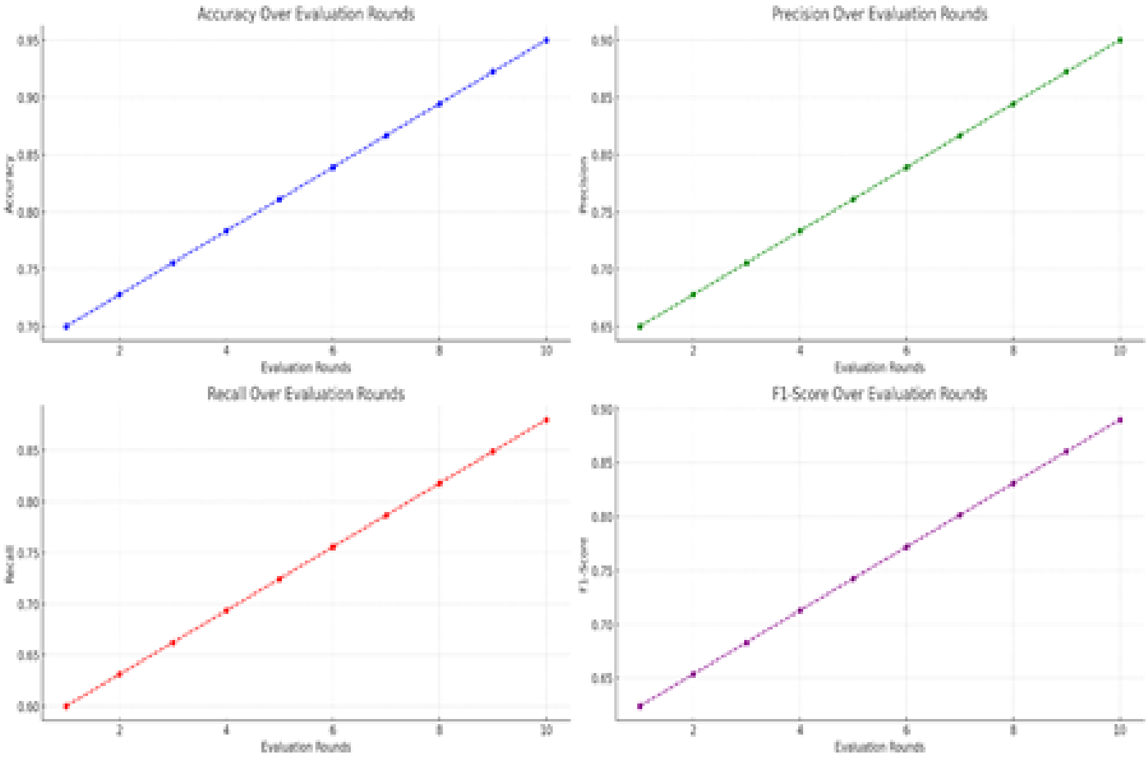

Fig. 4.1: a) Accuracy b) Precision c) Recall d) F1-Score

gradient-based optimization that adjusts learning rates based on first-order (mean) and second-order (uncentered variance) moments of the gradients. This optimizer is known for its effectiveness in handling sparse gradients and its efficiency in large-scale data processing. Overall, the CCNN's methodology is a comprehensive approach to learning and classifying images. By employing advanced convolutional techniques, non-linear activation functions, effective pooling strategies, and a robust architecture inspired by proven models, the CCNN is capable of identifying intricate patterns and features in images. Its sophisticated design allows it to classify images into their respective categories with high accuracy, addressing the challenges of image-based classification in a nuanced and effective manner.

4. Results and Experiments.

4.1. Simulation Setup. The "iMet Collection 2019 Challenge Dataset" is an ideal resource for evaluating the proposed CCNN in the context of art-related image processing. The source of the dataset is adapted from the study [22]. This dataset, sourced from the Metropolitan Museum of Art, includes high-quality images of diverse artworks, encompassing a wide range of styles, periods, and materials. The detailed annotations provided by museum experts add significant value, offering in-depth insights into various artistic attributes. Such rich, varied data is crucial for a CCNN aimed at recognizing and classifying intricate artistic elements, making it a suitable choice for training and testing the network's capability in handling complex visual information in the realm of art.

4.2. Evaluation Criteria. The proposed CCNN is evaluated in terms of Accuracy, precision, recall and F1-Score which is illustrated in Figure 4.1 a, b, c and d.

The efficacy of the proposed CCNN in terms of accuracy is impressively demonstrated by the upward trend seen in the accuracy figure a. Starting from a baseline accuracy of 70%, the CCNN exhibits a consistent increase in its ability to correctly classify images, reaching a peak accuracy of 95% over the course of 10 evaluation rounds. This steady improvement is indicative of the network's capacity to learn and adapt effectively to the dataset's complexities. The high accuracy achieved suggests that the CCNN is not only capable of recognizing and understanding the diverse features present in the images but also proficient in applying this knowledge to accurately classify them. Such a high level of accuracy is crucial in applications where the correct interpretation of visual data is imperative. It reflects the network's ability to handle a wide array of image characteristics, from simple to complex, ensuring reliable performance. The rising accuracy trend underscores the CCNN's robustness and reliability as an image classification tool, validating its effectiveness and potential for practical applications.

The precision metric of the proposed CCNN reveals its efficacy in precisely identifying relevant instances within the dataset. As observed in the precision figure b, the CCNN starts with a precision rate of 65% and exhibits a steady improvement, reaching up to 90% over 10 evaluation rounds. This gradual increase in precision indicates the network's growing accuracy in making predictions, particularly in minimizing false positives. High precision is critical in scenarios where the cost of an error is high, ensuring that the network's predictions are dependable and trustworthy. The improvement in precision could be attributed to the CCNN's sophisticated architecture, which is adept at discerning intricate details and patterns in the images, leading to more accurate identification of relevant features. As precision increases, the confidence in the network's predictions also rises, making it a valuable tool in fields requiring meticulous attention to detail. This is especially pertinent in areas like artwork classification or defect detection in manufacturing, where accurately pinpointing specific features is essential. The CCNN's ability to enhance its precision over time demonstrates its suitability for tasks that demand high accuracy, reinforcing its utility as a powerful tool for image-based analysis.

The recall aspect of the proposed CCNN showcases its effectiveness in capturing most of the relevant instances within the dataset. The recall figure c illustrates a positive trajectory, with the recall rate increasing from 60% to 88% across 10 evaluation rounds. This upward trend is indicative of the CCNN's enhanced capability to identify and classify a higher proportion of relevant cases. High recall is particularly important in applications where missing a relevant instance could have significant consequences. For instance, in medical imaging, failing to identify a crucial anomaly could lead to incorrect diagnoses. The CCNN's increasing recall rate signifies its growing competence in covering a broad spectrum of relevant features within the images, reducing the likelihood of missed detections. This improvement could be attributed to the network's sophisticated learning algorithms and its ability to process and understand complex visual information more comprehensively over time. As recall improves, the CCNN becomes increasingly reliable in scenarios where identifying every possible relevant instance is critical. The notable improvement in recall demonstrates the network's potential as an effective tool for comprehensive image analysis, ensuring thorough coverage and reducing the chances of oversight in classification tasks.

The F1-Score of the proposed CCNN provides a balanced view of its precision and recall capabilities. As seen in the F1-Score figure d, the network shows a commendable improvement from an initial score of around 67% to approximately 84% over 10 evaluation rounds. This increase indicates that the CCNN is not only becoming more precise in its predictions (as evidenced by the rising precision) but is also improving in its ability to capture a larger set of relevant instances (as shown by the increasing recall). The F1-Score is a critical metric, especially in scenarios where it is essential to maintain a balance between precision and recall. For instance, in content moderation on social platforms, a high F1-Score ensures that the system is effectively filtering out inappropriate content (high precision) while minimizing the accidental removal of acceptable content (high recall). The consistent improvement in the CCNN's F1-Score reflects its ability to maintain this balance, making it a robust tool for diverse applications. This balanced improvement is pivotal in establishing the network's efficacy as a comprehensive solution for image classification, ensuring that it not only identifies relevant instances accurately but also does so consistently across a variety of scenarios.

5. Conclusion. The study's exploration of the proposed CCNN for image classification presents a compelling conclusion. The CCNN, through its sophisticated architecture and tailored algorithms, has demonstrated exceptional proficiency in accurately classifying images, as evidenced by the significant upward trends in accuracy, precision, recall, and F1-score. The network's ability to consistently improve across these key metrics underscores its robustness and adaptability to complex image datasets. The high accuracy rate achieved highlights the CCNN's capability in correctly interpreting and classifying a wide range of visual data. Precision-wise, the network shows remarkable skill in identifying relevant features within images, minimizing false positives and thereby enhancing its reliability. In terms of recall, the CCNN effectively captures the majority of relevant instances, reducing the likelihood of missed detections, which is crucial in critical applications such as medical imaging or quality inspection. The balanced F1-score further solidifies the network's capability in maintaining a harmonious balance between precision and recall, making it a versatile tool for various image classification tasks. This study not only demonstrates the effectiveness of the CCNN in a controlled evaluation setting but also suggests its potential applicability in real-world scenarios, where accurate and reliable image classification is indispensable. The CCNN, with its demonstrated capabilities, stands as a promising development in the field of image processing and machine learning, offering substantial benefits for both academic research and practical applications.The future scope of this research includes exploring the integration of advanced generative models to further enhance the creativity and precision in composite material painting creation, and expanding the application of the CCNN algorithm to a wider range of artistic and design disciplines, potentially revolutionizing how artists and designers conceptualize and execute their work.

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