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Computer-Aided Design AND APPLICATIONS

Exploration of CAD and Neural Network Integration in Art Design and Cultural Heritage Protection

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Abstract. There is a close connection between art and design and intangible cultural Heritage (ICH). Art and design can study ICH, extract artistic elements from it, and then transform concepts into practical design. With the help of digital technology, high-precision replication, storage, and dissemination of ICH can be achieved, enabling more people to come into contact with and understand ICH. Computer-aided design (CAD) tools can help designers create designs more efficiently and achieve precise expression of design concepts. In order to innovate the means of digital ICH protection, this article combines CAD and neural network technology to propose an ICH art-style rendering algorithm based on deep neural networks (DNN). The successful use of this algorithm in the experimental phase has demonstrated that DNN can learn and simulate different artistic styles, adding rich artistic effects to ICH images. The CAD and neural network technology can provide unlimited art design and ICH protection.

Keywords: CAD; Neural Network; Art Design; Intangible Cultural Heritage
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1 INTRODUCTION

There is a close relationship between art design and ICH. ICH, as a vivid expression of human creativity and cultural diversity, contains rich elements such as modelling forms, patterns and production techniques, which are important references for art design. Barrile et al. [1] explored how to integrate art information methods using CAD and AR technology and create a cultural heritage application to enhance public awareness and protect cultural Heritage. CAD, as a powerful design and modelling tool, provides new possibilities for the integration of artistic information. Firstly, CAD can accurately create and edit three-dimensional models of artworks, capturing their detailed structures and features. Secondly, through parametric design, CAD can efficiently adjust and optimize the design elements of artworks; CAD can also convert artworks into digital archives for subsequent virtual displays and research purposes. Augmented reality (AR) technology can expand our visual experience by overlaying virtual information onto the real world. In art information integration, AR technology can be used to display virtual replicas of artworks or interactively integrate artworks with other environments. In addition, AR can also be used to create dynamic displays of artworks, allowing viewers to observe artworks from multiple perspectives, even internally, in order to gain a deeper understanding and perception. Firstly, the application can include precise 3D models, allowing users to appreciate cultural Heritage fully. Secondly, through AR technology, applications can provide an interactive experience, allowing users to engage in virtual interaction with cultural Heritage.

Art design can study ICH, extract the artistic elements, and then change from concept to actual design. This way of combining traditional culture with modern design can not only inherit and develop traditional culture but also promote art design. With the growth of information technology and AI, people's lifestyles are undergoing unprecedented changes. This era provides unprecedented opportunities. The combination of CAD and augmented reality (AR) especially provides us with powerful tools to create and maintain virtual Heritage. Bekele [2] explores how to utilize cloud-based collaboration and multimodal mixed reality for art design and cultural heritage protection. Cloud-based collaboration is a form of remote collaboration through cloud platforms. Cloud-based collaboration can promote team collaboration on a global scale, allowing team members to share and edit project files in real time regardless of their location. This provides the possibility for interdisciplinary cooperation, allowing experts from different backgrounds and professional fields to jointly participate in the protection of cultural Heritage. And real environments. In art design and cultural heritage protection, multimodal mixed reality provides multiple ways of display and interaction. For example, through AR technology, viewers can see virtual cultural relics and historical scenes in a real environment. Through VR technology, viewers can immerse themselves in the environment of cultural Heritage and experience historical events. This change also affects the fields of art design and ICH protection. Traditional art design and ICH protection methods are being integrated with emerging technologies. Digital heritage protection is a highly integrated art and technology, and it is a brand-new digital art form. In the protection of 3D/VR cultural heritage, CAD can be used to establish digital models of cultural Heritage to reproduce and display details accurately. For example, through CAD software, it is possible to accurately draw three-dimensional models of buildings, simulate materials and lighting, and better reproduce the appearance and details of buildings at different angles and times. In addition, CAD can also perform efficient parametric design, achieving rapid optimization and iteration of cultural heritage models by adjusting design parameters. Bozorgi et al. [3] explore how to integrate CAD and neural networks as the core 3D/VR technology for cultural heritage protection, providing new solutions. Analyzing and predicting the emotional response of audiences to the digital display of cultural Heritage through neural networks can help researchers better grasp the needs and feedback of audiences. Predicting a large amount of cultural heritage data can provide researchers with tools for data analysis and decision support.

ICH can be copied, stored, and disseminated with high precision so that more people can get in touch with and understand it. Taking Cantonese opera as an example, the classification of its singing genres has always been a research focus. Chen et al. [4] explored how to use artificial intelligence technology, especially the CoGCNet model. The CoGCNet model is a convolutional graph attention network model that can capture structural information in a graph by learning the relationships between nodes. In the task of classifying Cantonese opera singing genres, we can use the singer's singing style, timbre, techniques, and other characteristics as nodes and use the relationships between singers with similar styles as edges to construct a graph network of singing styles. Then, the CoGCNet model was used to learn the graph network and ultimately achieve the classification. A large amount of Cantonese opera singing data was selected for experiments, and the CoGCNet model was compared with traditional machine learning methods. The CoGCNet model has significant advantages in the classification task of Cantonese opera singing genres, with an accuracy improvement of about 10% compared to traditional machine learning methods. This not only expands the influence of ICH but also enhances the public's understanding of ICH protection. Digital technology can also help us to repair and reproduce ICH virtually and understand its original appearance and historical information without damaging the original ICH. Guo and Li [5] discussed how to integrate CAD with neural networks to innovate the design and production of art video streams. Designers can use CAD software to design basic elements such as video composition, colour, lighting, and shadow accurately. Designers can convert their creativity into concrete video content by manipulating CAD software. In the production of art video streams, neural networks can leverage their unique advantages. For example, by training neural networks to identify specific elements in videos, such as colours, shapes, actions, etc., designers can achieve automated editing and optimization of videos. In addition, neural networks can also be used to predict audience reactions, helping designers better understand audience preferences and optimize video design and production.

CAD, as a computer-aided design tool, provides infinite possibilities for art painting. In computer-aided art drawing, CAD can be used to create and edit images, including colour design, shape construction, lighting effects, etc. In addition, CAD also has powerful image processing functions, such as colour adjustment, filter application, etc., which can achieve fine processing and optimization of images. He and Sun [6] discussed how to integrate CAD and neural networks into computer-aided art painting to better showcase traditional artistic colours. Integrating CAD and neural networks can leverage their advantages. For example, designers can use CAD software to design basic elements of art painting and then use neural networks to optimize and predict images. At the same time, designers can also use the prediction results of neural networks to adjust the design scheme to achieve better results. By integrating CAD and neural networks, designers can gain more possibilities in computer-aided art drawing. The combination of precise design in CAD and the powerful predictive ability of neural networks can enable designers to understand the audience's reactions better and optimize the design and production of art paintings.

Nowadays, ICH has been paid attention to and protected by the state. If these treasures are used in the design, these ICH will exist and spread in another form. By utilizing deep learning techniques, models that can recognize and classify landscape paintings and classical private gardens can be trained. These models can automatically extract features and patterns from a large number of art images and design drawings, thereby achieving automatic classification and recognition of new images. Hong et al. [7] use it to transform original Chinese landscape paintings and classical private garden images into virtual scenes with a target aesthetic style. Specifically, the original image can be input into a neural network model, and then a virtual scene image with the target aesthetic style can be generated. They can be applied to the generation and rendering of virtual scenes, achieving the transformation and integration of different artistic styles. Using deep neural networks to analyze and learn data, extracting aesthetic features. These features can include aesthetic elements such as colour matching, line application, and spatial layout. Based on the extracted aesthetic features, use computer graphics technology to construct virtual scenes, including elements such as mountains, water, buildings, plants, etc. By adjusting rendering parameters and lighting conditions, achieve aesthetic style transformation of Chinese landscape painting or classical private gardens. Provide viewers with virtual reality (VR) devices or immersive display platforms, allowing them to experience the aesthetic style transition between Chinese landscape painting and classical private gardens firsthand. Viewers can change the elements and parameters in the scene through interactive operations and experience real-time changes in different aesthetic styles. Jin and Yang [8] discussed how to integrate CAD with neural networks to innovate the teaching mode of environmental art and design, improve teaching quality, and enhance students' practical abilities. CAD, as a computer-aided design tool, has the characteristics of high precision, is editable, and is easy to operate, providing strong support for environmental art design. CAD can help students accurately draw design drawings and carry out complex design work such as spatial planning, landscape design, interior decoration, etc. In addition, CAD can also use 3D modelling technology to enable students to experience design effects more intuitively and improve their spatial imagination and practical abilities.

By training neural networks, teachers can guide students to predict and optimize design drawings. For example, neural networks can be used to analyze the effects of different design schemes and select the best solution. This provides the possibility for applying neural networks to art design and ICH protection in this study. In order to innovate the means of digital ICH protection, this article combines CAD and neural network technology to propose a DNN-based ICH art-style rendering algorithm. This algorithm can learn a large amount of ICH image data, extract artistic style features from it, and then apply them to new designs, thereby achieving the inheritance and growth of ICH's artistic style. This algorithm can automatically adjust the design style, colour, layout, and other elements according to the designer's needs, generating a design scheme that conforms to the ICH artistic style and continuously improving design quality. Specifically, this study has the following innovations:

(1) This article combines CAD and neural network technology to propose a novel ICH art-style rendering algorithm. This algorithm learns a large amount of ICH image data, extracts artistic style features from it, and applies them to new designs, thereby achieving the inheritance and growth of ICH's artistic style.

(2) A continuous optimization and learning mechanism based on user feedback was adopted in the study, enabling the algorithm to automatically adjust based on user feedback. This innovation enhances the adaptability of the algorithm, enabling it to better meet the needs of designers and users.

The first section introduces the background and purpose; The second section explores the close connection between art and design and ICH; The third section explores new trends in digital heritage protection; The fourth section elaborates on the ICH art style rendering algorithm based on DNN in detail; The fifth section provides a detailed analysis of the experimental results and discusses their implications for ICH protection; The fifth section summarizes the research results and looks forward to future research directions.

2 RELATED WORK

Over time, many churches, monuments, and museums that embody Byzantine cultural characteristics have suffered varying degrees of damage. With this valuable cultural Heritage, the integration of computer-aided design (CAD) and neural networks using immersive technology has become an effective method. Kontopanagou et al. [9] explored the framework for constructing a church/monument/museum that utilizes CAD, neural networks, and immersive techniques to explore the influence of Byzantine culture. Using advanced scanning and measurement techniques, high-precision data collection is carried out on churches/monuments/museums influenced by Byzantine culture. They are using neural networks to process collected data for automatic classification and feature extraction. Through CAD technology and neural network models, damaged parts can be virtually repaired while developing targeted protection strategies. Modern aesthetic elements can be combined with traditional Byzantine culture to achieve innovative design. Through immersive technology, visitors can gain a deeper experience and understanding of the charm of Byzantine culture, promoting its inheritance and development.

Art and architectural Heritage is a precious cultural heritage of humanity, with extremely high historical, cultural, and artistic value. However, these heritage sites often face threats such as natural erosion and human destruction, making digital conservation an important means of protection. Li et al. [10] summarized the tools and technologies used in the integration of CAD (computer-aided design) and neural networks in the digital protection of artistic and architectural Heritage. By using CAD software, high-precision 3D modelling of art and architectural Heritage can be carried out, accurately obtaining detailed information such as structure, texture, and shape and providing basic data for subsequent protection and research. Using CAD technology, damaged art and architectural Heritage can be virtually restored. Through precise modelling and image processing, damaged parts can be repaired and their original appearance restored. Through CAD technology, innovative design can be carried out on art and architectural Heritage, combining modern aesthetics and traditional elements to create art and architectural Heritage that conforms to modern aesthetics, providing support for the inheritance and development of art and architecture. Through neural network technology, one art style can be transferred to another, achieving innovative design of artistic architectural Heritage. For example, modern fashion elements can be integrated into traditional art architectural design to create a brand-new artistic style. CAD and neural networks have become innovative core technologies. Especially for sculpture art design, the integration of these two will open up a new design mode. Liu and Yang [11] discussed how to integrate CAD and neural networks as the core to promote the progress of contemporary sculpture art design. Through CAD software, designers can accurately draw 3D models of sculptures and simulate them in virtual reality, thereby better grasping the details and effects of the design. In addition, CAD can also perform efficient parametric design, achieving rapid optimization and iteration of sculpture works by adjusting design parameters. A neural network is the connectivity of human brain neurons and has strong learning and prediction capabilities. In sculpture art design, emotion, aesthetics, and other aspects of sculpture works. For example, training neural networks to identify specific elements in sculpture works, such as lines, shapes, materials, etc., can help designers better understand the audience's aesthetic preferences. In addition, neural networks can also be used to predict sculpture works, thereby helping designers optimize the design and production of sculpture works. However, over time, these precious cultural heritages face threats such as damage, loss, and difficulties in inheritance. If the Qin Opera costumes are damaged or lost, CAD technology can be used to repair and restore them. By precise data measurement and model reconstruction, the original state of the costumes can be restored, and their service life can be extended. Liu et al. [12] discussed the application of CAD and neural network integration in the research. Through CAD software, high-precision 3D modelling and the details of costume structure, texture and shape can be obtained, providing basic data for subsequent protection and research. With CAD technology, damaged Qin Opera costumes can be virtually repaired. Through accurate modelling and image processing, damaged parts can be repaired, and the original appearance of costumes can be restored. Through CAD technology, Qin Opera opera costumes can be innovatively designed, and modern aesthetic and traditional elements can be combined to create Qin Opera opera costumes that conform to modern aesthetics, providing support for the Qin Opera art.

The application of digital twins and neural network-integrated image technology in art museums and cultural heritage protection is gradually emerging. This technology can create high-precision digital models and use neural networks for feature extraction and recognition, restoration, and innovative design of art and cultural Heritage. Luther et al. [13] explored the application of CAD digital twin and neural network-integrated image technology in art museums and cultural Heritage. Through CAD technology, high-precision 3D modelling can be performed on artistic works and cultural Heritage, obtaining detailed information such as structure, texture, and shape and providing basic data for subsequent protection and research. By utilizing CAD technology, damaged artworks and cultural Heritage can be virtually restored, and the damaged parts can be restored to their original appearance through precise modelling and image processing. Through neural network technology, one art style can be transferred to another, achieving innovative design of artistic works and cultural Heritage. For example, modern fashion elements can be integrated into traditional art design to create a brand-new artistic style. The integrated application of CAD digital twins and neural networks can achieve innovative designs of artworks and cultural Heritage, combining traditional elements with modern aesthetics. The integration application of CAD digital twins and neural networks requires interdisciplinary cooperation, including computer science, architecture, art, cultural heritage protection, and other fields. This interdisciplinary cooperation between different fields and promote the comprehensive development of cultural heritage protection work. Ancient ceramic art is an important heritage of human civilization, with extremely high historical, cultural, and artistic value. However, due to various reasons, many ancient ceramic artworks have been damaged or lost. In order to protect and restore these precious artworks, researchers are constantly exploring new technologies and methods. In recent years, virtual reality technology integrated with computer-aided design (CAD) and neural networks has gradually been applied in the field of ancient ceramic art restoration, achieving significant results. Ming et al. [14] provide a systematic review of the latest research on the integration of CAD and neural networks in virtual reality technology for ancient ceramic art restoration. CAD, as a powerful computer-aided design tool, has played an important role in the restoration of ancient ceramic art. Through precise modelling and image processing techniques, researchers can reconstruct lost ceramic artworks, repair damaged parts, and provide virtual displays and interactive experiences. It also classifies the characteristics and defects of ceramic artworks and provides repair suggestions and optimization solutions.

Traditional art weaving cultural Heritage is one of the precious cultural heritages of humanity, with unique historical, cultural, and artistic value. However, these heritage sites often face threats such as natural erosion and human destruction, making restoration and protection a crucial task. In the context of the integration project of CAD and neural networks, Nieto et al. [15] explored the collaborative workflow for the restoration and protection of traditional art-weaving cultural Heritage. Process the collected data, convert it into a computer-readable format, and standardize it to adapt to the learning and training of neural networks. Design a neural network model suitable for traditional art weaving cultural Heritage and use the training set for training to optimize the parameters and structure of the model. By combining modern aesthetics and traditional elements, utilizing CAD technology and neural network models, innovative design of traditional art weaving cultural heritage is carried out to create artworks that conform to modern aesthetics. In the integration project of CAD and neural networks, the restoration and protection of traditional art weaving cultural heritage can be achieved through data collection and processing, CAD model establishment, neural network model training and prediction, virtual restoration and protection, innovative design and inheritance, and interdisciplinary cooperation and communication. The restoration is one of the current research hotspots, and point cloud data, as one of the key technologies, has been widely applied. Point cloud data is a type of object surface spatial coordinate data obtained through technologies such as 3D laser scanning, which can be used for high-precision digital modelling and protection of cultural Heritage. However, point cloud data, extracting the required objects and features, is an important issue in the digital protection and restoration of cultural Heritage. In response to this issue, Pierdicca et al. [16] have designed a suitable neural network model for the semantic segmentation of point cloud data. The design of the loss function is aimed at optimizing the network model and improving segmentation accuracy. Traditional point cloud segmentation methods often rely on manual feature extraction and classifier design, making it difficult to meet the complex and ever-changing semantic segmentation needs. Therefore, point cloud semantic segmentation methods based on deep learning frameworks are of great significance. Based on manually extracted features or rules for classification, it is challenging to handle complex scenes and diverse cultural Heritage. The point cloud semantic segmentation method based on a deep learning framework can use deep neural networks to learn feature representations automatically, improving the accuracy and robustness of classification.

Heritage is an important component of the region's unique history and culture. However, many of these historically valuable buildings have been destroyed or abandoned. In order to protect and reassess this architectural Heritage, the use of CAD (computer-aided design) and neural network technology as the core has become a feasible method. Sanchez et al. [17] explored protecting and reassessing the state's local architectural Heritage. CAD, as a computer-aided design tool, provides precise modelling and efficient production for the protection of local architectural Heritage. The structure and appearance of local buildings can be accurately drawn, and their materials, construction, and historical background can be recorded in detail. In addition, CAD can also simulate virtual repair and protection plans to evaluate the actual effectiveness of various protection measures. In the protection of local architectural Heritage, neural networks can be used to analyze and predict data on architectural Heritage. For example, training neural networks to identify key information such as structural characteristics, material types, and historical value of buildings can assist researchers in better understanding the characteristics and value of local architectural Heritage. In addition, neural networks can also be used to predict audience reactions to local architectural Heritage, thereby helping to develop more precise protection and promotion strategies. Digital technology has become an important tool for protecting and inheriting cultural Heritage. The integration of CAD and neural networks provides new research and practical opportunities for the field of digital cultural Heritage. Schuster and Grainger [18] discussed integration technology to collaborate with students and discover lost museums together. CAD is a precise computer-aided design tool. Firstly, CAD can be used to create high-precision Cultural Heritage, fully capturing their shape, structure, and details. In addition, CAD can also be used to simulate virtual repair and protection plans to evaluate the actual effectiveness of various protection measures. In the field of digital cultural Heritage, neural networks can be used to learn and predict a large amount of cultural heritage data. For example, training neural networks to identify key information such as features, types, and values of cultural Heritage can assist researchers in better understanding the characteristics and values of cultural Heritage. In addition, neural networks can also be used to predict audience reactions to cultural Heritage, thereby helping to develop more precise protection and promotion strategies. To create high-precision cultural heritage models and digitize them for display and interactive experience. This collaborative model not only enhances students' understanding and skills in cultural heritage protection but also helps them discover lost museums, providing more clues and possibilities for protection work.

Dunhuang, an ancient city with rich historical and cultural Heritage, is a rare treasure trove of art in the world. However, factors such as wind and sand erosion, human destruction, and global climate change pose serious threats to it. Therefore, it is particularly important to adopt advanced technology for its protection and inheritance. Yahia and Bouslama [19] explore the thinking between digitalization and innovative promotion technologies. CAD (computer-aided design) provides Dunhuang Cultural Heritage. Firstly, through precise 3D modelling, CAD can fully capture the details and shapes of Dunhuang cultural relics, providing a foundation for subsequent protection and replication work. In addition, CAD can also be used to create virtual reality (VR) models, allowing viewers to experience the cultural charm of Dunhuang firsthand. Neural networks also have extensive applications in the protection of Dunhuang cultural heritage. For example, training neural networks to identify specific elements in Dunhuang murals can assist researchers in conducting in-depth analysis and understanding of murals. In addition, neural networks can also be used to predict audience reactions to Dunhuang culture, thereby helping to develop more precise protection and promotion strategies. The integration of CAD and neural networks between digitalization and innovative promotion technologies demonstrates their enormous potential in protecting Dunhuang's cultural heritage through the advantages of high-precision modelling, innovative design and aesthetic optimization, audience response prediction, data analysis and decision support. Firstly, through deep learning of multimedia data such as images, videos, and audio, more semantic information can be extracted for more accurate description and classification of artistic works. Secondly, through deep learning and natural language processing techniques, an automatic summarization and question-answering system for information related to artistic works can be achieved, providing viewers with a more convenient visiting experience. Zhao [20] explored how to use technology to design a personalized art museum exhibition. VR technology provides new possibilities for art museum exhibitions. Firstly, VR can achieve the restoration and reconstruction of artistic works, allowing the audience to intuitively observe the style of the original work. Secondly, through VR technology, the audience can delve into the artwork from a first-person perspective and feel the emotions and artistic conception conveyed by the artwork. In addition, VR can also simulate the artist's creative process and ideas, allowing the audience to understand better the artist's creative intention and the connotation of the artwork.

3 THE NEW TREND OF DIGITAL HERITAGE PROTECTION

3.1 Application of Digital Technology in ICH Protection

ICH represents various traditional cultures and craft skills, which have undergone countless trials and improvements in the long river of history, gradually forming unique aesthetic characteristics and cultural connotations. For art and design, these ICHs are valuable sources of inspiration and design materials.

The forms, patterns, and production techniques in ICH provide rich references for artistic design. Designers can draw inspiration from these traditional cultures, integrate them into modern design, and create works with unique charm. For example, Chinese traditional Paper Cuttings art is widely used in modern graphic design and product design, adding a unique oriental flavour to these works.

The philosophical ideas, values, and aesthetic concepts contained in ICH also provide profound thinking for art and design. Designers can draw wisdom from these traditional cultures, integrate them into their own designs, and give their works more profound cultural connotations. For example, the aesthetics of Zen Buddhism in China have had a profound impact on modern design, emphasizing concepts such as "simplicity," "nature," and "ethereal," which have become important guiding principles in modern design.

Art and design can not only draw inspiration and materials from ICH but also contribute to the inheritance and growth of ICH through their own practice and innovation.

Art and design can explore the deep cultural connotations of ICH through research and interpretation, providing the public with a more comprehensive and in-depth understanding. Designers can showcase the unique charm of ICH to the public and enhance their understanding of traditional culture through their own works and exhibitions.

Art and design can inject new vitality into ICH through innovative applications. Designers can use modern technological means to transform traditional culture, thereby creating works that have both traditional cultural charm and meet modern aesthetic needs. This innovative application and development can not only inject new vitality into traditional culture but also promote its dissemination in modern society.

The traditional tea culture in China is a typical example. Designers can creatively apply tea culture to design tea sets and tea room spaces with unique charm, combining traditional tea culture with modern life and promoting its dissemination in modern society. This innovative design not only enhances public respect for traditional culture but also opens up new paths for the inheritance of traditional culture. Digital technology can achieve high-precision replication and storage of ICH. By utilizing technologies such as 3D scanning and high-definition photography, ICH's 3D data and high-resolution images can be obtained, resulting in digital replicas that are almost identical to the original. These digital replicas can be used not only for research, display, and education but also as substitutes for display and dissemination in cases where the original is damaged or cannot be displayed.

Digital technology can achieve virtual repair of ICH. For those ICHs that have been damaged or lost, digital technology can be used for virtual repair. Using advanced technologies, including computer graphics and machine learning, we can virtually refill damaged parts and recreate lost ones with the help of historical data and research insights. This way, we can understand its original appearance without damaging the original ICH.

Digital technology can also achieve preventive protection for ICH. By utilizing technologies such as the IoT and sensors, the status of ICH can be monitored and analyzed in real-time, potential security risks can be identified in a timely manner, and effective measures can be taken for preventive protection. For example, we can deploy a sensor network around ICH to monitor real-time changes in environmental factors such as temperature, humidity, and light, providing strong support for the security protection of ICH.

3.2 Blending of Digital Technology and Art Design

Digital technology provides richer creative tools for art and design. Designers can use digital technology for virtual creation, thereby expressing their creativity more intuitively. Digital technology can also help designers more easily obtain and process various design materials to improve design efficiency.

Art and design provide a more eye-catching form of expression for the application of digital technology in ICH protection. Designers can use virtual reality (VR) to virtualize and reproduce ICH scenes, allowing users to experience the historical atmosphere of ICH firsthand. At the same time, interactive design methods can also be used to display digital replicas of ICH.

4 RENDERING ALGORITHM OF ICH ARTISTIC STYLE BASED ON DNN

The use of neural networks in image processing and computer vision has achieved significant results. In order to innovate digital ICH protection methods, this article introduces DNN into the field of art design and ICH protection and proposes an ICH art-style rendering algorithm based on DNN. This section will provide a principle, framework, and specific applications of the algorithm in art design and ICH protection.

4.1 Introduction of Algorithm Principle and Framework

This algorithm is mainly based on the principle of style transfer and achieves artistic style rendering of ICH images by training a DNN model. The algorithm includes the following steps:

(1) Style extraction: Using pre-trained DNN models to extract style features from ICH images.

(2) Content extraction: Similarly, using the DNN model, extract the content features of the input image, which are used to represent the main content of the image.

(3) Style transfer: Integrating the extracted style features and content features to generate new images with ICH artistic style.

(4) Optimization and adjustment: By defining a loss function to measure the differences in style and content between the generated image and the original ICH image, gradient descent and other optimization algorithms are used to train and adjust the generator and discriminator, making the generated image more in line with the expected artistic style.

Convolutional autoencoder is a deep learning model that combines the characteristics of convolutional neural networks (CNN) and autoencoders, used for image processing and computer vision tasks. Convolutional autoencoder combines the advantages of CNN and autoencoder and can be used for artistic style rendering tasks in ICH. A convolutional autoencoder model was constructed in the study, including a CNN encoder for extracting style and content features and a decoder for generating artistic-style rendered images. Input the input image into the trained model, extract style and content features through a CNN encoder, and then use a decoder to generate new images with ICH artistic style. The structure of the convolutional autoencoder is shown in Figure 1, with the upper part being the convolutional part and the lower part being the autoencoder part. The specific steps for using a convolutional autoencoder are as follows: input the voxelated image matrix of the ICH 3D model as input data into the convolutional autoencoder. Voxelization is a process of converting graphics into images, completed by the OpenCV graphics library. According to the needs of the experiment, perform a certain quantity of convolutional mapping and pooling operations. After meeting the requirements, proceed to the automatic encoder feature mapping and learning stage.

The framework of the algorithm mainly consists of the following parts:

(1) Data preprocessing: Preprocessing ICH images, including cropping, scaling, normalization, and other operations, to facilitate the processing and computation of neural network models.

(2) Model training: Using a large amount of ICH image data to train and adjust the DNN model, enabling it to extract style and content features accurately.

(3) Rendering generation: Input the input image into the trained model to generate a new image with ICH artistic style.

Assuming that there is a feature vector $h_i (i = 1, 2, ..., m)$, integrating the information of k feature vectors to get the vector h^*, the reasonable method is weighted average, that is:

$$h^* = \sum_{i=1}^{k} a_i h_i \tag{1}$$

a_i is the weight.

The target category corresponding to the maximum output vector of the Softmax layer is the final prediction result:

$$p_n = \frac{e^{x_m}}{\sum_n e^{x_n}} \tag{2}$$

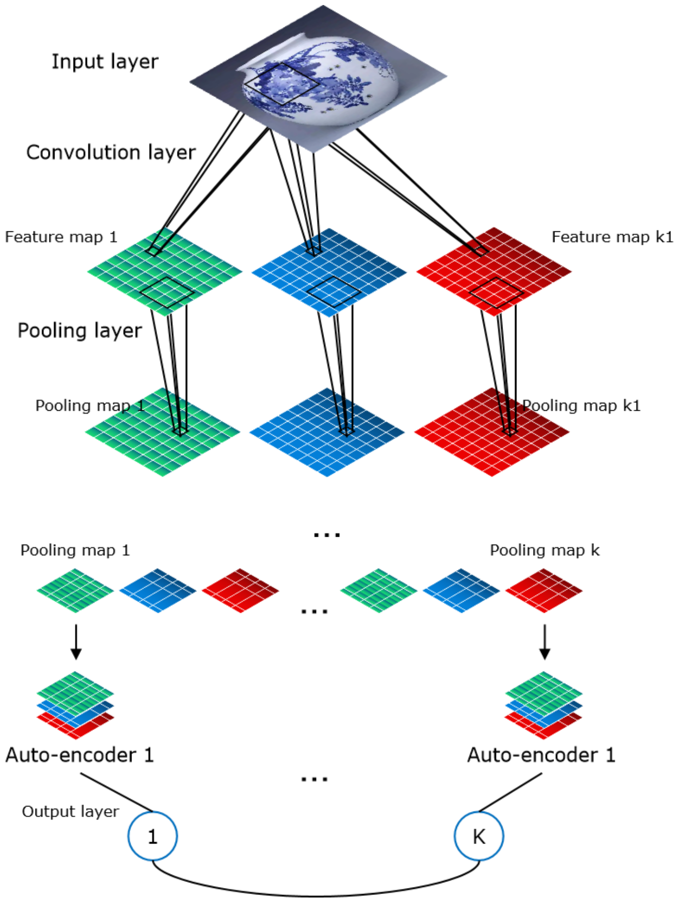

Figure 1: Structure of convolutional-automatic encoder.

Enter the m th element for Softmax, and the Softmax result of this element corresponding to each category, that is, the probability that the predicted result is the n th category.

Gaussian smoothing function is:

$$G(x,y,\sigma)=\frac{1}{2\pi\sigma^2}\exp(\frac{x^2+y^2}{2\sigma^2}) \tag{3}$$

$$\left|V^*(p')\right|(1-g^*(p))<\sum\nolimits_{p\in U(p)}(1-g^*(p)) \tag{4}$$

$$\Phi(p)=\begin{cases}1, & p\in M\\ 0, & p\notin M\end{cases} \tag{5}$$

Assign thresholds to gray pixels:

$$p(a_i)=\begin{cases}\dfrac{p}{h} & h_i>p\\ \dfrac{h_i}{h} & h_i<p\end{cases} \tag{6}$$

4.2 The Specific Application of Algorithms in Art Design and ICH Protection

The process of convolution operation is shown in Figure 2. The depth of each convolution kernel is equivalent to the network to be convolved. The convolution kernel will slide on the network layer to be convolved, in order from left to right and from top to bottom until the convolution process is completed. After each convolution, the original network will be compressed into a feature map. Therefore, the network layer after convolution depends on the number of convolution kernels. For example, if you want to match a 32 × thirty-two × If three photos are convolved, the depth of the convolution kernel should also be 3. If five convolution kernels are selected, the depth after convolution is five layers.

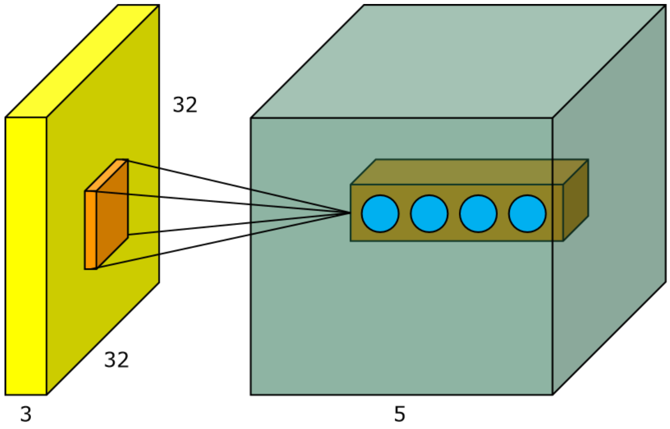

Figure 2: Schematic diagram of convolution operation.

Given a content image x_c and a style image x_s , respectively, let the final synthesized target image be x , and the definition of problem-solving is as follows:

$$x^* = \arg\min_x E_s(\varphi(x), \varphi(x_s)) + a_1 E_c(\varphi(x), \varphi(x_c)) + a_2 r(x) \tag{7}$$

Among them, E_s E_c respectively represent the loss function of the abstract style feature representation and the loss function of the abstract content feature representation reconstructed in the feature extractor, $r(x)$ represents the regularization option of the global spatial smoothness of the composite image, $\varphi(x)$ represents the abstract feature mapping set reconstructed and segmented in the feature extractor, and a_1 a_2 respectively represent the weight coefficients of the loss function and the regularization option. Among them, the expression of the loss function E_s represented by the abstract style features of the image is as follows:

$$E_s(\varphi(x), \varphi(x_s)) = \sum_{i=1}^{m} \left\| \Psi_i(\varphi(x)) - \Psi_{NN(i)}(\varphi(x_s)) \right\|^2 \tag{8}$$

Where m is the number base of $\Psi(\varphi(x))$, that is, the quantity of regional blocks after the segmentation of abstract features $\Psi_i(\varphi(x))$ represents a regional block in $\varphi(x)$, and all regional blocks $\Psi_i(\varphi(x))$ find the best matching regional block $\Psi_{NN(i)}(\varphi(x_s))$ through cross-correlation normalization method, and the expression is as follows:

$$NN(i) = \arg\min_{j=1,\ldots,m_s} \frac{\Psi_i(\varphi(x)) \cdot \Psi_j(\varphi(x_s))}{\left|\Psi_i(\varphi(x)) \cdot \left|\Psi_j(\varphi(x_s))\right|\right|} \tag{8}$$

The expression of the loss function E_c represented by the abstract content features of the image is as follows:

$$E_c(\varphi(x), \varphi(x_c)) = \left\|(\varphi(x) - \varphi(x_c))\right\|^2 \tag{10}$$

The expression of the regularization option $r(x)$ for global spatial smoothness is as follows:

$$r(x) = \sum_{i,j}((x_{i,j+1} - x_{i,j})^2 + (x_{i+1,j} - x_{i,j})^2) \tag{11}$$

Through trained models, automatic processing and rendering of ICH images can be achieved. By adjusting model parameters and rendering style, rendered images with high artistic and aesthetic value can be generated. In the experiment of using the sparsity of coefficients to render different ICH styles, the basis functions were obtained from 8 different ceramic artwork images (as shown in Figure 3).

Figure 3: Sample images of ceramic artworks used for training basis functions.

By applying this algorithm to the artistic style rendering of ICH images, digital replicas with high realism and artistic appeal can be created. These digital replicas can be used for various purposes such as exhibitions, education, research, etc., achieving digital reproduction of ICH. Designers can use this algorithm to extract the artistic style features of ICH and apply them to the design of various cultural and creative products. For example, clothing, household items, decorations, etc., with traditional cultural charm and modern aesthetic needs can be designed to promote the inheritance of traditional culture. For ICH that has been damaged or lost, this algorithm can be used for virtual repair and scene reproduction. By combining historical data and research results, virtual filling and restoration of damaged or lost parts can be carried out in the historical atmosphere of ICH.

5 EXPERIMENT AND RESULT ANALYSIS

5.1 Experimental Setup and Dataset Description

A series of experiments were conducted in this article to verify the effectiveness of the DNN-based ICH art style rendering algorithm.

Experimental setup:

⊖ Model architecture: This article adopts an automatic encoder model based on CNN. The decoder section consists of multiple deconvolution layers and upsampling layers used to generate rendered images from features.

⊜ Optimization algorithm: This study used Adam's optimization algorithm for model training, with an adjusted appropriately during the training process.

⊛ Hardware environment: All experiments were conducted on a computer with an NVIDIA GeForce GTX 1080 Ti graphics card to ensure efficient model training.

Dataset Description:

To train and evaluate the proposed model, the study used the following two datasets:

⊖ ICH Image Dataset: This dataset contains a series of high-quality ICH images covering multiple categories such as painting, sculpture, architecture, etc.

⊜ Art style rendering dataset: In order to verify the performance of the algorithm in art style rendering, this article also constructed an art style rendering dataset. These rendered images are created by professional artists based on ICH images and have undergone fine adjustments.

5.2 Presentation and Discussion of Experimental Results

Figure 4 illustrates the generation of dots in a 3D solid rendered image. Rendering is a computationally intensive process that uses ray tracing and other techniques to simulate the creation of realistic images. This process needs to consider factors such as point distribution, density, and overlap to ensure that the generated dots retain the main features of the original image while also having a unique artistic style.

(a) Three-dimensional geometric model | (b) Images rendered by traditional method | (c) Stippling generated by image

Figure 4: A stippling sketch is generated from an image rendered by a 3D entity.

In the training process of neural networks, the selection of initialization weights is crucial for the performance of the model. Inadequate initialization weights may lead to slow convergence of the training process and even fall into local minima. Figure 5 shows the variation curve of identification accuracy before adding overfitting measures. As the quantity of iterations increases, the accuracy shows a fluctuating upward trend, but the overall upward speed is slow, and the accuracy tends to stabilize in the later stage of training without significant improvement.

To improve this situation, the Dropout method was adopted in this study to prevent overfitting. Dropout is a regularization technique that enhances the model's generalization ability by randomly discarding a portion of neurons during the training process. In Figure 6, compared with the accuracy change curve before adding overfitting measures, the accuracy of the model has significantly improved. In the early stages of training, accuracy increases faster, and in the later stages of training, accuracy still shows a steady upward trend. This indicates that the Dropout method effectively alleviates the problem of the model getting stuck in local minima and improves the model's generalization ability.

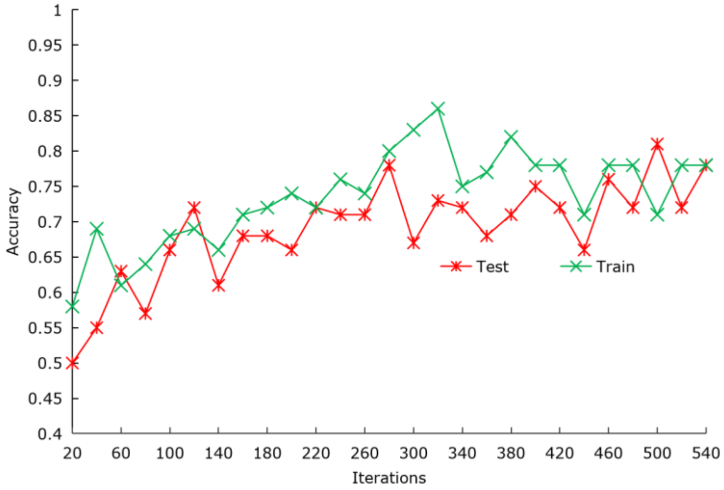

Figure 5: Changes in accuracy before fitting measures are added.

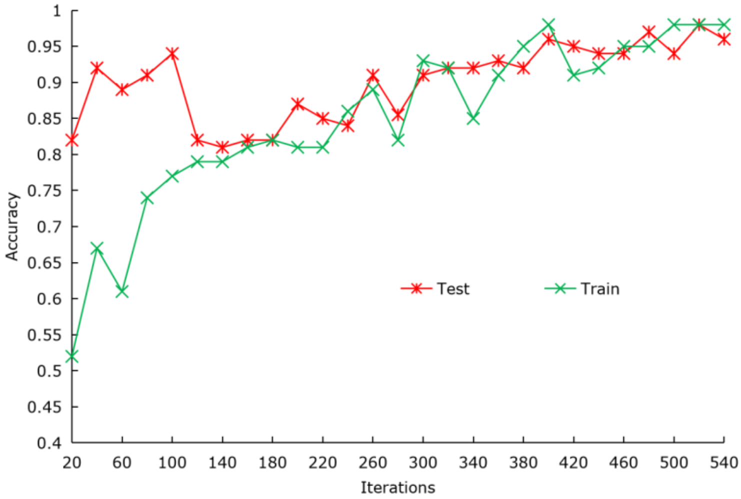

Figure 6: Changes in accuracy after adding over-fitting measures.

Figure 7 shows that it fluctuates less and exhibits good stability. This stability ensures that the algorithm can maintain good performance in different situations. Through comparative experiments and analysis of results, it can be concluded that the algorithm proposed in this article has significant advantages in response time and can quickly and stably complete artistic style rendering tasks.

5.3 The Enlightenment of the Results of ICH Protection

The excellent performance of the algorithm in artistic style rendering in this article demonstrates the enormous potential of CAD and neural networks of ICH protection. By training models to learn and simulate different artistic styles, rich artistic effects can be added to ICH images. This provides new possibilities for the digital protection and dissemination of ICH.

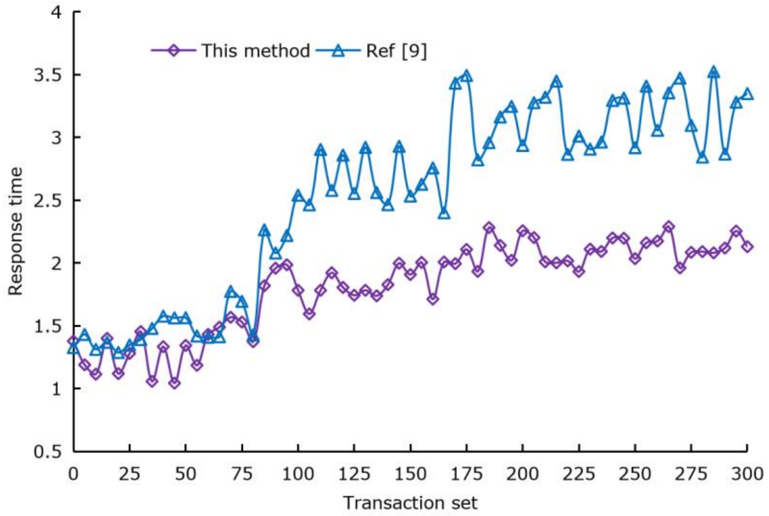

Figure 7: Response time of different algorithms.

The advantage of the proposed algorithm in response time, as demonstrated in the experimental results, means that the designer can process a large amount of ICH image data more efficiently. By utilizing the efficient processing capability of DNN, staff can accelerate the analysis, classification, and protection of ICH images.

The traditional ICH protection of professionals, while the application of DNN can achieve automated and intelligent processing. By combining deep learning and computer vision technology, more innovative application scenarios can be developed, bringing more possibilities for ICH protection.

For the processing and rendering of ICH images, it is necessary to ensure that the dataset used has high quality and accuracy and that the model can generalize to different artistic styles and ICH types. This requires us to continuously research and improve the architecture and training methods of the model to adapt to various complex art and design tasks.

6 SUMMARY AND PROSPECT

In the context of the growth of information technology and AI technology, people's lifestyles are undergoing unprecedented changes. This transformation also affects the fields of art design and ICH protection. Digital heritage protection is a highly integrated form of art and technology and is a new form of digital art. This article studies the application of CAD and neural networks in art design and ICH protection, proposes an ICH art-style rendering algorithm based on DNN, and verifies its advantages in art-style rendering and response time. The successful application of the algorithm in this article proves that DNN can learn and simulate different artistic styles, adding rich artistic effects to ICH images. The results also remind us to lay stress on the accuracy of the data.

In the future, more complex model structures and training methods can be attempted by the algorithm. On the other hand, more application scenarios and technological combinations, such as VR, AR, etc., can be explored to create richer and more diverse ICH experiences. We hope to bring more innovation to ICH protection through the continuous growth of deep learning and computer vision technology.

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