Automatic Generation Algorithm for Digital Sculpture Based on CAD and Machine Vision

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Abstract. CAD is a technology that utilizes computer technology to assist designers in designing and drawing. This study aims to combine CAD with machine vision technology and apply it to the automated generation of digital sculptures. By studying algorithm design and simulation experiments, an efficient and practical automated generation method for digital sculptures has been designed to improve the efficiency and quality of digital sculpture creation. To verify the effectiveness of the sculpture texture feature detection method based on deep learning (DL), experimental verification was conducted in this article. The results show that compared to sparse representation algorithms, texture synthesis algorithms, and structure prediction algorithms, our algorithm exhibits better image restoration performance. The improved sculpture automation generation algorithm is superior to the original algorithm in terms of recall and accuracy. The experiment verified the speed and efficiency advantages of real-time rendering algorithms in processing complex sculpture design scenes. It provides a more efficient solution for the creation and display of digital sculpture and is expected to promote technological progress in related fields.

Keywords: CAD; Machine Vision; Dl; Digital Sculpture; Textural Features
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1 INTRODUCTION

Computer-aided design and machine vision technology are important components of digital technology. CAD is a technology that uses computer technology to assist designers in design and drawing. In the field of sculpture design and manufacturing, accurate representation and classification of models is a key issue. The traditional representation method of sculpture models mainly relies on manual modeling, which requires a lot of time and skills and easily introduces human errors. To address this issue, Alymani et al. [1] proposed a graphic machine-learning classification method based on CAD machine vision using sculpture 3D topological models. In this step, we first use image capture devices to obtain the image of the sculpture and then use CAD machine vision technology to preprocess, extract features, and reconstruct the image in 3D to obtain the 3D model of the sculpture. The key to this process lies in using machine learning algorithms to automatically recognize and extract features from images, thereby improving the accuracy and efficiency of modeling. After obtaining the three-dimensional model of the sculpture, we use it as input and classify it using graphic machine learning techniques. We first extract features from the model, then use machine learning algorithms to train the model, and finally classify the new model based on the training results. The key here is to use machine learning algorithms to automatically learn and recognize the features of the model, thereby improving the accuracy and efficiency of classification. Its basic principle is to use the powerful computing power and graphics processing power of computers to help designers design more efficiently and accurately. Computer aided process planning (CAPP) has been widely applied in many fields. Especially in the production process of sculpture scenes, the application of CAPP has brought revolutionary changes to traditional handcrafting. Andriani et al. [2] explored how to use computer-aided process planning to optimize the production process of sculpture scenes. Computer assisted process planning is a method of optimizing manufacturing processes using computer technology. It integrates product design information, manufacturing resources, and process knowledge to generate feasible process plans, thereby improving production efficiency, reducing production costs, and enhancing product quality. The creation process of sculpture scenes often requires highly skilled manual skills such as sculptors and modelers. The creation of many sculpture scenes relies on the experience and feelings of the sculptor. In the production process of sculpture scenes, once errors occur, a large amount of correction work is often required and may even require a restart. By using CAD software, digital models of sculpture scenes can be established. This can not only help sculptors better understand design requirements but also detect and correct problems in the production process in advance. Through computer simulation technology, the production process of sculpture scenes can be simulated to predict possible problems and develop solutions in advance.

Machine vision is a technology that uses computer vision technology to process and analyze images and videos. Its basic principle is to use a computer vision algorithm to preprocess images and videos, extract features, classify and identify them, and realize automatic processing and analysis of images and videos. In the field of landscape design and sculpture manufacturing, the conversion from 2D CAD drawings to 3D solid models is a crucial step. However, this process often requires a significant amount of manual intervention and demands high skills and experience from designers. To address this issue, Byun and Sohn [3] developed a machine vision-based automation system that can automatically generate information CAD models of landscape sculptures from 2D CAD drawings. The image preprocessing module performs denoising, image segmentation, and other operations on the input CAD drawings to extract areas related to landscape sculpture. Then, the feature extraction module uses machine learning algorithms to perform feature analysis on the extracted area, identifying key information such as the shape, material, and texture of the sculpture. Finally, the model reconstruction module automatically generates a 3D CAD model of the landscape sculpture based on the recognition results. Image preprocessing is the first step of this system. We adopted a series of image processing techniques, including grayscale, denoising, binarization, and image segmentation, to extract areas related to landscape sculpture from CAD drawings. In addition, we further accurately locate the contours and details of the sculpture through techniques such as morphological processing and edge detection. CAD technology has been widely used in construction, machinery, electronics and other industries, and machine vision technology also plays an important role in automatic production lines, quality inspection and other fields. Accurate identification of the sculpture surface is crucial in the sculpture manufacturing process. Surface recognition involves precise understanding of sculpture shape, size, and details, all of which require efficient and precise detection methods. However, traditional surface detection methods are often complex and time-consuming, and for sculptures with complex shapes and details, their efficiency and accuracy are difficult to meet the needs of modern manufacturing. To address this issue, Chen et al. [4] proposed a fast surface recognition method for sculpture manufacturing using on-site point cloud processing and machine learning. Use 3D scanning technology to obtain point cloud data of sculptures. This technology obtains high-precision sculpture shape data by using devices such as

LiDAR or camera arrays to obtain point cloud data on the sculpture surface. This method is not only efficient, but also has little impact on the environment, and can achieve efficient and accurate detection of sculptures with complex shapes and details. However, the application of CAD and machine vision technology in the field of automatic generation of digital sculpture is still in its infancy.

With the continuous development of digital technology, information modeling of heritage sculptures has become an important research field. Heritage sculptures often have complex shapes and textures, thus requiring an efficient and accurate information modeling method. Croce et al. [5] proposed a semi-automatic method for modeling heritage sculpture information from semantic point clouds, utilizing machine vision learning techniques to achieve efficient and accurate modeling. In order to obtain the semantic point cloud of heritage sculptures, we used 3D laser scanning technology. This technology can quickly and accurately obtain surface shape and texture information of sculptures. However, due to factors such as scanning equipment and environment, the original point cloud data often contains noise and outliers. Therefore, we need to preprocess point cloud data, including denoising, point cloud registration, segmentation, and other operations. To verify the effectiveness of the method proposed in this article, we conducted experiments on a group of heritage sculptures. The experimental results show that this method can efficiently and accurately obtain semantic point cloud data of heritage sculptures and establish high-quality digital models. Compared with traditional modeling methods, this method has higher accuracy and efficiency while better preserving the details and features of sculptures. Digital sculpture is a 3D artistic work created by computer technology and digital art means. As a new art form, it has the characteristics of high creative freedom and strong expressive force. The creative process of digital sculpture usually includes modeling, texture mapping, lighting rendering, and other steps that can create various creative works of art. The traditional sculpture manufacturing process often relies on handicrafts and the skills of experienced artists. However, this method is not only inefficient but also difficult to replicate and promote. Feng et al. [6] proposed an artificial neural network (ANN) for fast parameterized electromagnetic modeling (EM modeling) to achieve machine learning for sculpture automation. Firstly, EM modeling is used to simulate and predict the electromagnetic characteristics of sculptures in different environments. Then, we use ANN to learn and parameterize the EM model. ANN is an artificial neural network that learns patterns and relationships from large amounts of data for prediction and classification. By training ANN, we can quickly predict the electromagnetic characteristics of sculptures under different conditions, providing a foundation for automated machine learning of sculptures. To verify the effectiveness of our method, we conducted a series of experiments. The experimental results show that our method can effectively predict the electromagnetic characteristics of sculptures and automate sculpture design and manufacturing. In addition, we also found that using ANN for parameterized EM modeling can greatly reduce computation time and improve prediction accuracy. The traditional digital sculpture generation method needs artists to design and sculpt manually, which is cumbersome and inefficient. Therefore, it is of great practical significance to study the automatic generation algorithm of digital sculpture based on CAD and machine vision.

The purpose of this study is to combine CAD with machine vision technology and apply it to the automatic generation of digital sculpture. Through the research on algorithm design and simulation experiments, we hope to develop an efficient and practical automatic generation method of digital sculpture and improve the creation efficiency and quality of digital sculpture.

(1) A new automatic sculpture generation algorithm is proposed, which combines DL and computer graphics technology to realize the automatic creation and editing of sculpture models.

(2) Aiming at the complexity and diversity of sculpture generation, this algorithm adopts a special network structure and training method, which effectively improves the quality and efficiency of sculpture generation.

In this study, theoretical analysis and simulation experiments are used to study. First of all, by consulting relevant literature and materials, we can deeply understand the principles and applications of CAD technology and machine vision technology. Then, combined with the characteristics and requirements of digital sculpture, an automatic generation algorithm of digital sculpture based on

CAD and machine vision is designed and implemented, and the texture features of sculpture are detected by DL to realize the automatic generation of digital sculpture. Finally, the effectiveness of the algorithm is verified, the experimental results are analyzed and discussed, and the future prospect is put forward.

2 RELATED WORK

With the continuous development of 3D printing technology, more and more sculpture products are being manufactured. However, detecting the texture features of these sculpture products remains a challenge. Traditional detection methods usually require a large amount of manual intervention and are easily influenced by subjective factors. To address this issue, Kadam et al. [7] utilized machine learning techniques to enhance texture feature detection in 3D-printed sculpture products. Texture feature detection is a method of extracting texture information from images. By analyzing the color, brightness, direction, and other information of pixels in an image, the texture features of the image can be determined. In the texture feature detection of 3D-printed sculpture products, we usually need to capture images of the product surface and use corresponding algorithms to extract texture features. Machine learning is a method of enabling machines to learn patterns and patterns from data. In texture feature detection, we can use machine learning algorithms to train models that can automatically extract and recognize texture features in images. By using machine learning techniques, we can automatically detect the texture features of 3D-printed sculpture products, thereby reducing the need for manual intervention. This not only improves the efficiency of detection but also reduces the cost of detection. Traditional plant morphology research methods often rely on manual measurement and mapping, which is time-consuming and makes it difficult to obtain comprehensive plant morphology data. To address this issue, Kartal et al. [8] proposed a machine learning-based digital plant model detection method that automatically generates a 3D crown scanning model. Use 3D scanning technology to obtain a 3D model of plants. This technology obtains point cloud data on plant surfaces through devices such as LiDAR or camera arrays and then converts this data into a 3D model through computer vision and image processing techniques. This method can obtain high-precision plant morphology data with high efficiency and minimal environmental impact. To verify the effectiveness of our method, we conducted a series of experiments. The experimental results indicate that our method can accurately and automatically detect and recognize the three-dimensional morphological features of plants. Compared with traditional measurement and drawing methods, our method not only improves efficiency, but also enables the acquisition of more comprehensive morphological data. In addition, our method can handle a large amount of data and has strong generalization ability. Sculpture texture feature recognition is an important part of digital sculpture manufacturing. Due to the diversity of sculpture materials and the complexity of textures, accurately identifying sculpture texture features is a challenging problem. Traditional texture recognition methods are mainly based on image processing and machine learning techniques, but these methods are often affected by factors such as lighting conditions and material surface pollution, making it difficult to obtain accurate results. To address this issue, Niu et al. [9] proposed a method of generating defect image samples using Generative Adversarial Networks (GANs) to improve the accuracy of sculpture texture feature recognition. Generators and discriminators. The generator is responsible for generating images, while the discriminator is responsible for determining whether the generated images are real. By continuously adjusting the parameters of the generator and discriminator during the training process, GAN can generate realistic defect image samples. We use these samples as part of the training set to improve the accuracy of the deep learning model. The experimental results show that using GAN generated defect image samples can improve the accuracy of deep learning models in recognizing sculpture texture features. Specifically, we achieved higher accuracy and recall on the dataset, while reducing false positive rates. In addition, we also found that using GAN generated defect image samples can enhance the model's adaptability to different lighting conditions and material surfaces, and improve the model's generalization ability.

With the rapid development of 3D printing technology, the application of 3D sculpture printing is becoming increasingly widespread. However, defect detection has always been a challenge in the 3D sculpture printing process. Traditional defect detection methods usually require manual inspection, which is inefficient and prone to errors. To address this issue, Paraskevoudis et al. [10] proposed a real-time 3D sculpture remote control parameter feature detection method based on computer vision and artificial intelligence. Preprocess 3D sculpture models using computer vision technology. Specifically, we first perform 3D reconstruction on the 3D sculpture model to obtain its 3D point cloud data. Then, we perform operations such as noise reduction, segmentation, and feature extraction on the point cloud data to obtain features for defect detection. Research on adjusting and controlling 3D sculpture printing parameters based on defect detection results. To verify the effectiveness of our method, we conducted a series of experiments. The experimental results show that our method can effectively detect defects in 3D sculpture models and achieve precise adjustment and control of printing parameters. Compared with traditional manual detection methods, our method not only improves efficiency but also reduces error rates. In addition, our method can also achieve remote control and real-time monitoring, facilitating the monitoring and management of the 3D sculpture printing process. Laser sculpture is a widely used technique for creating high-precision 3D models. However, the process of laser sculpture often requires manual operation, which is inefficient and prone to errors. To address this issue, Qin et al. [11] proposed an automatic generation method for laser sculpture fusion alternative construction directions based on machine vision clustering. Cluster analysis of laser sculpture data using machine vision technology. Specifically, we first preprocess the laser sculpture data to extract key features, and then use clustering algorithms (such as K-means) to cluster the features. Through cluster analysis, we can divide laser sculpture data into several categories, each representing a specific construction direction. To verify the effectiveness of our method, we conducted a series of experiments. The experimental results indicate that our method can effectively generate the construction direction of laser sculpture automatically. Compared with traditional manual operation methods, our method not only improves efficiency but also reduces error rates. In addition, our method can be flexibly adjusted and optimized according to different needs and conditions.

With the continuous development of digital sculpture technology, the application of digital sculpture works in creation and production is becoming increasingly widespread. The quality inspection of digital sculpture works is one of the important links in the production process of digital sculpture, and texture feature detection is a key part of digital sculpture quality inspection. The traditional texture feature detection methods for digital sculptures are usually based on manual visual inspection, which is not only inefficient but also susceptible to human factors. To address this issue, Ren et al. [12] proposed a machine vision based digital sculpture texture feature detection method that can achieve real-time rendering and automated detection. The purpose of texture feature detection in digital sculpture is to extract texture information from the surface of digital sculpture, including texture shape, texture direction, texture roughness, etc. We first use machine vision technology to obtain image information of digital sculpture surfaces and then use image processing techniques to preprocess and extract features from the images. On this basis, we use machine learning algorithms to classify and recognize the extracted features, thereby achieving automated detection of digital sculpture texture features. Use real-time rendering technology to present the texture feature information of digital sculptures for quality inspection and evaluation. We use shaders and rendering engines to achieve real-time rendering, improving rendering speed and efficiency by optimizing algorithms and computational processes. In the construction industry, monitoring and management of construction progress has always been an important link. However, for sculpture construction, due to its artistic and complex nature, traditional construction progress monitoring methods are often difficult to apply. To address this issue, Sami et al. [13] proposed a computer vision-based automated parameter monitoring method for sculpture construction progress. Computer vision is a method of analyzing and understanding images using image processing and machine learning techniques. By taking photos and videos of the construction process, computer vision can analyze and identify each stage of the construction process, providing a basis for monitoring the construction progress. Computer vision can analyze images during the construction process and detect construction quality issues, such as material defects and non-standard processes. By analyzing the images during the construction process, computer vision can automatically identify the construction progress and provide real-time monitoring information for management personnel. To verify the effectiveness of our method, we conducted a series of experiments. The experimental results show that the automated parameter monitoring method for sculpture construction progress based on computer vision can accurately predict the construction progress and effectively monitor quality issues and safety risks during the construction process. In addition, this method can also improve construction efficiency and reduce costs.

With the continuous development of digital technology, three-dimensional digital sculpture has become an important form of artistic expression. In the production process of digital sculpture, the selection and adjustment of process parameters have a significant impact on the quality and production efficiency of sculpture works. However, traditional process parameter adjustment methods mainly rely on manual experience and trial and error, which not only have low efficiency but may also introduce human errors. To address this issue, Tamir et al. [14] proposed a machine learning based method for monitoring and optimizing 3D digital sculpture process parameters. Machine learning is a method of completing specific tasks by allowing machines to learn patterns and patterns from data. Train a model through training data to monitor and optimize the process parameters of digital sculpture. In the production process of digital sculpture, process parameters include laser power, scanning speed, scanning spacing, etc. In order to achieve monitoring of process parameters, we first need to collect data on these parameters and associate them with the corresponding production results. Then, we use machine learning algorithms to train these data and obtain a model that can predict the relationship between process parameters and production results. By monitoring the changes in process parameters in real time, we can promptly detect defective process parameters and avoid producing sculpture works of poor quality. With the advent of the digital age, computer-aided design (CAD) has become an important tool in sculpture design. However, existing digital sculpture software is often expensive and requires high hardware requirements, which limits its popularity and application among a large number of artists. To address this issue, Wu et al. [15] proposed a rough registration method based on intelligent visual rendering and low-cost digital sculpture CAD drawings. Firstly, use intelligent visual rendering technology to preprocess digital sculpture CAD drawings; Then use image registration technology to perform coarse registration on the preprocessed image. Applying intelligent visual rendering technology to the preprocessing of digital sculpture CAD drawings, automatically recognizing, segmenting, and removing backgrounds on the drawings, in order to obtain images that only contain the sculpture part. To verify the effectiveness of our method, we conducted a series of experiments. The experimental results indicate that our method can effectively perform coarse registration on digital sculpture CAD drawings. Compared with traditional registration methods, our method has higher accuracy and stability, and faster processing speed. In addition, our method only requires lower hardware configuration, reducing the threshold for digital sculpture design.

3 INTEGRATED DEVELOPMENT OF CAD AND MACHINE VISION

At present, research on CAD and machine vision technology has achieved certain results. In terms of CAD technology, researchers have developed various efficient modeling and rendering algorithms, providing strong support for the creation of digital sculptures. In terms of machine vision technology, researchers have also proposed some DL based image recognition and processing methods, which provide possibilities for the automated generation of digital sculptures. However, the integration of CAD and machine vision technology in the field of automated generation of digital sculptures is still in the exploratory stage. Previous methods still have some problems, such as insufficient precision in generating results and lack of controllability in the generation process. Therefore, this article aims to develop an efficient and practical automated generation method for digital sculptures, in order to improve the efficiency of digital sculpture creation. Both CAD technology and machine vision technology are important components of digital technology, and their integration and development have broad application prospects. At present, the integration and development of CAD and machine vision is mainly reflected in the following aspects:

(1) CAD model reconstruction based on machine vision: scan and identify the object with machine vision technology to obtain the 3D shape and texture information of the object, and then use CAD technology to reconstruct and edit the model. This method can quickly transform physical objects into digital models and provide designers with more abundant design materials.

(2) Development of machine vision algorithm based on CAD: A large number of virtual sample data are generated by using the modeling and rendering functions of CAD technology, and then the machine vision algorithm is trained by using these data. This method can greatly improve the accuracy and generalization ability of machine vision algorithm, and provide more reliable technical support for automatic production line and quality inspection.

(3) Integrated application of CAD and machine vision: The CAD system and machine vision system are integrated to realize seamless docking and cooperative work. Designers can design and edit in CAD system and then use machine vision system for automatic processing and analysis. This method can greatly improve design efficiency and quality and provide more comprehensive technical support for digital design and manufacturing in various fields.

4 DESIGN OF AUTOMATIC GENERATION ALGORITHM FOR DIGITAL SCULPTURE

4.1 Modeling Technology of Digital Sculpture Based on CAD

Modeling is a very important step in the process of creating a digital sculpture. The modeling technology of digital sculpture based on CAD can use the powerful modeling function of the CAD system to create a 3D model of digital sculpture quickly and accurately. CAD system provides various modeling tools and technologies, such as polygon modeling, surface modeling, and parametric modeling, which can meet the creative needs of different types of digital sculptures. In addition, the CAD system also has a rich graphics library and model library, which can directly call the graphics and models in these libraries for design and editing, greatly improving the modeling efficiency.

4.2 Texture Feature Detection of Sculpture Based on DL

Sculpture, as an art form, its surface texture is an important means of expressing the details and texture of a work. However, traditional manual detection and recognition methods are inefficient and susceptible to subjective factors. Therefore, studying sculpture texture feature detection methods based on DL is of great significance. Sculpture texture feature detection based on DL is a method that utilizes DL techniques to detect and recognize the surface textures of sculptures automatically. Convolutional Neural Networks (CNN) have strong feature extraction ability and are suitable for automatic detection and recognition of sculpture textures; Generative Adversarial Networks (GAN), on the other hand, have strong generation ability and can be used to generate new texture samples enriching the diversity of sculpture textures. This article combines the two.

Firstly, in order to train DL models, it is necessary to construct a dataset containing various sculpture textures. The dataset is obtained by taking sculpture photos and obtaining them from public datasets. Its characteristic is that it can represent the difference between the true sample label and the predicted probability, and the smaller the difference, the more accurate the prediction. Meanwhile, in order to improve the performance of the model, this article uses ensemble learning techniques to integrate and optimize CNN and GAN models. Figure 1 shows a sculpture feature learning framework based on machine vision.

After careful training, the DL model is ready to be used for automatic detection and recognition of texture on sculpture surfaces. Initially, it is necessary to preprocess the input image, including meticulous size adjustment and precise normalization, to ensure the consistency of the image data and the accuracy of the model. After preprocessing, the image is input into the already trained DL model. This process is like injecting information into the model, enabling it to understand and analyze the visual information on the sculpture surface. After receiving image information, the model begins processing and analysis.

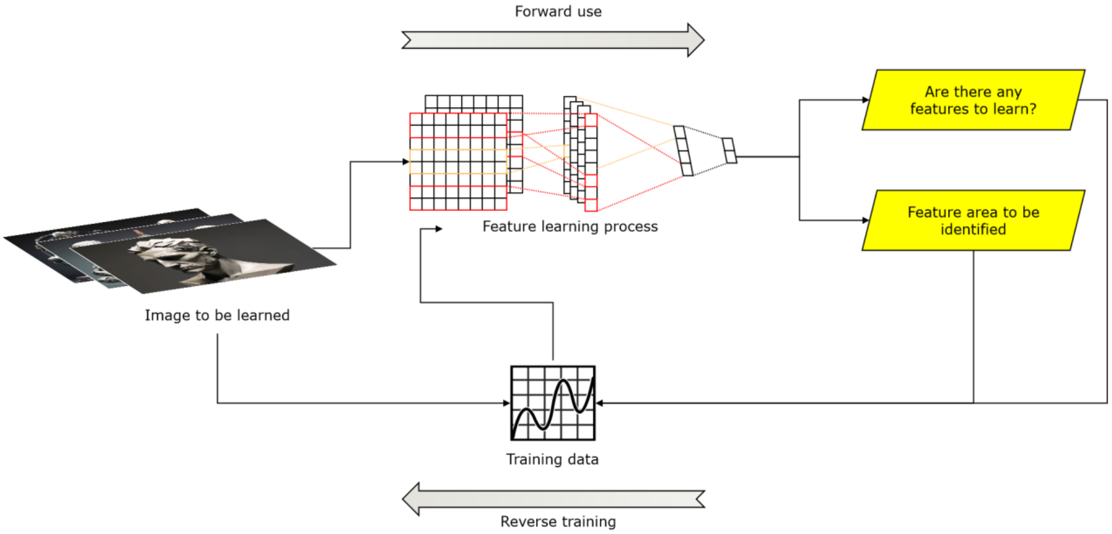

Figure 1: Sculpture feature learning framework based on machine vision.

After complex calculations, the model outputs texture feature maps. This image depicts in detail the texture features of different regions in the input image, presenting texture information in the form of data that was originally difficult to detect with the naked eye. After obtaining the texture feature map, post-processing and analysis are also required. Finally, sculptures can be classified or recognized based on the extracted texture information. Through this approach, we can gain a deeper and more accurate understanding of the artistic style and characteristics of sculpture, providing a new perspective and tool for art research and appreciation.

4.3 Realization of Automatic Generation Algorithm of Digital Sculpture

The automatic generation algorithm for digital sculptures is a method that utilizes computer technology and DL algorithms to generate digital sculptures automatically. This algorithm can automatically perform modeling, texture mapping, lighting rendering, and other operations based on user input and requirements, generating digital sculpture works that meet the requirements. The specific implementation steps are as follows:

(1) Input parameters: The user first needs to input relevant parameters, including the expected type of digital sculpture (such as characters, animals, abstracts, etc.), size (size or proportion), overall shape, and detailed features. These parameters will serve as important references for subsequent modeling, texture mapping, and lighting rendering.

(2) Modeling: After receiving user input, the algorithm will use CAD-based digital sculpture modeling technology for automatic modeling. This process involves using pre-set model templates and programmatic modeling based on parameters. The powerful modeling function of CAD systems is fully utilized here, which can quickly and accurately create 3D models of digital sculptures. The coordinate origin $O = 0,0,0$ and the image point coordinates of the space point A are:

$$a = x_a, y_a, f \tag{1}$$

Then, the linear equation of the straight line OA can be written as:

$$\frac{x}{x_a} = \frac{y}{y_a} = \frac{z}{f} \tag{2}$$

If the normal vector of the space plane is known:

$$n = B,C,D \tag{3}$$

If the coordinate of a point on the plane is x_0,y_0,z_0, the equation of the plane can be expressed as:

$$B\ x - x_0\ + C\ y - y_0\ + D\ z - z_0\ = 0 \tag{4}$$

According to the above formula, the coordinate values of space points can be solved:

$$A = kx_a, kx_a, kf \tag{5}$$

Where:

$$k = Bx_0 + Cy_0 + Dz_0\ /\ Bx_a + Cy_a + Df \tag{6}$$

(3) Texture mapping: After completing the modeling, the algorithm automatically performs texture mapping operations based on the type and style of the digital sculpture. This step involves DL and image processing techniques, identifying and generating appropriate textures through trained CNN and GAN models. The selection and mapping method of textures will directly affect the visual effect and style of the final work.

(4) Lighting rendering: After the texture mapping is completed, the algorithm will automatically perform lighting rendering operations based on the scene and lighting conditions of the digital sculpture. This step takes into account factors such as the position, color, and intensity of the light source, as well as the material and reflection characteristics of the object. Through complex calculations, it simulates the physical processes of light reflection and refraction on the surface of the object, thereby creating a realistic visual effect. Let the projection center be at the center of the image, and the difference between the coordinate values of the image point A in the display user area and the image center in the user area is the coordinate values of the image point in the image coordinate system:

$$A = x - lWidth / 2, y - lHeight / 2 \tag{7}$$

Where x,y is the coordinate of A point in the user area; $lWidth$ is the length of the image; $lHeight$ is the height of the image. In order to avoid the selection error, the method of multiple selection and averaging is adopted:

$$x,y = \left(\sum_{i=1,n} x_i / n, \sum_{i=1,n} y_i / n \right) \tag{8}$$

The binary group $\langle \phi,\theta \rangle$ is used to represent the deflection angle of the viewpoint relative to the model, ϕ represents the deflection angle in the horizontal direction, and θ represents the deflection angle in the rigid direction:

$$\begin{gathered} \phi = \arctan \frac{\sqrt{X_E^2 + Y_E^2}}{Z_E^2} \\ \theta = \frac{\pi}{2} - \arctan \frac{Y_E}{X_E} \end{gathered} \tag{9}$$

When the observation viewpoint is obtained, all two-dimensional models should be projected under this viewpoint to keep consistent with the digital sculpture structure to be built.

(5) Output: After the above steps, the algorithm will output the generated digital sculpture works. These works can be saved and displayed in various formats, such as common 3D model formats, image formats, or video formats. In addition, the algorithm also supports importing works into virtual reality (VR) or augmented reality (AR) environments for interactive display, providing users with an immersive artistic experience.

In addition, in order to continuously improve the quality and efficiency of generated works, this algorithm also designs feedback and optimization mechanisms. Users can assess and provide feedback on the generated digital sculpture works, pointing out areas of satisfaction or areas for improvement. These feedbacks will be absorbed and learned by the algorithm to optimize parameters and strategies for modeling, texture mapping, and lighting rendering, thereby achieving self-learning and continuous evolution of the algorithm.

Through the above steps and mechanisms, the digital sculpture automation generation algorithm has achieved full process automation from user input to final product output, greatly improving the efficiency and flexibility of digital sculpture creation. At the same time, the algorithm also adapts to the needs and preferences of different users through continuous learning and optimization, opening up broad prospects for the creation and application of digital sculpture.

5 SIMULATION EXPERIMENT OF AUTOMATIC GENERATION ALGORITHM FOR DIGITAL SCULPTURE

5.1 Simulation Experiment Environment and Parameter Setting

In order to verify the effectiveness of the sculpture texture feature detection method based on DL, experiments can be carried out. The specific experimental steps include: selecting the appropriate DL model and data set; Training and optimizing the model; Using the trained model to detect and identify the texture features of the test set; Analyze the experimental results and draw a conclusion. By analyzing and comparing the experimental results, we can assess the performance and improvement direction of the sculpture texture feature detection method based on DL. The following is a detailed description and analysis of these experiments. Experimental environment: The experiment was conducted on a server equipped with a high-performance GPU to support the computing needs of DL and computer graphics processing. Tools: Python is used as the main programming language, combined with DL frameworks such as TensorFlow and Keras to build and train the model. For the modeling and rendering of digital sculpture, Blender, an open source 3D graphics software, is adopted.

In order to train the DL model, this article uses a digital sculpture data set containing various styles and types. These data cover all kinds of artistic styles from ancient times to the present, from east to west, which ensures the generalization ability of the model. Specifically, the image set participating in the experiment consists of one content image and five style images. The image size is 720×1280. The model construction and algorithm realization are based on TensorFlow, a DL framework of Google open source, and some experimental results are shown in Figure 2. Figure 3 is an exploded example of a figure sculpture image.

In the experiment, this article adjusted the parameters of modeling, texture mapping, and lighting rendering based on the type, size, shape, and other characteristics of digital sculptures. For example, for modeling, different numbers of polygons and levels of detail are set; For texture mapping, the texture resolution and mapping method have been adjusted; For lighting rendering, the position, color, and intensity of the light source have been changed.

5.2 Simulation Experiment Results and Analysis

The purpose of this image restoration comparison experiment is to verify the restoration effect of different algorithms on damaged images. Three representative image restoration algorithms were selected in the experiment: sparse representation algorithm, texture synthesis algorithm, and structure prediction algorithm, to process and restore the same set of damaged images. In order to ensure the fairness of the experiment, all algorithms used the same parameter settings in the experiment. The specific parameter values are adjusted according to the algorithm's recommendations and experimental requirements. The specific experimental results are shown in Figure 4.

By analyzing the results in Figure 4, it can be concluded that the sparse representation algorithm has a poor effect on edge repair of defective areas. The texture synthesis algorithm, structure prediction algorithm, and our model have better repair effects on the edges within the defect area; However, compared to the structural prediction algorithm model, the model in this article has a stronger ability to repair the edges within the defect area; Compared with texture synthesis algorithms, although texture synthesis algorithms can effectively repair edges and textures in damaged areas, due to the propagation of errors, this algorithm introduces "new" edges in the process of repairing damaged areas; The model in this article can better control error propagation and achieve good repair results.

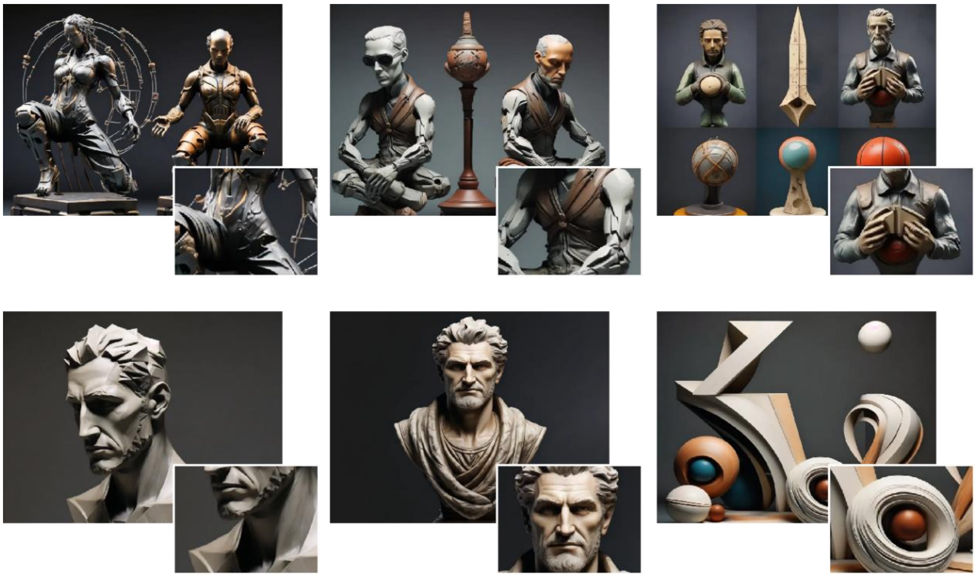

Figure 2: Partial experimental results.

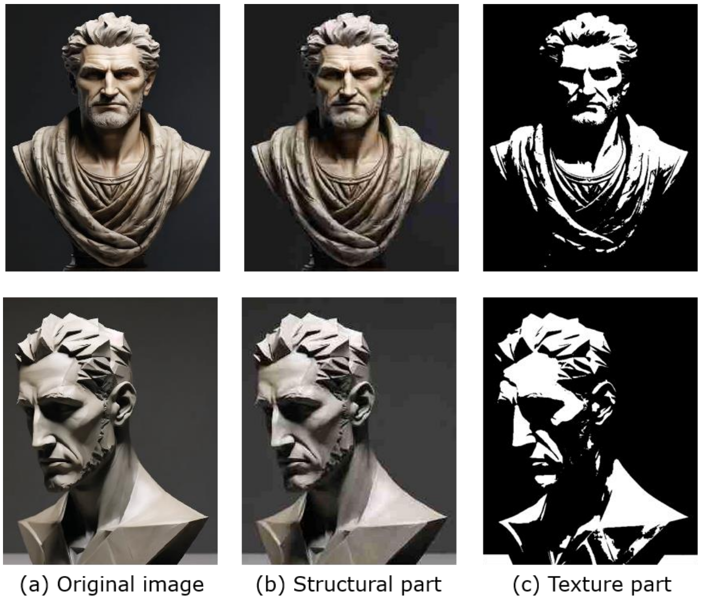

Figure 3: Image decomposition example.

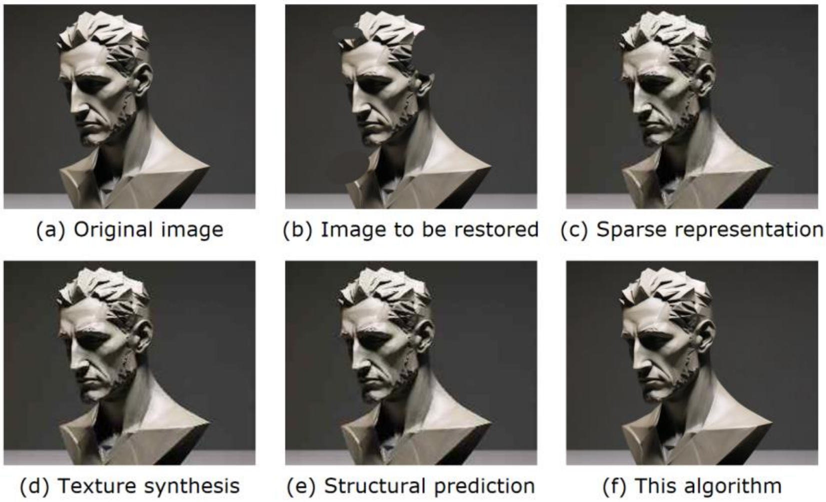

Figure 4: Contrast experiment of image restoration.

In order to verify the efficiency of the real-time rendering algorithm proposed in this article in processing complex sculpture design scenes, several sculpture design scenes with different complexities and characteristics were selected for testing. By comparing rendering speeds, the aim is to demonstrate the superiority of real-time rendering algorithms in animation rendering. The experiment was conducted in the same hardware environment to ensure fair comparison. A series of rendering tasks were performed for each scene, including static image rendering and animation rendering. Maintain consistent parameter settings for rendering tasks to ensure accuracy in comparison. Figure 5 shows the rendering speed of the algorithm.

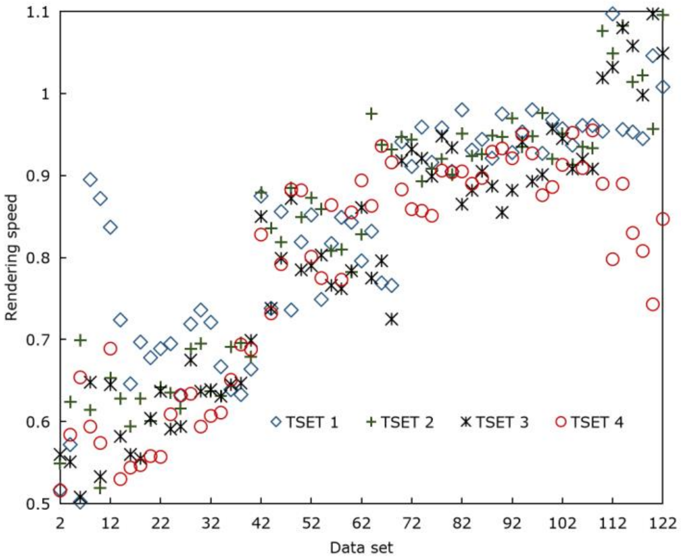

Figure 5: Rendering speed of algorithm.

From the experimental results, it can be seen that the real-time rendering algorithm has a considerable speed in animation rendering. This is mainly attributed to the efficient computation and optimization strategies adopted by the real-time rendering algorithm, which reduces the time required for rendering. This result indicates that the real-time rendering algorithm proposed in this article has high efficiency in animation rendering and can quickly handle rendering tasks of complex sculpture design scenes. It also proves the potential application value of real-time rendering algorithms in digital sculpture and other related fields.

In order to assess the performance of the sculpture automation generation algorithm proposed in this article, another set of comparative experiments were conducted. The experiment aims to compare and analyze the recall and accuracy of algorithms in sculpture generation tasks. By quantitatively evaluating these two indicators of the algorithm, we can gain a more comprehensive understanding of its advantages and disadvantages in automated sculpture generation. The experimental steps are as follows: First, use the same training dataset to train the algorithm before and after improvement; Then, run the algorithm before and after improvement on the test dataset to generate sculpture works. Finally, assess and compare the generated sculptures using recall and accuracy. The experimental results of recall and accuracy are shown in Figures 6 and 7.

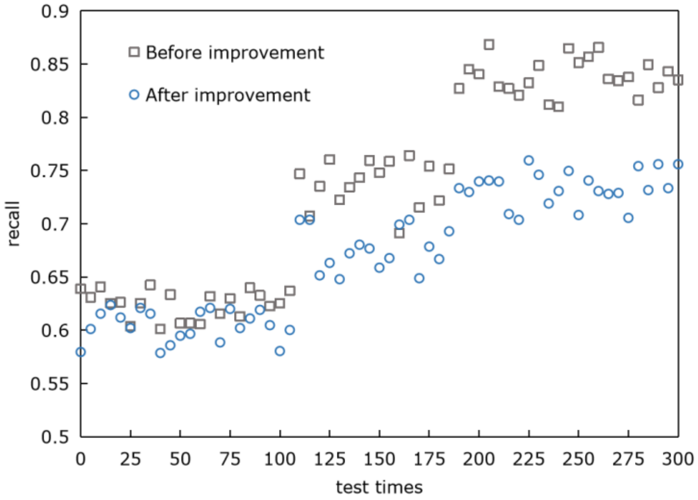

Figure 6: Comparison of recall of sculpture automatic generation.

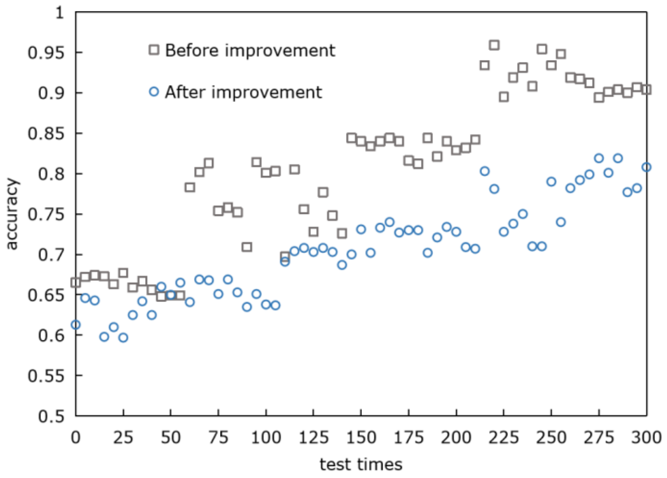

Figure 7: Comparison of accuracy of sculpture automatic generation.

Comparison of recall: Figure 6 shows the recall of sculpture generation tasks before and after algorithm improvement. From the results, it can be seen that the improved algorithm performs better in terms of recall, significantly higher than the algorithm before improvement. This indicates that the improved algorithm can generate more sculpture works that meet the requirements and has a wider range of applicability. Accuracy comparison: Figure 7 shows the accuracy of the algorithm before and after improvement in the sculpture generation task. From the results, it can be seen that the improved algorithm also performs well in terms of accuracy, slightly higher than the original algorithm. This means that the improved algorithm generates sculpture works that better meet the user's requirements and expectations, with higher quality.

By comparing and analyzing the results of recall and accuracy, the following conclusion can be drawn: the improved sculpture automation generation algorithm in this article is superior to the original algorithm in terms of recall and accuracy. This proves the superiority of the algorithm proposed in this article in automatically generating sculpture works that meet the requirements. Meanwhile, the experimental results also reveal the potential and flexibility of the algorithm proposed in this article in handling complex and diverse sculpture generation tasks.

For the above experiments, in order to verify the influence of basis functions at different scales on the experimental results, further training was conducted on eight different scales × 8. 12 × 12. 16 × Conduct experiments using 16 basis functions at three different scales. Extract eight corresponding values from the test graph × 8 pixels, 12 × 12 pixels, 16 × Construct three corresponding scale test matrices using 16-pixel sized image blocks, and map them to basis functions of the same scale. At the same time, the number of repetitions for calculating kurtosis from each image was increased from 50 to 100 times. Using the same experimental methods and steps, a classification experiment was conducted on geometric sculpture works and character sculpture works. The results are shown in Table 1.

Positive and negative basis functions	*Sculpture style*	*Recognition rate of different scales*		
		8×8	12×12	16×16
Geometric sculpture basis function	Geometric sculpture	62.56%	90.55%	88.65%
	Character sculpture	38.77%	10.66%	11.50%
Character sculpture basis function	Geometric sculpture	20.26%	21.17%	23.33%
	Character sculpture	81.31%	78.96%	78.47%
Geometric sculpture basis function	Geometric sculpture	61.17%	92.35%	92.82%
	Character sculpture	40.55%	9.66%	9.06%
Character sculpture basis function	Geometric sculpture	19.80%	18.55%	20.27%
	Character sculpture	80.64%	81.20%	79.88%

Table 1: Experimental results of positive and negative classification of basis functions of three scales based on kurtosis.

By analyzing the data obtained in Table 1, it can be seen that by increasing the number of kurtosis comparisons in the experiment and increasing the use of basis functions at different scales for experiments, although the experimental results did not improve significantly, it proved that the robustness and stability of using sparse encoding algorithm for classification experiments were relatively good.

6 CONCLUSION

The digital sculpture automation generation algorithm is a cutting-edge technology that integrates computer technology, DL, and artistic innovation. It can automatically complete the entire process of digital sculpture creation based on user input and requirements. The main focus of this article is on the research, experimentation, and comparative analysis of sculpture automation generation algorithms, aiming to provide a more advanced and effective technical solution for this field. After a series of experimental verification and comparative analysis, this article has drawn the following main conclusions and contributions:

Algorithm validity verification: The effectiveness of the proposed algorithm in sculpture generation tasks was verified through comparative experiments with three other representative automated generation algorithms. The results show that the algorithm proposed in this article performs well in both recall and accuracy key indicators, demonstrating its superiority in automated generation of sculpture works.

Technological innovation: The algorithm in this article combines various technical means such as automatic modeling, texture mapping, and lighting rendering to achieve efficient and automated generation of sculpture works. This innovation provides new tools and methods for the creation and design of digital sculpture, which helps to promote the continuous progress and growth of digital sculpture technology.

The value of art and design: By automatically generating digital sculpture works with complete structures and rich details, this algorithm demonstrates enormous potential in the field of art creation and design. This provides artists and designers with a new way of creation and tools, greatly expanding the application fields of digital sculpture.

Future research directions include: further optimizing DL models to improve performance; Research on cross modal sculpture texture feature detection methods to adapt to different types of sculpture works; Explore sculpture texture generation methods based on DL to enrich the diversity of sculpture works. With the continuous growth and improvement of DL technology, the automated generation method of digital sculptures based on DL is expected to achieve better results. Meanwhile, with the continuous improvement of computer hardware performance and the reduction of costs, the automated generation method of digital sculptures based on cloud computing and big data will also become a future research hotspot.

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