www.cad-journal.net
Computer-Aided Design AND APPLICATIONS

The Implementation of Improved Convolutional Neural Network Model in Art Pattern Design

Tan Wang[1] and Han Li[2]

[1]Fine Art College, Henan University, Kaifeng 475001, China,
10170193@vip.henu.edu.cn
[2]Fine Art College, Henan University, Kaifeng 475001, China,
animationlh@126.com

Corresponding author: Tan Wang, 10170193@vip.henu.edu.cn

Abstract. In art design, the application of artificial intelligence (AI) enables designers' design inspiration and ideas to be better integrated into art works. Computer-aided design (CAD) model of art design needs rich professional knowledge, so in most cases, the classification work is mainly done by engineers. In this article, driven by AI, the application of deep learning (DL) algorithm in art pattern CAD design is studied, and an art pattern CAD design algorithm based on improved convolutional neural network (CNN) model is proposed, which enables users to further optimize the automatically synthesized images, make style learning more flexible and get richer art pattern design effects. In this process, attention needs to be paid to computer-aided art and design, establish correct conceptual awareness, effectively carry out various art and design activities, and promote the good development of the AI era. Results show that this method can not only learn the style characteristics of several art samples and realize hierarchical drawing, but also provide users with a simple and feasible way to design art patterns according to reference samples.

Keywords: Art Patterns; Art Design; Artificial Intelligence; Cad; Deep Learning
DOI: https://doi.org/10.14733/cadaps.2024.S1.246-258

1 INTRODUCTION

Art design can add color to people's lives, create a beautiful living environment and bring warmth and comfort to the tense modern life. As a product of the development of sci & tech in modern life, AI helps people in many aspects of life, especially. The application of AI makes designers' design inspiration and ideas better integrated into art works. The CAD model of art design needs to have rich professional knowledge, so in most cases, the classification work is mainly carried out by engineers manually. In this process, establish correct conceptual awareness, effectively carry out various art and design activities, and promote the good development of the AI era. Fully excavating the characteristics of CAD model of art pattern design, scientifically managing the

existing CAD model base and reasonably reusing the models in the model base can shorten the time period of art pattern design and provide efficient auxiliary tools for art pattern designers.

DL can establish a neural connection structure that simulates the human brain and has made a new breakthrough in the field of machine learning. When the human brain processes signals such as images, sounds and texts, it will extract data features from the received input signals through the processing of multiple neural layers, so as to interpret the data. DL refers to the use of computer algorithms to simulate, analyze and monitor the data of the human brain, so as to better simulate the changes of the human brain and the dynamic changes of nerves through the data in real life, and provide theoretical reference for identifying predictive information. Image recognition research is the practical application of DL theory. This method first expresses the sensitivity of the next layer in the CNN, and then calculates the partial derivative of the overall error on the parameters of the CNN. The fully connected network model will confuse the location information of the units corresponding to the feature map, which will make it impossible to get accurate positioning results in the decoding process.

Traditional feature fusion methods often manually assign the weights of feature fusion and sum multiple features, so the rationality of the weights will directly affect the feature retrieval after fusion. This article repairs image data through image processing of global network information. Implemented the use of a small amount of local information to complete the overall network graph, combining local and global information to achieve more comprehensive image restoration. Although these methods all adopt the method of encoding before decoding, the implementation of the network varies in specific network designs. DL algorithm in art pattern CAD design and proposes an art pattern CAD algorithm based on an improved CNN model. The stylization of fractal patterns makes the generated creative patterns more in line with the characteristics of high artistic pattern boundary requirements and complete pattern details, achieving richer artistic pattern design effects.

This article investigates the effective implementation of computer-aided learning in the study of artistic patterns. The contribution of research and innovation lies in:

This article effectively utilizes the algorithm application efficiency of deep learning in art patterns. This enables users to utilize algorithms to generate rich pattern effects more quickly.

2. Research and propose an improved convolutional neural network (CNN) model for art pattern CAD algorithm, which makes image style learning more flexible.

3. The method proposed in this article not only effectively achieves layered graphics rendering, but also provides a feasible method for users.

Reasonable application of artistic image CAD can effectively promote the innovation of pattern design. The first section of the study elaborates on the background of professional knowledge in art and design, and lays the foundation for establishing a theoretical model for image recognition research using computers. Section 2 cites the image research results of relevant researchers. Analyzed the necessity of computer art software in art teaching. Section 3 analyzes the application of the improved CNN model in art pattern recognition. Section 4 simulates the art style learning algorithm for art modes. The inpainting of DL usually uses the method of encoding and decoding to complete the image information. Section 5 analyzed the experimental results and calculated the average retrieval accuracy of the proposed method. In the field of art and design, advanced artificial intelligence should be actively adopted. Continuously improving the overall artistic design effect and level, and forming a good artificial intelligence design mode. Section 6 summarizes the entire text, and the research has to some extent improved the retrieval and classification accuracy, verifying the effectiveness of the algorithm. DL excels in extracting nonlinear features.

2 RELATED WORK

Bacca et al. [1] classified the perception matrix parameters of a single pixel in a neural network. It considers the encoding aperture coupling learning of the compression architecture and achieves

pixel optimization by training the entire neural network. Chai [2] carried out functional analysis of the computer-aided design system for art drawing. It considers the overall level of art design, combined with computer design efficiency, and achieves complete functionality including architecture and data structure. Chen et al. [3] conducted image feature analysis of the overall framework, using similarity in feature descriptions for framework matching. It undergoes deep learning description evolution through local feature detection and determination of affine shape and direction. Ding and Dong [4] designed a heterogeneous representation network structure mapping model based on semantic contrast. By recognizing the emotional response of user artistic features, it constructs a color scheme for image perception. Feng [5] has provided high-level assistance in creating efficient virtual reality art and design teaching. It adopts CAD virtual reality technology as a new carrier and utilizes intelligent rendering and mapping tools for efficient artistic design creation modeling and scene rendering. Glaser et al. [6] conducted a unique chain analysis of the artistic structure of nanostructures. CAD software was used to trace and develop the complex structure of photons. It analyzed the institutional development of DNA using computer-aided intelligence technology. The detection of weld defects on radiographic films is crucial for ensuring the usability and safety of welds. Hou et al. [7] analyzed the traditional limitations of classifiers and implemented defect segmentation results through adaptive preprocessing. Jin and Yang [8] conducted a conceptual analysis of computer-aided design. It elaborates on the model color concept of environmental art teaching. By designing the environmental model advantages of artistic colors, the overall advantages of computer-aided design have been improved. Kang and Kim [9] conducted design and development of flat patterns to quickly generate 3D printing interface designs. It has developed a software simulation environment interface for the clothing field to quickly and easily generate 3D printed clothing. Liu et al. [10] conducted a visual design for the discussion of the status of scientific information media dissemination. Through the exploration and analysis of CAD, computer-aided design has become an indispensable tool in art design. It not only brings more efficient creative methods, but also brings more diverse forms.

The current machine vision intelligent mineral processing plays a crucial role. Image segmentation of the adhesion and overlap between mineral particles is an essential step for effective observation. Liu et al. [11] used different mineral image segmentation models to segment and overlap loss function. Tian et al. [12] simulated the generation of automatic batik patterns on a computer by proposing a CAD set for dyeing patterns. Through the construction of a two-dimensional iterative system [13]. Wang et al. [14] improved existing images based on deep learning of machine learning. It uses various echo models of tomography to describe the multidimensional structure of the image. Wang et al. [15] conducted deep learning network classification of image sets, which designed and analyzed matrix mapping image sets to represent non singular covariance on symmetric positive definite (SPD) manifolds. Wang et al. [16] conducted a theoretical analysis of the artistic characteristics of artistic graphics. By adopting specific artistic styles for clothing printing pattern design, it analyzes the art of generating geometric graphics in complex systems. More art creators are integrating computer-aided technology into artistic image design. Wu and Li [17] conducted a scientific exploration of cloud computing analysis in the field of graffiti art using CAD assisted visual communication. It combines art and computation with visual communication design elements to produce new works.

Wu [18] found that art graphics in computer-aided design are more easily applied in all aspects. It analyzes the necessity of computer art software in art teaching. We focused on exploring the application of computer graphics in universities through comparative analysis. Ye et al. [19] conducted a perception model for street visual quality analysis based on machine learning. It uses algorithms to construct a value evaluation model. Through design guidance on visual quality, it has been certified for detailed street view images and machine learning.

3 APPLICATION OF IMPROVED CNN MODEL IN ART PATTERN RECOGNITION

Based on the requirement of semantic information in art pattern recognition, it is need to get the features of image restoration in different degrees as much as possible. You can use a deep ANN

and then train with a large quantity of data. After the training is completed, the data in the target data set are input into the network, and then the features are extracted according to the depth of the network, and the feature map is saved as a new data set. If you use manual feature extraction, you should learn the data feature distribution with a small amount of data, but the method of manual feature extraction is too complicated and takes a long time. So we choose to use ANN to learn feature extraction from data.

Traditional feature fusion methods often allocate the weights of feature fusion manually, and sum multiple features, so the rationality of the weights will directly affect the feature retrieval after fusion. In the task of image restoration, CNN is also used as an encoder and decoder to transform the image features, and then fill the image holes according to the transformed features. The ANN classifier constructed in this article consists of five layers, namely, an input layer, Figure 1 shows the hidden layer and output layer structure content. The quantity of neurons in the input layer is determined by the dimension of the feature vector obtained by the algorithm. Logistic regression layer is used as the output layer of A.

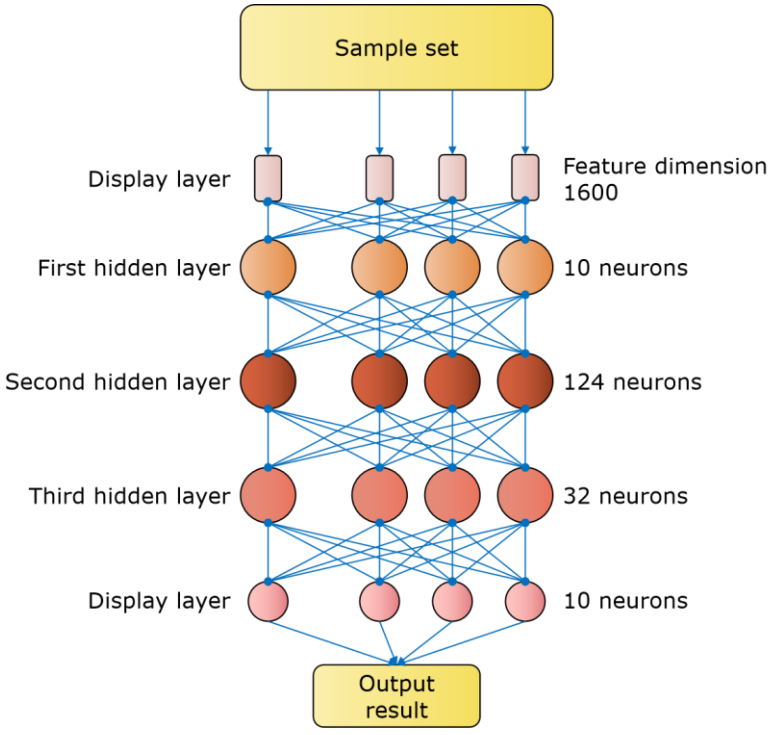

Figure 1: ANN structure diagram.

The connection between layers can be fully connected or convolution, and the parameters such as network weight and bias can be adjusted by back propagation algorithm. The biggest advantage of this network is that it can learn a large quantity of samples to extract features automatically without human intervention. Before learning a small amount of data, it is need to train a feature extraction network with a large amount of data as a prior source, then fix most parameters of the network, and to relearn the parameters of the last few layers of the network or modify the structure of the last few layers of the network before training. The data of the training prior network must be similar to the target data. If there is a big difference between the data of the training prior network and the target data, the features extracted from the network cannot represent the features of the target data.

In the actual training stage of network model, if the quantity of training samples is small, it can be found that there is a big difference between the output of training set and the output of verification set or test set. How to narrow the difference and improve the training ability is the content that people are constantly studying. Logistic sigmoidal function is a monotone function, which ensures that there will be no multiple local maxima and no undesirable extremum on the error surface. The mathematical expression of a Logistic sigmoidal function is:

$$\sigma(a)=\frac{1}{1+\exp(-a)} \tag{1}$$

Let X_i^k represent the sum of inputs of k layer neurons i, Y_i^k is the output, and the weights of $k-1$ layer neurons j to k layer neurons i are W_{ij}, then there is the following functional relationship:

$$Y_i^k = f\left(X_i^k\right) \tag{2}$$

$$X_i^k = \sum_{j=1}^{n+1} W_{ij} Y_j^{k-1} \tag{3}$$

Generally, f A is an asymmetric Sigmoid function:

$$f\left(x_i^k\right)=\frac{1}{1+\exp\left(-X_i^k\right)} \tag{4}$$

If the output layer is the m layer, the actual output of the i neuron in the output layer is Y_i^m. Let the corresponding human body signal be Y_i, and define the error function e as:

$$e=\frac{1}{2}\sum_i\left(Y_i^m-Y_i\right)^2 \tag{5}$$

The output of convolution layer and pooling layer is a two-dimensional feature map, and with category discrimination in the feature map, map this feature information to the sample label space, and judge the proportion of the input samples. The trained features are used to extract the network as a prior, and then the last layers of the network are trained with new data. In this way, the network can make use of the experience gained from the previous large-scale data training as a priori, and then the latter layers of networks can learn quickly according to the new data to get a new feature extraction network.

The fully connected layer is an operation to reduce the dimension of a two-dimensional feature map into a one-dimensional feature map, which destroys the spatial structure information of the feature map in the stage of dimension reduction, so it is not suitable to use the fully connected operation in some research work that relies heavily on the spatial feature information of the image. Because all neurons in the full connection layer participate in network training, the training parameters of the full connection layer account for the largest proportion in CNN. The main idea to solve the problem of identifying a small quantity of samples is to make full use of the existing small quantity of samples and establish a model from two aspects: how to express features and how to make features interrelated. At the same time, due to the small quantity of samples, the model is prone to over-fitting, so it is need to reduce the network parameters to avoid this problem. The CNN identification stage of art patterns is shown in Figure 2.

At first, users select representative sample style blocks from existing art works, and the algorithm automatically calculates the flow field of the target image to get the approximate brush direction when drawing, then learns the brush and texture characteristics of the sample style

blocks, and places artistic style brushes according to the direction field of the target image to generate the result image.

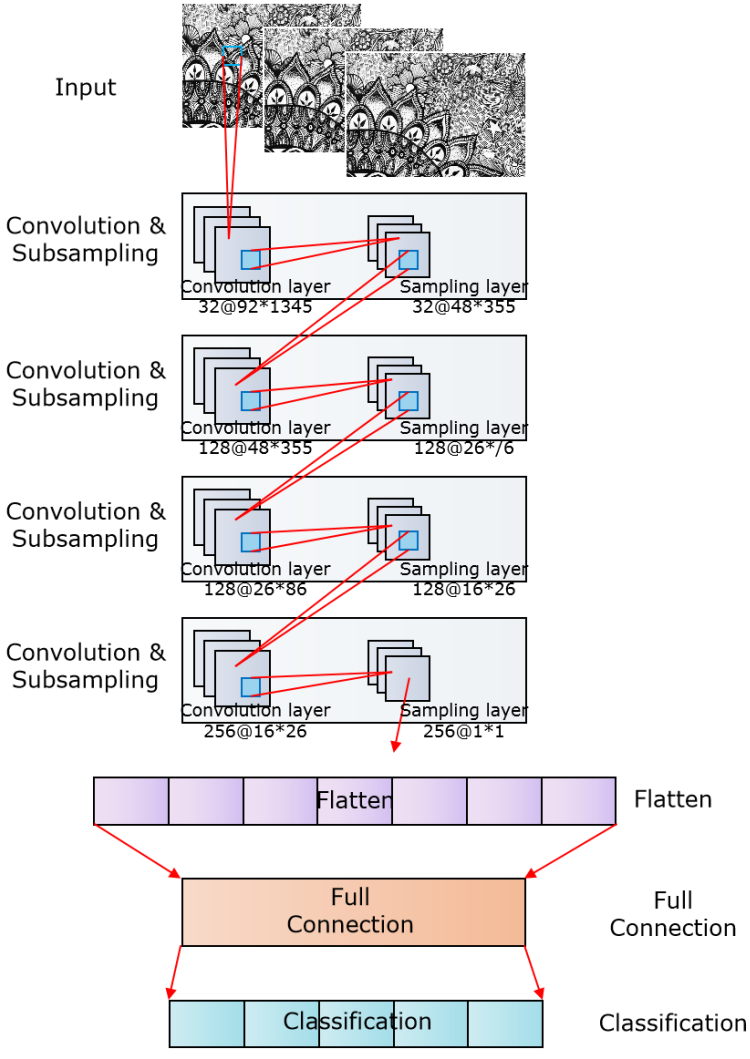

Figure 2: CNN identification stage of art patterns.

Based on the spatial structure information contained in model features, the problem of spatial structure information loss caused by view feature extraction method during projection is compensated, so that a more comprehensive 3D feature descriptor is constructed, and the limitation of using a single feature is overcome.

View features have strong discrimination, but in the stage of view projection, it will inevitably cause certain spatial structure loss; The model-based features retain the original spatial structure, but the fitting ability of the three-dimensional network is poor, and the extracted features are insufficient to represent the model. In this article, a feature fusion method based on unsupervised learning is constructed by using self-encoder, and the above two features are fused to realize the complementary advantages between different modal features, which makes the generated cross-modal fusion features more robust. In the information n integration part, two convolution

operations are carried out first, and two new layers of ANN are obtained. Then, a new feature map is obtained by fusing the feature map of the first layer with the feature map of the third layer.

Assuming that the state vector sequence of the system is $\{x_k, k \in N\}$, n_x is the dimension, and $x_k \in R^{n_x}$, which represents the state vector at k moment, the state space model of the system is:

$$x_k = f_k(x_{k-1}, u_{k-1}, v_{k-1}) \tag{6}$$

Observation equation:

$$y_k = h_k(x_k, w_k) \tag{7}$$

Where y_k is the observed value of the system state vector, f_k and h_k are known nonlinear functions. The prior distribution of initial state x_0 is $p(x_0)$. u_{k-1} is the input term, v_k and ω_k are independent and identically distributed state noise and observation noise.

The sensitivity of the convolution layer in CNN needs to be expressed by the sensitivity of the next layer, that is, the pool layer, and then the partial derivative of the total error to the parameters of the convolution layer is calculated. The fully connected network mode will lead to the confusion of the position information of the elements corresponding to the feature map, and the accurate spatial position cannot be guaranteed when decoding. However, the method of extended convolution can not only expand the receptive field but also keep the spatial invariance of convolution. It is need to up-sample the sensitivity of the pooling layer, and then multiply the obtained sensitivity of the pooling layer by the partial derivative of the activation function. The feature map obtained by the third layer network in the information integration part performs a new fusion operation with the fused feature map by jumping connection. The latest fused feature map is convolved to obtain the feature map of the last layer of ANN in the information integration part.

4 ART STYLE LEARNING ALGORITHM OF ART PATTERN

Generally, the image inpainting of DL adopts encoding-decoding method to complete the image information. Self-encoder is a typical unsupervised learning method, which is widely used in feature extraction, dimensionality reduction and data generation. The basic idea is to restore the data such as pictures or vectors input by the encoder at the output of the decoder, so that the coding features of the middle coding layer contain the hidden features of the input features. The initial input is the image to be repaired, and the output image of ANN is input into ANN again. In this way, even shallow ANN models can learn images with different restoration degrees. In this way, images are generated from coarse to fine, and the semantics obtained by the network are more and more advanced and the texture information is more and more refined by circular convolution. Because the self-encoder can extract the coding features of the input features by unsupervised learning, and the weight of each component of the features connected to the next layer of neurons can be automatically learned by back propagation algorithm without artificial allocation. Therefore, in this article, the self-encoder is applied to feature fusion to replace the traditional fusion method of artificially weighting empirical values. The flow chart of the art style learning algorithm is shown in Figure 3.

In order to keep the details of the fractal patterns in the stage of generating creative patterns, it will be more in line with the printing requirements of art patterns. There will not be a huge increase in parameters like the fully connected layer, and the expansion convolution can keep the quantity of parameters stable. After the extended convolution is completed, the feature map and the previously fused feature map are fused for the second time, and the fused feature map is convolved.

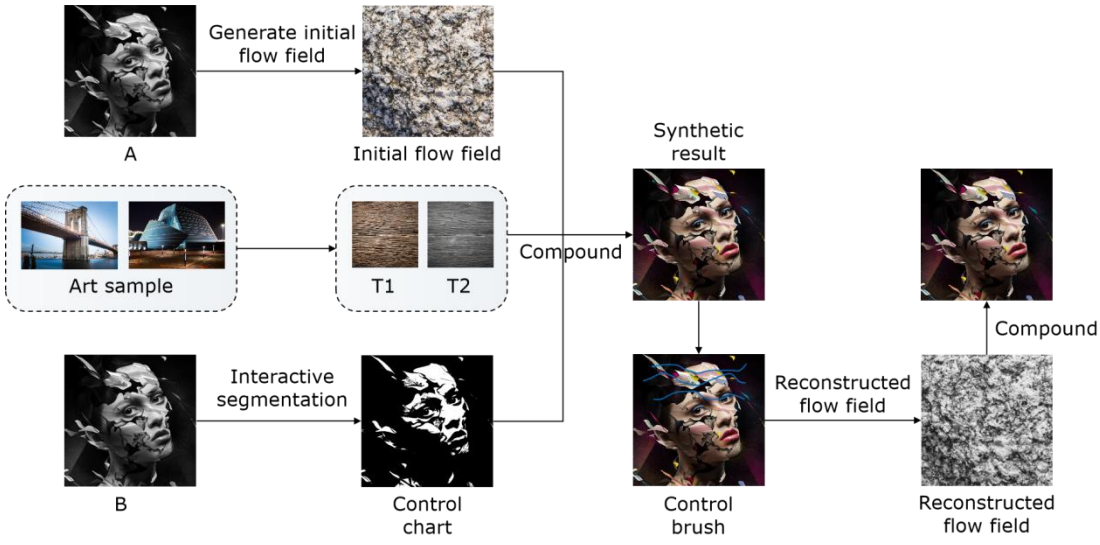

Figure 3: The flow of the art style learning algorithm.

With the deepening of CNN layers, the data transmitted between network layers will be biased towards two extreme changes, which will easily lead to the phenomenon of gradient disappearance or gradient explosion during training. Batch standardization makes the data distributed in the range of (0,1), which inhibits over-fitting to some extent and speeds up the convergence of the model. The mathematical expression of batch standardization is as follows:

$$\mu_B \leftarrow \frac{1}{m}\sum_{i=1}^{m} x_i \tag{8}$$

$$\sigma_B^2 \leftarrow \frac{1}{m}\sum_{i=0}^{m}\left(x_i + \mu_B\right) \tag{9}$$

$$\hat{x}_i \leftarrow \frac{x_i - \mu_B}{\sqrt{\sigma_B^2 + \varepsilon}} \tag{10}$$

$$y_i \leftarrow \gamma \hat{x}_i + \beta \tag{11}$$

Where μ_B and σ_B^2 respectively represent the mean and variance of m data in the set $B = \{x_1, x_2, \ldots, x_m\}$, and $\hat{x}_i$ represents the value of the i data after batch standardization. In batch standardization, learnable parameters γ and β are introduced to scale and translate the normalized data and protect the feature space distribution information learned by batch standardization layer. Batch standardization is generally carried out before the activation function is executed.

By establishing this relationship, the purpose of restraining art patterns through fractal patterns is achieved, so that the details of fractal patterns are not lost. Users can interactively segment the target image, specify the drawing styles of different regions, or draw control brushes in the target image to guide the generation of new image direction fields, rearrange the brush directions, and synthesize new result images.

5 EXPERIMENTAL RESULTS AND ANALYSIS

The algorithm in this article is mainly based on Tensor Flow platform, and NVIDIA-2080Ti GPU graphics card is used in hardware equipment. The use of GPU is helpful to accelerate the training of ANN. In the training, 100~200 pictures are randomly selected for each recognition task as the training set, and another 100 pictures are selected as the verification set. The quantity of rounds of training is set to 200, the quantity of cycles of each round of generating network is 50, and the batch size is 20. The quantity of turns and cycles are network parameters, so manual debugging is needed. Batch size has certain requirements for graphics card storage, and different devices can have different settings. The environmental configuration parameter requirements of the system are shown in Table 1.

Project	*Edition*
Operating system	Windows 11
CPU	Intel(R) Core(TM) I7-13700K
inte rnal storage	16GB
Hard drive	500G
GPU	RTX 2080Ti
Video storage	11G
DL Framework	TensorFlow 2.6
Database Management	Navicat for SQLite
Compiler	Python 3.8
Interface development	Qt Designer

Table 1: Requirements for environmental configuration parameters of the system.

When the quantity of input samples is increased, the quantity of equations of the equations increases, and the quantity of vectors in the basic solution system of the equations increases, so it is easier for the network model to achieve global optimization. The performance comparison results of the image database updating algorithm are shown in Figure 4.

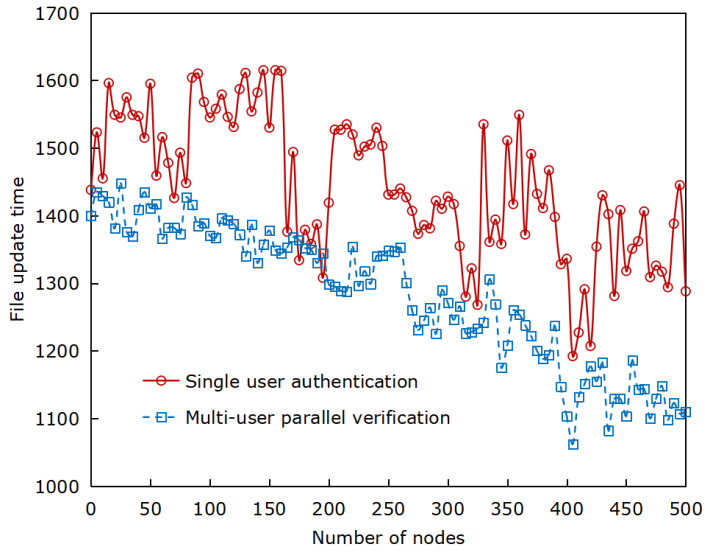

Figure 4: Performance comparison of image database updating algorithms.

It can be seen that with the increase of the quantity of nodes in the computing environment, the parallel verification algorithm has higher computational efficiency than the single-user verification algorithm.

Using DL-based art pattern CAD design can reduce a lot of design work and time compared with traditional art design methods. First of all, in different numbers of photos and cases, the art patterns are retrieved, and the retrieval time of art patterns with different numbers of nodes is tested. The result of the experiment is shown in Figure 5.

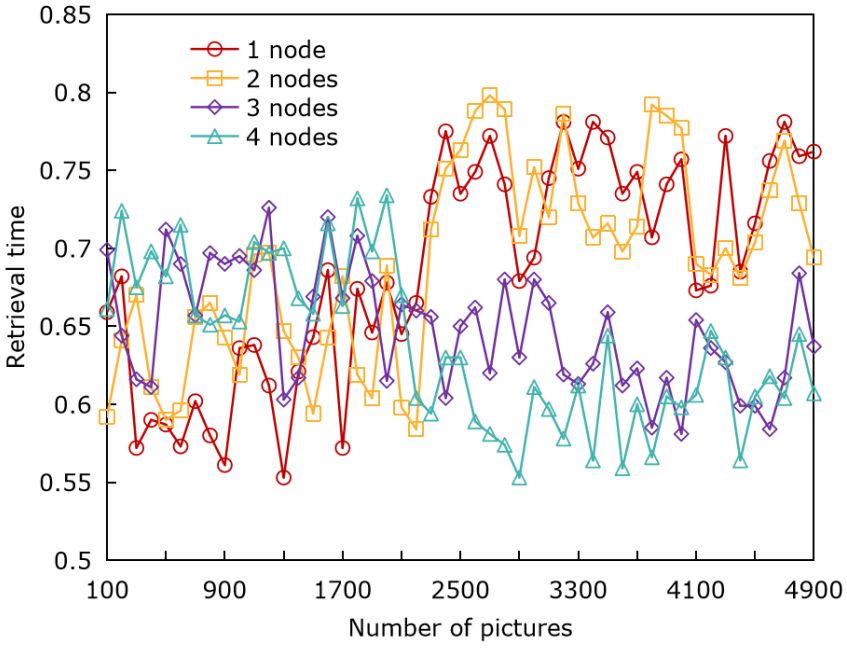

Figure 5: Time consumption of art pattern retrieval.

As can be seen from Figure 3, if the quantity of retrieved patterns is small, with the increase of image retrieval network nodes, the time required for art pattern retrieval has no obvious advantage or even increases or decreases. However, when the quantity of art pattern retrieval is increasing, the advantages of multi-point will become more and more obvious, and the retrieval efficiency will be obviously improved.

For the three-dimensional model of the model database, the placement position of the model is arbitrary. In order to make the extracted two-dimensional view uniform, the three-dimensional model is often preprocessed before the view extraction of the model. The average error rate of CNN classifier on the test set is 1.36%. Figure 6 shows the error curve of the whole training stage.

Sometimes there are synaptic weights in the network that have little influence on the network performance. When the overall classification of the network model has not been fitted, the classification effect of a single category is still poor. The data augmentation method of optimizing classification will increase the input samples with poor classification effect. Figure 7 shows the recall-precision curve of this algorithm. This article compares the retrieval effects of improved methods such as CNN, RNN, DBN and WNN in the semantic data set of art images.

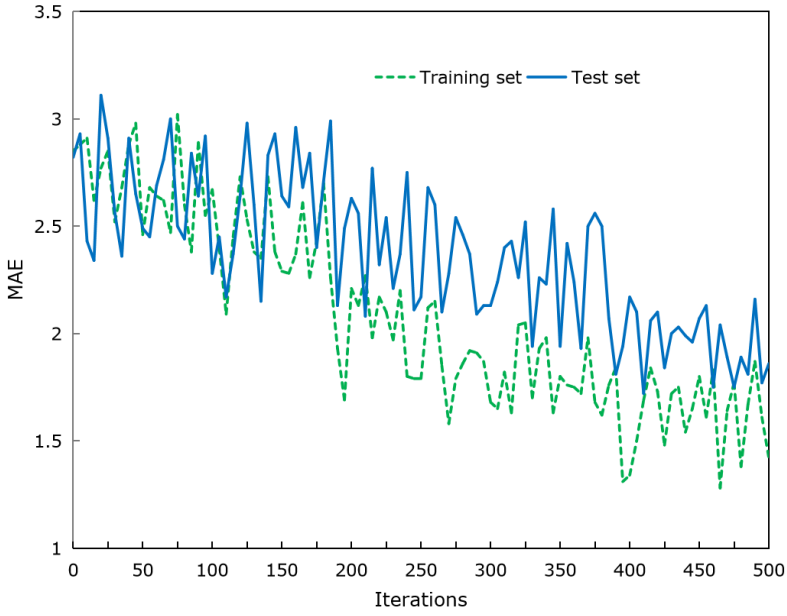

Figure 6: Error change curve in training stage.

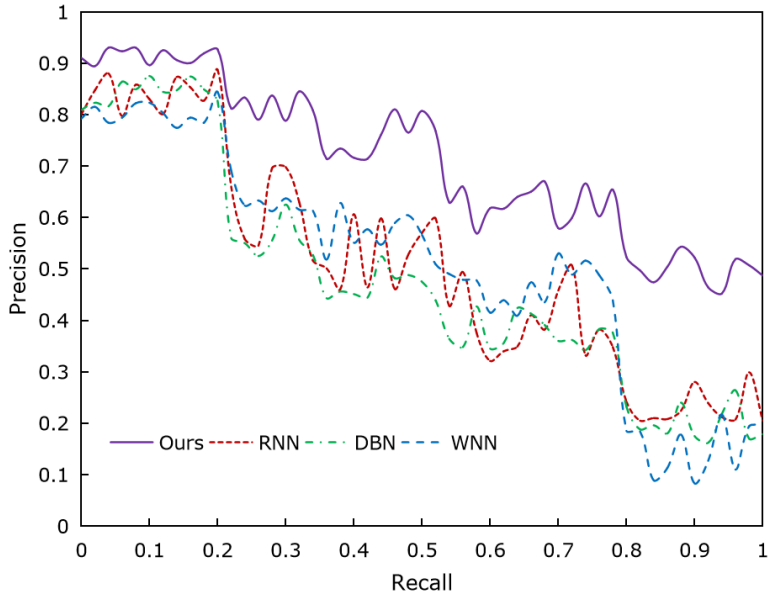

Figure 7: Recall-precision curve.

The circular marking curve in Figure 7 represents the recall precision curve of the method proposed in this article, and it can be seen that the area enclosed by it and the coordinate axis is larger than other comparative algorithms, which shows that the algorithm proposed in this article is better than the comparative method in retrieval effect. According to statistics, the average

retrieval accuracy is 96.7%, which is 9.6% higher than that of DBN, which has the highest average retrieval accuracy. Art pattern CAD design can promote the intelligent development of art design.

The design technology of art pattern CAD based on DL is mainly characterized in that it can transform some invisible information into graphics or images to be displayed in front of designers. Its graphics and images are bizarre in form and unique in style, which is beyond human imagination and can be an inexhaustible source of creation. In the field of art and design, advanced AI should be actively adopted, relevant experience should be summarized, and AI should be reasonably adopted in the fields of interior art design, product art design, and landscape art design, continuously improving the overall art and design effect and level, and forming a good AI design model.

6 CONCLUSION

The research has achieved good development in the level and effectiveness of art design. For the CAD design application of art patterns, it has improved the algorithm level and effectiveness based on deep learning and convolutional networks. Based on the spatial structure information contained in model features, the problem of spatial structure information loss caused by view feature extraction method during projection is compensated, so that a more comprehensive 3D feature descriptor is constructed, and the limitation of using a single feature is overcome. The simulation results show that the proposed algorithm is superior to the contrast method in retrieval effect. According to statistics, the average retrieval accuracy is 96.7%, which is 9.6% higher than that of DBN, which has the highest average retrieval accuracy. Compared with the single feature method, the fused features have improved the retrieval accuracy and classification accuracy to some extent, which verifies the effectiveness of the algorithm. DL is excellent at extracting nonlinear features, but in most cases DL needs a lot of data and time to train an ANN model to achieve a task. In the future research, the image analysis method is considered to analyze the image content online in more detail, and the application of DL in the field of CAD model is further explored.

Tan Wang, https://orcid.org/0009-0007-3888-9596
Han Li, https://orcid.org/0009-0005-3483-5289

REFERENCES

[1] Bacca, J.; Galvis, L.; Arguello, H.: Coupled deep learning coded aperture design for compressive image classification, Optics Express, 28(6), 2020, 8528-8540. https://doi.org/10.1364/OE.381479
[2] Chai, X.: Construction and implementation of computer aided design system for art graphics, Computer-Aided Design and Applications, 18(S1), 2021, 1-10. https://doi.org/10.14733/cadaps.2021.S1.1-10
[3] Chen, L.; Rottensteiner, F.; Heipke, C.: Feature detection and description for image matching: from hand-crafted design to deep learning, Geo-Spatial Information Science, 24(1), 2021, 58-74. https://doi.org/10.1080/10095020.2020.1843376
[4] Ding, M.; Dong, W.: Product color emotional design considering color layout, Color Research & Application, 44(2), 2019, 285-295. https://doi.org/10.1002/col.22338
[5] Feng, C.: An intelligent virtual reality technology in the teaching of art creation and design in colleges and universities, Journal of Intelligent & Fuzzy Systems, 40(2), 2021, 3699-3710. https://doi.org/10.3233/JIFS-189404
[6] Glaser, M.; Deb, S.; Seier, F.; Agrawal, A.; Liedl, T.; Douglas, S.; Smith, D.-M.: The art of designing DNA nanostructures with CAD software, Molecules, 26(8), 2021, 2287. https://doi.org/10.3390/molecules26082287

[7] Hou, W.; Zhang, D.; Wei, Y.; Guo, J.; Zhang, X.: Review on computer aided weld defect detection from radiography images, Applied Sciences, 10(5), 2020, 1878. https://doi.org/10.3390/app10051878
[8] Jin, H.; Yang, J.: Using computer-aided design software in teaching environmental art design, Computer-Aided Design and Applications, 19(1), 2021, 173-183. https://doi.org/10.14733/cadaps.2022.S1.173-183
[9] Kang, M.; Kim, S.: Fabrication of 3D printed garments using flat patterns and motifs, International Journal of Clothing Science and Technology, 31(5), 2019, 653-662. https://doi.org/10.1108/IJCST-02-2019-0019
[10] Liu, F.; Gao, Y.; Yu, Y.: Computer aided design in the diversified forms of artistic design, Computer-Aided Design and Applications, 19(3), 2021, 33-44. https://doi.org/10.14733/cadaps.2022.S3.33-44
[11] Liu, Y.; Zhang, Z.; Liu, X.; Wang, L.; Xia, X.: Efficient image segmentation based on deep learning for mineral image classification, Advanced Powder Technology, 32(10), 2021, 3885-3903. https://doi.org/10.1016/j.apt.2021.08.038
[12] Tian, G.; Yuan, Q.; Hu, T.; Shi, Y.: Auto-generation system based on fractal geometry for batik pattern design, Applied Sciences, 9(11), 2019, 2383. https://doi.org/10.3390/app9112383
[13] Verganti, R.; Vendraminelli, L.; Iansiti, M.: Innovation and design in the age of artificial intelligence, Journal of Product Innovation Management, 37(3), 2020, 212-227. https://doi.org/10.1111/jpim.12523
[14] Wang, G.; Ye, J.-C.; De, M.-B.: Deep learning for tomographic image reconstruction, Nature Machine Intelligence, 2(12), 2020, 737-748. https://doi.org/10.1038/s42256-020-00273-z
[15] Wang, R.; Wu, X. J.; Kittler, J.: SymNet: A simple symmetric positive definite manifold deep learning method for image set classification, IEEE Transactions on Neural Networks and Learning Systems, 33(5), 2021, 2208-2222. https://doi.org/10.1109/TNNLS.2020.3044176
[16] Wang, W.; Zhang, G.; Yang, L.; Wang, W.: Research on garment pattern design based on fractal graphics, Eurasip Journal on Image and Video Processing, 2019(1), 2019, 1-15. https://doi.org/10.1186/s13640-019-0431-x
[17] Wu, H.; Li, G.: Visual communication design elements of internet of things based on cloud computing applied in graffiti art schema, Soft Computing, 24(11), 2020, 8077-8086. https://doi.org/10.1007/s00500-019-04171-4
[18] Wu, Y.: Realization of fractal art pattern composition based on photoshop software, Computer-Aided Design and Applications, 17(S2), 2020, 123-133. https://doi.org/10.14733/cadaps.2020.S2.123-133
[19] Ye, Y.; Zeng, W.; Shen, Q.; Zhang, X.; Lu, Y.: The visual quality of streets: A human-centred continuous measurement based on machine learning algorithms and street view images, Environment and Planning B: Urban Analytics and City Science, 46(8), 2019, 1439-1457. https://doi.org/10.1177/2399808319828734