Optimization of User Interaction Experience of Traditional Craft Pattern Design Based on CAD and Virtual Reality

Yi Zou[1] and Wenjing Wang[2]

[1]Department of Information Technology, Zhengzhou Vocational College of Finance and Taxation, Zhengzhou, Henan 450048, China, zouyi@zzcsjr.edu.cn
[2]College of Art and Design, Zhengzhou College of Finance and Economics, Zhengzhou, Henan 450000, China, wwj2023@126.com

Corresponding author: Yi Zou, zouyi@zzcsjr.edu.cn

Abstract. Computer aided design (CAD) is a design tool using computers, which can help designers create, modify and optimize designs on the screen. Virtual reality (VR) technology can create a three-dimensional, immersive design environment, so that designers and users can interact in a more intuitive and vivid way. Through the combination of CAD and VR technology, the design process of traditional craft patterns can be optimized, the design efficiency can be improved, and a better user interaction experience can be provided. In this article, the combination of CAD and VR technology is applied to the traditional process pattern design, and the convolutional neural network (CNN) is introduced as the feature detection model, and the three-dimensional model is optimized by using the generator principle. In the feature detection experiment, the interactive system of process pattern design constructed by CNN method shows high accuracy and stability. In the subjective scoring experiment of generating animation, the interactive system of process pattern design constructed by CNN method performed best, with an average score of more than 85. Through in-depth research and growth of deep learning (DL) technologies such as CNN and GAN, it is possible to generate more realistic and natural 3D models of process patterns, thus providing better user interaction experience.

Keywords: Computer Aided Design; Virtual Reality; Traditional Craft Patterns; Feature Detection; Interactive Experience
DOI: https://doi.org/10.14733/cadaps.2024.S12.251-265

1 INTRODUCTION

In the past decades, the progress of computer technology has had a far-reaching impact on all walks of life, especially in the field of design. CAD is a tool for designing by computer, which can help designers to create, modify and optimize designs on the screen, instead of designing on physical paper or models. With the continuous development of virtual reality (VR) technology, the position of virtual reality narrative games in the gaming industry is increasing. However, how to accurately detect players' social attitudes in games is an urgent problem to be solved. Dobre et al. [1] explored the application and future development of immersive machine learning in social attitude detection in virtual reality narrative games. At present, there are few studies on social attitude detection in virtual reality narrative games. The published literature mainly focuses on traditional static data analysis, lacking accurate grasp of players' dynamic behavior and emotional changes during the game process. Therefore, it is imperative to develop a technology that can detect players' social attitudes in real-time and accurately. By collecting data on players' language, behavior, and facial expressions, sufficient information is provided for subsequent analysis. Using natural language processing technology, analyze players' text conversations in the game, extract emotional features, and grasp players' emotional changes.

By using a deep learning model, train and learn the above data to achieve automatic recognition and classification of players' social attitudes. This design method can not only improve the design efficiency, but also reduce the error rate and waste of resources. Moreover, the growth of VR technology has also brought new possibilities to the design field. VR technology can create a three-dimensional and immersive design environment, so that designers and users can interact in a more intuitive and vivid way. Gao et al. [2] explored the application background, advantages, and limitations of virtual reality in cultural learning. By summarizing the main methods and technologies of current cultural learning, analyzing the application prospects and potential of virtual reality in it, and introducing the research methods, results, and conclusions adopted. The study selected Oculus Rift S as a virtual reality device and designed a series of virtual reality scenes with the theme of "cultural learning". We selected different types of cultural content, including historical architecture, traditional festivals, art, etc., and classified and analyzed them. At the same time, we have also developed an evaluation system to measure students' learning outcomes after using virtual reality technology. The results show that virtual reality technology has significant advantages in cultural learning. Firstly, by simulating the real environment, students can better understand cultural content and improve learning efficiency. Secondly, virtual reality technology can provide real emotional experiences, helping students better understand and experience the connotations of culture. Finally, by simulating real-life scenarios, students' memory has been deepened, making them more accurate in recalling and understanding cultural content. Through VR, designers can see the design effect in real time during the design process, while users can experience the design products in a more realistic way before the design is completed. In the field of gaming, the key technology of immersive tactile interactive gaming human-computer interaction based on VR technology has become a new trend. Gao [3] discussed the background and significance of this key technology, as well as its application and future development trends in the gaming field. Gesture recognition technology uses computer vision and deep learning technologies to recognize user hand movements and gestures, and convert them into interactive instructions in the virtual world. For example, users can use gestures to control characters, items, or perform specific operations in the game. This technology increases the interactivity and realism of the game, allowing users to interact more naturally with the game. Speech recognition technology converts users' speech into text or commands for interaction in a virtual environment. This technology allows users to control games, query information, or communicate with virtual characters through verbal commands. Speech recognition technology plays an important role in enhancing game interactivity and user experience.

Traditional craft pattern design is a complicated work that needs rich experience, and through the combination of CAD and VR technology, the design process can be optimized, the design efficiency can be improved, and a better user interaction experience can be provided. How to quickly and effectively retrieve the required models in massive 3D models has become an important issue. Traditional text or keyword-based retrieval methods cannot effectively solve this problem, as they cannot accurately describe the structure and features of 3D models. Therefore, Gao et al. [4] analyzed that view-based 3D model retrieval has gradually become a research hotspot. View-based 3D model retrieval refers to the retrieval method of analyzing the views of 3D models, extracting their features, and performing similarity matching. It needs to consider issues such as how to extract features from 3D models, how to represent features, and how to match features. This article will explore deep learning methods for view-based 3D model retrieval, including research on feature extraction, feature representation, and feature matching. Deep learning is a branch of machine learning that simulates the workings of human brain neural networks by constructing multi-layer neural networks, thereby enabling the processing and analysis of complex data. In view-based 3D model retrieval, deep learning can be used to learn the feature representation of 3D models, thereby achieving more accurate and efficient retrieval. However, although CAD and VR technology are widely used in the design field, there are relatively few studies on applying them to traditional craft pattern design and optimizing user interaction experience. Therefore, the purpose of this study is to optimize the traditional craft pattern design and improve the user interaction experience by combining CAD and VR technology. Road feature detection is one of the key tasks in autonomous driving and intelligent transportation systems. Accurate and efficient detection of road features is crucial for vehicle control, navigation, and traffic flow analysis. Convolutional neural networks (CNN), as a powerful deep learning algorithm, have achieved significant results in the field of image processing, including road feature detection. However, traditional CNN has some limitations in processing road feature detection, such as insufficient adaptability to complex scenes and low computational efficiency. To address these issues, Kuo and Tsai [5] proposed a road feature detection method based on adaptive square joint convolutional neural network (ASU-CNN). Convolutional neural networks have been widely used in the field of image processing. In terms of road feature detection, traditional CNN models such as VGG and ResNet have been used to extract features from road images and have achieved good results. However, these models have certain performance limitations when dealing with complex road scenes. On this basis, this paper proposes an adaptive square joint convolutional neural network, aiming to further improve the accuracy and efficiency of road feature detection.

Virtual reality technology is a computer technology that can create and experience virtual worlds. In digital media communication, virtual reality technology can provide an immersive experience, making the audience feel as if they are in a news scene or scene. Li and Wenjie [6] discussed the application of these two technologies in digital media communication and how they can improve communication effectiveness and accuracy. Virtual reality technology and digital twin technology can be combined and applied in digital media communication to further improve the effectiveness and accuracy of digital media communication. For example, in news reporting, digital twin technology can be used to provide real-time feedback on the news scene, while virtual reality technology can also be used to immerse the audience in the atmosphere of the news scene. By using digital twin technology to model data in the physical world, and then using virtual reality technology for simulation, the audience can more realistically experience various aspects of news events. By combining augmented reality with virtual reality technology, the effect of virtual reality integration can be achieved in digital media communication, thereby further enhancing the audience's sense of immersion and participation. In this study, CNN is used as the feature detection model. CNN is a DL model, which is especially suitable for processing images and visual information. In our research, CNN will be used to extract the features of traditional craft patterns, which will be used to guide the generator to optimize the three-dimensional model. The generator principle is a method of model generation through machine learning, which can generate new and similar outputs according to given input data. In the research, the generator principle will be used to generate three-dimensional models according to the characteristics of traditional process patterns. Through this method, the traditional craft pattern can be optimized, making it more realistic in vision and more in line with the original handmade products.

The main significance of this study is to improve the efficiency and effect of traditional craft pattern design and optimize the user interaction experience. By combining CAD and VR technology, we can better understand and master the design process, improve the work efficiency of designers, and provide users with a more real and intuitive design experience. The innovations of this study mainly include the following aspects:

(1) The combination of CAD and VR technology is applied to the traditional craft pattern design, which provides a new perspective and method for the design process and is expected to improve the design efficiency and effect.

(2) CNN is introduced as a feature detection model to effectively extract the features of traditional craft patterns, which provides a basis for the subsequent 3D model optimization.

(3) Using the generator principle to optimize the three-dimensional model, so that the generated model is more realistic in vision and more in line with the original handmade products, which enriches the traditional process pattern design methods.

(4) By combining CAD and VR technology, it can provide users with a more real and intuitive design experience, so that users can better participate in the design process.

The research will be divided into the following steps: firstly, the existing CAD and VR technologies are discussed and analyzed to understand their working principles and application scope; Then select the appropriate CNN model for feature detection, and train a three-dimensional model generator according to the generator principle to generate three-dimensional models according to the characteristics of traditional craft patterns; Then evaluate and optimize the user interaction experience through user testing, and adjust and improve according to the feedback; Finally, the whole research process is summarized and analyzed, and possible improvement suggestions and future research directions are put forward.

2 THEORETICAL BASIS

Li and Hsu [7] studied automatic terrain feature recognition methods for remote sensing images and provided a detailed introduction to the implementation process of deep learning methods. Through experimental comparison, it has been shown that deep learning has high accuracy and robustness in terrain feature recognition of remote sensing images, and has broad application prospects and future research directions. However, the application of deep learning methods still faces challenges such as data quality, model selection, and optimization algorithms. Future research can focus on the following aspects: 1) improving the robustness and scalability of data quality; 2) Explore deep learning models and algorithms suitable for remote sensing images; 3) Combining multi-source and multi-scale data for comprehensive analysis to improve recognition accuracy; 4) Integrating deep learning with other technologies such as GIS and GPS to achieve more comprehensive terrain feature recognition and application. Computer graphics technology can help designers achieve more realistic and intuitive product visualization modeling. Through 3D modeling technology, designers can transform product design solutions into 3D models to better observe and evaluate the feasibility and effectiveness of product design. Lu et al. [8] detailed the implementation steps of this method and explored its application in computer-aided design and computer graphics. After developing an optimized design plan, the designer needs to verify the plan to ensure its effectiveness and feasibility. This can be achieved through comparative experiments, user testing, and other methods. Through comparative experiments, designers can compare the differences in product performance, user experience, and other aspects before and after optimization. Through user testing, designers can understand user feedback and evaluations of the optimized product, thereby confirming the effectiveness of the optimization plan.

Mahajan et al. [9] Automated robot motion detection using computer vision and deep learning technology. Computer vision and deep learning technologies provide new solutions for automatic robot motion detection. Computer vision technology can extract various motion features of robots by analyzing image or video information, providing a basis for subsequent decision-making and judgment. Deep learning technology can utilize a large amount of data to train models, allowing them to automatically learn and recognize various actions, thereby achieving more accurate action detection. In the field of intelligent manufacturing, automatic robot motion detection using computer vision and deep learning technology can help factories achieve automated production, improve production efficiency and quality. For example, by monitoring the robot arm in real-time, it is possible to determine whether the position and posture of the object it is grasping are correct, thereby achieving automatic correction and adjustment. In the field of smart homes, this technology can help home care robots achieve more accurate behavioral judgments, thereby improving their service capabilities and efficiency. Traditional bleeding detection methods mainly include methods based on color, edge detection, and texture analysis. These methods can achieve good results in some cases, but their accuracy and reliability need to be improved when dealing with complex retinal images. With the development of deep learning technology, more and more researchers are applying deep learning to bleeding detection and have achieved certain results. However, most of these methods are based on 2D images and have limited processing power for 3D images. Maqsod et al. [10] proposed a bleeding detection method based on a 3D CNN deep learning framework and feature fusion. This method establishes a 3D CNN model, fully utilizes 3D information for bleeding detection, and adopts feature fusion technology to fuse different features to improve the accuracy and reliability of bleeding detection. This article uses experimental evaluation to validate the bleeding detection method based on the 3D CNN deep learning framework and feature fusion. The experimental results indicate that this method has high accuracy and reliability in bleeding detection. Compared with traditional bleeding detection methods, this method has significantly improved accuracy and reliability. With the rapid development of technology, we are witnessing a new interdisciplinary field - the integration of virtual and reality. This fusion has opened up a new perspective for us to study and analyze the fit between the real world and the virtual world.

Shiau et al. [11] used Pok é mon Go, a phenomenon level augmented reality (AR) game, as an example to delve into the development of a scale for the integration of the real world and the virtual world. Pok é mon Go is a location-based augmented reality game. It perfectly combines virtual characters with the real environment, allowing players to capture virtual Pok é mon in the real world. This fusion is not only reflected in visual effects, but also further blurs the boundary between real and virtual. By using devices such as mobile phones, players can see virtual Pok é mon in the real environment, as if they really exist in the real world. Traditional craftsmanship, as a treasure of human civilization, contains rich cultural connotations and unique artistic values. However, with the acceleration of modernization, many traditional crafts have gradually lost their living space and are facing the threat of extinction. In order to protect and inherit this precious cultural heritage, Stefanidi et al. [12] took measures to transfer traditional craftsmanship from the physical world to the virtual world. By scanning and recognizing traditional handicraft images, they are transformed into computer recognizable data. Introducing machine vision and artificial intelligence technology to simulate the coordination of eyes and hands during the manual production process, achieving automation of handicraft production. Through virtual reality technology, users can intuitively experience the production process of traditional handicrafts and experience their unique charm in a virtual environment. Trunfio et al. [13] explored the application background of virtual reality and augmented reality in the service model of cultural heritage museums, as well as their impact on the overall experience and satisfaction of tourists. The application of virtual reality and augmented reality technology in the service model of cultural heritage museums aims to provide tourists with a more immersive experience. The application of VR and AR technology enables tourists to understand and interact with cultural heritage in an intuitive and vivid way. This innovative service model is more attractive than traditional display methods, while also better protecting and inheriting cultural heritage. The study adopted a random sampling method and selected a certain number of tourists for investigation. Firstly, we collected tourists' perceptions and attitudes towards virtual reality and augmented reality technology through a questionnaire survey. In addition, we conducted in-depth interviews to understand the actual user experience and satisfaction of tourists with these technologies. In the digital era, museums have gradually moved from physical space to virtual space. The emergence of virtual reality (VR) technology allows us to simulate realistic 3D scenes through computers, providing viewers with an immersive visiting experience. In this context, the invisible museum has emerged. It is user centered and utilizes VR technology to create personalized virtual 3D exhibitions, allowing viewers to enjoy the immersive pleasure of visiting at home. Zidianakis et al. [14] VR supports the creation of virtual 3D exhibitions in museums. By using VR technology to present museum exhibits in virtual 3D format, visitors can visit them at home through devices. This new museum model eliminates the hassle of visitors walking around and searching for exhibits in physical museums, and avoids the problem of some exhibits being unable to be displayed due to venue limitations. Compared with traditional physical museums, invisible museums have higher flexibility and convenience. Model training is a key step in deep learning models, and through training with a large amount of data, the model can be equipped with learning and prediction capabilities. The training process involves parameter setting, optimization algorithm selection, and learning rate adjustment. After training, it is necessary to evaluate the model to determine its performance. Common evaluation indicators include accuracy, recall, F1 score, etc. Evaluation methods can include cross validation, ROC curves, and AUC values. After training and evaluating the model, experimental results can be obtained. The performance of the model may vary on different datasets. To verify the generalization ability of the model, comparative experiments need to be conducted to compare it with other peptide feature detection methods. Zohora et al. [15] used a dataset consisting of HCD-MS2 and LTQ-FT-MS2. Through comparative experiments, it was found that the deep learning model for peptide feature detection based on LC-MS profiles outperformed traditional peptide feature detection methods in terms of accuracy and recall.

3 METHODOLOGY

3.1 Process Pattern Feature Detection

The theoretical basis of this study mainly covers CAD, VR technology, CNN and generator principle and other related fields.

CAD is mainly used in the design stage of traditional craft patterns in this article. CAD is an auxiliary design tool that integrates computer hardware, software and graphics technology, which allows designers to create, modify, analyze and optimize designs on computers. CAD has a wide range of applications, from simple two-dimensional drawing to complex three-dimensional model design.

Furthermore, CAD is used to realize the automatic design process in this article. Specifically, this article uses the algorithm and model base in CAD software to realize the automatic generation of two-dimensional and three-dimensional models of traditional process patterns. This automatic design not only greatly improves the design efficiency, but also reduces human errors and waste of resources.

VR technology provides support for the user interaction experience. VR is a computer technology. By simulating various elements of the real world, users can immerse themselves in the computer-generated environment and interact with it. This technology can create a very realistic visual, auditory and tactile experience, enabling participants to operate and interact as if they were in the real world.

In this article, an immersive traditional craft pattern design environment is created by using VR technology. In this environment, users can interact with the 3D model through virtual handles or gestures, and rotate, scale and move the model. This interactive mode not only improves the user's participation and interest in design, but also optimizes the user's interactive experience.

CNN is an important model for feature detection in this article. CNN is a DL network structure, which is especially suitable for processing images and visual information. In the research, CNN will be used to extract features from traditional craft patterns, and these features will be used to guide the generator to optimize the three-dimensional model.

Specifically, firstly, the traditional craft patterns are converted into digital images by using CAD software, and then the features of the images are detected by using CNN model. These features include not only the shape and color information of the pattern, but also its texture and structure information. This feature information will be used to train a Conditional Generation Antagonistic Network (GAN) model to generate a realistic 3D model.

The generator principle is the theoretical basis of this article for 3D model optimization. The generator principle is a method of model generation through machine learning, which can generate new and similar outputs according to given input data. In our research, the generator principle will be used to generate three-dimensional models according to the characteristics of traditional craft patterns.

In this article, a cGAN is used to generate the 3D model. The network consists of a generator and a discriminator, and through antagonistic training between them, the difference between the generated model and the real model is minimized. The advantage of this method is that it cannot only generate a realistic three-dimensional model, but also ensure that the generated model has certain novelty and creativity.

Feature detection is a key step in the optimization of user interaction experience of traditional craft pattern design based on CAD and VR. This section will introduce how to use CNN to detect the characteristics of process patterns, and its structure is shown in Figure 1.

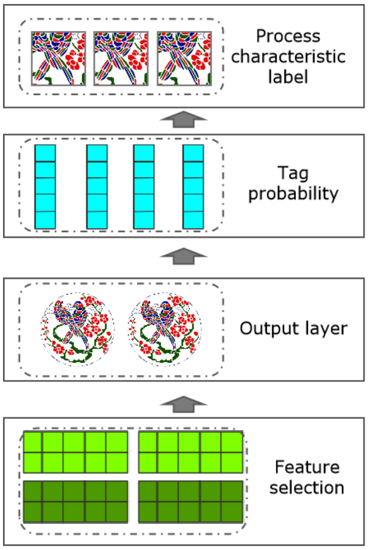

Figure 1: Feature detection model of process pattern.

First, it is necessary to convert the traditional process patterns into digital images. Because traditional craft patterns are usually composed of complex textures and structures, it is necessary to choose appropriate image resolution and color space to ensure the quality and accuracy of images. After the conversion, a series of digital images can be obtained, which can be used as the input of CNN model.

The specific calculation is as follows:

$$y_a^l = f\left(w_a^l \otimes x_a^l + b_a^l\right) \tag{1}$$

Among them, y_a^l is the output value of the a neuron in the l layer; w_a^l is the weight of the convolutional kernel; x_a^l is the input value; b_a^l is offset; $\otimes$ is the convolution operation, and $f(\cdot)$ is the activation function. After performing convolution on the feature map, the output size is smaller than the input size. In order to ensure that the input and output feature sizes are consistent, it is necessary to fill in the input data. The commonly used filling methods include zero filling and repeated boundary filling.

CNN is a DL network structure, especially suitable for processing images and visual information. In the research, the basic structures such as convolution layer, pooling layer and fully connected layer are selected to build CNN model. Specifically, the feature information in the image is extracted step by step by stacking a plurality of convolution layers and pooling layers. This feature information includes not only the shape and color information of the pattern, but also its texture and structure information.

Let X_i^k represent the sum of inputs of neurons i in k layer, and Y_i^k is the output. The weights of neurons j in layer $k-1$ to i in layer k are W_{ij}, so 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 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:

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

In the training process of CNN model, cGAN skills are used to improve the performance of the model. GAN is a model composed of two neural networks: generator and discriminator. Through the antagonistic training of these two networks, we can get more accurate feature information. Through the above method, the feature information of traditional craft patterns can be successfully extracted. This feature information will be used to train a cGAN model to generate a realistic 3D model. This feature detection method based on CNN can not only improve the efficiency and effect of design, but also ensure the novelty and creativity of the generated model.

3.2 Optimization of Three-Dimensional Model of Traditional Process

After feature detection based on CNN, these features need to be further used to optimize the three-dimensional model of traditional craft patterns. This section will introduce how to use cGAN to optimize the 3D model. CGAN is a special GAN model, which is used to generate images conforming to given conditions. In the research, cGAN is used to generate a three-dimensional model according to the characteristics of traditional craft patterns. Specifically, firstly, the extracted feature information is input into the generator as a condition, and then the output of the generator is evaluated and optimized by the discriminator. Generator is one of the core components of cGAN, which is used to generate realistic three-dimensional models according to conditional information. A multi-layer neural network is used to build the generator. The neural network accepts conditional feature information as input and outputs a three-dimensional model. In order to make the model generated by the generator more realistic, a technique called "skip" is adopted, which enables the generator to consider more details and features when generating the three-dimensional model.

The relationship between the camera coordinate system and the world coordinate system can be described by the rotation matrix R and the translation vector T. The transformation relationship between a certain point P in space in the world coordinate system and the camera coordinate system is as follows:

$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = \begin{bmatrix} R & T \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} \tag{6}$$

Among them, $(X_w, Y_w, Z_w, 1)^T$ and $(X_c, Y_c, Z_c, 1)^T$ are the homogeneous coordinates of spatial point P in the world coordinate system and camera coordinate system, respectively; R is 3 × Orthogonal matrix of 3; T is a three-dimensional translation vector.

Discriminator is another core component of cGAN, which is used to evaluate whether the generated model is realistic or not. This article studies the use of a neural network similar to a generator to construct a discriminator. The neural network accepts a three-dimensional model as input and outputs an evaluation score. In order to make the discriminator accurately evaluate the fidelity of the three-dimensional model, a gradient descent algorithm is used to train the weight parameters of the discriminator. For views expressing polyhedra, define the following plane gradient:

$$(G_x, G_y) = \left(\frac{\partial(-Z)}{\partial X}, \frac{\partial(-Z)}{\partial Y} \right) \tag{7}$$

From this, a corresponding gradient space is formed, and a corresponding graph is defined in the gradient space based on the specificity of the gradient and view. Its points, lines, and surfaces correspond one-to-one to the points, lines, and surfaces in the original space, and are understood and reconstructed by marking the graphics in gradient space.

In the training process, the generator and the discriminator will be trained many times to minimize the loss function between them. Specifically, the loss function of the generator is to maximize the probability that the discriminator will judge the generated model as true, while the loss function of the discriminator is to identify the difference between the generated model and the real model. Through this antagonistic training, a more realistic three-dimensional model can be obtained. The multi-level generator structure in this article is shown in Figure 2.

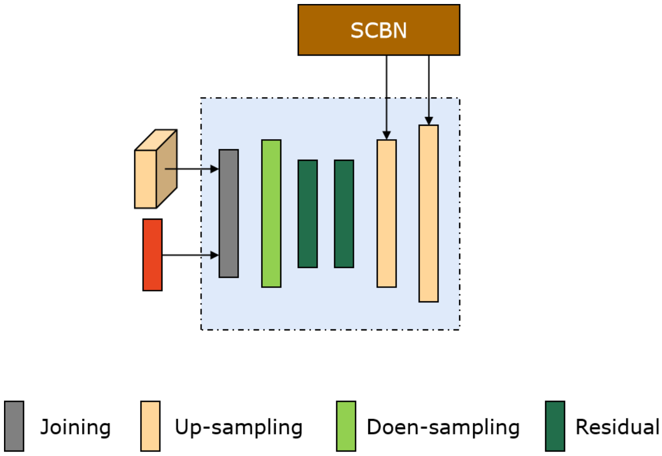

Figure 2: Multi-level generator structure.

The working process of the generator is shown in Figure 3.

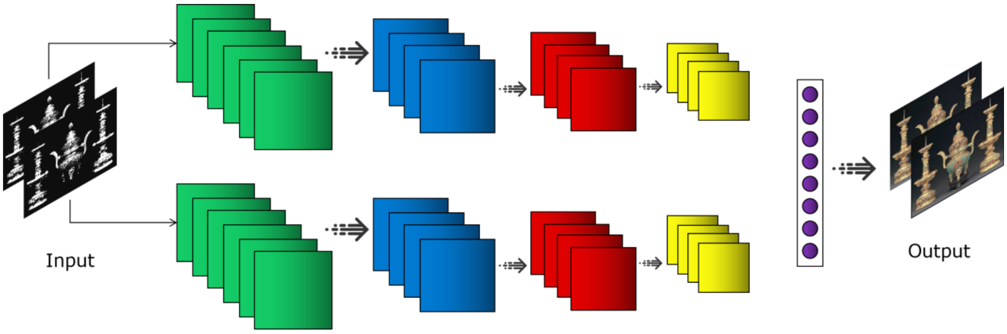

Figure 3: Schematic diagram of generator working process.

According to the boundary, the radius a,b,c and the center point $O=(x_0,y_0,z_0)$of the ellipsoid in three dimensions can be obtained, and then each point in the area can be parameterized by the following expression:

$$\begin{aligned} x &= x_0 + a\cos\theta\sin\varphi \\ y &= y_0 + b\sin\theta\sin\varphi \\ z &= z_0 + c\cos\varphi \end{aligned} \tag{8}$$

After the boundary is determined, the deformation coefficient ω of this area can be obtained according to the result compared with the standard deviation of the average art image position. Calculate each feature vertex in the region to obtain a new vertex position:

$$v' = o + \gamma\omega\lambda(r)(v-o) \tag{9}$$

Where v represents the original vertex position, v' is the new position after deformation, and r is the radius of the region. γ is the proportional factor of user interaction control.

Through the above method, the three-dimensional model of traditional craft pattern can be successfully optimized. These optimized models can not only improve the efficiency and effect of design, but also provide users with a more real and intuitive design experience. This cGAN-based 3D model optimization method can also provide useful reference for other similar research and promote the further growth of CAD and VR technology in the design field.

4 EXPERIMENTAL ANALYSIS OF USER INTERACTION EXPERIENCE OPTIMIZATION OF THREE-DIMENSIONAL MODEL

The research content of this article is to optimize the three-dimensional model of traditional craft pattern by using CNN and generator principle. The pattern features are extracted by training CNN model, and then the three-dimensional model is generated by using the generator principle, and the user interaction experience is optimized. From the network convergence trend diagram (Figure 4), the algorithm has converged to a certain extent after 38 iterations, which shows that the optimization method based on this model is effective and can achieve a better user interaction experience.

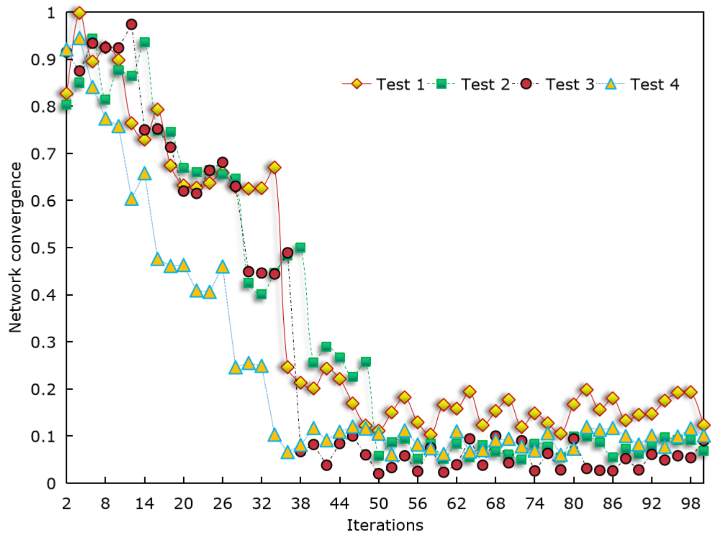

Figure 4: Network convergence trend diagram.

In the early iteration, the error decreased rapidly. With the increase of iteration times, the rate of error decrease gradually slows down, which indicates that the model may enter a smooth region during the training process, and also shows that DL models usually need a lot of data and computing resources to obtain the best performance. Generally speaking, there will be a convergence threshold in the training process of DL model. When the error of model training is lower than this threshold, the training process will stop. After about 38 iterations, the error has been reduced to a certain extent (possibly close to the convergence threshold), so the algorithm stops iteration.

The experimental results show that the feature detection accuracy of the interactive system of process pattern design constructed in this article is as shown in Figure 5. The comparison of feature detection accuracy of different methods is shown in Figure 6.

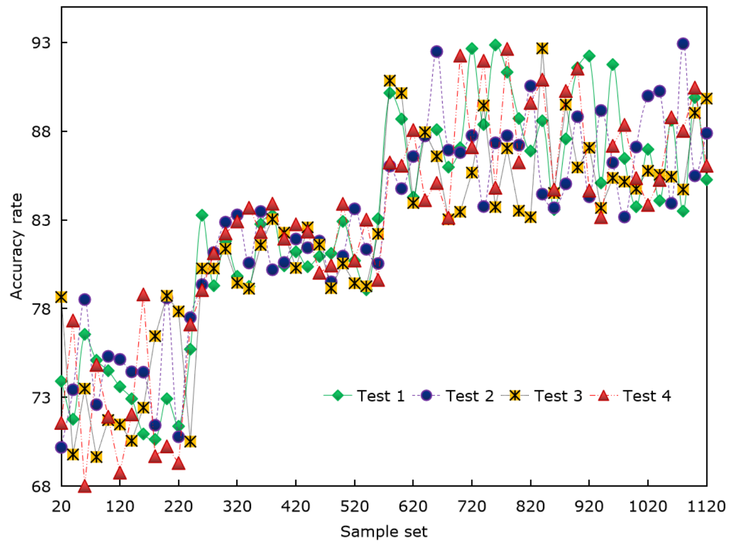

Figure 5: Accuracy of feature detection by CNN method.

The accuracy of feature detection obtained through four experiments (Test 1, Test 2, Test 3 and Test 4) has remained at a high level. This shows that the interactive system of process pattern design in this article has good stability and accuracy in feature detection.

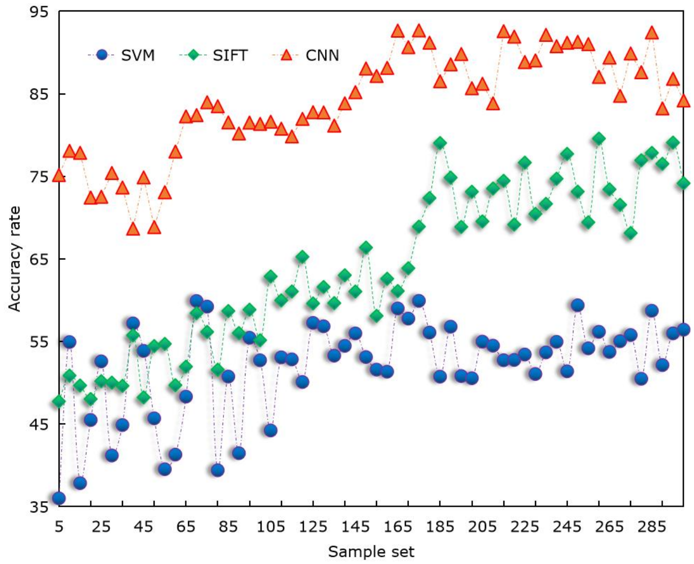

Figure 6: Comparison of feature detection accuracy.

From the experimental results, the feature detection accuracy of the interactive system of process pattern design constructed by CNN method is excellent, which can reach about 90%, and its accuracy is stable in many experiments. This result is consistent with the theoretical discussion on the advantages of CNN in processing images and visual information. CNN's deep network structure and special learning method make it have great advantages in dealing with complex texture and structure information, which is the key ability needed by traditional craft pattern design. Comparing the accuracy of feature detection of different methods, we can see that SIFT algorithm is the second, and the accuracy is about 80%. SIFT algorithm is a classical local feature description algorithm, which can extract key points and feature descriptors of images at different scales and rotation angles. However, from the experimental results, its accuracy is slightly lower than that of CNN method when dealing with the feature detection task of process pattern design. This may be because SIFT algorithm pays more attention to extracting key points and feature descriptors of images, but it may be slightly insufficient in dealing with complex texture and structure information. The accuracy of feature detection using SVM algorithm is only 60%. From the experimental results, it has a low accuracy when dealing with the feature detection task of process pattern design. This may be because it is difficult for SVM algorithm to effectively learn and distinguish the characteristics of different patterns when dealing with process patterns with complex texture and structure information.

Figure 7 shows the subjective scoring results of animation generated by the interactive system of process pattern design. The comparative results show that the interactive system of process pattern design constructed by CNN has the highest subjective scoring results, and the average score can reach above 85. This experimental result is consistent with the above experimental results of feature detection, which further proves the effectiveness of CNN method in the interactive system of process pattern design.

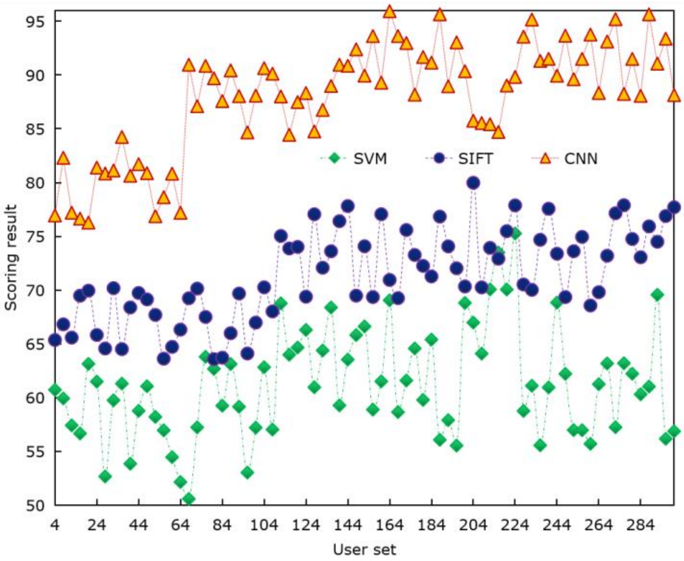

Figure 7: Subjective scoring result.

Judging from the subjective scoring results, the interactive system of process pattern design constructed by CNN method has the best performance in generating animation, and its average score can reach above 85. This scoring result shows that users are satisfied with the output results of the system and think that the animation generated by it has high quality and accuracy. Moreover, the scoring results also show that users recognize the advantages of CNN method in processing images and visual information. Different algorithms also show different characteristics in subjective scoring. The scores of SIFT algorithm and SVM algorithm are low in subjective evaluation, which may be due to their limitations in dealing with complex texture and structure information. However, the score of CNN method is higher in subjective evaluation, which fully shows the advantages of CNN method in processing images and visual information and its outstanding performance in generating animation.

In the feature detection experiment, the interactive system of process pattern design constructed by CNN method shows high accuracy and stability. This experimental result is of great significance for improving the performance and accuracy of the interactive system of process pattern design. In the subjective scoring experiment of generating animation, the interactive system of process pattern design constructed by CNN method performed best, with an average score of more than 85. This scoring result shows that users are satisfied with the output results of the system and think that the animation generated by it has high quality and accuracy. These experimental results fully prove the advantages of CNN in processing images and visual information, and the effectiveness in realizing the interactive system of process pattern design. Moreover, these experimental results also provide a useful reference for the combination of CAD and VR technology in the design field, which is of great significance for improving design efficiency and quality.

5 CONCLUSION

In this article, the combination of CAD and VR technology is applied to the traditional process pattern design, and CNN is introduced as the feature detection model, and the three-dimensional model is optimized by using the generator principle. The experimental results show that the interactive system of process pattern design constructed by CNN method has high accuracy and stability in feature detection. CNN's DL framework gives it a significant advantage in dealing with complex texture and structure information, which is fully reflected in dealing with the task of feature detection and recognition of traditional craft patterns. This result shows that feature detection using CNN is effective and can provide accurate feature information for subsequent 3D model optimization. The unique advantages of CNN in processing images and visual information make it play an important role in the interactive system of process pattern design. It is an effective way to realize efficient and high-quality three-dimensional model generation of process patterns by using CNN for feature detection and cGAN for model optimization. This research conclusion has important enlightenment significance for further promoting the combination of CAD and VR technology in the design field. Through in-depth research and growth of DL technologies such as CNN and GAN, it is possible to generate more realistic and natural 3D models of process patterns, thus providing better user interaction experience.

This study not only helps to improve the efficiency and effect of traditional craft pattern design, but also provides new ideas and methods for the further growth of CAD and VR technology in the design field. Therefore, the research results will have a positive impact on the design field and provide valuable reference for future design research and practice.

Yi Zou, https://orcid.org/0009-0004-6976-8461
Wenjing Wang, https://orcid.org/0009-0007-1500-146X

REFERENCES

[1] Dobre, G.-C.; Gillies, M.; Pan, X.: Immersive machine learning for social attitude detection in virtual reality narrative games, Virtual Reality, 26(4), 2022, 1519-1538. https://doi.org/10.1007/s10055-022-00644-4
[2] Gao, L.; Wan, B.; Liu, G.; Xie, G.; Huang, J.; Meng, G.: Investigating the effectiveness of virtual reality for culture learning, International Journal of Human–Computer Interaction, 37(18), 2021, 1771-1781. https://doi.org/10.1080/10447318.2021.1913858
[3] Gao, P.: Key technologies of human–computer interaction for immersive somatosensory interactive games using VR technology, Soft Computing, 26(20), 2022, 10947-10956. https://doi.org/10.1007/s00500-022-07240-3
[4] Gao, Z.; Li, Y.; Wan, S.: Exploring deep learning for view-based 3D model retrieval, ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM), 16(1), 2020, 1-21. https://doi.org/10.1145/3377876
[5] Kuo, C.-L.; Tsai, M.-H.: Road characteristics detection based on joint convolutional neural networks with adaptive squares, ISPRS International Journal of Geo-Information, 10(6), 2021, 377. https://doi.org/10.3390/ijgi10060377
[6] Li, M.; Wenjie, S.: Application of virtual reality technology and digital twin in digital media communication, Journal of Intelligent & Fuzzy Systems: Applications in Engineering and Technology, 40(4), 2021, 6655-6667. https://doi.org/10.3233/JIFS-189501
[7] Li, W.; Hsu, C.-Y.: Automated terrain feature identification from remote sensing imagery: a deep learning approach, International Journal of Geographical Information Science, 34(4), 2020, 637-660. https://doi.org/10.1080/13658816.2018.1542697
[8] Lu, W.-H.; Ni, Y.-H.; Cai, Z.-B.: User review data-driven product optimization design method, Journal of Computer-Aided Design & Computer Graphics, 34(03), 2022, 482-490. https://doi.org/10.3724/SP.J.1089.2022.19097
[9] Mahajan, H.-B.; Uke, N.; Pise, P.; Shahade, M.; Dixit, V.-G.; Bhavsar, S.; Deshpande, S.-D.: Automatic robot Manoeuvres detection using computer vision and deep learning techniques: a perspective of internet of robotics things (IoRT), Multimedia Tools and Applications, 82(15), 2023, 23251-23276. https://doi.org/10.1007/s11042-022-14253-5
[10] Maqsood, S.; Damaševičius, R.; Maskeliūnas, R.: Hemorrhage detection based on 3D CNN deep learning framework and feature fusion for evaluating retinal abnormality in diabetic patients, Sensors, 21(11), 2021, 3865. https://doi.org/10.3390/s21113865

[11] Shiau, W.-L.; Huang, L.-C.: Scale development for analyzing the fit of real and virtual world integration: an example of Pokémon Go, Information Technology & People, 36(2), 2023, 500-531. https://doi.org/10.1108/ITP-11-2020-0793
[12] Stefanidi, E.; Partarakis, N.; Zabulis, X.; Adami, I.; Ntoa, S.; Papagiannakis, G.: Transferring traditional crafts from the physical to the virtual world: An authoring and visualization method and platform, ACM Journal on Computing and Cultural Heritage (JOCCH), 15(2), 2022, 1-24. https://doi.org/10.1145/3484397
[13] Trunfio, M.; Lucia, M.-D.; Campana, S.; Magnelli, A.: Innovating the cultural heritage museum service model through virtual reality and augmented reality: The effects on the overall visitor experience and satisfaction, Journal of Heritage Tourism, 17(1), 2022, 1-19. https://doi.org/10.1080/1743873X.2020.1850742
[14] Zidianakis, E.; Partarakis, N.; Ntoa, S.; Dimopoulos, A.; Kopidaki, S.; Ntagianta, A.; Stephanidis, C.: The invisible museum: A user-centric platform for creating virtual 3D exhibitions with VR support, Electronics, 10(3), 2021, 363. https://doi.org/10.3390/electronics10030363
[15] Zohora, F.-T.; Rahman, M.-Z.; Tran, N.-H.; Xin, L.; Shan, B.; Li, M.: DeepIso: a deep learning model for peptide feature detection from LC-MS map, Scientific Reports, 9(1), 2019, 17168. https://doi.org/10.1038/s41598-019-52954-4