Style Classification and Generation of Furniture Design Styles: A Method Based on Generative Adversarial Networks

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Abstract. The purpose of this study is to provide a new method for the classification and generation of furniture design styles through the integration of DL (Deep Learning) and CAD technology. The introduction part expounds on the development status of the furniture design industry, makes it clear that the goal of this study is to provide a new method for the classification and generation of furniture design styles, and points out the potential value and influence of this method on the furniture design industry. Then, the data set preparation, DL model construction, and CAD integration method are described in detail. The experiment and simulation part shows the experimental environment, steps, and results. The results show that the model not only performs well on the training data but also has good generalization ability and can deal with unknown data. At the same time, after integrating the DL model with CAD software, users' scores on the diversity and innovation of furniture design styles have been significantly improved. It proves the effectiveness of this research method in the classification and generation of furniture design styles. It is concluded that the method proposed in this study has high accuracy and practicability in the classification and generation of furniture design styles and provides a new idea for the intelligent and automatic development of the furniture design industry.

Keywords: Furniture Design; Deep Learning; Generative Adversarial Networks; Computer-Aided Design Technology; Style Classification; Design Generation
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1 INTRODUCTION

As an important branch of the manufacturing industry, the furniture design industry has developed rapidly. In the field of home design, digital images also play a crucial role. Just like in the field of cultural relic preservation, the image interpretation and description used in home design also face subjective challenges. They are not only the main means of showcasing design achievements but also key tools for recording the preservation status of home elements and evaluating the rationality and durability of designs. Polygonization not only helps to describe these features more accurately but also provides more accurate and intuitive information for subsequent statistical analysis, design optimization, and customer communication. Amura et al. [1] developed a quantitative analysis method. These algorithms can efficiently separate different features in images and create binary masks for statistical analysis and polygonization. By applying edge detection algorithms, we can accurately identify the edges of home elements, thereby determining their shape and size. Automatically identify areas in home design images that correspond to specific features such as colour, material, size, etc., and polygonize them. Considering the complexity and diversity of home design projects, our approach aims to provide a flexible and easy-to-use platform. Its colour segmentation can divide the image into different regions based on colour differences, making it easier for us to analyze the distribution and matching of materials. Although deep learning methods have made significant progress in multiple fields, their applications in the specific industrial environment of home design and production are still relatively limited. Image processing technology in the modern manufacturing industry is not only limited to the production of automotive series but also gradually penetrating the field of home design. There are a wide variety of products in the field of home design, with different shapes, textures, and colours, which increases the difficulty of using deep learning techniques for image processing and 3D pose estimation. Bäuerle et al. [2] introduced domain randomization methods into the 3D pose estimation of ECUs and other components in the field of home design. Especially in the production process of electronic control units (ECUs) and intelligent components in home products, image processing technology plays a crucial role. During the installation process of smart home products, our method can quickly and accurately estimate the 3D pose of components from low-resolution RGB images, thereby achieving automated assembly and calibration.

However, the furniture design industry is standing at a crossroads full of challenges and opportunities. With the increasingly fierce market competition, consumer demands are becoming more diverse and personalized. Traditional furniture design methods, although classic and rich in heritage, have revealed their limitations in meeting modern people's pursuit of unique and differentiated aesthetics and lifestyles. Home designers are adopting 3D printing technology as their innovative tool to create unique and personalized furniture, decorations, and home accessories. 3D printing technology, as a revolutionary manufacturing method, has been widely applied in many industries including home design. Chan et al. [3] create furniture with unique textures, colours, and shapes, or customize personalized home decor according to customer needs. It has developed a 3D printing theoretical design process model specifically for home design. It also improves the degree of personalization and customization of products, meeting the growing personalized needs of consumers. This model will integrate the theory, practical concepts, physical prototype technology, and in-depth evaluation of various design elements of 3D printing technology. Intended to help designers create 3D-printed home prototypes with multi-colour surface textures more efficiently and accurately. In addition to the fashion industry, home design is also a stage for 3D printing technology to showcase its skills. They are no longer limited by traditional production methods and material choices, but can quickly realize various complex design concepts through 3D printing technology. Weaving, as an ancient technique that carries profound historical and cultural heritage, always exudes eternal charm with its unique beauty and unique craftsmanship. In-home design, Chang [4] utilizes parametric design methods to construct 3D models with knitted features. The flourishing development of the cultural and creative industry has led designers to attempt to combine traditional weaving techniques with modern design concepts. Parametric design, as an emerging design method, defines the form and properties of the design by setting a series of parameters, making the design process more flexible and controllable. In the field of home design that emphasizes personalization and cultural inheritance today, weaving art has become an important source for designers to draw inspiration and seek innovation. These models can incorporate various totem patterns and weaving elements, and display different textures, shapes, and colours through fine parameter adjustments, thereby creating unique home design works. By combining traditional weaving techniques with modern manufacturing techniques, we can not only preserve the inherent spiritual connotations of weaving art but also inject new vitality into it.

Chang and his team [5] recently launched an innovative mobile augmented reality (MAR) application, which is ingenious and brings a new interactive experience to home design education. Through cutting-edge AR technology, users can feel as if they are in a magical virtual world, easily placing 3D models of various home elements in their chosen positions. (such as sofas, bookshelves, lighting fixtures, etc.) into the design scene and interact with them intuitively on mobile devices. The system not only supports the import of custom layout drawings but also automatically generates corresponding 3D models based on typical home design floor plans. Through this approach, students can learn in practice and experience the visual effects and spatial changes brought about by different design decisions in real time, thereby deepening their unique understanding and perception of home design. To verify the effectiveness of this MAR application in home design teaching, we adopted John Keller's ARCS learning motivation model. The results fully demonstrate the enormous potential of MAR technology in improving the effectiveness of home design teaching. In the context of deep integration between smart homes and smart grids (SGs), demand-side management (DSM) has become an important means. Traditional cloud-centric data science analysis services have limitations in response speed and on-site perception. In the latest developments in smart home design, Chen et al. [6] designed and implemented a furniture design prototype with intelligent edge analysis capabilities. This architecture utilizes edge analysis technology to provide the next generation of intelligent sensing infrastructure for the smart home field. From the perspective of home design, this prototype furniture is not only traditional but also a smart home node that integrates intelligence, data collection, and analysis. With the help of advanced artificial intelligence algorithms, these data, as valuable resources for home design, provide us with a unique perspective to optimize furniture design. Make it more in line with user comfort and usage habits, thereby improving their quality of life. Our prototype design not only integrates cutting-edge artificial intelligence technology but also pays special attention to demand side management (DSM) in smart homes to create a more intelligent home environment, such as user's sitting habits, usage frequency, etc. The experimental results show that these strategies exhibit good performance in smart home DSM scenarios. They verified the feasibility and effectiveness of the intelligent edge analysis furniture prototype and the architecture designed for this work.

Graphics not only effectively convey design concepts and styles but also visually display the layout, color matching, and material selection of home spaces. Fan and Li [7] aim to optimize existing computer graphics and image processing technologies, aiming to inspire creative inspiration for home designers and further enhance their innovation capabilities. The furniture design style interior design course is a key link in cultivating students' painting and design abilities. Although digital design software has significant advantages in improving efficiency and presentation effects, students generally recognize the fundamental role of hand drawing skills in the design process. The core objective of Farooq et al.'s [8] research is to comprehensively evaluate students' preferences for furniture design style hand-drawn and digital design software. We should not only focus on the application of technology but also emphasize the indispensable role of hand drawing skills in design understanding. These students, as quasi-professionals about to enter society, their perspectives and needs are of great significance for understanding the current situation and future development trends of design education. During the survey, we particularly focused on the attitudes and preferences of students towards hand drawing skills and digital design software. Its research reveals the important role of hand drawing skills and digital design software in teaching interior design and furniture design styles.

It provides new possibilities for the automatic classification and generation of furniture design styles. CAD technology can realize the automation and accuracy of furniture design, and greatly improve the design efficiency.

The innovations of this paper are as follows:

(1) Deep integration technology: This paper innovatively integrates DL and CAD technology, which provides a new method for automatic classification and generation of furniture design styles.

(2) Combination of style classification and generation: Different from previous studies, this paper not only pays attention to the classification of furniture design styles but also further explores the automatic generation of styles, providing designers with richer design resources and inspiration.

(3) Overcoming data limitation: Aiming at the quality and quantity of data sets in current research, this paper adopts a new data processing method.

Firstly, this paper introduces the background and challenges of the furniture design industry and expounds on the application prospect of DL and CAD technology in furniture design. Then, through a literature review, this paper combs the furniture design style, the application of DL and CAD technology in furniture design, and the current research status of furniture design style classification and generation. Subsequently, the methodology adopted in this study is elaborated in detail, including data set preparation, DL model construction and CAD integration method. At the same time, the experiment process and results are shown through the experiment and simulation chapters, and the results are analyzed in depth.

2 RELATED WORK

In the field of home design, the introduction of BIM undoubtedly injects new vitality into the entire design process. It enables designers to present design concepts more intuitively, simulate actual usage scenarios more accurately, and ensure the rationality and practicality of the design. In addition, BIM technology also helps to achieve sustainable development in home design by optimizing design solutions, reducing resource waste, and reducing environmental impact [9]. This digital approach not only ensures the quality of the design but also helps ensure timely delivery of the project. Case studies have shown that through SAR technology, home textures in BIM models can be projected onto physical models clearly and realistically, providing users with intuitive and realistic home design previews. SAR not only enhances real-world objects by directly presenting graphics on physical objects using digital projectors but also brings users a more immersive experience [10]. To gain a deeper understanding of the performance of SAR, they also conducted qualitative analysis by changing the projection parameters and testing the visual effects under different projection conditions.

Juan and his team [11] are committed to developing an interior design and decoration decision support system that combines virtual reality technology. The system first starts from the user's selected spatial layout and constructs a realistic "spatial scene" through virtual reality technology, allowing users to experience different design effects firsthand. This system is user-centred and aims to provide more comprehensive and efficient design assistance for home design enthusiasts and professionals. It can help users prioritize different spatial scenes based on set standards and weights. To more accurately meet the personalized needs of users, the system also introduces TOPSIS technology, which is a multi-attribute decision analysis method. Under a limited decoration budget, the system also adopts a binary integer programming method, providing users with the optimal preliminary solution. In this way, users can have a clearer understanding of their preferences and make wiser decisions in the subsequent design process. This method can ensure design quality while maximizing cost control, enabling users to achieve satisfactory design results within budget. Especially recognizing the advantages in improving the feasibility, communication efficiency, and design decision-making speed of virtual reality-based interior design. Blockchain technology, with its decentralized, transparent, and tamper-proof features, provides new ideas. Implementing smart home design in the context of the Internet of Things (IoT), although it brings great convenience and possibilities, also faces numerous challenges, especially considering the expected scale and extensive deployment needs of the Internet of Things. Khan et al. [12] introduced an innovative resource efficient, blockchain-based security and private smart home solution. This system utilizes blockchain technology to ensure the integrity and immutability of data. The direct application of blockchain technology in smart home applications faces challenges such as high computational resource consumption and long processing time, which limits its widespread application on IoT devices. Simultaneously combining deep extreme learning machines to process and analyze the massive data generated by smart home devices to provide more intelligent and personalized home services. The experimental results show that our method can achieve lower computational overhead and faster processing speed while ensuring security and privacy, providing the possibility for the widespread application of smart homes.

Lee et al. [13] delved into how AR systems affect the review process of home design from the user's perspective. The research results indicate that compared to other systems, AR systems exhibit higher efficiency in home design reviews. At present, most research and technological development is mainly focused on the technical level, resulting in relatively limited attention to the application of AR systems in the field of home design for end-users. Participants can observe and understand the details of home design more intuitively, thereby more effectively examining various visual elements [14]. During the development process, SolidWorks and 3DsMAX were chosen as 3D model development tools to create high-quality and detailed home design models. To provide a more realistic experience, HTC VIVE has been chosen as the VR device, allowing users to explore and design their home space firsthand. Liu et al. [15] proposed a system that combines the IoT and adopts more interior design information models in home design. It constructs a virtual model corresponding to the physical home space by integrating BIM models with real-time operations. The SVM model can automatically learn and recognize various possible danger modes in the home environment and, based on this, determine the type and level of danger. Users can view the real-time status of their home environment anytime and anywhere, receive danger alarms and location information, and obtain danger-handling suggestions. This model can reflect various states of the home environment in real time, providing comprehensive and accurate data support for safety management [16].

Information-based modelling technology has brought unprecedented solutions to the construction industry. This trend also shows great potential in the field of home design. In the field of home design, Rasmussen et al. [17] introduced Home Topology Ontology (HTO) as the core vocabulary for implementing BIM maturity level 3. To achieve this vision, the Link Data Model and Best Practices proposed guide modern network applications. Interoperable, distributed, and network-based interdisciplinary information exchange can be carried out among stakeholders. Through HTO, we can effectively integrate and exchange various information related to home design, thereby improving design efficiency, optimizing construction processes, and providing users with a better living experience. HTO provides a high-level description of home space structure, including rooms, floors, the home elements they contain (such as furniture, appliances, etc.), and a 3D model representation of these elements. To verify the effectiveness of HTO in practical applications, it explored how to combine HTO with other ontologies to describe information such as home product catalogs. The knowledge of the design process in the field of home design has also not been fully explored and developed. Triatmaja [18] answered various challenges faced by home design students in completing design tasks by delving into specific design processes and methods. By carefully analyzing the design documents of students in home design courses, conducting in-depth interviews with students and instructors, and conducting extensive literature research, we can comprehensively examine various aspects of the home design process. It aims to explore process models and design methods that are more suitable for the field of home design. To provide more targeted guidance and support for students and practitioners in home design while also bringing innovation and inspiration to the entire industry. After systematic research and empirical analysis, they have successfully discovered a process model and design method that is highly compatible with students majoring in home design, which we call the "DT-DI Home Design Model." Specifically, we have noticed that different process models and design methods can more accurately meet design requirements and effectively answer key questions in home design research plans when completing home design tasks.

In the traditional home design process, there are often many obstacles in communication and feedback between customers and designers, which not only affect the efficiency of design but also may lead to significant differences between the final design results and customer expectations. The combination of AI and VR technology can provide customers with an immersive experience environment, allowing them to more intuitively experience the design effect and provide their own opinions and suggestions in a timely manner. In the research of Wu and Han [19], they elaborated on the construction process of interactive home design systems, from technology selection, and integration to application, each step has been carefully considered and planned. and provided detailed analysis and design methods. Through this series of evaluation tests, the proposed interactive home design system is feasible and has broad market application prospects. After system validation experiments, we found that the sensitivity of the operating handle in the left, right, front, and rear directions is as high as 99.38%, 99.36%, 99.49%, and 99.21%, respectively, which fully proves the accuracy and response speed of the system. Simultaneously eliminating the physical distance between designers, clients, and the home space to be designed in order to meet the diverse needs of modern home life more accurately. These data not only validate the performance of the system under high concurrency conditions but also reflect user satisfaction and immersion in the system. Introducing teaching not only optimizes teaching methods but also enriches teaching content. The optimization of interior design course construction can be carried out from two levels: strategic and structural. Through 3D simulation software, Yang [20] presented design cases more intuitively, helping students understand design concepts and techniques. At the structural level, it optimizes the course structure and reasonably arranges the ratio of theoretical courses to practical courses. This ensures that students are able to master both theoretical knowledge and practical operational skills. At the same time, students can also use 3D simulation technology for practical operations, deepen their understanding of design principles, and improve design abilities and innovative thinking through hands-on design, simulation, and modification. In terms of the teaching system, its construction has improved the teaching platform and management system, providing strong support for the smooth implementation of the teaching process.

3 CLASSIFICATION AND GENERATION MODEL OF FURNITURE DESIGN STYLE

3.1 Preparation of Furniture Image Data Set

Furniture design style is one of the important elements in furniture design, which reflects the cultural characteristics and aesthetic pursuits in different periods and regions. From classical to modern, the design style of furniture has undergone many changes and developments (as shown in Table 1). Classical styles such as Baroque and Rococo are famous for their exquisite carvings and gorgeous decorations. The modern style pays attention to simplicity, practicality, and functionality. In addition, there are many regional styles, such as Chinese style, Japanese style, and Nordic styles.

Furniture design style	*Style characteristic*
Modern simplicity	Simple, fresh, remove redundant decoration, pay attention to practicality and sense of space, characterized by simple lines and geometric shapes.
Nordic style	Natural and comfortable, made of wood cotton and linen, emphasizing environmental protection and warmth, soft colours, attention to detail and handicraft texture.
Industrial style	Rough, retro, using elements such as metal, bare brick walls and pipes to show personality and originality, often integrated into the characteristics of the old industrial era.
New Chinese style	Combining Chinese tradition with modern simplicity, based on Chinese elements, modern design concepts are added to show oriental aesthetics and modern practicality.
European classicism	Elegant and romantic, characterized by exquisite carving and gorgeous decoration, it is common in European court and classical architectural style home environments.
Mediterranean style	Bright and relaxed, characterized by blue and white tones and natural materials, it creates an atmosphere of a seaside holiday and pays attention to the openness and permeability of space.
American	Simple and natural, with wooden furniture and cotton and linen fabrics as the

country style	main elements, warm colours, emphasizing comfort and practicality, often integrated with handmade products and nostalgic elements.

Table 1: The change and development of modern furniture design style.

These styles represent the diversity and change of modern furniture design, and each style has its own unique aesthetic and practical characteristics, which meet the needs and aesthetic preferences of different people for the home environment. Understanding the characteristics and development process of various furniture design styles will help us better inspiration and direction for furniture design. In recent years, with the continuous development of DL and CAD technology, more and more researchers have begun to explore the application of these technologies in furniture design, which is for the automatic classification and generation of furniture design styles. CAD technology can also automate and improve the accuracy of furniture design.

However, there are still some problems in the current research. Firstly, the quality and quantity of data sets limit the training effect and generalization ability of the model; Secondly, how to accurately classify and generate complex and diverse furniture design styles is still a challenge; Finally, how to effectively combine the DL model with CAD software to realize the automation and intelligence of furniture design is also a problem to be solved. Therefore, this study aims to propose a classification and generation method of furniture design style based on DL and CAD to solve the above problems.

In order to train and test the DL model, this study uses multiple sources of furniture design image data sets. These data sets include images of furniture design from various styles from ancient times to the present, aiming to cover as wide a range of styles and design elements as possible. The source of the data set mainly includes an open image library, an archive of design magazines, and image resources of online furniture sales platforms.

In the preprocessing stage of a data set, this study carried out image cleaning, scaling, cropping, and normalization to ensure that the model could learn and identify image features better. The cleaning process includes removing blurred, repeated, or low-quality images. Scaling and cropping are to unify the image size and facilitate model processing. Normalization eliminates the differences between different images caused by illumination, contrast, and other factors. In terms of labeling methods, this study adopts a combination of manual labeling and semi-automatic labeling. Manual labeling is mainly used to determine the style category of furniture in the image, which is completed by professional designers and furniture industry experts. Semi-automatic labeling uses existing labeling tools and algorithms to identify and label the design elements in the image, such as lines, textures, and colors.

3.2 Classification and Generation of Furniture Style

In this paper, the application of GAN as the core structure of the DL model in furniture design style classification and image generation is deeply discussed. The task of the generator is to generate a new image, and its goal is to deceive the discriminator as much as possible and make it think that the generated image is true. The responsibility of the discriminator is to distinguish which images are "fake" images generated by the generator and which are "real" images from the real world.

The generator loss function plays an important role in GAN, which measures the difference between the samples generated by the generator and the real samples. The calculation formula is as follows:

$$L_{gen} = -E_z\left[\log D(G(z))\right] \tag{1}$$

Among them, the data generated by the generator is called $G(z)$, the probability label output by the discriminator $D(x)$, which is expressed as z. The discriminator loss function is defined as follows:

$$L_{dis} = E_x\left[\log\ D\ G\ x\ \ \right] + E_z\left[\log\ 1 - D\ G\ z\ \ \right] \tag{2}$$

Among them, x is real data, and L_{dis} aims to maximize the probability that the discriminator will judge the real data as real through the data generated by it while minimizing the probability that the discriminator will judge the data generated as real.

In the context of furniture design, the generator is given the task of generating furniture images with specific styles. Through a large number of training data and careful model design, the generator can gradually capture the inherent laws and style characteristics of real furniture images, thus generating furniture images with consistent style and realistic details. This ability provides furniture designers with endless creative inspiration and means of realization. At the same time, the discriminator plays the role of style gatekeeper, and its task is to accurately identify the generated images that try to "muddle through". Through continuous confrontation training, the sensitivity of the discriminator to furniture style is gradually improved, so that it can more accurately judge whether the image meets the specific style requirements. The GAN model is shown in Figure 1.

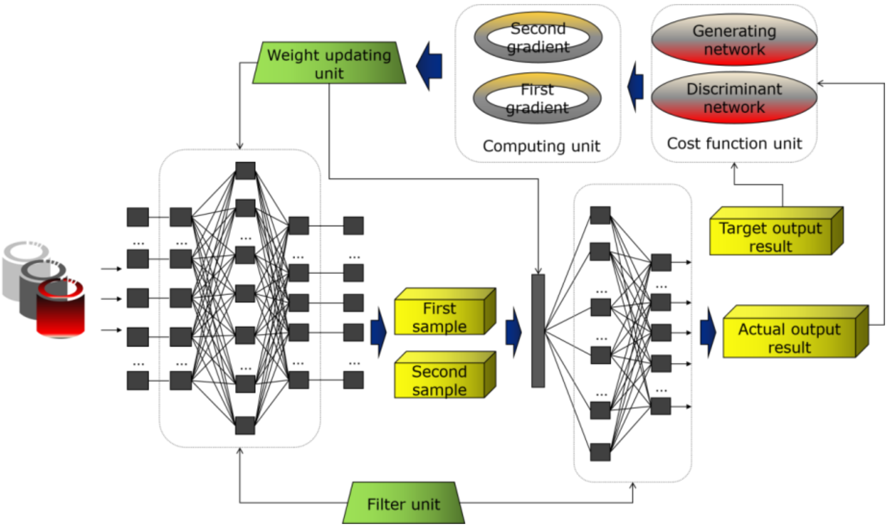

Figure 1: GAN model.

Assuming that there is a set of d -dimensional furniture style features, classifying t_i feature points for furniture style i, the feature data of furniture style i can be expressed as:

$$X^i = x_1^i, x_2^i, \cdots, x_{t_i}^i \in R^{d\times t_i} \tag{3}$$

A c classification prediction model can represent the mapping from input to category, namely:

$$f\left(X^i\right): R^{d\times t_i} \rightarrow 0,1,\cdots,c \tag{4}$$

A data set containing n furniture style features can be described as:

$$D = \left(X^i, Y^i\right)_{i=1}^{n} \tag{5}$$

Among them, Y^i is the target label of furniture style. The calculation formula for model storage space S is as follows:

$$S = S_f + S_p = \left|X\right| B_a + \left|W\right| B_w \tag{6}$$

Where S_f, S_p represents the storage requirements of activation and weight, X, W is the index set of all activation and weight in the GAN network, and B_a, B_w respectively represents the accuracy of activation and weight.

In order to further improve the performance of the model, a classifier network is skillfully integrated into the architecture of GAN. This classifier network is responsible for the detailed style classification of furniture images. Its output not only provides powerful auxiliary information for the discriminator so that it can judge the authenticity of the image more accurately but also adds a layer of style recognition ability to the whole system. The output process of GAN is similar to the traditional simple neural network, and the corresponding probability classification function will be chosen according to whether the problem is a classification problem or a regression problem. Among them, the Softmax function, as a probability function, is not only applied to the output of classification tasks but also can be extended to the generation model. These probability values are calculated by a normalized equation, which is as follows:

$$\sigma_j = p\ y = j \middle| x\ = \frac{e^{x^{T_{w_j}}}}{\sum_k^k e^{x^{T_{w_k}}}} \tag{7}$$

$$j \in \left[0, 1, \cdots, k\right] \tag{8}$$

Where k is the number of furniture style categories? $p\ y = j \middle| x$ is the given style feature value x and weight w_j, and the probability that the category j is the correct category in the k category. In order to evaluate the system's service performance, this section introduces the performance index of SHR (Service Hit Rate). This index reflects the ability of the system to successfully meet the user's service request in a given time. A high SHR value usually means that the system has good stability and reliability and can effectively handle the needs of users. The calculation formula is as follows:

$$SHR = \frac{N_{ser}}{N_{red}} = \frac{N_{ser}}{N_{res}} \times \frac{N_{res}}{N_{red}} = CHR \times CRR \tag{9}$$

4 EXPERIMENT AND SIMULATION

DL framework such as TensorFlow is used to build and train the model. In terms of experimental steps, this paper first trains and verifies the DL model. In the training process, the prepared data set is used, and the appropriate optimization algorithm and learning rate are adopted to adjust the model parameters. In the process of verification, this paper uses an independent verification set and adjusts and optimizes the model according to the verification results. Next, we carried out the furniture design style classification experiment. By inputting the test images into the trained model, the style category to which each image belongs can be obtained. By comparing with real labels, the classification accuracy of the model is calculated, and it is analyzed and discussed in detail. Figure 2 shows the model training.

The diagonal data in Figure 2 represents the prediction error of the loss function value of the model at a certain iteration or step. The curve depicts the trend of the loss function value as training progresses. As the training progresses, the value of the loss function gradually decreases, indicating that the model is gradually learning and optimizing its parameters. The loss function gradually decreases over time, indicating that the model can gradually learn the features of the data and optimize the objective function during the training process; that is, the model can gradually adapt and fit the training data.

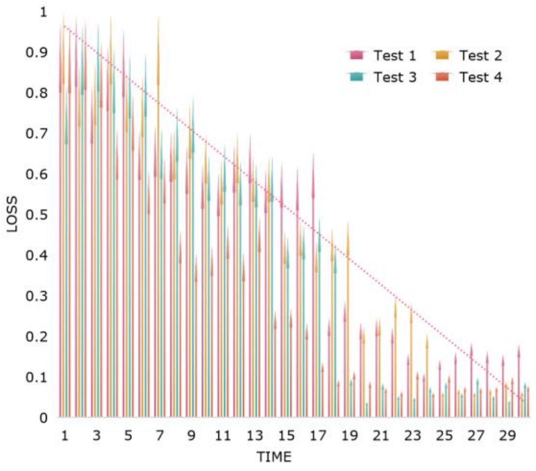

Figure 2: Model training situation.

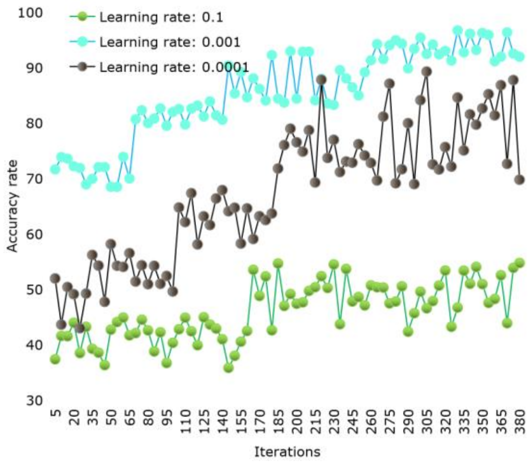

Figure 3: Learning rate test.

Figure 3 provides a detailed analysis and intuitive basis for selecting the optimal learning rate by showing the changes in model accuracy under different learning rates. Learning rate, as a core hyperparameter in machine learning, has a crucial impact on the training effectiveness and convergence speed of the model. In Figure 3, we can see that as the learning rate gradually increases from a smaller value, the accuracy of the model usually first rises to a peak and then decreases. This is because when the learning rate is too low, the update step size of the model parameters is too small, leading to the slow convergence speed of the model and even the possibility of falling into local optimal solutions. However, when the learning rate is too high, the update step size of the model parameters is too large, which may cause the model to oscillate near the optimal solution and even fail to converge. Specifically, when the learning rate is set to 0.01, the model exhibits high accuracy. This indicates that at this specific learning rate, the model can achieve faster parameter update speed while ensuring training stability, thereby effectively learning the inherent laws and features of the data. Therefore, choosing 0.01 as the learning rate is reasonable and helps the model quickly converge to the optimal solution during the training process. Figure 4 shows the classification accuracy of the model.

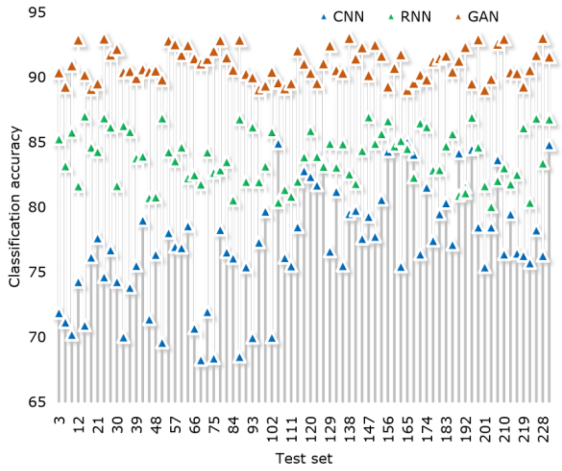

Figure 4: Classification accuracy of the model.

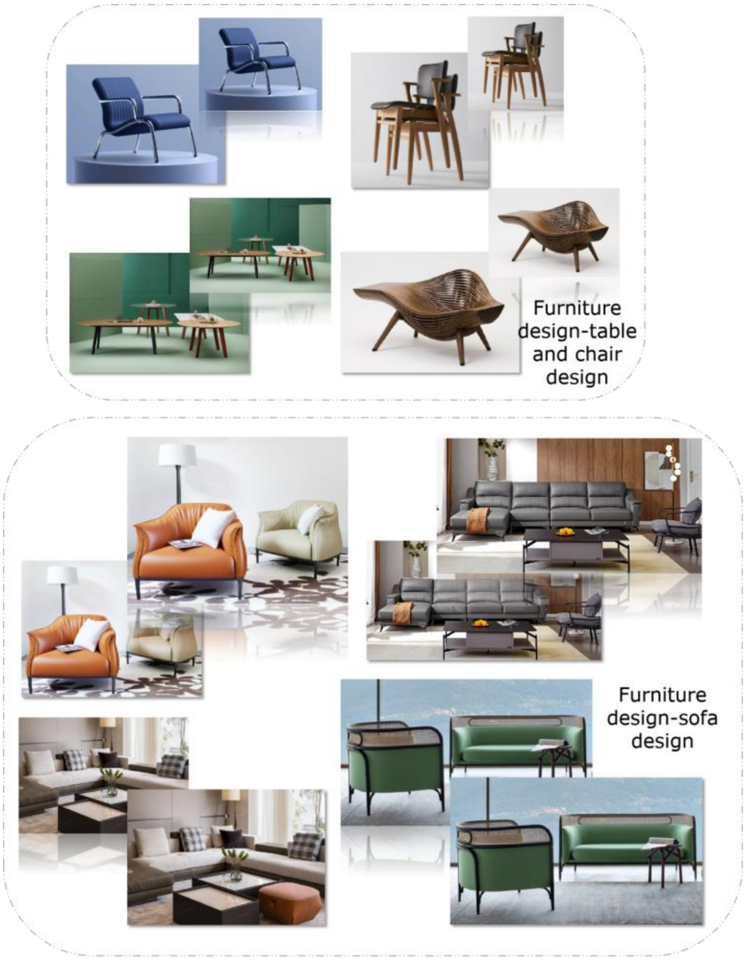

Figure 5: Furniture image.

Figure 4 compares the performance of CNN (Convolutional Neural Network), RNN (Recurrent Neural Network), and GAN (Generative Adversarial Network) in classification tasks, particularly in terms of their classification accuracy. It can be clearly seen from the graph that all three models have achieved certain results in classification tasks, but the classification accuracy of the GAN model is particularly outstanding, reaching over 96%. This indicates that the model effectively learned the features of the data during the training process and was able to accurately classify the samples in the test set into corresponding categories. This high accuracy not only verifies the rationality of the model design but also proves the effectiveness of the selected hyperparameters such as learning rate and optimization algorithm.

In addition, this section also carried out the furniture design generation experiment. By adjusting the input parameters of the generator, we generate furniture images with different styles and characteristics, as shown in Figure 5.

Evaluation aspect	*Evaluation index*	*Score range*	*Test score*	*Interpretation of results*
Image quality	SSIM	0-1	0.92	The closer the SSIM value is to 1, the more similar the generated image is to the original image in structure. The score of this study is 0.92, which shows that the generated furniture image retains most of the structural information of the original image and has high quality.
	PSNR	Generally,> 30dB is the higher quality.	35.2dB	The higher the PSNR value, the better the image quality. The score of this study is 35.2dB, far exceeding the threshold of 30dB, which further verifies the high quality of the generated image.
Image Diversity	Perceptual loss	In theory, the smaller the better.	0.08	Perceptual loss is used to measure the similarity of two images in feature space. The score of this study is 0.08, which is relatively low, indicating that the generated image is very close to the original image in characteristics, but it also retains enough diversity.
	Diversity index	Depending on the specific data set	0.75	The diversity index is used to measure the diversity of generated images. The score of this study is 0.75, which shows that the generated furniture images have a certain diversity and can meet the needs of different users.

Table 2: Evaluation results of quality and diversity of furniture image generation.

Table 2 presents the quality and diversity evaluation results of furniture image generation. By synthesizing the scores of several evaluation indexes, it can be concluded that the method proposed in this study can generate furniture images with high quality and diversity, which provides an effective image generation tool for the furniture design field.

Finally, we integrated the DL model with CAD software and made a simulation experiment. The experimental results are shown in Figures 6 and 7.

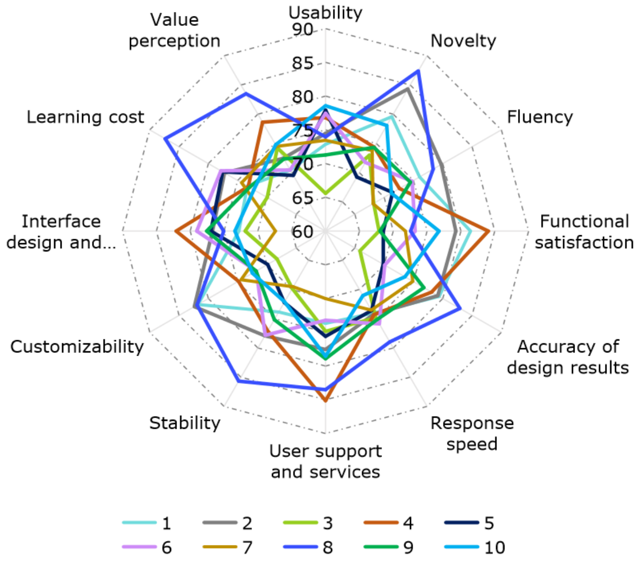

Figure 6: User rating before integration.

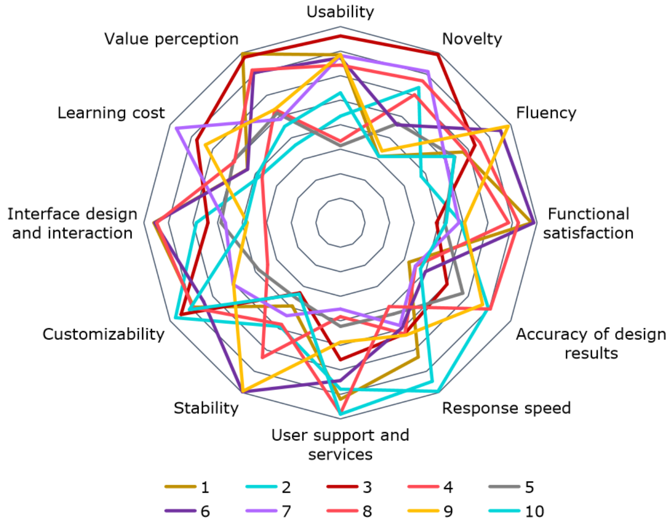

Figure 7: User rating after integration.

It can be seen that after integrating the DL model with CAD software, the scores of users' diversity and innovation have been significantly improved.

5 DISCUSSION

Compared with the existing furniture design style classification and generation methods, the method proposed in this study combines DL and CAD technologies, showing obvious advantages. Previous methods are often based on manually extracted features or simple machine learning algorithms, which have limited effect on the classification of complex and diverse furniture design styles. The DL model adopted in this study can automatically learn the deep-seated features in images and achieve more accurate style classification. At the same time, compared with the existing furniture design generation methods, the furniture images generated by GAN in this study are more realistic and diverse.

Although this research method has achieved remarkable results in the classification and generation of furniture design styles, there are still some limitations. First of all, the training of the DL model needs a lot of labelled data, and for some rare or emerging styles, the classification and generation effect may be affected by insufficient data. In the future, unsupervised or semi-supervised learning methods can be considered to reduce the dependence on labelled data. Secondly, although CAD integration improves the automation of design when the generated image is converted into CAD editable format, there may still be problems of detail loss or deformation. In order to solve this problem, we can study more advanced conversion algorithms from image to vector graphics.

6 CONCLUSIONS

Through the organic combination of DL and CAD technology, this study deeply explored the classification and generation of furniture design styles and achieved remarkable research results. The following are the core conclusions of this study:

This study successfully integrated DL and CAD technology and verified the effectiveness of this integration technology in the classification and generation of furniture design styles. The furniture design scheme generated by GAN not only maintains the characteristics of the original design style but also shows rich diversity and innovation. By automatically extracting image features from the DL model, combined with the accuracy and editability of CAD technology, this study introduces a brand-new and intelligent design method for furniture design. Through the experimental verification, the DL model adopted in this study shows excellent performance in the task of furniture design style classification. Compared with other methods, the method of this study can identify and classify various furniture design styles more accurately, and provide designers and consumers with more accurate style references. In addition, this study successfully integrated the DL model with CAD software and realized the automation and intelligence of furniture design. This integration method not only improves the design efficiency but also enables the design scheme to be directly applied to actual production and processing, greatly shortening the cycle from design to product.

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