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

Interior Design Assessment System Based on Computer Vision and Multimedia

Guoliang Song[1] and Shuhuang Zhu[2]

[1]School of Art and Design, Fuzhou Technology And Business University, Fuzhou, Fujian 350715, China, songguoliang@fzgsxy.edu.cn
[2]School of Technology, Fuzhou Technology And Business University, Fuzhou, Fujian 350715, China, zhushuhuang@fzgsxy.edu.cn

Corresponding author: Guoliang Song, songguoliang@fzgsxy.edu.cn

Abstract. Advancements in computer vision and artificial intelligence have presented fresh possibilities for interior design. Multimedia Computer-Aided Design (CAD) technology incorporates computer graphics, image processing, and human-computer interaction, among other techniques, to enhance the conventional CAD design process, making it more intuitive, lively, and productive. The objective of this article is to devise and put into action an interior design assessment system rooted in computer vision and integrate it with multimedia CAD, ultimately elevating the efficiency and precision of interior design assessments. The assessment system can not only accurately capture key design elements such as spatial layout, color matching, and material selection but also provide real-time feedback to designers to help them find potential problems in the initial stage of design and make timely adjustments. The case analysis shows that the assessment system performs well in practical applications and is widely recognized by designers. Through continuous improvement and optimization, the system is expected to become a powerful auxiliary tool for interior design in the future and promote the industry to develop in a more efficient and accurate direction.

Keywords: Interior Design; Computer Aided Design; Computer Vision; Assessment System
DOI: https://doi.org/10.14733/cadaps.2024.S25.264-278

1 INTRODUCTION

In the era of information and digitization, the interior design industry is experiencing profound transformations. Traditional methods, such as hand-drawn sketches and basic CAD, are struggling to cater to the increasingly diverse and personalized demands of the marketplace. 3D reconstruction technology can accurately restore the geometric structure and details of indoor spaces, providing important data support for interior design and decoration. However, traditional 3D reconstruction methods often face problems such as large data volume, high computational complexity, and

insufficient reconstruction accuracy. To address these issues, Arce et al. [1] explored the iterative development of 3D reconstruction techniques for indoor spaces using optimized view planning algorithms. This algorithm determines the optimal camera position and shooting angle by analyzing the geometric structure and feature point distribution of indoor space, in order to obtain as much spatial information as possible. At the same time, the algorithm also considers factors such as lighting conditions and occlusion relationships to ensure high quality and low noise of the obtained image data. The emergence of computer vision and artificial intelligence presents novel opportunities for interior design. The challenge now lies in harnessing these cutting-edge technologies to enhance the efficiency, quality, and user satisfaction of interior designs, a topic that has sparked significant interest within and beyond the industry. Although traditional 2D CAD drawings can provide basic building information, there are obvious shortcomings in 3D space display, collision detection, and construction simulation. Therefore, the system of automatically generating building interior information models (BIMs) from 2D CAD drawings has become an important trend in industry development. Its sustainable development is of great significance for improving the overall level and competitiveness of the construction industry. Byun and Sohn [2] automatically extracted geometric information, material information, and spatial relationships from CAD drawings through advanced algorithms and image processing techniques. And generate the corresponding 3D BIM model. This automated generation method not only greatly improves work efficiency and reduces manual errors, but also makes the BIM model more accurate and refined.

The Atrous Convolutional Neural Network (ACNN), a novel deep learning approach, has made notable breakthroughs in computer vision. Its distinctive atrous convolutional architecture allows for a broader receptive field, capturing richer contextual details without compromising model simplicity. Computer vision and computer graphics have shown strong application potential in multiple fields. In the field of indoor space reconstruction, these two technologies play an indispensable role. They can not only help us understand and analyze indoor spaces more accurately but also provide strong technical support for interior design and decoration. Computer vision technology can extract three-dimensional spatial information from two-dimensional images through image recognition and three-dimensional reconstruction algorithms. This information includes the geometric structure of the indoor space, object positions, dimensions, etc., providing basic data for subsequent spatial analysis and design. Dhar and Pal [3] analyzed the use of computer vision technology for indoor environment perception and monitoring. By installing cameras or sensors indoors, we can obtain real-time images and video data of the indoor environment, and then analyze the layout, lighting, temperature, and other information of the indoor space. These pieces of information are of great significance for optimizing indoor environments and improving living comfort. This article introduces a computer vision-based interior design assessment system and explores its integration with multimedia CAD. By leveraging ACNN and other leading technologies, we aim to facilitate swift, precise, and comprehensive assessments of interior design proposals, ultimately guiding designers toward more effective scheme optimization. At the same time, it is also expected that the system can be deeply integrated with multimedia CAD software to provide designers with a more intelligent, efficient, and convenient design environment. The study of marine environmental impact based on computer vision provides new ideas and inspiration for 3D interior design. Duan [4] explored how to use computer vision technology to capture features of the marine environment. And apply it to three-dimensional interior design to create an indoor space that is both beautiful and ocean-like. Computer vision technology can accurately capture and analyze various features of the marine environment through methods such as image processing and pattern recognition. These features include the color of the ocean, changes in light and shadow, and wave shapes, which together constitute the unique visual effect of the ocean. By extracting and analyzing these features, we can gain a deeper understanding of the visual characteristics and aesthetic value of the marine environment, providing strong support for subsequent interior design.

In the field of indoor construction, indoor construction progress monitoring technology based on computer CAD vision is gradually becoming an important means to improve construction efficiency and ensure construction quality. Ekanayake et al. [5] explored the principles, applications, and development prospects of indoor construction progress monitoring technology based on computer

CAD vision. The indoor construction progress monitoring technology based on computer CAD vision mainly relies on computer vision and CAD technology. Real-time images of the construction site are captured by cameras installed on the construction site, and computer vision technology is used to process and analyze the images, extracting information related to the construction progress. At the same time, combining CAD technology, the extracted information is compared with the construction design drawings to achieve real-time monitoring of construction progress. Before an in-depth study, this article first combs the related theories such as computer vision, ACNN, and multimedia CAD technology. We found that although these technologies have made remarkable achievements in their respective fields, there are still many challenges in the combined application of interior design assessment in this specific application scenario. For example, how to accurately extract the characteristics of interior design images, how to build an assessment model that conforms to the characteristics of interior design, and how to realize the seamless connection between the assessment system and multimedia CAD software. Addressing these challenges, this article proposes an interior design assessment model grounded in ACNN and elucidates the design rationale and execution framework. By incorporating the Atrous Involuntary structure, the model enhances its receptive field, bolstering its capability to discern distinct features within interior design images. To substantiate the assessment system's efficacy, a comprehensive experimental and comparative analysis was conducted. The findings reveal that the system delivers impressive assessment outcomes across a diverse array of interior design imagery, outperforming traditional assessment methodologies in numerous assessment metrics. Furthermore, we've seamlessly integrated the system with multimedia CAD software, underscoring its notable benefits in elevating design proficiency through real-world applications.

The principal innovations presented in this article encompass:

(1) In this article, ACNN is applied to the field of interior design assessment. Through its unique Atrous Involuntary structure, it effectively expands the receptive field and improves the ability to extract the features of interior design images.

(2) This article constructs an interior design assessment system that integrates computer vision technology and multimedia CAD. The system can quickly evaluate and feedback the interior design scheme, and provide a more intelligent and efficient design environment for designers.

(3) In the process of system design, user privacy, and data security are fully considered in this article. By adopting advanced encryption technology and data processing methods, the collected image data will not be leaked and abused.

Structural arrangement:

1. Introduction: Briefly describe the research background, purpose, and significance, and propose the importance of an interior design assessment system based on computer vision and ACNN.

2. Related theories and technologies: Overview of the basic knowledge of computer vision, ACNN, and multimedia CAD technology and their applications in interior design.

3. Assessment system design: Provide a detailed introduction to the requirements analysis, architecture design, ACNN model construction, and selection of assessment indicators for the assessment system.

4. Application implementation: Explore the integration method of assessment system and multimedia CAD, and demonstrate its application effect through case analysis.

5. Experimental results: Display the experimental design, compare and analyze the results, and verify the effectiveness of the assessment system.

6. Conclusion and outlook: Summarize research findings, point out limitations and shortcomings, and look forward to future research directions.

2 RELATED THEORY AND TECHNOLOGY

In the digital age, the rapid development of image processing and computer vision technology has provided us with new ways to understand and analyze architectural spaces. Among them, deep neural networks, as a powerful tool, have been widely used to extract key information such as architectural spatial layout, color matching, and material wireframes from images. Deep neural networks have demonstrated excellent capabilities in extracting architectural spatial layouts. Traditional architectural spatial layout recognition mainly relies on manual measurement and drawing, which is not only time-consuming and labor-intensive but also prone to errors. Esmaeily and Rezaeian [6] trained models using deep neural networks to automatically recognize and analyze architectural elements in images. Such as walls, doors and windows, stairs, etc., to construct an accurate spatial layout model. This automation method greatly improves efficiency, reduces human error, and provides strong support for building design and planning. The interactive design and preview technology of indoor scene color snapshots has emerged, providing users with a more intuitive and realistic design preview experience. Fu et al. [7] explored the characteristics, applications, and future development trends of interactive design and preview technology for color snapshots of indoor scenes. The interactive design of indoor scene color snapshots mainly focuses on the friendliness of the user interface and the convenience of operation. Designers use carefully designed interactive interfaces to enable users to easily perform scene selection, color matching, furniture placement, and other operations. At the same time, interaction design also focuses on providing rich feedback mechanisms, such as real-time rendering, dynamic adjustment, etc., so that users can see the effects of design changes in real-time and make better design decisions.

Traditional interior design effects often rely on floor plans, renderings, and physical models, but these methods often struggle to accurately convey the spatial sense and details of the design. Virtual reality technology builds a three-dimensional virtual space, making the display of design schemes more intuitive and vivid. Virtual reality (VR) technology is gradually changing the face of the traditional interior design industry. It provides unprecedented interactive experiences for designers and owners by creating highly simulated 3D environments, not only achieving revolutionary breakthroughs in effect display but also giving birth to many innovations in practical modes. Guo [8] discussed the simulation evaluation of virtual reality in interior design and practical mode innovation. By utilizing virtual reality technology, designers can optimize and test their design plans multiple times in a virtual environment to find the optimal spatial layout and functional configuration. With the continuous development of deep learning technology, its application in the field of architecture is also becoming increasingly widespread. As an important stage achievement of a construction project, the accuracy and precision of the completion model are crucial for subsequent interior design and landscape planning. The advantages of deep learning in visual processing make it play an important role in interior design evaluation in completed model landscape architecture. Traditional interior design evaluation often relies on the designer's experience and intuition, as well as manual measurement and drawing. This method is not only time-consuming and labor-intensive but also susceptible to human factors, resulting in inaccurate and inconsistent evaluation results. Han et al. [9] used deep learning techniques to learn and analyze a large amount of data, automatically extracting key information from the completed model, thereby achieving a precise evaluation of interior design.

In the field of residential interior design, using virtual reality to achieve real-time visualization of digital 3D modeling before construction not only provides designers with new design ideas but also brings owners a more intuitive and realistic experience. Joy and Raja [10] have built a three-dimensional virtual environment, allowing users to experience the changes in space and the details of design firsthand. Digital 3D modeling, on the other hand, converts design solutions into 3D models to present design effects more intuitively. By combining the two, real-time visualization of residential interior design and construction can be achieved, providing a more accurate and efficient communication platform for designers and owners. Digital 3D modeling allows designers to make real-time adjustments and optimizations to design schemes in a virtual environment, quickly generate multiple schemes for comparison, and thus find the best design scheme. As an important

component of urban space, the landscape design of subway station entrances not only affects the image display of the city but also directly affects the travel experience and quality of life of citizens. Therefore, scientific evaluation of the landscape efficiency of subway station entrances is of great significance for optimizing urban spatial layout and improving urban quality. Li et al. [11] conducted an evaluation study on the landscape efficiency of subway station entrances in the main urban area of Nanjing based on structural equation modeling. When constructing the model, it identified the main indicators for evaluating the landscape efficiency of subway station entrances, including landscape aesthetics, functional practicality, cultural display, ecological and environmental protection, etc.

As an important tool for showcasing and interacting with indoor spaces, display platforms not only affect designers' knowledge acquisition but also directly affect user engagement and experience. Among them, three-dimensional geometric visualization technology plays a crucial role in display platforms due to its intuitive and vivid characteristics. 3D geometric visualization technology can significantly improve the efficiency of designers in acquiring knowledge of indoor spaces. Although traditional two-dimensional drawings can convey basic spatial information, they have limitations in expressing the three-dimensional sense and details of space. 3D geometric visualization technology can realistically restore the form, structure, and materials of indoor spaces, allowing designers to have a more intuitive understanding of spatial layout and detailed design. This intuitiveness not only helps designers quickly capture design inspiration but also reduces errors and rework caused by misunderstandings [12]. In this transformation, digital twins and digital shadows, as two important concepts, play crucial roles. They not only provide strong technical support for the intelligence and sustainable development of the building environment but also greatly change our understanding of the construction industry. Sepagozar [13] comprehensively and accurately models and simulates physical entities through digital means. In the field of architecture, digital twin technology can achieve simulation and optimization of the entire lifecycle of buildings. From design, and construction to operation and maintenance, every step can be finely managed and controlled through digital twin technology. This not only improves the efficiency and quality of construction projects but also greatly reduces resource waste and environmental pollution.

In the planning of smart city infrastructure construction, the combination of digital twins and CyberGIS can play a huge potential. Shirowzhan et al. [14] constructed a virtual model of urban infrastructure using digital twin technology to simulate and predict planning schemes and evaluated their degree of improvement in connectivity. It utilizes CyberGIS technology to integrate and analyze urban spatial information. This can identify key factors and bottlenecks that affect connectivity, providing targeted optimization suggestions for planners. Finally, through the real-time interaction and feedback mechanism between digital twins and CyberGIS, the planning scheme is continuously optimized to achieve intelligent and sustainable development of urban infrastructure construction. The application of 3D computer-aided simulation technology in the field of interior design is becoming increasingly widespread. This technology can not only improve design efficiency and reduce design costs, but also provide students with a more intuitive and vivid learning experience. Therefore, Yang [15] has introduced 3D computer-aided simulation technology into interior design optimization teaching, which is of great significance for improving teaching quality and cultivating innovative talents. 3D simulation technology can realistically simulate the layout, colors, materials, and other aspects of indoor spaces, enabling students to intuitively experience the effects of design schemes and better understand the intentions and requirements of the design. Through computer simulation, designers can easily adjust and optimize design schemes, quickly generate multiple schemes for comparison, and thus find the best design scheme. 3D simulation technology can also simulate the physical environment of indoor spaces such as lighting and ventilation, helping designers predict the effectiveness of design schemes in practical use, reducing the workload of later modifications and adjustments.

3 DESIGN OF INTERIOR DESIGN ASSESSMENT SYSTEM BASED ON COMPUTER VISION

Computer vision is the field dedicated to investigating methods that enable machines to "see." This involves utilizing cameras and computers to detect, follow, and gauge objects, eliminating the need for human visual perception. Additionally, it encompasses further image manipulation to produce visuals more amenable to human observation or instrumental analysis. The discipline explores relevant theories and technologies, striving to create an intelligent system capable of extracting information from images or multi-dimensional data. Computer vision technology usually includes image processing, image analysis, image understanding, and other levels, in which image processing focuses on image preprocessing and enhancement, image analysis focuses on extracting features from images, and image understanding involves deep-seated interpretation and reasoning of image content.

ACNN is a special convolutional neural network, which expands the receptive field by introducing Atrous Convolutive, so as to capture more contextual information without increasing the complexity and calculation of the model. Atrous convolutional expands the receptive field by inserting zero values into the convolution kernel, which can increase the network's perception of input data while maintaining the resolution of the feature map. The characteristics of ACNN can be summarized as follows: firstly, it can capture more contextual information by expanding the receptive field through Atrous Convolutive; Secondly, ACNN keeps the resolution of the feature map unchanged, which is beneficial to the retention of detailed information; Finally, ACNN can control the size and shape of the receptive field by adjusting the void ratio, which makes the network more flexible and customizable in the application. These characteristics together constitute the advantages of ACNN in image processing and other fields.

Multimedia CAD technology uses computer graphics, image processing, human-computer interaction, and other technical means to make the traditional CAD design process more intuitive, vivid, and efficient. Multimedia CAD technology can not only deal with 2D graphics and 3D models but also support the integration and editing of multimedia elements such as audio and video. In the field of interior design, multimedia CAD technology plays an important role. Designers can use CAD software to model and render indoor space and generate realistic renderings and animation demonstrations. At the same time, by introducing multimedia elements such as background music and commentary, the appeal and expressiveness of the design scheme can be enhanced.

As computer vision and artificial intelligence technology continue to evolve, numerous scholars have ventured into exploring their potential applications within interior design. By training a large number of interior design image data, the deep learning model can automatically learn the feature representation of different styles and realize the automatic classification of new images. By wearing devices such as VR helmets or AR glasses, users can feel the effect and atmosphere of the design scheme in an immersive way. This can not only improve users' participation and satisfaction but also help designers better understand and meet users' needs. VR and AR technologies also support multi-person online collaboration and real-time interaction, which further improves the efficiency of interior design. As artificial intelligence technology continues to advance, computer vision has demonstrated its exceptional potential across various domains. In interior design, traditional assessment techniques typically hinge on designers' expertise and subjective opinions, resulting in a lack of impartial and standardized assessment metrics. To address this challenge, this article introduces a computer vision-based interior design assessment system, which aims to provide a comprehensive and unbiased quantitative assessment of interior design proposals. This section will elaborate on the design idea, implementation process, and application of key technologies of the assessment system in detail.

3.1 System Requirement Analysis

Before designing the assessment system, we first made an in-depth analysis of the needs of interior design assessment. The assessment of interior design is not only the assessment of aesthetics but also the comprehensive consideration of space layout, color matching, and material selection.

Therefore, an excellent assessment system should be able to accurately capture these design elements and give quantitative assessment results.

3.2 System Overall Architecture Design

Based on the above demand analysis, we designed an assessment system that includes four main modules: image preprocessing, feature extraction, assessment model construction, and result output. The image preprocessing module is responsible for denoising and enhancing the input interior design image to improve the accuracy of subsequent feature extraction. The feature extraction module uses computer vision technology to extract the key design elements from the preprocessed image. The assessment model building module uses a machine learning algorithm to build an assessment model according to the extracted features and gives quantitative assessment results. Finally, the result output module presents the assessment results to users in an intuitive way, so that users can optimize and adjust according to the assessment results. The overall architecture of the system is shown in Figure 1.

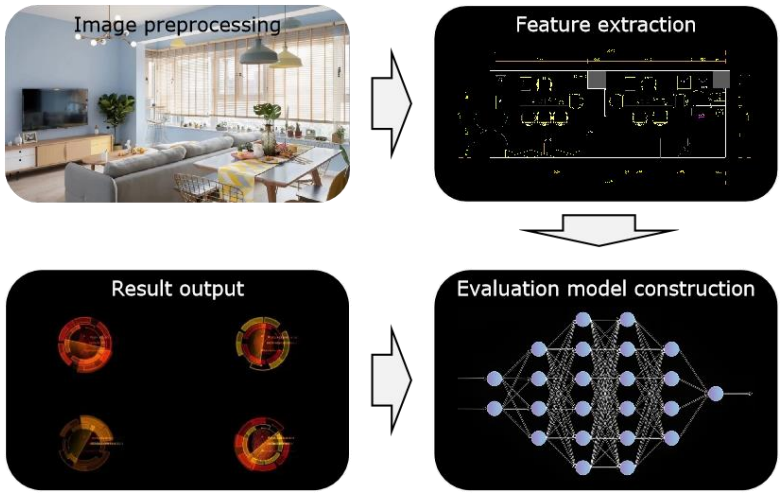

Figure 1: Overall system architecture.

3.3 Image Preprocessing and Feature Extraction

In order to improve the performance of ACNN, this article preprocesses and extracts the features of the input interior design images. Pre-processing includes denoising, scaling, and other operations to ensure image quality. The feature extraction module extracts the following features from the image: Color feature: color histogram is used to represent the color information of the image. The color characteristics are expressed as:

$$F_{color}\ I\ = \sum_{i=1}^{N} p_i * hist\ I_i \tag{1}$$

Where I is the image, N what is the number of color channels, p_i what is the channel weight and $hist\ I_i$ what is the color histogram?

Texture features: Local Binary Pattern (LBP) is used to extract texture information. Texture features are expressed as:

$$F_{texture}\ I\ = \sum_{i=1}^{N} g_i * LBP\ I_i \tag{2}$$

Where I is the image, N what is the number of texture regions, g_i what is the region weight, and $LBP\ I_i$ what is the local binary pattern?

Shape features: Edge detection and contour extraction are used to obtain shape information. The shape features are expressed as:

$$F_{shape}\ I = \sum_{i=1}^{N} h_i * edge\ I_i \tag{3}$$

Where I is the image, N what is the number of shape regions, h_i what is the region's weight, and $edge\ I_i$ what is the edge detection result?

Structural features: The HOG (directional gradient histogram) descriptor is used to represent the structural information of the image. The structural features are expressed as:

$$F_{structure}\ I = \sum_{i=1}^{N} f_i * HOG\ I_i \tag{4}$$

Where I is the image, N what is the number of structural regions, f what is the region's weight and $HOG\ I_i$ what is the direction gradient histogram?

3.4 Construction of Interior Design Assessment Model Based on ACNN

The assessment model of interior design aims to comprehensively capture the characteristics of core elements, such as spatial layout, color matching, and material selection, so as to evaluate the overall effect of interior design accurately. We use a multi-level convolution structure to extract image features and combine attention mechanisms to make the model pay more attention to key areas and important elements. According to the characteristics of interior design data sets, the transfer learning method is adopted, and the pre-training model is used to improve the assessment accuracy while reducing the dependence on a large number of labeled data. In the process of model construction, I put into the interior design rules and principles, such as the fluency of moving lines and the principle of color matching, to guide model learning. At the same time, the close cooperation with interior designers ensures the practicability and reliability of the assessment model, making it more in line with the actual application requirements.

ACNN can expand the receptive field without increasing the model parameters by introducing the Atrous Involuntary structure, thus better capturing the contextual information in the image. This is very important for interior design assessment, because all elements in interior design are interrelated, and the change of one element may affect the effect of the whole design scheme. Figure 2 is a schematic diagram of the ACNN structure.

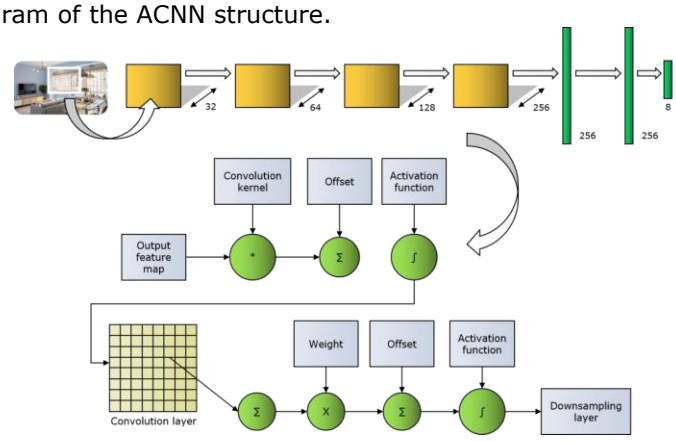

Figure 2: ACNN structure.

Atrous convolutional can increase the receptive field while keeping the number of parameters unchanged. For the input characteristic graph x and convolution kernel w, the output y of atrous convolutional can be expressed as:

$$y[i] = \sum_k x[i + r \cdot k] \cdot w[k] \tag{5}$$

In this context, r represents the void ratio, a crucial factor that regulates the spacing between convolution kernel elements. By modifying this ratio, one can expand the receptive field without adding extra parameters, thereby enhancing the ability to grasp comprehensive details from the interior design imagery.

For the feature graph with input size W_{in}, H_{in}, after passing through the convolution layer (step size S, padding P, convolution kernel size K, and void ratio D, the output size W_{out}, H_{out} is:

$$W_{out} = \frac{W_{in} + 2P - DK}{S} + 1 \tag{6}$$

$$H_{out} = \frac{H_{in} + 2P - DK}{S} + 1 \tag{7}$$

ReLU activation function is used to increase the nonlinearity of the model to capture the complex patterns in interior design better:

$$f\ x\ = \max\ 0, x \tag{8}$$

To expedite the training process and enhance model performance, batch normalization is employed:

$$\hat{x} = \frac{x - \mu B}{\sqrt{\sigma^2 B + \varepsilon}} \tag{9}$$

$$y = \gamma \hat{x} + \beta \tag{10}$$

In this context, μB represents the mean, $\sigma^2 B$ the standard deviation of the batch, while ε serving as a small constant to avoid division by zero. Additionally, γ and β are parameters that can be learned. By minimizing the internal covariant shift, the model achieves more consistent learning across diverse batches of data.

Through these improvements, the assessment model can capture the key information in interior design images more accurately and give more accurate assessment results.

4 APPLICATION OF ASSESSMENT SYSTEM IN MULTIMEDIA CAD

4.1 Integration of Assessment System and Multimedia CAD

In order to realize the smooth integration of the assessment system and multimedia CAD, the first problem to be solved is data interface and compatibility. Specifically, the assessment system should be embedded into multimedia CAD software as a plug-in or module, so that it can directly read and process CAD design data. At the same time, the consistency of data format and coordinate system must be ensured to avoid data conversion and alignment errors.

In the process of integration, the application program interface (API) technology is adopted to realize the data exchange and communication between the assessment system and multimedia CAD software by defining standard interface functions. When using CAD software, designers can call the assessment system to evaluate the current scheme at any time, without manual data format conversion or platform jumping.

4.2 Real-Time Assessment and Feedback

After integrating the assessment system, designers can get the assessment results and feedback in real-time during the design process. This is of great value to designers, and the scheme can be adjusted in time according to the assessment results to avoid large-scale modification in the later period.

In order to realize real-time assessment, an incremental assessment method is adopted. When designers modify design elements in CAD software, the assessment system only reevaluates the modified part, not the whole scheme. This greatly reduces the assessment time and improves the design efficiency. At the same time, an intuitive visual interface is designed for the assessment results, so that designers can see the assessment scores of each element and the advantages and disadvantages of the scheme at a glance.

4.3 Case Study of Interior Design

In order to verify the practical application effect of the assessment system in multimedia CAD, a series of case studies are carried out. The case covers different types of interior design projects such as residences, offices, and commercial space. Figure 3 shows some design examples. In each case, professional designers are invited to use the multimedia CAD software of the integrated assessment system to design and record their experience and feedback. Tables 1 and 2 show the application effect of the assessment system.

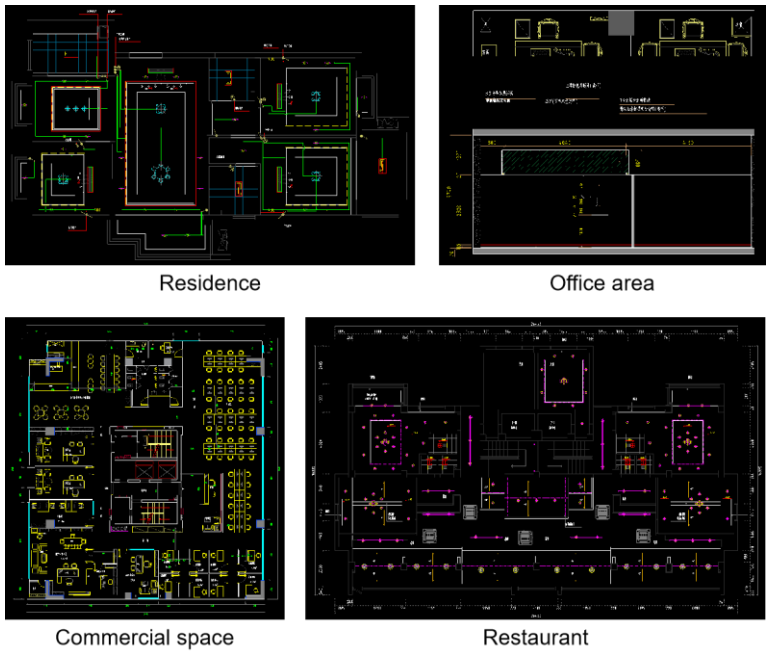

Figure 3: Example of interior design.

Assessment index	*Average score (1-10)*	*Standard deviation*	*Top score*	*Lowest score*
Improvement of design efficiency	7.8	1.2	10	5
Design quality	8.2	0.9	10	7

improvement				
Accuracy of problem identification	8.5	0.7	10	7
User satisfaction	8.9	0.6	10	8

Table 1: Assessment system use effect statistics.

Case type	*Average score (1-100)*	*Top score*	*Lowest score*
Residential design	85.0	95	75
Office design	80.0	90	70
Commercial space design	88.0	98	80
Other types of design	82.0	88	75

Table 2: Assessment scores of different types of design cases.

The results show that most designers agree with the integrated assessment system and think it is helpful to evaluate the design scheme more objectively. At the same time, it is pointed out that the real-time assessment function is of great help to improve design efficiency and quality. In practical application, the assessment system can effectively identify design problems that are difficult to find by traditional methods, such as unreasonable spatial layout and uncoordinated color matching. After these problems are adjusted in time, the overall quality of the scheme and user satisfaction are significantly improved.

5 ANALYSIS OF EXPERIMENTAL RESULTS

5.1 Experimental Results

In this section, CNN, RNN, SVM, and RF are compared with the ACNN algorithm proposed in this article. Experimental indicators include accuracy, recall, F1 score, and processing time. Among them, is accuracy: the assessment system correctly classifies or evaluates the proportion of interior design samples. The system's assessment ability is directly proportional to its accuracy; the higher the accuracy, the more reliable the assessments. The recall rate quantifies the system's ability to correctly identify positive samples (such as exceptional designs), with a higher recall rate indicating a stronger recognition capability. The F1 score serves as a comprehensive metric that balances both accuracy and recall, offering a holistic assessment of the system's performance; a higher F1 score signifies better overall accuracy and recall. Processing time is a critical factor in assessing the system's efficiency, with shorter processing times indicating greater efficiency in handling individual interior design images. The comparison of accuracy is shown in Figure 4.

The results of Figure 4 show that the ACNN algorithm is superior to CNN, RNN, SVM, and RF in accuracy. This means that the ACNN algorithm can more accurately capture and evaluate the key elements in interior design, such as space layout, color matching, and material selection. Figure 5 shows a comparison of recall rates.

For the interior design assessment system, a high recall rate means that the system can find the problems and advantages in the design more comprehensively. Figure 5 shows that ACNN has also achieved the best performance in the recall rate, which means that it can evaluate all aspects of the design scheme more comprehensively. The comparison of F1 scores is shown in Figure 6.

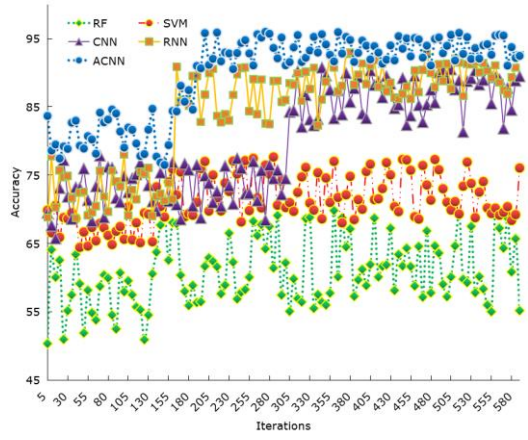

Figure 4: Accuracy comparison.

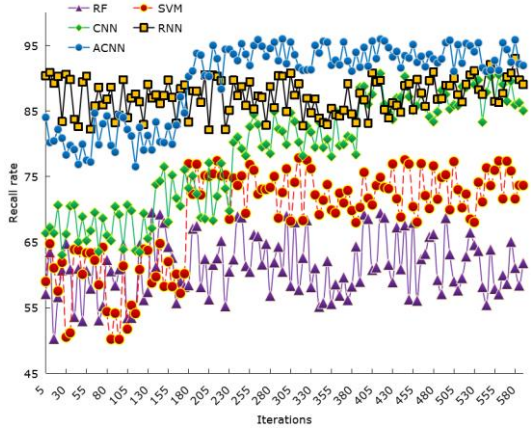

Figure 5: Comparison of recall rates.

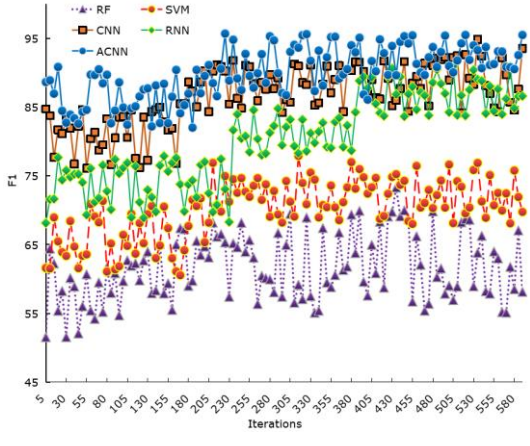

Figure 6: F1 score comparison.

Figure 6 shows that ACNN is also superior to other algorithms in F1 score, which shows that it has the best comprehensive performance, which is accurate and comprehensive. The comparison of processing time is shown in Figure 7.

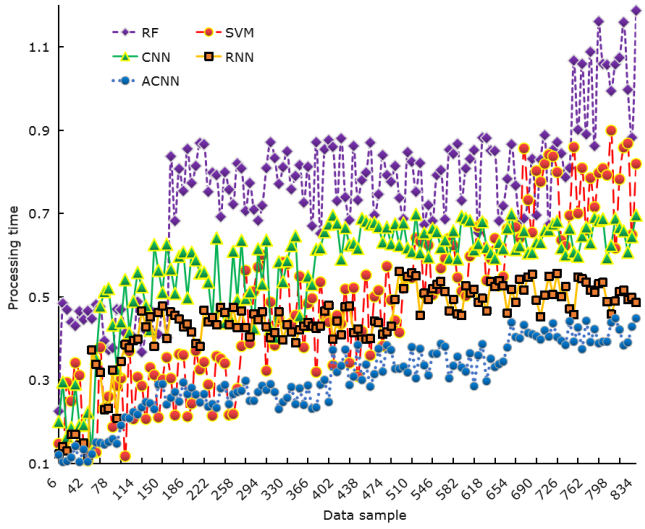

Figure 7: Comparison of processing time.

Processing time is particularly important for real-time feedback systems. An efficient algorithm can give assessment results in a short time, thus helping designers to find problems and make adjustments faster. Figure 7 shows that the processing time of ACNN is shortened by 8~69% compared with other algorithms. This means that ACNN not only performs well in assessment accuracy but also has significant advantages in processing speed.

To sum up, the ACNN algorithm proposed in this article shows excellent performance in the interior design assessment system. Compared with CNN, RNN, SVM, and RF, the accuracy, recall and F1 scores of this algorithm are better, with an average of over 92%. At the same time, the processing time of the proposed algorithm is short, which is about 8~69% shorter than other algorithms. This shows that the ACNN algorithm can improve the assessment efficiency and accuracy of interior design schemes, and provide a powerful and practical tool for designers.

5.2 Practical Application Prospect

The interior design assessment system based on computer vision has broad practical application prospects. The following are several potential application areas:

Real-time design feedback and adjustment

In the process of interior design, designers usually need to constantly adjust and optimize the scheme. By integrating the system, designers can get real-time feedback on spatial layout, color matching, and material selection at the early stage of design. This helps them find potential problems in time and make adjustments, thus saving time and improving design quality.

Customer participation and communication

The system can also be used as an interactive tool to let customers participate in the design process more actively. Customers can intuitively see the effects of different design schemes through the system, and communicate with designers in real time to jointly determine the final design scheme. This will help to improve customer satisfaction and the practicability of the design scheme.

Automatic design assessment and optimization

With the development of technology, the interior design assessment system can further realize the functions of automatic assessment and optimization. According to the preset assessment criteria and algorithms, the system can automatically grade and rank the design schemes and even put forward optimization suggestions. This will greatly improve the efficiency and accuracy of design, and at the same time reduce the workload of designers.

Multimedia CAD integration and extension

Integrating the system with multimedia CAD software can provide designers with a more comprehensive and efficient design tool. Designers can directly call the system in CAD software for design assessment, and at the same time use the powerful functions of CAD software to modify and optimize the scheme. In addition, the system can also be integrated with other design-related software, such as 3D rendering software and virtual reality software, so as to build a complete design ecosystem.

Market trend analysis and forecast

Through the assessment and analysis of a large number of interior design schemes, the system can help designers and market researchers understand the current market trends and consumer preferences. This helps designers to better grasp the market direction and develop a design scheme that is more in line with market demand. At the same time, it can also provide valuable market information and product improvement suggestions for home brands and product manufacturers.

6 CONCLUSIONS

Under the background of information and digitalization, the interior design industry is undergoing unprecedented changes. Traditional hand-drawn drawings and simple CAD have gradually failed to meet the growing diversified and personalized needs of the market. This article puts forward an interior design assessment model based on ACNN and expounds on the design idea and implementation process of the model. The model effectively expands the receptive field and improves the ability to extract the features of interior design images by introducing the Atrous Involuntary structure.

The application of assessment systems in multimedia CAD has achieved remarkable results. It not only improves the design efficiency but also reduces the revision times of the design scheme and improves customer satisfaction. The interior design assessment system based on computer vision and its application in multimedia CAD indicates that interior design will move toward the direction of intelligence, interaction, personalization, and customization. Computer vision technology makes design assessment more intelligent, accurate, and efficient, while the combination of multimedia CAD brings a more real and dynamic virtual design experience. This innovation not only improves the design quality, but also shortens the design cycle, promotes intuitive communication with users, meets the market demand for personalization and customization, and opens up a new road for the future development of the interior design industry.

Guoliang Song, https://orcid.org/0009-0002-7224-1922
Shuhuang Zhu, https://orcid.org/0009-0009-2464-2060

REFERENCES

[1] Arce, S.; Vernon, C.-A.; Hammond, J.; Newell, V.; Janson, J.; Franke, K.-W.; Hedengren, J.-D.: Automated 3D reconstruction using optimized view-planning algorithms for iterative development of structure-from-motion models, Remote Sensing, 12(13), 2020, 2169. https://doi.org/10.3390/rs12132169

[2] Byun, Y.; Sohn, B.-S.: ABGS: A system for the automatic generation of building information models from two-dimensional CAD drawings, Sustainability, 12(17), 2020, 6713. https://doi.org/10.3390/su12176713

[3] Dhar, S.; Pal, S.: Surface reconstruction: Roles in the field of computer vision and computer graphics, International Journal of Image and Graphics, 22(01), 2022, 2250008. https://doi.org/10.1142/S0219467822500085
[4] Duan, S.: Three-dimensional interior design study considering the impacts of a marine climate, Journal of Coastal Research, 115(SI), 2020, 247-249. https://doi.org/10.2112/JCR-SI115-078.1
[5] Ekanayake, B.; Wong, J.-K.-W.; Fini, A.-A.-F.; Smith, P.: Computer vision-based interior construction progress monitoring: A literature review and future research directions, Automation in Construction, 127(1), 2021, 103705. https://doi.org/10.1016/j.autcon.2021.103705
[6] Esmaeily, Z.; Rezaeian, M.: Building roof wireframe extraction from aerial images using a three-stream deep neural network, Journal of Electronic Imaging, 32(1), 2023, 013001. https://doi.org/10.1117/1.JEI.32.1.013001
[7] Fu, Q.; Yan, H.; Fu, H.; Li, X.: Interactive design and preview of colored snapshots of indoor scenes, Computer Graphics Forum, 39(7), 2020, 543-552. https://doi.org/10.1111/cgf.14166
[8] Guo, L.: Simulation evaluation of virtual reality in interior design effect display and practice mode innovation, Soft Computing, 27(12), 2023, 8371-8380. https://doi.org/10.1007/s00500-023-08110-2
[9] Han, S.; Jiang, Y.; Huang, Y.; Wang, M.; Bai, Y.; Spool, W.-A.: Scan2drawing: use of deep learning for as-built model landscape architecture, Journal of Construction Engineering and Management, 149(5), 2023, 04023027. https://doi.org/10.1061/JCEMD4.COENG-13077
[10] Joy, E.; Raja, C.: Digital 3D modeling for preconstruction real-time visualization of home interior design through virtual reality, Construction Innovation, 24(2), 2024, 643-653. https://doi.org/10.1108/CI-10-2020-0174
[11] Li, Z.; Lin, X.; Han, X.; Lu, X.; Zhao, H.: Landscape efficiency assessment of urban subway station entrance based on structural equation model: case study of main urban area of Nanjing, Buildings, 12(3), 2022, 294. https://doi.org/10.3390/buildings12030294
[12] Lu, F.; Nanjappan, V.; Parsons, P.; Yu, L.; Liang, H.-N.: Effect of display platforms on spatial knowledge acquisition and engagement: An evaluation with 3D geometry visualizations, Journal of Visualization, 26(3), 2023, 667-686. https://doi.org/10.1007/s12650-022-00889-w
[13] Sepasgozar, S.-M.: Differentiating digital twin from digital shadow: Elucidating a paradigm shift to expedite a smart, sustainable built environment, Buildings, 11(4), 2021, 151. https://doi.org/10.3390/buildings11040151
[14] Shirowzhan, S.; Tan, W.; Sepasgozar, S.-M.: Digital twin and CyberGIS for improving connectivity and measuring the impact of infrastructure construction planning in smart cities, ISPRS International Journal of Geo-Information, 9(4), 2020, 240. https://doi.org/10.3390/ijgi9040240
[15] Yang, J.: Teaching optimization of interior design based on 3D computer-aided simulation, Computer-Aided Design and Applications, 18(S4), 2021, 72-83. https://doi.org/10.14733/cadaps.2021.S4.72-83