Application of Intelligent Building Design Combining CAD Technology and Machine Learning Models

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Abstract. This study focuses on constructing and validating an innovative, intelligent building design model and exploring its practical application effects in the field of education. This study integrates machine learning (ML) and computer-aided design (CAD) technologies to develop a novel building model that can automatically draft preliminary design plans to achieve this goal. Afterward, the ML model was carefully trained and optimized to ensure its close integration with CAD technology. A series of rigorous simulation experiments were designed in this study to verify the reliability of the model. The study collected different performance schemes under CAD technology and conducted different case analyses and evaluations on the precise planning of architectural design. By analyzing the intelligent data of CAD machine models in educational construction, it explores spatial optimization in architectural design. The CAD visualization of building models involves making decisions on the correlation between data in the generation of educational plans. The study not only optimized and controlled the machine space evaluation model in architectural space design but also optimized the utilization efficiency of the model's behaviour analysis.

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1 INTRODUCTION

Intelligent buildings also focus on the aesthetic appearance and coordination with the environment, striving to create both practical and aesthetically pleasing architectural works. This integrated design enables intelligent buildings to provide more convenient and efficient services while meeting basic functional requirements. Through automatic monitoring and information management functions, intelligent buildings can grasp the real-time operation status of equipment inside the building, and they can discover and solve problems in a timely manner. Secondly, intelligent buildings emphasize the integration and collaboration of systems. It organically combines multiple systems, such as power technology, electronic control systems, and electronic information technology, to achieve information sharing and optimized resource utilization. At the same time, intelligent buildings can also provide personalized services based on the needs and preferences of residents, such as intelligent lighting, intelligent air conditioning, etc., creating a comfortable and convenient living environment for residents [1]. The importance of digital twins as a core component of smart cities is self-evident. They not only revealed the key methods involved in building digital twins but also pointed out the various challenges faced in this process. This study provides a new perspective and strong support for the construction and management of smart cities. By collecting and analyzing urban operational data in real-time, digital twins can accurately capture the dynamic changes of cities and provide a scientific decision-making basis for urban managers. In modern society, with the rapid development of technology, intelligent buildings have become an indispensable part of urban life. In this context, reinforcement learning, as an efficient machine learning control technology, has begun to receive widespread attention. However, with the increasing expectations of residents for the comfort of their living environment, the control and management of intelligent buildings have become increasingly important and complex. These buildings are equipped with numerous advanced intelligent devices, aiming to provide people with a more comfortable and convenient living environment. Applying reinforcement learning to intelligent building control can effectively reduce energy consumption and improve the efficiency of building operations. This learning approach gives reinforcement learning unique advantages in solving complex control problems. Intelligently adjust the working status of building air conditioning, lighting and other equipment, thereby ensuring the comfort of residents while minimizing energy consumption. Baduge et al. [2] found the optimal behavioural strategy by continuously learning, trial and error in the interaction between intelligent agents and the environment. The emergence of this technology enables building managers to have a more intuitive and comprehensive understanding of the operational status of buildings and infrastructure, thereby enabling more precise and efficient operation and maintenance management. In order to further explore the potential application of XR technology in intelligent building operation and maintenance, Casini [3] conducted a detailed review study. By using XR technology to simulate various complex operations and maintenance tasks, the performance of personnel in technical operations and maintenance tasks has been improved.

However, given the novelty and rapid development of XR in the AECO department, we still know very little about its specific limitations and integration drawbacks in the construction process workflow. In the process of architectural design, digital tools are no longer just auxiliary means but have become key elements supporting complex structures. Architectural education is not only about imparting design theory and skills but more importantly, it is about cultivating students' comprehensive qualities and innovative abilities. Although traditional hand drawing and sketching techniques still occupy an important position in architectural education, in this digital wave, architectural education must also keep up with the times. Ceylan [4] has incorporated digital tools and computer-aided design into important teaching agendas. The graphic demonstrations provided by digital tools play a crucial role in expressing design concepts and promoting effective communication between designers and audiences., Students are also beginning to be exposed to digital methods of graphic communication. Different digital software provides a variety of functions, allowing students to express their design concepts more flexibly.

The interactive technology and implementation of intelligent building design are the top priorities of these studies. By examining these alternative systems, Erdolu [5] was able to gain a more comprehensive understanding of their potential advantages and limitations. The key considerations in these efforts are the variables and interrelationships in architectural design, known as the "thinking framework". It aims to reveal its role and limitations in guiding the research and application of CAD input and interaction technology. This alternative framework not only helps us to have a more comprehensive understanding of the essence and application of CAD technology, but also provides us with richer questions, considerations, and investigation avenues. As researchers and city authorities around the world increasingly focus on sustainable development, smart buildings have become a key area for achieving this goal. Singapore, as one of the world's top smart cities, has been actively adopting advanced technologies in various fields, including smart buildings. Based on this background, Huseien and Shah [6] delved into the international trends of 5G applications in smart buildings, as well as the progress made by Singapore in the research and testing of 5G laboratories. The country is at the forefront of the application of 5G technology, providing strong support for the development of intelligent buildings. By utilizing 5G technology, intelligent buildings can achieve more efficient and intelligent energy management, safety monitoring, and operational maintenance. These applications not only enhance the functionality and comfort of buildings but also make positive contributions to the sustainable development of cities.

The contributions of this paper can be summarized as follows::

1. Innovatively integrate ML and CAD technologies to achieve intelligent and automated design processes;

2. Comprehensively evaluate the reliability of intelligent building design models through simulation experiments and practical application cases.

This article is divided into six parts. First, review the development history and current application status of CAD technology and ML through literature research method; Secondly, empirical research methods are used to collect data and train and optimize intelligent building design models; Next, verify the reliability of the model through simulation and explore its application prospects in the field of education; Finally, summarize the research findings and provide constructive suggestions and prospects for future research directions.

2 RELATED WORK

With the continuous advancement of technology and the expansion of application scenarios, it is believed that the Internet of Things will play a more important role in the construction and operation stages of buildings. Given the potential impact of IoT technology on the construction industry and the growing interest in interdisciplinary research in academia. Jia et al. [7] delved into the latest applications and adoption of the Internet of Things in the development of intelligent buildings. They summarized the current enabling technologies of the Internet of Things, with a particular focus on those widely applied in the fields of architecture and related fields. Not only does it cover the core content directly related to smart buildings, but it also delves into the depth of related topics. Through application examples, it is clear to see the important role of Internet of Things technology in promoting the intelligent process of the construction industry. These technologies are divided into three different levels based on the traditional Internet of Things architecture, each of which provides strong support for the development of intelligent buildings. With the continuous improvement and optimization of algorithm frameworks, they will play a more important role in architectural design, promoting innovation and development in architectural design. The characteristic of the algorithm framework lies in its flexibility, which allows architects to use rewritable example scripts and adjustable algorithm modules to adjust and optimize according to their own design needs. Traditional modelling methods are often too cumbersome and difficult to intuitively express the geometric intentions of designers. Lin [8] delved into how to apply an innovative algorithm framework - based on the previously proposed STGf algorithm framework - to assist architects in modelling topology algorithms through simple geometric intent input. Integrating topology knowledge with the algorithmic process of parametric design enables architects to more efficiently achieve design intentions. By applying this algorithm framework, architects can more flexibly control and adjust the topology of the model, achieving more precise and efficient design.

Livshits et al. [9] proposed a method for establishing computer-aided design heuristic algorithms in these two fields. Due to the many unpredictable connections between different architectural themes, its idea is to link these factors together. Commonalities were found in the initial input simulations of optics and architectural design, and they also discovered many similar processes in both. Based on the analysis of these two knowledge areas, and utilizing evaluations from optical and architectural experts. It reflects the prospect of using new technologies in design-building information modelling, which can be extended from architectural design to optical design, etc. With the support of Auto CAD technology, Ma et al. [10] collaborated closely with professionals to design and successfully construct the Auto CAD model. We conducted an in-depth analysis and comparison of teaching modes based on network architecture design. This system not only helps students easily access course resource information but also effectively displays the teaching process, helping students to deeply understand course content. The complexity of its engineering and construction projects continues to climb, from scale to shape, and then to function, every detail exhibits unprecedented complexity. This model not only has a high degree of authenticity and accuracy but also can help students better understand and master the essence of architectural design. At the same time, they also conducted an in-depth comparative analysis between traditional 2D design and cross-disciplinary collaborative design based on Auto CAD technology and found that the latter has significant advantages in efficiency and accuracy.

Nie et al. [11] innovatively proposed a new method called FM_GMC, which combines the strategy of grid partitioning and high-density clustering of key points in the grid. Based on this density information, we further identified anchor units, adjacent units, and boundary units, which provide important references for our subsequent clustering processing. Divide the image into several grids and calculate the density of key points in each grid. Finally, we used the nearest neighbour distance ratio (NNDR) method to perform key point matching within similar clusters. This method can effectively screen out key points with a high matching degree, and improve the accuracy and efficiency of matching. To verify the effectiveness of our proposed method, they conducted experiments on the 3D reconstruction dataset of Jinci Temple and 141 typical architectural images. Provided new ideas and methods for image-based 3D reconstruction of ancient Chinese architecture. Panteli et al. [12] are committed to delving into the latest developments in BIM-integrated modelling in the field of intelligent buildings, particularly how IoT applications seamlessly integrate with building intelligent operations. By utilizing IoT technology, buildings can monitor various operational data in real time and effectively analyze and manage it through BIM platforms, significantly improving the operational efficiency of buildings. In the pre-construction stage, they delved into the application trends of BIM in architectural design and optimization. When the building is completed and enters the operational phase, the combination of BIM and the Internet of Things brings revolutionary changes to the intelligent operation of buildings. To achieve the widespread application of BIM technology in the field of architecture, interoperability is an issue that cannot be ignored. Therefore, based on the latest progress in the standardization process, they explored the issue of data sharing between BIM-related applications, in order to provide strong support for the future development of BIM technology.

The future vision of intelligent buildings is to create an environment that makes residents' lives simpler and more comfortable. Whether optimizing energy use, improving living comfort, or enhancing building safety, machine learning and big data analysis can bring unprecedented breakthroughs to intelligent buildings. They can help us deeply understand the patterns behind data, providing timely action guidance and wiser decision-making basis. In the process of mining this information, machine learning and big data analysis techniques play a crucial role. To achieve this goal, intelligent buildings need to utilize various devices and sensors to generate and capture a large amount of streaming data [13]. Tastan et al. [14] conducted an in-depth comparison of two 3D modelling methods in an immersive virtual reality (IVR) environment. In order to ensure the reliability and depth of the research results, an open questionnaire survey was conducted immediately after the modelling meeting. In the data analysis stage, they adopted qualitative coding methods, focusing on the availability and constraints of modelling techniques, as well as the impact of real-time scale features during the modelling process. Through this approach, valuable written data on modelling experience and the modelling methods investigated were collected. 20 graduate students and two field experts were gathered to participate in this experimental research. These data provide us with an intuitive perception of the participants, which helps us to have a more comprehensive understanding of the modelling process. The research results indicate that DM modelling exhibits advantages in multiple aspects.

The current 3D reconstruction technology has many complexities in network construction, usage, and storage, which undoubtedly affects the efficiency of cultural landscape heritage reconstruction. Zhang et al. [15] proposed an innovative solution: combining the binary feature extraction algorithm of the circumference with cloud computing technology to achieve efficient 3D reconstruction. Compared with other coarse registration algorithms, their proposed improved algorithm demonstrates significant advantages and effectively proves its effectiveness in practical applications. This improvement not only improves the registration accuracy but also makes the registration effect more ideal. The experimental data shows that the interior point rate of the CBD algorithm in this article is over 72%, which is much higher than the interior point rate of other different algorithms. In order to better meet the needs of the three-dimensional reconstruction of cultural landscape heritage, this article also improves the 4PSC point cloud rough registration algorithm.

3 CAD TECHNOLOGY AND ML BASIC THEORY

3.1 CAD Technology Overview

CAD, also known as computer-aided design, refers to the use of computer technology to perform drawing, design analysis, and simulation tasks. From the initial simple 2D graphic drawing to the integration of advanced functions such as 3D modelling and simulation analysis, the evolution of CAD technology can be described as rapid progress, and its application in the design field is becoming increasingly widespread and in-depth. CAD technology can assist designers in structural analysis and energy consumption simulation operations of buildings.

3.2 ML Overview

In the fields of quantum multibody physics and quantum computing, machine learning provides effective simulation and optimization methods for handling complex quantum systems, promoting the development of quantum technology. On the contrary, machine learning has also borrowed from the thinking and modelling methods of physics, developing a series of novel and efficient algorithms and tools. Physics, as a science that explores the fundamental laws and phenomena of nature, provides valuable insights and theories for machine learning. This article explores in detail the application of machine learning technology in several key fields of physics. This two-way communication and integration not only promotes the progress of machine learning technology but also provides new perspectives and tools for the research of physics. In the fields of particle physics and cosmology, machine learning helps scientists extract valuable information from massive experimental data, revealing the mysteries of the universe and the properties of particles. In addition to exploring the application level, we also focused on the research and development of new computing architectures brought about by the cross-fusion between machine learning and physics.

3.3 Exploration of the Integration of CAD and ML

By analyzing a large amount of design data, machine learning algorithms can automatically extract design patterns and trends, providing valuable reference information for designers, thereby improving design efficiency and accuracy. By analyzing user behavior data, machine learning can understand their usage habits and preferences and provide personalized recommendations and suggestions for users. Traditional optimization methods are often time-consuming and labor-intensive, while machine learning can quickly find the optimal design solution through intelligent algorithms that automatically search and adjust design parameters. Secondly, machine learning plays a crucial role in the optimization design process of CAD. In complex design problems, it is often necessary to adjust numerous parameters to achieve optimal results.

4 BUILDING AN INTELLIGENT BUILDING DESIGN MODEL

4.1 Analysis of Requirements and Objectives

For example, designers may face pressure to produce multiple innovative design solutions in a short period of time or need to improve the energy efficiency and spatial optimization utilization of buildings. The precise grasp of these requirements sets clear target directions for the model.

In terms of goal planning, the intelligent building design model should be able to achieve the following core functions: firstly, it should be able to independently produce innovative building solutions that meet design criteria and specifications; Secondly, it should provide targeted design improvement suggestions to help reduce building costs, improve energy efficiency, and enhance living experience; Thirdly, it is necessary to have the ability to learn and continuously improve design solutions based on past design cases and user feedback.

4.2 Cultivation and Improvement of ML Models

Data is the cornerstone of building ML models. In order to create an intelligent building design model, this article collected rich architectural design-related data from multiple channels, including floor plans, elevations, sections, various design parameters, and user feedback. These data are sourced from publicly available building databases, historical project archives of industry companies, and user research results.

Data preprocessing is an indispensable step. Through this step, it is possible to effectively remove interference information and outliers from the data, convert the data into a format that the model can recognize, and ensure that all data is measured under the same standards, thereby improving the training effectiveness and prediction accuracy of the model.

Feature extraction is the extraction of useful information from raw data for model training. In the intelligent building design model, key features include the scale, shape, direction, material characteristics, etc. of the building. These features can be extracted from raw data through techniques such as image processing and text mining. Feature selection is aimed at removing redundant and irrelevant features to reduce model complexity and improve prediction accuracy. The commonly used feature selection techniques include filtering, wrapping, and embedding. This article selects the filtering method as the main method for feature selection. After completing feature extraction and selection, the ML model enters the training and optimization stage. Based on the characteristics of the problem and the attributes of the data, this article has selected a suitable ML algorithm for model training, mainly focusing on deep neural network models. The structure of this model can be understood by referring to Figure 1.

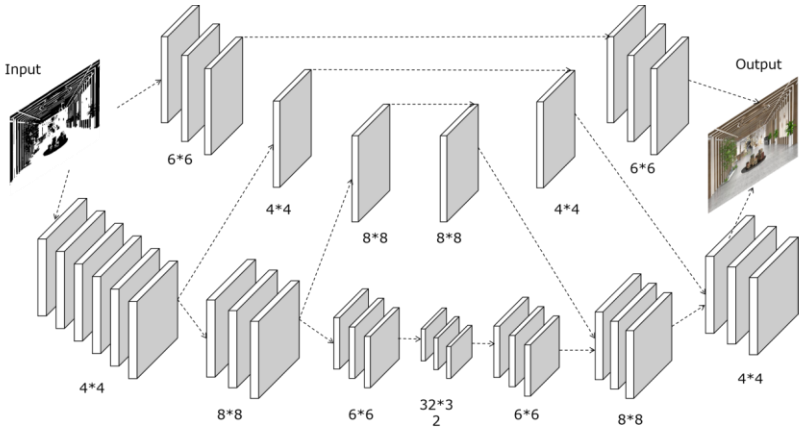

Figure 1: DNN model.

Based on the model constructed in this article, the following is a new overview of the image-processing steps in architectural design:

The first step is to capture or collect raw architectural design image data, which may come from multiple sources, such as the designer's preliminary ideas, digital drawing software output, or scanned paper design drawings. These original images provide material for subsequent work.

The second step is to perform detailed pre-processing on the collected images. This process may include adjusting colour balance, enhancing image clarity, removing unnecessary elements to ensure significant improvement in image quality, and preparing for the next step of feature recognition and analysis.

$$f(x) \approx f_k(x) = \sum_y \left[g_k(y) - n_k(y) \right] h_k^{BP}(m_k'(x) - y) \tag{1}$$

g_k maybe the original image was affected by noise, blur, and other interferences.

n_k represents noise data superimposed on the original image during image processing. This type of noise may come from various factors, such as equipment noise, environmental interference, etc. n_k is defined on the image domain g_k, and g_k represents the pixel range of the entire image.

h_k^{BP} is an approximate representation of the inverse process of the point spread function (PSF). The point spread function describes how a point light source in an image forms a diffused spot through an imaging system, while LL performs reverse processing on this process in an attempt to restore the original point light source signal.

After sparse encoding processing, the dictionary of building image blocks can be represented as:

$$D_h = \arg\min_{D^h, A} \left\| X^h - D^h A \right\|_2^2 + \lambda \left\| A \right\|_1 \tag{2}$$

$$D_l = \arg\min_{D^l, A} \left\| Y^l - D^l A \right\|_2^2 + \lambda \left\| A \right\|_1 \tag{3}$$

The original architectural design image blocks can be approximated as a linear combination of a few base vectors in a dictionary, and the sparsity of this representation helps to extract key features from the image and perform efficient compression and storage.

Given a set of high-resolution image blocks $X^h = \{x_1, x_2, \cdots, x_n\}$ and a set of low-resolution image blocks $Y^l = \{y_1, y_2, \cdots, y_n\}$, along with their corresponding sparse matrices A. Through sparse encoding, image blocks can be effectively represented as linear combinations of a few atoms in the dictionary. In order to obtain the final super-resolution image I_h, the perception map W_d is used to guide the fusion process of edge reconstruction image I_e and detail reconstruction image I_d. This process can be described using the following formula:

$$I_h(x) = \begin{cases} W_d(x) \cdot I_d(x) + \left[1 - W_d(x)\right] \cdot I_e(x), & x \in \bigcup_n R_n \\ I_e(x), & x \notin \bigcup_n R_n \end{cases} \tag{4}$$

In this formula, the perception image W_d plays a crucial role in determining the weights of edge information and detail information in the final super-resolution image. Through this approach, it is possible to more accurately reconstruct the details and edges of the image, thereby obtaining high-quality super-resolution images.

After sparse encoding, the dictionary representation of architectural design image blocks can be explained through specific formulas. In the subsequent model training phase, selecting appropriate loss functions and optimization algorithms is particularly important, as it relates to the degree of fitting of the model to the training data and its future generalization performance.

To evaluate the degree of deviation between model predictions and real data, we introduced the concept of loss function. This function can quantify the difference between the predicted value and the true value. Among numerous loss functions, mean squared error (MSE) is widely favoured in regression problems due to its simplicity and effectiveness. The MSE calculation formula is:

$$MSE = \frac{1}{n} \sum_{i=1}^{n} \left(Y_i - \hat{Y}_i \right)^2 \tag{5}$$

$$m_t = \beta_1 \cdot m_{t-1} + \ 1 - \beta_1 \ \cdot g_t \tag{6}$$

Second-order moment estimation (related to the average value of gradient squared), named v_t here:

$$v_t = \beta_2 \cdot v_{t-1} + \ 1 - \beta_2 \ \cdot g_t^2 \tag{7}$$

$$\hat{m}_t = \frac{m_t}{1 - \beta_1^t} \tag{8}$$

$$\hat{v}_t = \frac{v_t}{1 - \beta_2^t} \tag{9}$$

After completing all necessary calculations, adjust the parameter θ based on the deviation corrected first-order and second-order moment estimates obtained from the previous calculations:

$$\theta_{t+1} = \theta_t - \frac{\alpha \cdot \hat{m}_t}{\sqrt{\hat{v}_t} + \in} \tag{10}$$

As a key hyperparameter, setting the learning rate is crucial for model training. In optimization algorithms, to prevent division by zero during the update process, a very small number is usually introduced in the denominator, which we call a stable term. If the learning rate is too low, it may cause the training process to be too slow and even fall into local optima. This parameter is a core element in the optimization process, which determines how much the parameter should be adjusted in each iteration and how quickly it should be adjusted. If the learning rate is too high, it may cause the model to oscillate and fail to converge during the training process. In this case, choosing the appropriate optimization algorithm is particularly important. Although this stable term is small, its role cannot be ignored. It ensures the stability and accuracy of calculations and prevents numerical instability caused by small denominators. The Adam algorithm can not only help the model quickly break free from the constraints of local optimal solutions and approach the global optimal solution faster, but it is not very sensitive to the setting of the learning rate. It cleverly combines gradient descent and momentum methods to form an efficient optimization strategy. When dealing with complex problems such as architectural design, the parameter space of the model is often extremely large and filled with numerous local optimal solutions. These characteristics of the Adam algorithm make it excellent for modelling complex problems such as architectural design. This means that in practical applications, researchers do not need to adjust the initial learning rate too finely, thereby simplifying the process of parameter adjustment and improving the stability of model training.

4.3 The combination of CAD and Machine ML

Combining CAD technology with ML models is the key to improving design efficiency and quality. The following are several ways to achieve this combination:

Extension function development: Design specialized extension functions for CAD systems, which can link and apply mature ML models that have been trained, thereby providing intelligent assistance for design work. Designers can instantly obtain improvement suggestions or automatically generate design ideas from the model through these extended functions when using CAD tools.

Data exchange mechanism: Building a data exchange bridge between CAD systems and ML models. The CAD system can output design data to the ML model for analysis, and the ML model can also give feedback on optimized results or new design concepts back to the CAD system.

Integration of operation interface: Directly integrate the functional options of ML models in the operation interface of CAD systems. In this way, designers can directly utilize ML models within the CAD system without having to jump to other application platforms.

Team collaboration environment: Create a collaboration platform that allows designers, engineers, and ML experts to collaborate in the same environment. ML models can provide design ideas based on data, and designers and engineers can evaluate and adjust these ideas based on their professional knowledge and practical experience.

This article chooses the combination of "extended function development". This approach allows the intelligent functions of ML models to be directly integrated into the CAD systems used by designers on a daily basis, providing them with real-time design assistance. Designers can quickly obtain model optimization opinions or automatically generate design solutions through extended functionality during the design process, thereby effectively improving the efficiency and quality of design work. Meanwhile, this approach has a lower learning threshold for designers, as they can smoothly use these intelligent features in familiar CAD environments without the need for additional learning of new tools or software.

5 MODEL RELIABILITY VERIFICATION

5.1 Design and Implementation

To thoroughly examine the stability and effectiveness of intelligent building design models, this study has set up a simulation experiment section. Among the carefully selected experimental subjects, a universally representative school library architectural design was specifically selected as a case study. Based on the specific characteristics and practical needs of these cases, we have developed diverse design parameters and objective functions, aiming to simulate various scenarios that may be encountered in the real design process fully. Through these meticulous settings, we hope to evaluate the reliability and practicality of the model more accurately. Figure 2 shows an overview of some selected architectural design cases.

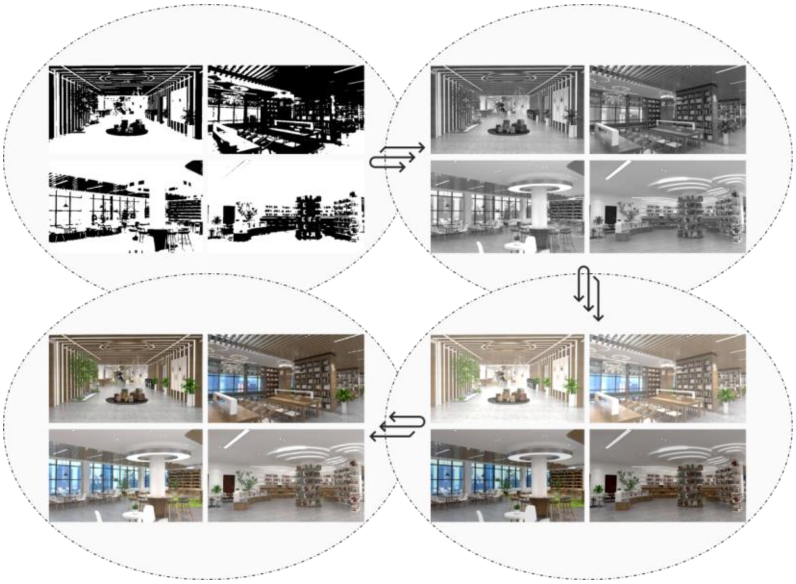

Figure 2: Design case.

In the process of advancing simulation experiments, this study adopted the control variable method, which involves gradually changing parameters or conditions to gain insight into the model's response and performance in various scenarios. At the same time, to form an effective control, the experiment also adopted a design approach based on decision tree models for comparative design. Figure 3 visually illustrates the accuracy of the model.

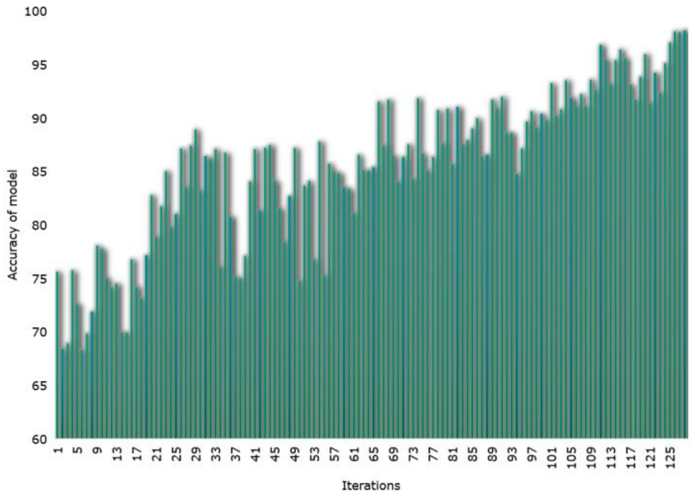

Figure 3: Accuracy test.

From Figure 3, it can be clearly observed that the intelligent building design model proposed in this study demonstrates excellent accuracy. This discovery strongly confirms the credibility of the model in the field of architectural design. High-precision models can better capture and reflect the complex relationships between design elements, thereby generating design solutions that are more in line with practical requirements. For designers, this is undoubtedly a powerful assistance, which not only improves the efficiency of design but also greatly enhances the accuracy and quality of design schemes.

Figure 4 shows a comparison of design time for different models.

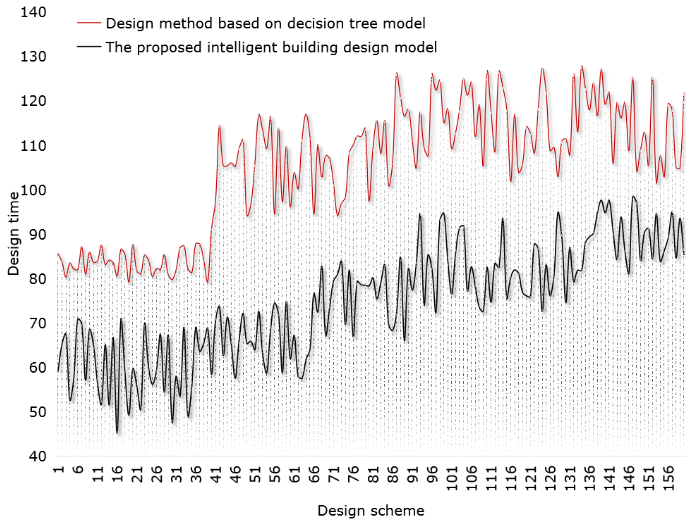

Figure 4: Design time.

As for the efficiency of spatial utilization of design schemes generated by different models, Figure 5 provides an intuitive demonstration.

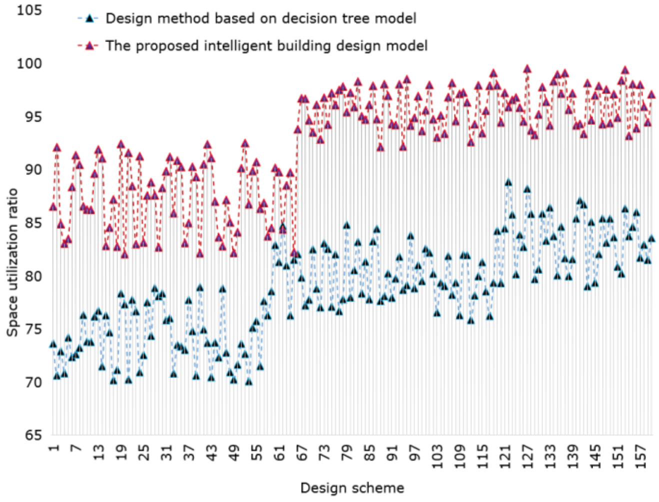

Figure 5: Space utilization rate.

The experimental results reveal that compared with design based on decision tree models, intelligent building design models are able to output design solutions that meet design specifications and requirements in most cases and exhibit better performance in spatial utilization. It is worth mentioning that the model also has the ability to self-learn and optimise based on user feedback and historical data, thereby continuously improving the quality of design solutions and user satisfaction.

In order to comprehensively evaluate the performance of intelligent building design models, this study also invited multiple experts from the architectural design industry to subjectively evaluate the design schemes generated by the models. The evaluation results are shown in Figure 6.

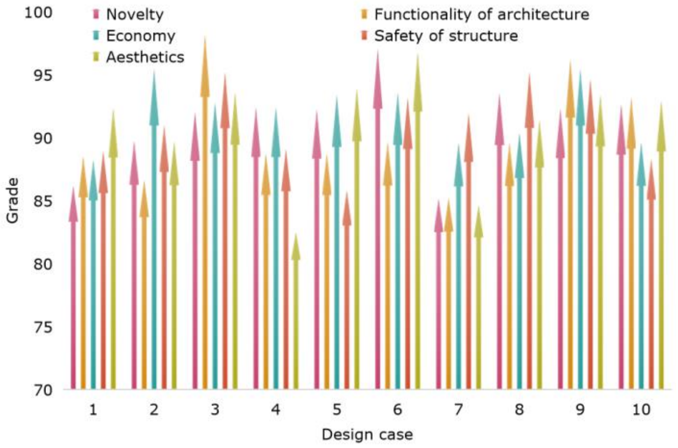

Figure 6: Expert evaluation.

The expert review comments reveal that the solutions generated based on the intelligent building design model have received widespread praise and are considered innovative and applicable. This achievement is attributed to the comprehensive ability of the model to handle design elements and meet user needs, which can automatically create unique and practical architectural concepts.

5.2 Reliability Analysis

This model can not only automatically generate design schemes that conform to strict design specifications and industry standards. It can draw experience from historical data and continuously optimize and upgrade itself through deep learning and machine learning techniques. More importantly, it can dynamically adjust based on real-time feedback from users, making each design more in line with their expectations and needs. Greatly reducing the workload of designers and significantly improving design efficiency, allowing designers to devote more energy to creative and optimization work. This continuous learning and progress feature enables intelligent building design models to flexibly respond to the constantly changing design needs in the market, providing higher-quality design solutions.

6 THE APPLICATION OF INTELLIGENT BUILDING DESIGN

6.1 Practical Application of Intelligent Building Design

In the field of education, intelligent building design models are gradually demonstrating their unparalleled potential for widespread application. This can not only improve the utilization rate of the library but also provide students with a more comfortable and convenient reading environment, thereby further stimulating their reading interest and enthusiasm. By finely optimizing the layout and lighting system of the classroom, this model can create a more suitable learning environment, and improve student learning efficiency and comfort. Taking the school library as an example, this model can intelligently plan the most reasonable space layout and shelf arrangement through in-depth analysis of students' reading habits and specific functional requirements of the library.

Figure 7 shows the specific design schemes for these application scenarios.

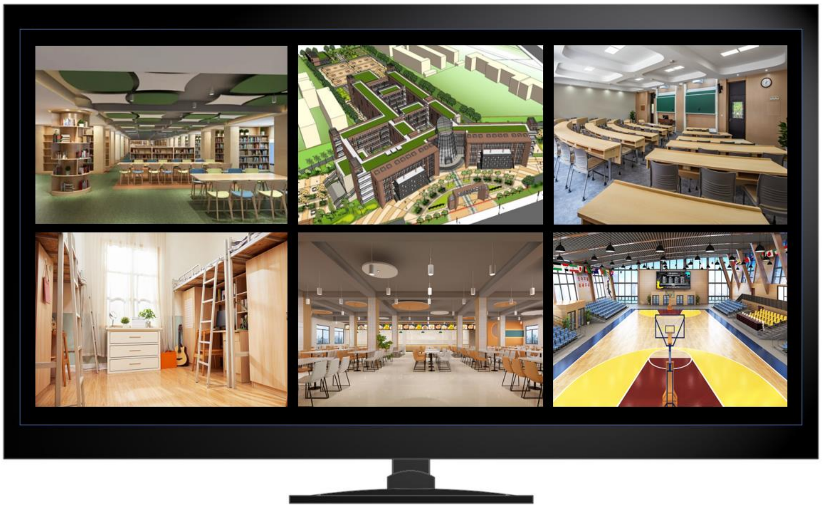

Figure 7: Design Plan.

6.2 Application Effect Feedback

Whether it is the size of the classroom, the arrangement of seats, or the brightness and colour temperature of lighting, all are carefully calculated and simulated by the model to ensure the best learning effect. For student dormitories, this model can take into account the living habits and privacy needs of students and design a practical and beautiful living space. The specific evaluation data is detailed in Table 1.

Evaluation methods	*Evaluation indicators*	*Result (average score)*
questionnaire survey on-the-spot investigation	User Satisfaction Index (10 out of 10)	8.9
	Appearance design evaluation (5 points as the maximum score standard)	4.6
	Daily practicality rating (5 points as the maximum score standard)	4.8
Evaluation methods questionnaire survey on-the-spot investigation	Spatial planning and layout rationality (10 out of 10)	9.2
	Functional fit (based on the degree of satisfaction of students with various functional needs, with a maximum score of 10 points)	9.0
	Overall comfort experience (covering multiple dimensions such as environment, lighting, and ventilation, with a maximum score of 10 points)	8.8
User Feedback	Positive feedback percentage	95%
	The total number of collected suggestions and areas for improvement	25

Table 1: Application effect evaluation.

The comprehensive evaluation shows that the application of intelligent building design models in educational buildings has achieved significant results. The questionnaire survey showed that users gave high praise to the model-generated solutions in terms of satisfaction, aesthetics, and practicality. The on-site investigation further confirmed the excellent performance of the design scheme in spatial layout, functional implementation, and comfort. User feedback not only provides positive feedback but also valuable improvement suggestions, including increasing humanized design, meeting personalized needs, and optimizing space utilization and energy conservation and emission reduction.

6.3 Challenges and Improvement Strategies Faced

Although the application effect of the model in educational architecture is significant, it still needs improvement. Considering the complexity of architectural design, such as regional characteristics and campus culture, the model has not yet fully met the personalized design needs of users. In some cases, the design output of the model may need to be manually adjusted to achieve optimal results.

To address these challenges, it is recommended to take the following improvement measures: enhance the interaction between users and models, enable users to participate more directly in the design process, and better meet personalized needs; Designers can unleash and optimize their creativity based on the generated models, incorporating more design thinking and humanistic care; Continuously optimize the dataset and algorithms of the model, improve its adaptability and accuracy, and address diverse design challenges. By implementing these measures, the application of intelligent building design models in educational buildings is expected to reach new heights.

7 CONCLUSIONS

This study successfully developed a leading intelligent building design model and verified its reliability through experimental simulation. In the practical application of educational buildings, this model demonstrates the ability to automatically generate design schemes that meet industry standards and design requirements, thereby significantly improving the quality of design. The achievements achieved include:

(1) This study creatively combines machine learning technology with computer-aided design to construct an intelligent model that can automatically generate design drafts based on customer needs and design principles.

(2) Through simulation testing, the stability of the model in diverse design environments was confirmed, highlighting its outstanding performance in accelerating the design process and optimizing design solutions.

(3) In the field of educational architecture, this model demonstrates the ability to meet the needs of special education functions, significantly improving the practicality of educational facilities.

This study injects new intelligent elements into the field of architectural design and provides a solid foundation for the advancement of intelligent building design technology. With the continuous innovation of technology and the increasing abundance of data resources, intelligent building design is gradually becoming an important direction for industry development, providing strong support for designers and driving the continuous transformation and development of the architectural design industry. Looking ahead to the future, the continuous progress of technology and the accumulation of data resources will make intelligent building design models play a more core role in the field of architecture, becoming an indispensable assistant for designers and leading the entire industry to new innovation peaks.

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