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Computer-Aided Design AND APPLICATIONS

Intelligent Collaborative Application of Fuzzy Neural Network and CAD in Green Architectural Design

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Abstract. Green buildings attempt to fully consider energy conservation, ecosystem protection, and Sustainability in the design and construction process, striving to minimize the impact on the ecosystem while meeting people's living and work needs. In practical operation, accurately predicting and controlling building energy consumption remains a challenging issue. A fuzzy neural network (FNN) is a computational model that simulates human brain neural networks and has the ability to handle fuzzy information and nonlinear problems. This article proposes a building load forecasting model based on FNN and applies it in collaboration with computer-aided design (CAD) technology in green architectural design. This model can learn and train various parameters of buildings to predict their energy consumption, thereby providing architects with a more accurate design basis. The model has shown excellent performance in both cooling load and electricity load prediction, with its maximum relative error and average relative error controlled at very low levels. In terms of cooling load prediction, the model achieved excellent performance with a maximum relative error of 3.8% and an average relative error of 1.4%. The model also achieved a high-precision prediction in electricity load forecasting with a maximum relative error of 3.7% and an average relative error of 1.1%.

Keywords: Green Architectural Design; CAD; Fuzzy Neural Network; Building Load Forecasting
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1 INTRODUCTION

With the increasingly serious problems of global climate change, resource depletion, and environmental degradation, human society is seeking a more sustainable and environmentally friendly mode of development. In this process, the concept and practice of green building have gradually attracted global attention and recognition. With society's increasing attention to energy demand and environmental protection, green buildings and intelligent buildings have become the development trends in the field of architecture. The combination of neural networks and computer-aided design (CAD) provides a new solution for improving energy management in smart buildings in green building design. Agostinelli et al. [1] explored the implementation principles and advantages of neural networks and CAD in improving the energy management of intelligent buildings in green building design. Neural networks are algorithms that simulate the workings of the human nervous system, capable of learning and recognizing complex patterns. By combining it with CAD, various factors, such as building structure, materials, environment, etc., can be considered in green building design, thus formulating more optimized design schemes. Meanwhile, intelligent management of energy in smart buildings can be achieved through real-time monitoring and data analysis. Specifically, neural networks can be used to predict energy consumption and demand in smart buildings, while CAD can be used to design the structure and layout of green buildings. By deploying sensors and monitoring systems, it is possible to monitor the energy consumption and demand of smart buildings in real-time and input monitoring data into neural networks for learning and analysis, thereby adjusting and controlling energy supply. The rise of green buildings is actually a reflection and improvement of traditional architectural methods. Traditional architectural design often only pays attention to the function and aesthetics of architecture but ignores the influence of architecture on the ecosystem. Green buildings use environmentally friendly materials, renewable energy, and energy-saving technologies to reduce energy consumption and environmental pollution. Intelligent buildings, on the other hand, improve the operational efficiency and management level of buildings through information technology and automation systems. However, in hot climate conditions, the cooling load and Sustainability of green intelligent buildings have become key issues. Bekdaş et al. [2] explored the use of CAD (computer-aided design) and machine learning to predict and optimize the cooling load and Sustainability of green intelligent buildings. Predicting the cooling load of green intelligent buildings through machine learning models, taking into account factors such as climate change and energy price fluctuations. Based on the cooling load prediction results, evaluate the Sustainability of green intelligent buildings, including indicators such as energy efficiency and environmental impact. Based on the evaluation results, optimize the design scheme of green intelligent buildings using CAD to reduce cooling load and energy consumption. By using machine learning models to monitor and analyze the operational data of green intelligent buildings, potential problems can be identified and resolved in a timely manner, improving operational efficiency and management levels.

Green buildings, on the other hand, try to fully consider energy saving, ecosystem protection and Sustainability in the stage of design and construction and strive to meet people's living and working needs while minimizing the impact on the ecosystem. Environmentally friendly energy has become an important global task. Roof microbial fuel cells (BMPFC), as a new type of energy conversion equipment, can convert plant waste and microorganisms into electricity while achieving effective utilization of waste. Chou et al. [3] studied a metaheuristic optimization deep learning algorithm for predicting sustainable energy generation in rooftop plant microbial fuel cells. Through experimental verification, we found that the algorithm can effectively improve the energy generation efficiency of MFC. Through comparative experiments, we found that the energy generation efficiency of MFC optimized by a meta-heuristic deep learning algorithm has significantly improved. Specifically, the optimized energy generation efficiency of MFC has increased by about 20%, which is of great significance for achieving the widespread application of MFC. In addition, we also found that meta-heuristic optimization deep learning algorithms can quickly find the best design parameters and operating conditions, which provides the possibility for rapid optimization of MFC. Meanwhile, the algorithm has good generalization performance and can adapt to different MFC designs and environmental conditions. In recent years, with the popularization of renewable energy and green concepts, sustainable development, and other concepts, the development speed of green buildings has been accelerating day by day, and the expectations of society for green buildings are gradually rising. More and more countries and regions have begun to formulate and implement green building standards to encourage the growth of green buildings. Green buildings and green hotels have become increasingly popular choices. These choices reflect tourists' concern for environmental protection and their pursuit of sustainable tourism. CAD green building intelligent collaborative design is a method that utilizes computer-aided design (CAD) technology and intelligent collaborative working principles to achieve digital management and optimization of the entire lifecycle of green building design, construction, and operation. This design method can improve building energy efficiency, reduce environmental impact, and improve building efficiency and comfort. Cynthia and Wu [4] analyzed that tourists' perception of CAD green buildings' intelligent collaborative design may be influenced by multiple factors. Some people may be familiar with this design method, while others may not be familiar or interested in it. Some people may believe that this design method can improve the Sustainability and environmental friendliness of buildings, while others may believe that this design method will increase the cost and maintenance difficulty of buildings. Staying in a green hotel may have a positive impact on tourists. Green hotels typically adopt sustainable building and operating methods to reduce energy consumption and environmental impact while providing a healthier and more comfortable environment. These hotels usually offer more environmental services and activities, such as eco-friendly tours, bike rentals, energy-efficient air conditioning, etc. These services and activities can provide tourists with a deeper understanding of environmental protection and sustainable development and promote their environmental awareness and behaviour. Moreover, the market demand for green buildings is also increasing, and more developers and investors are beginning to pay attention to the market prospects and commercial value of green buildings.

In practice, accurately predicting and controlling building energy consumption is still a challenging problem. In order to solve this problem, researchers are exploring various new technologies and methods. As an important type of building in cities, high-rise buildings have a significant impact on the urban environment and energy balance due to their energy consumption and self-sufficiency in production. In recent years, the rapid development of artificial intelligence (AI) and computer-aided design (CAD) technology has provided new possibilities for solving this problem. Ekici et al. [5] aim to explore how to optimize the design and energy management of high-rise buildings using CAD and AI technologies to achieve self-sufficiency in energy consumption and production. CAD technology provides architectural designers with a full process solution from conceptual design to detailed design and then to construction drawing design. By using CAD software, designers can accurately simulate the physical characteristics of buildings, such as shape, materials, structure, etc., and predict their impact on energy consumption. In addition, CAD can also help designers identify potential energy consumption issues in the early stages through data analysis and optimization algorithms, thereby improving design solutions and reducing building energy consumption. The use of CAD and AI technology can achieve comprehensive optimization of high-rise building design and energy management in order to achieve self-sufficiency in energy consumption and production. This can not only reduce energy consumption and environmental impact in cities but also improve the Sustainability and economy of buildings.

With the increasing awareness of environmental protection, green buildings have become an important component of the field of architectural design. By adopting green building parameters, energy consumption can be effectively reduced, environmental pollution can be reduced, and the Sustainability of buildings can be improved. However, widely utilizing green building parameters remains a challenge. In recent years, genetic algorithms based on CAD have shown great potential in optimizing design. Elshafei et al. [6] explored how to widely utilize green building parameters in building environments using CAD-based genetic schemes. A genetic algorithm is an optimization algorithm based on the principle of biological evolution. In green building design, genetic algorithms can be used to optimize structural design, energy systems, and environmental control of buildings. For example, by using genetic algorithms, the layout and shape of buildings can be optimized to improve their natural lighting and ventilation performance. In addition, genetic algorithms can also be used to optimize the energy system of buildings, such as solar panels, wind power generation, etc., to improve their energy utilization efficiency. By using green building parameters and renewable energy, the Sustainability of buildings can be greatly improved. With the increasing severity of the global energy crisis and environmental pollution, intelligent green buildings have become an important development direction in the construction industry. In order to achieve the load intelligent collaborative application of green intelligent buildings, advanced technological means are needed to accurately predict and optimize the control of building energy consumption. Fallah et al. [7] proposed a novel neural network based on electrostatic discharge algorithm optimization for intelligent load coordination applications in green intelligent buildings to improve building energy utilization efficiency and management level. The new neural network optimized based on the electrostatic discharge algorithm proposed in this article has better prediction accuracy and generalization ability than traditional neural networks and can be better applied to load intelligent collaborative applications in green intelligent buildings. Through experimental verification, the model is superior to traditional neural networks in both prediction accuracy and generalization ability and can be better applied to load intelligent collaborative applications in green intelligent buildings. In the future, further research can be conducted on how to combine other optimization algorithms with neural networks to improve their performance and adaptability.

The intelligent collaborative parametric design method is an architectural design method based on computer-aided design (CAD) technology and intelligent algorithms. It achieves optimized design in various aspects, such as building shape, structure, materials, etc., by encoding and optimizing the parameters of architectural design. The intelligent collaborative parameterized design method can improve the efficiency and quality of architectural design while reducing construction costs and resource consumption. Gao et al. [8] took a certain office building as an example and used the intelligent collaborative parameterized design integrated simulation method in green building design based on multi-objective optimization for design. First, utilize intelligent collaborative parametric design methods to code and optimize aspects such as building appearance, structure, and materials. Then, use multi-objective optimization algorithms to evaluate and optimize the optimized architectural design scheme. Next, integrated simulation methods will be used to simulate and analyze the optimized architectural design scheme in various aspects, such as energy efficiency, indoor environmental quality, and construction cost. Finally, based on the simulation analysis results, real-time tracking and optimization of the architectural design scheme are carried out. The final architectural design scheme has good energy efficiency, indoor environmental quality, and lower construction costs. By combining with CAD technology, the model can also realize an automatic and intelligent architectural design process. This research has important practical value and social significance. First of all, through accurate energy consumption prediction and control, the operating cost and maintenance costs of buildings can be reduced, and the economic burden of residents can be reduced. Secondly, green buildings can reduce the damage to the ecosystem and improve the quality of life of residents. Finally, the promotion and application of green building concepts and technologies can promote the growth of the whole construction industry in a more sustainable direction. The following is the innovation of this article:

The innovative points of this article can be listed one by one as follows:

1. Building load prediction model based on FNN: This study proposes a building load prediction model based on FNN. This model utilizes the advantages of FNN in handling fuzzy information and nonlinear problems and can more accurately predict the energy consumption of buildings.

2. Collaborative application of FNN and CAD technology: This study combines FNN and CAD technology to achieve intelligent collaborative application of the two. Architects can predict and adjust building energy consumption in real-time during the design process, achieving efficient, automated, and intelligent green architectural design.

3. Optimization of green architectural design: With the collaborative application of FNN and CAD technology, architects can adjust and optimize the building scheme during the design phase based on energy consumption prediction results.

4. Promoting Green Building Practice: This study has promoted the widespread application and promotion of green buildings in practice by applying advanced AI technology to green architectural design. This helps to promote the transformation of the construction industry and enhance its sustainable development capabilities.

This article is divided into five sections. The first section introduces the research background, purpose, methods, and structure. The second section analyzed the relevant theoretical foundations and analyzed the requirements for green architectural design. The third section elaborates on the construction principle and implementation steps of a building load forecasting model based on FNN and CAD. The fourth section describes the experimental design, data preparation, and experimental ecosystem and presents the experimental results to evaluate the model performance. Section 5 summarizes the entire text and proposes possible directions for improvement.

2 THEORETICAL OVERVIEW AND DEMAND ANALYSIS

Green buildings have become an important direction for sustainable development. Green buildings reduce energy consumption and environmental pollution by adopting renewable energy, energy-saving technologies, and environmentally friendly materials. However, in hot climate conditions, the cooling and energy efficiency of green buildings have become key issues. Therefore, optimizing and predicting the thermal performance of green buildings has become an important issue. Khalil et al. [9] explored the optimization and prediction of the thermal performance of different green building forms in hot climates using genetic algorithms and machine learning. Genetic algorithms can be used to optimize the design parameters of green buildings, such as material properties, structural layout, etc., in order to improve the thermal insulation performance and energy efficiency of buildings. Machine learning can be used to learn the thermal performance patterns of green buildings from historical data and predict their thermal performance under future climate conditions. By combining genetic algorithm and machine learning, the optimal green building design scheme can be found, and its thermal performance can be predicted under different climate conditions. Green buildings have become an important direction for sustainable development. Green buildings use environmentally friendly materials, renewable energy, and energy-saving technologies to reduce energy consumption and environmental pollution. In order to better manage and optimize the energy use of green buildings, the combination of artificial intelligence (AI) and drone technology has become a new research hotspot. Khan et al. [10] explored the application of AI in green building concepts for energy auditing using drone technology under different environmental conditions. Energy auditing is the monitoring, analysis, and evaluation of building energy consumption and is an important means of achieving building energy efficiency. By combining AI and drone technology, precise control and optimized management of building energy consumption can be achieved. Using AI to establish a model for building energy consumption, including models for building heat conduction, air circulation, and electricity usage. By analyzing these models, the energy consumption characteristics of buildings and potential energy-saving spaces can be identified. Different types and styles of buildings will have different energy consumption characteristics. By utilizing AI and drone technology, modelling and analysis can be conducted for different types of buildings, and more targeted energy-saving optimization suggestions can be proposed. With the increasing attention to sustainable architecture and urban planning, passive building design with green roofs has become a research hotspot. This design method can significantly reduce the energy consumption of buildings and improve the urban environment by utilizing the shading, insulation, and natural cooling characteristics of green plants. However, optimizing the design of passive buildings with green roofs remains a challenging issue. Therefore, Lin et al. [11] proposed applying machine learning and swarm intelligence algorithms to the design optimization of passive green roof buildings. In passive building design optimization of green roofs, machine learning can be used to predict and analyze building performance, providing decision support for designers. The swarm intelligence algorithm is an optimization algorithm based on group behaviour and collaboration, which can be used to find the optimal solution for the passive building design of green roofs. By collecting a large amount of design data on passive green roof buildings and utilizing machine learning algorithms, we can train a model that can predict building performance. This model can predict the thermal comfort, energy consumption, and environmental impact of buildings based on different design parameters, such as plant species, layout, thickness, etc. By predicting the results, designers can better understand the performance of passive buildings with green roofs, thereby optimizing the design scheme.

Intelligent buildings use information technology, automation technology, artificial intelligence and other means to intelligently manage and control buildings in order to improve their energy utilization efficiency and management level. CAD (Computer Aided Design) technology provides powerful tools for architectural design, enabling detailed design and simulation of building structures. However, further exploration is needed on how to effectively combine artificial intelligence with CAD technology to achieve intelligent collaborative applications in residential buildings. Moayedi and Mosavi [12] proposed a dual-objective CAD neural network model for predicting intelligent collaborative applications in residential areas. The dual objective CAD neural network model is an intelligent prediction model that combines neural networks and CAD technology. The model has two main objectives: firstly, to use neural networks to predict building energy consumption; secondly, to use CAD technology to optimize the design of building structures. Accurate energy consumption prediction and analysis can provide a scientific basis for the design and operation management of residential buildings to support more scientific and reasonable decision-making and management methods. By combining real-time monitoring technology, potential problems can be identified and solved in a timely manner to improve the energy utilization efficiency of residential buildings. Green buildings use environmentally friendly materials, renewable energy, and energy-saving technologies to reduce energy consumption and environmental pollution. In order to better design and optimize green buildings, it is particularly important to predict the heat load energy inside the building. Moayedi and Van [13] explored the feasibility of combining computer-aided design (CAD) optimization with fuzzy inference systems to predict the thermal load energy inside green buildings. Establish a physical model of green buildings using CAD technology and simulate and predict the thermal environment of the building using a fuzzy inference system. Based on the prediction results of the fuzzy reasoning system, use CAD technology to optimize the design of building structures and adjust the configuration of materials and energy systems. By optimizing the model through CAD, a fuzzy inference system is used again to predict and analyze the heat load energy. By optimizing design and management, the impact on the environment can be reduced, achieving the goal of environmental protection and sustainable development. At the same time, the combination of CAD optimization and fuzzy reasoning systems has high flexibility and scalability, providing greater potential and flexibility for future architectural design and energy management. CAD optimization design can improve the structural design of buildings and enhance their quality and stability while combining fuzzy inference systems for thermal environment prediction can enhance the rationality and adaptability of the design.

With the increasing awareness of sustainable development and environmental protection in society, green buildings have become an important development direction in the field of architecture. Green buildings are designed with the concepts of energy conservation, environmental protection, and health, fully utilizing natural conditions and renewable energy to reduce energy consumption and environmental pollution. In green building design, photovoltaic installation and battery energy storage are important means to achieve a sustainable energy supply. Machine learning technology has made significant progress in many fields and is widely applied in the field of intelligent energy management. In the design of green buildings with photovoltaic installation and battery energy storage, the introduction of machine learning technology can achieve intelligent collaborative management of household intelligent energy systems, further improve energy utilization efficiency, and achieve a more sustainable energy supply. Rojek et al. [14] can intelligently manage photovoltaic systems and improve energy efficiency through machine learning techniques. For example, using machine learning algorithms to learn and analyze data such as weather forecasts, photovoltaic panel status, and grid loads can predict the future power generation of photovoltaic systems and provide a basis for power scheduling. As an important component of urban infrastructure, the operation of the sewage system directly affects the ecological environment of the city and the quality of life of residents. However, due to various factors, sewer overflow problems often occur, causing inconvenience to the urban environment and residents' lives. Intelligent management has become crucial to solve this problem. Siddiqi et al. [15] explored the application of fuzzy neural networks and CAD (computer-aided design) in intelligent management of joint sewer overflow and analyzed their implementation principles and advantages. A fuzzy neural network is an algorithm that simulates human thinking and decision-making processes and can handle uncertainty and fuzziness. By combining it with CAD, various factors, such as terrain, climate, flow rate, etc., can be considered in sewer design to develop more optimized design solutions. Meanwhile, intelligent management of sewer systems can be achieved through real-time monitoring and data analysis. By deploying sensors and monitoring systems, real-time monitoring of the flow and overflow situation of the sewer system can be achieved. The monitoring data is inputted into the fuzzy neural network for learning and analysis in order to adjust and control the operation of the sewer system. Combining fuzzy neural networks with CAD can provide decision-makers with more comprehensive and accurate data support, helping them make wiser decisions. Sakiyama et al. [16] analyzed that sensitivity analysis can be effectively applied to parameterized design platforms to optimize the design of green intelligent buildings. Radial-based algorithms have high sensitivity and robustness to parameter changes when processing large-scale and high-dimensional data, thus playing an important role in sensitivity analysis. Sensitivity analysis mainly evaluates the impact of parameter changes on model output by studying the sensitivity of model outputs (such as building energy efficiency, carbon emissions, etc.) to input parameters (such as building shape, material type, size, etc.). This can help designers understand which parameters have a significant impact on building performance and optimize these parameters to achieve better performance. By applying sensitivity analysis to parameterized design platforms and using radial-based algorithms for optimization, the design performance of green intelligent buildings can be effectively improved. This can not only improve the energy efficiency of buildings and reduce carbon emissions but also achieve better building shapes and structures.

Simtinică et al. [17] explored how to evaluate the integrated application of artificial intelligence CAD (computer-aided design) in green intelligent building service control strategies and used civil environmental engineering models for simulation and optimization. Singh and Thomas [18] explored the application of hybrid artificial neural networks (ANN) and multi-objective evolutionary algorithms in passive design strategy optimization of energy-saving buildings through case study methods. Firstly, an overview of passive design strategies for energy-efficient buildings was provided, and the basic principles and advantages of ANN and multi-objective evolutionary algorithms were introduced. Then, through a practical case study, it demonstrated how to combine these two technologies to optimize design strategies. Finally, the potential and limitations of this method in optimizing passive design strategies for energy-efficient buildings were discussed. The passive design strategies for energy-efficient buildings mainly include four aspects: natural lighting, ventilation, insulation, and noise reduction. A reasonable passive design strategy can significantly reduce building energy consumption, improve indoor environmental quality, and reduce the impact on the environment. Using ANN to learn and predict these data, obtain an energy consumption prediction model for office buildings. Next, the multi-objective evolutionary algorithm is used to optimize the energy consumption prediction model and obtain a set of optimal passive design strategies. Finally, applying this strategy to the design and renovation of office buildings has achieved significant energy-saving effects. Xu et al. [19] explored energy-saving optimization methods based on machine learning using the atrium roof of elastic ventilation commercial complexes as the research object. The atrium roof of a flexible, ventilated commercial complex is a unique architectural form characterized by an open architectural design and a flowing spatial design. This structure can effectively promote air circulation and improve building comfort and energy efficiency. However, the energy consumption of the atrium roof mainly comes from three aspects: solar radiation, internal load, and equipment load. Based on the established model, analyze the energy consumption and energy-saving potential of the atrium roof. Elastic ventilation is a method that combines natural ventilation and mechanical ventilation to regulate indoor air flow and temperature distribution effectively. In green intelligent buildings, the atrium roof is an important space with high energy consumption and environmental impact. Through elastic ventilation technology, we can achieve energy-saving optimization of the atrium roof. Computer vision interaction design is an interdisciplinary approach that combines computer technology, artificial intelligence, and design thinking. It achieves human-computer interaction and data visualization through technologies such as image recognition, machine learning, and natural language processing. In urban planning and management, computer vision interaction design helps to improve decision-making efficiency and accuracy while reducing labour costs. Based on the case of rooftop garden landscape plants in ocean cities, Zhang and Kim [20] explore the application of computer vision interaction design in sustainable urban development. The design and management of rooftop garden landscape plants are of great significance. By utilizing computer vision interaction design, we can intelligently identify and monitor these plants, thereby better protecting and maintaining them. Specifically, we can use image recognition technology to classify and recognize rooftop garden landscape plants, which helps us understand the growth and distribution of plants. Meanwhile, by using machine learning algorithms to process and analyze image data, we can predict the growth trends and potential threats that plants may face. This can not only improve the maintenance efficiency of rooftop garden landscapes but also provide valuable data support for urban planners.

3 BUILDING LOAD FORECASTING MODEL BASED ON FNN AND CAD

FNN is a computational model that simulates human brain neural networks, combining the advantages of fuzzy logic and neural networks. Fuzzy logic can handle fuzzy information, while neural networks have self-learning and adaptive capabilities. Therefore, FNN has strong capabilities in dealing with uncertainty, complexity, and nonlinear problems. In green architectural design, energy consumption prediction is a complex problem that involves multiple influencing factors and parameters. Traditional prediction methods often struggle to handle these uncertainties. FNN can establish a nonlinear mapping relationship between energy consumption and influencing factors through learning and training, achieving accurate energy consumption prediction.

CAD technology is widely used in the field of architectural design. CAD software can help architects efficiently carry out design work, including drawing, modelling, analysis, and other aspects. By combining with FNN, CAD technology can achieve automated and intelligent architectural design processes. By embedding FNN into CAD systems, architects can predict building energy consumption in real-time during the design process and optimize based on the predicted results.

With the increasing severity of global climate change and resource depletion, the demand for green buildings is becoming increasingly urgent. Green buildings aim to reduce the impact of buildings on the ecosystem. By adopting design methods such as renewable energy, high-efficiency energy-saving equipment, natural lighting, and ventilation, green buildings can reduce energy consumption and operating costs and improve the quality of life and environmental benefits of residents. Architects need to consider multiple factors during the design phase, such as building appearance, functional requirements, structural safety, equipment systems, etc. Moreover, it is needed to accurately predict and control the energy consumption of buildings to ensure that the performance of green buildings achieves the expected results.

In order to solve the problem of energy consumption prediction and control in green architectural design, this study proposes a building load prediction model based on FNN and applies it in collaboration with CAD technology. The demand for this collaborative application is mainly reflected in the following aspects:

(1) Improving the accuracy of energy consumption prediction: Through the learning and training of FNN, a nonlinear mapping relationship between energy consumption and influencing factors can be established, thereby improving the accuracy of energy consumption prediction.

(2) Implementing an intelligent architectural design process: By embedding FNN into CAD systems, automated and intelligent architectural design processes can be achieved. Architects can predict building energy consumption in real-time during the design process and make adjustments based on the predicted results.

(3) Promoting the application of green buildings: Applying advanced AI technology to green architectural design can promote the popularization of green building concepts. This helps to increase the acceptance of green buildings and promote their widespread application in practice. Traditional energy consumption prediction methods are often based on empirical formulas or simplified models, which are difficult to reflect the actual energy consumption of buildings accurately. Therefore, researching high-precision building load forecasting technology is crucial for promoting the growth of

green architectural design. This section will elaborate on the building load forecasting model based on FNN and CAD in detail. This model combines the advantages of FNN and CAD technology, aiming to achieve automation and intelligence of load forecasting in green architectural design. Architects can more accurately predict building loads during the design phase, providing the scientific basis for green architectural design.

3.1 FNN Principle

FNN is a neural network algorithm that simulates the fuzzy thinking patterns of the human brain, capable of handling uncertainty and fuzzy information, and has been widely applied in fields such as prediction and decision-making. As an important tool in architectural design, CAD technology can provide rich building information and model data, providing basic data support for building load forecasting. The input layer is responsible for receiving various parameters of the building, such as building area, building height, wall materials, equipment power, etc. The fuzzification layer fuzzifies the input parameters and generates corresponding fuzzy sets. The rule layer calculates the relationship between input parameters and energy consumption based on a pre-set rule library. The output layer deblurs the output of the rule layer to obtain specific energy consumption prediction values. The deblurring layer adopts the centroid method for deblurring processing, converting the fuzzy output into specific numerical outputs. For a single hidden layer neural network (Figure 1), suppose there are any N samples (X_i, t_i) where:

$$X_i = [x_{i1}, x_{i2}, \dots, x_{in}]^T \in R^n \tag{1}$$

$$t_i = [t_{i1}, t_{i2}, \dots, t_{im}]^T \in R^m \tag{2}$$

The quantity of hidden layer nodes is L. At this time, the single hidden layer neural network is:

$$\sum_{i=1}^{L} \beta_i g(W_i \cdot X_j + b_i) = o_j \tag{3}$$

Where $g(x)$ are the activation function and the input weight matrix is

$$W_i = [w_{i1}, w_{i2}, \dots, w_{in}]^T \tag{4}$$

β_i is the output weight and b_i is the bias of the i hidden layer unit. $W_i \cdot X_j$ Represents the inner product of W_i and W_j.

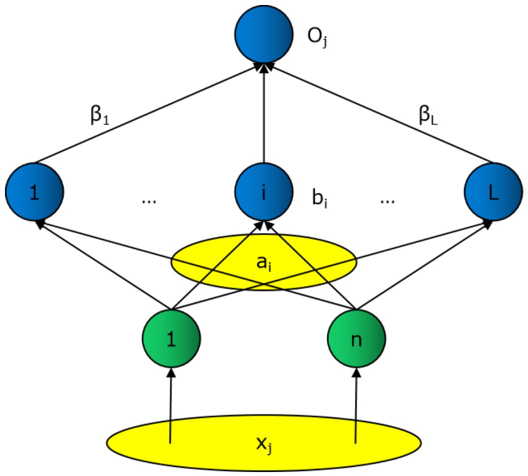

Figure 1: FNN structure of the single hidden layer.

Build a neural network model based on the FNN algorithm that can handle uncertainty and ambiguity information. This model has multiple input nodes for receiving environment variable data and an output node for predicting building loads. During the training process, the model will gradually learn the mapping relationship between building load and environment variables by adjusting network parameters and structure based on the input environment variable data. After completing the model training, use the model for building load prediction. Input real-time environment variable data into the model, and the model will output corresponding building load prediction values based on the learned mapping relationships.

The FNN model is optimized using a learning algorithm based on error backpropagation, which includes three stages: forward propagation, error calculation, and backpropagation. In the forward propagation stage, the input parameters are passed to the output layer to obtain the predicted energy consumption value. The error calculation stage compares the predicted values with the actual energy consumption values. In the backpropagation stage, the model parameters are adjusted based on the error to gradually approach the actual energy consumption value.

3.2 Construction of Building Load Forecasting Model

The heating demand of buildings is met through heating stations, which constitute a centralized heating system. Their function is to connect the heating network and end users. According to the conditions of the heating network and the actual needs of end users, the heating station will adjust and convert the heating network to ensure the reasonable distribution of heat. In this process, centralized measurement and measurement of thermal medium parameters are also required. The operation of a heating station can be divided into two main steps: first, the primary heat source arrives at the heat exchange station through pipelines, exchanges heat with the secondary heat source inside the heat exchanger, transfers heat to the secondary heat source, and then the secondary heat source delivers heat to the user through pipelines; Secondly, after the secondary water flows through the filter and purifier, it circulates into the heat exchanger and is heated by high-temperature water or steam. After heating is completed, the cooled high-temperature water or steam will become high-temperature return water or condensate, which will return to the heat source and complete the heat recovery cycle. During this process, the water replenishment pump will maintain stable pressure in the system, preventing water loss and pipeline under pressure caused by pipeline leakage. Sensors are installed for monitoring at every stage of the entire process to ensure the safety and normal operation of the equipment. The structure of the heating station system is shown in Figure 2.

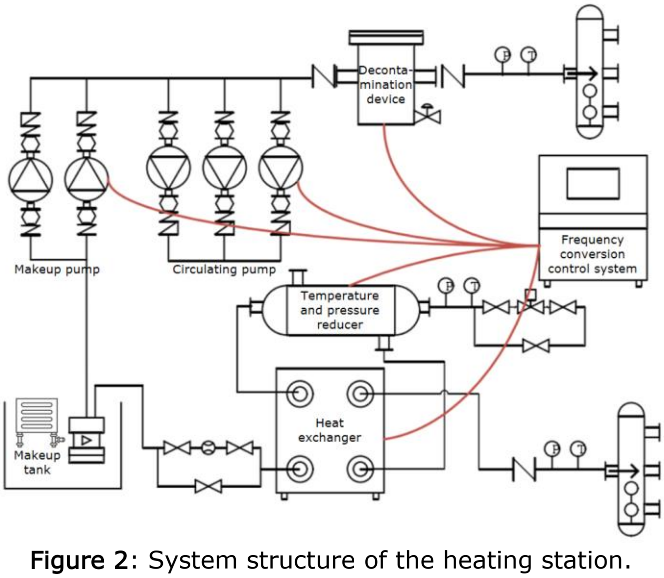

Figure 2: System structure of the heating station.

Assuming the dependent variable is Y, with k independent variables being $X_1, X_2, X_3, ..., X_k$. A multiple linear regression model can be established as follows:

$$\hat{Y} = \sum_{i=1}^{k} \beta_i X_i + \beta_0 \tag{5}$$

Where $\beta_0, \beta_1, \beta_2, ..., \beta_k$ is $k+1$ parameters to be determined, and $\hat{Y}$ is the estimated value of dependent variable Y. According to the n group data in the sample, the following equations can be established:

$$\begin{cases} \beta_1 X_{11} + \beta_2 X_{12} + \beta_3 X_{13} + \cdots + \beta_k X_{1k} + \beta_0 = Y_1 \\ \beta_1 X_{21} + \beta_2 X_{22} + \beta_3 X_{33} + \cdots + \beta_k X_{2k} + \beta_0 = Y_2 \\ \cdots \\ \beta_1 X_{m1} + \beta_2 X_{m2} + \beta_3 X_{m3} + \cdots + \beta_k X_{mk} + \beta_0 = Y_m \\ \cdots \\ \beta_1 X_{n1} + \beta_2 X_{n2} + \beta_3 X_{13} + \cdots + \beta_k X_{1k} + \beta_0 = Y_n \end{cases} \tag{6}$$

$(x_{m1}, x_{m2}, x_{m3}, ..., x_{mk}, Y_m)$ Represents the m group of data, where $m = 1,2,3,...,n$. According to the principle of least squares, in order to minimize the difference between the estimated value and the true value, it is needed to:

$$Q = \min \sum_{m=1}^{n} (Y_m - \hat{Y}_m)^2 \tag{7}$$

The derivation of the equation can be obtained according to the necessary and sufficient conditions for taking the extreme value:

$$\frac{\partial Q}{\partial \beta_0} = -2 \sum_{m=1}^{n} (Y_m - \hat{Y}_m)^2 = 0 \tag{8}$$

$$\frac{\partial Q}{\partial \beta_i} = -2 \sum_{m=1}^{n} (Y_m - \hat{Y}_m) X_{im} = 0 \tag{9}$$

According to the above equations, the corresponding $\beta_0, \beta_1, \beta_2, ..., \beta_k$ is solved and substituted into the original expression, which is the final multiple linear regression model.

Integrate the proposed FNN model into the CAD system to achieve collaborative application between the two. Architects can directly call FNN models in CAD systems for energy consumption prediction and analysis. Architects can input various parameters of buildings in the design phase and then call the FNN model to predict energy consumption. The predicted results can be presented to architects in the form of charts or numerical values, providing a reference basis for design decisions. By utilizing the parametric design function of CAD systems, various parameters of buildings can be optimized and adjusted. By adjusting the parameter values and observing the trend of energy consumption prediction results, find the optimal design solution.

4 RESULT ANALYSIS AND DISCUSSION

4.1 Experimental Data and Parameter Design

The data used in the experiment comes from 1200 sets of hourly simulated load data of buildings during the summer months of June and October. In order to ensure the quality and consistency of the data, preprocessing work was carried out, including data cleaning, format conversion, and standardization processing. The preprocessed data is used for subsequent model training and validation. To evaluate the performance of the model, 1200 sets of data were randomly divided into training samples and validation samples, each consisting of 600 sets. The training samples are used to train the FNN model, and the validation samples are used to evaluate the predictive performance of the model. By randomly dividing, the representativeness of training and validation samples can be ensured, and the generalization ability of the model can be improved. Write a program according to the steps of the FNN algorithm and set the number of neural network nodes to 300. Train the prediction model using training samples, and gradually learn the mapping relationship between building energy consumption and various parameters through iteration and optimization. Using root mean square error (RMSE) as the evaluation metric for training models:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i}^{n}(\hat{Y}(i) - Y(i))^2} \tag{10}$$

Where n is the quantity of training samples; $Y(i)$ is the simulation load, which acts as the actual system to collect data here; $\hat{Y}(i)$ is the load forecast value of the forecast model.

4.2 Experimental Results

Figure 3 shows the error variation during the training stage of the load forecasting model. As the quantity of training iterations increases, the prediction error of the model shows a gradually decreasing trend. This indicates that the model is gradually learning the inherent patterns and patterns in the data and optimizing its own parameters and structure to improve prediction accuracy.

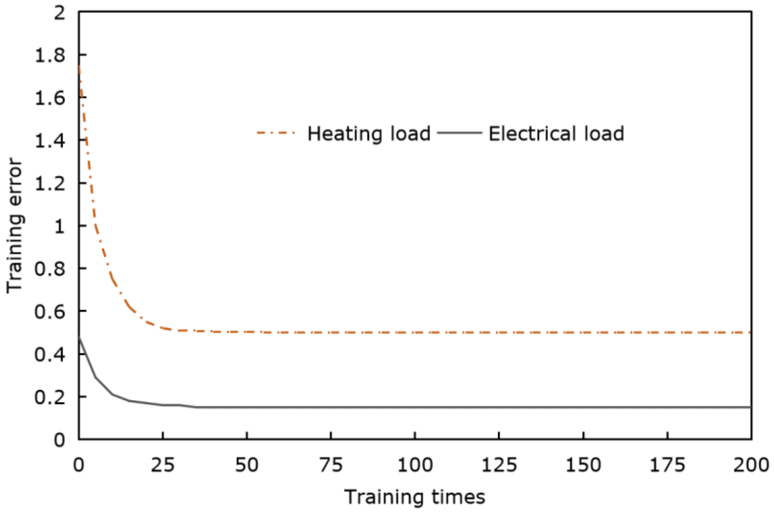

Figure 3: Training error of load forecasting model.

In the early stages of training, the prediction error of the model is relatively large, which is due to the model not fully learning the characteristics of the data or the parameter settings not being reasonable enough. However, as the training progresses, the model gradually adjusts and optimizes its own parameters and structure to adapt to the distribution and changes of the data. This gradually reduces the prediction error and tends to stabilize. The speed of reducing training errors gradually slows down, which may be because the model has already learned most of the data information, and the space for further optimization is limited. This also suggests that we need to set reasonable parameters, such as the number of iterations and learning rate during the training process, to avoid overfitting and underfitting.

Figures 4 and 5 show the verification process and error curve of building cooling load prediction, while Figures 6 and 7 show the verification process and error curve of building electrical load prediction, respectively. The maximum relative error of the FNN building dynamic load prediction model in cold load validation is 3.8%, with an average relative error of 1.4%. The maximum relative error in electrical load validation is 3.7%, with an average relative error of 1.1%. The simulation results show that a building load forecasting model with high accuracy and strong universality can be obtained through the FNN model.

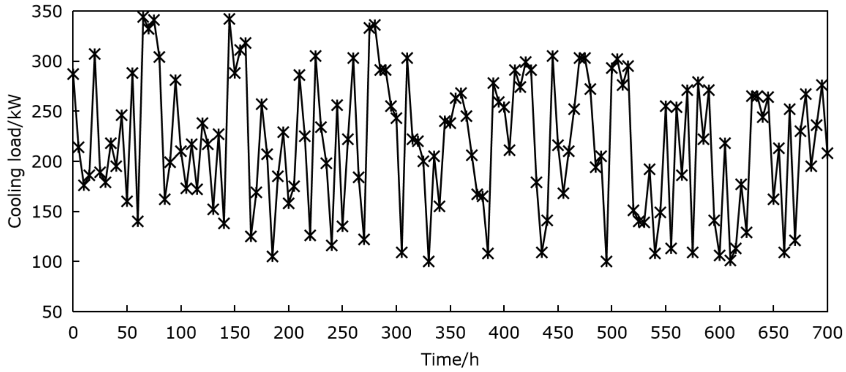

Figure 4: Verification stage of cooling load forecasting.

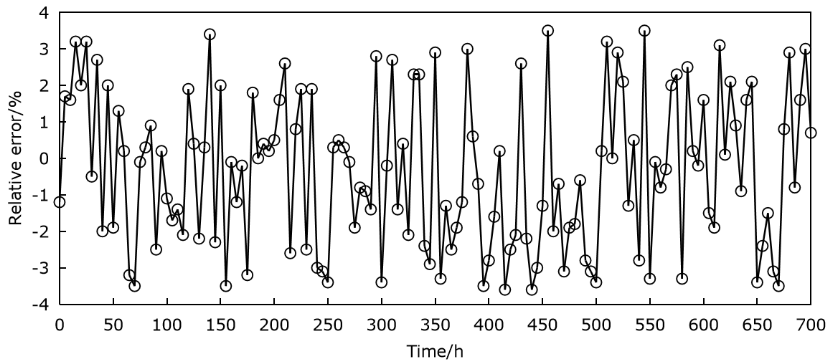

Figure 5: Error curve of cooling load forecast.

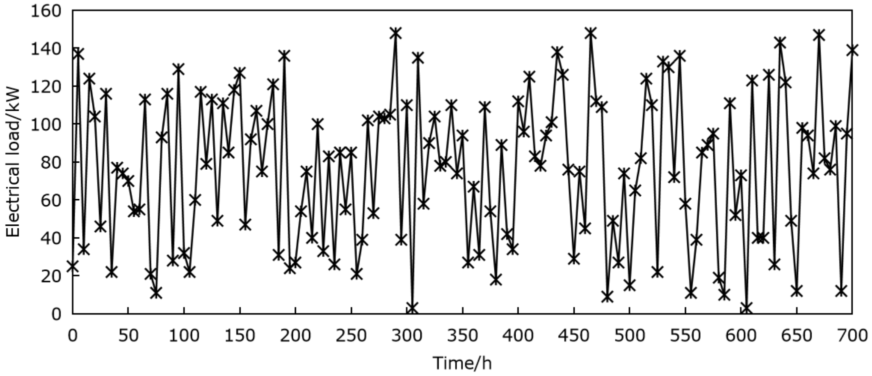

Figure 6: Verification stage of electric load forecasting.

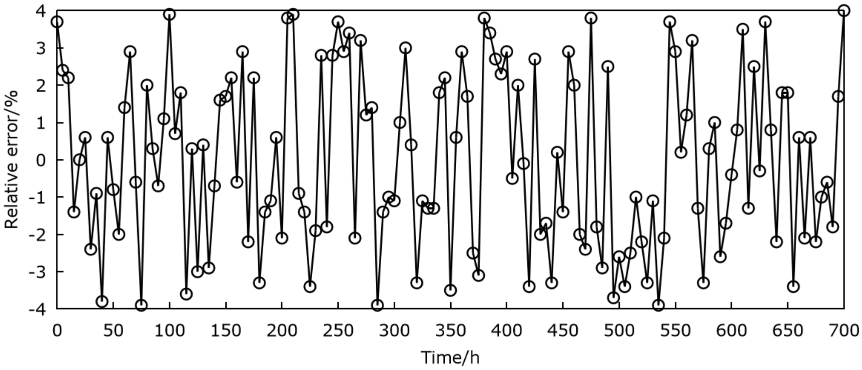

Figure 7: Error curve of electric load forecasting.

By integrating FNN models into CAD systems, automated and intelligent architectural design processes can be achieved. Architects can predict building energy consumption in real time during the design phase and make adjustments based on the predicted results. By adjusting the model structure and learning algorithms, it can adapt to the energy consumption prediction needs of different types of buildings and different regions. In addition, other influencing factors, such as meteorological data and pedestrian flow, can be incorporated into the model to improve the comprehensiveness of energy consumption prediction further.

4.3 Discussion

By integrating the FNN model into a CAD system, this study achieves an automated and intelligent architectural design process, enabling architects to predict building energy consumption in real time during the design phase and make adjustments based on these predicted results. By training the FNN model to process a large amount of building performance data, we have successfully constructed a system that can accurately predict building energy consumption. The model has shown excellent performance in both cooling load and electricity load prediction, with its maximum relative error and average relative error controlled at very low levels. In terms of cooling load prediction, the model achieved excellent performance with a maximum relative error of 3.8% and an average relative error of 1.4%. In electricity load forecasting, the model also achieved a high-precision prediction with a maximum relative error of 3.7% and an average relative error of 1.1%. These data not only validate the accuracy of the FNN model but also confirm its effectiveness in handling complex and variable building performance data. By adjusting the model structure and learning algorithms, the model can easily adapt to the energy consumption prediction needs of different types of buildings and regions. This means that whether it is commercial buildings, residential buildings, or public facilities such as schools and hospitals, the model can provide accurate and reliable energy consumption predictions.

In addition to basic building performance and climate condition data, other influencing factors such as meteorological data and pedestrian flow can also be incorporated into the model to further improve the comprehensiveness of energy consumption prediction. For example, real-time weather data can be put into the model to make energy consumption predictions based on current weather conditions. Alternatively, the pedestrian flow data inside the building can be input into the model to predict the building's energy consumption based on changes in pedestrian flow. This comprehensive predictive ability enables the model to provide richer energy consumption prediction information.

Integrating FNN models into CAD systems not only improves the efficiency and quality of architectural design but also promotes the development and innovation of green architectural design. This method enables architects to comprehensively consider the energy consumption of buildings during the design phase, thereby designing more energy-efficient and environmentally friendly buildings. This is of great significance for promoting global sustainable development and addressing climate change.

5 CONCLUSION

Green buildings attempt to fully consider energy conservation, ecosystem protection, and Sustainability in the design and construction process, striving to minimize the impact on the ecosystem while meeting people's living and work needs. This study successfully constructed and validated a building load forecasting model based on FNN and CAD. By introducing the FNN algorithm, the model can handle uncertainty, complexity, and nonlinear problems, thereby improving the accuracy of load forecasting. In addition, the integration of models with CAD systems has achieved an automated and intelligent architectural design process, enabling architects to predict building energy consumption in real time during the design phase and adjust and optimize based on the predicted results.

The results show that the model has good performance in predicting summer building loads and has achieved high-precision results in predicting cooling loads and electricity loads. Specifically, the maximum relative error for cooling load forecasting is 3.8%, with an average relative error of 1.4%. The maximum relative error for electricity load forecasting is 3.7%, with an average relative error of 1.1%. These results indicate that a building load prediction model with high accuracy and strong universality can be obtained through the FNN model, providing a scientific basis for energy consumption prediction in green architectural design.

Future research can consider further optimizing the model structure and algorithms to improve prediction accuracy and studying the demand for building load forecasting in different seasons and regions. In addition, integration with other technologies can be explored to promote the growth of green architectural design.

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