Deep Learning-based Automatic Optimization of Design Smart Home

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Abstract. In this article, the DL (Deep Learning) algorithm, CAD (Computer Aided Design) technology, and other technologies and methods in different fields are comprehensively applied to solve some key problems in the field of smart home design. Specifically, this article constructs an automatic optimization model, which can automatically adjust the control strategy of equipment according to the individual needs and habits of users and realize the automatic control and optimization of equipment. When constructing the automatic optimization model, this article fully considers the issues of security and privacy protection and adopts encryption, access control and other technologies to ensure the security of the system while following the relevant privacy protection laws and standards. The results show that the identification accuracy of this model for user behaviour patterns and habits reaches 95%, which is significantly higher than the traditional behaviour identification methods. Moreover, the design time using this model is shortened by about 40% on average; The design quality score is improved by about 20% on average. In addition, most users give high marks to the smart home design model based on the DL algorithm, with an average score of more than 8.5. This cross-domain comprehensive application mode has great innovation and practical value and can provide a reference for technological innovation and application in other fields.

Keywords: Deep Learning; Computer-Aided Design; Smart Home Design; User Behavior Pattern; Automation Optimization
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1 INTRODUCTION

With the continuous progress of science and technology and the rapid growth of globalization, people's quality of life has been significantly improved, especially in the living environment. In order to improve the intelligence and user experience of smart home systems, Africa [1] proposes a design and implementation method for a smart home system based on deep learning algorithms and CAD implementation using a group tracker. Deep learning algorithms can be used for object recognition in smart homes, including the recognition of items such as furniture, appliances, and decorations. By training deep neural networks, automatic recognition and classification of household items can be achieved. Deep learning algorithms can understand behaviour in homes, including the relationships between human behaviour and objects. For example, by analyzing video sequences, it can be inferred that people are engaged in household activities such as cooking and cleaning. Through the simulation and simulation functions of CAD software, smart home systems can be simulated and tested during the design phase. Meanwhile, the design and parameters of the system can be optimized through the analysis of simulated data. In practical systems, deep learning algorithms can be combined with CAD implementation to achieve automatic recognition, behavioural understanding, emotional analysis, and other functions of household items. At the same time, items can be grouped and analyzed through a group tracker to achieve higher levels of intelligent functionality. For example, when an elderly person falls, it can automatically trigger an emergency call or notify family members. Smart home systems are increasingly favoured by people because of their convenience, comfort, and energy savings. However, the traditional smart home design process mainly relies on manual experience and professional knowledge, and there are some problems, such as a long design cycle, high cost, and difficulty guaranteeing the effect. The concept of a distributed smart grid has been proposed and has gradually become an important development direction for smart home design. Ali et al. [2] introduced how to use computer-aided design (CAD) tools and state-of-the-art artificial intelligence technology to achieve a distributed smart grid for smart home design. A distributed smart grid is a smart home system that combines advanced sensor technology, communication technology, data analysis technology, and artificial intelligence technology. It can achieve real-time monitoring and control of household equipment, optimize energy distribution and utilization, and improve energy efficiency and comfort of the home. In the process of implementing a distributed smart grid, CAD and artificial intelligence technology can work together to optimize smart home design. Firstly, designers can use CAD software for home layout and device design and integrate various smart home devices. Then, through artificial intelligence technology, the sensor data is learned and analyzed to achieve an accurate prediction of the behaviour and preferences of family members. These prediction results can help designers optimize the home layout and equipment configuration to improve energy efficiency and comfort of homes. At the same time, artificial intelligence technology can also monitor and analyze the operating data of devices in real-time, timely discovering and solving problems during device operation. For example, by analyzing the operating data of air conditioning systems, energy efficiency bottlenecks can be identified, and optimization suggestions can be proposed. By studying the lighting system, the brightness and colour temperature of the lighting equipment can be automatically adjusted to improve the lighting quality. Therefore, how to realize the automatic optimization of smart home design has become a hot issue in current research. Intelligent energy consumption management refers to the monitoring, analysis, and control of household electricity consumption through intelligent technology in order to achieve the goals of energy conservation, emission reduction, and energy consumption reduction. By monitoring and analyzing household electricity consumption, Alzoubi [3] can promptly identify and solve the problem of energy waste, thereby reducing energy consumption and achieving the goal of energy conservation. Intelligent energy management can reduce household carbon emissions, thereby reducing the impact on the environment, which is beneficial for environmental protection and sustainable development. Intelligent energy consumption management can achieve intelligent control of electricity, improve the comfort and convenience of household life, and also reduce household energy costs. The deep learning algorithm is a computational model that simulates the neural network structure of the human brain. It can automatically extract the features of input data, thereby achieving data classification, prediction, and control. By using deep learning algorithms to learn historical power data, it is possible to predict future power loads. By predicting the power load, power scheduling and optimization can be carried out in advance to avoid overload and waste of power load. The application of deep learning algorithms and CAD to achieve machine learning of intelligent energy consumption in smart homes is of great significance and value. CAD technology can provide support for building model building, energy consumption simulation, and equipment optimization layout for intelligent energy consumption management. The combination of deep learning algorithms and CAD technology can achieve more accurate, efficient, and intelligent home energy management.

As an important branch of AI, DL has made remarkable achievements in many fields, such as image identification, speech identification and natural language processing. CAD has also been widely used in many industries, such as architecture, machinery and electronics. In today's digital world, the demand for smart home systems is growing day by day. The core of a non-invasive smart home automation system lies in utilizing big data, deep learning algorithms, CAD technology, and cognitive computing to achieve a comprehensive perception and understanding of the home environment. Asaithambi et al. [4] utilized big data and cognitive computing to develop non-invasive smart home automation systems that can more accurately predict user needs and provide personalized services. This system can learn and understand the living habits of family members and automatically adjust environmental conditions to improve comfort and energy efficiency. Deep learning algorithms play a crucial role in non-invasive smart home automation. Through deep learning and training on a large amount of data, the system can automatically recognize and understand the behaviour patterns and habits of family members, thereby making intelligent decisions and automatic control. For example, through deep learning algorithms, the system can determine when family members wake up and sleep, thereby automatically adjusting environmental parameters such as lighting brightness and indoor temperature. CAD technology also plays an important role in non-invasive smart home automation. Through CAD technology, the structure and layout of houses can be accurately simulated and designed, providing necessary basic data for non-invasive smart home automation systems. In addition, CAD technology can also be used to optimize the layout and connection methods of home equipment in order to achieve more efficient energy utilization and a more comfortable living environment. Therefore, this study considers combining the DL algorithm with CAD and applying it to the automatic optimization of smart home design in order to improve design efficiency. Deep learning (DL), as an important branch of machine learning, has been widely applied in complex tasks such as image recognition, speech recognition, and natural language processing. In the fields of architecture and home furnishings, deep learning has also demonstrated strong capabilities, especially in energy efficiency analysis and classification of smart homes. Using deep learning image recognition techniques, Benavente and Ibadah [5] classified and recognized images of home devices, thereby predicting their energy consumption. By learning and recognizing images of household air conditioners, lights, televisions, and other equipment, we can predict the energy consumption of different devices under different conditions. Deep learning speech recognition technology can also be applied in the field of smart homes. Through speech recognition, we can achieve remote control of home devices, thereby achieving energy conservation. For example, when the owner says, "Turn on the living room light," the smart home system can recognize the owner's instructions through voice recognition technology and automatically control the switch of the living room light. The natural language processing techniques of deep learning can be used to analyze the host's lifestyle habits and needs and then provide more personalized intelligent suggestions. For example, by analyzing the owner's lifestyle habits, smart home systems can provide more personalized energy-saving suggestions for the owner, such as adjusting the air conditioning temperature, selecting appropriate lighting schemes, etc.

The main purpose of this article is to explore the application of DL algorithm and CAD in intelligent home design automation optimization. This study adopts the methods of literature research, model construction and simulation experiment. The specific research framework is as follows: (1) Through literature research, this article examines the research status and development trend of the DL algorithm, CAD, and intelligent home design automation optimization. (2) Build a smart home design model based on the DL algorithm through a model-building method to realize the automatic optimization of a design. (3) The proposed method is verified and evaluated by simulation experiments.

The innovation of this article is mainly reflected in the following aspects:

(1) In this article, the DL algorithm is introduced into the field of home design, and users' behaviour patterns and habits are identified by training models so as to provide decision support for subsequent home design. This method can automatically extract and analyze a large quantity of user data and improve the intelligence level of home design.

(2) In this article, CAD is applied to the smart home system, and the digitalization and visualization of the home environment are realized by establishing a 3D model of the home environment. This method improves the efficiency and accuracy of home design and reduces the design cost.

(3) This article constructs an automatic optimization model, which can automatically adjust the control strategy of equipment according to the individual needs and habits of users and realize the automatic control and optimization of equipment. This method improves the energy efficiency ratio and user experience of household equipment and reduces energy consumption.

This article is divided into six sections. Section Ⅰ: Introduction, which introduces the research background and significance, research purposes and problems, research methods and framework, and the structural arrangement of the article. Section II: Literature review, combing and evaluating the research status of DL algorithm, CAD and intelligent home design automation optimization. Section III: DL algorithm and CAD foundation, introducing related principles, models and combination methods. Section Ⅳ: the construction of an intelligent home design automation optimization model, detailing the construction and implementation process of the model. Section V: Simulation experiment and result analysis to verify and evaluate the proposed method. Section VI: Discussion and prospect, discussing and explaining the experimental results, and putting forward suggestions and prospects for future research.

2 RELATED WORK

With the rapid development of technology, smart home devices are becoming increasingly popular, among which intelligent sweeping robots are loved by consumers because they can greatly reduce the burden of household chores. In today's intelligent sweeping robots, activity recognition based on IoT sensor algorithms is gradually becoming an important technological trend. Bouchabou et al. [6] explored how to use deep learning technology to improve the recognition ability of intelligent sweeping robots for household activities, thereby providing more personalized and intelligent cleaning services. IoT sensor algorithms play an important role in intelligent sweeping robots. By installing RGB cameras, the sweeping robot can obtain video stream data. By using deep learning algorithms, models can be trained to analyze video stream data in real-time, thereby identifying different activity scenarios, such as someone in a room or TV playing. Through the built-in microphone, the sweeping robot can capture the sound in the home. Deep learning algorithms can train models to classify and recognize these sounds, such as distinguishing between television sounds, human speech sounds, etc., in order to further identify different activity scenes. The fusion of data from different sensors can improve the perception and recognition ability of the sweeping robot to the environment. Deep learning algorithms can train models to fuse multi-source data effectively, thereby more accurately identifying various activity scenes in households. Fei et al. [7] proposed a comprehensive design method for smart home control of shear wall structures using generative adversarial networks and CAD. The shear wall structure is a common form of building structure with good seismic performance and spatial flexibility. In the field of smart homes, by applying generative adversarial networks and CAD technology, we can achieve intelligent control of shear wall structures to improve the utilization and comfort of home space. Generative Adversarial Network is a deep learning model consisting of two parts: a generator and a discriminator. The generator is responsible for generating new data samples, while the discriminator is responsible for discriminating the generated data samples. By training and generating adversarial networks, they can grasp the control laws of home devices and achieve automated control of the devices. For example, generating adversarial networks based on indoor temperature, humidity, and other parameters can automatically adjust the temperature and humidity of air conditioning. By utilizing generative adversarial networks, it is possible to model the home environment and achieve real-time monitoring and prediction of the home environment. For example, by modelling the position and opening of windows, it is possible to predict the brightness of indoor light under different weather conditions. By designing shear wall structures reasonably, home space can be utilized more reasonably, thereby improving the utilization rate of space.

With the rapid development of artificial intelligence and Internet of Things technology, smart home systems have become a part of modern life. However, how to make smart home systems more intelligent and personalized to meet the needs of different users is still the focus of current research. Ghods et al. [8] proposed an iterative design method for visual analysis of clinical doctors in smart homes based on deep learning algorithms and CAD implementation. Through deep learning algorithms, image recognition can be performed in the home environment, including the recognition of furniture, appliances, decorations, and other items, as well as the recognition of people, animals, and other living organisms. By using deep learning algorithms to analyze image sequences, human behaviour and activities, such as cooking, laundry, cleaning, etc., can be identified. In the iterative design of visual analysis in smart homes, clinical doctors in the environment refer to the involvement of clinical doctors in the design process, providing professional medical knowledge and experience to improve the medical relevance and practicality of the design. Using CAD software, clinical doctors and designers can jointly construct 3D models, integrating medical knowledge and experience into the design, making the home environment more in line with medical standards and user needs. Through the virtual simulation function of CAD software, designers can view the design effect in real-time during the design process and timely discover and correct problems in the design. At the same time, clinical doctors can also evaluate and analyze the simulation results to ensure the effectiveness and safety of the design. Future smart home systems will pay more attention to seamless integration between devices, including various household appliances, smart sensors, security systems, etc. Guo et al. [9] use IoT technology to connect these devices to each other and communicate with the cloud, achieving more efficient and intelligent management. The application of artificial intelligence and machine learning technology in the field of smart homes will be more extensive. These technologies can help smart home systems better learn and adapt to user habits, thereby providing more personalized and intelligent services. With the popularization of smart home devices, home safety and privacy protection issues are also receiving increasing attention. Future smart home systems will place greater emphasis on security and privacy protection, including functions such as data encryption, access control, and remote monitoring. The concept of smart cities is gradually becoming popular, and smart home systems will pay more attention to integration with smart cities, including information sharing and collaborative work in energy management, public safety, transportation, and other aspects. Smart home products are one of the important application areas of artificial intelligence technology and also a practical application and verification platform for literature theory. Through product design and development, the correctness and effectiveness of the algorithms and models proposed in the literature can be verified, further promoting the development and application of artificial intelligence technology in the field of smart homes.

Smart home systems are an important component of modern life, and the design and implementation of remote controls are key components of smart home systems. In order to improve the user experience and intelligence level of smart home systems, Hamzah et al. [10] proposed a design and implementation method for an HDL (Hardware Description Language) remote control based on deep learning algorithms and CAD implementation. By using deep learning algorithms to learn and analyze user behaviour data, predict and handle potentially dangerous situations in advance, such as elderly people falling, children accidentally touching, etc. Based on user usage habits and behaviour patterns, establish an intelligent recommendation system using deep learning algorithms to recommend the most suitable and personalized home devices and usage scenarios to users. By using deep learning algorithms to learn and analyze environmental data, automatically adjust the working status and parameters of home devices to achieve the best user experience. Through the simulation and simulation functions of CAD software, designers can perform functional verification and performance testing on the HDL remote control during the design phase, ensuring that its functionality and performance meet the design requirements. After completing the design of the HDL remote control, designers can use CAD software for integration and debugging to ensure that the remote control and other parts of the smart home system can work properly. With the rapid development of technology and the widespread application of artificial intelligence, the intelligence of home design and electrical energy-saving management have become research hotspots. Liu et al. [11] proposed an intelligent electrical energy-saving management optimization strategy for home design based on deep reinforcement learning, aiming to achieve a more efficient, comfortable, and energy-saving home living environment. The intelligence and electrical energy-saving management of home design are of great significance for improving the comfort and energy utilization efficiency of home life. Traditional home design and management methods often lack intelligence and energy-saving awareness, leading to energy waste and environmental pollution. Therefore, studying an intelligent electrical energy-saving management optimization strategy based on deep reinforcement learning is of great significance for achieving a green, intelligent, and comfortable home life. Deep reinforcement learning is a machine learning method that combines deep learning and reinforcement learning with powerful feature learning and intelligent decision-making capabilities. Apply the trained model to the smart electrical energy-saving management system for home design, achieving the functions of smart home design, smart electrical control, and smart energy consumption management.

With the rapid development of technology and the promotion of digital transformation, smart home systems have become an important component of modern life. In this context, an energy-saving smart home system based on big data and machine learning - HEMS Internet of Things has emerged. Big data technology plays an important role in this system. By collecting and analyzing various data within households, we can gain deeper insights and valuable insights. From power usage to device operation modes, from environmental factors to lifestyle habits, all of these data can be captured and used to optimize the performance of smart home systems. Through big data technology, Machorro et al. [12] can monitor household energy usage in real-time, predict future energy demand, and automatically adjust device operation status to achieve more efficient energy utilization. For example, the system can predict the needs of family members at night based on real-time data and automatically adjust the settings of air conditioning and lighting equipment to ensure a comfortable indoor environment while reducing energy consumption. The application of machine learning in this system enables the HEMS Internet of Things to self-learn and improve to adapt better to home environments. By using machine learning algorithms, the system can analyze historical data, identify patterns and trends, and predict future behaviour based on them. For example, by analyzing data on the living habits and environmental factors of family members, the system can learn how to automatically adjust the operating status of devices under different time periods and weather conditions. In smart homes, utilizing smartphone data and sensor-based LSTM networks for light remote control and human activity recognition is an emerging technological trend. By combining technologies such as the Internet of Things, artificial intelligence, and mobile communication, this system can achieve a smarter and more personalized home experience. Smart home devices have become a part of people's daily lives. Among them, intelligent lighting systems play an important role in improving home comfort and energy conservation. Meanwhile, through sensors and artificial intelligence technology, smart home systems can achieve recognition of human activities and further optimize the operation of home devices. Mekruksavanich and Jitpattanakul [13] explored how to utilize smartphone data and sensor-based LSTM (Long Short Term Memory) networks to achieve light remote control and human activity recognition in smart homes. In smart homes, LSTM can be applied to the processing and analysis of sensor data. By training LSTM models, real-time processing and prediction of sensor data can be achieved, thereby achieving recognition of human activities. For example, by analyzing the sound data of sensors, LSTM can recognize the voice commands of family members. By analyzing the light data from sensors, LSTM can identify the activity scenes of family members, such as eating, watching movies, etc. These recognition results can be used for the automation control and optimized operation of smart home devices.

The Internet of Things technology provides new possibilities for the design and implementation of smart home systems. Against the backdrop of numerous home security issues becoming increasingly prominent, Murad et al. [14] designed and implemented a two-level secure smart home system based on Internet of Things technology. This article will provide a detailed introduction to the architecture, functions, characteristics, and implementation of the system. The system adopts Internet of Things technology to connect home devices, sensors, controllers, etc., through wireless networks, forming a unified home network. The network then interacts with cloud servers through the internet to achieve remote monitoring and management. Including functions such as intrusion prevention, fire prevention, theft prevention, and leakage prevention, real-time monitoring is carried out through intelligent sensors, cameras, door locks, and other devices. Once abnormal situations are detected, an alarm is immediately triggered, and notifications are sent to the user's mobile phone. Through IoT technology and big data analysis, deep learning can be conducted on the behaviour patterns of family members, and potentially dangerous situations can be predicted and handled in advance. For example, the system can analyze the daily routine and lifestyle habits of family members, predict the probability of fire, leakage, etc., and provide early warning. With the rapid development of smart home and smart environment technology, the placement of motion sensors has become a key issue in achieving automation and energy conservation. To address this issue, Nasrollahzadeh et al. [15] proposed a hybrid WOA-PSO algorithm that combines the advantages of both WOA and PSO algorithms to optimize the placement of motion sensors in smart homes and environments. Smart homes and smart environments can achieve intelligent control and optimized management through automation devices, sensors, etc., improving living comfort and energy efficiency. Among them, motion sensors are one of the key devices for achieving smart homes and smart environments. However, properly placing motion sensors to monitor the behaviour and activities of family members while avoiding false alarms and omissions is a challenging issue. The hybrid WOA-PSO algorithm combines the fast searchability of the WOA algorithm with the collaborative ability of the PSO algorithm, simulates the search process of the WOA algorithm through eagle swarm simulation, and utilizes the swarm intelligence of the PSO algorithm to achieve collaboration and information sharing. In smart homes and environments, the placement of motion sensors requires consideration of multiple factors, such as monitoring range, obstructions, installation height, and angle. The hybrid WOA-PSO algorithm can find the optimal placement position for motion sensors by modelling and analyzing these factors.

The application of artificial intelligence and Internet of Things technology in the field of smart homes is becoming increasingly popular. Among them, the smart home lighting system, as an important component, achieves more intelligent and personalized lighting control through the combination of deep learning algorithms and computer-aided design (CAD) technology. Sepasgozar et al. [16] reviewed the systematic content of applying deep learning algorithms and CAD to implement the application of artificial intelligence and the Internet of Things in smart home lighting. Traditional home lighting systems typically use manual switches or simple timed controls, which cannot meet the intelligent and personalized needs of modern households. By applying deep learning algorithms and CAD technology, automated control of smart home lighting systems can be achieved, improving lighting quality and energy efficiency. Through deep learning algorithms, it is possible to identify the behaviour and activities of family members, such as the position of people in the room, types of activities, etc., in order to achieve automatic control of the lighting. Deep learning algorithms can combine image sensors and light sensors to recognize indoor lighting environments, including lighting intensity, colour temperature, direction, etc., thereby automatically adjusting the brightness and colour of the lights. Deep learning algorithms can also recognize the emotional states of family members, such as mood, fatigue level, etc., and adjust the colour and brightness of lights based on their emotional states. Deep learning algorithms and artificial neural networks have been widely applied in smart home systems. In order to select the best artificial neural network model, Teslyuk et al. [17] combined deep learning algorithms and computer-aided design (CAD) technology to achieve more accurate, efficient, and intelligent home system control. By monitoring and analyzing various parameters of the home environment (such as temperature, humidity, lighting, etc.), artificial neural networks can automatically identify different environmental patterns, thereby achieving intelligent control of the home environment. Artificial neural networks can predict the operating status of home devices and make decisions based on the prediction results, thereby achieving automated control of home devices. For example, it can predict future electricity consumption based on historical electricity consumption data and automatically adjust the operating mode of air conditioning to save energy. Artificial neural networks can learn optimal control strategies to achieve optimal control of home devices. For example, by learning indoor temperature data from different time periods, the temperature setting of the air conditioner can be automatically adjusted to achieve optimal comfort. Deep learning algorithms are an important branch of artificial neural networks that can automatically extract features from input data, greatly simplifying the design and training process of artificial neural networks.

Traditional smart home design often only focuses on basic functional implementation without fully considering higher-level design and user experience needs. To address this issue, Yang [18] proposed a 3D indoor smart home design optimization teaching method based on deep learning algorithms and computer-aided design (CAD) technology. Based on user usage habits and behaviour patterns, establish an intelligent recommendation system using deep learning algorithms to recommend the most suitable and personalized home devices and usage scenarios to users. By using deep learning algorithms to learn and analyze environmental data, automatically adjust the working status and parameters of home devices to achieve the best user experience. By using CAD software, teachers can guide students in constructing 3D models, enabling them to have a more intuitive understanding of the spatial structure and layout of home design. Through the virtual simulation function of CAD software, students can view the design effect in real-time during the design process and discover and correct problems in the design in a timely manner. The method proposed in this article is based on deep learning algorithms and CAD implementation to assist in the optimization teaching of 3D indoor smart home design, aiming to improve the level and quality of smart home design. By using deep learning algorithms to predict and analyze user behaviour, as well as CAD-assisted simulation in 3D interior design optimization teaching, students can be guided to better understand and master the technology and methods of smart home design. With the rapid development of Internet of Things (IoT) technology, smart home automation has become a common demand. Through the Internet of Things technology, home devices can be interconnected, thereby improving home safety, convenience, and comfort. The edge computing paradigm of the Internet of Things, as a new computing model, can better meet the needs of smart home automation. Yar et al. [19] discussed how to use the edge computing paradigm of the Internet of Things to achieve smart home automation. The edge computing paradigm of the Internet of Things is a new computing model that migrates computing tasks from the cloud to the edge of devices. In this mode, the device can process and analyze local data in real-time, reduce data transmission latency, and improve response speed and efficiency. Meanwhile, as data does not require remote transmission to the cloud, it also ensures the security of user privacy. In smart home systems, a large number of devices generate a large amount of data. The edge computing paradigm of the Internet of Things can be used to process and analyze these data in real-time so as to better realize the collaborative work between devices. For example, by analyzing the lifestyle and behaviour patterns of family members in real-time, smart home systems can automatically adjust the device's operating status and provide more personalized services.

3 DL ALGORITHM AND CAD FOUNDATION

3.1 DL Algorithm Model and CAD Principle

At present, the research on the DL algorithm mainly focuses on the improvement of model structure, the optimization of the learning algorithm, and the expansion of application scenarios. The system can automatically identify users' behaviour patterns and habits and carry out intelligent control and optimization. Experimental results show that the system can improve the energy efficiency ratio and user experience, as well as reduce energy consumption. CAD is a tool that has been widely used in many industries, such as architecture, machinery, and electronics. At present, the research of CAD mainly focuses on model construction, parametric design, collaborative design, and so on. In the field of smart homes, CAD is also widely used in the design and optimization of home products. With the continuous growth of computer technology, CAD is also improving and perfecting. At present, some intelligent CAD systems have appeared that can automatically design and optimize household products according to users' needs. These systems can not only improve the design efficiency but also reduce the design cost and time. At present, many researchers have tried to apply the DL algorithm and CAD to the automatic optimization of smart home design. These studies mainly focus on the following aspects: smart home control system based on the DL algorithm, smart home product design based on CAD, and the combination of the DL algorithm and CAD. By combining the data analysis ability of ML and the collaborative decision-making ability of multi-agents, the automatic layout, control and optimization of smart home devices are realized. Although the DL algorithm and CAD have made some achievements in the automatic optimization of smart home design, there are still several problems to be solved: data acquisition and labelling, model generalization ability, security and privacy protection of smart home systems, and personalized demand of smart home products. DL is a branch of ML which processes and analyzes a large amount of data based on the NN (Neural Network) model. Its core idea is to simulate the learning stage of the human brain by constructing multi-layer NN so as to realize automatic learning and identification of complex data [14]. The training process of DL mainly includes two steps: forward propagation and backward propagation. Forward propagation is to get the output result by passing the input data through NN; Backpropagation is to adjust the parameters of NN according to the error between the output result and the real result so that the output result is closer to the real result.

CAD is a design technology using computers. Its core idea is to use the computer's powerful computing power and graphics processing power to assist designers in design and drawing so as to improve design efficiency. The components and common tools of the CAD system are shown in Table 1.

<table>
<tr><th>Component</th><th>Functional description</th><th>Commonly used CAD tools</th><th>Characteristic</th></tr>
<tr><td>User Interface</td><td>An interface for users to interact.</td><td rowspan="4">AutoCAD, SolidWorks, SketchUp, etc.</td><td>Provide intuitive and easy-to-use operation interface and tools.</td></tr>
<tr><td>Graphic processing system</td><td>Responsible for the generation, editing and display of graphics.</td><td>Provide powerful graphics processing functions.</td></tr>
<tr><td>Database Management System</td><td>Manage design data and documents, including design history, version control, etc.</td><td>Provide management and sharing functions of design data.</td></tr>
<tr><td>API (Application Program Interface)</td><td>Provide an interface for data exchange with other systems.</td><td>Provide rich API and plug-in interfaces.</td></tr>
</table>

Table 1: Components and common tools of CAD system.

Commonly used CAD tools such as AutoCAD, SolidWorks, and SketchUp provide rich drawing and editing functions, such as 2D drawing, 3D modelling, assembly design, motion simulation, etc. And interfaces for data exchange with other systems, which are widely used in various fields such as architecture, machinery, electronics, and automobiles. These tools are constantly upgraded and improved, providing designers with more efficient and intelligent design tools and environments.

3.2 The combination of DL Algorithm and CAD

The combination of DL algorithm and CAD mainly includes the following ways:

(1) Automatic generation of CAD model based on DL: Using the DL algorithm to generate the CAD model automatically can reduce designers' workload and improve design efficiency. The specific methods include generating a new CAD model by using the generated countermeasure network or

identifying and extracting the features of the existing CAD model by using the convolutional neural network and then generating a new CAD model according to these features.

(2) Optimization of CAD model based on DL: Using DL algorithm to optimize CAD model can improve design quality and performance. Specific methods include using the DL algorithm to optimize the parameters of the CAD model or using a reinforcement learning algorithm to optimize the behaviour of the CAD model.

(3) Integration of smart home control system and CAD system based on DL: Applying DL algorithm to smart home control system and integrating it with CAD system can realize automatic optimization of smart home design. The specific methods include using the DL algorithm to identify and analyze users' behaviours and needs, then automatically adjusting the settings and control strategies of smart home devices, and automatically designing and optimizing the home environment by using a CAD system.

The combination of the DL algorithm and CAD can realize the automatic optimization of smart home design and improve design efficiency. This combination method can not only be applied to the field of smart homes but also be extended to the design and optimization problems in other fields.

4 CONSTRUCTION OF INTELLIGENT HOME DESIGN AUTOMATION OPTIMIZATION MODEL

4.1 Construction of Smart Home Design Model Based on DL Algorithm

The problem of smart home design mainly focuses on how to provide a comfortable, convenient and energy-saving living environment for users according to their individual needs and habits. In order to achieve this goal, it is necessary to deeply analyze and understand the needs of users and, at the same time, consider the cooperative work of various devices and systems. Firstly, this article analyzes the demand for smart home design. Demand analysis mainly includes the following aspects: (1) User behaviour identification: Identify users' daily behaviour patterns, such as schedule and common equipment, so as to provide personalized services for users. (2) Equipment control strategy: According to users' behaviours and needs, formulate reasonable equipment control strategies, such as temperature adjustment and lighting control. (3) Security and privacy protection: Ensure the security of the smart home system, protect users' privacy, and prevent unauthorized access and operation. (4) Energy efficiency and environmental stewardship: Enhance the operational modalities of equipment, minimize energy usage, elevate the system's energy efficiency ratio, and attain energy conservation and emission reduction objectives.

To fulfill the need for automated optimization in smart home design, this segment presents a model for smart home design that relies on the DL algorithm. By combining the DL algorithm with the characteristics of a smart home system, this model realizes the functions of identifying and analyzing user behaviour, optimizing device control strategy, and protecting security and privacy. In order to meet the needs of model training, this article collects user behaviour data through sensors and devices in smart home systems, such as the time of switching devices, the running state of devices, the user's activity trajectory and so on. Collect the usage data of equipment, such as running time, power, energy consumption, etc., through the log and equipment interface of the smart home system. Moreover, the collected data are cleaned and processed to remove abnormal values and duplicate values to ensure the accuracy and consistency of the data. Moreover, the data are normalized and standardized to facilitate the subsequent model training and analysis. In this article, the Sigmoid function with certain closed-value characteristics and continuously differentiable is selected as the transfer function of system neurons. Its function expression is:

$$f(x) = \frac{1}{1 + e^{-x}} \tag{1}$$

During network training, the computation approach for determining the total loss function remains consistent across all channels. This function encompasses both classification loss (denoted as BL) and regression loss (denoted as MSE). The formula to calculate the overall loss is as follows:

$$ML = BL(y, \hat{y}) + aME(y' - \hat{y}') \tag{2}$$

The aforementioned equation a represents a weighting factor that balances the classification loss and regression loss. The identification network facilitates iterative prediction, and the methodology for calculating these predictions is outlined as follows:

$$S^I = \rho^I(F, S^{I-1}, L^{I-1}) \quad \forall t < 2 \tag{3}$$

$$L' = \Phi^t(F, S^{t-1}, L^{t-1}) \quad \forall t < 2 \tag{4}$$

The behaviour identification model is one of the core parts of this study. Its main function is to identify and analyze users' behaviours by using the DL algorithm and extract users' behaviour patterns and habits. Firstly, the cleaned and processed data are preprocessed, such as segmentation and labelling, which is convenient for subsequent model training and analysis. Then, the DL algorithm is used to build a behaviour identification model to realize automatic identification and classification of user behaviours. The labelled data are used for model training, and the identification accuracy and generalization ability of the model is improved by adjusting the parameters and structure of the model. Finally, the trained model is used to identify and analyze the user's behaviour and to extract the user's behaviour patterns and habits, such as the user's activity time, activity frequency, equipment use preference and so on. The expression of user behaviour identification result of the network is as follows:

$$O(T_1, T_2) = H(g(SlowFast(T_1, W), SlowFast(T_2, W))) \tag{5}$$

Where $SlowFast(T_1, W)$ is the prediction result of user behavior? The consistency function is the aggregation function g, and the average value is taken. The prediction function H is a Softmax function, and compared with the original SlowFast network, a partial consistent function is added, so the loss function is:

$$L(y, G) = -\sum_{i=1}^{C} y_i (G_i - \log \sum_{j=1}^{c} \exp G_j) \tag{6}$$

The above loss function represents the level of overall confidence. Where C is the quantity of behavior categories, y_i is the confidence level of the i category, and G_i is the calculated value of the partially consistent function:

$$G_i = g(SlowFast(T_1, W), SlowFast(T_2, W)) \tag{7}$$

The control strategy optimization model is another core part of this study. The specific implementation methods are as follows: (1) Establish the mathematical model of control strategy optimization: transform the control problem of smart home devices into mathematical problems, such as establishing objective functions, constraints and so on. (2) Optimization by DL algorithm: The control strategy is optimized by a DL algorithm, such as a reinforcement learning algorithm, and the automatic control and optimization of the equipment are realized by adjusting the running time and power of the equipment. (3) Realize the integration with other systems: Realize the integration with other systems through API, which is convenient for users to carry out secondary development and system integration.

4.2 Realization of Smart Home Design Model

CAD is pivotal in the process of actualizing the smart home design model. The detailed implementation procedure is outlined below: (1) Building a home environment model: Using CAD tools, building a 3D model of the home environment. This model needs to describe the layout of the room, the location of the equipment and other related spatial information in detail. In this way, designers can preview and adjust the layout of household equipment in the virtual environment to ensure their convenience and comfort in practical use. In this article, detailed data of the home environment, including the size, shape, and location of doors and windows, are collected by means of measurement or laser scanning. According to the collected data, the 3D model of the home environment is established by using CAD tools. This model needs to restore the actual home environment as much as possible, including walls, doors and windows, furniture and other details. According to the design requirements, optimize the 3D model, such as adjusting the room layout and equipment location, to meet the actual needs of users. (2) Equipment selection and configuration: according to the user's needs and budget, select the appropriate smart home equipment and configure and install it. In this process, the equipment is simulated by using CAD tools to preview the actual effect of the equipment so as to ensure that the appearance and performance of the equipment match the home environment. (3) Control system integration: the control strategy optimized by the DL algorithm is integrated into the smart home control system to realize automatic control and optimization of equipment. In this process, CAD tools are used to simulate the system and preview the actual effect of the system. CAD can help designers integrate and debug the system to ensure its stability and reliability. (4) Effect evaluation and optimization: evaluate the operation effect of smart home systems, such as comfort and energy consumption, and optimize and adjust according to the evaluation results. Through the realization of the above four steps, CAD plays a key role in the design model of a smart home, helping designers improve design efficiency and reduce project cost and risk. Figure 1 shows the DL model.

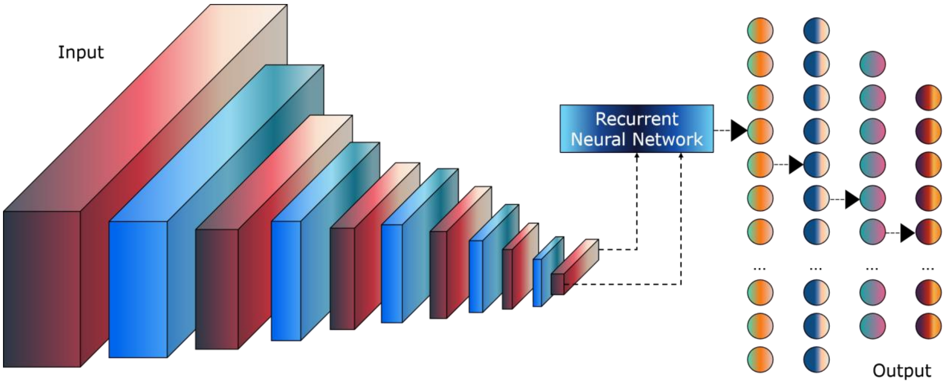


Figure 1: DL model.

In the smart home design model based on the DL algorithm, the down-sampling layer is to sample every feature map obtained from the previous layer, which reduces the size of the feature map. The sampling operation formula with scale $S_1 \times S_2$ is:

$$y_{mn} = \frac{1}{s_1 s_2} \sum_{j=0}^{s_2 - 1} \sum_{i=0}^{s_1 - 1} x_m \times s_1 + i, n \times s_2 + j \tag{8}$$

Where x is the two-dimensional input vector and y is the output after sampling. The down-sampling layer can dramatically reduce the computational complexity of the network and make the network invariant to the translation and scaling of objects, making the network more robust. Parameters can also be taken in the down-sampling layer, and the formula of the down-sampling layer with parameters is as follows:

$$y'_{mn} = f(a y_{mn} + b) \tag{9}$$

Where y_{mn} is obtained from formula (8), a and b are corresponding parameters, and function f is the activation function.

In addition, the security and privacy protection mechanism is an important part of this study. Its main function is to ensure the security of the system by using encryption, access control and other technologies, and at the same time, comply with relevant privacy protection laws and standards. In this article, users' sensitive data is encrypted to ensure the confidentiality and integrity of the data. Access control technology is used to manage the access rights of users to prevent unauthorized access and operation. Moreover, follow relevant privacy protection laws and standards, such as GDPR, to ensure that users' privacy rights and interests are fully guaranteed.

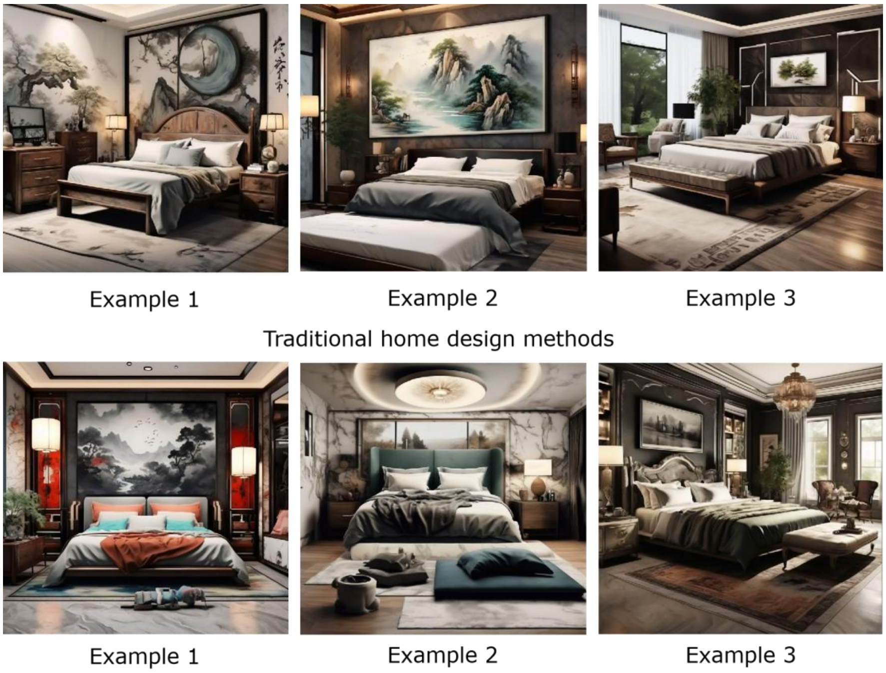
This section constructs an automatic optimization model of smart home design based on the DL algorithm and CAD. The model can provide a comfortable, convenient and energy-saving living environment for users according to their individual needs and habits and, at the same time, improve design efficiency. Subsequent chapters will verify the feasibility of the model through simulation experiments.

5 SIMULATION EXPERIMENT AND RESULT ANALYSIS

In order to verify the validity and feasibility of the automatic optimization model of smart home design based on the DL algorithm and CAD, this section carries out simulation experiments and analyzes and evaluates the experimental results in detail.

5.1 Experimental Environment and Parameter Setting

The experimental environment mainly includes a computer equipped with DL framework and CAD software. In order to simulate the real smart home environment, this section adopts the open-source smart home data set, which contains the usage data of various devices, user behaviour data and so on. Before the experiment, the data were preprocessed to ensure the accuracy and consistency of the data. Moreover, the home environment is modelled, and 3D models of room layout and equipment location are established by using CAD tools. Figure 2 shows an example of a smart home design model based on the DL algorithm and traditional home design method.



Output of smart home design model based on deep learning algorithm

2A Smart home design-bedroom example

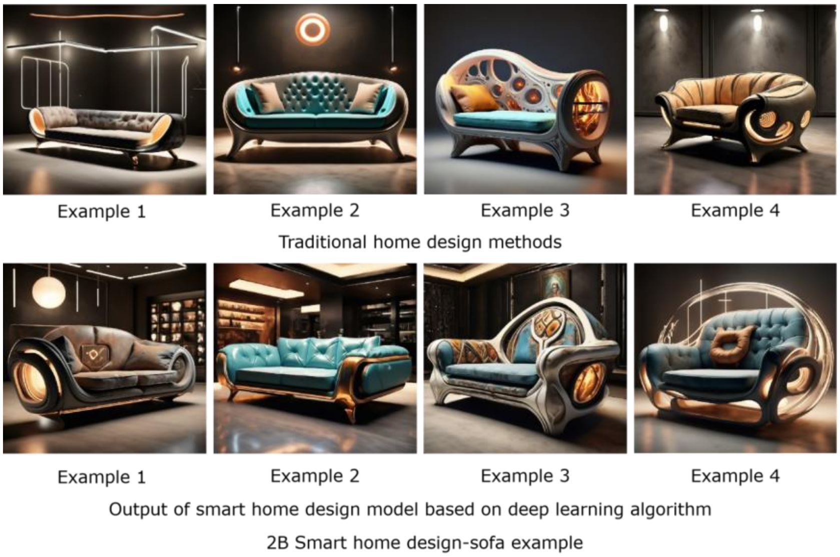


Figure 2: Smart home design example.

The experimental process in this section mainly includes the following steps: (1) Data loading and preprocessing: loading the preprocessed data into the DL model for further processing and analysis. (2) Model training and optimization: The DL algorithm is used to train and optimize the model, including the behaviour identification model and control strategy optimization model. (3) Modeling and equipment selection of home environment: Modeling and equipment selection of home environment with CAD tools, which provides a basis for subsequent control system integration. (4) Control system integration and testing: the trained DL model is integrated into the smart home control system and tested and evaluated.

5.2 Experimental Results and Performance Evaluation

In this section, the traditional behaviour identification method is used to compare with this model. The accuracy of this model in identifying users' behaviour patterns and habits is shown in Figure 3. The comparison with other traditional behaviour identification methods is shown in Figure 4.

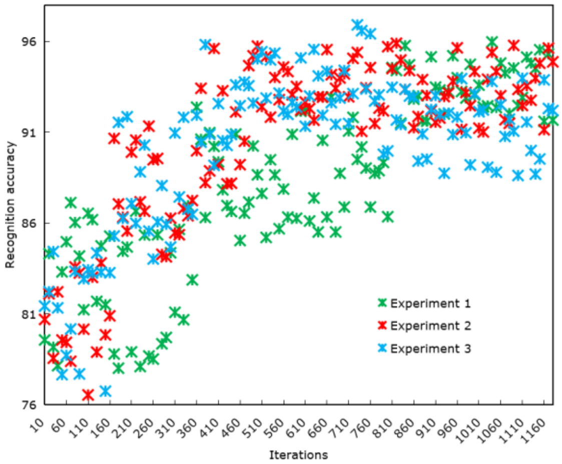


Figure 3: Accuracy of user behaviour patterns and habit identification.

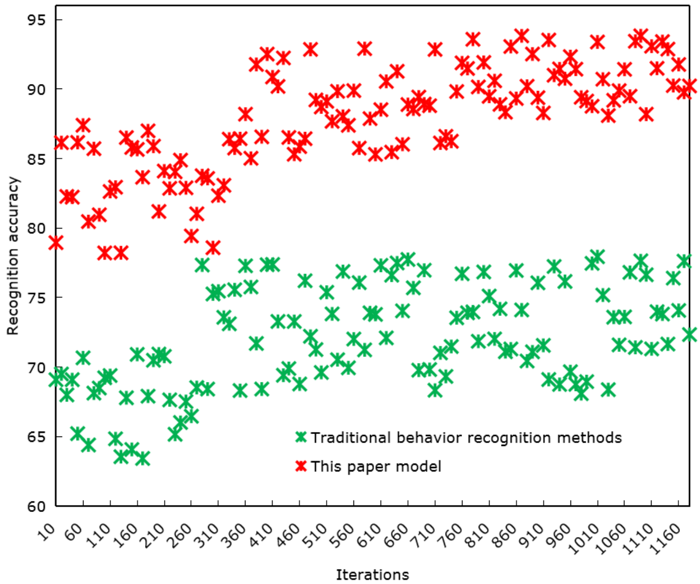


Figure 4: Comparison of different behaviour identification methods.

The identification accuracy of this model for user behaviour patterns and habits reaches 95%, which is significantly higher than the traditional behaviour identification methods. The model in this article performs well in identifying users' behaviour patterns and can accurately identify users' behaviour habits and laws. Specifically, the model can accurately identify the time and frequency of users' daily behaviours, such as getting up, eating and sleeping every day, as well as users' preferences and habits in using smart home devices. The smart home design model based on the DL algorithm is used for smart home design. The design efficiency is shown in Figure 5, and the design quality score is shown in Figure 6.

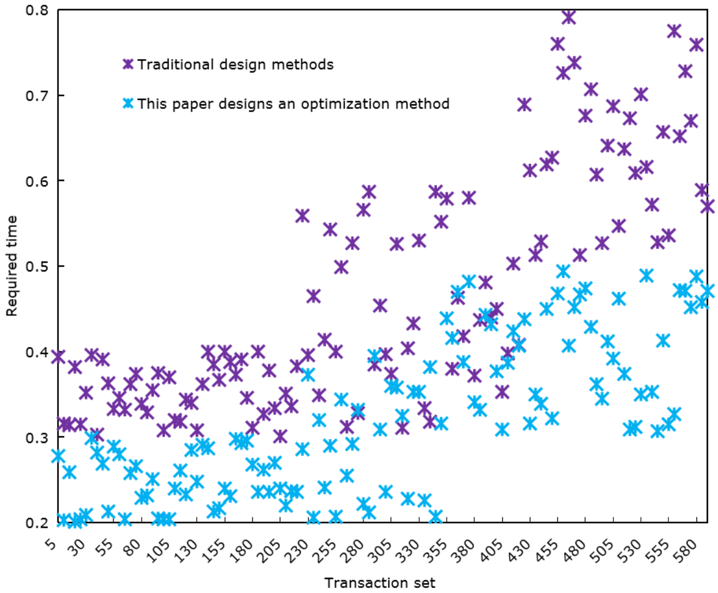


Figure 5: Design efficiency of the smart home design model.

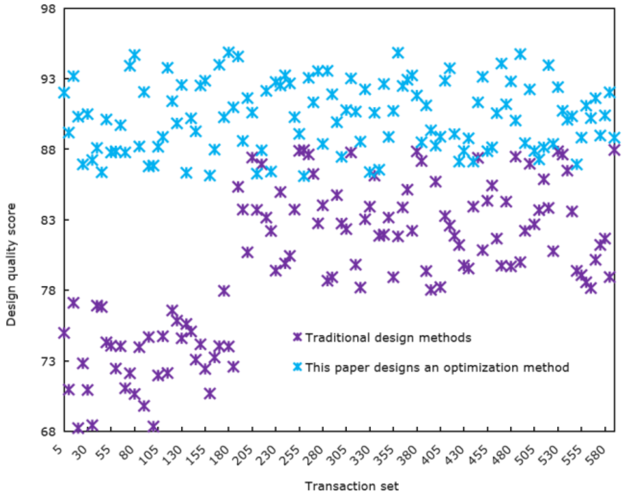


Figure 6: Design quality score of the smart home design model.

As can be seen from Figure 5, the efficiency of smart home design using this model is obviously higher than the traditional design method. The design time using this model is shortened by about 40% on average. This is mainly because this model adopts the DL algorithm for equipment selection and configuration, which can automatically extract users' behaviour patterns and habits, thus reducing the time for manually selecting and configuring equipment. Moreover, this model also integrates the design and optimization of a control system, which can automatically generate control strategies and conduct simulation tests, thus improving the design efficiency.

As can be seen from the design quality score results in Figure 6, the quality score of smart home design using this model is also significantly higher than that of the traditional design method. Specifically, the quality score of the design using this model is improved by about 20% on average. This is mainly because the model in this article can select and configure equipment according to users' behaviour patterns and habits, which is more in line with users' actual needs and usage habits. Moreover, this model also integrates the design and optimization of the control system, which can be automatically controlled and optimized according to the user's behaviour and needs, thus improving the comfort and practicability of the system. The user rating is shown in Figure 7.

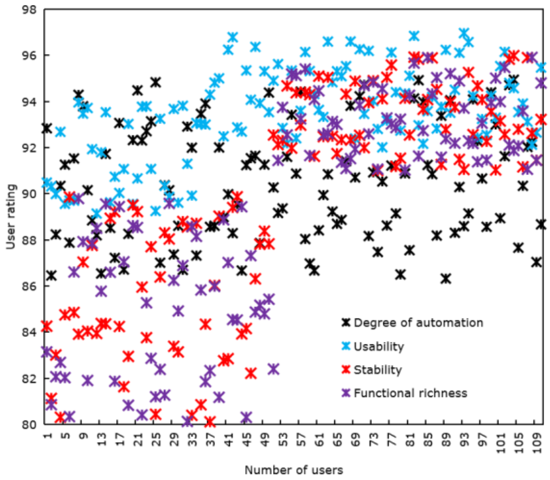


Figure 7: User rating.

Most users give a high score to the smart home design model based on the DL algorithm, with an average score of more than 8.5. This shows that users have a positive attitude towards the performance of this model in smart home design.

Through the detailed analysis and evaluation of the experimental results, this article draws the following conclusions:

(1) The behaviour identification model based on the DL algorithm can effectively identify users' behaviour patterns and habits, which provides strong support for subsequent equipment control and optimization. Compared with other traditional behaviour identification methods, this model has higher accuracy and generalization ability.

(2) The control strategy optimization model based on the DL algorithm can automatically adjust the control strategy of the equipment according to the user's behaviour and demand and realize the automatic control and optimization of the equipment. Compared with other traditional control methods, this model has a higher energy efficiency ratio and user experience.

(3) The home environment modelling and equipment selection based on CAD can improve the design efficiency and provide a basis for the subsequent control system integration. Compared with other traditional design methods, this method has higher flexibility and expansibility.

(4) By combining the DL algorithm with CAD, the automatic optimization model of smart home design constructed in this article can realize automatic optimization of smart home design and improve design efficiency. Moreover, the model also has high security and privacy protection functions, which can protect users' privacy and data security.

6 CONCLUSIONS

The main research of this article is embodied in the combination of DL algorithm and home design, the integration of CAD and smart home systems, the construction of automatic optimization models, the consideration of security and privacy protection, and the comprehensive application across fields. The validity and feasibility of the automatic optimization model of smart home design based on the DL algorithm and CAD are verified by simulation experiments.

Experiments show that the smart home design model based on the DL algorithm proposed in this article has significantly improved the identification accuracy of user behaviour patterns and habits and provided strong support for the automatic control and optimization of smart home systems. Moreover, the smart home design model based on the DL algorithm can significantly improve design efficiency. Moreover, users have a high evaluation of the smart home design model based on the DL algorithm, and most of them think that it has a good performance in terms of ease of use, stability and functional richness. This further verifies the effectiveness and practicability of the model in smart home design. This model can provide a new solution for smart home design, improve design efficiency, and meet the individual needs and habits of users. In the future, the application scope of smart home design models based on the DL algorithm can be further expanded to include intelligent security, intelligent environmental monitoring, and other fields to meet the diverse needs of different users.

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REFERENCES

[1] Africa, A.-D.-M.: Design and implementation of smart home system using packet tracer, International Journal of Advanced Trends in Computer Science and Engineering, 9(4), 2020, 5710-5715. https://doi.org/10.30534/ijatcse/2020/223942020
[2] Ali, S.-S.; Choi, B.-J.: State-of-the-art artificial intelligence techniques for distributed smart grids: A review, Electronics, 9(6), 2020, 1030. https://doi.org/10.3390/electronics9061030

[3] Alzoubi, A.: Machine learning for intelligent energy consumption in smart homes. International Journal of Computations, Information and Manufacturing (IJCIM), 2(1), 2022, 62-75. https://doi.org/10.54489/ijcim.v2i1.75
[4] Asaithambi, S.-P.-R.; Venkatraman, S.; Venkatraman, R.: Big data and personalisation for non-intrusive smart home automation, Big Data and Cognitive Computing, 5(1), 2021, 6. https://doi.org/10.3390/bdcc5010006
[5] Benavente, P.-C.; Ibadah, N.: Buildings energy efficiency analysis and classification using various machine learning technique classifiers, Energies, 13(13), 2020, 3497. https://doi.org/10.3390/en13133497
[6] Bouchabou, D.; Nguyen, S.-M.; Lohr, C.; LeDuc, B.; Kanellos, I.: A survey of human activity recognition in smart homes based on IoT sensors algorithms: Taxonomies, challenges, and opportunities with deep learning, Sensors, 21(18), 2021, 6037. https://doi.org/10.3390/s21186037
[7] Fei, Y.; Liao, W.; Zhang, S.; Yin, P.; Han, B.; Zhao, P.; Lu, X.: Integrated schematic design method for shear wall structures: a practical application of generative adversarial networks, Buildings, 12(9), 2022, 1295. https://doi.org/10.3390/buildings12091295
[8] Ghods, A.; Caffrey, K.; Lin, B.: Iterative design of visual analytics for a clinician-in-the-loop smart home, biomedical and health informatics, IEEE Journal of Biomedical and Health Informatics, 23(4), 2019, 1742-1748. https://doi.org/10.1109/JBHI.2018.2864287
[9] Guo, X.; Shen, Z.; Zhang, Y.; Wu, T.: Review on the application of artificial intelligence in smart homes, Smart Cities, 2(3), 2019, 402-420. https://doi.org/10.3390/smartcities2030025
[10] Hamzah, I.-H.; Suhaimi, M.-S.-Z.; Malik, A.-A.: Design and implementation of HDL remote controller for smart home system, Indonesian Journal of Electrical Engineering and Computer Science, 20(1), 2020, 117-124. https://doi.org/10.11591/ijeecs.v20.i1.pp117-124
[11] Liu, Y.; Zhang, D.; Gooi, H.-B.: Optimization strategy based on deep reinforcement learning for home energy management, CSEE Journal of Power and Energy Systems, 6(3), 2020, 572-582. https://doi.org/10.17775/CSEEJPES.2019.02890
[12] Machorro, C.-I.; Hernández, G.; Paredes, V.-M.-A.; Rodríguez, M.-L.; Sánchez, C.-J.-L.; Olmedo, A.-J.-O.: HEMS-IoT: A big data and machine learning-based smart home system for energy saving, Energies, 13(5), 2020, 1097. https://doi.org/10.3390/en13051097
[13] Mekruksavanich, S.; Jitpattanakul, A.: LSTM networks using smartphone data for sensor-based human activity recognition in smart homes, Sensors, 21(5), 2021, 1636. https://doi.org/10.3390/s21051636
[14] Murad, M.; Bayat, O.; Marhoon, H.-M.: Design and implementation of a smart home system with two levels of security based on IoT technology, Indonesian Journal of Electrical Engineering and Computer Science, 21(1), 2021, 546-557. https://doi.org/10.11591/ijeecs.v21.i1.pp546-557
[15] Nasrollahzadeh, S.; Maadani, M.; Pourmina, M.-A.: Optimal motion sensor placement in smart homes and intelligent environments using a hybrid WOA-PSO algorithm, Journal of Reliable Intelligent Environments, 8(4), 2022, 345-357. https://doi.org/10.1007/s40860-021-00157-y
[16] Sepasgozar, S.; Karimi, R.; Farahzadi, L.; Moezzi, F.; Shirowzhan, S.-M.; Ebrahimzadeh, S.; Aye, L.: A systematic content review of artificial intelligence and the internet of things applications in smart home, Applied Sciences, 10(9), 2020, 3074. https://doi.org/10.3390/app10093074
[17] Teslyuk, V.; Kazarian, A.; Kryvinska, N.; Tsmots, I.: Optimal artificial neural network type selection method for usage in smart house systems, Sensors, 21(1), 2020, 47. https://doi.org/10.3390/s21010047
[18] Yang, J.: Teaching Optimization of interior design based on three-dimensional computer-aided simulation, Computer-Aided Design and Applications, 18(S4), 2021, 72-83. https://doi.org/10.14733/cadaps.2021.S4.72-83
[19] Yar, H.; Imran, A.-S.; Khan, Z.-A.; Sajjad, M.; Kastrati, Z.: Towards smart home automation using IoT-enabled edge-computing paradigm, Sensors, 21(14), 2021, 4932. https://doi.org/10.3390/s21144932