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Research Article

Optimization of Network Home Management System Based on Big Data

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Network home has become a research hotspot in today's society, and it can improve the comfort, safety, and convenience of people's lives. The traditional network home model only makes certain actions to the home system according to people's instructions, and it is difficult to realize the intelligence of network home. This also limits the security and convenience of an online home. This study makes full use of the advantages of big data technology in processing nonlinear data, and applies the convolutional neural network (CNN) method and long and short-term memory (LSTM) neural network method to the network home system. CNN can be used to extract people's behavior information, and LSTM can be used to extract people's speech features. CNN method can establish the relationship between people's behavior information, speech information, and network home management system. At the same time, this research mainly analyzes the lighting system, home appliance system, security system, and floor heating system in the network home system. The results show that the CNN-LSTM method has high accuracy in predicting the four systems of network home. The largest prediction error is only 2.78%, and this part of the error comes from the prediction of the home appliance system. The smallest prediction error is only 0.98%.

1. Introduction

With the continuous advancement of Internet technology and Internet of Things technology, smart home systems have entered people's lives [1, 2]. It can connect lighting systems, security systems, digital cinema systems, and network home appliance systems in home life. Smart home system takes people's residence as a platform, and uses network communication technology, automatic control technology, etc. to integrate and control home-related equipment [3, 4]. Smart home will bring great convenience to family life, which will also create a life of artistry, safety, and comfort. Compared with the traditional home mode, the smart home model not only has the function of living, but it can also realize the intelligent living environment [5]. At the same time, smart home environment can realize the information exchange between the external equipment and residential environment, and it can realize the operation status of the residential equipment as well. The traditional home mode only realizes the interconnection of indoor electronic devices, but it cannot realize automatic settings according to people's daily preferences [6, 7]. The smart home model automatically sets home electronic devices according to people's daily habits, daily preferences, time, etc. [8, 9]. Big data technology collects data on people preferences for home electronic settings, and it also collects data over time. Moreover, big data technology can better handle the relationship between smart home data. The connection between big data technology and smart home model is also a trend in today's smart home development [10]. There is a large amount of data in the network smart home system, which can become the data used for the learning of big data technology. Big data technology can learn the correlation of smart home systems from this data.

Big data technology is a product of the rapid development of computers, which can help people deal with tedious tasks [11, 12]. Big data technology has been widely used in many aspects of life, it can extract features between data, and it can also map the relationship between nonlinear data. Big data technology is mainly divided into supervised learning, unsupervised learning, and reinforcement learning [13, 14]. It can not only deal with the nonlinear relationship between data, but also deal with the data related to the environment [15, 16]. Big data technology is a general term for using massive data to process feature relationships. CNN and LSTM methods are an algorithm of big data technology. In the process of smart home control, it will involve features of pattern recognition and speech recognition. Relevant algorithms in big data technology can better handle these features, and it can also transform the processed feature information. Big data technology will be converted into a control signal for the smart home system. Many types of feature processing algorithms have emerged in the field of big data [17]. CNN can handle graphic features well, and it has been used in the field of graphic recognition, such as the recognition of traffic signals and image recognition in the medical field. LSTM recurrent neural network can better deal with time-related feature information, and it has been widely used in the field of speech recognition. Whether it is a spatial feature or a time-related feature, algorithms related to big data technology can better complete feature extraction and prediction tasks [18].

The main purpose of realizing smart home is to form an effective open-loop system of household appliances, security systems, and network systems in people's living rooms, which can perform corresponding actions according to people's instructions and operations. The application of big data technology in smart home systems can fully tap people's preferences and frequencies of electrical systems, security systems, and other equipment. Then, the relevant algorithms of big data technology can extract the image and voice features of the smart home system, which can realize intelligent home control. The application process of big data technology in the network home is also an open-loop system, which can make real-time changes according to people's behavioral characteristics and voice characteristics. At the same time, it can also memorize these behavioral characteristics of people, which is the source of data constantly updated by big data technology. Compared with the traditional network home mode, the network home in the big data mode can realize more intelligent control. It can make corresponding execution instructions according to people life characteristics. These life characteristics have a strong relationship with the usage patterns and frequencies of hardware such as electronic equipment and security systems.

This research uses big data technology to design and study the system of network home furnishing. It also analyzes the application of CNN and LSTM neural network in network home furnishing feature prediction. The remaining part of this paper is organized as follows: Section 1 mainly introduces the relevant background of network home and the relevant background of big data technology. The research status of smart home is introduced in Section 2. Section 3 mainly introduces the design scheme of CNN and LSTM method applied in network smart home system, and it also introduces the principle of CNN and LSTM method. The feasibility and accuracy of CNN and LSTM methods in network home systems are analyzed in Section 4. Section 5 is the concluding part of the article.

2. Related Work

The smart home system is already a system pursued by people today, which can improve the quality, comfort, and safety of people's lives. Many researchers have done a lot of research on the security and control systems of smart home systems. Tang et al. [19] have found that the smart home has shown a stage of rapid development. They explored the relationship between consumers' values and the theory of smart home systems, and the impact of smart homes on people's lives was also analyzed. The research results show that the perception module of smart home can affect consumers' value concept. Antic et al. [20] have worked on an advanced smart home model. They have effectively integrated smart home models with third-party apps, infotainment, and more. At the same time, they proposed a smart home model that combines virtual devices and physical twin devices, which is beneficial to external service functions for users. Miandashti et al. [21] have explored the relationship between user system definition conflict and smart home using the relationship between user experience and smart home. The research results show that the proposed conflict detection model helps users to have a good sense of experience in the use of smart home. This conflict checking mode can provide a good reference for system developers and users of smart homes. Chi et al. [22] used big data technology to design a smart home management control scheme. At the same time, he uses the hybrid particle swarm optimization method to optimize and control the smart home system. The research results show that the control optimization model can realize the optimal control of smart home well, and has better communication performance and management effect. It has certain application value for the promotion and development of smart home. Yang et al. [23] built a smart home control system using computer control technology, electronic information technology, and the Internet of Things (IoT) platform. At the same time, it also uses pattern recognition technology and speech recognition modules to design smart home systems. The research results show that the smart home system has the advantages of low operating cost and high precision. The IoT system brings a higher safety factor to the smart home system. Yang et al. [24] designed an information hiding algorithm using data encryption standard (DES) encryption technology and Least Significant Bit (LSB) method, which will be used in the control system of smart home. The LBS algorithm can provide hidden ciphertext for the data of the smart home system. The research results show that the improved LBS algorithm can improve the security and robustness of smart home algorithms. The method can effectively improve the security and confidentiality of the data of the smart home system. Ming et al. [25] have discovered the role of IoT technology in smart home systems. He uses contextual fuzzy logic to realize the application of IoT in smart home system. Fuzzy logic algorithms can analyze real-time data collected by smart home systems, and it can also enable efficient feedback. The research results show that the accuracy of the algorithm proposed in this study reaches 90.5%, and the corresponding time has also been greatly improved. Through the above literature review, it can be found that researchers have applied Internet of Things technology and fuzzy measurement strategies to study the control system and security of smart homes. However, the application of big data technology in the network home system is still relatively small. This research uses the neural network method to study the relevant characteristics of the network home system, which can realize the feature extraction and nonlinear data mapping functions of the smart home system. The network smart home system designed in this study can realize the ability of home electronic devices to actively perform tasks according to people's behavioral characteristics and speech characteristics, which is the ability that most smart home systems do not exist.

3. The Application Algorithm of Big Data Technology in Network Home

3.1. The Significance of Big Data Technology for Network Home. The main goal of this study is to use CNN and LSTM methods to map the relationship between people's behavioral information, verbal information, and network home control factors. The appliance system, security system, and lighting system of the network home need to be controlled by human factors. It cannot be automatically controlled according to people's behavior habits, which also limits the development of the network home in the direction of convenience. People's living habits, behavior information, and speech characteristics are closely related to the control system of the network home. The network smart home system requires the algorithm to be reliable and stable. CNN and LSTM techniques have been proven in many fields. This can ensure the stability of the operation of the network smart home system. Once the CNN and LSTM model training are completed, the network home system can automatically control people's behavioral and speech information. This is conducive to the realization of the convenience and comfort of the network home.

3.2. The Network Home System Design and CNN Algorithm Introduction. Network home is a way to use Internet technology and IoT technology to realize the integration of indoor equipment. It integrates the indoor security system, home appliance system, curtain control system, etc. This research mainly integrates the CNN and LSTM methods in the network home system, which will further realize the convenience and intelligence of the network home. Figure 1 shows the system design based on big data technology. Big data technology here refers to CNN and LSTM algorithms. It can be seen from Figure 1 that there is a feedback mechanism in the application of CNN and LSTM algorithms in the network home. People's behavior information and speech features will be used as the input data of the network home, and the computer system will learn the relationship between people's behavior information and the network home control system. When the CNN and LSTM models are trained, every action and speech of people will affect the control system. CNN method can give an instruction to each device in the network home to execute the corresponding device to operate. Likewise, the feedback mechanism of the network home will perform data feedback to users. After the relevant features of the network smart home system are extracted by CNN and LSTM, it will transmit instructions to electronic devices. The operation of these electronic devices will be communicated to the user.

The big data model designed by this system will contain two types of information. One is people's behavior information, and the other is people's speech information. CNN will be used to process the extraction of people's behavioral information features. Figure 2 shows the operation flow of CNN. It mainly includes convolutional layers, pooling layers, and activation functions. There is a weight sharing mechanism in the convolutional layer, which will reduce the amount of parameter calculation. The pooling layer will further reduce the amount of parameters in the CNN calculation process. The behavior information of network home users will be used as the input data of CNN, and the output data will be the control system data of network home. In this study, the input to CNN is people's behavioral features as well as speech features. The output of the CNN is the instruction sent to the electronic device.

For a CNN algorithm, it will involve many hyperparameters such as filters and stride. Hyperparameters will affect the direction of the CNN iteration process. Equation (1) shows the relationship that the hyperparameters of CNN satisfy. Equation (2) shows the calculation process of the input layer of CNN, which convolves the weights and biases according to the hyperparameters in Equation (1). p is the step size. k is the number of filters. s stands for sliding step. X represents the input dataset. V is the form of the output of the dataset after convolution. The number of filters is set to 64. The sliding step size is set to 1. The learning rate is 0.001.

$$w' = \frac{(w + 2p - k)}{s} + 1, \tag{1}$$

$$V = \text{conv2}(W, X, ''\text{valid}'') + b. \tag{2}$$

In the calculation process of CNN, this will involve a large number of derivative operations. This is also the key for CNN to find the direction of gradient descent. It finds the value with the smallest gradient through the derivation operation. Equations (3) and (4) show the derivation of weights and biases. In Tensor Flow, the derivation operation will be done by automatic differentiation algorithm. The W and u are the weight matrix and the bias parameter, respectively.

$$\Delta\omega_{ji} = -\eta \frac{\partial E}{\partial \omega_{ji}}, \tag{3}$$

$$\Delta u_{ij} = -\eta \frac{\partial E \partial}{\partial u_{ij}}. \tag{4}$$

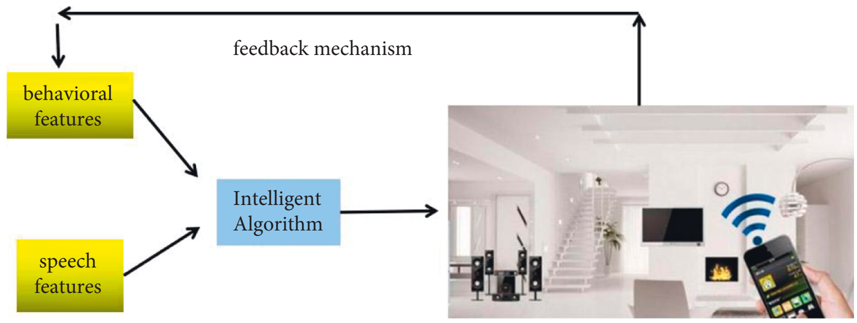

Figure 1: The system design of network home based on big data technology.

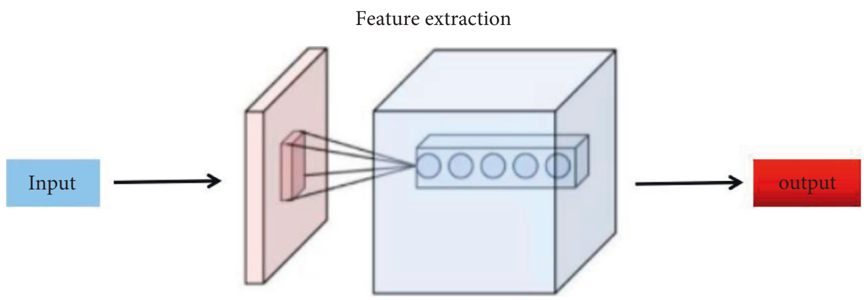

Figure 2: The workflow of CNN algorithm.

For CNN, loss function and activation function are two key functions. The loss function will calculate the error between the predicted value and the actual value, which will guide the direction of gradient descent. Equation (5) shows the calculation process of the loss function. d is the real value, y^L is the optimized value.

$$E = \frac{1}{2}\left\| d - y^L \right\|_2^2. \tag{5}$$

3.3. The Introduction to Hybrid CNN-LSTM Algorithm. The hybrid CNN-LSTM method will fully combine the advantages of the CNN and LSTM algorithms. It can not only extract the spatial features of the network home system, but also can extract the temporal features of the system. The output data of the CNN algorithm is the input data of the LSTM algorithm, which is a continuous process. Figure 3 shows the workflow of the hybrid algorithm. The application of the hybrid method in the network home system is mainly divided into two processes. For the first process, CNN processes people's behavioral information and speech information, and it will complete the spatial feature extraction of these features. For the second process, the LSTM algorithm will use the output data of CNN as its own input data, and it will make full use of the gate structure of LSTM to extract temporal features. The LSTM algorithm can memorize and process the historical information of features, which is mainly due to the gate structure of the LSTM algorithm. The output of the CNN algorithm is the instructions for the smart home. These instructions have some temporal correlation, and it will be input into the LSTM in the form of a time series, which will be further extracted with temporal features.

The LSTM algorithm is mainly composed of four structures: input gate, forget gate, refresh gate, and output gate. The parameter calculation amount of LSTM is larger than that of CNN algorithm because it does not have a weight sharing mechanism. Equation (6) illustrates the computation of the input gate of the LSTM. The input gate of LSTM mainly inputs current state information and historical state information, which is different from the CNN algorithm. The CNN algorithm only inputs the information of the current state, and it cannot preserve the temporal characteristics of the features. This is also the biggest advantage of LSTM over the CNN algorithm. Where h_{t-1} is the historical state data, and the σ and tanh represent the activation function. W and b are the weight matrix and the bias parameter, respectively.

$$f_t = \sigma\left(w_f \bullet [h_{t-1}, P_t] + b_f\right). \tag{6}$$

The forget gate is the key link of LSTM, which is responsible for filtering historical state information. Equation (7) shows the calculation process of the forget gate. For more critical temporal features, the forget gate will give these features a relatively large weight. For less critical features, the forget gate will give these temporal features less weight. When passing through the input gate, it only inputs features with larger weights, and it filters features with smaller weights. After the temporal feature information passes through the input gate and the forget gate, these data need to be processed nonlinearly. Equation (8) shows the process of nonlinear processing of temporal features, which fuses current state information with historical state information. The tanh is the activation function.

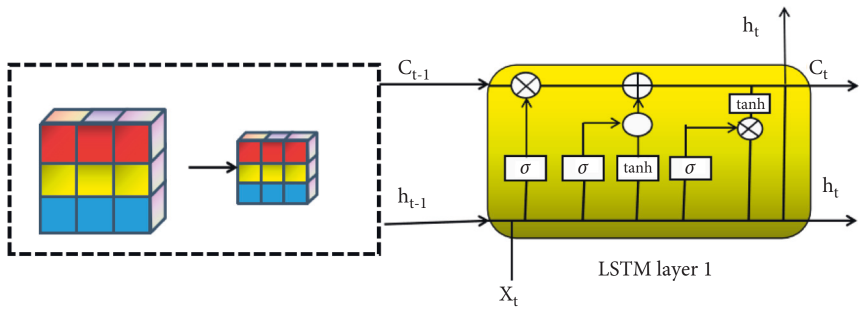

FIGURE 3: The workflow of CNN-LSTM algorithm.

$$i_t = \sigma(\omega_i \bullet [h_{i-1}, P_t] + b_i), \tag{7}$$

$$\widetilde{C}_t = \tanh(w_c \bullet [h_{t-1}, P_t] + b_c). \tag{8}$$

Equation (9) shows the calculation process of the refresh gate of LSTM, which reweights two kinds of temporal state information. c_t is the state unit of the LSTM at time t.

$$\overrightarrow{C}_t = f_t \times \overrightarrow{C}_{t-1} + i_t \times \overrightarrow{C}_t. \tag{9}$$

The output gate is a gate structure that outputs temporal features, and these temporal data have gone through the feature extraction process of the LSTM algorithm. Equation (10) shows the calculation process of the output gate, which selectively outputs current state information and historical state information. Equation (11) shows the operation process of the activation function of LSTM, which is also the key to nonlinear data processing. c_t is the state unit of the LSTM at time t. The tanh is the activation function.

$$O_t = \sigma\left(w_o \bullet \left[\overrightarrow{h}_{t-1}, P_t\right] + b_o\right), \tag{10}$$

$$\overrightarrow{h}_t = O_t \times \tanh\left(\overrightarrow{C}_t\right). \tag{11}$$

4. Result Analysis and Discussion

The dataset used in this study is the related data of the network home system of many households in Shanghai. After the dataset is collected, it needs to go through a data preprocessing step. This research will use a normalized data preprocessing method to process the datasets of behavioral and speech features related to networked smart homes. Figure 4 shows the prediction errors of 4 devices of the network home system using the single CNN method and the hybrid CNN-LSTM algorithm. 1–4 represent the four different systems of the smart home. Overall, both neural network methods can better predict the operation of the four devices in the network home. However, the prediction error obtained with the hybrid CNN-LSTM method is relatively small compared to the single CNN method. This means that the network home system has obvious time characteristics. It needs to consider the temporal characteristics of the network home system when utilizing big data technology. The largest prediction error is only 2.78% by CNN-LSTM method, and this part of the prediction error comes from the operation of home appliances in the network home. This is because the home appliances in the network home are frequently used, and their data characteristics fluctuate greatly. The smallest prediction error is only 0.98%. This part of the error is trustworthy enough in the utilization of the network home. The equipment operation prediction error of the other two households is within 2%, which is also a reasonable and acceptable prediction error. The prediction error of the single CNN algorithm is 1.12%, and the prediction error obtained by the hybrid CNN-LSTM method is 0.98%. This also shows that the prediction error of the hybrid CNN-LSTM in predicting the relevant features of the network smart home system has achieved a lot of improvement.

For the network home system, the lighting system is frequently used. Figure 5 shows the predicted distribution of lighting systems in a networked home using a hybrid CNN-LSTM approach. The blue curve represents the predicted value of the lighting system, and the red curve represents the actual value of the lighting system. It can be seen from Figure 5 that the data of the lighting system has a large fluctuation over time. This is a feature that is difficult to predict for a hybrid CNN-LSTM approach. However, CNN-LSTM better captures the changing trends and eigenvalues of the lighting system in this study. Larger prediction errors for lighting systems mainly occur in the interval 10 to 20. In other intervals, the predicted values of the lighting system are in good agreement with the data values of the actual lighting system. In the interval 10 to 20, people's behavioral characteristics and speech characteristics change greatly, which may be due to the large change of indoor flow of people. These features are difficult for hybrid CNN-LSTM to capture. Overall, the CNN-LSTM method can better predict the lighting system of the network home.

In the network home, the security system is a relatively special system. The security system is basically working around the clock. This feature is easier to predict using the hybrid CNN-LSTM method. Figure 6 shows the predicted distribution of security systems for networked homes. In Figure 6, the yellow data points represent the predicted values of the security system in the networked smart home system, and the purple data points represent the actual values of the security system. It can be seen from Figure 6 that the data of security system in the interval 0 to 10 are lower, which may be due to the low

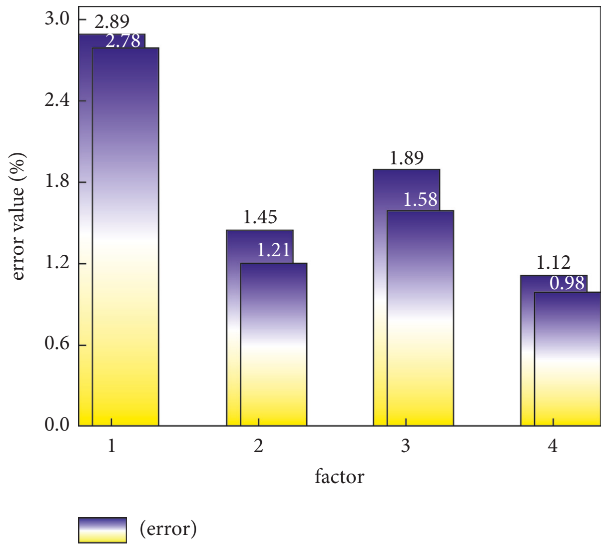

Figure 4: The prediction error of network home control system.

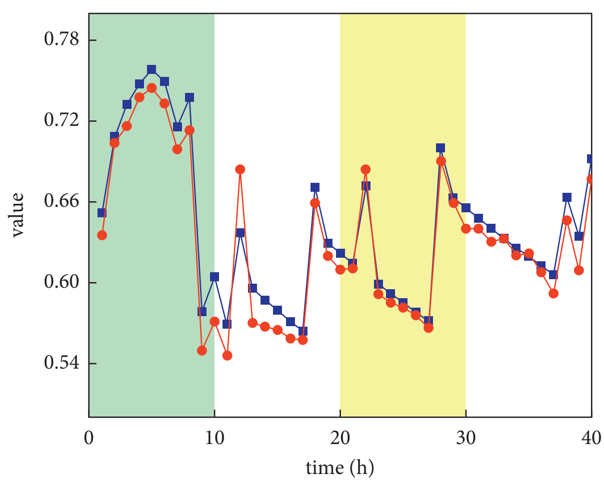

Figure 5: The predicted distribution of lighting systems over time.

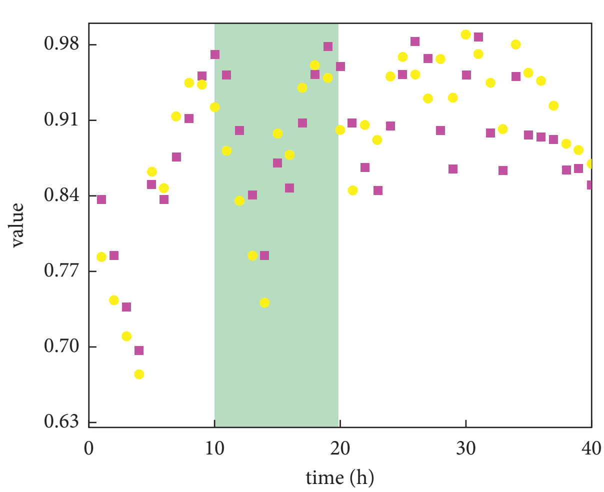

Figure 6: The predicted value distribution of security system.

frequency of use at this stage. In other areas, the security system is in a high state of operation. In the interval 0 to 10, the difference between the predicted value of the security system and the actual value is relatively small. In other intervals, the predicted value of the security system is larger than the interval between 0 and 10. However, this part of the error of the security system also has enough confidence. The large prediction error of the security system mainly occurs in the interval 10 to 20, which is also due to the high frequency of use of the security system during this period.

The operation prediction of home appliances is the most complex set of equipment in the network home system, with a large number of home appliances and more complex usage frequencies. This leads to the difficulty of CNN-LSTM in predicting the running state of home appliances. Figure 7 shows the prediction error distribution of the home appliance system of the network home system. In general, the prediction error of the home appliance system has a certain level of hierarchy, which is mainly related to the layout of the home appliance system. In areas where home appliances are frequently used, there is a small prediction error, and the prediction error is basically distributed within 3%. However, in areas where home appliances are frequently used, there is a large prediction error. This part of the area may be the living room area, where televisions, air conditioners, and other systems are used more frequently, and the behavioral and speech characteristics of this part of the area vary greatly. This leads to a large prediction error in this part of the region. In the learning and training phase of CNN-LSTM, more data are needed to provide behavioral and speech characteristics of this region.

The floor heating system is also the relational environment of the network home system. If the floor heating system can be precisely controlled, it will save a lot of energy and it will also improve the comfort of people's lives. Figure 8 shows the predicted distribution of underfloor heating systems for networked homes. It can be seen that the CNN-LSTM algorithm can accurately predict the temperature changes of the floor heating system according to people's behavior information and speech information. At the same time, the prediction error distribution of the floor heating system is relatively uniform, which shows that the hybrid CNN-LSTM method has high stability in predicting the floor heating system of the network home. Figure 9 shows the numerical distribution of the floor heating system of the network home. For Figure 9, this method can intuitively display the distribution form and numerical size of the data points. At the same time, the numerical distribution of the electric heating system is relatively wide, which can intuitively display the prediction difference. The blue dots represent the predicted values of the floor heating system data, and the green dots represent the actual values of the floor heating system data. In general, the predicted value of the floor heating system and the actual value of the floor heating system have little difference, whether it is the size of the value or the distribution trend of the value.

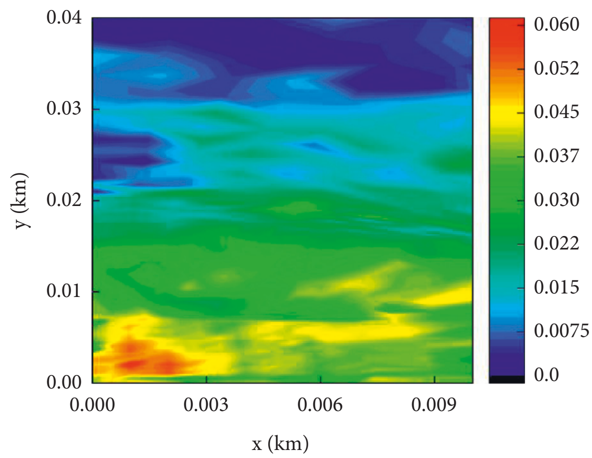

Figure 7: The operation prediction error distribution of home appliance system in network home system.

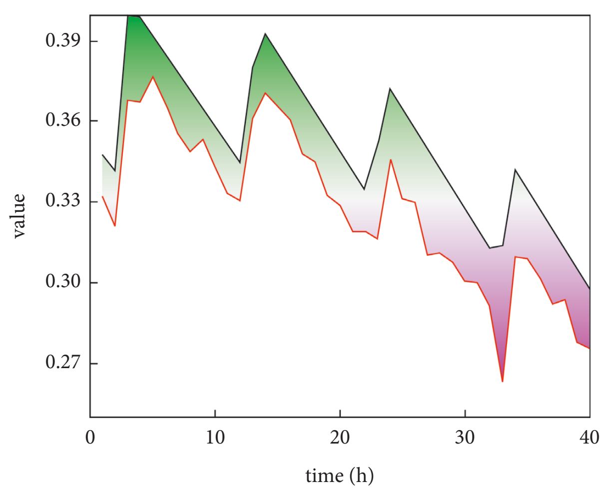

Figure 8: Predicted distribution of underfloor heating systems for networked homes.

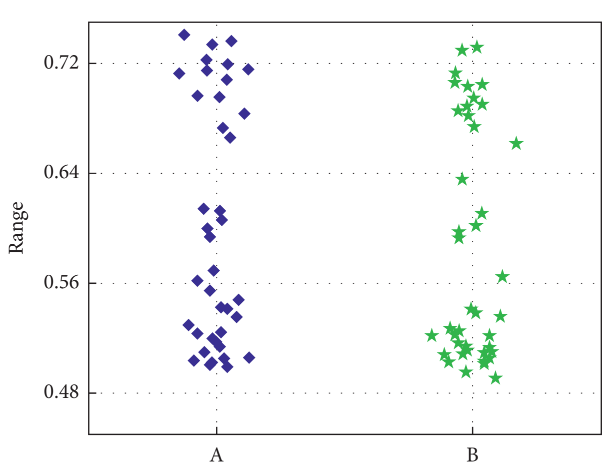

Figure 9: The numerical distribution of floor heating system of network home.

5. Conclusion

With the continuous development of Internet of Things technology and Internet technology, the network home system has made great progress. The network home system can improve the comfort, convenience and safety of people's lives. It is difficult for the traditional network home system to realize the intelligence of the home system and the feedback mechanism of the control system. This research uses big data technology to optimize the design of the network home management system. It can not only maintain the function of traditional network home, it can further improve the convenience and comfort of network home system.

This study uses CNN to extract people's behavioral features, and it also uses LSTM method to extract people's speech features. It can combine CNN-LSTM and network home system to realize the intelligent control of home system based on people's behavior information and speech information. In general, CNN-LSTM has high accuracy in predicting the security system, lighting system, home appliance system, and floor heating system of the network home. The largest error is only 2.78%, and this part of the error mainly comes from the prediction of the home appliance system. The appliance system is the most widely distributed and most frequently used system in network home, and this part of the error is also trustworthy. The hybrid CNN-LSTM method also captures the peak value and changing trend of the lighting system well, and the error in this part is relatively small. For the floor heating system, the distribution trend of the predicted value of CNN-LSTM is in good agreement with the actual value.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declare that they there are no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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