Prediction analysis of building energy consumption based on artificial intelligence technology

Jia Li[1], Wenzhang Sun[2,*]
1.New Generation Information Technology Industry Institute, Shandong Polytechnic, Jinan Shandong 250104, China
2.Crystal Materials Research Institute, Shandong University, Jinan Shandong 250013, China

Jia Li email: 1795@sdp.edu.cn
CA Wenzhang Sun email: 160701205@stu.cuz.edu.cn

Abstract: In order to improve the accuracy of building energy consumption prediction, promote the construction of energy-saving buildings, and build an energy-saving and environmental friendly society, this paper aims to conduct an in-depth study on the building energy consumption prediction method based on artificial intelligence algorithm. Firstly, the relevant data are collected and processed, and the historical data of building energy consumption are preprocessed through the analysis method of Pearson correlation coefficient and multiple linear regression. Then the energy consumption prediction method based on genetic optimization decision tree is used to predict the building energy consumption, and the subtree characteristics generated by the decision tree are optimized through genetic algorithm. The evaluation process, optimization process and generation process of the subset of energy consumption characteristics are described in detail, Take the predicted R-square value of the model as the standard of iterative evaluation, so as to achieve the prediction of building energy consumption, and complete the research on building energy consumption prediction based on artificial intelligence algorithm. Through experimental verification, compared with other prediction methods, the building energy consumption prediction method proposed in this paper can effectively reduce the error of energy consumption prediction, improve the efficiency and accuracy of building energy consumption prediction, and has the value of wide promotion.
Keywords: Artificial intelligence; Prediction of building energy consumption; Genetic optimization algorithm; Decision tree method;

1.Introduction

With the gradual progress of science and technology and society, the living standard of the public has also been significantly improved. The construction industry, which is closely related to the life of the public, is an important part of it. With the social progress, the construction industry has flourished, the number of buildings has gradually increased, and the styles of buildings have become richer. However, the public's demand for the construction industry is not only the comfort of daily life and workplace, but also the pursuit of intelligence and energy conservation. Carrying out scientific energy-saving design for buildings can also promote global energy conservation and emission reduction on the basis of meeting the basic needs of the public in daily life.

At present, China is in an important stage of building and developing energy-saving and environmental protection. Compared with the construction industry, energy-saving transformation must be carried out, because China's building energy-saving technology started relatively late than some developed countries, resulting in the gradual increase of building energy consumption. At present, the existing building energy consumption prediction methods still have some shortcomings, and there is an urgent need to develop a simple and high-precision building energy consumption prediction method. According to the relevant laws of our country, if the transmission coefficient of building exterior wall and the index of thermal inertia cannot meet the relevant provisions, the annual power consumption index of air conditioning and heating cannot exceed the annual power consumption index of building air conditioning and heating. Therefore, before the design of buildings, we must establish scientific energy consumption prediction methods to carry out scientific prediction of building energy consumption, which is the basis of building an energy-saving and environmental friendly society, and it is also the key requirements of relevant national laws. The accurate prediction of building energy consumption is of great significance to the energy-saving design in the process of building design or building reconstruction. Therefore, this paper makes an in-depth study on the prediction method of building energy consumption.

The innovations of this paper are as follows: (1) collect and process the relevant data, preprocess the historical data of building energy consumption through the analysis method of Pearson correlation coefficient and multiple linear regression, then predict the building energy consumption using the energy consumption prediction method based on genetic optimization decision tree, and select the best sub tree characteristics generated by the decision tree through genetic algorithm, The evaluation process, optimization process and generation process of energy consumption feature subset are described in detail, and the model prediction R-square value is taken as the standard of iterative evaluation to achieve the important purpose of building energy consumption prediction. (2) Compared with other prediction methods, the building energy consumption prediction method proposed in this paper can effectively reduce the error of energy consumption prediction, improve the efficiency and accuracy of building energy consumption prediction, and has the value of wide promotion.

2. Related work

With the gradual improvement of public awareness of energy conservation, in order to control the level of building energy consumption, relevant experts have conducted in-depth research on the prediction method of building energy consumption. Ji t y et al. will use time series features and classification features when carrying out regression prediction on building energy consumption, and the traditional model can only aim at one of these features. Therefore, a neural network based on one-dimensional convolution and word embedding is proposed, in which one-dimensional convolution extracts the features of time series, and the word embedding model can carry out embedded calculation on discrete features, so as to build a building energy consumption prediction model that can deal with time series features and classification features at the same time. Compared with other methods, it is proved that the prediction efficiency of the prediction model proposed in this paper has better performance. In terms of parameter adjustment, the Bayesian based optimization parameter optimization algorithm is used to find the optimal parameters in the search space. Compared with manual parameter adjustment, the parameter optimization algorithm can improve the performance of the model in a relatively fast time. The experimental simulation results show that, The proposed building energy consumption prediction model has good performance, but the model does not improve the accuracy of prediction [1]. Xiao R et al. proposed a building energy consumption prediction method with support vector machine according to the characteristics of strong nonlinearity and uncertainty of building energy consumption. The test method of univariate model is used to predict the input variables of the model, the grid search method is introduced to optimize the parameters of the prediction model, and the uncertainty of building energy consumption is described through the confidence interval of the fitting error of the prediction model. Take relevant cases to verify the proposed building energy consumption prediction method. The verification results show that the absolute percentage error of the prediction model after grid search optimization is significantly reduced and has high prediction accuracy. After adding confidence intervals, MAPE is significantly reduced in different seasons, reflecting the fluctuation of building operation. The proposed method can optimize the operation of building, but the process is relatively complex [2]. In order to improve the prediction accuracy of building energy consumption, Lu y proposed a building energy consumption prediction method based on the combination of cycle characteristics and deep learning. In the process of calculation, the cycle characteristics of building energy consumption cycle are considered to improve the accuracy of building prediction. The building cycle characteristics and residual energy consumption are extracted by spectrum analysis method, and the building energy consumption prediction model is established by deep learning method. In order to verify the effectiveness of the proposed method, the model is applied to a commercial building, and compared with other algorithms. The comparison results show that, Whether compared with data regression model or other methods, the proposed method has obvious advantages in prediction stability and prediction efficiency, and is suitable for building energy consumption prediction, but this method has the problem of poor prediction accuracy [3]. Li l et al. the neural network analyzing radial basis function is applied to building energy consumption prediction because of its relatively simple network results, good network adaptability and relatively fast learning convergence speed. Because the existing building energy consumption data and the key factors affecting energy consumption are insufficient in analysis, and the network parameters are not clear, the accuracy of building energy consumption prediction cannot meet the practical needs, Therefore, the particle swarm optimization algorithm and Marquardt algorithm are adopted to optimize the prediction model parameters. Taking an office building as the research object, the conditions that affect the building energy consumption constraints are clarified, and the network input parameters are learned, so as to improve the accuracy of the building energy consumption prediction model. The experimental results show that the absolute error and relative error of the improved method are significantly reduced, but there is still a problem of low prediction accuracy [4].

3. Data collection and processing of building energy consumption prediction

3.1 Data collection

Various factors affecting building energy consumption are shown in Figure 1.

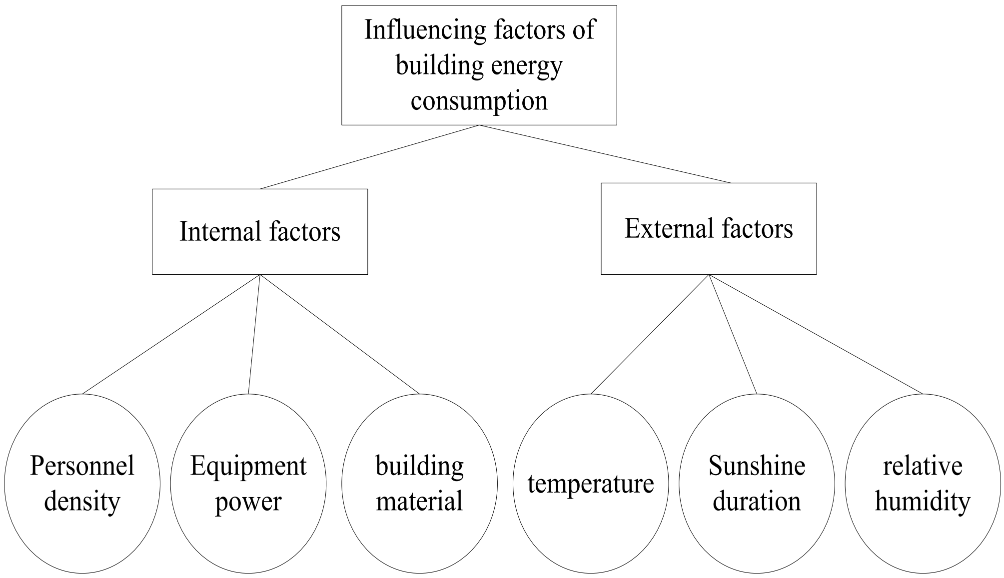

Figure 1 various factors affecting building energy consumption

3.2 Preprocessing of prediction data

（1）Analysis method of Pearson correlation coefficient

Common correlation analysis methods are shown in Figure 2. Among them, Spearman's correlation coefficient and Kendall's correlation coefficient analysis method are not sensitive to the data error value and extreme value response in the building energy consumption data. They are mostly used for the monotonic relationship response between variables, and cannot evaluate the linear relationship between quantities like Pearson's correlation coefficient analysis method [5-6]. Therefore, Pearson correlation coefficient is selected to analyze the building energy consumption data. The correlation coefficient represents the relationship between consecutive variables, which can be defined as:

$$P_{XY} = \frac{Cov(X,Y)}{\sqrt{D(X)}\sqrt{D(Y)}} = \frac{E((X-EX)(Y-EY))}{\sqrt{D(X)}\sqrt{D(Y)}} \quad (1)$$

$$Cov(X,Y) = 2E((X-EY)(Y-EY)) \quad (2)$$

In formula (1) and (2), E represents the mean, D represents the variance, and $\sqrt{D(X)}\sqrt{D(Y)}$ represents the standard deviation. $Cov(X,Y)$ represents the covariance between variables X and Y, and the correlation coefficient P_{XY} represents the quotient between the covariance and standard deviation between the two variables. The approximate range of values is [-1,1], in which the greater the absolute value, the stronger the correlation.

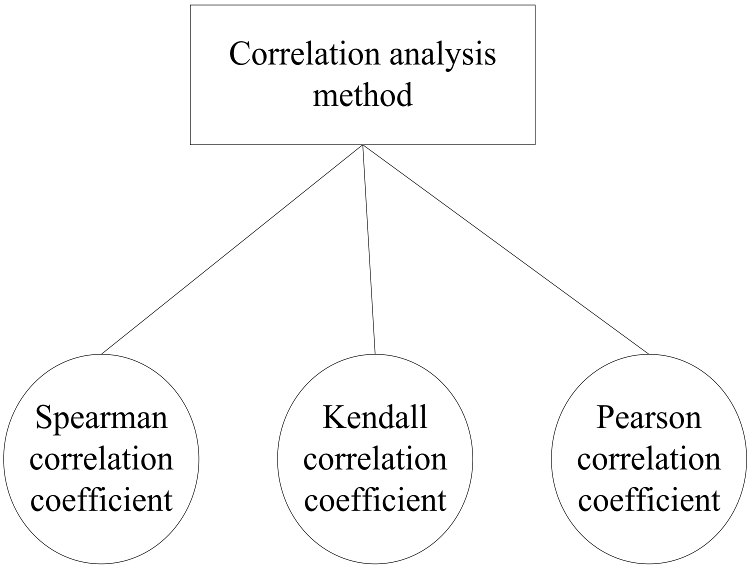

Figure 2 common correlation analysis methods

The calculation results of Pearson correlation coefficient between various variables can be obtained by spss22.0 software, and the results are shown in Figure 3.

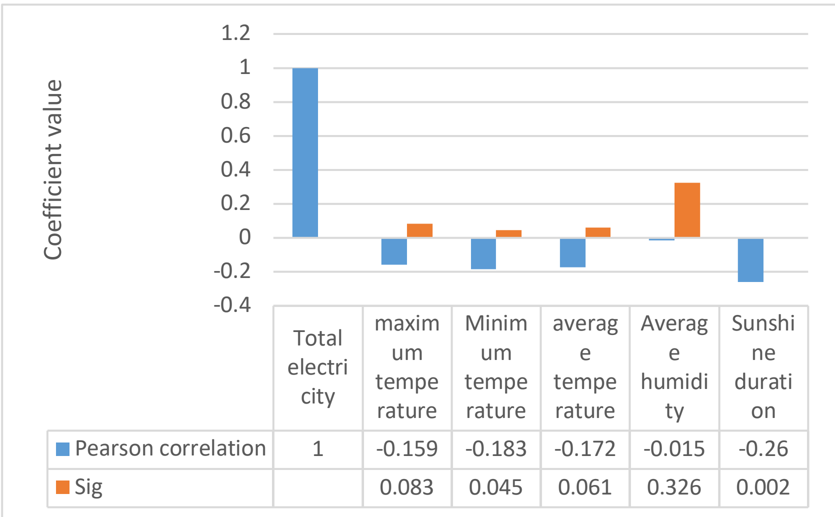

Figure 3 Correlation between daily total power consumption and external factors

As can be seen from Figure 3, since the correlation coefficient value between daily energy consumption and relative humidity is -0.015, and the sig value is 0.326, it shows that the relative humidity and building energy consumption are weakly correlated, so the impact of this meteorological characteristic value on the building energy consumption prediction results is relatively small, other factors and modeling are statistically significant, and there is a correlation relationship with the total power consumption [7-8].

Combined with the above, removing the factor of relative humidity, on the basis of the original five-dimensional data, through Pearson's correlation coefficient backwashing method, it can not only reduce the sample dimension of building energy consumption data, but also reduce the mutual influence of various influencing factors.

（2） Multiple linear regression

After reducing the mutual influence of various image factors, carry out multiple linear regression fitting for the remaining factors, and the results of software analysis are shown in Table 1.

Table 1 correlation coefficient of multiple linear regression model

	B	Standard error	Trial coefficient	T	Sig
constant	9089.30	1381.20		6.57	0
maximum temperature	33.54	24.13	0.46	1.38	0.17
Minimum temperature	31.83	31.75	0.37	1.00	0.31
Sunshine duration	-503.46	121.50	-1.05	-4.14	0.20

By analyzing table 1, we can get the model of multiple linear regression prediction as follows:

$$\begin{aligned} Y &= 9089.30 + Z \\ Z &= 33.54X_1 + 31.83X_2 + 503.46X_3 \end{aligned} \qquad (3)$$

In formula (3), Y represents the total daily power consumption, in kwh; X_1 represents the highest temperature, X_2 represents the lowest temperature, and X_3 represents the sunshine time.

Using Pearson's correlation coefficient analysis method and multiple linear regression screening, the average humidity and average temperature are excluded variables and are not added to the building energy consumption prediction model [9-10]. Formula (3) shows that the three-dimensional data weather factors can replace the original energy consumption data as the follow-up training set and prediction set to predict the energy consumption of buildings.

4. Prediction method of building energy consumption based on artificial intelligence algorithm

Genetic algorithm is a feature optimization algorithm with high scalability evaluation function. Gradient improved decision tree is a learning model that integrates sub trees based on feature division. For the prediction of building energy consumption, genetic algorithm and decision tree have very high consistency [11-12]. Therefore, this paper predicts building energy consumption based on genetic optimization decision tree method. The main process of the prediction model is shown in Figure 4.

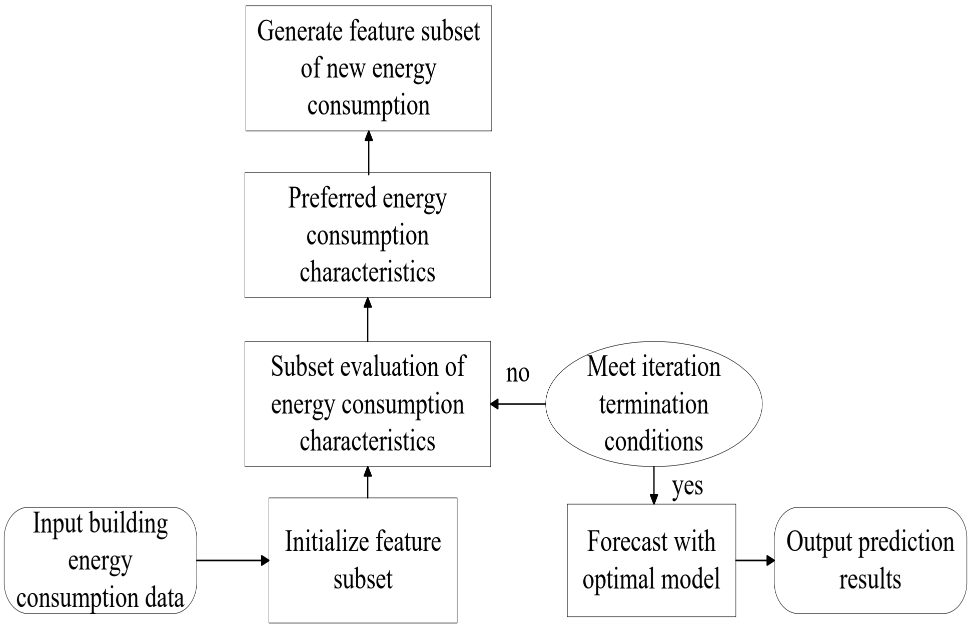

Figure 4 genetic optimization gradient decision tree model process

4.1 Mapping rules for subset of building energy consumption characteristics

This paper mainly adopts binary method to encode genes, which can express the two states of genetic algorithm for building energy consumption: gene selection and non selection. Binary coding $G=\{g_1,g_2,\cdots,g_m\}$ is carried out for the feature subset $F=\{f_1,f_2,\cdots,f_m\}$ of the energy consumption feature set after pre screening, and the rule is:

$$g_i = encode(f_i) = \begin{cases} 1, & f_i \quad is \quad selected \\ 0, & f_i \quad is \quad notselected \end{cases} \quad (4)$$

In the prediction model of building energy consumption, any feature is mapped into a gene on the gene string. When this feature is selected, the corresponding gene ID is 1, otherwise it is 0, and the reverse process is the process of decoding [13-14].

The process of population initialization will generate many initial random binary gene strings, which can be understood as the characteristic sub cluster of random initialization energy consumption, that is, $Population=\{G_1,G_2,\cdots,G_n\}$, $G_i(1\le i\le n)$ represents the comprehensive consideration of the characteristic subset of building energy consumption in the process of genetic evolution.

4.2 Evaluation process of energy consumption characteristic subset

Set a data set of building energy consumption with n data, and the largest one can generate subtree M . For the subset of building energy consumption characteristics mapped by the current gene string, the matrix sample of the generated data is expressed as:

$$S=\{(x_1,y_1),(x_2,y_2),\cdots,(x_n,y_n)\} \quad (5)$$

Any x generated according to the mapping rules of gene string is:

$$x_i=\{feature_{i1},feature_{i2},\cdots,feature_{in}\}, i\in[1,n] \quad (6)$$

For the selection of the segmentation point of the subtree, traverse the building energy consumption characteristic $feature_j$ of any variable x_i as the segmentation point, and obtain two segmentation regions:

$$\begin{aligned} Area_1(i,j) &= \left\{ x_k \middle| x_k^{feature_j} \leq x_i^{feature_j} \right\} \\ Area_2(i,j) &= \left\{ x_k \middle| x_k^{feature_j} \leq x_i^{feature_j} \right\} \end{aligned} \quad (7)$$

Calculate the variance in the segmentation point area, which is expressed as:

$$\mathrm{var}iance(i,j,n) = \min_{Avg_n} \sum_{x_i \in Area_n(i.j)} (y_i - Avg_n)^2 \quad (8)$$

In formula (8), Avg_1 and Avg_2 represent the mean value of the segmentation region.

For the m-th subtree of the selected commutation feature and threshold, the local average of the data divided into the same region is the prediction result.

$$f_m(x_i) = \frac{1}{N_{area_{x_i}}} \sum_{x_j \in area_{x_i}} y_i \quad (9)$$

In formula (9), $area_{x_i}$ represents the division area of x_i, $N_{area_{x_i}}$ represents the number of data in the division area, and y_i represents the actual value of the jth data [15-16].

Because the prediction process of building energy consumption data is a regression problem, the mean square error is adopted for the prediction result of the decision tree, and the loss function is expressed as:

$$r_{id} = L(y_i, f_m(x_i)) = [y_i - f_m(x_i)]^2 \quad (10)$$

In formula (10), r_{im} represents the mean square error of the prediction of the m-th subtree for a certain data, and $f_m(x_i)$ represents the prediction value.

In the process of repeated iterations in the above steps, the error value of good prediction results can be subdivided, so that the difference between the predicted value of building energy consumption and the actual value can be updated after each iteration generates a subtree:

$$f_m(x) = f_{m-1}(x) + T_m(x:\Theta_m) \quad (11)$$

After M iterations, add multiple subtrees to obtain the final learning model:

$$f(x) = \sum_{m=0}^{M} T_m(x:\Theta_m) \quad (12)$$

According to the final model prediction, the R-square evaluation value is regarded as the fitness of the feature string, and R-square is defined as:

$$R^2 = 1 - \frac{\sum_{j=1}^{n} (y_i - \hat{y}_j)^2}{\sum_{j=1}^{n} (y_i - \bar{y})^2} \quad (13)$$

In formula (12), y_i represents the real value of the jth data of the energy consumption data sample S, $\hat{y}_j$ represents the predicted value of the final model for the jth variable, and $\bar{y}$ represents the mean value of the response variable y of the data sample S.

4.3 Optimization process of building energy consumption feature subset

After calculating the fitness of the population gene string, Q gene strings must be selected from the population according to the corresponding strategies, so as to form a new population, that is, the process of selecting the optimal characteristics of building energy consumption [17-18]. Among them, Q represents the size of the population. This paper adopts roulette to select gene strings. Let the current population $Population = \{G_1, G_2, \cdots, G_Q\}$ represent Q characteristic subsets of building energy consumption, and take Q gene strings from the population to form a new population. The probability of any gene string being selected is:

$$P_{G_i} = \frac{fitness(G_i)}{\sum_{j=1}^{n} fitness(G_j)} \quad (14)$$

In formula (14), $fitness(G_i)$ represents the fitness of the ith gene.

The elite strategy is adopted to optimize the gene selection process, so that the gap between the fitness of the population gene string is more obvious. The base value of the population fitness is subtracted from the fitness of any gene string i. the probability of the gene string being selected in the roulette is:

$$P_{G_i} = \frac{d_i}{\sum_{j=1}^{n} d_j} = \frac{fitness(G_i) - \min(fitness(G_i))}{\sum_{j=1}^{n} \left[fitness(G_j) - \min(fitness(G_i)) \right]} \quad (15)$$

For the dominant gene string, the probability of being selected will be higher, and the probability of being selected for the relatively inferior gene string will be lower. Therefore, this strategy ensures that the eigenvalue of the building energy consumption model has a high priority.

4.4 Generation process of feature subset

Because the characteristic dimension of building energy consumption is relatively high, the population cannot cover all feature subsets at one time. Therefore, in the process of selecting building energy consumption characteristics by genetic algorithm, new feature subsets must be generated according to randomness. The way to generate new feature subsets is gene string mutation and crossover [19-20]. Based on variance, we can measure the differences of set elements, so we take variance as the standard to measure whether there is premature phenomenon in the population. The characteristic diversity of population $Population = \{G_1, G_2, \cdots, G_Q\}$ is expressed as:

$$\mathrm{var}_{Population} = \frac{\sum_{j=1}^{n}\left[fitness(G_j) - avg(fitness(G))\right]^2}{n} \quad (16)$$

In formula (16), $fitness(G_j)$ represents the fitness of the jth gene string, and $avg(fitness(G))$ represents the average fitness of the population.

During initialization, the initial crossover rate and mutation rate can be increased, and then adaptive adjustment can be carried out.

$$\begin{cases} P_c = P_c - \alpha \times \mathrm{var}_{Population} \\ P_m = P_m - \alpha \times \mathrm{var}_{Population} \end{cases} \quad (17)$$

Based on the adaptive adjustment strategy, if a certain building energy consumption feature in the population accounts for a large proportion, the gene string variance of the population will be reduced, and the mutation rate and crossover rate will be increased, resulting in an increase in the probability of new individuals, covering many characteristics of building energy consumption, so as to prevent falling into local optimization. When the characteristics of building energy consumption in the population increase, the gene string variance of the population will also increase, The mutation rate and crossover rate will decrease, so that the formation of new individuals will gradually stabilize. This method can ensure that the characteristics of building energy consumption can remain stable in the process of selecting. Through the above process, the research on building energy consumption prediction method based on artificial intelligence algorithm is completed.

5. Experimental result

In order to verify the effectiveness of the building energy consumption prediction method based on artificial intelligence algorithm proposed in this paper, simulation experiments are carried out. Table 2 shows the experimental environment data. Pro/ tool is used to draw the three-dimensional model of the building. The specific building material is acrylic plate. Figure 5 shows the three-dimensional model of the three-story building.

Table 2 shows the experimental environment data

project	data
Experimental environment	PC
simulation environment	Matlab 7
CPU	3.0G
operating system	Windows 7
Memory	12G

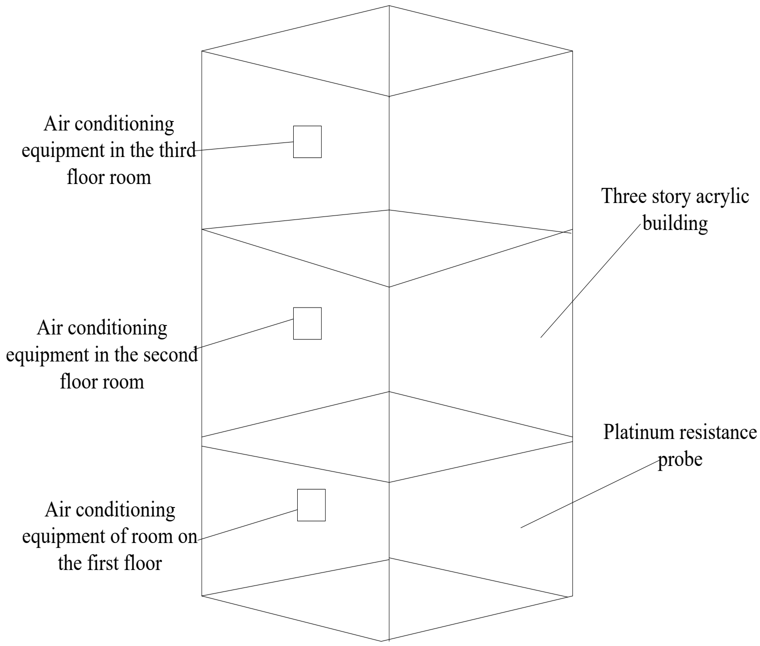

Figure 5 three dimensional model of the three storey building

Figure 6 shows the prediction error comparison between the building energy consumption prediction method based on artificial intelligence algorithm proposed in this paper and the building energy consumption prediction method proposed in literature [1] and literature [2].

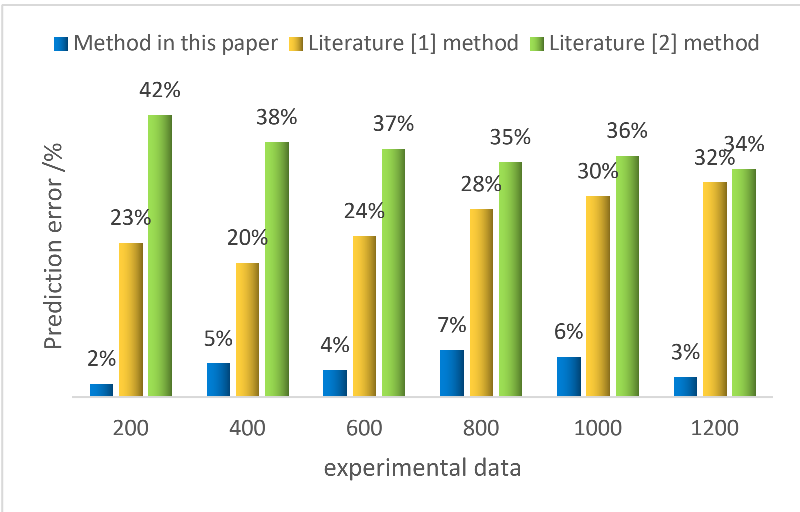

Figure 6 Comparison of building energy consumption prediction errors of different methods

By analyzing Figure 6, it can be seen that the prediction error when using the energy consumption prediction method proposed in literature [1] to predict building energy consumption is high. When there are few data samples, the prediction error is small, but with the gradual increase of data samples, the prediction error is also gradually increasing. The prediction error when using the energy consumption prediction method proposed in literature [2] to predict building energy consumption is also relatively high. When there are few data samples, There is a high prediction error, but with the gradual increase of data samples, the prediction error gradually decreases, but the overall fluctuation is small. At the end of the experiment, the energy consumption prediction error is not only higher than the method proposed in this paper, but also higher than the method proposed in literature [1]. The overall error of the prediction of building energy consumption using the method proposed in this paper is relatively small. From the beginning of the experiment to the end of the experiment, the fluctuation of the prediction error has been controlled below 8%, because this paper uses genetic optimization to improve the decision tree algorithm, and takes the value of the prediction model R-square as the iterative evaluation standard to reduce the prediction error, which shows that the method proposed in this paper is suitable for the prediction of building energy consumption, It can effectively reduce the prediction error. Table 3 shows the comparison of prediction efficiency between the building energy consumption prediction method based on artificial intelligence algorithm proposed in this paper and the building energy consumption prediction method proposed in literature [1] and literature [2].

Table 3 Comparison of building energy consumption prediction efficiency of different methods

different methods	Prediction time /s
Method in this paper	23
Literature [1] method	48
Literature [2] method	51

It can be seen from table 3 that the prediction time of building energy consumption proposed in literature [1] and literature [2] is significantly slower than the method proposed in this paper, with the prediction time of 48S and 51s respectively, while the prediction time of building energy consumption using the method proposed in this paper is 23S, which shows that the efficiency of building energy consumption prediction can be effectively improved by using the method proposed in this paper. Figure 7 shows the comparison between the prediction accuracy of building energy consumption using the method in this paper and the methods proposed in literature [1] and literature [2].

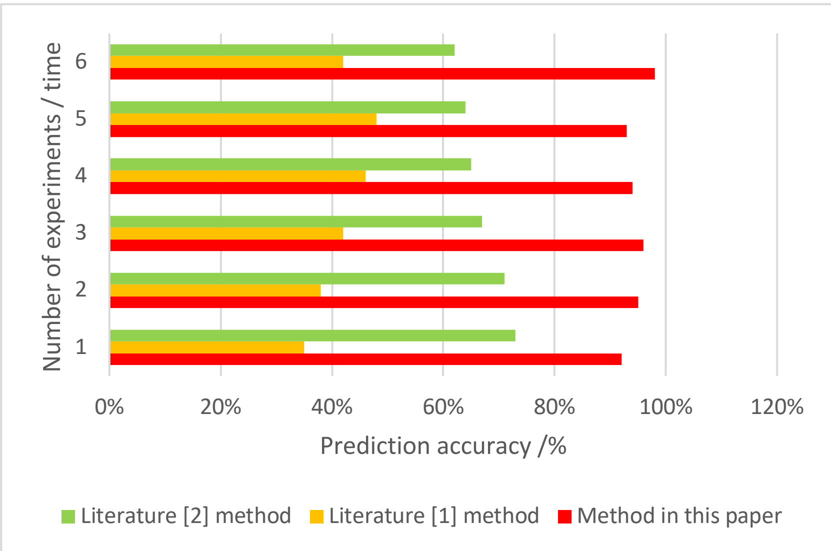

Figure 7 Comparison of prediction accuracy of building energy consumption by different methods

Six experiments were carried out with different methods. As can be seen from Figure 7, the prediction accuracy of the method proposed in document [1] for building energy consumption was different in each experiment, but the overall prediction accuracy was not higher than 50%. The prediction accuracy of the method proposed in document [2] for building energy consumption passed six experiments, and the prediction accuracy from the initial prediction accuracy of the experiment to the end of the experiment was from 73% to 62%, The accuracy of using the method proposed in this paper to predict building energy consumption has been stable at more than 90% through six tests, because this paper uses the method of combining genetic algorithm and decision tree to predict building energy consumption, which effectively improves the accuracy of building energy consumption prediction. This shows that using the method proposed in this paper can ensure the high accuracy of building energy consumption prediction, and has certain practical value.

6. Conclusions

In order to improve the accuracy of building energy consumption prediction, this paper studies the prediction method of building energy consumption, puts forward the prediction method of building energy consumption based on artificial intelligence algorithm, collects and processes the relevant data, preprocesses the historical data of building energy consumption through the analysis method of Pearson correlation coefficient and multiple linear regression, and uses the prediction method of genetic optimization decision tree to predict building energy consumption, The effectiveness of the proposed method is verified by experiments, which can effectively improve the accuracy of building energy consumption prediction. When designing buildings, we can predict the specific situation of building energy consumption in advance, which is of great significance to the construction of energy-saving buildings, and can also help users adjust the operation mode of building air conditioning system in time, which plays a positive role in global climate change.

References

[1]T. Y. Ji, T. S. Wang, “Building Energy Consumption Prediction Based on Word Embedding and Convolutional Neural Network,”*Journal of South China University of Technology(Natural Science Edition),* vol.49,no.6,pp.40-48,2021.

[2]R. Xiao, Z. Q. Wei, and X. Q. Zhai, “Hourly Energy Consumption Forecasting for Office Buildings Based on Support Vector Machine,”*Journal of Shanghai Jiaotong University,*vol.554,no.3,pp.331-336,2021.

[3]Y. Lu, “Research on Building Energy Consumption Prediction Method Based on Cycle Feature and Deep Learning Algorithm,”*Industrial Heating,*vol.51,no.5,pp.31-35,2022.

[4]L. Li， X. H. Yang, and L. Cao, “Building Energy Consumption Prediction Based on Improved RBF Neural Network,”*Building Energy EFFICIENCY*,vol.49,no.1,pp.81-86,2021.

[5]J. M. Dou, H. Y. Ma, “Prediction of Building Energy Consumption Based on Ensemble Artificial Neural Networks,”*Computer Simulation,*vol.39,no.5,pp.438-443,2022.

[6]X. F. Zhang, “Research on building BIM energy consumption prediction algorithm based on wavelet neural network,”*Machine Tool & Hydraulics*,vol.46,no.24,pp.42-47,2018.

[7]H. Gao, T. J. Dang, “Energy Consumption Prediction Model for CBD Buildings Based on EnergyPlus,”Building Energy EFFICIENCY,vol.469,no.12,pp.43-46,2018.

[8]W. W. Gao, “Research on the Design of Chinese Network Aided Instruction System Based on Computer,”*Techniques of Automation and Applications,*vol.39,no.7,pp.166-169,2020.

[9]P. Li, X. L. ZHou, “Building Energy Consumption Forecasting Method Based on Depth CRBM Model,”*Natural Science Journal of Xiangtan University,*vol.39,no.2,pp.45-48,2017.

[10]G. Liu, X. Q. Li, Z. Han, “Design of distance teaching system based on wavelet neural network,”*Journal of Chongqing University(Natural Science Edition)*,vol.45,no.5,pp.79-95,2022.
[11]Bharati, Subrato Podder, Prajoy Mondal, M. Rubaiyat Hossain. “Visualization and prediction of energy consumption in smart homes,” *International journal of hybrid intelligent systems*, vol.16,no.2,pp.81-97,2020.
[12]Togashi E , Watanabe K I , Honma M . “Prediction of the lighting energy-saving effect by human detection control with an office worker agent model,” *Journal of Environmental Engineering (Transactions of AIJ)*,vol.83,no.753,pp.891-899,2018.
[13]Adenuga O T , Mpofu K , Ramatsetse B I . “Exploring energy efficiency prediction method for Industry 4.0: a reconfigurable vibrating screen case study,” *Procedia Manufacturing*,vol.51,no.30,pp.243-250,2020.
[14]Jaroov, Petra, Vala. “Computational Prediction and Control of Energy Consumption for Heating in Building Structures,” *AIP Conference Proceedings*, vol.1863,no.1,pp.1-4,2017.
[15]Billah M , Anwar A , Rahman Z . “Bi-Level Poisoning Attack Model and Countermeasure for Appliance Consumption Data of Smart Homes,” *Energies*,vol.14,no.13,pp.3887,2021.
[16]Kim K S , Lee S , Huang K . “A Scalable Deep Neural Network Architecture for Multi-Building and Multi-Floor Indoor Localization Based on Wi-Fi Fingerprinting,” *Big Data Analytics*,vol.3,no.1,pp.4,2017.
[17]Gupta R K , Kapsali M , Gregg M . “Comparative building performance evaluation of a 'sustainable' community centre and a public library building,” *Building Services Engineering Research & Technology*, vol.38,no.6,pp.691-710,2017.
[18]Hwang, Seok-Ho. “A Study on Prediction Method for Low-Depth Ground Temperature by using Surface Energy Balance Equation,” *Journal of Korean Institute of Architectural Sustainable Environment and Building Systems*,vol.11,no.2,pp.142-148,2017.
[19]Iwai K , Asano Y , Fujiki N . “A STUDY ON ENERGY CONSUMPTION AND POWER SAVING ACTUAL CONDITION OF DETACHED HOUSES IN NAGANO, YAMANASHI AND NIIGATA BEFORE AND AFTER THE EARTHIQUAKE DISASTER,” *Journal of Environmental Engineering*,vol.83,no.743,pp.87-96,2018.
[20]Picardmasson M , Loslier J , Paquin. “Consumption of energy drinks among Québec college students,” *Canadian journal of public health = Revue canadienne de sante publique*,vol.107,no.6,pp.514,2017.