ENERGY CONSUMPTION MODELLING ANALYSIS OF PREFABRICATED BUILDINGS BASED ON KPCA - WL SSVM

by

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The energy consumption of prefabricated buildings under multi-layer building materials system is affected by different weight factors. In order to improve the level of energy consumption prediction, a method of energy consumption prediction of prefabricated buildings under multi-layer building materials system based on KPCA - WL SSVM is proposed. Taking indoor ambient temperature, lighting conditions, utilization rate of electric facilities, etc. as the combined weight of assembled building energy consumption under multi-layer building materials system structure, the energy consumption simulation and energy consumption allocation model of assembled building under multi-layer building materials system structure controlled by multi-component energy consumption parameter support vector machine is established, and the support vector machine based on KPCA - WL SSVM and principal component analysis dynamic fitting method are adopted. The energy consumption parameters of prefabricated buildings under multi-layer building materials system structure are detected and estimated, and the energy consumption patterns, energy consumption distribution with different characteristics and energy consumption prediction model parameters of prefabricated buildings under multi-layer building materials system structure are obtained. Then, the emission factor and power consumption factor prediction model of prefabricated buildings under multi-layer building materials system structure is established, and the dynamic prediction and evaluation of energy consumption of prefabricated buildings under multi-layer building materials system structure are realized. The test results show that the fitting degree of energy consumption prediction of prefabricated buildings under multi-layer building material system structure is high, the model optimization design of energy consumption of prefabricated buildings is realized, the prediction accuracy of building energy consumption is good, and the energy consumption can be effectively reduced.

Key words: *KPCA, WL SSVM, assembled building, energy consumption modelling*

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Introduction

As an important device for indoor environment regulation, prefabricated buildings with multi-layer structural material system are indispensable in modern life. The main role of energy consumption products of prefabricated buildings with multi-layer structural material system is that in the process of inner ring temperature regulation, energy consumption control and prediction can effectively and automatically adjust indoor and outdoor dynamic environmental factors, meet the thermal comfort needs of human body and reduce energy expenditure. The prediction and control of energy consumption is particularly important in the control of prefabricated buildings under multi-layer building materials system. The prediction model of energy consumption of prefabricated buildings under multi-layer building materials system is built. By adjusting the temperature parameters and energy consumption factors, according to the thermal comfort requirements of human body, combined with the automatic control system of prefabricated buildings under multi-layer building materials system, the thermal fluctuation is reduced, while the level of automatic adjustment and control of energy consumption of prefabricated buildings under multi-layer building materials system is improved [1].

At present, in the research of energy consumption prediction of prefabricated buildings under multi-layer building materials system, the automatic prediction of energy consumption of prefabricated buildings under multi-layer building materials system is realized mainly through dynamic temperature regulation, energy consumption analysis and energy consumption prediction algorithm design, comparison of indoor thermal environment factors of prefabricated buildings under multi-layer building materials system and optimization control algorithm [2]. At present, the energy consumption prediction methods of prefabricated buildings under the multi-layer building material system structure include DBSCAN clustering algorithm analysis method, BP neural network prediction algorithm, association rule mining algorithm and K-Means clustering prediction algorithm [3-5], *etc.* Ridwana *et al*. [6], it investigates conventional regression modelling in building energy estimation and proposes three models with data classifications to improve their performance. Correlation coefficient and root mean squared error values improve noticeably for the proposed models and they can potentially be utilized for energy conservation purposes and energy savings in the buildings. Sun *et al*. [7], a design scheme of building energy consumption monitoring model based on parallel cloud computing is proposed. In this method, building energy consumption data is collected in parallel cloud computing mode, and the big data mining and characteristic extraction methods are adopted to reconstruct the building energy consumption data characteristics and fuse the parallel collected data. Correlation analysis is performed to samples of the fused data, and relevant building energy consumption data is processed with linear fitting, and then the results are output.

To solve the aforementioned problems, this paper proposes a method of energy consumption prediction of prefabricated buildings based on KPCA - WL SSVM. Firstly, it analyzes the constraint parameters of energy consumption of prefabricated buildings under multilayer building materials system, then designs the energy consumption model function of prefabricated buildings under multilayer building materials system, and adopts KPCA - WL SSVM learning to realize the energy consumption prediction and optimization of prefabricated buildings under multilayer building materials system. Finally, the experimental test analysis shows that this method has superior performance in improving the prediction accuracy of energy consumption of prefabricated buildings under the multi-story building material system structure.

Analysis of energy consumption distribution structure and energy consumption parameters of prefabricated buildings under multi-layer structural material system structure

Structural model of energy consumption distribution of prefabricated buildings under multi-layer structural material system structure

In order to predict the energy consumption of prefabricated buildings under the multi-layer building materials system, a distribution structure model of energy consumption of prefabricated buildings under the multi-layer building materials system is established by combining the method of adjusting the cooling/heating load overhead of prefabricated buildings under the multi-layer building materials system, and the load is eliminated by adjusting the air supply volume through energy allocation and load dynamic adjustment. Taking indoor ambient temperature, lighting conditions, utilization rate of electrical facilities*, etc.* as the combined weight of energy consumption of prefabricated buildings under multi-layer building materials system structure, the energy consumption simulation structure model of prefabricated buildings under multi-layer building materials system structure is established [8]. Combined with the dynamic temperature control strategy, the energy consumption threshold is analyzed by establishing the corresponding overall control model for energy consumption prediction of prefabricated buildings under multi-layer building materials system structure. Under the working condition of summer, the hourly energy consumption analysis of prefabricated buildings under the multi-layer structural material system structure is carried out, the energy consumption patterns are controlled in groups, the decision tree of energy consumption patterns is established [9, 10], and the energy consumption prediction model is built by integrating the design strategy of energy consumption analysis [11]. The overall realization technical diagram is shown in fig. 1.

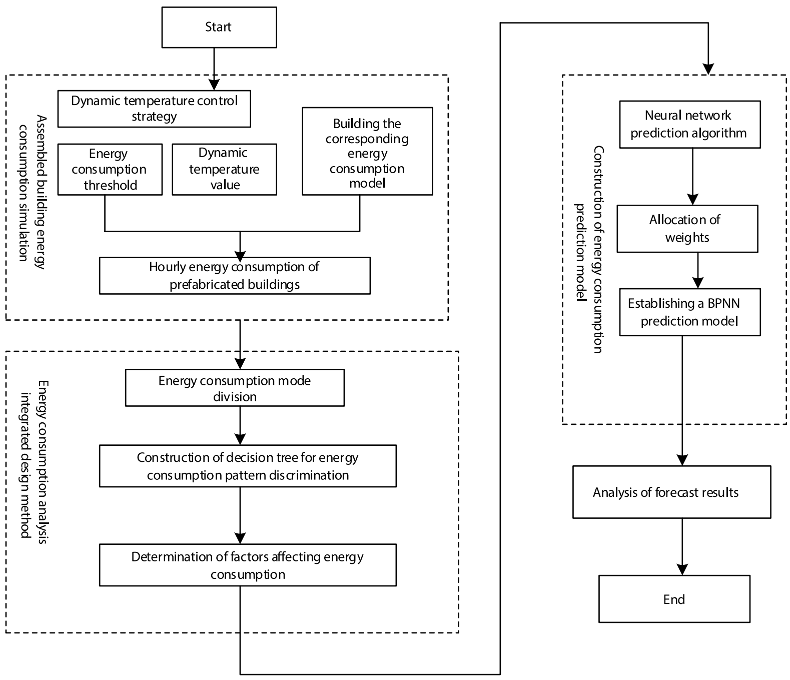


Figure 1. Technical structure diagram for energy consumption prediction of fabricated buildings under multi-layer structural material system structure

Based on the load and heat balance analysis of the energy consumption of the fabricated building under the multi-layer structural material system structure [12], the energy consumption transfer model of the fabricated building under the multi-layer structural material system structure is established as shown in fig. 2.

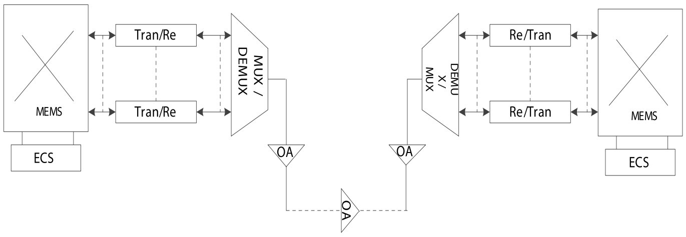


Figure 2. Energy transfer model of fabricated building under multi-layer structural material system structure

In fig. 2, the energy consumption transmission of the fabricated building system under the multi-layer structural material system structure is composed of three modules of load, system and equipment. according to the heat flux of the fabricated building distribution wall under the multi-layer structural material system structure, the heat flux in and out parameters of the inner surface of the wall are obtained, and the energy consumption of any node:

$$P_n^{\text{node}} = P^{\text{ECS}} + P^{\text{MEMS}} F \times W + \left(P^{\text{tran}} + P^{\text{Re}}\right) c_n \tag{1}$$

where P^{ECS} is the energy consumption of a unit of the system heat and cold source of the fabricated building under the multi-layer structural material system structure, P^{MEMS} – the energy consumption of a unit in the heat balance exchange matrix of the outer surface of the room, P^{tran} and P^{Re} are the transfer system of the heat transfer function and the long-wave radiation exchange flux, respectively, and c_n – the heat balance flux of the outer surface of the room. Based on the previous analysis of indoor air heat balance parameters, a multi-component energy consumption parameter support vector machine control-based energy consumption simulation and energy consumption allocation model for the fabricated building under the multi-layer structural material system structure is established, and the energy consumption allocation structure design of the fabricated building under the multi-layer structural material system structure is carried out by combining the analysis of air convection and water evaporation heat [13-15].

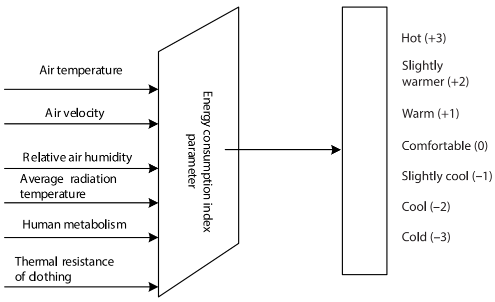


Figure 3. Corresponding relationship between energy consumption constraint parameters of fabricated building and human body sensation under multi-layer structural material system structure

Analysis of energy consumption and cost parameters

The energy consumption modelling method of the assembled building system under the multi-layer structural material system structure adopting dynamic temperature control is characterized in that according to the air temperature, the average heat radiation temperature and the external surface temperature as constraint independent variables [16-19], the temperature sensed by the human body is divided into seven indexes, namely, heat (+3), slightly warm (+2), warm (+1), comfortable (0), slightly cool (–1), cool (–2), and cold (–3), and the corresponding relationship between the energy consumption constraint parameters of the assembled building under the multi-layer structural material system structure and the human body sensation is obtained by combining the differences among individuals as shown in fig. 3.

According to fig. 3, the corresponding relationship between the energy consumption constraint parameters of the fabricated building under the multi-layer structural material system structure and the human body sensation, an energy consumption detection model for energy consumption simulation based on multi-component energy consumption parameter support vector machine control is established [20], and the dynamic temperature control output is obtained by combining the energy consumption distribution No. k on the fabricated building thermal path *ij* under the multi-layer structural material system structure under the current environment:

$$P_{ij,k} = \left(\frac{d_l}{d_{\text{span}}} - 1 \right) P^{\text{ILA}} + P^{\text{Pr}e} + P^{\text{post}} \tag{2}$$

where d_l is the maximum value of the temperature control range of a thermal path (between nodes), d_{span} – the hourly dynamic temperature set point of the fabricated building system under the multi-layer structural material system structure, which is usually set at 26 °C, and P^{ILA} and P^{post} are outdoor hourly air temperature energy consumption loss and pre-amplifier and post-amplifier energy consumption, respectively.

Based on the energy consumption simulation and dynamic control of the fabricated building system under the multi-layer structural material system structure, the temperature parameters are dynamically adjusted, and the energy consumption of one path in the thermal environment of the fabricated building room under the multi-layer structural material system structure is obtained:

$$P_{ij}^{l} = \sum_{k} P_{ij,k} \tag{3}$$

In the active state, the combined weight analysis and dynamic neural network prediction method are adopted to construct the energy consumption prediction model of the assembled building under the multi-layer structural material system structure. According to the analysis result of the energy consumption cost parameters, the weight and offset term of the energy consumption prediction of the assembled building under the multi-layer structural material system structure are obtained by adopting the temperature prediction model optimization design method [18].

Prediction and optimization of energy consumption of prefabricated buildings under layered structure material system structure

Detection and estimation of energy consumption parameters of fabricated buildings under multi-storey structural material system structure

By dynamically adjusting the indoor thermal environment time by time, a dynamic detection model of the energy consumption of the assembled building under the multi-layer structural material system structure is established. Under the type II temperature allocation, through the thermal comfort analysis of the human body, the independent co-distribution control objective function under the constraint that the thermal environment of the assembled building room under the multi-layer structural material system structure can meet the thermal comfort requirements of the human body is obtained:

$$V_{res}(r) = \frac{\sum_{i=1}^{N} \left\{ E_{res}^{r}(n_i) - E_a^{r} \right\}^2}{N} \tag{4}$$

where $E^r_{res}(n_i)$ is the hourly energy consumption of the fabricated building system under the indoor dual-channel multi-layer structural material system structure, E^r_a – the instantaneous energy consumption under the steady-state temperature control strategy, N – the number of fabricated building nodes under the multi-layer structural material system structure, at node n_i, based on the dynamic temperature control strategy, the obtained E^r_a represents the thermal control method of the fabricated building under the multi-layer structural material system structure meeting the minimum energy cost threshold condition, and the output heat loss is obtained based on the dynamic temperature control. The K-means clustering algorithm is adopted to cluster the hourly energy consumption data set, and the energy consumption output at different times is obtained by combining the construction of the objective function of energy consumption prediction:

$$E_R = \sum_{r=1}^{L_i} \sum_{n_j \in S_i^r} E_{Rx}(l) \tag{5}$$

where $E_{Rx}(l)$ is the relative distance between the energy consumption test samples, L_i – the energy consumption model partition parameter, and S^r_i – the cluster where the sample data points are partitioned to the nearest cluster center. By using the statistical decision analysis method, introducing the characteristic quantities of thermal balance in the wall, thermal balance on the inner surface of the room and thermal balance on the outer surface of the room, the dynamic pressure distribution of thermal balance in the wall is obtained:

$$E_T = \sum_{r=1}^{L_i} \sum_{n_g \in N_i^r} E_{Tx}\left[l, d_{(n_i, n_g)}\right] \tag{6}$$

where N^r_i is the cluster parameter set of the R-round super energy consumption prediction, E_{Tx} – the indoor air heat balance parameter, and $d_{(ni,ng)}$ – the ambiguity, under the action of gap flow, the load of energy consumption prediction of fabricated building under multi-layer structural material system structure is obtained:

$$E_F = \sum_{r=1}^{L_i} l_r E_{DF} \tag{7}$$

where l_r is the zero energy consumption control threshold and E_{DF} – the evolution variable of the energy consumption of the fabricated building system under the multi-layer structural material system structure, and the sum of the energy consumption expenses of the air loop, the cold and hot water loop and the cooling water loop is obtained by neural network prediction.

Wherein, E_R is the loop energy consumption of the related factors of building energy conservation, E_T is the loop energy consumption of cold and hot water, E_F is the loop energy consumption of the thermal environment of the fabricated building room under the multi-layer construction material system structure, $E_{Rx}(l)$ is the radiation heat dissipation of the thermal environment of the fabricated building room under the multi-layer construction material system structure, E_{DF} is the proportion of visible light, and E_{Tx} is the lighting power, according to the multi-phase equivalent saturation characteristic distribution of the energy consumption of the water supply system of the ultra-high-rise building, according to the aforementioned analysis. Based on the multi-component energy consumption parameter support vector machine control, the energy consumption simulation and energy consumption allocation model of the fabricated building under the multi-layer structural material system structure is established. The KPCA - WL SSVM based support vector machine and principal component analysis dynamic fitting method are adopted to realize the detection and estimation of the energy consumption parameter of the fabricated building under the multi-layer structural material system structure [21].

Building energy consumption prediction simulation

Based on the analysis of air-flow and heat resistance characteristics of materials, the energy balance state of the room heat capacity is obtained to meet $\phi C_0^\infty \in(\Omega)$ and $g'_\varepsilon = 0$, and the energy balance equation of the room heat capacity is established. Based on the sub-lattice stress tensor analysis, the energy balance characteristic quantity is obtained to be represented by $\{v_1, v_2,..., v_v\}$, and the energy information output to the room by the heating system:

$$X(C) = \sum_{k=1}^{d} \frac{|a_s|}{|E|} \times K(a_s) \tag{9}$$

where E is the indoor air heat flow rate, $K(a_s)$ – the cold air permeate heat flow rate, and a_s – the heat flow rate of the heating system. According to the output characteristics of the heat flow rate of the heating system, the heat energy consumption fluid density is obtained:

$$\Delta E = -\eta \left[\left(\frac{\partial E}{\partial \omega} \right)^2 + \left(\frac{\partial E}{\partial b} \right)^2 \right] \tag{10}$$

wherein E is the designed cold air permeability, η – the heat ratio coefficient caused by air convection and water evaporation, ω – the distribution coefficient of convective heat flow state, and b – the long-wave radiant heat flux. A hydrodynamic viscosity prediction model is established to obtain the energy consumption model, energy consumption different characteristic distribution and energy consumption prediction model parameters of the fabricated building under the multi-layer structural material system structure, and then a prediction model of emission factors and power consumption factors of the fabricated building under the multi-layer structural material system structure is established to realize dynamic prediction and evaluation of the energy consumption of the fabricated building under the multi-layer structural material system structure. The implementation flow of energy consumption prediction is shown in fig. 4.

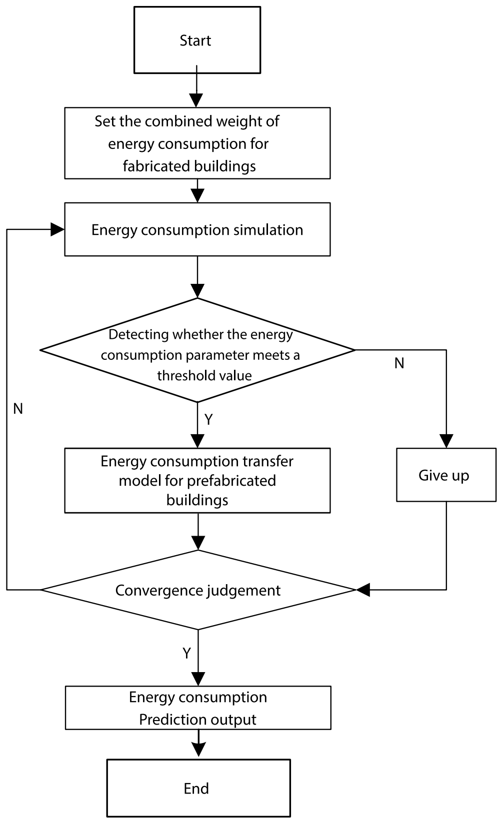


Figure 4. Implementation flow of energy consumption prediction

Simulation and test

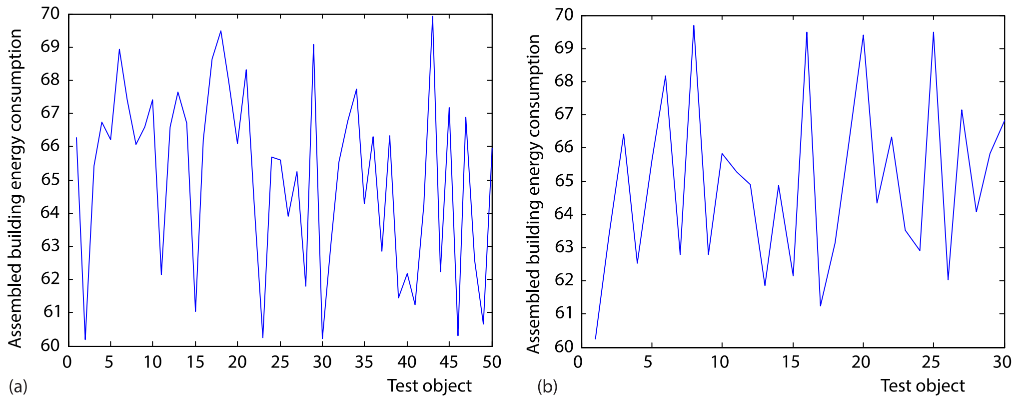
In this paper, OpenStudio software with EnergyPlus engine and good visual interface is used to analyze the building energy consumption and study the relationship between different attribute parameters of enclosure structure and building energy consumption. The shape coefficient of the building (*i.e.* the shape factor of the building) is in accordance with the relevant specifications: within 3 storeys of the building, the shape coefficient of the building shall not exceed 0.86. The number of building floors is between 4 and 12, and the building figure coefficient does not exceed 0.47. The building number is more than 12, and the building figure coefficient does not exceed 0.35. Plane size, plane shape and design height determine the building shape factor. Building width and length determine the relevant factors, therefore, at the beginning of design, the key is to control the depth and width of the building. The wider the surface, the better the building lighting, the more heat, and the better the indoor natural ventilation effect. However, the rooms of the buildings are too large and the furniture is inconvenient and unattractive. The type of building with relatively small width and large depth not only increases the density of the building, but also increases the floor area ratio. At the same time, the small width weakens the contact area between the external wall and the outdoor, resulting in better energy-saving effect. At the same time, the building should have a certain building height, which is convenient for people to demand for its use, the structural characteristics needed by the building itself, the land use rate and people's demand for air and sunshine. From an economic point of view, the height of a building is also closely related to the cost and energy consumption. The lower the height, the smaller the indoor space and the less wall materials, which reduces the construction cost and the load of heating and air conditioning. It is very important to save the energy consumption of the building. According to the relevant national codes, the height of the building should not exceed 2.8 m. Attention should be paid to control the height during the design process. Considering the common buildings in daily life, the floor height is generally about 3 m. See tab. 1 for the fitting of thermodynamic parameters such as heat conduction, air heat balance load and convective heat flux of fabricated building under multi-layer structural material system structure.

Table 1. Fitting values of thermodynamic parameters of assembled building under multi-storey structure material system structure

Model	Heat conduction pressure rating	Air heat balance load [kN]	Convective heat flux [kPa]
MH280×140	0.413	1156.468	31.132
MH200×100	0.406	420.894	35.760
MH300×200	0.387	326.248	30.471
MH500×300	0.404	157.060	30.476
MH400×200	0.411	725.710	32.011
MH300×100	0.386	99.121	31.568
MH200×200	0.401	866.207	31.796

According to the results of parameter fitting and setting of the fabricated building under the multi-layer structural material system structure in tab. 1, the energy consumption of the fabricated building under the multi-layer structural material system structure is predicted, and the time series of energy consumption of the fabricated building under the multi-layer structural material system structure is obtained as shown in fig. 5.

Based on the actual situation of the surrounding and regional locations of the built buildings, the energy consumption of the assembled building in the original energy-saving scheme is simulated by using the OpenStudio main program. The relevant settings in the software are set according to national standards, specifications and parameter boundary conditions, and the energy consumption of heating, air conditioning and total heating and air conditioning in the original energy-saving scheme is 34566.51 kWh, 6764.12 kWh, and 85384.63 kWh, respectively. The predicted results using the method and traditional PID prediction algorithm are shown in fig. 6.



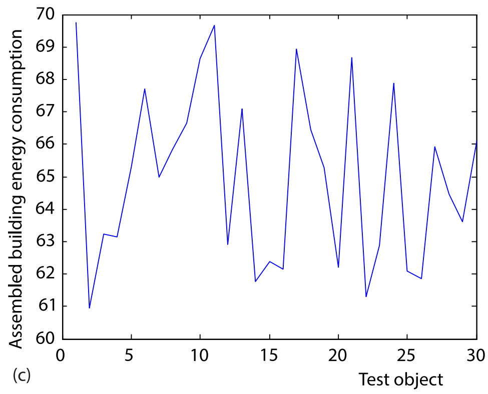


Figure 5. Time series of energy consumption of fabricated buildings under multi-storey structural material system structure; (a) Sample 1, (b) Sample 2, and (c) Sample 3

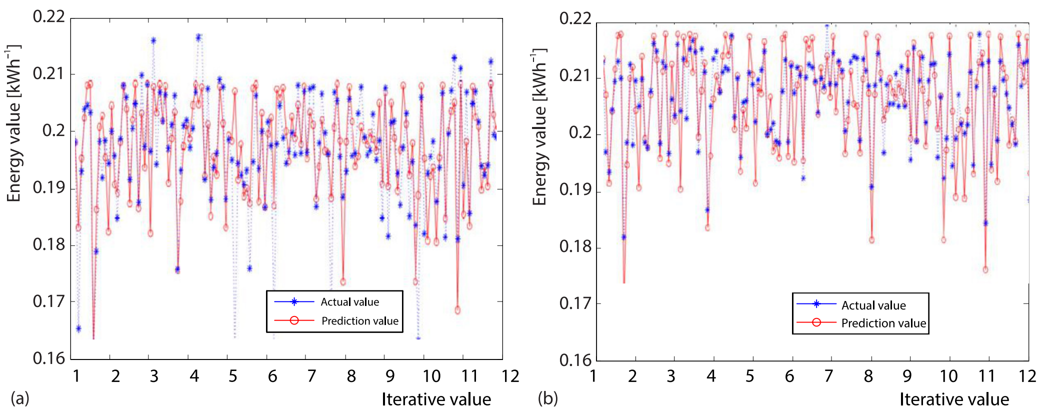


Figure 6. Energy consumption forecast results; (a) PID prediction algorithm and (b) this method

From the analysis of the previous simulation results, it can be seen that the prediction accuracy of the fabricated building system under the multi-layer building material system structure by this method is higher, which is 27.8% higher than that of the traditional method, and the convergence value of the test is shown in fig. 7.

According to the analysis of fig. 7, this method can converge to the lowest energy consumption in a short time, and improve the capacity of the prefabricated building system under the multi-layer building material system structure. The error of energy consumption pre-

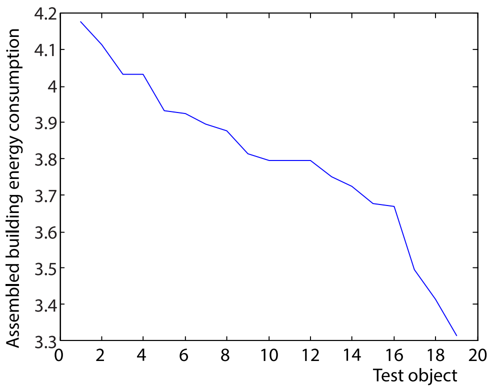


Figure 7. Prediction convergence fitting curve

diction is tested by using three different methods. The comparison results are shown in tab. 2, and the analysis of tab. 2 shows that the error of energy consumption prediction modelling by this method is small.

Table 2. Comparison of prediction errors of energy consumption

Iterative steps	This method	PID	BP
10	0.078	0.182	0.197
20	0.075	0.174	0.192
30	0.074	0.174	0.190
40	0.077	0.177	0.193
50	0.080	0.181	0.201
60	0.079	0.176	0.199
70	0.080	0.183	0.202
80	0.077	0.179	0.195
90	0.078	0.172	0.197

Conclusions

In this paper, the energy consumption prediction method of prefabricated buildings based on KPCA - WL SSVM multi-layer structural material system is proposed. Taking indoor ambient temperature, lighting conditions, utilization rate of electric facilities*, etc.* as the combined weight of assembled building energy consumption under multi-layer building materials system structure, the energy consumption simulation and energy consumption allocation model of assembled building under multi-layer building materials system structure controlled by multi-component energy consumption parameter support vector machine is established, and the support vector machine based on KPCA - WL SSVM and principal component analysis dynamic fitting method are adopted. The energy consumption parameters of prefabricated buildings under multi-layer building materials system structure are detected and estimated, and the energy consumption patterns, energy consumption distribution with different characteristics and energy consumption prediction model parameters of prefabricated buildings under multi-layer building materials system structure are obtained. Then, the emission factor and power consumption factor prediction model of prefabricated buildings under multi-layer building materials system structure is established, and the dynamic prediction and evaluation of energy consumption of prefabricated buildings under multi-layer building materials system structure are realized.

In this paper, starting from the energy-saving effect of the built prefabricated building envelope, using theoretical analysis, computer numerical simulation, reliability verification and case engineering comparison*, etc.*, the energy-saving situation of prefabricated buildings in the western Sichuan plain and the quantitative relationship between building envelope attribute factors and energy consumption are deeply studied, and a research scheme suitable for the energy-saving optimization of prefabricated buildings is provided.

- On the theoretical basis, the author first analyzed and summarized the energy-saving development and present situation of prefabricated building envelope in China, then briefly described the climate characteristics of hot summer and cold winter areas, and summarized the influence of prefabricated building envelope on energy consumption factors. This paper comprehensively analyzes the related factors affecting building energy efficiency, investigates and analyzes the built prefabricated buildings, finds out the energy-saving problems of the built buildings in combination with the national standards and relevant codes, and proposes to discuss the quantitative relationship between building energy efficiency and building envelope attribute factors on the basis of considering all regional influences.
- Comparing the analysis methods of building energy consumption based on reading, considering the complex influencing factors and many comprehensive factors, computer numerical simulation is selected for this study. Compare the advantages and disadvantages of simulation software, determine the advantages and strengths of OpenStudio software, and verify the reliability of the software.
- Before the simulation study, define the irrelevant variables of this experiment, determine the boundary conditions of the model, and briefly introduce the technical and economic indicators to determine the advantages and disadvantages of the enclosure structure and the window-wall ratio correction indicators that affect human safety and comfort.

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