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Prediction of Building Power Consumption Based on GA-WNN

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Abstract. With the continuous development of urban modernization, the power consumption of building is increasing rapidly. In the context of the basic national policy of sustainable development, energy conservation and emission reduction of building energy consumption is imperative. In this paper, the relevant influencing factors of building electricity consumption are considered comprehensively. The wavelet neural network combined with genetic algorithm is (GA-WNN) used to predict the power consumption of buildings. The experimental results show that the prediction effect and relative error of GA-WNN algorithm are better than other prediction methods. The unique advantages of the algorithm in the field of building power consumption prediction can provide a scientific basis for energy saving and consumption reduction. It can facilitate managers to formulate efficient energy management solutions to optimize resource allocation.

1. Introduction

At present, the electricity consumption of buildings accounts for a very large proportion of daily electricity consumption in cities. Large public buildings such as factories, enterprises, shopping malls and schools are strongly promoting energy conservation and emission reduction. Forecasting the power consumption of buildings can help managers to formulate economic and reasonable power consumption plans in the process of electricity use, and timely discover energy use abnormalities and control the risk of power consumption.

The power consumption of buildings is affected by many non-linear and complex factors, so it is difficult to accurately predict through general mathematical models. Prediction methods such as data statistics, causal prediction, and regression analysis are not effective in power forecasting^[1], while neural networks have great advantages in dealing with various nonlinear influencing factors, and have good abilities of self-organization, self-learning, and self-adaptation, and etc^[2]. Establishing a neural network model for influencing factors of power consumption can realize nonlinear induction of multiple influencing factors and improve the prediction accuracy of building electricity. In this paper, the wavelet neural network combined with genetic algorithm is used to predict the power consumption of buildings. Wavelet neural network can not only describe the signal characteristics in the time-frequency domain, but also shows good convergence in the training process. However, the wavelet neural network model is prone to fall into local extremum during the training process, affecting the weight distribution of the overall structure^[3]. In order to improve the prediction accuracy of the algorithm, I added a genetic algorithm to optimize the wavelet neural network. Genetic algorithm finds the global optimal solution by simulating natural selection and genetic mechanism. Genetic algorithm has strong abilities of fast global search and algorithm transplantation. It can enhance the ability of



single wavelet neural network in global optimization, avoid falling into local minimum, make the network model have fast predictive ability and good robustness. Comparing and studying the prediction effect of BP neural network, wavelet neural network and GA-WNN in the field of building power consumption, the experimental results show that GA-WNN model has better prediction effect and lower relative error.

2. Overview of common forecasting methods

Several commonly used forecasting methods of building power consumption are briefly described as follows:

(1)BP neural network. BP neural network model has a good ability to deal with nonlinear problems and is widely used in power load forecasting with multiple influencing factors. However, the disadvantage is that the algorithm is greatly affected by the initial parameters, and it is prone to over-fitting^[4].

(2)Grey prediction. According to the gray theory, the gray prediction system ignores the details of the model. The model mainly reflects the characteristics of the sample data, and does not require massive data, so that many unmeasurable factors can be avoided in the prediction of building power consumption. But the disadvantage is that it only works for a small amount of data prediction. The larger the gradation, the lower the prediction accuracy. In the prediction of building power consumption, the situation of power consumption is changeable. So the prediction effect of this method is prone to large deviation, and its universality is not strong.

(3)Wavelet neural network. The space-time sequence is analyzed by Fourier transform, and then combined with the BP neural network structure to achieve the inductive ability of nonlinear factors. Wavelet neural network has played an important role in earthquake prediction, pattern recognition, medical diagnosis and other fields. However, the disadvantage is that the choice of wavelet base and decomposition scale is very troublesome^[4].

3. GA-WNN algorithm

3.1. Wavelet neural network

Wavelet analysis theory is an extension of the Fourier analysis method. Wavelet Neural Network (WNN) is a combination of wavelet analysis theory and artificial neural network theory. In the wavelet neural network, the activation function (for example, the sigmoid function) is replaced with a wavelet basis function, and the weight and activation threshold of the corresponding input layer to the hidden layer are replaced by the expansion coefficient and the translation coefficient of the wavelet function. The core is to use the wavelet function reconstruction theory: the linear combination of the continuous wavelet basis functions formed by the mother wavelet (meeting the admissibility condition) through the expansion and translation transformation is square integrable in $L^2(\mathbb{R})$. The wavelet basis function is listed below.

$$\psi_{ab} = \frac{1}{\sqrt{a}} \psi\left(\frac{x-b}{a}\right)$$

In the formula, “a” is the expansion coefficient and “b” is the translation coefficient.

This paper selects the classical three-layer neural network structure for fitting arbitrary nonlinear curves by considering the practical application scenarios of building power consumption, the training duration of neural network, the size of network model and the prediction performance of the model. In addition, this paper mainly realizes the application of predicting single output value (i.e. power consumption) by inputting influence factors into the network model. The structure of the wavelet neural network is shown in Figure 1.

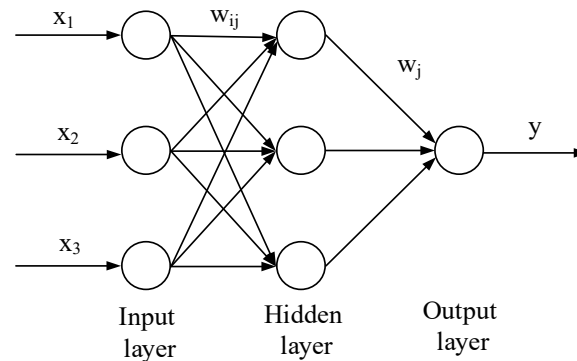


Figure 1. Wavelet neural network model structure.

In Fig. 1, x_n ($n = 1, 2, 3...$) represents the n th input information of the wavelet neural network. In this paper, n is 3. “ W_{ij} ” represents the connection weight of the input layer node and the hidden layer node. “ W_j ” represents the connection weight of the hidden layer node and the output layer node. “ y ” represents the output information of the network.

3.2. Combination of genetic algorithm and wavelet neural network

Genetic algorithm (GA) is a random search method. Its main feature is directly operating on structural objects. It adopts the probabilistic optimization method to automatically searches and acquires the global space, and adaptively adjusts the search direction to optimize the weight parameters of the neural network. The GA flow chart is displayed in Figure 2.

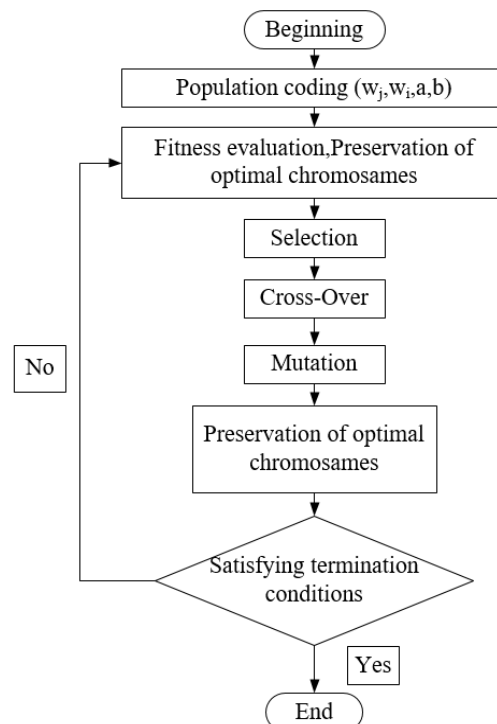


Figure 2. Genetic algorithm flow chart.

The steps of combining genetic algorithm with wavelet neural network are as follows:

(1) Coding: The four initial parameters of genetic algorithms, “ w_{ij} ”, “ w_j ”, “ a_i ”, and “ b_i ” are coded as real numbers (where “ a_i ” is the scaling factor and “ b_i ” is the translation factor of the wavelet function).

(2) Setting fitness function: $f = \frac{1}{E+1}$, where “E” is the error function.

(3) Selection: The fitness value is calculated by traversing the sample. Individuals with greater fitness are more likely to be selected.

(4) Cross-mutation: According to the performance of training data, the crossover and mutation probability are set and adjusted. Then we should re-enter the selection process.

(5) Decoding: According to the encoding mode, the obtained optimal code is decoded and reduced to each network parameter. Then the optimal solution of each parameter is obtained.

4. Prediction of building power consumption based on GA-WNN

There are many factors affecting the power consumption of buildings. In the daily use, the number of users, the average temperature and the average humidity are the main factors. In order to make the temperature and humidity data convenient for network model training, we usually normalize the temperature and humidity. In this paper, the three main influencing factors of building power consumption, namely, the number of users on the day, the normalization coefficient of the average temperature on the day, and the normalization coefficient of the average humidity on the day, are taken as the input factors of the input layer. According to the energy consumption record of a building in the past three years, the daily electricity consumption of the building is taken as a label to generate the data of the samples to be trained. The sample data format is shown in Table 1.

Table 1. Sample data caption.

Code	Number of users	Average temperature (normalized)	Average Humidity (normalized)	Daily power consumption (kWh)
1	3042	0.34	0.66	1846
2	2980	0.22	0.79	1723
3	2700	0.37	0.61	2142

Matlab is used as the experimental platform to establish GA-WNN energy consumption prediction model. The sample data is input into the network and trained. In this paper, 70% of the total data is randomly used for network training and 30% for network verification. During the training process, according to the characteristics of the building energy consumption, historical data and the prediction bias of the model, we need to appropriately adjust the training iteration number of the network model, the cross-mutation probability of the genetic algorithm, and the proportion of data used for training and verification. Through repeated comparison and verification, according to the error convergence effect, a most representative training model is selected. Through the test of the sample, the comparison curve between the predicted power consumption and the corresponding historical real power consumption is shown in Figure 3.



Figure 3. GA-WNN model prediction result graph.

In the figure, the full line TRUE represents the actual power consumption of the building on that day, and the imaginary line PREDICT represents the power consumption predicted by GA-WNN

model. The GA-WNN model selected in this paper has a high prediction accuracy, and the relative error range is 3%. The relative error figure is shown in Figure 4.

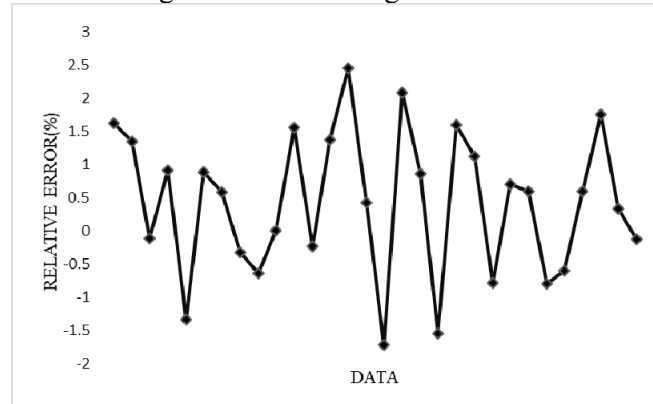


Figure 4. GA-WNN model relative error diagram.

For the same sample data, the prediction results of BP neural network and wavelet neural network are obtained and compared with the prediction results of GA-WNN. The comparison results are shown in Table 2.

Table 2. Prediction results comparison caption.

Sample number	Actual power consumption (kWh)	BP prediction result (kWh)	BP relative error (%)	WNN prediction (kWh)	WNN relative error (%)	GA-WNN prediction result (kWh)	GA-WNN relative error (%)
1	3042	3156.38	3.76	3019.49	-0.74	3035.00	-0.23
2	2980	3032.75	1.77	2800.60	-6.02	3020.83	1.37
3	3519	3394.08	-3.55	3551.37	0.92	3605.22	2.45
4	3109	3297.41	6.06	3240.51	4.23	3122.06	0.42
5	3040	2884.66	-5.11	3137.89	3.22	2957.62	-2.71
6	503	524.78	4.33	485.65	-3.45	517.49	2.88
7	477	506.05	6.09	489.59	2.64	481.10	0.86
8	3122	3346.78	7.20	3266.24	4.62	3073.61	-1.55
9	3080	2881.34	-6.45	3069.53	-0.34	3129.28	1.60
10	2700	2902.77	7.51	2816.91	4.33	2730.24	1.12
Minimum relative error \ (%)		\	1.77	\	-0.34	\	-0.23
Average relative error \ (%)		\	5.18	\	3.05	\	1.52
Maximum relative error \ (%)		\	7.51	\	-6.02	\	2.88

The prediction result graph of Figure 3 and the relative error graph of Figure 4 show that GA-WNN has excellent predictive ability in building power consumption forecasting. The comparison data of the prediction results in Table 2 shows that the average relative error of the BP neural network prediction model is about 5%, and the average relative error of the wavelet neural network prediction model is about 3%, while the GA-WNN prediction model is significantly lower than the previous two methods, which is reduced to about 1.5%. The result indicates that the GA-WNN neural network algorithm has higher prediction accuracy and better prediction effect of building power consumption.

5. Conclusion

In view of the problems of multiple non-linear influencing factors and difficulty in power consumption prediction, the GA-WNN adopted in this paper combines the advantages of genetic algorithm to find the global optimal solution and the advantages of WNN self-learning and self-adaptation, and it overcomes the limitation that the network is easy to fall into local minimum, then achieves a good prediction effect in building power consumption. Compared with other prediction methods listed in this paper, the experimental data confirms that GA-WNN has more advantages in predicting building power consumption, which can better provide decision-making basis for enterprise management and reference for energy saving and consumption reduction.

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