Application of Neural Network Optimized by Mind Evolutionary Computation in Building Energy Prediction

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Abstract. Building Energy forecasting plays an important role in energy management and plan. Using mind evolutionary algorithm to find the optimal network weights and threshold, to optimize the BP neural network, can overcome the problem of the BP neural network into a local minimum point. The optimized network is used for time series prediction, and the same month forecast, to get two predictive values. Then two kinds of predictive values are put into neural network, to get the final forecast value. The effectiveness of the method was verified by experiment with the energy value of three buildings in Hefei.

1. Introduction

To predict building energy consumption, and improving the short-term power load forecasting accuracy, is useful to make electricity plans, to analyze energy saving, to determine power load in advance and to improve the security of power. For buildings with automatic meter reading system, energy consumption hour by hour can be predicted. But at present, automatic meter reading systems are not installed in many buildings, and only electricity meters are read monthly, therefore monthly electricity forecast is still important[1-3].

As the time of learning and training of neural network is long, it is easy to get into local minimum point and cannot modify all parameters of the whole situation, the prediction results are not good[4-7].

BP neural network is optimized by using the algorithm of thinking optimization, and we combine two forecasting methods. The advantage of the thought evolution algorithm is that it has high overall search efficiency and obtains the global optimal solution using the evaluation function. The neural network optimal network weight value and corresponding node threshold can be determined by the thought evolution algorithm.

2. Programming based on mind evolution algorithm

In this paper, two methods are used to predict energy consumption, and the predicted value is imported into the network for training, as shown in FIG. 2-2. A forecasting method is month by month forecast. Electricity energy consumption values of the each month in accordance with the time sequence arrangement first. Then using the first three months of the energy consumption values, the number of persons in the building, the maximum and minimum temperature of this month, energy consumption of this month is predicted. Staff features are relatively fixed in similar month. Another method is the
same month forecast, using energy values in the previous few years. The advantage of this method is that the energy consumption of the same month has the characteristics of seasonal variation. For example, at winter and summer, air conditioning is usually used for heating and cooling, so the energy consumption is increased at these seasons.

Two predictions are made through the mind evolutionary algorithm to optimize neural network to complete, predictive value and error value of the two methods are input into neural network optimized by mind evolutionary algorithm to get final predicted value.

Electricity consumption of some three office buildings is recorded in Hefei area for five years. The statistics include data on monthly energy consumption for nearly five years, the number of people entering and leaving buildings, the average maximum temperature and minimum temperature per month. The same month data is placed on the same line as the monthly forecast method. For the month-to-month prediction method, the data of each month is arranged in chronological order. The data of the first 3 months, persons’ number in and out of the building, and the monthly highest and lowest temperature are put in the same line. And then we go to normalization and convert it to the absolute value less than 1.

According to the predicted data characteristics, the number of network nodes and transfer functions of neural networks are determined. Set learning rate, error, and number of steps. According to the direction of reducing error of network output and actual output, the weight and threshold should be fixed step by step[8].

Output layer weight adjustment formula is as follow:

\[
\Delta w_{lk} = \eta \sum_{p=1}^{r} \sum_{k=1}^{L} (T_p^k - o_p^k) \cdot \psi'(net_k) \cdot y_i ~~~~~(2-1)
\]

Output layer threshold adjustment formula is as follow:

\[
\Delta a_k = \eta \sum_{p=1}^{r} (T_p^k - o_p^k) \cdot \psi'(net_k) ~~~~~(2-2)
\]

Implicit layer weight adjustment formula is as follow:

\[
\Delta w_{ij} = \eta \sum_{p=1}^{r} \sum_{k=1}^{L} (T_p^k - o_p^k) \cdot \psi'(net_k) \cdot w_{lk} \cdot \phi'(net_i) \cdot x_j ~~~~~(2-3)
\]

Implicit threshold adjustment formula is as follow:

\[
\Delta \theta_i = \eta \sum_{p=1}^{r} \sum_{k=1}^{L} (T_p^k - o_p^k) \cdot \psi'(net_k) \cdot w_{lk} \cdot \phi'(net_i) ~~~~~(2-4)
\]

The \( \eta \) represents the learning rate, \( x_j \) represents the input variable, \( y_i \) represents the implicit layer output, \( net_k \) represents the input of the output layer, and \( o_k \) represents the output of the output layer.

In this case, according to the test, when the number of neurons used in the implicit layer is less than 5, the mean square root error is small, so the number of neurons in the design is set as 5.

| Table 2-1 | the relationship between the number of hidden neurons, steps and the root mean square error |
|-----------|-----------------------------------------------|
| the number of hidden neurons | 3   | 4   | 5   | 6   | 7   |
| step number     | 12  | 12  | 9   | 11  | 17  |
| root mean square error | 0.5507 | 0.9386 | 0.4226 | 0.5107 | 0.5508 |

The main process of mind evolutionary algorithm to optimize the BP neural network is as shown in figure 2-2: sample preprocessing, normalized, into the value whose absolute value is less than 1, is input to the network whose weights and threshold generated randomly. If the error is less than or equal to the value, we can save the network; If the error is greater than the allowable value, the learning
parameters are adjusted, convergence and foreignization operation are made to calculate the adaptive value, and the weight and threshold value with high score are used for neural network.

(1) Generation of initial group
In the solution space, P individuals are randomly generated as a group. The structural information of the neural network mainly includes the number of middle layers and the number of neurons in the middle layer. The score of the neurons in the middle layer can be calculated using the fitness function.

(2) Generation of subgroups
The inverse of the mean square error between the target value T and the actual output O is recorded as the score of the thought evolution algorithm. Each individual's score is calculated, from high to low arrangement, and then select the first M + T individual as a superior, so each child group number is P/(M + T). Set the population size as 300, child population winning number as 5, temporary population number as 5, and the group size as 30.

(3) Convergence operation
The individual with high scores is set as the center, and subgroup is formed in the normal distribution. In the convergence process, within each subgroup, the superior individual becomes the winner of the subgroup. If the individual of the winner no longer changes, it indicates that the subgroup has evolved and matured.

(4) Alienation operation
In the process of alienation, the subgroups compete for the global winners of the space. The temporary subgroups with high score will be the new winners; Temporary subgroups with low scores will abandon the individuals and are released into the entire solution space.

(5) Convergence discrimination in the algorithm of mind evolution
Check whether the convergence condition of the maximum iterations is satisfied, and if it is not satisfied, return the third and fourth steps to continue operations until the condition is met[9-11].

In this design, comprehensive prediction algorithm is used, and the general idea is shown in figure 2-1. Using optimization algorithm for prediction in the same month, and forecasting month by month, first six months of electricity energy consumption values are get. The power consumption of the two methods show value as input quantity, the actual value as output, the neural network is trained. In the forecast, the energy consumption values of these two methods are input into the network, and the final energy consumption value of the next six months will be obtained.

![Figure 2-1. structure diagram of comprehensive prediction system](image-url)
3. Analysis of Calculation Results
The total error is used to evaluate the algorithm. The sum of absolute values of each relative error is defined as the total error of the algorithm. Using the BP neural network with the same month forecast method, using the weather data and personnel data, the relative prediction error of electricity consumption forecast of office buildings 1, is 0.994035. Using optimization algorithms and month by month forecast method, using the weather data, and personnel data, the results of the relative error is 0.59737.

Using the optimization algorithm and the same month prediction method, the relative error is 0.62939. The overall accuracy is higher than the monthly prediction method, but some months’ forecasted values have a large error.

Using the comprehensive prediction method, the relative error is 0.29097, which can further reduce the error. The calculation errors of various forecasting methods are shown in table 3-1. The error of various prediction methods can be compared with the bar chart, which is more intuitive, as shown in Fig.3-1. The actual energy consumption of the three buildings in the last six months and the prediction of energy consumption are shown in the line chart, as shown in Fig. 3-2. It can be seen that compared with the monthly forecast and the same month prediction algorithm, the error of comprehensive prediction algorithm is small. For Fig. 3-2 (b), the second building uses new equipment during the seasonal replacement. The electricity situation changed greatly, so the monthly prediction method has a great error.

Table 3-1. Error comparison of prediction method

| months | errors of BP neural network (%) | errors of the same month prediction method (%) | errors of monthly prediction method (%) | errors of comprehensive prediction method (%) |
|--------|--------------------------------|-----------------------------------------------|----------------------------------------|---------------------------------------------|
| 1      | 25.67545                       | 12.57155                                      | 13.81114                               | -8.59014                                   |
| 2      | 18.28229                       | 12.61377                                      | 8.797651                               | -13.5028                                   |
| 3      | 11.23118                       | -1.81442                                      | 2.626645                               | -2.10697                                   |
| 4      | -18.8261                       | 6.893049                                      | 25.48743                               | 4.548805                                   |
| 5      | -23.8989                       | -15.7389                                      | 6.769985                               | 0.234335                                   |
| 6      | 1.489553                       | -10.1053                                      | 5.446173                               | -0.11398                                   |
From the prediction results, some monthly prediction error is small, some monthly prediction error is small, and the overall error of the comprehensive prediction method is the smallest.

![Error comparison of several prediction algorithms](image)

**Figure 3-1.** Error comparison of several prediction algorithms
Figure 3-2. Actual energy consumption and prediction energy consumption

4. Conclusion
This paper uses the neural network optimized by mind evolution algorithm to predict the electrical energy, which is more accurate and has less iterative step than neural network prediction. Selecting the average maximum temperature, average minimum temperature and personnel data as the characteristic quantity is helpful to improve the network prediction accuracy. Using comprehensive prediction method combining by two monthly electricity consumption forecast ways, makes up for their shortcomings, and further improves the prediction accuracy. It’s applied widely, and is worth using for daily consumption forecast in building and industrial power. However, the activity characteristics and behavior of personnel have great influence on energy consumption of building energy, which needs to be further studied.

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