Back propagation neural network rainfall prediction model based on particle swarm optimization

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Abstract. It is a feasible method to use neural network construction to predict rainfall in the region. However, the error of this method is bigger, and its error is from the neural network structure itself. In view of the problem that the rainfall prediction precision based on BP neural network construction is low, this thesis proposes to optimize BP neural network rainfall prediction model with particle swarm optimization (PSO) algorithm, and then use the same training samples and testing samples to conduct a simulation experiment to the forecast model before and after optimization. The results show that the experimental testing result of the forecast model after optimization is more in line with the actual value.

Keywords: Rainfall, BP neural network, Particle swarm optimization algorithm, Prediction model.

1. Introduction
The size of rainfall is closely related to agricultural production, and its quantitative value is an important indicator measuring regional degree of drought. Too little rainfall will bring drought, but too much rainfall will bring floods. If the rainfall can be more scientifically and accurately predicted, the government’s functional departments involved in agriculture, forestry and water can prepare well in advance to formulate drought-resistant measures of preventing waterlogging, improve the ability of dealing with natural disasters, and reduce disaster losses to a minimum. Therefore, it is of great significance to study the rainfall forecast and how to improve the prediction accuracy [1].

Traditional prediction methods are divided into two categories, namely, probabilistic method [2-6] and time series prediction method [7-10], which are mainly used to solve linear problem, but the traditional methods for nonlinear problems are not easy to reveal their laws. BP (back propagation) neural network is introduced and rainfall forecast model is constructed by using BP neural network. Because the factor affecting BP neural network is its weights and threshold values rather than a specific formula (model), the forecast model constructed by using BP neural network to predict the natural phenomena such as rainfall is a typical nonlinear prediction model, and the model itself avoids the effect of man-made parameters. Meanwhile, the prediction results depend on objective historical data, so it can more truly reflect the essence of natural phenomenon and its internal relations. However, the existing prediction models based on BP neural network (BPNN) have a number of problems, such as low prediction accuracy and large error, so in view of the above problems, this thesis puts forward a method of optimizing the prediction model, namely, particle swarm optimization (PSO) algorithm, and builds
BP neural network model based on PSO algorithm (PSO - BPNN) to forecast rainfall. Then, through optimizing the weights and threshold values of BP neural network, the stability and robustness and prediction accuracy of the prediction model are improved.

2. Prediction principle and model optimization

2.1. Particle swarm optimization

The basic idea of particle swarm optimization (PSO) is to find the optimum solution through the collaboration and information sharing between individuals in the group, and it is a typical group intelligent search optimization algorithm. According to the basic idea, it can be known that each particle’s search behavior would be affected by other particles’ search behavior. The updating formula of the algorithm is as follows:

\[
\begin{align*}
  v_{id}(t+1) &= \omega v_{id}(t) + c_1 r_1 (p_{id}(t) - x_{id}(t)) + c_2 r_2 (p_{gd} - x_{id}(t)) \\
  x_{id}(t+1) &= x_{id}(t) + v_{id}(t+1)
\end{align*}
\]  

In this formula, and are a acceleration constant, which is between 0 and 2, and are a random number, and is a weight factor.

2.2. Prediction principle

In general, rainfall prediction models are constructed by means of selecting prediction methods. The prediction method used in this paper is that the data of the fifth consecutive year is used as the independent variable, and the data of the 6th year is used as the function (result), and so on. The mathematical formula is described below.

\[
y = f(x_1, x_2, x_3, x_4, x_5)
\]  

In this formula, are input values, and y is the prediction value of rainfall, and f is the predicted mathematical model. Based on the rainfall prediction model constructed according to formula (2), the number of input nodes is 5 (inputnum=5), and the number of output nodes is 1 (outputnum=1).

2.3. Use particle swarm optimization to optimize BP neural network rainfall prediction model

Using particle swarm optimization to optimize BP neural network rainfall prediction model is divided into: determination of BP prediction model structure, using particle swarm optimization (PSO) to optimize and predict BP neural network rainfall prediction model.

First of all, the network structure is determined according to the number of nodes of the prediction model’s input layer, output layer and hidden layer, and then the weight values and threshold values of the forecast model are lined in a proper order to form the coordinate of n-dimensional spacial points, and get a reversible mapping F from predictive model to n-dimensional space. The individual in particle swarm algorithm is the coordinates of n-dimensional spacial points, and the particle swarm algorithm realizes the optimization of weights and threshold of BP neural network through reversible mapping F, namely, the optimization of prediction model. Each individual in the swarm corresponds to all weights and thresholds of a group of prediction models, every individual uses fitness function to calculate the corresponding fitness value, and then finds the best matched individual through the best fitness value.
3. Simulation experiment
Prediction principle and model optimization

3.1. Experimental data
The simulation experimental data of this paper is from the average rainfall of a region from 1951 to 2015 (unit: mm). The data sequence in the table is divided into two parts: training samples and test samples. The rainfall data from 1951 to 2000 is used as training samples, and the rainfall data from 2001 to 2010 is used as test samples. The validity of BP-PSO prediction model is verified through two parts of data.

In order to improve the operating efficiency of simulation program in Matlab environment, the original data in Table 1 is pre-processed according to Formula (2), namely, the original data is transformed into the data matrix which can be directly called by Matlab. Method is as follows: the data of first five years is used as the independent variable, and the data of the sixth year is used as its function (results), constituting a matrix of six lines and 60 columns, the column number is from 1 to 60. Each column is a set of experimental data, and the first five rows of each group of data are the values of independent variables, and the sixth row is the corresponding function values (results). The training data and prediction data of the forecasting model are obtained by using the above method, as shown in Table 1.

|     | 1   | 2   | 3   | 4   | 5    | ...... | 60   |
|-----|-----|-----|-----|-----|------|-------|------|
| 1   | 1640.5 | 1213.4 | 1305.0 | 1015.5 | 1104.8 | ...... | 1376.9 |
| 2   | 1213.4 | 1305.0 | 1015.5 | 1104.8 | 1101.0 | ...... | 1252.9 |
| 3   | 1305.0 | 1015.5 | 1104.8 | 1101.0 | 1243.9 | ...... | 1086.8 |
| 4   | 1015.5 | 1104.8 | 1101.0 | 1243.9 | 1063.8 | ...... | 1569.3 |
| 5   | 1104.8 | 1101.0 | 1243.9 | 1063.8 | 1624.9 | ...... | 1234.7 |
| 60  | 1101.0 | 1243.9 | 1063.8 | 1624.9 | 1235.0 | ...... | 1222.3 |

3.2. Experimental results
The training samples and test samples are simulated in BPNN prediction model and BP-PSONN prediction model respectively, and the following experimental results are obtained.

![Figure 1. Actual values, BPNN and PSO-BPNN test output chart](image-url)
4. Discussion
Figure 1 shows the test output results of BPNN and PSO - BPNN. Through comparing the test results with actual values of 10 group of data of the two prediction models (actual average annual rainfall from 2006 to 2015), it can be seen that the prediction results of PSO - BPNN model are more highly in line with its actual values, that is, the prediction results of BPNN model optimized by PSO are more close to the real rainfall capacity than BPNN model, indicating that PSO - BPNN forecast model is more suitable for the prediction of regional annual rainfall capacity.

Figure 2 shows the statistical error of test results of BPNN and PSO - BPNN, and it can be seen from Figure 2: using PSO - BPNN forecast model to forecast 10 groups of test data, the error value of the prediction results output by eight groups of tests is less than the output error of BPNN.

It can be seen from Table 2 that the average error of BPNN model is 22.24%, and the average error of PSO_BPNN prediction model is 14.28%, so the average error value of PSO_BPNN prediction model is significantly less than that of BPNN model.

5. Conclusions and Future Work
As discussed above, the error rate of PSO-BPNN prediction model is relatively stable, and PSO-BPNN prediction model has better prediction performance and more accurate prediction results than basic BP prediction model.
PSO algorithm is a typical meta-model swarm intelligent algorithm. In recent years, the swarm intelligence algorithm has developed greatly in theory and application. At present, the research focuses are ant colony algorithm, monkey algorithm, fish swarm algorithm, fire insect algorithm, etc. Next, we will use the above hot algorithms to optimize BP rainfall forecast models, so as to find a better and more excellent solution to improve the model’s prediction precision and find a new way for improving rainfall prediction accuracy.

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