Application of Improved Particle-Swarm-Optimization Neural Network in Coalmine Safety Evaluation

HE Rongjun [1], DU Yunhang [2]

[1]ChongQing Vocational Institute of Engineering, ChongQing 402260, China

[2]YunNan Vocational Institute of Energy Technology, YunNan 655001, China

E-mail: rongjunh@163.com

Abstract. Based on the principle of improved particle-swarm-optimization neural network, a comprehensive evaluation model is established by taking into account the various indexes of coal mine safety evaluation. The method is based on neural networks, and uses improved particle-swarm-optimization to find the optimal balance weight, and improves the convergence speed and accuracy of the neural network. Practice has proved that the model has the ability of global optimization of the improved particle swarm optimization algorithm and the extensive mapping ability of the neural network. It has a strong prediction ability and provides an important way for coal mine safety evaluation.

1. Introduction

The purpose of safety evaluation is to realize the whole process control, establish the optimal decision plan, improve the essential security of the system, and realize the scientific technology and management of safety[1]. Coal mine is a complex system coexisting with many factors[2], including artificial, mechanical and natural environment. At present, the application of safety evaluation method to coal mine has been paid great attention to. It is of great significance [3] to identify and eliminate the hidden danger of coal mine safety and improve the status of safety production management in coal mine.

At present, the commonly used methods of coal mine safety evaluation include safety inspection table, accident analysis method, index evaluation method and fuzzy comprehensive evaluation method[4], etc. However, because these methods have some limitations in practical applications[5], cannot play a better evaluation effect. In order to choose more effective evaluation method, the improved particle-neural-network is applied to the coal mine safety evaluation. This method can overcome the shortcomings of the traditional coal mine safety evaluation method, and the scientific security evaluation results can be quickly obtained to overcome the problems of the traditional BP neural network, such as slow training speed and easy to fall into the local minimum point [6].

2. Neural network and improved particle swarm optimization

2.1. BP neural network

BP neural network [7] is a widely used neural network model at present. The structure of BP neural network is divided into input layer, output layer and hidden layer. The whole connection is used between layers and layers, as shown in Figure 1.
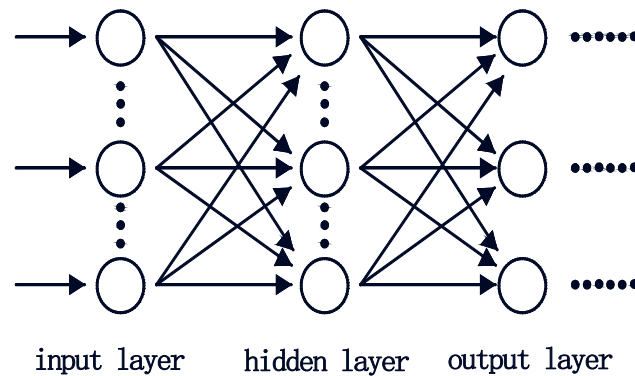
Figure 1. Three layer BP neural network

BP neural network is divided into two processes: forward and backward transmission. The first process is the forward transmission of signals, and the second process is the error of backward transmission. When the signal is forward, the input layer is input into the sample information, and the hidden layer (single layer or multilayer) is processed and transmitted to the output layer to complete forward propagation learning. The error reverse transfer is the actual output layer and the expected output is not required to be transferred to the process. The error gradient is used to output the error, then return forward, and transfer the error to the neural unit of the input layer, which change the weight of the front layer. In this way, weights are adjusted repeatedly, that is, the whole learning and training process of BP neural network. This process, until the output error of the network is less than the allowable value, or achieves the set learning times, has the appropriate network connection value, and establishes the nonlinear image for the new sample. Practice has proved that BP neural network has high fidelity and nonlinear mapping ability.

2.2. Improved particle swarm optimization (PSO) algorithm

Particle swarm optimization[8], abbreviated as PSO, is a new evolutionary algorithm. It is similar to genetic algorithm. Based on random solution, the iterative method is used to find the best solution. The fitness is used to evaluate the quality of the solution. However, it is different from the genetic algorithm. The rule of PSO is simpler, and the "cross" and "mutation" operations are eliminated directly, and the global optimization can be achieved through the optimal solution of the current search.

Inertia weight, as the most important parameter in adjustable parameters, directly affects the balance between global and local search ability of algorithm accuracy. In order to find the best balance weight of inertia, we need to improve PSO. We choose the nonlinear decreasing weight strategy [9]. After testing, the improved PSO algorithm can speed up the decrease of the inertia weight in the early stage, make it enter the local search as soon as possible, and improve the training precision of the later particle swarm optimization.

2.3. Training of BP neural network based on improved PSO

In the process of practical application, the reverse transfer speed of BP neural network is slow, and it is easy to fall into the local point, and the improved PSO algorithm has the characteristics of fast training speed, small error and strong global search ability. Therefore, the improved PSO algorithm and the BP neural network can be combined, and the improved PSO algorithm is used to optimize the BP neural network of the connection weights of each layer. It can completely overcome the shortcomings of the BP neural network and improve the learning ability of the BP neural network [10].

The detailed procedure of optimizing neural network weights based on improved PSO is as follows:

The first step is the initialization of the particle swarm parameters. The parameters include BP neural network topology, error limits, and the maximum number of iterations.

The second step is to train the BP neural network and evaluate the particles. Each individual's corresponding neural network is trained to train the training samples, and the weights of each component in the neural network are mapped and the weights of the neural network are iteratively optimized. In the process of weight optimization, each training needs the classification of a given sample set to ensure that the training set used in each training is different. In order to ensure the training neural network has a strong generalization processing model, in the practical application process, most of the samples can be used as the training set, and a few samples are used as the test set. The mean square error E generated by each network in the training set is calculated, and the fitness function $f(x)$ is used as the objective function to calculate the fitness of the individual. The formula is as follows:

$$E(X_p) = \frac{1}{2n}\sum_{p=1}^{n}\sum_{k=0}^{c}\left(Y_{K,P}(X_P) - t_{k,p}\right) \qquad (1)$$

$$f(x) = \frac{1}{1 + E(X)} \qquad (2)$$

Among them, $t_{k,p}$ refers to the set output of training sample P at the output of K.

We evaluate all the individuals in the particle swarm (each particle is a flying particle), and find the best individual to determine whether the particle needs updating. A single particle is updated based on particle swarm optimization algorithm to update the speed of a single particle.

The third step is the termination condition of the algorithm. When the target function value is less than the set value, the algorithm terminates.

3. Coal mine safety evaluation model and algorithm

3.1. Coal mine safety evaluation based on improved PSO-BP neural network
The improved PSO has strong global optimization capability and is not interfered by other factors. Based on the improved PSO-BP neural network, it can make full use of the generalization mapping ability of the neural network, and can get the result quickly and accurately in the case of multiple and complicated samples. The idea of establishing a coal mine safety evaluation model which is fuzzy in the collected data is established to improve the input and output of BP neural network and the weight of particle swarm optimization (PSO) to optimize the BP neural network. It avoids the problem solution that the random network of the initial weights of the neural network can easily fall into the local optimal problem, thus establishing the nonlinear mapping relationship between coal mine safety evaluation index and evaluation grade. The concrete safety evaluation model of coal mine is composed of ten safety evaluation indexes, five safety evaluation grades in the output layer and hidden layer in the middle layer, thus the neural network model is established.

3.2. Concrete algorithm of coal mine safety evaluation model
The algorithm set up the coal mine safety evaluation model first determines the least square as the objective function, and then through the evaluation index of the mine site, the sample set of the BP neural network is obtained, the neural network is learned, and the improved particle swarm optimization algorithm is used to optimize the weight coefficient of the neural network, and the coal mine safety evaluation index and the nonlinear mapping relation of the evaluation grade are established, and the coal mine safety evaluation model is obtained.

4. Application examples
Based on the measured data of the Huangling area in Shanxi, the quantitative evaluation index system is formulated.The input layer of the coal mine safety evaluation model is ten safety evaluation indexes [11], including the roof (relative coefficient) X_1, the geological structure (relative coefficient) X_2, the coal seam thickness X_3, the coal seam dip X_4, the mining depth X_5, the mine average water flow X_6, the mine gas emission X_7, the natural ignition X_8, the coal quality volatilization X_9, and the depth X_{10} with

the impact ground pressure. Among them, eight mine data as training samples ($Y_1 \sim Y_8$), two mines as inspection samples ($C_1 \sim C_2$), a total of ten sets of sample data. The output layer of the evaluation model is five security evaluation levels, of which *I* level (00001) corresponds to "safety", *II* (00010) corresponds to "safer", *III* level (00100) corresponds to "general safety", *IV* level (01000) corresponds to "unsafe", and *V* level (10000) corresponds to "very unsafe". Programming in MATLAB environment, the model's sample data and prediction results are shown in Table 1.

Table 1. Sample data and prediction results

Safety evaluation index	X_1	X_2	X_3 /m	X_4 /°	X_5 /m	X_6 / (m³.h⁻¹)	X_7 / (m³.t⁻¹)	X_8	X_9	X_{10}	Safety evaluation grade	
											Real value	Predicted value
Training sample												
Y_1	1	1	2.8	12.0	95	165	2.6	14	10.0	300	00001	0 0 0.0011 0.0056 0.9913
Y_2	3	3	3.7	18.0	125	280	7.2	10	14.6	410	00010	0 0 0.0035 0.9970 0.0108
Y_3	4	1	2.5	5.0	463	154	6.21	13	31.7	540	00010	0 0 0.0023 0.9891 0.0025
Y_4	6	6	4.6	32.0	285	615	12.0	8	23.2	510	00100	0 0.0015 0.9991 0.0041 0
Y_5	9	9	11.6	60.0	540	980	28.0	5	48.0	700	10000	0.9955 0.0063 0.0105 0 0
Y_6	8	8	6.2	48.0	395	920	18.5	7	31.0	615	01000	0.0108 0.9975 0.0025 0 0
Y_7	7	3	3.2	20.0	410	400	4.55	6	28.0	500	00100	0 0.0006 0.9878 0.0012 0
Y_8	5	5	4.2	28.0	380	900	21.0	6	32.0	605	01000	0.0051 0.9910 0.0046 0 0
Test sample												
C_1	6	3	3.2	24.0	450	460	4.8	6	26.0	550	00100	0 0.0019 0.9893 0.0102 0
C_2	4	1	2.65	4.5	446	150	6.15	14	30.0	545	00010	0 0 0.0015 0.9921 0.0007

It can be seen from the above table that the predicted values of the coal mine safety evaluation model based on the improved particle swarm neural network are all consistent with the real values, which further verify the expected effect of the coal mine safety evaluation method and ensure the accuracy of the model.

5. Conclusions
The improved PSO algorithm has the advantages of good performance, high global accuracy and fast training speed. This method is applied to the safety evaluation of coal mine. The method is reliable and meets the requirements of coal mine safety evaluation. It has the advantages of simple operation and strong adaptability in practical application, which provides an important way for the safety evaluation of coal mine.

As a potential neural network training method, improved PSO algorithm will be applied in more fields. In addition, indicators for coal mine safety evaluation can be further studied.

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