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Fault Diagnosis of Coal Mine Equipment Based on Improved GA Optimized BP Neural Network

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Abstract

In the face of more and more faults in coal mine equipment, this paper presents the method of combining genetic algorithm (GA) and BP neural network to predict the failure. According to genetic algorithm has a very slow convergence speed, easy to fall into local optimum, this paper uses chaos and reverse individual learning initialization, followed by the use of differential algorithm to operate on the optimal individual. Finally, the improved fitness function is applied to the selection operation, and the accuracy of operation is improved by mutation probability and crossover probability. The improved algorithm is applied to the BP neural network to improve the training effect. The simulation results show that the proposed algorithm improves the accuracy and stability compared to the traditional BP neural network.

Keywords*: Genetic Algorithm, BP Neural Network, Mutation Probability, Crossover Probability*

1.Introduction

Along with in recent years the rapid development of the national economy, the social demand for coal resources is increasing and the quality of coal mine equipment is related to an important part of the coal resources mining, especially frequent coal equipment fault will seriously influence the quality of coal mining. How to better diagnose the fault of the coal mine equipment has become one of the hot spots in the current research. Literature [2] proposed energy operator algorithm is combined with peak energy and resonance demodulation fault analysis method, and to mine water pump as an example, on time domain vibration signal envelope, demodulation draw the waveform of frequency that the peak energy of the vibration signal spectrum and spectral characteristics of frequency and fault about can be used to predict the coal mine electrical and mechanical equipment fault state and type, prevention and repair of mine electromechanical equipment health management plan; In order to make the support vector machine get better classification performance in the fault diagnosis of the pump, the differential evolution algorithm is applied to the optimization of the support vector machine in literature [3]; The principle of differential evolution algorithm is analyzed, and the model of pump fault diagnosis based on support vector machine model is constructed. The engineering practice shows that the differential evolution algorithm proposed by the author has a good diagnostic effect on the fault diagnosis method of the support vector machine; Literature [4] proposed based on expert system and artificial neural network fault diagnosis of mechanical equipment system, the system first of all be able to accurate positioning of mechanical equipment fault. Secondly, through the expert system to put forward solutions to fault; In this paper, the characteristics of each fault in the vibration signal with specific frequency components are proposed, and the vibration signals collected by wavelet transform to reduce the noise and extract the characteristic frequency of the literature [5]. Experimental results show

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that this fault diagnosis method is of high accuracy and short time; A BP neural network based on optimal weights of the literature [6] neural network is proposed in this paper. It is proved that the method has faster convergence speed and higher diagnostic accuracy by the example of distribution network, and has good application prospects; Literature [7] proposed using wavelet packet decomposition technology and equipment of coal mine fan signal of each frequency band energy feature extraction, BP neural network as input feature vector is constructed. And with the help of mine fan fault diagnosis on the LabVIEW platform; Literature [8] analysis under heavy load and variable load under the condition of failure mechanism and bearing of coal mine motor equipment of weak fault signal characteristics and structure matching signal scale adaptive lifting wavelet transform, the vibration signal of more sophisticated analysis, coal mine motor bearing fault online monitoring and intelligent fault diagnosis is realized. A BP neural network based on RLS algorithm is proposed to detect the fault of mine ventilation system; The structure of BP neural network is introduced in this paper. The RLS learning algorithm and simulation process are introduced in detail. The simulation results show that the BP neural network based on RLS algorithm can meet the requirements of mine ventilation system fault detection.

BP neural network is one of the rapid development of artificial intelligence technology in recent years. It has a great number of adaptive learning ability, and has a wide range of applications in solving nonlinear problems. But BP neural network has some limitations in the search space, when the search space is increased, it will fall into the local optimum, which will affect the accuracy of prediction. Genetic algorithm (GA) is an adaptive optimization algorithm, it is mainly to select the population, crossover and mutation operation, so as to determine the search direction. It can find the optimal solution in the global space, which makes up the deficiency of BP neural network. But due to genetic algorithm has some disadvantages. Therefore, this thesis introduces difference algorithm and the chaos algorithm to optimize genetic algorithm, through the improvement of the fitness function, crossover probability and mutation probability to improve individual selection effect, so as to improve the search precision of the BP neural network, prediction and analysis for coal mining equipment fault.

2. The Principle of BP Neural Network

BP neural network is a multilayer feedforward network model, and mainly consists of input layer, hidden layer and output layer three parts, signal by backpropagation and backpropagation through the input layer to the hidden layer, then in neuronal function, the restriction of the network weights and threshold, the signal is transmitted to the output layer. BP neural network for coal mine equipment fault prediction mainly includes 2 parts of network training and network prediction. Network training mainly through a neural network function, the threshold value and weight of samples for training and learning, and the result is stored in the threshold and the weights. Continuous training of the samples to obtain a wealth of training results for the identification of samples to provide more accurate help. Network prediction through the training of coal mine equipment samples results, understand and store the development model of the sample sequence and make a certain prediction. As shown in Figure 1.

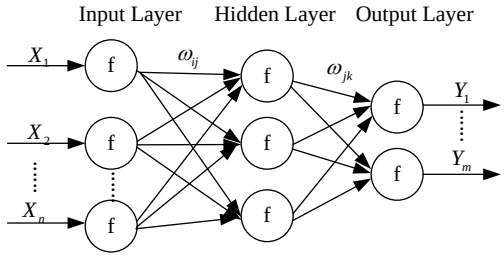

Figure 1.

3. Improved Genetic Algorithm to Optimize BP Neural Network

3.1 Basic Genetic Algorithm

Genetic algorithm is based on the nature of the "survival of the fittest" principle of a set of intelligent algorithms, mainly through the population selection, crossover and mutation and other operations, and then achieve the purpose of optimization. Through the fitness function to select the excellent individual cross to generate the next generation of individuals, and constantly iterative cycle, and ultimately meet the conditions of the individual, resulting in the optimal solution.

(1) Select: The operation is mainly in the population through the fitness function to select individuals for breeding offspring, the better the individual is easy to be selected out, multiply into excellent individuals, and gradually close to the desired value.

(2) Intersect: Two individuals are selected, and the location of the individual's chromosomes are crossed to produce new individuals.

(3) Variation: Set a certain probability to choose the individual, the individual of the chromosome variation, thereby enhancing the individual's fitness.

3.2. Chaos Algorithm and Reverse Learning

In this paper, chaos is introduced into the optimization variables of genetic algorithm, and the chaotic variables are selected, copied, crossover and mutation operations are carried out by encoding. In this paper, the classical Logistic function is used to generate chaotic variables:

$$x^{k+1} = 4x^k(1 - x^k) \tag{1}$$

In the Formula (1), x^k is a chaotic variable, and k is the number of iterations. The chaotic variables are as follows x^k conversion between the range of $[a, b]$ expression

$$y^k = \frac{x^k - a}{b - a} \tag{2}$$

The solution obtained within the range of values stored, get a collection of

$$y^k = \{y_1^k, y_2^k, \cdots y_k^k\} .$$

Reverse learning is a method to deal with the nonlinear solution. By comparing the solution and the set of the inverse solution, the optimal solution is selected as the initial solution, which can effectively deal with the uneven distribution of the initial connection.

$$
\begin{aligned}
&for\ i = 1\ to\ a\ do \\
&\quad for\ j = 1\ to\ b\ do \\
&\quad\quad y^{k'} = (y_{\min} + y_{\max}) / 2 + y^{k} \\
&\quad endfor \\
&endfor
\end{aligned} \tag{3}
$$

The y^k obtained from Formula (2) was compared with that obtained from $y^{k'}$ formula (3), and the individual combination with the best fitness value was selected as the initial population of genetic algorithm.

3.3 Difference Algorithm

Difference algorithm is a heuristic random search algorithm, which is based on the optimization problem of the individual in the population. $X = [X_1^0, X_2^0, \cdots X_N^0]$ initial solution algorithm based on chaotic algorithm herein described previously and reverse algorithm obtained, each solution is a solution of $X_i = (x_{i1}, x_{i2} \cdots x_{in})$ n -dimensional vector having, mainly variation, interactivity and choice of three parts.

(1) Mutation operation: The variation pattern of the first i individual x_i^g (4) in the second generation population of the differential algorithm g .

$$V_i^{g+1} = x_i^g + F * (x_{r1}^g - x_{r2}^g) \tag{4}$$

In the Formula (4), V_i^{g+1} is a variant of the population in the individual, F as a random factor, is mainly used to control the degree of difference between the vector, the set value of [0,1].

(2) Crossover operation: Through a certain probability choice, the variation of the second i individual x_i^g and the father of the individual V_i^{g+1} in the first cross, to get a new individual.

$$\kappa_i^g = \begin{cases} V_i^{g+1}, & t \in [0,1] \\ x_i^g, otherwise \end{cases} \tag{5}$$

In the Formula (9), it can be guaranteed that there is a random integer between 0 and 1 in the crossover process, which can ensure that the $\kappa_{i,j}$ has at least one component from $y_{i,j}$.

(3) Select operation. The individual selection using the "greedy" strategy, using fitness function f to compare the size of, choose f values individual into the next generation, by mutation and crossover operation after the production of new κ_i^g individuals and a generation of individual x_i^g were compared, if less than remain x_i^g unchanged, or directly into the next generation.

3.4. The Choice of Fitness Function

In order to get a better individual, the choice of fitness function is very important. In this paper, based on the positive sequence of adaptive degree function is constructed, its main purpose is to function values are sorted in a descending order, according to the objective function value of the size in the population individuals are sequentially arranged, and then sorting these individuals according to the mapping relationship between the calculated value of the fitness function. The positive sequence mainly consider the individual algorithms and sort order has a certain relationship, depends in position in the

population and algorithm calculation amount is too small, very suitable for the BP neural network is applied. The fitness function for the construction of the forward sequence is

$$f_i = 1 - \frac{i+1}{N}, i = 1, 2, \cdots N \tag{6}$$

In the Formula (6), i represents the population of individuals, and N is the size of the population, and the fitness value of the two neighboring individuals is poor:

$$f_{i+1} - f_i = -\frac{1}{N} \tag{7}$$

The Formula (7) shows that the difference between the adjacent individuals depends on the size of the population, so the probability is calculated according to the choice of the roulette, the probability of the first i individual is selected:

$$p_i = \frac{N - i + 1}{\sum_{i=1}^{N} N - i + 1}, i = 1, 2, \cdots N \tag{9}$$

The probability error of two adjacent individuals is chosen as:

$$p_{i+1} - p_i = -\frac{1}{\sum_{i=1}^{N} N - i + 1}, i = 1, 2, \cdots N \tag{10}$$

$$f(x_i) = \sum_{i=1}^{n} p_i * (y_i^{'} - y_i) \tag{11}$$

From Formula (10) can be found, the probability of an individual being selected between adjacent relatively small, which is guaranteed not because the probability of being selected among individuals too large to influence the choice of the operation, especially when the population size increases when, the smaller the difference, so as to improve the ability of individual choice, and to improve the chances of an individual to be selected, increases the variety of diversity. In the Formula (11), SS and DD respectively represent the actual and ideal output values of BP neural networks.

3.5. Crossover Probability and Mutation Probability Selection

In traditional GA, crossover operation and mutation operation of the probability values for generally remained constant when crossover probability is small easy to make the algorithm because of the lack of diversity of falling into local optimum, otherwise easily lead to individual is difficult to approximate the advantages, the variation operation, although the increase in the diversity of the population, but the effect to the performance of individual latter. Based on the research of adaptive algorithm, this paper improves the crossover probability and mutation probability [10], such as the Formula (11) and the Formula (12).

$$p_c = \begin{cases} 0.9^{\lambda * \frac{f_{\max} - f_{avg}}{f_{avg} - f_{\min}}} & M_1 \le M_2 \\ 0.9 - \frac{0.3 * (f - f_{\min})}{f_{\max} - f_{\min}} & otherwise \end{cases} \tag{11}$$

$$p_m = \begin{cases} 0.1^{\lambda * \frac{f_{\max} - f_{avg}}{f_{avg} - f_{\min}}} & M_1 \le M_2 \\ 0.1 - \frac{0.09 * (f - f_{\min})}{f_{\max} - f_{\min}} & otherwise \end{cases} \tag{12}$$

In the formula, $f_{\min}$, f_{avg} and $f_{\max}$ indicate respectively the smallest population

fitness value, the average fitness values and the maximum fitness value, M_1 indicates individual fitness value is less than the average fitness values, M_2 indicates individual fitness value is greater than the average fitness values, λ is control parameters, ensure the ratio between [0-1].

3.6. Algorithm Flow

Genetic algorithm to further optimize the BP neural network including BP neural network weights and threshold, genetic algorithm and BP neural network output three parts. By determining the structure of BP neural network to determine the number of layers and nodes of the network, corresponding to the length of the genetic algorithm. Genetic algorithm of population and individuals were recorded in the weights and thresholds of the network. Through the individual fitness function calculates the fitness value is calculated to ensure optimized individuals more accurate and improve the accuracy of BP neural network to predict.

Step1: Initialize the BP neural network weights and threshold value, to determine the parameters of GA

Step2: GA algorithm uses chaos algorithm and reverse learning to initialize the individual, and its

Step3: Training computational fitness in BP neural network

Step4: Difference algorithm selects the operation, the use of crossover probability and mutation probability of its operation

Step5: Select the new fitness function, if the conditions to meet the conditions to turn 6, otherwise the turn Step 3

Step6: Obtain the optimal weights and threshold

Step7: The calculation error of updating the weights and threshold, if the condition is satisfied, go to Step 8, otherwise go to Step 6

Step8: End of the simulation, get the predicted value

4. Simulation Experiment

4.1 Comparison of Convergence Stability of Algorithms

The data from Chongqing area of a coal mine actual production process in the coal mine fault, by nearly 5 years of data collected a total of 2000 fault size, selected 1800 as the experimental samples as training data, the remaining 200 as a predictive validation samples. The training effect of BP neural network is shown in Figure 2. In the same condition, the algorithm can achieve fast convergence and stability through the 40 iteration. Compared with the BP neural network, the algorithm is improved by 60%.

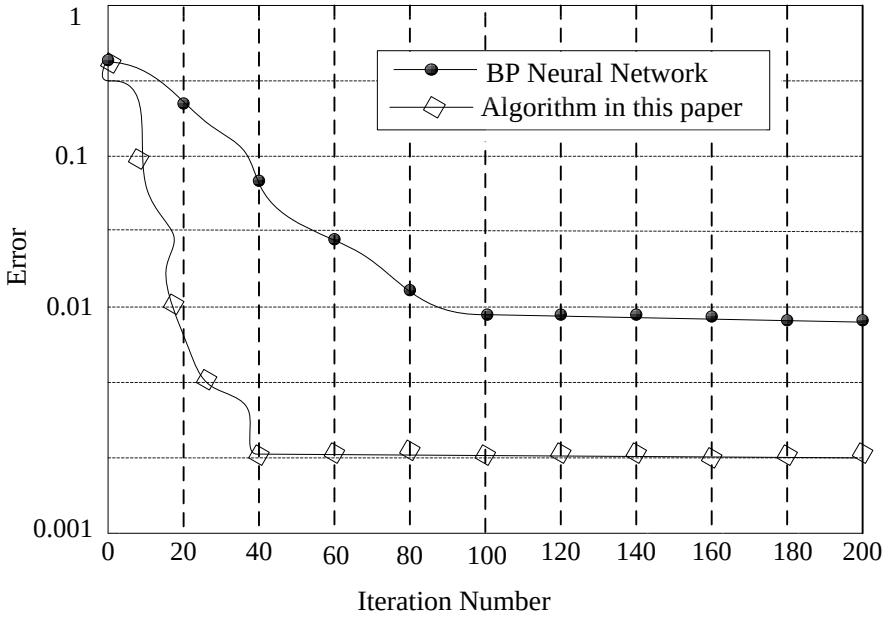

Figure 2. Comparison of Convergence and Stability of Two Algorithms

4.2. Comparison of Equipment Fault Error

In the experiment, set the input layer node is 3, implicit layer of nodes is 6, the output nodes, genetic algorithm coding individual length of 24, with a population size of 10, evolution times of 50, the range of [0.1,0.9] p_c range for [0.01,0.1]. Experiments are carried out for 50 times, and the average absolute error, mean square error and root mean square error are compared, and the results are shown in Figure 3to 5.

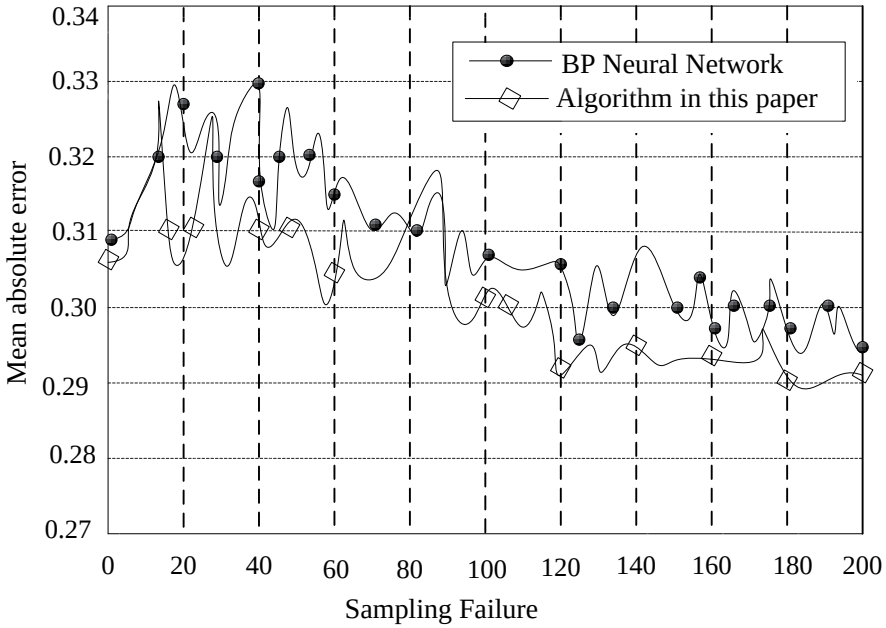

Figure 3. Comparison of the Average Absolute Error of 2 Algorithms

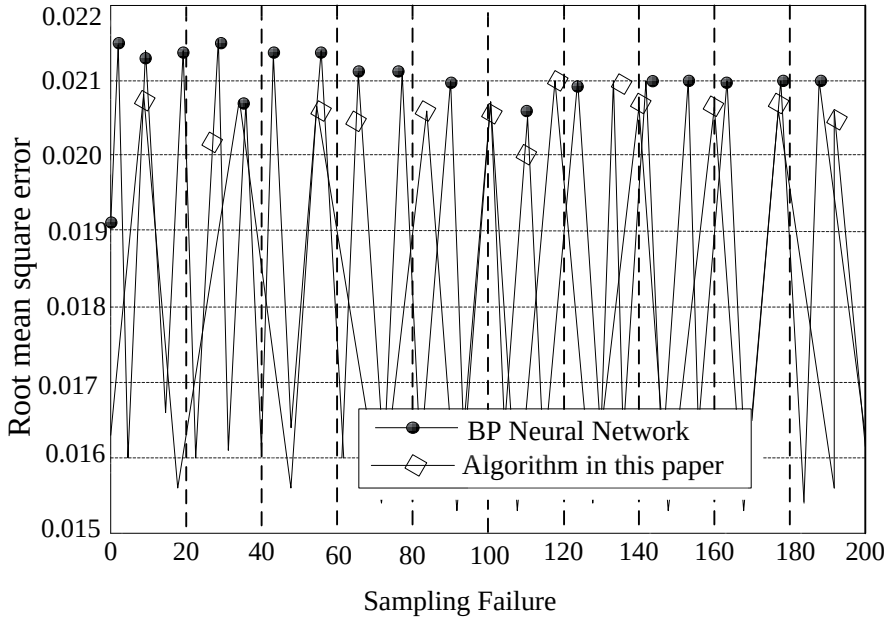

Figure 4. Comparison of 2 Algorithms in Mean Square Error

From Figure 3-5 can be found through 200 fault of comparative analysis, prediction of the algorithm results close to the expected value, high prediction accuracy, compared with the traditional BP neural network, algorithm in this paper in the coal equipment fault prediction showed a good effect. Especially for the improvement of GA algorithm, the performance of the algorithm is improved, and it is helpful to optimize the BP neural algorithm.

5.Conclusion

This paper describes the prediction of coal mine equipment based on improved genetic algorithm and BP neural network, the improved genetic algorithm, the performance of the algorithm is improved to a great extent, in BP neural network to optimize the network weights and threshold, reducing the prediction results are not accurate risk. Simulation experiments show that improved genetic algorithm to optimize the BP in terms of prediction accuracy and stability are superior to the traditional BP neural network.

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