Application of BP Neural Network Optimized By GA in Radar Target Recognition

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Abstract

In radar target recognition, BP neural network classification algorithm is used to realize recognition. Since BP neural network adopts gradient descent method, its initial weights are randomly set up, which leads to BP neural network easily falling into local minimum. Therefore, the genetic algorithm (GA) is used to optimize the weights of BP network nodes. The experimental results based on one dimension distance image (HRRP) simulation data show that the performance of the BP neural network based on genetic algorithm is stable and is not easy to fall into local minimum.

Keywords

BP neural network; genetic algorithm (GA); radar target recognition (RATR); high resolution range profile (HRRP).

1. Introduction

BP neural network is a kind of artificial neural network. It is a multi-layer feedforward artificial neural network using nonlinear activation function. It has a simple and powerful model and easy to implement algorithm. The classifier has been successfully applied to many practical classification problems. BP neural network is simple in structure, but how to select appropriate parameters to form a network is a problem that needs further study. Evolutionary algorithm is a mature global optimization method. It has the characteristics of self-organizing and self-adaptive. It has high robustness and wide applicability. The most important thing is that it is not restricted by the nature of the problem. Based on this, the genetic algorithm (GA) in evolutionary algorithm is used to optimize the parameters of BP neural network model.

2. BP Neural Network

2.1 BP Neural Network

BP is a learning algorithm with a tutor. Main idea: for R input learning samples, the output samples corresponding to them are known as: The purpose of learning is to modify the weight value by using the error between the actual output of the network and the target vector to make the actual output close to the desired target vector as much as possible, that is, to minimize the minimum mean square error of the network output layer.

The BP algorithm is composed of two parts: the forward transmission of information and the backpropagation of errors.

2.1.1 Positive Propagation Of Information

For the positive transmission of information, the output of the hidden layer can be drawn from the formula (with only one hidden layer).

$$y_i = f(net_j) = f(\sum_{i=1}^{n+1}(\omega_{ji}x_i + \theta_j)) \quad (1)$$

Among them, input for the network sample; the connection weight for the input layer to the hidden l ayer; and the activation function.

At the same time, the output of the output layer can be obtained.

$$o_k = f(\sum_{k=1}^{m+1}(\omega_{ki}y_j)) \quad (2)$$

The output of the hidden layer; the connection weight for the hidden layer to the output layer; K is the number of neurons in the network output layer; m, n is the number of the network input layer and the output layer neuron respectively.

The mean square error of the actual output of the sample relative to the objective function T is obtained.

$$E = \frac{1}{2}\sum_k (t_k - o_k)^2 \quad (3)$$

2.1.2 Back propagation of error and weight change of hidden layer

Then the value of weight coefficient is improved along the gradient direction of E gradient, and the network is gradually convergent. The weight correction formula is as follows:

$$\omega_{kj}(t+1) = \omega_{kj}(t) + \Delta\omega_{kj}(t) \quad (4)$$

$$\Delta\omega_{kj}(t) = \eta(o_k - t_k(t))\, f(\omega_{kj}(t)) = \eta\delta_{kj}(t) \quad (5)$$

$$\omega_{ji}(t+1) = \omega_{ji}(t) + \Delta\omega_{ji}(t) \quad (6)$$

$$\Delta\omega_{ji}(t) = \eta(o_k - t_k(t))\, f'(o_k(t))\,\omega_{ji}(t(t))\, f'(y_j(t)) = \eta\delta_{kj}\omega_{ji}(t(t))\, f'(y_j(t)) \quad (7)$$

In order to input various target sample values to the network, the weights of each layer are corrected according to formula (4) and (6) until E achieves the set of error requirements. The learning results of the neural network for the input samples are stored in the connection strength of the neuron, that is, the weight and the threshold of the network. The training process of the sample is the training process of the network, and the storage and processing of the information can not be separated.

2.2 BP Network Training Process

The BP network is a multilayer feedforward feedback network. According to the universal approximation theorem, if the hidden layer nodes can be set freely according to the needs, then the nodes with three layers of S like I/O properties can approximate any function with finite discontinuity points at any precision. So when we study the BP network, we assume that the network has three layers: input layer, hidden layer and output layer.

The BP network training process can be roughly divided into the following steps:

1) Select the useful sample pairs from the sample set, and send the input samples to the input nodes of the BP network.

2) Calculate the output value that the BP network should input;

3) Get the error between the actual output of BP network and the ideal output (output sample).

4) Adjust the weight of the network according to the algorithm to reduce the error.

5) Repeat 1~4 to achieve preset training requirements (maximum permissible error, maximum training frequency, etc.).

From the above steps, we can see that: 1), 2) is the forward process from the input node to the output node; the 3) and the 4 step is the error back transfer process from the output node to the input node - this is the origin of the BP algorithm.

2.3 The Establishment Of BP Network Model

2.3.1 The Determination of the Number of Nodes in The Output Layer of the Input Layer.

Increasing the number of layers can reduce the error and improve the accuracy, but at the same time, it also complicates the network and increases the training time of the network. The BP network designed in this paper is a simple three layer network. The number of output layers can determine the number of nodes in the output layer, such as the recognition of the three types of radar targets, and the three classes of targets in the output layer (100010001), so the number of nodes in the output layer is 3.

2.3.2 The Determination of The Number of Nodes in the Hidden Layer.

The improvement of network training accuracy can be achieved by using a hidden layer to increase the number of neurons. The implementation of this structure is much more than that of adding more hidden layers. Therefore, in the network design of this paper, the higher training precision is obtained by increasing the number of hidden layer neurons, and the result is that the network can quickly reach the desired error when the number of nodes in the hidden layer is 20.

2.3.3 Transfer Function

In BP neural network, the output of each node of the hidden layer and the output layer can not be separated from the transfer function. The transfer function of the input layer to the hidden layer, the hidden layer and the hidden layer neuron generally chooses the log-sigmoid type function, and the tan-sigmoid type function.

The general forms of the transfer function are as follows:

$$f\left(x\right)=\frac{e^{x}-e^{-x}}{e^{x}+e^{-x}} \tag{8}$$

$$g(x)=\frac{1}{1+\exp[-x]} \tag{9}$$

2.3.4 Network Parameter Selection

(1) Learning rate. The rate of learning determines the amount of weights generated in each cycle of training. The high learning rate may lead to the instability of the system; however, the low learning rate leads to a long training time and may converge slowly, but it can ensure that the network error values jump out of the local minimum and eventually tend to the minimum error. In general, a small learning rate is chosen to ensure the stability of the system. The learning rate is selected between 0.01-0.8.

As for the selection of the initial value, a few different learning rates are selected in the design of the neural network. The selection of the selected learning rate is judged by observing the rate of the square error and the rate of error after each training. If the error is very fast, the learning rate is appropriate and if the error is incorrect. Wobble shows that the learning rate is too large. Every specific neural network should have a suitable learning rate, but for a more complex network, there may be a different learning rate in the different locations of the error surface. In order to reduce the number of training times and the training time of the search rate, the suitable method is to adopt the adaptive learning rate of change. Network training has different learning rates at different stages. Generally speaking, the higher the learning rate, the faster the convergence is, but it is easy to oscillate, while the learning rate is too low and the convergence is slower.

(2) The selection of the expectation error. When training the neural network, a suitable expectation error should be determined through comparison training. This is determined by the number of nodes in the hidden layer, because the smaller expected error is satisfied by increasing the number of nodes in the hidden layer and the training time. In general, two networks with different expectation errors can be trained at the same time, and finally determined by comprehensive comparison.

3. BP Neural Network Optimized by GA

BP neural network is the most widely used network, but the learning algorithm of the network has the disadvantages of slow training speed, easy to fall into local minimum and weak global search ability. But the genetic algorithm does not require the continuity of the target function, and its search is global. Therefore, it is easy to get the global optimal solution, or the performance is very good. Good suboptimal solution. Therefore, combined with genetic algorithm, the accuracy of artificial neural network can be improved.

3.1 Genetic Algorithm (Genetic Algorithms, GA)

Genetic algorithm is an adaptive search algorithm derived from the evolution rules of nature. Genetic algorithm uses group search technology. Unlike other search algorithms, it starts from the initial population of the problem instead of starting from a single solution. The genetic algorithm simultaneously deals with multiple individuals in the group, that is to evaluate the adaptability of multiple solutions in the space according to the adaptability of the individual, determine the genetic operation according to the size of the fitness, and then produce a new population by crossover and mutation, and gradually make the population evolve to include the approximate optimal solution. The optimal solution of the problem is [8]. Therefore, genetic algorithm has strong self-organization, self-adaptive and self-learning habits.

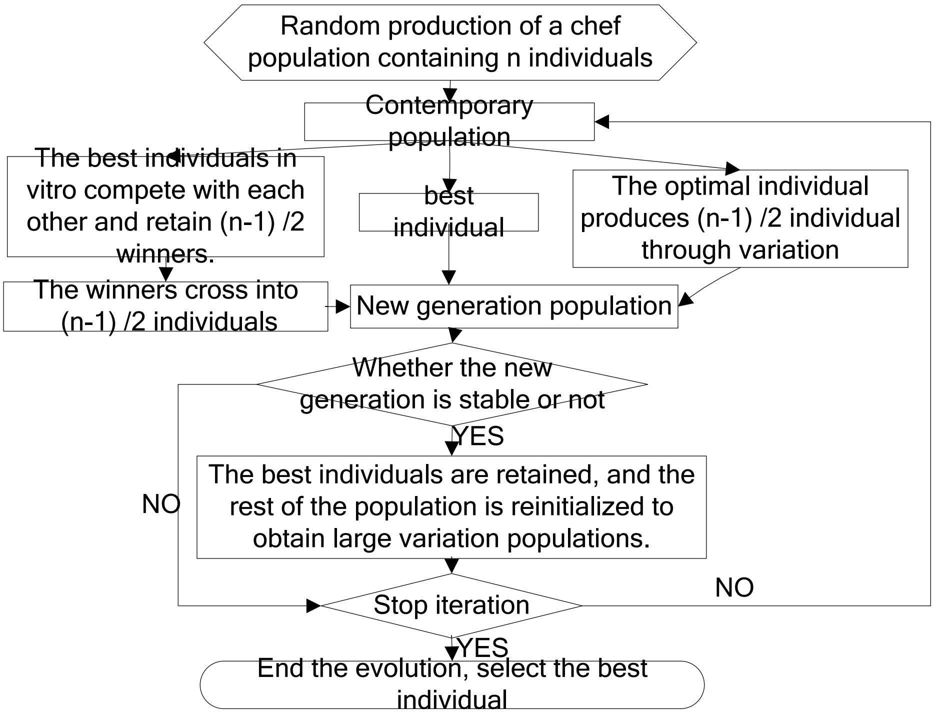

Fig 1. The process of BP network based on genetic algorithm optimization

3.2 Parameter Optimization Based on GA

In the training and learning process of the BP network, the determination of the connection weights of the hidden layer neurons is very important. If the selection is improper, it may lead to the poor generalization ability and the large convergence error. So far, there is still no effective solution in theory. In this way, the genetic algorithm is used to optimize the structure parameters of BP network, and the weight of the neuron is transformed into the particle in the genetic algorithm to iterate continuously, and the global optimal solution is sought.

The specific process of BP network optimization based on genetic algorithm is shown in Figure 1.

(1) The initialization of population parameters, and the range of variables in individual variables depends on the estimation of specific engineering application background.

(2) Each individual in the population is assigned to the unknown number in turn; the fitness function value of the population is obtained. In many cases, the system is calculated directly by the error minimum as the fitness value. In the BP neural network optimization of genetic algorithm, the absolute error value is directly used as the objective function, that is, the fitness function.

(3) Using genetic algorithm selection, crossover and mutation operations to find the optimal individual polar population.

(4) Calculate the fitness value of new species until the termination condition is satisfied, otherwise the execution step (3) is returned.

4. Simulation Experiment

4.1 Experimental Data

In this paper, the multi scattering point model of four different shapes of radar targets is simulated as the test target, and the target with the number of scattered points of 5, the "V" type target, the "dry" type target with the number of 9 and the "small" type target in total are four targets. In the experiment, the radar transmitting signal bandwidth is 150MHZ, and the distance resolution is 1m and SNR is 20. A high resolution range image of four kinds of simulation targets, such as "V", "dry" and "small" in the attitude angle range of 0o to 180o, is calculated. The odd attitude angle sample is used as the training sample, and the even attitude sample is used as the test sample, thus the training sample set M and the test sample set X are obtained.

4.2 The Recognition Effect of Optimized PSO-SVM On Radar Target HRRP.

Taking into account the characteristics of radar target HRRP's translational sensitivity and so on, we first extract the shift invariant KPCA feature of the radar target HRRP based on the center distance, and then proceed the experiment. In the experiment, a two layer neural network is designed. The activation function of each neuron in the hidden layer of the network is a hyperbolic tangent, the activation function of each neuron in the output layer is a linear function, and there are 5 neurons in the hidden layer, and the weight is optimized by genetic algorithm.

The unoptimized BP neural network classifier and the GA optimized BP neural network classifier are used to identify the samples of multiple simulation targets in the range of three attitude angles (0o-30o, 0o-60o, 0o-90o, respectively). The results of the 100 simulation experiments are such as table 2 and table 3, respectively. Show.

Table 1. the recognition results of two algorithms for multiple targets in different range of attitude angles.

target	Correct recognition rate of BP			Correct recognition rate of GA-BP		
	0o-30o	0o-60o	0o-60o	0o-30o	0o-60o	0o-90o
“1”	0.9807	0.9762	0.9715	0.9926	0.9914	0.9897
“V”	0.9724	0.9651	0.9513	0.9905	0.9841	0.9812
“dry”	0.9221	0.9134	0.9001	0.9863	0.9789	0.9773
“small”	0.9208	0.9110	0.9035	0.9721	0.9762	0.9602
Average recognition rate	0.9490	0.9414	0.9316	0.9854	0.9827	0.9771

As can be seen from table 1, the average BP recognition rate is 94.1% for four targets in three different attitude angles. With GA parameters optimized, the recognition rates of three different attitude angles are over 97%, and the average recognition rate is 98.2%. Thus, to identify the radar target HRRP, the GA algorithm can find the optimal value of the network parameters more accurately and effectively, so that the recognition error of the BP neural network can be reduced and the classification recognition accuracy is raised to improve the performance of the classifier. Thus, the validity of the BP model using the GA optimization parameter is fully proved.

4.3 Test Experiment on Convergence Performance of Improved Algorithm

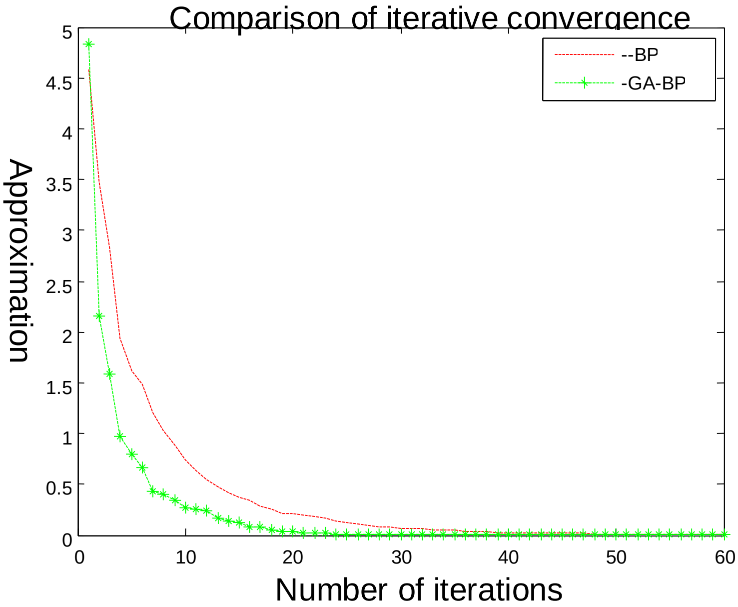

Fig 2. approximation curves of mean square error (MSE) for each algorithm.

It can be seen from the operation results that, compared with the simple BP neural network method, the BP network optimized by genetic algorithm has much shorter running time, faster convergence speed, and the curves of the genetic algorithm and neural network calculation results are shown as illustrated.

Table 2. The speed of convergence of the three algorithms

algorithm	relative velocity
BP	1
GA-BP	20

The relative speed of the two algorithms is listed in Table 2. By comparison, it is found that the BP network based on GA optimization can search for the optimization of the parameters of a large number of atomic realization vectors in a very short time, which greatly improves the computational efficiency.

5. Conclusion

Genetic algorithm is a highly parallel biological intelligence algorithm, which can solve the problem of function optimization quickly. The BP network algorithm based on genetic algorithm optimizes the weights and thresholds of the neural network, and obtains the corresponding weights and thresholds. Thus the structure of BP neural network can be controlled steadily and the recognition rate in radar target recognition can be improved. Therefore, the BP neural network optimized by GA is used in the whole body. The algorithm is desirable in the performance of the algorithm.

References

[1] Jiao Li Cheng, Zhou Weida, Zhang Li, et al. Intelligent target recognition and classification [M], Beijing: Science Press, 2010.

[2] Wu Jie. Radar automatic target recognition technology based on high resolution range profile [D]. Nanjing: Nanjing University of Aeronautics & Astronautics, 2011.

[3] Jiang Tongqiang, Ren Ye. GA-BP neural network and its application in the safety evaluation of liquid milk [J]. science and technology of food industry, 2017, 38 (5): 289-292.

[4] Application of [4] Huang Yaning, Chen Haochong, Song Xiaobing. GA-BP neural network in deformation prediction of deep foundation pit [J]. engineering construction, 2017, 49 (10): 31-34.

[5] Zhou Dehong, Feng Hao, Cheng Yue Qi, et al. The application of genetic algorithm optimized BP neural network to the assessment of the number of earthquake deaths [J]. safety and Environment Journal, 2017 (6): 2267-2272.
[6] Chen W, Yang P, Liu C, et al. Application of BP Neural Network in Radar Target Recognition[J]. Electronic Science & Technology, 2010.
[7] Zhang X, Gao Y. Based on momentum method BP neural network in the target recognition research and application[J]. Proceedings of SPIE - The International Society for Optical Engineering, 2011, 8193(24):9879-9891.
[8] Yang J, Zhou J, Wang F. A Study on the Application of GA-BP Neural Network in the Bridge Reliability Assessment[C]// International Conference on Computational Intelligence and Security. IEEE Computer Society, 2008:540-545.
[9] Jin X P, Chun-Sheng L I. Application of BP Neural Network Based on Genetic Algorithm in Water Resources Quota[J]. Water Resources & Power, 2018.
[10] Zhang Q, Zhang Y, Chen L I. Application of BP neural network based on genetic algorithm optimization in Chinese medicine massage robot[J]. Applied Science & Technology, 2017.
[11] Li X, Zhang T, Wang J. A Recognition Method of Plate Shape Defect Based on RBF-BP Neural Network Optimized by Genetic Algorithm[C]China control and decision-making conference. 2014:3992-3996.
[12] Rongrong R, Jia F, Jinbo C, et al. The application of BP neural network optimized by genetic algorithm in students' comprehensive quality evaluation[J]. International Journal of Simulation -- Systems, Science & Techno, 2016.
[13] Liu J, Xu X, Li T, et al. The Research of PV MPPT based on RBF-BP Neural Network Optimized by GA[J]. 2015.