An Improved BP Neural Network based on IPSO and Its Application

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Abstract—**Considering the fact that BP Neural Network has the defects of being easily falling into partial extreme value, to avoid the limitation of particle swarm algorithm we come up with an improved BP Neural Network applied in Neural Network training. This method means using nonlinear decreasing weight factor to change the fundamental ways of PSO first, and then using the developed PSO ways to optimize the original weight and threshold value of Neural Network. This method strengthens the ability of BP algorithm to solve the nonlinear problems and improve rapidity of convergence and the ability to search optimal value. We apply the improved particle swarm algorithm to agricultural land classification. Compared with BP method, this kind of algorithm can minimize errors and improve rapidity of convergence at the same time.**

Index Terms—**BP Neural Network, IPSO, agricultural land classification, inertia weight**

I. Introduction

The artificial Neural Network possesses the ability of processing database in parallel, organizing and learning by itself. It has made great achievements in many fields[1~3]. BP Network is a widely used neural network. Theoretically, BP Neural Network may approach any continual nonlinear function. However, affected greatly by the sample, it may fall into partial minimum value, thus it can't ensure that it converge the minimum value in overall situations.

Particle Swarm Optimization (PSO) was originally brought up by Dr. Eberhart and Dr. Eberhart in 1995.It was based on the optimal algorithm of swarm intelligence. It guides optimal search through swarm intelligence producing by the corporation and competition among particles[4]. It is simple, flexible and easily achievable .In early stage, the searching speed is fast, but later it becomes slower. Particle swarm shows intensive similarity, thus falling into partial optimum. It becomes necessary to improve the algorithm of particle swarm. Domestic and foreign researchers trained the neural network weights and topology structure [5-9] by using particle swarm optimization (PSO) algorithm.But the basic PSO algorithm prones to Slow convergence and even Stagnation phenomenon In the proximity of the optimal solution,which Leads the network training to achieve the ideal effect difficultly. Therefore many scholars put forward the improved PSO algorithm. The paper [5] combined PSO algorithm with BP algorithm , trained neural network, and achieved good results; The paper [6] Improved RBF neural network hidden layer center value determines the precision by using of PSO algorithm based on the subtractive clustering method;The paper[7] Improved after training the network generalization performance using adaptive search factor instering PSO algorithm;The paper[8] Improved the convergence speed of BP neural network and precision by improving the PSO algorithm learning factor and inertia weight factor.However, the above results are not ideal.

This text adopts the combination of improved particle swarm algorithm and Neural Network to optimize the parameter of Neural Network, and avoid the partial optimum point, thus it increases the robustness of network. The result of simulation shows that the optimizing methods speed the rapidity of convergence obviously, and the precision of simulation increase greatly.

II. The Optimal Algorithm Of Basic Particle Swarm

The optimal algorithm of improved particle swarm is not dependent of fields of problems. However, it uses the code of decision variable as Operation object and adaption function as searching objects. Furthermore, it can use the information from various searching points. It applies to solve the problem about nonlinearity and non-differentiable function and multiple objectives. It has been applied to many scientific fields[10], but it still has many problems.

A. The Optimal Algorithm of Basic Particle Swarm

Supposing in the D-dimensional objects searching space, there is a community composed of N particle. The "I" particle represent a D-dimensional vector, $x_i = (x_{i1}, x_{i2}, \ldots, x_{id})$ .It means that the "i" particle represents its position in this space. Every position of particle "X" is a potential solution . If we put "x" into objective function, we can know the adaptive value. we can know whether the "x" is the optimal answer based on

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the adaptive value .The speed of particle is also a D-dimensional, it also recorded as $v_i = (v_{i1}, v_{i2}, \ldots, v_{id})$. We record the particle I to the h times, the optimal position was $p_i = (p_{i1}, p_{i2}, \ldots, p_{id})$.All the particles to the h times, the optimal position was $p_{gd} = (p_{i1}, p_{i2}, \ldots, p_{id})$. The basic formulas are as follows:

$$v_{id}^{t+1} = wv_{id}^t + c_1 r_1^t (p_{id}^t - x_{id}^t) + c_2 r_2^t (p_{gd}^t - x_{id}^t) \quad (1)$$

$$x_{id}^{t+1} = x_{id}^t + v_{id}^{t+1} \quad (2)$$

In this formula: C_1 and C_2 represent speeding coefficient, adjusting the maxim step length that flying to the best particle in whole situation and the individual best particle respectively. Appropriate C_1 and C_2 can speed up the convergence and avoid falling into partial optimality.r_1 and r_2 are random number between 0 and 1, for controlling the weight of speed. W is Inertia factor .It was oriented toward overall searching. We usually take the original value as 0.9, and make it to 0.1 with the addition and reduction of the times of iteration .It mainly used to total searching, making the searching space converge to a certain space. Then we can get the solution in high degree of accuracy by partial refined searching[11].

B. The Optimal Algorithm of Improved Particle Swarm

With the increasing number of dimension of problems, basic PSO algorithm is easily falling into partial extreme value, thus influence the optimal function of algorithm. Someone brought up with improved algorithm. Many scholars' research shows that "w has a great influence on the algorithm of particle swarm[12]. When the "w" is bigger, the algorithm has a strong ability in total searching, and when the "W" is smaller, it is good for partial searching. "Therefore, in recent years, some scholars brought up many schemes[13-15] .According to formula (2), literature [8] came up with LDW(Linearly Decreasing Inertia Weight),that is

$$w = w_{\max} - \frac{t \times (w_{\max} - w_{\min})}{t_{\max}} \quad (3)$$

w_{max} and w_{min} represent the maximum and minimum value of W respectively. "t "is the step of iteration. t_{max} is the maximum iteration step. However, there are still problems in formula (3). In the primary period of operation, if it detects the optimal point, it wants to converge to the optimal point promptly. However, the linear reduction slows down the speed of convergence of algorithm. In the later period of function, with the reduction of "w", it may make the ability of total searching decline, and the variety awaken. Finally it may easily falling into partial optimum[16~18]. In this text, we use the PSO method of nonlinear variation weight with momentum to improve this method. That is: $w = w_{\max} - \dfrac{t \times (w_{\max} - w_{\min})}{2^{\theta} t_{\max}}$ (4)

2^{θ} is momentum, when in $\theta = \dfrac{t}{t_{\max}}$, t is smaller, 2^{θ} is near to 1,and w is near to $w_{\max}$., it ensure the ability of total searching.. With the increasing of t, w reduces in non linearity, ensuring the searching ability in partial areas. In the later period ($t = t_{\max}$), avoiding the problems caused by the decrease of w.That is, the reduction ability of total searching and the decline of variety. In order to test the validity of the improved algorithm,in the text,4 classic test functions test convergence performance between the traditional PSO and the IPSO.

$$F1: f(x) = \sum_{i=1}^{n} x_i^2, -100 < x_i < 100 \quad (5)$$

$$F2: f(x) = \sum_{i=1}^{n} (100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2), -30 < x_i < 30 \quad (6)$$

$$F3: f(x) = \sum_{i=1}^{n} (x_i^2 - 10\cos(2\pi x_i) + 10), -5.12 < x_i < 5.12 \quad (7)$$

$$F4: f(x) = \frac{1}{4000} \sum_{i=1}^{n} x_i^2 - \prod \cos(\frac{x_i}{\sqrt{i}}) + 1, -60 < x_i < 60 \quad (8)$$

In the test, particle swarm particle number is 45, dimension respectively is10 and20, C1, C2 are set to 2.10, cycle number is 1200. The standard PSO algorithm w is 0.60; Wmax, and wmin are 0.85,0.45, the maximum speed limit Wmax = 1. 4 testing functions are used to test each of the algorithms for 40 times. Different PSO algorithm function performance test results are shown in table1.

From table 1,we can conclude, the results of IPSO algorithm are better than the standard PSO algorithm and LDW-PSO algorithm results for the test function of F1, F2, F3 and F4 when the dimension respectively is 10 and20. Therefore, compared with way of the Linearly Decreasing Inertia Weight, The IPSO algorithm can be flexibly adjusted the global search and local search In the algorithm implementation process, so that it has better global search and local search ability

III. THE IMPROVED PSO—BP ARTIFICIAL NEURAL NETWORK ALGORITHM

A. BP Neural

The standard BP Neural Network consists of input layer, one or several hidden layers and an input layer, as the Figure shows below.

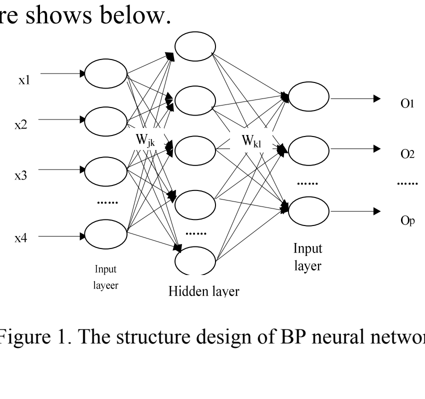


Figure 1. The structure design of BP neural network

The node action function of BP neural network is generally "S" function. Common activation function f(x) is derivable Sigmoid function:

$$f(x) = \frac{1}{1+e^{-x}} \quad (9)$$

Error function R is

$$R = \frac{\sum (Y_{mj} - Y_j)^2}{2} \quad (j=1,2,\ldots,n) \quad (10)$$

In this formula, Y_j is expected out; Y_{mj} is actual output; n is sample length.

The uniform expression of weight modified formula of BP algorithm is:

$$W_{ij}(t+1) = W_{ij}(t) + \eta \delta_{pj} O_{pj} \quad (11)$$

In this formula, W_{ij} is the connecting weight of neurons; η is networks learning rate; O_{pj} is the output of sample p; δ_{pj} is error correction value.

B. BP Algorithm

The specific process of BP algorithm can be generalized as follows:

Step1:Select n samples as a training set.

Step2:Initialize weight and biases value in neural network. The initialized values are always random numbers between (-1,1).

Every sample in the training set needs the following processing:

Step3:According to the size of every connection weight, the data of input layer are weighted and inputed into the activation function of hidden layer, then new values are obtained. According to the size of every connection weight, the new values are weighted and inputed into the activation function of output layer, and the output results of output layer are calculated.

Step 4:If there exists error between output result and desired result, the calculation training is wrong.

Step 5:Adjust weight and biases value.

Step 6:According to new weight and biases values, the output layer is calculated. The calculation doesn't stop until the training set meets the stopping condition.

C. The Improved Particle Swarm Algorithm Optimizes Neural Network

The method that we apply Improved Particle Swarm Optimization (IPSO) to train BP Network is: IPSO-BP algorithm is to use IPSO algorithm to optimize the original weight and the threshold value. When the algorithm ends, we can find the point near the overall situation optimal point. On the base of IPSO algorithm, we can use BP algorithm to search overall situation by starting from here and then achieve the network training goal. In the particle swarm, every particle's position represents weights set among the BP network during the resent iteration. The dimension of every particle is decided by the number of the weight and the threshold value serving as connecting bridge.

The concrete process can be narrated as follows:

Step 1: Initialization. n_i is the number of neure in the hidden layer , n_o represent the number of neure in input layer.So , the dimension of particle swarm D is:

$$D = n_h + n_o + n_i + n_h \times n_h + n_o \quad (12)$$

Step2: Setting fitness function of particle swarm,in this text ,we choose mean square error in BP Neural Network as fitness function of particle swarm.

$$E = \frac{1}{M}\sum_{K}^{m}\sum_{j=1}^{n_0}(y_{kj} - \bar{y}_{kj})^2 \quad (13)$$

Y_{kj} is the output in theory based on sample K. $\bar{y}_{kj}$ is the virtual output based on sample K. M is the number of Neural Network.

Step 3: Using the improved particle swarm algorithm to optimize the weight and the threshold value of BP network.

Step 4: Coming to the optimal weight and the threshold value based on formula (10)

$$g_{best} = [h_1, h_2, \ldots, h_{n_h}, o_1, o_2, \ldots, o_{n_o}, ih_1, ih_2, \ldots, ih_{n_i \times n_h}, ho_1, ho_2, \ldots, h_{o_h \times n_o}] \quad (14)$$

$h_i(i=1,2,\ldots,n_k)$ is the threshold value in the hidden layer. $o_i(i=1,2,\ldots,n_o)$ is the threshold value in the output layer. $ih_i(i=1,2,\ldots,n_i \times n_h)$ is the weight between the hidden layer and the input layer. $ho_i(i=1,2,\ldots,n_h \times n_o)$ is the weight between the hidden layer and the output layer.

Step 5: Letting the optimal weight and the threshold value as the original weight and the threshold value of BP network, and then put them into Neural Network for training. Adjusting the weight and the threshold value based on BP algorithm until the function index of the network's Mean Square Error (MSE) < e. e is the preseted expected index.

IV. THE APPLICATION OF IPSO－BP NETWORK ALGORITHM IN AGRICULTURAL LAND CLASSIFICATION

A. The Fundamental Information in Research Area

A county town of Hunan province, located in upper reaches of the Zijiang River, has warm weather, abundant rainfall and soil of good quality. It has various kinds of land resources .For example, hilly lands accounts for 50.9%, the plain and table land account for 28.1%. Therefore, it has advantage for developing agriculture. The northern hilly lands is good for planting trees and fruits, the southern plains are the main home of rice and fish. The characteristics of land utilization are: high utility ratio, obvious difference of land utilization, low ratio of urban land, lacking of arable land.

B. The Application of Algorithm

Neural Network is to train the sample that have already results, and then spread the dealing model to research area. Therefore, when we use the model of the sample, we train the sample from training samples from field survey sample points, and then let the familiar with the domain expert to give the expected output value of

sample. The input layer of network is the factors affecting the classification of agricultural land. They can be classified as natural factors (the slope of land, surface feature, altitude, effective thickness of land layers , quality of the surface ground, section plane structure, organic matter, PH number, types of water, water level)；And the social economical factors are:
(irrigation ratio 、 conditions of drain 、 developing situations 、 benefit of operation, the distance of cultivation)；factor of location (road convenience , bus stops, influence of the downtown、influence of produce fair). The output layer is the evaluation mark, and The node number is 1,we define the optimal value of hidden layer by trial-and-error method. When we apply the model, according to the guide of classification of agriculture land, we define the factors form from 3 aspects, that is: natural, social economical and location, and then collect 40samples for experts' evaluation. After testing by trial-and-error method, we adopt the structure containing the 19 input node, 7 hidden layer node and 1 output node.

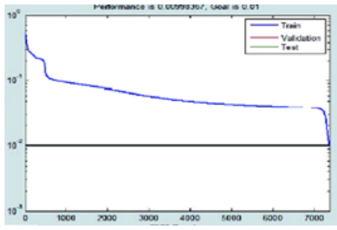
C. Effects Analysis

We take 37 samples from 40 as training sample, 3 for detecting samples and then we use 2 groups of sample to train and detect the standard BP Neural Network and the BP Neural Network optimized by improved particle swarm , the results are as follows.

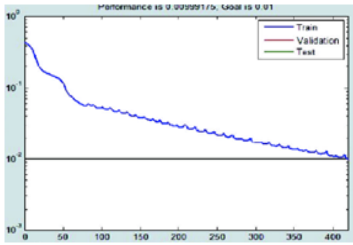
The process of concrete network training is as figure 2,from figure 2(a), we can conclude that BP network needs iteration for 7357 times until the error is converged to 0.01,as the figure 2(b)shows, the IPSO-BP Neural Network only need iteration for 425 times until the error is converged to 0.01.Therefore, compared with standard BP Neural Network, the IPSO-BP Neural Network increase the speed of convergence obviously.

After being trained for 500 times, the error of 37 training samples are showed by figure 3,we can conclude from figure 3 that, the error of samples trained by IPSO-BP Neural Network is between 0.01and 0.001. However, the error of samples trained by BP Neural Network is still between 0.1 and 1 .

Detecting 2 kinds of Neural Network by 3 samples, we show the imitating results are in table 2, we can conclude that the relative error of imitating results trained by IPSO-BP Neural Network can be controlled in the range of 1.5%. The imitating result is the same with real results. However, the relative error in the imitating results of Neural Network is greater than the IPSO-BP Neural Network. The imitating result of sample 38 is different from the real one .It means that the detecting precision trained by IPSO-BP Neural Network model is greater than BP Neural Network.



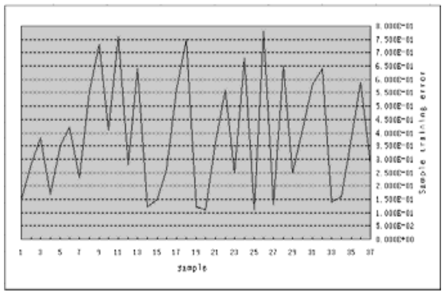
(a)BP Algorithm (7357 times) Learning Curve



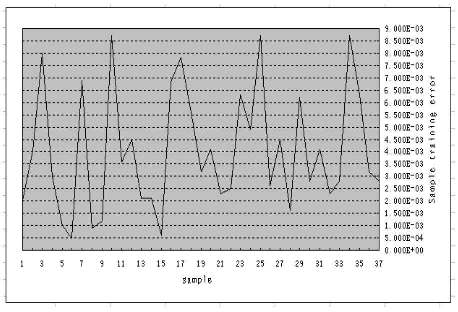
(b) IPSO- BP Algorithm Learning Curve

Figure 2 Simulation Result

The error curve of network model after being trained for 500 times is as follows.



(a)Training-error curve of BP neural network



(b)Training-error curve of IPSO-BP neural network

Figure 3 Training-error curve

V. CONCLUSION

(1) The improved particle swarm algorithm in this text helps solve the defect of the traditional particle swarm algorithm, which easily falls into partial extreme value and has low convergence accuracy. This kind of algorithm optimizes the weight and the threshold value of BP Neural Network, and achieves the parameter combination that the optimal particle corresponds in BP Neural Network. Therefore, it optimizes parameter of BP Neural Network and improves the generalization ability and self-study ability of BP Neural Network.

(2) The method for agricultural land classification

based on IPSO-BP Neural Network has many advantages. For instance, it has high prediction precision, good stability, high speed of convergence. The percentage error of the classification precision can be controlled within 1.5%. This method has many advantages over traditional BP Neural Network in following aspects. For a start, it can reduce iteration times. Then it has great output stability, and high convergence and precision of prediction. It proves that adopting IPSO-BP Neural Network model for agricultural land classification is attainable and practical.

(3) This text brings up a algorithm that the improved particle swarm optimize Neural Network. It provides a scientific and an effective way for agricultural land classification.

TABLE1

THE EXPERIMENTAL RESULTS

Function	***Dimension***	***PSO***	***IPSO***	***LDW-PSO***
F1	10	1. 4066e-007	1.9362e-013	1.3682e-010
	20	0.0313	6.4239e-004	0.0021
F2	10	2. 4011	0.7125	1.9653
	20	30. 9754	25.9857	27.8963
F3	10	11. 7214	8.4965	9. 7246
	20	28. 7832	22.2578	25.8962
F4	10	6. 2315	5.3165	6. 0311
	20	28.9821	22.0121	30. 2010

TABLE 2

THE COMPARISON OF DETECTING RESULT ABOUT AGRICULTURAL LAND CLASSIFICATION BASED ON BP NEURAL NETWORK MODEL AND IPSO-BP NEURAL NETWORK MODEL

serial-number	***Facts***		***BP Neural Network structure***			***IPSO-BP Neural Network structure***		
	Real marks	Grade of agricultural land	Detectig mark	Relative error	Detecting grade	Detecting marks	Relative error	Detecting grade
38	78.56	Third grade	80.21	2.10%	Second grade	79.12	0.71%	Third grade
39	92.85	First grade	91.23	1.74%	First grade	93.58	0.79%	First grade
40	62.38	Fourth grade	64.58	3.52%	Fourth grade	61.56	1.31%	Fourth grade

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