Mathematics teaching quality evaluation research based on harmony search BP neural network

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Abstract

The focus of improving the quality of mathematics education is to improve the quality of teaching, so that teaching evaluation is the key to improve the teaching quality of education. BP algorithm is used to evaluate mathematics teaching quality, but it is easy to fall into local optimum and has low convergence speed. Harmony search is used to optimize weight and threshold of BP neural network. Then mathematics teaching quality evaluation based on improved BP neural network is proposed. The experiment results show that the improved BP neural network has faster convergence speed and is more precise than traditional BP neural network. It can evaluate teaching quality more scientifically and accurately.

Keywords: mathematics teaching quality evaluation; BP neural network; harmony search.

1 Introduction

How to improve the teaching quality of higher education has become the focus of current higher education work. Teaching evaluation is the key measure to improve the teaching quality, thus making scientific and reasonable teaching quality evaluation system for university teacher is particularly important. Teaching evaluation belongs to the nonlinear classification problem. The traditional evaluation method requires that the evaluation indexes have linear relationship, which is difficult to rule out all sorts of randomness and subjectivity, and is easy to cause the evaluation results distortion and bias.

Teaching evaluation system design based on the improved algorithm of grey relational analysis was proposed by LIU Shujuan[1]. The model of teaching evaluation index based on AHP was proposed by FENG Li-xia[2]. The innovation method of the evaluating system for the student-oriented class teaching quality was proposed by ZHANG Yun-jun[3].Investigation on the quality of classroom teaching in medical colleges was given by WANG Xiao-dan[4].A model of evaluating teaching quality in military academies based on the BP neural network was proposed by SHU Chong-sheng[5]. The application of university teaching evaluation based on GA-BP neural network was proposed by WEI Meng[6]. Comparative study of assessment methods of teaching quality for university teachers was given by LI Yanling[7].Research of deepening the teaching reform and improving the classroom instruction quality was given by SHI Jing-xiu[8]. The model of teaching quality evaluation based on BP neural networks and its application was proposed by Wang Xuhui[9].Research on teaching quality evaluation in the college based on BP neural network was given by MianMian Cai[10].Lei Bai proposed the model of evaluating teaching quality based on BP neural network algorithm[11]. BP artificial neural networks model of college-student evaluation based on the fuzzy judgments was proposed by SHANG Yao[12]. Quality evaluation method of classroom teaching based on fuzzy neural network was proposed by ZHOU Shi-guan [13]. The model of analysis and estimate for teaching quality based on BP neural network was proposed by WU Tong [14]. Neural network evaluation system for teaching quality based on time series modelling was proposed by DONG Xiu-fang [15]. The synthetically evaluation to the teaching qualities based on neural network was proposed by WANG Zheng-wu[16]. Evaluation research on assessment of clinical nursing teaching quality based on fuzzy comprehensive evaluation method was proposed by Mei Sun [17]. Studies on application of fuzzy comprehensive evaluation method in piano teaching of colleges were proposed by Yuan Qin [18]. Study on the evaluation of the training effect of swimmer based on fuzzy comprehensive evaluation method was proposed by Zhang Zhao-qing[19]. An improved comprehensive evaluation model based on ant colony optimazation for people sports culture was proposed by WU Yong [20]. The study on venture capital project appraisal using AHP-Fuzzy comprehensive wvaluation methods was given by Zhijian Lu [21].

The paper is organized as follows. In the next section, the improved BP algorithm based on harmony search is proposed. In Section 3, the process of mathematics teaching quality evaluation is given. In Section 4, in order to test the prediction effect of proposed BP scheme, experiment is done and the improved BP algorithm is compared with traditional BP neural network. In section 5, some conclusions are given.

2 The improved BP algorithm based on harmony search

BP training process is divided into forward propagation of input signals and backward propagation of error signals.

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According to the supervised learning approach, specific algorithm steps are described below.

Step1. Network parameter is initialized. w_{ij} And θ_j are initialized to random numbers belonging to $[-1,1]$. Set the maximum iteration number M and targeted error. The square error SSE is initialized to $0, t = 1,2,...,M$.

Step2. Take the first input sample vector x and its corresponding expected output vector T from training data set.

Step3. The input signal is propagated forward. Calculate input vector I_i of hidden layer and output layer neuron to the last layer

$$I_i = \sum w_{ij} o_j + \theta_j$$

$$o_j = \frac{1}{1+e^{-I_j}}$$

Step4. Calculate square error SSE

$$SSE = sumsqr(T_j - O_j)$$

Step5. According to the expected output vector O_j of sample x, calculate error vector of each neuron of output layer.

$$ERR_j = O_j(1-O_j)(T_j - O_j)$$

Step6. Adjust weight and threshold according the following formula.

$$w_{ij} = w_{ij} + \alpha ERR_j O_j$$

$$\theta_j = \theta_j + \alpha ERR_j$$

Step7. When $t = M$ or SSE is less than targeted error, the algorithm stops. Otherwise turn to step 2 to go on.

In this paper, the organic combination of harmony search algorithm and neural network is realized. Firstly harmonic algorithm is used to train the network. Then BP network is used to solve the result accurately. Because a range of the weight is obtained firstly, the trained network can avoid local minimum to considerable extent. Besides, the number of training and the final weight can also be in a relatively stable state. Training speed can also be greatly accelerated. The improved BP network based on harmony algorithm is as follows.

Step1. Initialize the size of harmony memory, considering rate of harmony memory, pitch adjusting rate, and iteration number. If the size of harmony memory is too big, it will affect convergence speed. Considering rate of harmony memory will affect local shrinkage. Considering rate of harmony memory is 0.95, the size of harmony memory is 10, pitch adjusting rate is 0.05 and iteration number is 50.

Step2. An initial swarm is generated randomly, which is put into harmony memory. Each individual of this swarm corresponds to a group of weight and threshold of neural network. The targeted function is

$F_i = ERR_i$.

Step3.Produce the new solution

$X^{new} = (X_1^{new}, X_2^{new}, \ldots X_n^{new})$.

The disturbance principle is

$$X^{new} = X^{new} + 2 \cdot u \cdot rand - u$$

u represents bandwidth and $rand$ represents a random number between 0 and 1.

Step4.Update memory. Determine whether the new solution is the worst solution in harmony memory. If the new solution is the worst solution, the worst solution is replaced by the new solution. Then the New Harmony memory is obtained.

Step5.Terminate the loop condition. When the maximum number of iterations arrives, the loop is terminated.

3 The process of mathematics teaching quality evaluation

The number of evaluated indexes is seven. X_1 Represents course schedule, teaching depth and reasonable degree of learning burden. X_2 represents combining degree with practice and whether it can reflect the modern scientific and technological achievements. X_3 represents that clear, structured, and focused degree of the lecture. X_4 represents that interpretation is vivid, attractive and can connect typical theory with practice. X_5 represents that the guiding learning method is correct, which can train students' analysis ability. X_6 represents that preparation is enough, fully explanation is skilled, and correcting students' papers is careful. X_7 represents the teaching is improved constantly. The evaluated target is represented by the teaching effect, including examination, classroom discipline, student performance, problem-solving ability, etc. The process of improved principal component analysis is as follows.

Step1. Collect n number of samples of p dimension of random vector.

$n \succ p$, $X = (x_1, x_2, \ldots, x_p)^T$,

$x_i = (x_{i1}, x_{i2}, \ldots, x_{ip})^T$, $i = 1,2,\ldots,n$.

Step2. Carry out average processing for the element of X. $z_{ij} = \frac{x_{ij}}{\overline{x_j}}$, $j = 1,2,\ldots,p$, $\overline{x_j} = \frac{1}{n}\sum_{i=1}^{n} x_{ij}$. Solve covariance matrix $V = (v_{ij})_{p \times p}$, according to

$$v_{ij} = \frac{S_{ij}}{\overline{x_i} \cdot \overline{x_j}}.$$

Step3. Solve the characteristic equation of variance

matrix V, $\left|V-\lambda I_p\right|=0$.

Step4. Calculate the variance contribution rate and the cumulative variance contribution rate of each principal component. For each λ_j, solve the equation group $Vb=\lambda_j b$ To obtain unit feature vector $b_j^0=\frac{b_j}{\|b_j\|}$.

Step5. Solve m number of principal component of $z_i=(z_{i1},z_{i2},\ldots,z_{ip})^T$, $u_{ij}=z_i^T b_j^o$. The principle component decision matrix is

$$U=\begin{bmatrix} u_{11} & u_{12} & \ldots & u_{1m} \\ u_{21} & u_{22} & \ldots & u_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ u_{n1} & u_{n2} & \ldots & u_{nm} \end{bmatrix}.$$

TABLE 1 cumulative contribution rate, principal component contribution rate and eigenvalue

Principal component	1	2	3	4
eigenvalue	2.7826	1.8449	0.9215	0.4973
principal component contribution rate	39.75%	26.36%	13.16%	6.33%
cumulative contribution rate	39.75%	66.11%	79.27%	85.6%

The surveyed objects are asked to give a mark for each evaluated index. 68 numbers of questionnaires are sent out. Teaching quality questionnaire table is shown in table 2. The score is between 0 and 9. After questionnaire survey, shows cumulative contribution rate, principal component contribution rate and eigenvalue are shown in table 1. Cumulative contribution rate of the first four factors reaches 85.6%, suggesting that the four factors basically represent 85.6% of the information of the original seven factors. At last, the seven indexes are reduced to the first four indexes. Then the improved BP algorithm based on harmony algorithm is used for teaching quality evaluation. Teaching quality evaluation model based on BP network is shown in figure 1.

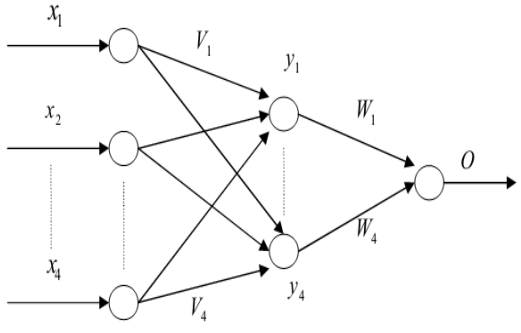

FIGURE 1 Teaching quality evaluation model based on BP network

4 The experiment and analysis

Because there are four evaluated indexes, the number of neurons of input layer is $n=4$. The number of the neurons of output layer is $m=1$ and learning rate is 0.04. According to

$$s=\sqrt{0.43mn+0.12m^2+2.54n+0.77m+0.35}+0.51,$$

$s=4$. Error curve when accuracy is 0.01 is shown in figure 2, error curve when accuracy is 0.001 is shown in figure 3 and error curve when accuracy is 0.0001 is shown in figure 4. The horizon axis represents training number and the vertical axis represents the mean square error. The first 60 groups of data is used as training set and 8 groups of data is used for testing.

The predictive value and expected value of BP algorithm and improved BP algorithm is shown in table 3. Another experiment is also done to test the convergence speed of improved BP network and the result is shown in table 3.

The improved BP based on harmony search algorithm has better approximation ability and more accurate prediction effect than BP neural network. Thus the proposed BP algorithm can evaluate teaching quality more scientifically and accurately. From table 4, it can be concluded that improved BP has faster convergence speed than traditional BP algorithm.

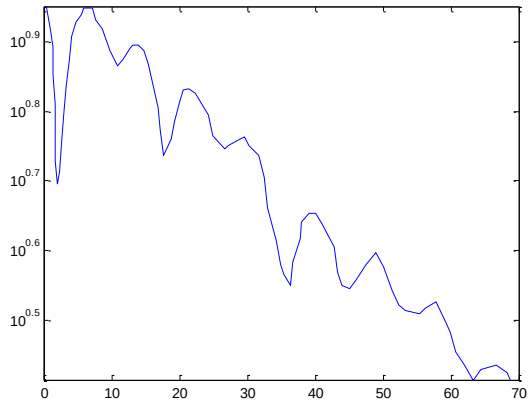

FIGURE 2 Error curve when accuracy is 0.01

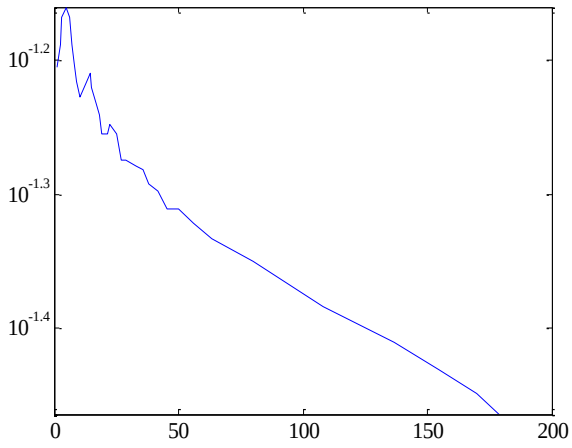

FIGURE 3 Error curve when accuracy is 0.001

TABLE 2 Teaching quality questionnaire table

X1	X2	X3	X4	X5	X6	X7
6	9	5	7	4	5	6.5
7	5.5	6	5.5	4	7	7.5
7.5	4	8	6.5	3	6	7
6.5	5.5	6	7	8	7	7
7.5	8.5	5	7.5	7	8.5	7.5
6	9	5	6.5	5	6.5	5.5
4	7.5	3	5.5	7	4.5	6
6.5	5	7	4.5	4	6	7
4	9	5	6	9	7.5	6
4	8	6	5.5	6	6.5	6
5.5	4	4	3	2	4	6
8	5	9	5.5	8	7	7
7	6	8	7	5	6.5	7
6	6.5	8	4	7	7	6.5
7	6.5	7	6	6	7	7
7	3	6	5	4	5.5	6.5
4	6.5	5	4.5	9	7	6.5
3.5	6	2	6	8	5.5	6.5
6	8	7	7.5	5	6.5	7
6.5	6.5	6	5	4	6.5	6
9	6.5	8	6	8	6.5	8
8.5	4	9	5.5	8	8.5	8
6	7.5	6	7.5	6	7	7.5
5.5	5	7	6	5	5.5	7.5
5.5	9	5.5	8	3.5	6	6
6	6	6	6	5	7	7.5
8	5	7	5.5	3	6	7
6.5	6	6	6.5	8	7	7.5
8.5	8.5	5.5	8	7	8.5	7.5
5	9	5	7.5	5	7.5	7.5
4	8	3	6	7	4.5	6
6.5	5.5	6	4.5	4.5	6	7
5	8.5	5	7	8.5	7.5	7
9	4	9	5.5	8	7	7
7	6	9	6	5	6.5	7
6	6.5	9	4	7	7	6.5
7	7	7	6	6	7	7
8	2	5	5	5	5.5	6.5
4.5	6	5	5.5	9	8	6.5
3.5	7	3	6	7	5	6
6	7	6	4	5	6.5	6
9	6	9	6.5	7	6.5	8
8.5	4.5	9	5	8	8.5	8
5	7.5	5.5	7.5	5.5	7	7.5
6	5	7	6	5	5	7.5
6.5	4	5.5	6	9	8.5	4.5
6	6	6	7.5	5	6.5	7
7	7.5	8	7	8.5	7	7.5
4	4	3	4.5	5	6.5	5.5
5	5.5	6.5	5	4	5.5	6
8	5	6	5	5.5	6	7
6	5	8	5.5	4	4	4.5
4	8	6	5	6	5	7
5.5	4	4	3	2.5	4	6
8	7.5	7	7	8.5	7.7	8
6	9	5.5	6.5	5	6.5	6
8.5	8.5	5.5	7	8	8.5	7.5
3	9	6	6	7	6	6
5	4	4	3	3	4	6
8	7	7	6	6	5.5	6.5
3.5	4.5	5	5.5	4	4.5	5.5
7	7	7	6	6	7	7
5	5	6.5	5.5	4	5.5	6
6	5	8	5	5.5	6	7
6	9	7	7.5	4	6.5	7
7.5	6.5	5	4.5	5.5	6.5	7
5.5	5	7.5	6	5	7.5	7

TABLE 3 Comparison of BP algorithm and improved BP algorithm

serial	BP algorithm		Improved BP		expected value
	Predictive value	error	Error	curve	
1	7.06	8.62%	6.45	0.77%	6.5
2	7.02	40.40%	4.71	5.80%	5
3	6.52	0.31%	6.25	3.85%	6.5
4	7.70	0.65%	7.5	3.23%	7.75
5	6.24	16.80%	7.79	3.87%	7.5
6	6.76	12.77%	8.09	4.39%	7.75
7	7.41	1.20%	7.75	3.33%	7.5
8	5.31	24.14%	6.75	3.57%	7

TABLE 4 Convergence performance comparison

algorithm	the number of neuron in the hidden layer	20	40
Improved BP	accuracy	47.02×10^{-30}	663.3×10^{-30}
	time(s)	0.6	5.4
BP	accuracy	0.12	0.61
	time(s)	0.12	0.61

TABLE 5 Convergence performance comparison

algorithm	the number of neuron in the hidden layer	60	80
Improved BP	accuracy	993.3×10^{-30}	1803.1×10^{-30}
	time(s)	13.6	26.0
BP	accuracy	1.35	1.95
	time(s)	1.35	1.95

TABLE 6 Convergence performance comparison

algorithm	the number of neuron in the hidden layer	100
Improved BP	accuracy	3233.5×10^{-30}
	time(s)	45.5
BP	accuracy	2.45
	time(s)	2.45

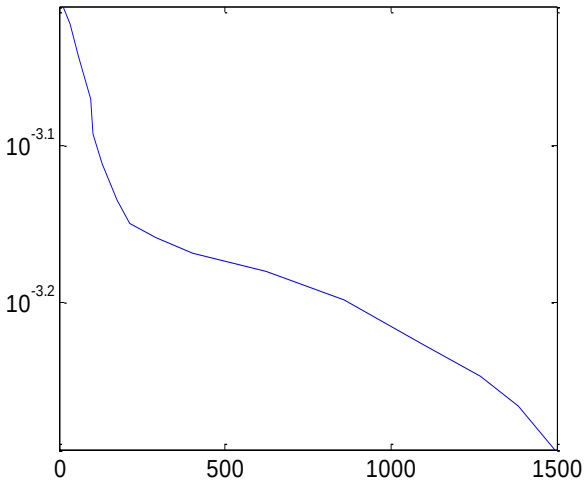

FIGURE 4 Error curve when accuracy is 0.0001

5 Conclusions

Mathematics teaching quality evaluation model based on BP neural network is investigated. In order to overcome the defects of BP algorithm, an improved BP network based on harmony search is proposed, which has fast convergence speed and strong learning ability. The experiment results show that the proposed algorithm can evaluate teaching quality more precisely.

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