

A Teaching Quality Evaluation Model Based on a Wavelet Neural Network Improved by Particle Swarm Optimization

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Abstract: *In order to improve the teaching quality of higher education, the paper constructed a teaching quality evaluation index system with five first level indicators and twenty two second level indicators according to the teaching level evaluation index system of ordinary higher education. For the complex nonlinear relationships between the evaluation indices, a mathematical model for evaluating the teaching quality based on WNN, whose parameters were optimized by PSO, was presented in the paper. The experimental results showed that the method proposed could better improve the accuracy of the teaching quality evaluation target by making the mean square error of the actual output value and the desired output value smaller. Simultaneously, the method has been widely used in teaching quality evaluation of our college.*

Keywords: *Teaching quality, evaluation index, Wavelet neural network, Particle swarm optimization, evaluation model.*

1. Introduction

In recent years, with the strategy of developing the country by relying on science and education which have been developed, the scale of institutions of higher education is expanding at a high speed. Teaching is the central work of higher education, and teaching quality is the lifeline for the survival and development of the colleges. In order to ensure and improve the quality of teaching higher education, the teaching quality evaluation becomes a critical and important initiative. However, the teaching quality evaluation involves multiple evaluation subjects with heavy workloads, and the evaluation is a statistically tedious process. Therefore, how to use the information technology in order to evaluate the teaching quality scientifically and accurately, is quite worth to study.

During the earliest usages of artificial evaluation ways, the evaluation results of the teaching quality were very subjective, unscientific, and the accuracy of evaluation was very low, which cannot efficiently reflect the real level of teaching by the teachers. Then, some traditional methods, such as summation, weighted summation, have emerged due to the advantages of computing simplicity. But they usually reduce the reliability and credibility of the evaluation results, and could not analyze the evaluation results statistically. Recently, with the rapid development of information technology and its application in the field of education, some evaluation methods based on them were proposed, such as Multiple linear regression, Partial least squares, Analytical Hierarchy Process (AHP), Fuzzy comprehensive evaluation, and so on. Multiple linear regression and partial least squares evaluate the goal based on linear relationship. AHP is a decision method combining qualitative and quantitative analysis, which aims at solving the problem of hierarchy. According to the characteristics of all factors of each level, AHP expresses the relative importance of each level quantitatively, and then builds up the mathematic model. Although AHP can get the weights of the evaluation factors, it requires linear relationships between the evaluation indices. Otherwise, the evaluation results will be affected. Fuzzy comprehensive evaluation [1] utilized the comprehensive assessment model of fuzzy mathematics to evaluate the teaching quality indices, and drew a conclusion. The key of fuzzy comprehensive evaluation is to confirm the factor sets and construct reasonably a matrix of fuzzy evaluation. However, different matrices obtained by different experts with inconsistency, will lead to inconsistent results eventually. To solve these problems, a number of data mining technologies [2] were applied into the evaluation of the teaching quality. A decision tree [3] was used for teaching quality evaluation of colleges with the purpose to improve the teaching levels of teachers. A support vector machine [4] with default and chosen parameters was applied to enhance the evaluation accuracy. In [5] the information of the teaching quality and employment status of colleges and universities were extracted by using data mining technology based on rough set theory. The relevant rules were analyzed and the evaluation model was established, which can improve the evaluation better.

The common features of the methods above mentioned use only one algorithm for prediction of the quality evaluation indicators. Recently, in order to improve the accuracy and speed of the teaching quality evaluation further, some combined

methods are put forward. Luo Mei [6] proposed a comprehensive model, called AHP-DEA-FCE for teaching quality evaluation by using 15 indicators, which have efficiently exerted each method's advantages. Liu Lianxin et al. [7] offered a method of analytic hierarchy process and fuzzy comprehensive evaluation which has stronger evaluation ability. A framework based on fuzzy AHP and comprehensive evaluation methods was presented in [8] which could obtain a scientific and objective evaluation result. Başaran et al. [9] proposed a novel hybrid method, called CCA-FRB, which combined the conventional content analysis method and FRB systems, and was more suitable for the verbal data obtained from SET questionnaires. Although these methods have some applications, the teaching quality evaluation process involves a lot of teaching quality indicators and the impacts of different indicators are not the same. So, the evaluation model is a complex nonlinear classification problem. An artificial neural network (ANN) with its non-linear mapping, learning classification, real-time optimization and other features, has been widely used in teaching quality evaluation [10, 11]. A Wavelet Neural Network (WNN) [12] is the perfect combination of wavelet analysis and artificial neural network theory, and it has the advantages of both. The paper presents a method to optimize the parameters of a wavelet neural network using Particle Swarm Optimization (PSO), and constructs a teaching quality evaluation model called PSO-WNN, which is based on WNN and optimized by PSO.

The rest of the paper is organized as follows: Section 2 introduces the teaching quality evaluation index system. Section 3 presents our methods. In Section 4 the supporting experiment results and discussions are presented. Finally, conclusions are drawn in Section 5.

2. Constructing teaching quality evaluation index system

During the process of teaching evaluation, the teaching quality evaluation indicators are in a top priority. Meanwhile, a colleague of mine is in an important stage of development, called "quality improvement" recently. So, in order to ensure and improve the quality teaching, it is particularly important to develop a scientific and rational teaching quality evaluation index system. To make the classroom teaching quality evaluation more scientific, comprehensive, accurate and operable, combined with experts' evaluation of the indicators, a teaching quality evaluation index system was established based on multiple evaluation subjects according to the teaching level evaluation index system of ordinary higher education. Therefore, the evaluation index domain $V = \{\text{first level index } X_i\}$, and each X_i includes many second level sub-indices x_j , which refer to the second grade assessment indicators of the teaching level evaluation of ordinary higher education.

There are five first level indicators in our evaluation system, which include the teaching norms X_1 , teaching attitude X_2 , teaching content X_3 , teaching methods X_4 , teaching effectiveness X_5 . Each first level indicator can be refined into a number of secondary indicators, a total of 22 secondary indicators, namely x_1, x_2, \dots, x_{22} , where the specific meaning of each indicator is shown in Table 1.

Table 1. Teaching quality evaluation index system

First level index	Second level index
Teaching norms	Normalize the format of “teaching plan”, “teaching schedule” and “syllabus”
	Make “teaching plan” and “teaching schedule” be consistent with “syllabus”
Teaching attitude	Make lectures be consistent with teaching content in the progress of “Teaching schedule”
	Diligent and pragmatic, rigorous scholarship
	Implement teaching standards, and comply with the teaching discipline
	Appearance is decorous, be a model for others
	Teach by precept and example, teaching
Teaching content	Have a passion for teaching, and can attract the attention of students
	Elaborate on the problem in simple terms, and be illuminating
	Concise exposition of the problem is accurate, focused, with clear thinking
	Be skilled on the course content, which is handled very skillfully
	Rich in contents and with a large amount of information
Teaching methods	Reflect the new ideas, new concepts, new achievements of the related disciplines
	To give students inspiration of thinking, associating, innovating
	Mobilize students' emotion, warm up classroom atmosphere, and get along well with students
	Teach with multimedia, which makes the class vivid and lively, and with the ability of strong information skills in teaching design
	Use the blackboard combined with the multimedia, and clear handwriting
Teaching effectiveness	Teachers interact with students, and cultivate the students' autonomous learning ability
	The students' test scores distribute reasonably
	Better understand and grasp the knowledge, and achieve higher teaching objectives
	Improve the abilities of solving problems, self-exploration, collaboration and innovation to some extent
	Stimulate student's learning interest, and improve student's interest in the subject

3. The optimized teaching quality evaluation model

The relationships between teaching quality evaluation indicators and evaluation objectives are quite complex, and can be classified into non-linear relationships. The wavelet neural network with fast convergence characteristics has a stronger ability to learn, while PSO is used to optimize the various parameters of the wavelet neural network. The paper proposed a teaching quality evaluation model, called PSO-WNN, using a wavelet neural network optimized by PSO.

3.1. Wavelet neural network

The wavelet neural network is a combination of wavelet analysis theory and ANN, which takes full advantage of the time-frequency characteristics of the wavelet transform and self-learning ability of the neural network. Compared to the artificial neural network, WNN shows better prediction accuracy, convergence rate and fault tolerance to the complex nonlinear, uncertain, unknown system.

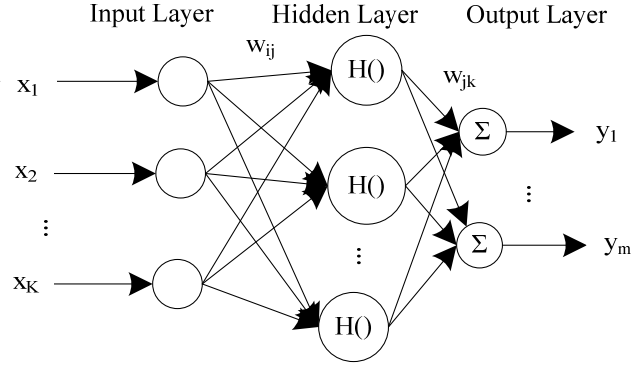


Fig. 1. Topology structure of WNN

Based on BP neural network, WNN takes the wavelet basis function as the transfer function of a hidden layer, with the signal forward propagation, while the deviation back propagation. The wavelet neural network topology is shown in Fig. 1. There: x_i , $i = 1, \dots, K$, is the input, y_j is the output; w_{ij} , $i = 1, \dots, K$, $j = 1, \dots, L$, denotes the connection weights between the input layer and hidden layer, w_{jk} , $j = 1, \dots, L$, $k = 1, \dots, M$, denotes the connection weights between the hidden layer and output layer: K is the number of input nodes; L is the number of hidden nodes; M is the number of output nodes. When inputting the signal sequence x_i , $i = 1, \dots, K$, the output equation of the hidden layer is

$$(1) \quad h(j) = h_j \left[\frac{\sum_{i=1}^K w_{ij} x_i - b_j}{a_j} \right], \quad j = 1, 2, \dots, L,$$

where: $h(j)$ is the output value for the hidden layer node j ; a_j is the dilation factor; b_j is the translation factor of h_j ; h_j is the wavelet function.

In this paper, $h(\cdot)$ is the wavelet basis function, using Morlet wavelet function which is a complex wavelet modulated by a Gaussian function with advantage of Time-Frequency regularity. Compared with a real wavelet, Morlet wavelet can reflect the size of different scales of time series and its distribution in time domain is more accurate. The expression is

$$(2) \quad h(x) = \cos(1.75x) e^{-x^2/2}.$$

The output equation of the output layer is

$$(3) \quad y(k) = \sum_{i=1}^L w_{ik} h(i), \quad k = 1, 2, \dots, M,$$

where: l is the number of the hidden layer nodes; m is the number of the output layer nodes; w_{ik} denotes the connection weights between the hidden layer and output layer; $h(i)$ denotes the output result of a hidden layer node i .

3.2. Particle swarm optimization

Particle Swarm Optimization (PSO) [13] is a typical swarm intelligence algorithm for finding the optimal solution of the optimization problem, PSO is utilized to optimize the parameters of WNN in this paper. PSO algorithm assumes that each possible solution of the system is a particle, whose characteristics are represented by position X , velocity V , and fitness value f . The particles fly in the search space, according to the flight experience of their own, that is an individual extreme value P_b , and flight experience of their companions, that is a group extreme value P_g . Moreover, they constantly update themselves, and create a new generation of groups.

Assume that there is a D -dimensional solution space, which is composed by a swarm of particles named $X = (X_1, X_2, \dots, X_n)$. Among them, the position of the i -th particle in D -dimensional solution space is represented by $X_i = (x_{i1}, x_{i2}, \dots, x_{iD})^T$. The velocity of the i -th particle is represented as $V_i = (V_{i1}, V_{i2}, \dots, V_{iD})^T$. The corresponding individual extreme value is denoted by $P_{bi} = (P_{bi1}, P_{bi2}, \dots, P_{biD})^T$, the group extreme value is denoted by $P_g = (P_{g1}, P_{g2}, \dots, P_{gD})^T$. By iterative computing repeatedly, the velocity and position of the particles in the D -dimensional space are updated through P_b and P_g according to

$$(4) \quad V_{id}^{k+1} = wV_{id}^k + c_1r_1(P_{bid}^k - X_{id}^k) + c_2r_2(P_{gd}^k - X_{id}^k),$$

$$(5) \quad X_{id}^{k+1} = X_{id}^k + V_{id}^{k+1},$$

where: $d = 1, 2, \dots, D$, D is the dimension of the space; $i = 1, 2, \dots, n$, n is the swarm size; k is number of iterations; c_1 and c_2 are the acceleration coefficients which are nonnegative constants, their values being 2; r_1 and r_2 are random numbers distributed in the range of $[0, 1]$; w is the internal weight coefficient.

3.3. A hybrid model

In order to overcome the shortcomings of the traditional teaching quality evaluation model, an improved prediction model of WNN was established based on the topology of BP, whose signal forward propagation, while the deviation back propagation, and the wavelet function is accepted as the transfer function of the hidden layer nodes. Secondly, PSO optimization algorithm was used to optimize the connection weights and thresholds of WNN. The values of the evaluation indicators of the classroom teaching quality constituted the input vector, and the evaluation values (that is, the evaluation results of experts) constituted the output vector of the model. Then, the network structure and training samples were designed, and the network was trained until the prediction deviation met the specified requirements. Finally, the acquired teaching quality evaluation model was used to predict test data. The framework of the model is shown in Fig. 2.

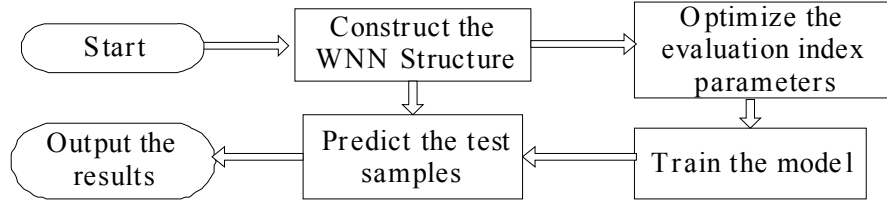


Fig. 2. The framework of a teaching quality evaluation model

The structure of WNN prediction model is determined by the number of nodes in different layers. In the paper, a three-layer structure of 22-6-1 is chosen. The nodes of the input layer are 22, which means 22 secondary indicators of teaching quality index system as input to the network model. The nodes of the hidden layer are 6, the node of the output layer is 1, which means the predicted output of the network.

The process of the **Algorithm WNN** based on PSO algorithm is in eight steps.

Step 1. Initialize the population using WNN network parameters.

Step 2. Calculate the fitness value of each particle and determine P_b and P_g .

Step 3. Update the velocity V and position X of the particle according to equations (4) and (5).

Step 4. Stop the search process, if the iteration times of the particles reach the maximum, or the particles reach the optimal position. Otherwise, return to Step 2 and continue the iterative optimization.

Step 5. Initialize WNN network parameters using the optimal solution.

Step 6. Train WNN using the training data, output training results, and calculate the prediction error e of the network.

Step 7. Correct the shift factor b_k , stretching factor a_k , and network weights w_{ij} according to the prediction error e calculated in Step 6, which makes the prediction close to the desired result.

Step 8. End the training process of the network if the training times reach the maximum, or reach the permissible error range; otherwise, return to Step 6.

In the process of PSO optimization, in order to prevent the particles from falling into a partial optimal solution, or blindly searching in the solution space, V_i and X_i of the particle are limited within a set range of $[-V_{\max}, V_{\max}]$ and $[-X_{\max}, X_{\max}]$.

4. Results and discussion

In the experiment, the model of a three-layer WNN optimized by PSO was used to predict the evaluation result of teaching quality evaluation index data, in which the number of neurons of the input layer, the hidden layer the and output layer were 22, 6 and 1 respectively. The 1000 experimental samples were randomly selected from the summary data of teacher quality evaluation in our college, among which, the 22 evaluation indices values belong to $[0, 100]$, which was aggregated from the scores achieved by experts, teachers and students together. The evaluation goal was

determined by experts. The front 800 samples were taken as training data, and the latter 200 samples were taken as test data.

In order to evaluate and analyze the experimental results, a Mean Square Error (MSE) is used to measure the performance between the different models. Therefore, Y and Y' represent the actual value and the predicted value of the evaluation goal respectively. The formula is shown in equation (6).

$$(6) \quad \text{MSE} = \frac{1}{n} \sum_{i=1}^n (Y_i - Y'_i)^2.$$

The diagrams of the prediction results and the prediction error were used in the experiment to analyze the prediction performance between a wavelet neural network and PSO-WNN. The graphs below show the distribution of the predicted and desired results of 200 test samples. By comparing the various prediction results and real data of the network, the accuracy of various algorithms was analyzed.

The teaching quality evaluation samples were trained using a wavelet neural network, then 200 test samples were predicted, whose forecast results basically reflected the trend of the evaluation target, but there were some large deviations. Fig. 3 shows the predicted results, and Fig. 4 shows the prediction error of WNN.

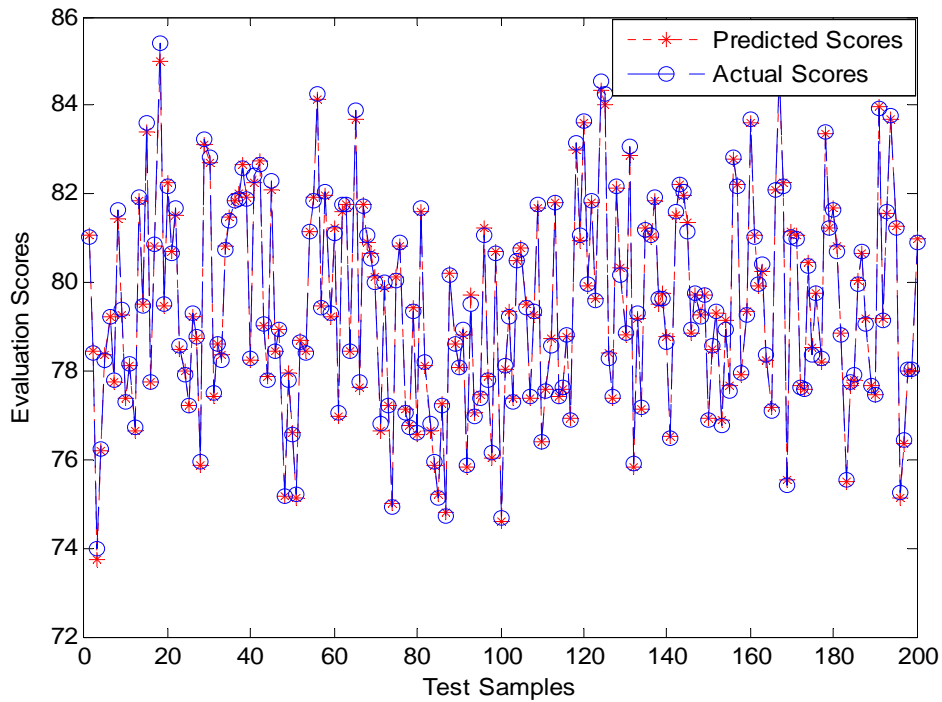


Fig. 3. The prediction results of WNN

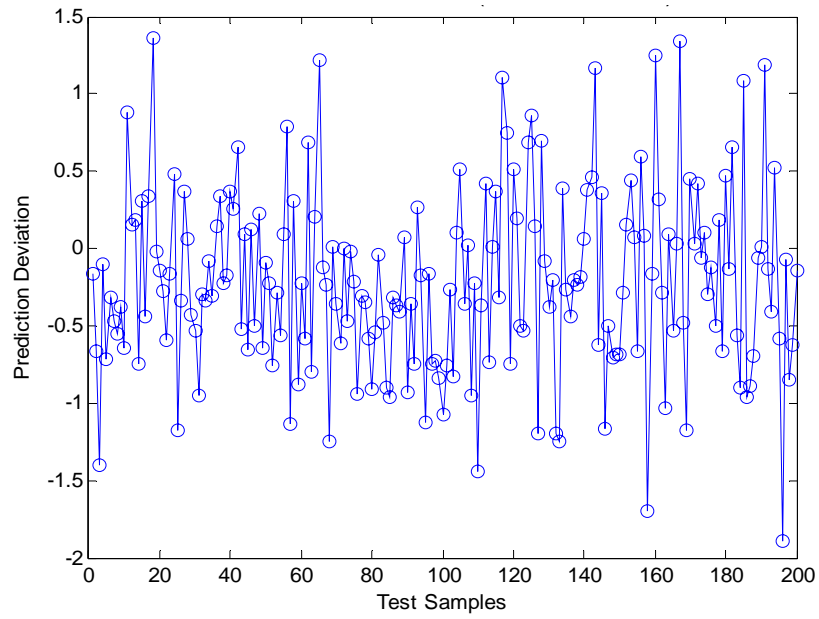


Fig. 4. The prediction deviation of WNN

The WNN network model optimized by PSO was used to train the teaching quality evaluation samples, and the test samples were predicted by the trained model. Fig. 5 shows the predicted results, and Fig. 6 shows the prediction error of WNN optimized by PSO.

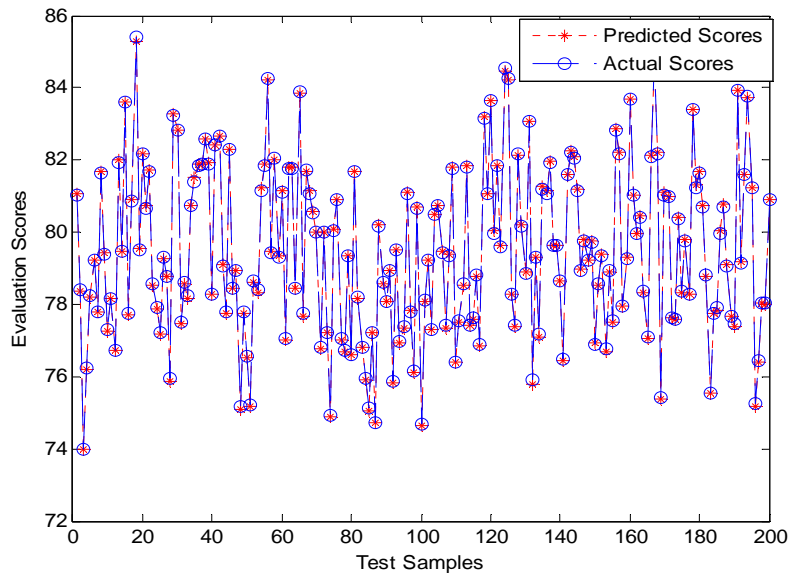


Fig. 5. The prediction results of PSO-WNN

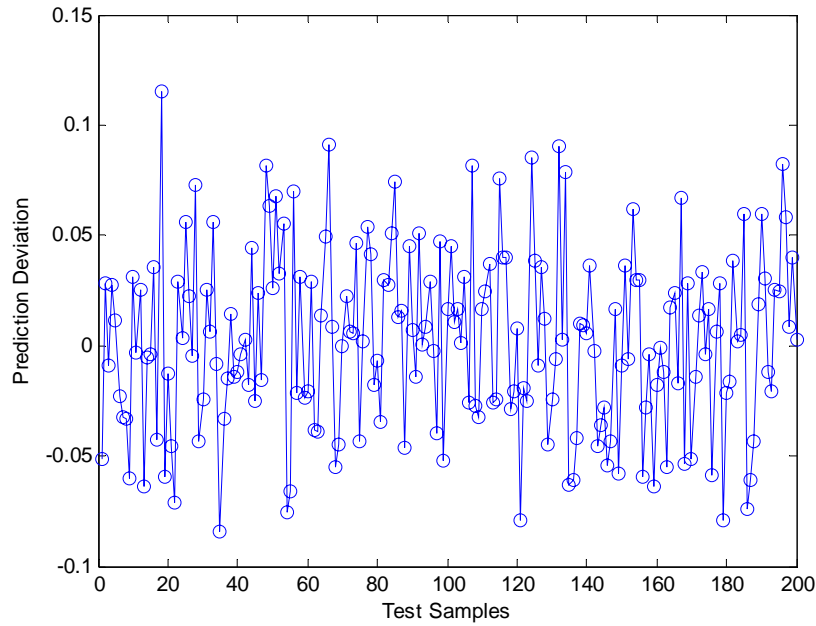


Fig. 6. The prediction deviation of PSO-WNN

By comparing the prediction results and the prediction error between the two methods above given, it can be seen that the prediction results of PSO-WNN are closer to the real experimental data with higher accuracy. In order to evaluate the performance of prediction clearly, Table 2 shows the mean square error of two methods with an average value obtained from 50 times Monte Carlo experiments.

Table 2. The MSE of WNN and PSO-WNN

Model	WNN	PSO-WNN
MSE	0.1419	0.0281

5. Conclusion

With the expansion of the scale of higher institutions, the way to improve the teaching quality of higher education becomes imminent. Referring to the teaching level evaluation index system of ordinary higher education and according to the actual situation of our colleagues, we have designed a teaching quality evaluation system, which includes 5 first-level indicators and 22 secondary indicators. Secondly, aiming at the complicated nonlinear relations between the evaluation indices, wavelet neural network was taken into account to make full use of the characteristics of the time-frequency of the wavelet transform, strong ability of learning and fault tolerance. Then the teaching quality evaluation model of PSO-WNN was established, and PSO was chosen to optimize the parameters of WNN. By comparing with the traditional models, the experimental results show that PSO-WNN model has improved the accuracy of the teaching quality evaluation considerably. PSO-WNN model has a bright application prospect in teaching management because of making the evaluation results more scientific.

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