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Research on Comprehensive Evaluation of Higher Education based on BP Neural Network and PSO Algorithm

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Abstract

In the past four decades, the expansion of higher education has become a mainstream trend in the development of higher education in the world, and has had a profound impact on all dimensions of society and the higher education system. Therefore, this article established a higher education system evaluation model, and evaluated higher education in the six countries of the United States, Australia, Germany, Japan, Brazil, and Turkey. First, we selected 11 indicators such as the education index and the number of universities in the above six countries as the secondary indicators, and used the principal component analysis method to reduce the 11 indicators into 3 primary indicators, which are scientific research achievements and university construction. And the implementation status of higher education. Next, we use BP neural network to establish an evaluation model. Considering the shortcomings of BP neural network such as slow convergence speed and low accuracy, we use PSO algorithm to improve it, which greatly improves the convergence and generalization ability. Finally, a complete higher education health evaluation model is obtained.

Keywords

System of Higher Education; PCA; BP Neural Network; PSO Algorithm.

1. Introduction

In the era of knowledge-based economy, the development of higher education is becoming more and more diversified. Globally, the proportion of people receiving higher education is increasing. There are about 32 countries and regions whose gross enrollment rate of higher education exceeds 50% [1]. According to Martin Trow's 'Three-Stage Theory' of higher education development, these countries have entered the stage of popularization of higher education of which some other scholars have studied and believe that trend will reshape the new relationship between the state, education and society, and there will also be some changes in the characteristics of the higher education system.[2] In the process of promoting the popularization of higher education, the prediction of a country's higher education system has been confirmed and revised constantly. It is of great theoretical significance and practical value to clarify this issue for promoting the healthy and sustainable development of higher education.[3].

2. National Higher Education Measurement Indicators

We collect 11 indicators from three aspects of university construction, scientific research achievements and the implementation status of higher education:

University construction in higher education.

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Universities are the main venues for higher education. From the national level, a healthy university system should be stable.

Stability reflects the foundation of a university, including sufficient financial resources and the integrity of the university system. A university can guarantee the smooth operation only if it has sufficient financial input. Therefore, we choose National education investment proportion as one indicator. In addition, the number of universities reflects the height, diversity and integrity of the construction of universities in a country to a certain extent, so we choose the number of universities as one indicator. The employment rate reflects enterprises' recognition of the construction of universities, because only countries with good construction of universities can cultivate graduates who are more likely to be recognized by companies in the society. So, we choose employment rate of college graduates as one indicator.

Scientific research achievements in higher education.

Scientific research is the foundation of a strong university. No matter what kind of colleges, they need to think highly of scientific research. Among them, number of SCI papers and the number of international well-known awards won are the direct reflection of a university's scientific research ability. Therefore, we choose number of SCI papers, number of Nobel Prize winners and number of Fields Medal winners as indicators. In addition, the QS World University Rankings uses a series of indicators to measure the academic influence of each university. Among them, the peer evaluation weight in the academic field accounts for 40%, and the evaluation data is authoritative. Therefore, QS ranked top 200 universities is selected.

Implementation status in higher education.

University construction is the basic index of higher education development, and scientific research achievements is the past achievements of higher education development. To comprehensively evaluate a country's higher education system, we should also focus on the implementation status including the quality, fairness and popularity of higher education.

Because the amount of tuition reflects the skewed educational resources and can reflect the quality of school education, we choose average higher educational tuition as one indicator. The ratio of male to female has always been a hot topic, which can well reflect the fairness of higher education, so we choose female-male enrollment ratio as one indicator. To characterize the popularization of higher education, we naturally choose higher education enrollment rate. In addition, in order to comprehensively evaluate the education popularity, we choose the education index as an indicator.

Table 1. Higher Education Measurement Indicators

First-level Indicators	Second-level Indicators
Scientific research results	Number of SCI papers
	Number of Nobel Prize winners
	Number of Fields Medal winners
	QS ranked top 200 universities
Implementation status	Average higher educational tuition
	Female-male enrollment ratio
	Higher education enrollment rate
	Education Index
University construction	National education investment proportion
	Employment rate of college graduates
	Number of universities

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After the above discussion, we select 3 first-level indicators and 11 second-level indicators, and regard the data of 11 indicators corresponding to a single country and a single year as a sample to analyze.[3].

We need to normalize the data first, that is, dimensionless. In this way, the influence of dimension and order of magnitude between each index can be eliminated and the neural network can be guaranteed to go on.

Then, linear functions are used to convert the original data linearization method to the range of [0,1]. The normalization formula is as follows:

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}} \tag{1}$$

X_{norm} is normalized data, X Is the original data, X_{max}, X_{min} are the maximum and minimum values of the original data set, respectively.

This method realizes equal scaling of the original data.

Next, we carry out the principal component analysis again of the second-level indicators subordinated to the three first-level indicators, that to say, we respectively carry out principal component analysis on three first-level indicators. The correlation tests were all passed, and the result is in the Table 2.

Table 2. Principal Component Analysis Results

Indicators	**Ingredients**		
	Scientific Research Results	***Implementation Status***	***University Construction***
Number of SCI papers	0.254		
Number of Nobel Prize winners	0.251		
Number of Fields Medal winners	0.253		
QS ranked top 200 universities	0.254		
Average higher education tuition		0.5409	
Female-male enrollment ratio		0.3261	
Higher education enrollment rate		0.5267	
Education Index		0.5689	
National education investment proportion			-0.7054
Employment rate of college graduates			-0.0549
Number of universities			0.7067

Finally, we use the factor score coefficient and the original standardized data to obtain the scores of each principal component.

The formula can be expressed as:

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$$F_i = \beta_{i1}X_1 + \beta_{i2}X_2 + \cdots + \beta_{in}X_n \quad (2)$$

3. Higher Education Evaluation Model based on BP Neural Network

The evaluation system of BP neural network is established according to the three first-level indexes extracted in the previous. In the absence of data and training sets, we chose to use standard data for training and to evaluate the health status of higher education in six countries over five years. In the evaluation, according to the previous general evaluation of the world education system by UNESCO and the relatively obvious facts, we take the health of higher education in the United States as the fifth level, and the health of higher education in Turkey as the first level, as the reference standard, and classify them step by step.

Assume $r(X_i, X_j)$is the correlation coefficient between X_i and X_j,having:

$$r(X_i, X_j) = \frac{Cov(X_i, X_j)}{\sqrt{Var[X_i]Var[X_j]}} \quad (3)$$

$Cov(X_i, X_j)$ is the covariance between X_i and X_j, $Var[X_i]$is the variance of X_i, $Var[X_j]$is the varianceo of X_j.

We can according to the size of the correlation coefficient between all index variables to determine whether the input data is feasible, if most of the is greater than or equal to 0.2, suggests using three first-level indicators is initially feasible. The Table 3 shows that our data is feasible.

Table 3. The degree of correlation between the principal components

	Scientific Research Results	**University Construction**	**Implementation Status**
Scientific Research Results	1	0.9657	0.7288
University Construction	0.9657	1	0.6726
Implementation Status	0.7288	0.6726	1

BP neural network is a multi-layer feedforward neural network trained according to the error reverse propagation algorithm, and it is the most widely used neural network. The topological structure of BP neural network is shown in Figure 1.[4].

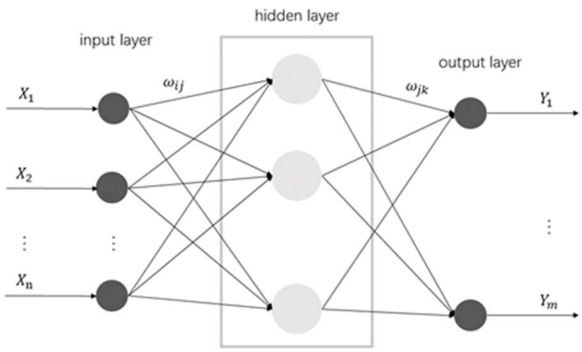

Figure 1. BP neural network topology structure diagram

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Gives a figure, with n, m output neurons, three input neurons of hidden layer neurons multilayer feedforward neural network structure. $X_1, X_2, \cdots, X_n$ is BP neural network input values, $Y_1, Y_2, \cdots, Y_m$ is BP neural network prediction, ω_{ij} and ω_{jk} is the weights of BP neural network. As can be seen from Figure, BP neural network can be regarded as a non-linear function. The network input value and predicted value are independent variables and dependent variables of the function respectively. When the input node number is$n$,output node number is m, BP neural network is expressed from of dependent and independent variables to a function mapping relationship.

The BP neural network must be trained before prediction, through which the network has associative memory and predictive ability. The training process of BP neural network includes network initialization, output calculation of hidden layer, output calculation of output layer, error calculation, weight update, threshold update and judgment of whether algorithm iteration is over.

Since there are three input indexes, the input layer is set as three nodes and the output layer is set as one node. Meanwhile, we selected different number of hidden layer nodes, and finally concluded that when the number of hidden layer neurons is 9, the error is minimum, so the structure of the neural network is 3-9-1. In this model, we choose the sigmoid function as the activation function.

When constructing the evaluation model of BP neural network, it is necessary to have a certain number of learning samples to establish the evaluation system. In order to minimize the error of evaluation, we use the behavior of anchor quantitative method and define different scale levels according to principal component evaluation score of six countries. Finally, we draw a reference standard shown in the Table 4. Based on this criterion, a data set satisfying the conditions is constructed as a standard training sample.

Table 4. Comprehensive evaluation index of health status of national higher education

Horizontal Scale	Scientific Research Results	University Construction	Implementation Status
IV	SRR≥0.95	UC≥0.59	1.62≥IS
IV	0.95>SRR≥0.20	0.59>UC≥-0.20	1.62>IS≥1.22
III	0.20>SRR≥0.12	-0.20>UC≥-0.39	1.22>IS≥1.00
II	0.12>SRR≥0.03	-0.39>UC≥-0.59	1.00>IS≥0.46
I	0.03≥SRR	-0.59≥UC	IS≥0.46

In the repeated tests of BP neural network, we find that the established BP neural network is not stable, and the convergence time is often too long, and the weight value and threshold value of each test differ greatly. This indicates that it is difficult for a simple BP neural network to achieve a good evaluation effect under this data.

Therefore, it is considered to add particle swarm optimization algorithm into the neural network. The reasons are as follows: using the global search ability of particle swarm optimization algorithm to optimize the neural network topology, connection weight and threshold; At the same time, the neural network can be embedded into the particle swarm optimization algorithm. The speed of the particle determines the direction and distance of the particle's movement, and the speed can be adjusted dynamically with the movement experience of the particle itself and other particles, so as to realize the optimization of the individual in the solvable space.[5].

PSO is initialized as a group of random particles (random solutions). Then, we iterate to find the optimal solution. In each iteration, the particle updates itself by tracking two 'extremes' (pbest, gbest). After finding these two optimal values, the particle updates its own velocity and position using the following formula.

Assume in a D -dimension search space, one group consists of n particles, where the i-th particle is expressed as a D-dimension vector $X = (X_1, X_2, \cdots, X_n)$, representing the location of i-th particle in D-dimension search space, It also represents a potential solution to a problem. Among that, the speed of the i -th particle is $V_i = [V_{i1}, V_{i2}, \cdots, V_{iD}]^T$, its individual extremum is $P_i = [P_{i1}, P_{i2}, \cdots, P_{iD}]^T$, global extremum of the group is $P_g = [P_{g1}, P_{g2}, \cdots, P_{gD}]^T$.

In each iteration, the particle updates its own speed and position through individual extremum and global extremum, and the updating formula is as follows:

$$V_{id}^{k+1} = \omega V_{id}^{k} + c_1 r_1 \left(P_{id}^{k} - X_{id}^{k}\right) + c_2 r_2 \left(P_{gd}^{k} - X_{id}^{k}\right) \tag{4}$$

$$X_{id}^{k+1} = X_{id}^{k} + V_{id}^{k+1} \tag{5}$$

In formula, ω is inertia weight; k is the number of current iterations; $V_{id}$is speed of particle; c_1 and c_2 is a non-negative constant, called the acceleration factor; r_1 and r_2 is a random number between the distribution $[0,1]$. In order to prevent the blind search of particles, it is generally recommended to limit their position and velocity to a certain range.

The nonlinear function optimized in this case is:

$$y = -c_1\, exp(-0.2\sqrt{\frac{1}{2}\sum_{j=1}^{n} x_j^2}) - exp(\frac{1}{n}\sum_{j=1}^{n} cos(2\pi x_j)) + c_1 + e \tag{6}$$

when $c_1 = 20, e = 2.71282, n = 2$, this function is Ackley function, and its graph is shown in the Figure 2.

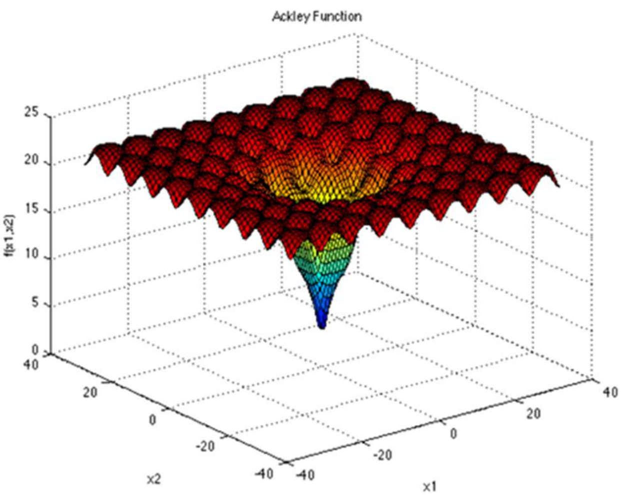

Figure 2. Ackley function

As can be seen from the graph of the function, this function has many local minimum points, the minimum point is 0 and the minimum position is (0, 0).

The flow chart of function extremum optimization algorithm based on PSO algorithm is shown in the Figure 3.

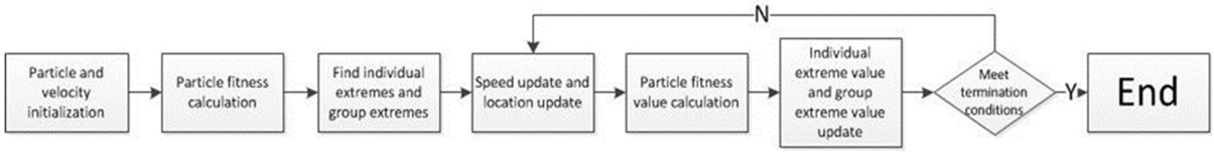

Figure 3. PSO algorithm

For this example, the fitness function is the Ackley function expression, and the fitness value is the function value. The number of population particles is 20, the dimension of each particle is 2, and the number of iteration evolution of the algorithm is 100.

The training error of PSO-BP network is shown in the Figure 4:

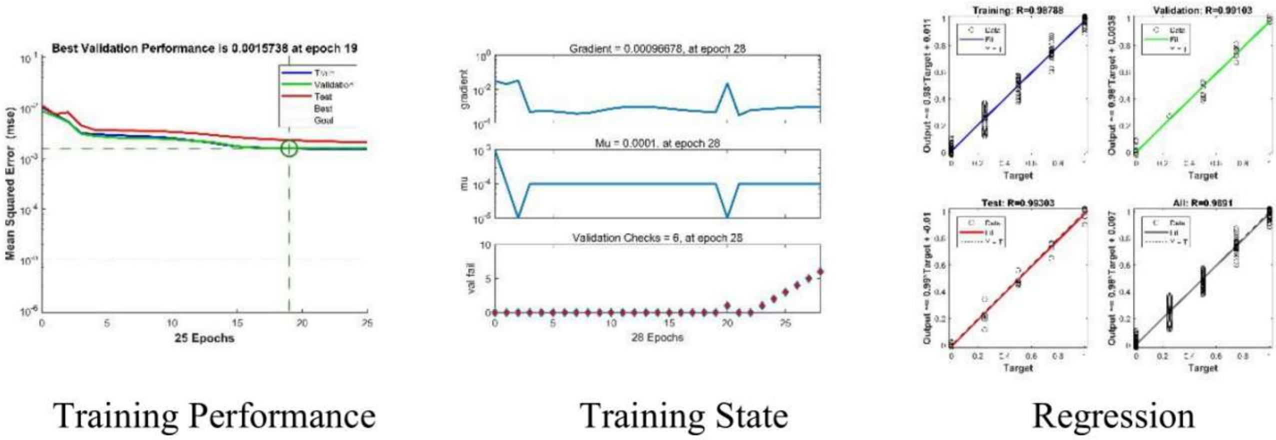

Figure 4. BP neural network training error graph combined with particle swarm

Based on our model for evaluating the health status of national higher education, we can obtain specific ratings for six countries as follows:

Table 5. Evaluation results

Country	The United States	Australia	Germany	Japan	Brazil	Turkey
Rating	V	IV	III	III	II	I

This conclusion is consistent with the predetermined classification and empirical facts, proving that our evaluation model has high credibility.

4. Conclusion

In this paper, we construct evaluation models for the health status and sustainability of higher education in different countries, and use the model to evaluate the higher education in some countries. First, the 11 indicators selected were quantified and standardized, then principal component analysis was conducted to obtain three principal components. Then, we carried out principal component analysis on the three first-level indicators respectively, obtained the three principal components, and calculated the score of each principal component, which was used as the data of the following evaluation model. Finally, the principal component point of each country is substituted into the BP neural network results for testing, and the conclusion is consistent with the predetermined classification and empirical facts.

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