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Health Evaluation Model of higher Education based on optimized BP Neural Network Model

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Abstract: This paper mainly studies the comprehensive evaluation of the development level of higher education system, and establishes the health evaluation model and sustainable evaluation model. First of all, this paper divides the indicators of higher education into three aspects, collects the data of 7 countries with different development levels, and establishes 11 indicators for evaluating the development quality of higher education. Principal component analysis is used to reduce 11 secondary indicators to 3 first-level indicators. Secondly, the BP neural network is used to construct three first-order indexes as input vectors, and genetic algorithm is used to improve the accuracy and convergence of the model.

1. Introduction

Higher education is an important part of a country's development and national progress, so it is necessary to study its health. Through the analysis of the literature, it is found that many current education index systems [1] have different emphasis, but their core evaluation dimensions tend to be consistent. Self-evaluation, peer review and quantitative analysis are the mainstream methods to evaluate higher education in the world [2].

2. Data preprocessing

This paper establishes an index system around 11 indicators and 7 countries and uses the data of a single country and a single year as samples for analysis[3] [4].

Table 1: Comprehensive evaluation indicators

Evaluation item	First level indicator	Secondary indicators
Higher Education development level	Higher Education Development Performance Index	Number of NSC papers (X_1)
		Number of Fields Medal winners(X_2)
		Number of Nobel Prize winners (X_3)
		QS World University Rankings ranked top 200 universities (X_4)
		Education index （X_5）
	Higher Education investment indicators	The proportion of educational expenditure per student in per capita GDP (X_6)
		Higher Education expenditure accounts for government education expenditure (X_7)
		Number of universities (X_8)
		Number of university students (X_9)
	Higher Education future development indicators	Graduate employment rate (X_{10})
		Gross enrollment rate of higher education (X_{11})

3. Index construction and data dimensionality reduction

3.1 Standardizing

In order to eliminate the dimensionless influence of different variables, it is necessary to standardize the variables first.

$$x_{ij} = \frac{X_{ij} - \bar{X}_j}{S_j} \qquad (1.)$$

x_{ij} is the normalized data; X_{ij} is the original data;, $\bar{X}_j$ is the mean of the original data; S_j The mean of the original data.

3.2 Calculation of correlation coefficient

R is the standardized sample covariance matrix

$$R = \frac{\sum_{k=1}^{n} (x_{ki} - \bar{x}_i)(x_{kj} - \bar{x}_j)}{\sqrt{\sum_{k=1}^{n} (x_{ki} - \bar{x}_i)^2 \sum_{k=1}^{n} (x_{kj} - \bar{x}_j)^2}} \qquad (2.)$$

n is the number of samples and it is 8 in this article.

3.3 Calculate contribution rate and cumulative contribution rate

$$contribution\ rate = \frac{\lambda_i}{\sum_{k=1}^{p} \lambda_k} (i = 1, 2, \cdots p) \tag{3.}$$

$$cumulative\ contribution\ rate = \frac{\sum_{k=1}^{i} \lambda_k}{\sum_{k=1}^{p} \lambda_k} (i = 1, 2, \cdots, p) \tag{4.}$$

λ_i is the eigenvalue of the i-th index data, and p is the number of indicators. In this paper, p is 11.

3.4 Principal component score

Generally, the first, second, ... m-th principal components corresponding to the eigenvalues whose cumulative contribution rate exceeds 80% are taken.

$$F_i = \alpha_i x_1 + \alpha_2 x_2 + \cdots + \alpha_m x_m \tag{5.}$$

3.5 Results of system construction

The comprehensive score of the principal component is obtained by multiplying the score of each component and the contribution rate of the principal component after rotation. The specific expression is:

(1) Higher Education Development Performance Index $= 0.453x_1 + 0.055x_2 + 0.103x_3 + 0.463x_4 - 0.248x_5$.

Cumulative contribution rate is 82.181%.

(2) Higher Education investment indicators $= 0.453x_6 - 0.164x_7 + 0.444x_8 + 0.207x_9$.

Cumulative contribution rate is 82.455%.

(3) Higher Education future development indicators $= 0.626x_{10} + 0.626x_{11}$.

Cumulative contribution rate is 86.447%.

In summary, through principal component analysis, the various indicators of national higher education are reduced into three categories, and the weights of each indicator in each component are different.

4. Health Evaluation Model of Higher Education system

4.1 The Establishment of GA-BP Neural network evaluation model

In order to solve the problem that it is difficult to determine the structure parameters and weight parameters of neural network for health evaluation of higher education system, and the prediction accuracy is low, genetic algorithm is used to optimize the topological structure and weight of BP neural network. For this reason, we use genetic algorithm to optimize the topological structure and network weight of BP neural network. The evaluation model of GA-BP neural network is established [5].

After completing the factor analysis of the original variables, the paper use SPSS to test the correlation of the three first-level indicators extracted. As shown in the following table, the correlation coefficient between two indicators is greater than 0.2, so these three indicators can be selected as the input layer of the neural network.

Table 2: Correlation coefficient

Index	Higher Education Development Performance Index	Higher Education investment indicators	Higher Education future development indicators
Higher Education Development Performance Index	1.000	.281	-.746
Higher Education investment indicators	.281	1.000	-.218
Higher Education future development indicators	.746	-.218	1.000

The input variables of the Neural Network are the three first-level indicators in the above-mentioned indicator system. The number of nodes in the output layer of the network is 1. There are 5 types of national higher education health status to be evaluated. Therefore, in the model, the input layer has 3 nodes, the hidden layer has 5 nodes and the output layer has 1 node.

4.2 Establishment of GA-BP Neural Network Model

Step1: Determine the fitness function and activation function.

We use training samples to train each individual and calculate the learning error of each individual to determine the fitness value. The method of calculating the learning error is as follows: (1) Calculate the output of nodes in the hidden layer and output layer in the network.

$$y_j = f\left(\sum_{i=1}^{L} a_{ij} x_i - w_j\right), i = 1, 2, \ldots L \tag{6.}$$

Function f is a *Sigmoid* function $f = \frac{1}{1+e^{-x}}$.

(2) Calculate the network error.

$$E_j = (t_j - y_j) \cdot y_j \cdot (1 - y_j) \tag{7.}$$

t_j is expected error; E_j is network error.

(3) Compare the network error with the maximum allowable error.

If the conditions are met, the iteration ends, otherwise, after correcting the weight according to the formula, go to (1) to recalculate.

$$a_{ij}(k+1) = a_{ij}(k) + \alpha E_j x_i \tag{8.}$$

$a_{ij}(k+1)$ is the connection weight of the k+1 cycle; $a_{ij}(k)$ is the connection weight of the k cycle; α is Learning rate.

Step 2: Set parameters.

The paper need to set parameters including crossover probability P_c, mutation probability P_m, BP network structure parameters and accuracy.

Table 3: Initial data setting of simulation experiment

PARAMETER NAME	DATA VALUE
POPULATION SIZE	175
LEARNING RATE	0.1
P_c	0.4
P_m	0.1
DTRAINING TIMES	100
PARAMETER DIMENSION	3
BP NETWORK STRUCTURE	3-5-1

Step 3: Genetic algorithm optimizes the weight value and threshold value.

A set of weights and threshold distributions are randomly generated, and the individuals are encoded by real number coding. Formulas (4), (5) and (6) are used to calculate individual fitness, and genetic operators further optimize network weights and thresholds through selection, inheritance, crossover and selection.

Step 4: Use BP algorithm to adjust until the conditions are met.

4.3 The Solution

After solving the problem, compare the actual value with the training value.

Table 4: Comparison of training value and actual value

Test sample number	Test values	Actual values	Relative error
1	5.0000	5.2093	0.0419
2	5.0000	5.1909	0.0382
3	5.0000	5.1724	0.0345
4	5.0000	5.1537	0.0307
5	5.0000	5.1348	0.0270
6	5.0000	5.1158	0.0232
7	5.0000	2.0965	0.0193

Table 5: National rating

Nation	Rank
United States	A
South Africa	D
Denmark	C
Germany	A
Japan	C
India	D
Australia	D

As a result, the actual value fits well with the training value. After multiple iterations, we were able to obtain the ratings for the seven countries from 2013 to 2021, with A rating of E for (0.5, 1.5), D for (1.5, 2.5), C for (2.5, 3.5), B for (3.5, 4.5), and A for 4.5 and above. According to the national higher education health status evaluation model we established, the specific ratings of seven countries are:

5. Conclusion

In this paper, the GA-BP neural network model is used to evaluate the development level of the higher education system and the health status of the current higher education system. Using the method of principal component analysis, 11 secondary indicators are summarized into 3 primary indicators. The improved BP neural network is used to construct three first-order indexes as input vectors, and genetic algorithm is used to improve the accuracy and convergence of the model.

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