Retraction

Retracted: Analysis of Performance Evaluation Model for Higher Education Informatization by Means of PLS-BP Model

Discrete Dynamics in Nature and Society

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope

(2) Discrepancies in the description of the research reported

(3) Discrepancies between the availability of data and the research described

(4) Inappropriate citations

(5) Incoherent, meaningless and/or irrelevant content included in the article

(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] K. Dong, D. Zhang, X. Liu, and D. Guo, "Analysis of Performance Evaluation Model for Higher Education Informatization by Means of PLS-BP Model," *Discrete Dynamics in Nature and Society*, vol. 2022, Article ID 9239812, 12 pages, 2022.

Research Article

Analysis of Performance Evaluation Model for Higher Education Informatization by Means of PLS-BP Model

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In order to improve the intelligent level of higher education informatization, a novel performance evaluation model of higher education informatization by means of PLS-BP model is proposed. The principles of partial least squares (PLS) method and back propagation (BP) neural network are introduced firstly. The main components of the data are extracted by PLS method, and then combined with BP neural network, the PLS-BP model is constructed. At the end of the article, the PLS-BP evaluation model is simulated and analyzed. From the comparison results, the error between the PLS-BP evaluation model and traditional performance evaluation is relatively small, and the maximum relative error is 2.32%. The comparison results verify the accuracy of the PLS-BP model. This model presented in this paper provides a new way for the performance evaluation of higher education informatization.

1. Introduction

Higher education can serve science and technology and promote the rapid development of economy and society. At the same time, it can provide human resources for social development. In addition, higher education can provide an educational resource platform, which is conducive to the improvement of comprehensive national strength [1]. The informatization of higher education is the only way for all countries in the world to meet the challenges of the knowledge economy and realize the modernization of education [2, 3]. Meanwhile, the informatization of higher education is also a significant index to measure the comprehensive strength of education [4, 5]. Education informatization is the basis and conditions for establishing a learning society [6].

The focuses of the future development of education informatization are how to achieve the further integration and coordinated development of education [7]. For this goal, the evaluation of education informatization level must be

gradually changed from "investment-based" to "performance-based," and the application and development of education informatization must be promoted through the performance evaluation of education informatization [8–10].

The research on performance evaluation is earlier, and the results are relatively significant. Benson et al. [11] evaluated the operation capacity of the education financial system based on the distribution of education resources, the efficiency of education resource distribution, and whether the provision of education services is sufficient. Ho et al. [12] selected data from 48 states in the USA as a sample, conducted regression analysis, and conducted a research and analysis on the economies of scale of college education. Zhang [13] evaluated the traditional ERP performance evaluation theory and expounded the defects of the method. Based on ERP method, combined with ERP implementation objectives, ERP performance evaluation objects and principles, an ERP performance evaluation model based on balanced scorecard is proposed. Rumualdus [14] proposed

the use of balanced scorecards to study the enterprise performance evaluation. The four factors of finance, customers, internal business, and learning and growth are used as evaluation indicators to give a detailed overview of the performance evaluation system. Dantas et al. [15] introduced the balanced scorecard method to educational institutions. The applicability of the National Business Learning Service (SENAC/RN) in educational institutions was studied. Lu et al. [16] conducted related research based on the DEA method, combined with the analysis of input and output. Wu et al. [17] studied the evaluation model and system of education informatization by using the grey fuzzy method and designed a set of evaluation system for the problem of information loss in education informatization.

Rao et al. [18] combined particle swarm optimization (PSO), Hopfield neural network, and BP neural network for equipment fault diagnosis. Cheng et al. [19] used BP neural network for damp heat detection. Based on variable input genetic algorithm (GA) and BP neural network, a temperature and humidity monitoring and prediction model is proposed. Bai et al. [20, 21] l combined BP neural network with robot kinematics and proposed a new robot inverse kinematics model algorithm combining FOA optimization and BP neural network. Wang et al. [22] applied BP neural network model to college students' sports performance prediction. By comparing the results of the established sports performance prediction model with the experimental data, the accuracy of the BP neural network model is verified. In the process of studying the knowledge fusion risk of innovation ecosystem, Wang et al. [23] found that integrating risk assessment with BP network model can achieve more accurate prediction of risk assessment.

The above literature has verified the wide applicability of BP neural network. With the deepening of research, BP neural network has gradually attracted people's attention in the research process of performance evaluation-related fields. In order to identify the dynamic short-term performance behavior of enterprise employees, Li et al. [24] proposed a BP neural network fuzzy system combined performance evaluation model. It overcomes the influence of factors such as potential value and performance changes on the results of performance evaluation. Yang et al. [25] introduced BP neural network model in the research process of higher education teaching management evaluation. By comparing the evaluation results of five universities, the wide applicability of BP neural network is further verified. Zhang et al.[13] researched knowledge management theory and performance evaluation method based on BP neural network, which further proves the feasibility of BP neural network in the field of performance evaluation. Traditional BP neural network has only been introduced into the field of comprehensive performance evaluation in recent years. In the process of performance evaluation, there may be a nonlinear relationship between the evaluation object and the comprehensive index, which will lead to the difference between the evaluation results and the actual results. In addition, the evaluation objects with weak correlation will also cause differences in results.

In view of the above problems, this paper proposes a performance evaluation model for higher education informatization by means of PLS-BP model. The principles of partial least squares (PLS) method and back propagation (BP) neural network are introduced firstly. The main components of the data are extracted by PLS method, and then combined with BP neural network, the PLS-BP model is constructed. At the end of the article, the PLS-BP evaluation model is simulated and analyzed.

2. Principle and Data Processing of PLS-BP Method

2.1. Principle of PLS. In the multivariate statistical data analysis methods, there are mainly the following two methods: the model method represented by multivariate linearity and the cognitive method represented by principal component analysis. Performing regression modeling before the independent variable and the dependent variable and expecting to get the relationship between the two variables is the main working idea of ordinary multiple regression analysis, but this method has received more restrictions in practical applications, of which the most important the problem is the multiple correlations between independent variables. PLS [26] can effectively overcome this problem. Unlike the traditional method, it no longer directly considers the regression modeling between two sets of variables, but extracts several pairs of systems with the best from the variable system. Explain the new comprehensive variables (also known as components) of the ability, and then use them for modeling. In terms of component extraction, the principal component analysis method is mostly used for the extraction of components in a single data table, and the canonical correlation analysis considers the extraction of components between two data tables and analyzes the correlation between the two tables. In fact, after PLS regression formally integrates the extraction methods of these two components, a new component extraction method is given, and it is used in the regression modeling analysis between the two data tables.

In general, the PLS provided a new method of multi-dependent variable to multi-independent regression modeling; at the same time, in the data in terms of simplification or dimensionality reduction, the advantages of principal component analysis methods and canonical correlation analysis methods have been absorbed, and a new component extraction method has been provided, which brings great convenience to the analysis of multivariate statistical data. The principle and detection method of PLS method are introduced as follows.

The first is the basic principle of PLS. Suppose there are P variables $y_1, y_2, \ldots, y_p$ and m variables $x_1, x_2, \ldots, x_m$. When PLS performs regression operation, the first value t_1 in the independent variable is selected firstly. That is, $t_1 = k_1 x_1 + k_2 x_2 + \ldots + k_m x_m$, where k_i ($i = 1, 2, ..., m$). At the same time, the same processing method needs to be used to extract the first component u_1 from the dependent variable data. The Lagrangian multiplier method is used to maximize the correlation between t_1 and u_1 [27]. Secondly, construct the

regression equation of dependent variables $y_1, y_2, \ldots, y_p$ and t_1. If the current regression equation can achieve satisfactory accuracy, the algorithm can be aborted. Otherwise, continue to extract the second pair of components from the remaining information until satisfactory accuracy can be obtained. If finally extracting r components $t_1, t_2, \ldots, t_r$ from the set of independent variables, the PLS regression method first builds the regression equation of $y_1, y_2, \ldots, y_p$ and $t_1, t_2, \ldots, t_r$. Then, it is transformed into the regression equation of $y_1, y_2, \ldots, y_p$ and $x_1, x_2, \ldots, x_m$, which is called the PLS regression equation.

The next step is to perform a crossvalidation test [27]. Similar to the principal component analysis method, the PLS method generally does not need to extract the r components $t_1, t_2, \ldots, t_r$ to construct the regression equation and only needs to select the first component $(1 \leq r)$ to obtain the prediction for a regression model with a good level, and we can use the crossvalidity test to determine the number of principal components required.

The i-th observation $(i = 1, 2, \ldots, n)$ is removed each time, and the PLS regression method is used to build the model for the remaining n-1 observations. The regression equation fitted after selecting h components is studied, and the i-th observation point removed before is substituted into the regression equation established by us to obtain the predicted value of Y_j $(j = 1, 2, \ldots, p)$ at the i-th observation point $\overline{y_{(i)j}}(h)$.

Repeat the above calculations for $i = 1, 2, \ldots, n$, and the sum of squared prediction errors of the j-th dependent variable Y_j $(j = 1, 2, \ldots, p)$ can be obtained. When h components are extracted, (1) is shown in [28].

$$\text{PRESS}_j(h) = \sum_{i=1}^{n} \left(y_{ij} - \overline{y_{(i)j}}(h) \right)^2, \tag{1}$$

where $j = 1, 2, \ldots, p$.

At this time, the sum of squares of prediction errors of $Y = (y_1, y_2, \ldots, y_p)^{\text{T}}$ is shown in (2).

$$\text{PRESS}(h) = \sum_{j=1}^{p} \text{PRESS}_j(h). \tag{2}$$

Moreover, all the sample points are used to establish a regression equation containing h components. If the value of the i-th sample point is recorded as $\overline{y_{ij}}(h)$, the sum of squared errors for Y_j can be given as:

$$SS_j(h) = \sum_{i=1}^{n} \left(y_{ij} - \overline{y_{ij}}(h) \right)^2. \tag{3}$$

Thus, the sum of squared errors of Y can be obtained by (4).

$$SS(h) = \sum_{j=1}^{n} SS_j(h). \tag{4}$$

When the $PRESS(h)$ is the minimum value, h at this time is the number of components we need to extract for modeling. Generally speaking, the value of $PRESS(h)$ is usually larger than that of $SS(h)$, and the value of $SS(h)$ is

smaller than that of $SS(h$-1) [29]. Therefore, the smaller the ratio of $PRESS(h)/SS(h$-1), the better to obtain the ideal expected value. Generally, we set the threshold as 0.05, as shown in (5).

$$\frac{\text{PRESS}(h)}{SS(h-1)} \leq (1 - 0.05)^2 = 0.95^2. \tag{5}$$

Based on (5), adding a new component t_h is helpful to improve the model and improve its accuracy. To this end, we define the crossvalidity expression as shown in the following equation.

$$Q_h^2 = 1 - \frac{\text{PRESS}(h)}{SS(h-1)}. \tag{6}$$

Based on the above equation, before the end of each round of calculation of modeling, crossvalidation is performed on it. If $Q_h^2 < 1 - 0.95^2 = 0.0975$ is calculated in the h-th step, we can consider that the modeling meets the accuracy requirements; that is, the algorithm is suspended.

2.2. Principle of BP Neural Network. BP neural network [30] is a multilayer feedforward neural network, and its error propagation direction is back propagation. The principle of BP neural network is to imitate the working mode of human brain neurons and simplify the work of human brain neurons. In the process of learning and research using neural network system, we do not need to directly understand the corresponding relationship between independent variables and dependent variables, which highlights the absolute advantage of neural network system. Neural network has a three-layer information transmission structure, including input layer, middle layer, and output layer. For the three-tier structure, the connection form of the two interconnected structures is arbitrary, and the three-tier structure cannot be connected across layers.

Figure 1 shows the structure of three-layer BP neural network. As can be seen from Figure 1, the whole network system is composed of three layers. It corresponds to the information transmission process in nerve cells. In the neural network model, there are two kinds of signals: working signal and error signal. The working signal is composed of the value input by the user, and the error signal is the difference between the expected result and the real value.

Among the learning principles and methods of BP neural network, the steepest descent method should be used most. After the user sets the initial weight, the data previously entered by the user will be transmitted to the middle layer. The middle layer uses the selected learning function to learn and transmit the learning results to the output layer. If the error is smaller than the allowable range, the result will be output directly. Otherwise, the error exceeds the specified error range, and the error result will be back propagated from the output layer to the middle layer and then back propagated to the input layer. At this time, the input layer adjusts the initial weight and continues to transmit the result to the middle layer. The middle layer will adjust the corresponding weight and threshold and then transmit the result to the output layer. At this time, continue to compare
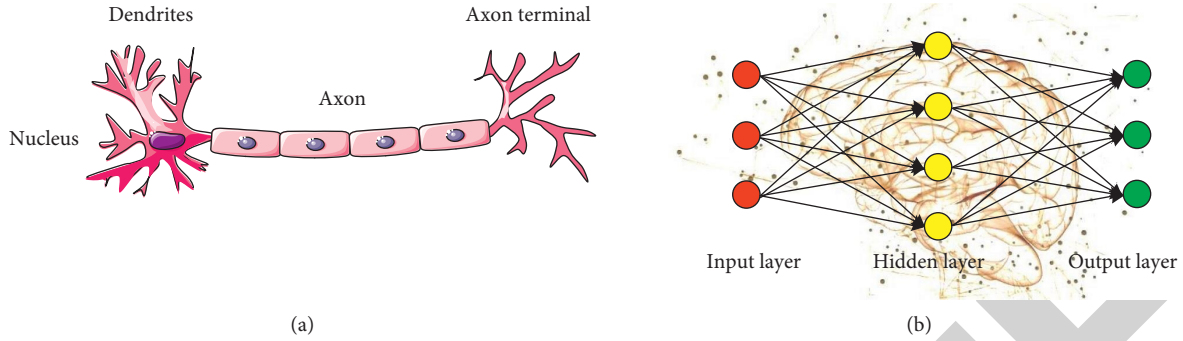
FIGURE 1: Structure diagram of three-layer BP neural network: (a) neural cell structure; (b) BP neural network.

the error with the expected value and repeat the above steps, until the output result. This process is to minimize the sum of squares of errors of the network.

Figure 2 shows the structure and algorithm flowchart of BP neural network. This working process is divided into two parts—Part 1: the calculation and learning process of forward propagation and Part 2: the error back propagation process when the error between the real value and the predicted value exceeds the error set by the user.

As mentioned earlier, the forward propagation process includes the sequential propagation of three layers. Similar to human nerve cells, each layer in the network is connected to each other. At the end of the forward propagation process, if the error is too large, the error will enter the back propagation process of three layers. In this process, the network will automatically adjust the initial weight and threshold set by the user. This step is to ensure that the output error is within the error range set by the user. When this purpose is achieved, the learning process ends.

3. Construction of Evaluation Model

3.1. Evaluation Indicator. The performance evaluation of education informatization can be simplified to the evaluation of the six constituent elements of the model of education informatization performance evaluation. Therefore, these six elements constitute the primary indexes of the system. Considering the operability of the index system, these six elements need to be further decomposed, and the decomposition result is the secondary indicators of the index system. In order to implement the evaluation, we also need to analyze the connotation and extension of education informatization performance evaluation, that is, from which angles to evaluate education informatization performance. The decomposition of evaluation angles constitutes three-level and four-level indicators. For each indicator item, observation points need to be set and explain the data items that each index needs to collect. The four-level indicators and observation points together constitute a complete education informatization performance evaluation index system. Because of the length, this paper only discusses the general index system of education informatization performance evaluation. On this basis, we can get the evaluation index system of each specific education category.
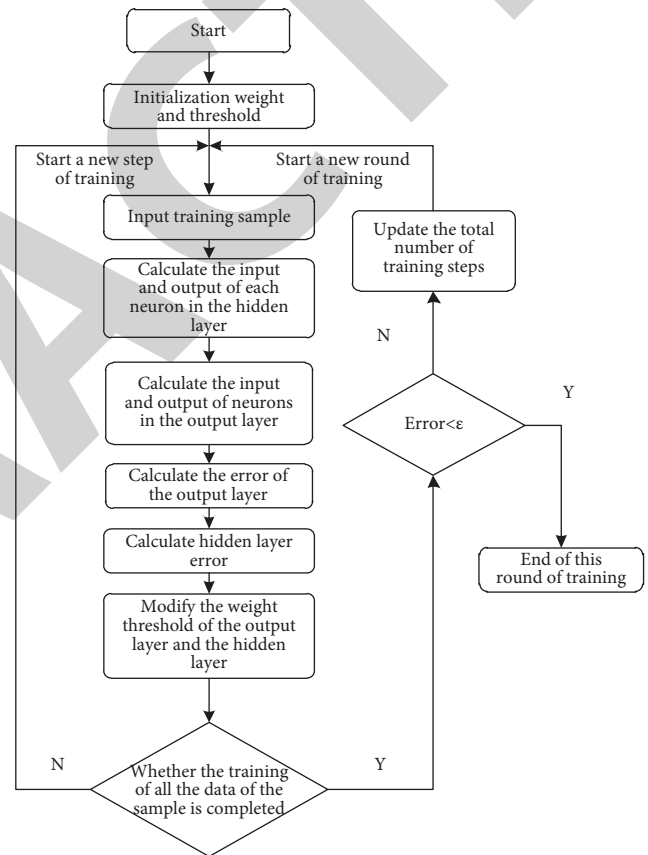

FIGURE 2: Calculation flowchart of BP neural network.

To sum up, the primary indicators of the performance evaluation system of higher education informatization include career development, user effect, business activities and processes, infrastructure, information system and data, and informatization team. According to the literature [18], the composition and proportion of college education information system are introduced. Figure 3 shows the performance evaluation indicators of education informatization. The decomposition of the first-level indicators constitutes the second-level indicators. Because this paper studies the general performance evaluation index system of education informatization, different education categories such as colleges and universities, vocational education, basic
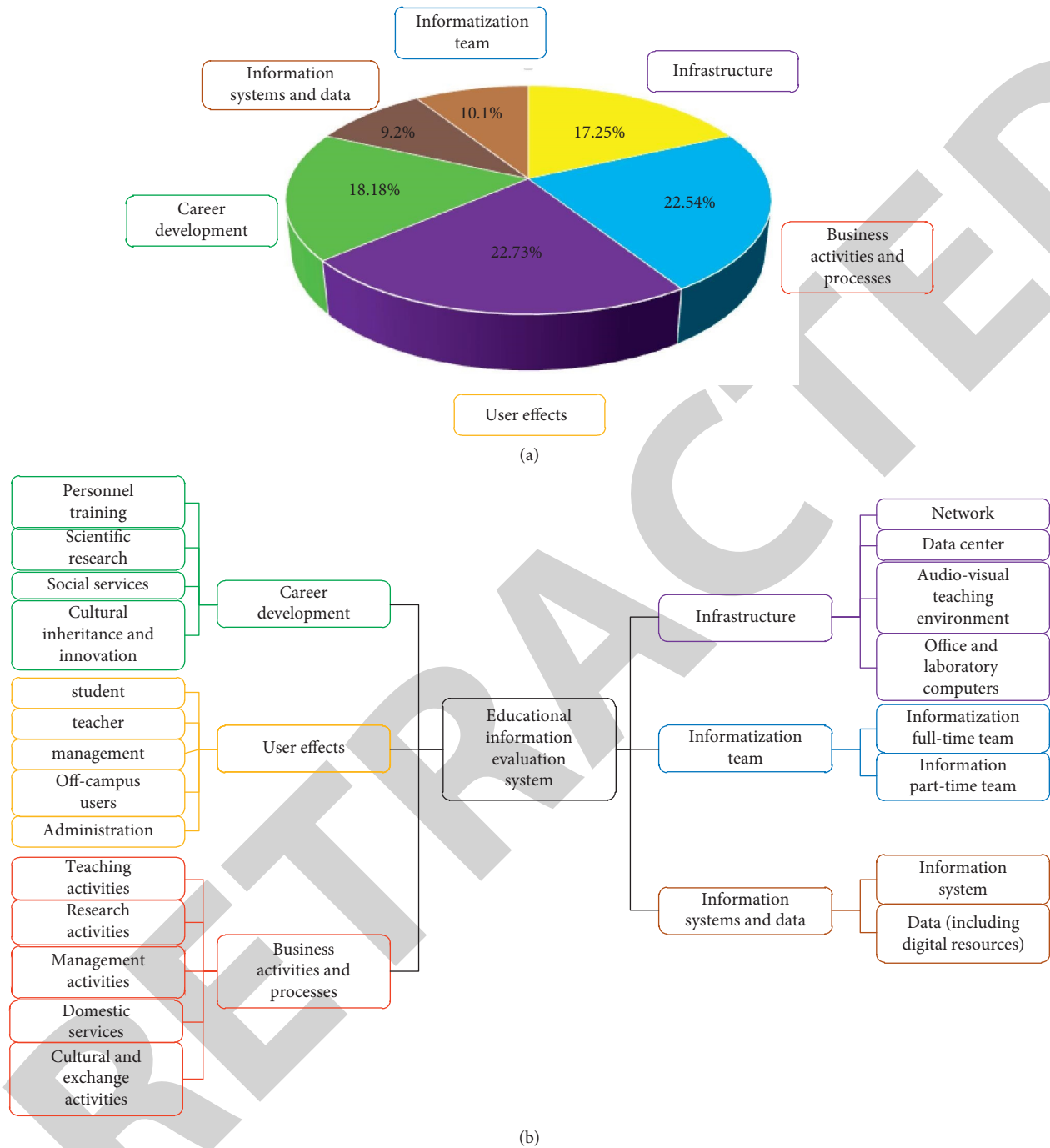
Figure 3: Performance evaluation indicators of education informatization: (a) proportion; (b) component.

education, preschool education, and educational administration are considered in the decomposition.

(1) Throughout the various education categories, personnel training, scientific research, social services, cultural inheritance, and innovation are the main goals of the development of education. Therefore, the secondary index "career development" is further decomposed into these four secondary indicators.

(2) Students, teachers, administrators, administrative departments, and off-campus users are the main service objects of education informatization. The performance evaluation of user effects in education informatization performance mainly considers the informatization experience of these five types of users. Therefore, the first-level indicator "user effect" is further broken down into these five secondary indicators.

(3) Through the analysis of various education businesses, we found that the business of education mainly includes five types of activities: teaching activities, scientific research activities, management

activities, life services, and cultural and exchange activities. These five types of activities are supported, so these five types of activities are regarded as the second-level indicators of the first-level indicator "business activities and processes." By evaluating the support performance of education informatization for these 5 types of activities, the evaluation of education informatization's contribution to educational business activities supports performance with processes.

(4) Information infrastructure includes four types of content: network, data center, audiovisual teaching environment, and office and laboratory computer equipment, which reflects the hardware construction results of education informatization. Therefore, the first-level indicator "infrastructure" is broken down into these four. The secondary index evaluates the construction performance of education information infrastructure.

(5) Information system and data are important results of informatization construction, reflecting the achievements and effects of education information technology application. Therefore, the first-level index "information system and data" is decomposed into two second-level indicators, information system and data, and evaluates the performance of education informatization in terms of information systems and data.

(6) The informatization team includes not only a full-time informatization team—professional and technical personnel in the network information center, but also a part-time informatization team—management departments, departmental information officers, and network management teams. The informatization team is the executor of the construction of education informatization. The first-level indicator "informatization team" is decomposed into two second-level indicators, namely, a full-time informatization team and a part-time informatization team.

3.2. Evaluation Model. This section introduces the construction process of the PLS-BP evaluation model in detail. The principal components of independent variables are extracted by LPS method, and then, the extracted principal components are input into the network model. Moreover, we set the performance score as the output of the network model. Based on the above settings, PLS-BP prediction model can be obtained. Then, the neural network learning, parameter adjustment, model fitting, and testing are carried out, and then, the relevant prediction is carried out. The specific processing flow is described in detail below.

Assume that there are input variable $X = (X_1, X_2, \ldots, X_i)$, the middle layer output variable $Y = (Y_1, Y_2, \ldots, Y_j)$, and the output layer variable $Z = (Z_1, Z_2, \ldots, Z_j)$. In the same time, the expected output target variable $T = (T_1, T_2, \ldots, T_l)$. The

W_{ij} and W_{jl} are the connection weights of input layer and middle layer, respectively. Corresponding to the learning samples $X_1, X_2, \ldots, X_i$, the output samples are $Z_1, Z_2, \ldots, Z_l$.

The implementation process of BP network is introduced below. Firstly, the number of nodes of three layers needs to be determined. There are many factors affecting the performance evaluation. This index has been summarized in section 3.1. Therefore, if the data of 22 indexes are directly selected for network learning and training, the number of input layer nodes can be determined to be 22. After the number of input layers is determined, the number of middle layer nodes needs to be set. Taking the optimal number of middle layer nodes can not only construct a good BP neural network structure, but also make the learning time meet the requirements, improve the fault tolerance and generalization ability of network training, and accelerate the convergence speed of data, so that the function calculation results approach the expected output and improve the prediction accuracy. At present, there is no generally applicable method and theory to determine the number of middle layer nodes, which generally adopts empirical equation. The empirical equation used in this paper is as follows.

$$q = n + p + a, \tag{7}$$

where n, q, p are the number of three-layer nodes of the prediction model, respectively, and a is a constant numerical value (usually take 1–10).

Firstly, 10 nodes in the middle layer are trained and tested. Then, add a number, try again until the convergence speed of the network to the data is no longer accelerated, and determine the optimal number of middle tier nodes. Through continuous attempts, the optimal number of middle layer nodes of the prediction model can be determined to be 18. After the above process is completed, the next step is to determine the node value of the output layer of the prediction model. The purpose of constructing the university education informatization performance evaluation model based on PLS-BP model is to grasp the current situation of different university education informatization performances as a whole, and its output result is the performance evaluation level. The prediction model structure designed in this paper has only one output result, that is, the predicted value of higher education informatization performance. Therefore, it can be determined that the node value of the output layer of the prediction model is 1. To sum up, the PLS-BP prediction model designed in this paper is $22 \times 18 \times 1$.

The next step is the initialization of the threshold and the connection weight of the PLS-BP prediction model to ensure that the large weighted input cannot saturate the network. Generally set the initial connection weight (Weight) and threshold value (Bias) of the PLS-BP prediction model to any number in the interval $(-1, 1)$ to ensure that the weights and thresholds of each layer are initialized with small random numbers. The essential purpose is to gradually correct the threshold and weight of the network, so as to achieve the target error requirement of the network.

For the model in this paper, there are 22 inputs, and each input has an appropriate weight W to connect to the next

layer of the network. However, W represents the strength of the connection of each layer of the PLS-BP prediction model. The network transfer function includes logarithmic sigmoid function, linear purelin function, and tangent simoid function. This article is a simulation analysis of the performance evaluation model of college education informatization. The middle layer uses the tangent logarithmic function sigmoid transfer function.

After determining the transfer function of the three-layer network structure of the PLS-BP prediction model, use the function initff to reinitialize the PLS-BP prediction model. The function initff can realize the reinitialization of BP neural network, and the command statement is "net = init(net);"". The output vectors of the middle layer and the output layer can be expressed by the (8) and (9).

$$Y = f_1 \left(\sum_i W_{ij} x_i + b_i \right), \tag{8}$$

$$Z = f_2 \left(\sum_j W_{jl} y_j + b_l \right), \tag{9}$$

where f_1 is the "tansig"; f_2 is the "purelin"; and b_i, and b_l are the confinement values of the middle layer and the output layer, respectively.

The error of the prediction model is $E = T\text{-}Y$. When E is less than the error we set, the program will terminate. Otherwise, the above operation will continue. The error set in this paper is $\varepsilon = 0.0001$.

The node error of the output layer is shown in the following equation.

$$\delta_l = (T - Z)Z(1 - Z). \tag{10}$$

Middle layer node error is

$$\delta_j = Y(1 - Y) \sum \delta_l W_{jl}. \tag{11}$$

The weight correction amount of the middle layer neuron is

$$\Delta W_{jl} = -\eta \frac{\partial E}{\partial W_{jl}}. \tag{12}$$

The weight correction amount of the output layer neuron is

$$\Delta W_{ij} = -\eta \frac{\partial E}{\partial W_{ij}}. \tag{13}$$

where η is the network learning rate, with a value range of $0 < \eta < 1$. The learning rate n is related to the learning convergence rate of the prediction model (usually set $\eta = 0.01$).

The correction equation of connection threshold and weight can be found in the following. The weights between the three layers can be expressed by (14) and (15), respectively.

$$W_{ij} = W_{ij} + \alpha \delta_j X, \tag{14}$$

$$W_{jl} = W_{jl} + \alpha \delta_l X. \tag{15}$$

The thresholds between the three layers can be expressed by (16) and (17), respectively.

$$b_i = b_i + \beta \delta_j, \tag{16}$$

$$b_l = b_l + \beta \delta_l. \tag{17}$$

4. Results and Discussion

4.1. Standardized Inspection. When using the PLS method to extract the principal components for PLS regression analysis, the results of the three parameters of the informatization part-time team, cultural heritage innovation, and case personnel are consistent in 40 samples of four universities; that is, the change of the three parameters has a contribution rate of 0 to the overall,. The data come from the survey results of Beijing Academy of Social Sciences. Therefore, three parameters are eliminated on the basis of the original 22 indicators.

The number of principal components extracted is 3. The standardized factor scores of the extracted 3 principal components are shown in Figure 4.

From the above figure, it can be concluded that the first component has a large coefficient in equal variables. This part focuses on the assessment of basic settings and coordination of physical resource allocation; the second component has a large coefficient in equal variables. This part focuses on user effect, improvement of service level, and support; the third component has a large coefficient in equal variables, which can be regarded as a factor of career development.

4.2. Comparison Results and Analysis. The fitting and testing of the PLS-BP model take the extracted 3 principal components as the input. The 40 performance scores (scores ranging from 0 to 10 points) are obtained from the original expert consultation as the output. After 118 iterations of the model, the mean square error reached after training is 0.0000539.

In order to be able to more intuitively and clearly determine the development status of education informatization in various universities, the research reviews previous studies and adopts the classic "SMART" principle [31] to classify the education informatization performance of colleges and universities. A four-level division method is used, namely, excellent (≥8 points), good (≥6 points, <8 points), fair (ision metho<6 points), and poor (<3 points). To evaluate the performance of the PLS-BP model, the performance score obtained by the simulation of the model is compared with the performance score calculated by the traditional linear regression model and BP evaluation model, as shown in Figure 5.

As can be seen from the comparison results of scores in Figure 5(a), the results based on PLS-BP evaluation model are closer to the traditional results than those based on BP model. And as can be seen from the relative error in Figure 5(b), the maximum relative error based on PLS-BP evaluation model is 3.64%, while the maximum relative error
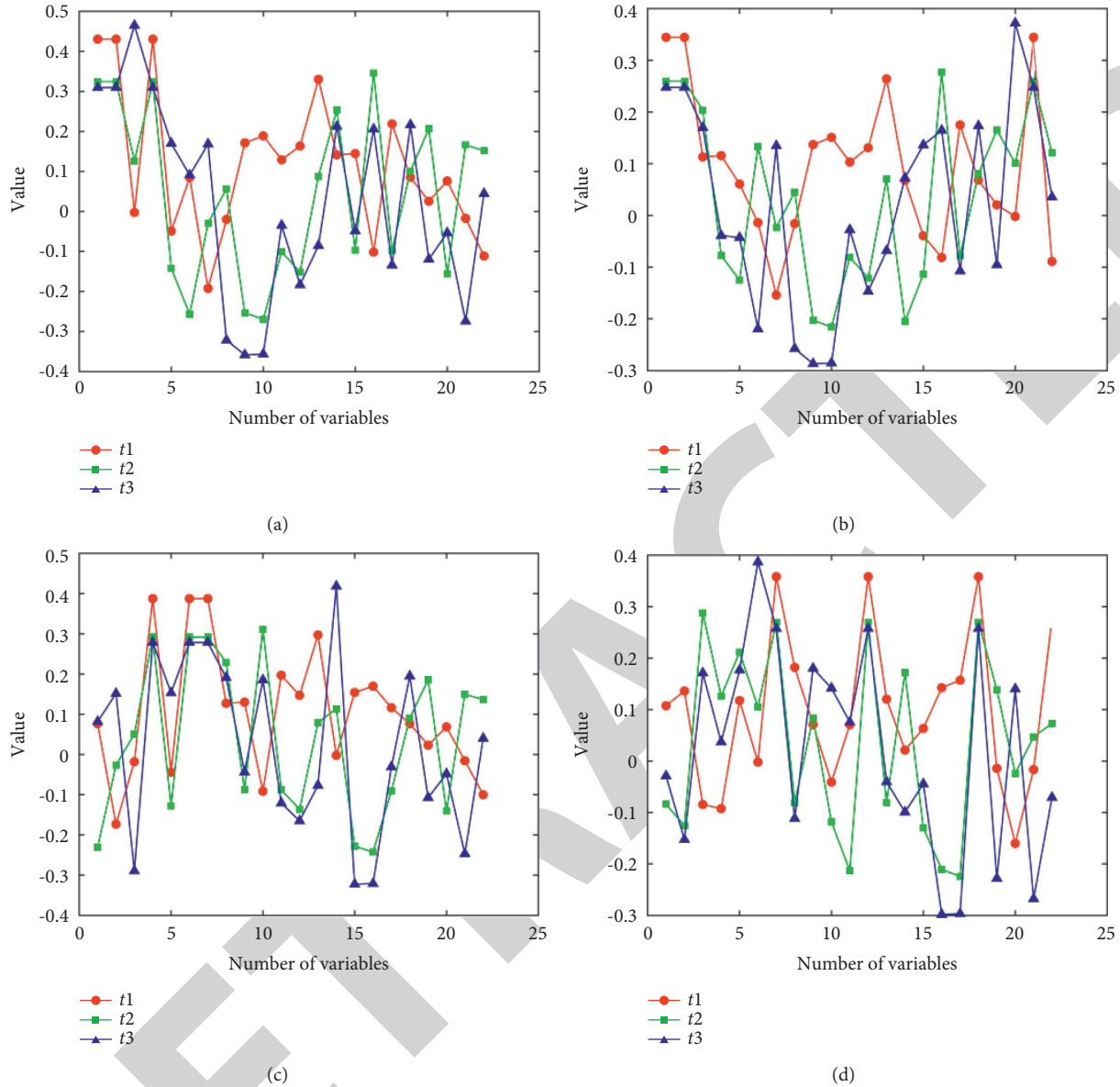
FIGURE 4: Standardized factor score: (a) University 1; (b) University 2; (c) University 3; (d) University 4.

based on BP model is 2.29%. The comparison results verify the accuracy of the evaluation model in this paper. To evaluate the performance of the PLS-BP model, the performance score obtained by the simulation of the model is compared with the performance score calculated by the traditional linear regression model. The comparison results can be found in Figure 6.

It can be seen from Figure 6 that the prediction results of PLS-BP model have the same trend as the performance evaluation results of traditional expert consultation, which shows that the application of PLS-BP model can better complete the nonlinear mapping from informatization performance evaluation index to performance score. Figure 7 shows the relative error between

traditional performance score and PLS-BP model performance score.

Based on the comparison results of 40 data samples in Figures 6 and 7, the maximum relative error between traditional performance score and PLS-BP model performance score is 2.32%.

This model provides a new way for higher education informatization performance evaluation. The PLS-BP model can be solidified and applied to the performance evaluation of education informatization in other colleges and universities, so as to avoid the interference of human factors as much as possible; at the same time, it also proves that the application of PLS-BP model to evaluate the education informatization performance of colleges and universities is effective and feasible.
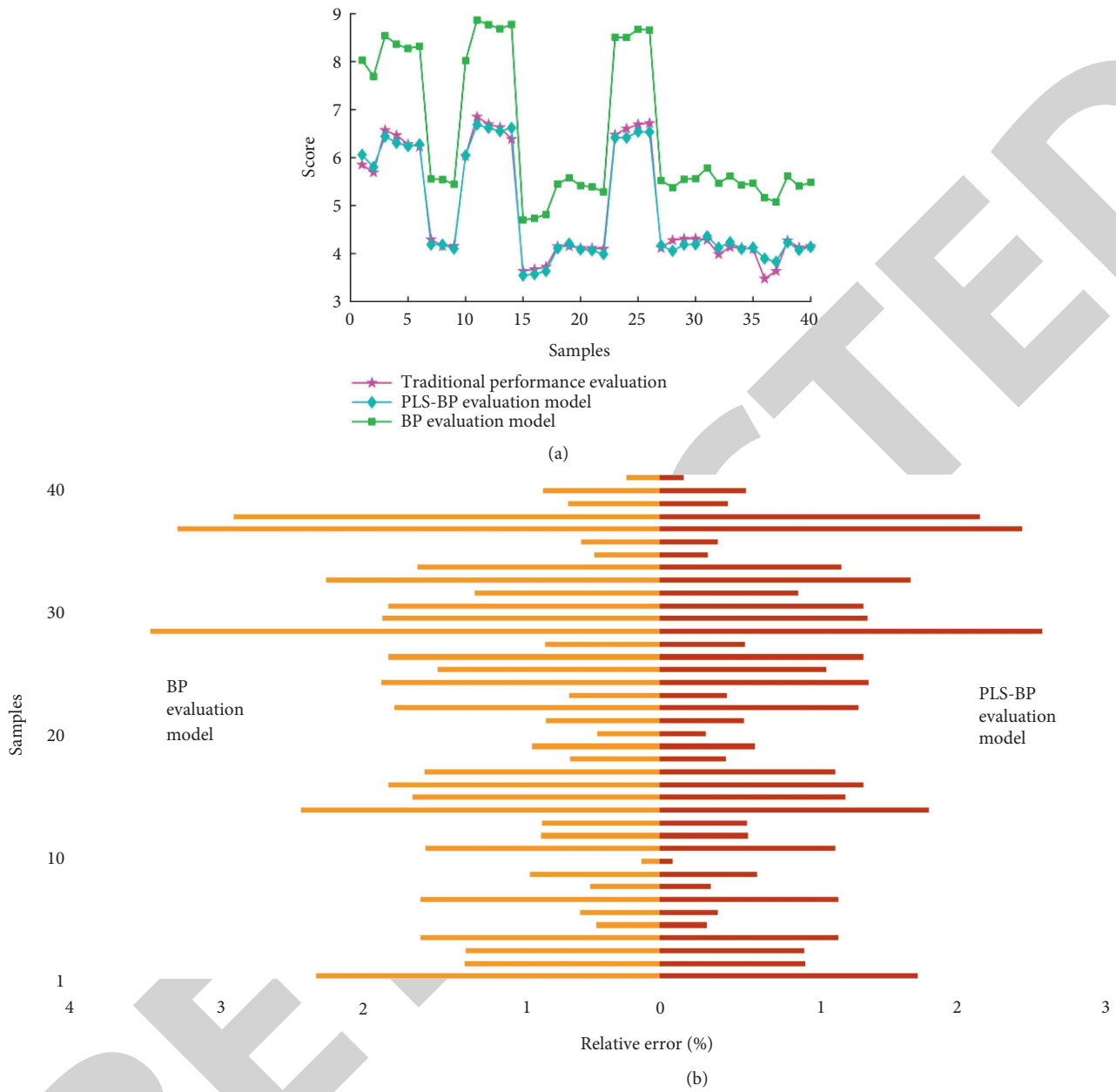
(a)

(b)

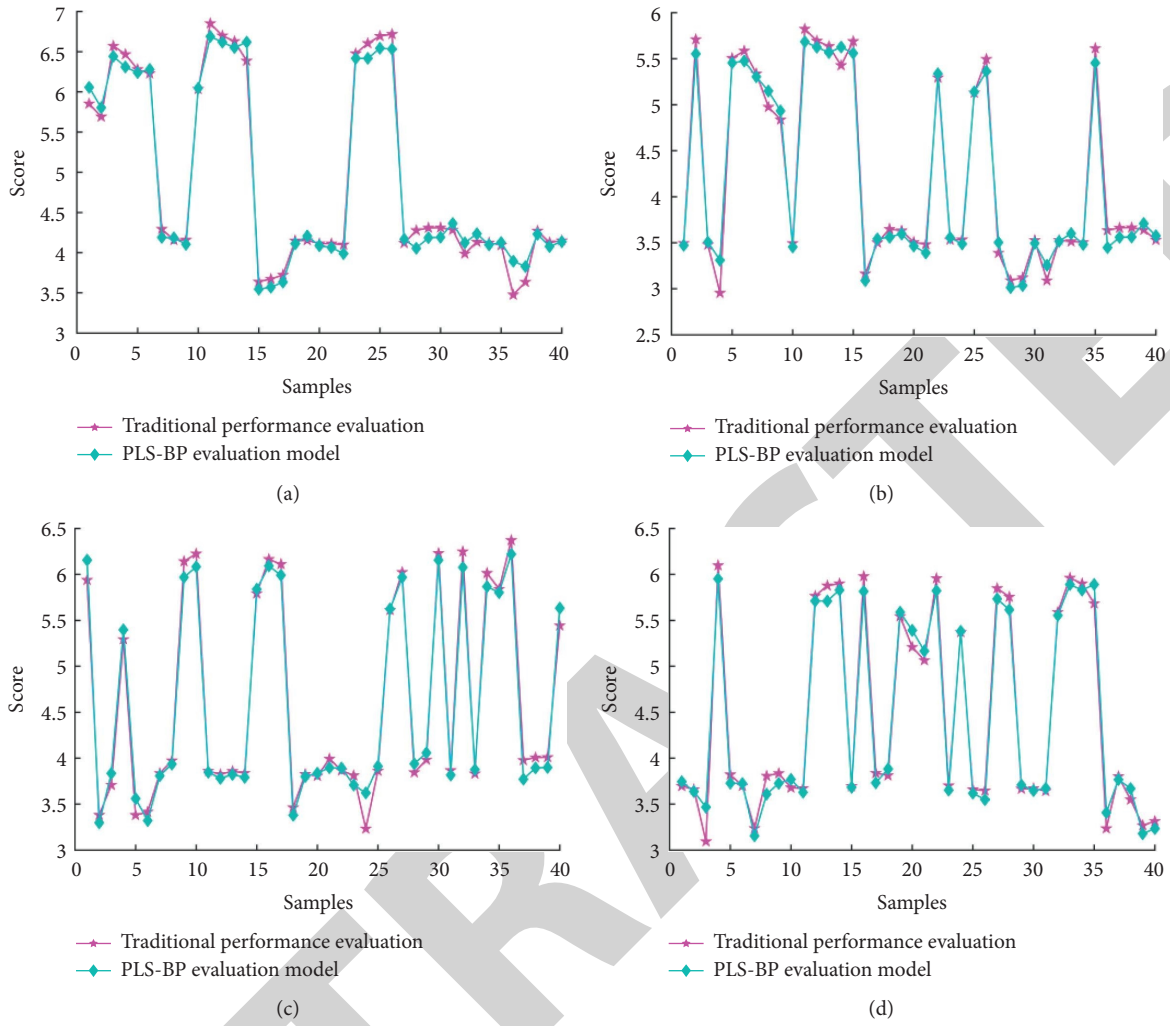Figure 5: Comparison results of performance score: (a) scores; (b) relative error.

Figure 6: Comparison results of performance score: (a) University 1; (b) University 2; (c) University 3; (d) University 4.
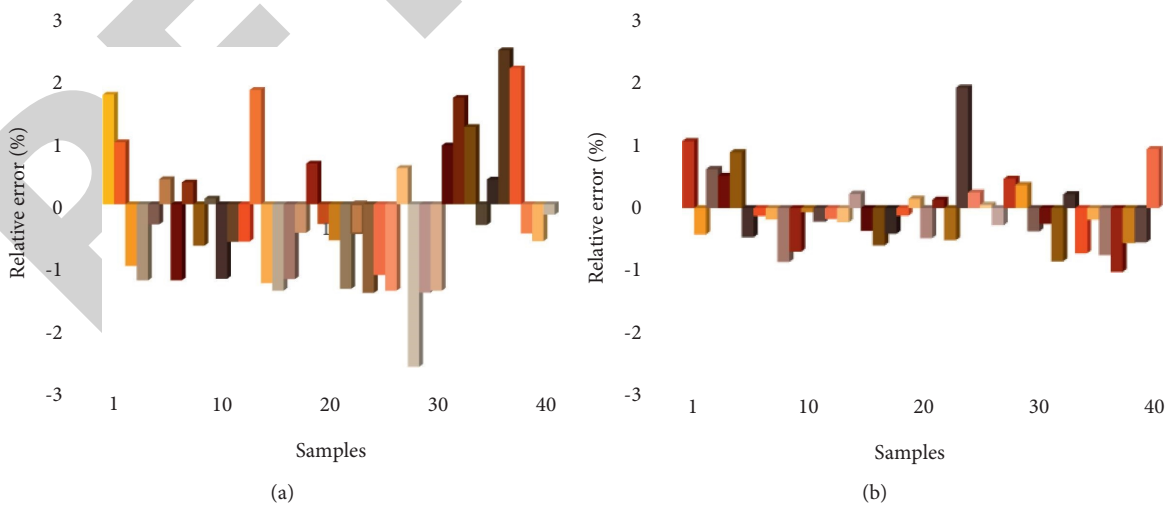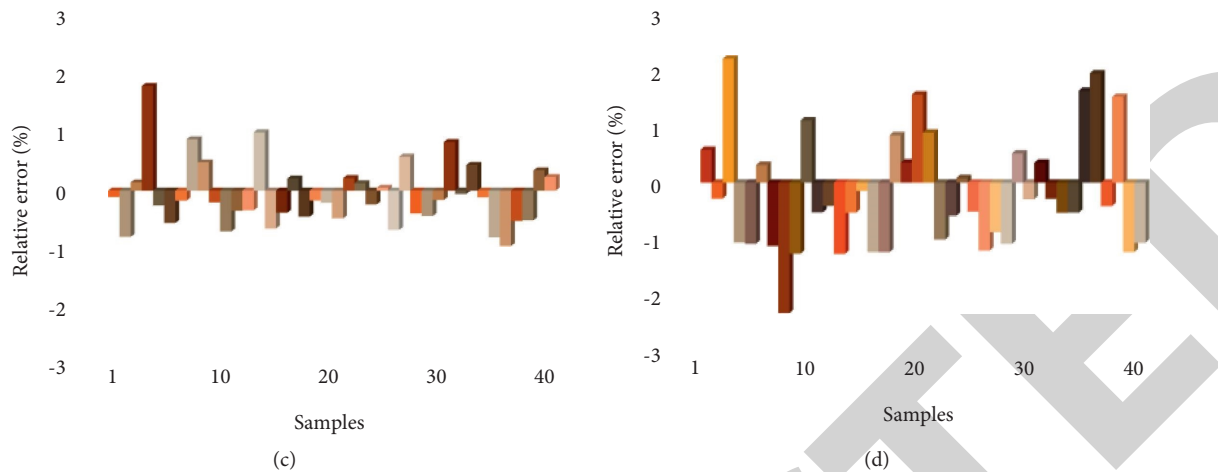

Figure 7: Continued.

(c)

(d)

Figure 7: Relative error: (a) University 1; (b) University 2; (c) University 3; (d) University 4.

5. Conclusion

Combined with PLS method and BP neural network, a performance evaluation model of higher education informatization based on PLS-BP model is proposed. In order to evaluate the performance of PLS-BP model, the performance scores obtained by model simulation are compared with those calculated by traditional linear regression model and BP evaluation model. The comparison results show that the evaluation results based on PLS-BP model are closer to the traditional evaluation results than those based on BP model. Moreover, the maximum relative error based on PLS-BP evaluation model is 3.64%, while the maximum relative error based on BP model is 2.29%. Finally, this paper uses the evaluation model to evaluate the performance of four universities. The maximum relative error is 2.32%. The comprehensive comparison results show that the model can effectively realize the performance evaluation of education informatization in colleges and universities. It has significantly improved the intelligent level of university education informatization performance evaluation.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Y. Liu, "Evaluation algorithm of teaching work quality in colleges and universities based on deep denoising autoencoder network [J]," *Mobile Information Systems*, vol. 2021, no. 6, pp. 1574–1583, Article ID 8161985, 2021.

[2] L. Wang, "An analysis of the university informatization construction based on information resource planning," *Applied Mechanics and Materials*, vol. 513-517, no. 9, pp. 2020–2023, 2014.

[3] S. P. Li and X. L. Yuan, "Application of linear regression mathematical model in the evaluation of teachers' informatization quality [J]," *Complexity*, vol. 4, no. 1076, pp. 2785–2787, 2021.

[4] X. Y. Duan and P. W. Hou, "Research on teaching quality evaluation model of physical education based on simulated annealing algorithm [J]," *Mobile Information Systems*, vol. 2021, no. 10, pp. 1574–1579, Article ID 4407512, 2021.

[5] X. L. Dong and X. Y. Chen, "Research on online teaching of college teachers under the background of education informatization [C]," *2nd International Conference on Computer Science Communication and Network Security (CSCNS)*, vol. 336, no. 12, pp. 22–29, 2020.

[6] K. Seyun, "Effects of informatization mind on information development efforts and academic achievement of university students major in sports [J]," *The International Journal of Internet, Broadcasting and Communication*, vol. 13, no. 2, pp. 166–172, 2021.

[7] J. P. Liu, "Evaluation and numerical simulation of music education informationization based on the local linear regression method [J]," *Complexity*, vol. 2021, no. 1076, pp. 1076–1084, Article ID 3304505, 2021.

[8] R. Lu and T. Lei, "Short-term load forecast using maximum overlap discrete wavelet transform and BP neural network based on chaos theory [M]," in *Proceedings of the Chinese Control And Decision Conference (CCDC)*, pp. 6029–6033, IEEE, Nanchang, China, June 2019.

[9] S. Liu and J. Wang, "Ice and snow talent training based on construction and analysis of artificial intelligence education informatization teaching model," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 2, pp. 3421–3431, 2021.

[10] I. A. Savchenko, S. S. Barseghyan, and S. S. Barseghyan, "Bilingualism as a phenomenon of transcultural communication in foreign language teaching," *Vestnik Tomskogo gosudarstvennogo universiteta*, vol. 2021, no. 463, pp. 188–195, 2021.

[11] M. C. Berger and T. Kostal, "Financial resources, regulation, and enrollment in US public higher education [J]," *Economics of Education Review*, vol. 21, no. 2, pp. 101–110, 2019.

[12] K. H S J and Y. C. Lilian Chan, "Performance measurement and the implementation of balanced scorecards in municipal

governments [J]," *The Journal of Government Financial Management*, vol. 2018, no. 51, pp. 1–15, 2018.

[13] X. J. Zhang, "Performance measurement of ERP implementation based on the balanced scorecards [J]," *Acta Scientiarum Naturalium Universiatis Nankaiensis*, vol. 32, no. 5, 2015.

[14] B. Rumualdus, "The implementation of balanced scorecard method to company X performance measurement in Accounting Department [J]," *Economics of Education Review*, vol. 2016, no. 5, pp. 205–213, 2016.

[15] J. E. Dantas and J. Costa, "Implementation of the balanced scorecard in an educationalinstitution [C]," in *Proceedings of the 9th International Conference on Hybrid Learning (ICHL)*, vol. 6, no. 5, pp. 208–215, Barcelona, SPAIN, July 2017.

[16] C. Lu, C. Li, and D. Wu, "Districts performance evaluation of informatization of basic education based on DEA [C]," in *Proceedings of the 8th International Conference on Hybrid Learning (ICHL)*, pp. 359–369, Springer, Wuhan, China, 27 July 2015.

[17] D. Wu, C. Zhou, M. Chen, and J. Xu, "Evaluation model and system of ICT in education based on gray fuzzy method [C]," *International Symposium on Educational Technology (ISET)*, vol. 2017, no. 1, pp. 85–89, 2017.

[18] H. Rao, M. Z. Li, and Q. R. Hu, "Fault diagnosis method based on PSO-optimized H-BP neural network [C]," *3rd International Symposium on Intelligent Information Technology Application*, vol. 2019, no. 11, pp. 272–284, 2019.

[19] P. Cheng, D. Chen, and J. Wang, "Research on prediction model of thermal and moisture comfort of underwear based on principal component analysis and Genetic Algorithm-Back Propagation neural network," *International Journal of Nonlinear Sciences and Numerical Stimulation*, vol. 22, no. 6, pp. 607–619, 2021.

[20] Y. H. Bai, M. Z. Luo, and F. L. Pang, "An algorithm for solving robot inverse kinematics based on FOA optimized BP neural network [J]," *Applied Sciences-Basel*, vol. 11, no. 15, 2021.

[21] N. Zeng, H. Zhang, W. Liu, J. Liang, and F. E. Alsaadi, "A switching delayed PSO optimized extreme learning machine for short-term load forecasting," *Neurocomputing*, vol. 240, no. 5, pp. 175–182, 2017.

[22] J. J. Wang, "Analysis of sports performance prediction model based on GA-BP neural network algorithm [J]," *Computational Intelligence and Neuroscience*, vol. 2021, no. 8, pp. 1687–1695, Article ID 4091821, 2021.

[23] L. Wang and X. Bi, "Risk assessment of knowledge fusion in an innovation ecosystem based on a GA-BP neural network," *Cognitive Systems Research*, vol. 66, no. 5, pp. 201–210, 2021.

[24] Y. Z. Li, "Study on the BP neural network fuzzy system combination performance appraisal model [C]," *International Conference on Management Science and Engineering*, vol. 8, no. 23, pp. 1257–1261, 2017.

[25] X. Yang, J. Zhou, and D. Wen, "An optimized BP neural network model for teaching management evaluation," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 2, pp. 3215–3221, 2021.

[26] U. Beyaztas and H. L. Shang, "A partial least squares approach for function-on-function interaction regression," *Computational Statistics*, vol. 36, no. 2, pp. 911–939, 2021.

[27] X. H. Wu and D. Z. Chen, "Recent development of non-linear patrital least squares in chemometrics [J]," *Chinese Journal of Analytical Chemistry*, vol. 32, no. 4, pp. 534–540, 2017.

[28] G. Mateos-Aparicio, "Partial least squares (PLS) methods: origins, evolution, and application to social sciences [J]," *Communications in Statistics - Theory and Methods*, vol. 40, no. 13, pp. 2305–2317, 2021.

[29] G. Russolillo and L. Trinchera, "PLS algorithms for non-metric data [C]," in *Proceedings of the 6th International Conference on Partial Least Squares and Related Methods*, pp. 60–65, Beijing, China, September 2019.

[30] S. X. Ma, X. X. Shi, C. L. Yu, and W. Wang, "Research on improved prediction model of blasting vibration speed by BP neural network [C]," in *Proceedings of the IEEE 5th Information Technology and Mechatronics Engineering Conference (ITOEC)*, vol. 2020, no. 6, pp. 1149–1154, IEEE, Chongqing, China, 12 June 2020.

[31] F. Y. Li, W. J. Chen, W. J. Chen et al., "Smart growth prediction based on support vector regression [C]," in *Proceedings of the 2nd International Conference on Modelling, Simulation and Applied Mathematics (MSAM)*, pp. 152–155, Bangkok, Thailand, March 2017.