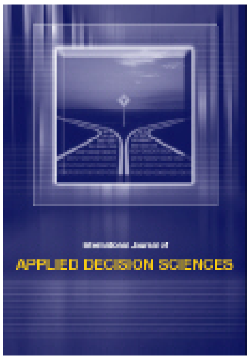


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# Design and application of university laboratory safety evaluation system based on fuzzy analytic hierarchy process and back propagation neural network

Chengli Guan, Yue Yang, Changhui Chen, Jianhao Feng

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# Design and application of university laboratory safety evaluation system based on fuzzy analytic hierarchy process and back propagation neural network

Chengli Guan and Yue Yang*

Yangjiang Polytechnic,
Yangjiang, 529566, China
Email: guanchengli@126.com
Email: yueyangscut@163.com
*Corresponding author

Changhui Chen

Guangzhou Panyu Polytechnic,
Guanzhou, 511483, China
Email: 56019563@qq.com

Jianhao Feng

Yangjiang Polytechnic,
Yangjiang, 529566, China
Email: 17047438@qq.com

**Abstract:** In view of the present questions of university laboratory management and security, the scientific and reasonable index system of laboratory safety evaluation was constructed from five aspects, such as safety rules and regulations, environmental safety, emergency management, publicity and education, equipment and reagents, and personnel factors. Fuzzy analytic hierarchy process (FAHP) was used to determine the weight of criteria layer, index layer and laboratory safety level, respectively. Then, the laboratory safety evaluation model using back propagation (BP) neural network based on MATLAB was constructed. The quantitative index layer data is used as the network input. The existing evaluation results were trained first, and then the unknown data were tested. The correlation coefficient between the target value and network prediction value could reach 0.9725. Moreover, the evaluation results were consistent with the conclusion of FAHP, which shows that the model has good applicability. It provides a more scientific, intelligent and simple quantitative evaluation method for evaluation of university laboratory safety.

**Keywords:** university laboratory safety; BP neural network; fuzzy analytic hierarchy process; evaluation model; evaluation index.

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**Biographical notes:** Chengli Guan is a senior experimentalist with MD, is currently working in Network and Educational Technology Center, Yangjiang Polytechnic, Guangdong Yangjiang, China. His research interests include system theory and information technology.

Yue Yang is an Associate Professor with MD, is currently working in Department of Food and Environmental Engineering, Yangjiang Polytechnic, Guangdong Yangjiang, China. Her research interests include environmental engineering technology and functional materials research.

Changhui Chen is a senior experimentalist with MD, is currently working in Network Technology Center, Guangzhou Panyu Polytechnic, Guangdong Guangzhou, China. His research interests include system theory and information technology.

Jianhao Feng is an assistant experimentalist with BD, is currently working in Equipment and Training Center, Yangjiang Polytechnic, Guangdong Yangjiang, China. His research interests include information and experiment technology research.

## 1 Introduction

University laboratory is an important symbol of high-level university construction and its comprehensive ability. It is also an important platform for practical teaching, high-quality innovative talents training, innovative scientific research and high-quality social service (Wang, 2019; Tai and Lee, 2007). And the premise and guarantee to realise the above functions needs the safe and stable operation of university laboratory (Xiang et al., 2014; Zhu, 2021; Outaki and Kerak, 2021). Over recent years, with the rapid development of domestic higher education, the hardware and software construction of university laboratory has also been greatly developed (Zhang et al., 2021b). Following the expansion of lab resource sharing, increase of experimental instruments and equipment, enhancement of lab opening, improvement in the number of participants in lab activities, and the increasingly onerous task about lab teaching and scientific research, the backward and safety problems of laboratory management system are increasingly prominent (Dickmann et al., 2015; Peng et al., 2019; Liu and Zhou, 2021). And university laboratory accidents occur from time to time, even fire, explosion, leakage of highly toxic substances and other major safety problems have occurred and caused heavy losses (Wu et al., 2020; Salazar-Escoboza et al., 2020; Jirkof and Schmutz, 2019). For example, when a university laboratory treated wastewater of landfill leachate in 2018, an explosion at the scene of the lab killed three graduate students. Therefore, it is essential to conduct the research on the construction and management of university laboratory and carry out the systematic and scientific safety management evaluation for the laboratory to ensure the safe and stable operation of university laboratory (Zhang et al., 2021a; Anom et al., 2021).

The hidden danger factors of laboratory safety involve a wide range, and the importance and influence degree of each factor varies (Pan and Wu, 2019). In addition, there are many kinds of instruments and equipment in the laboratory, and the experimental operation methods are different (Andrzej et al., 2021). Therefore, the traditional laboratory safety evaluation uses the way of records and manual inspections in order to monitor and manage the laboratory, which is hard to ensure the inspection quality, then resulting in great limitations of the evaluation accuracy (Li et al., 2021; Dominika et al., 2021). It can only make a qualitative and rough evaluation of the safety of the laboratory system, but not a quantitative evaluation of the risk degree (Saeedpoor and Vafadarnikjoo, 2015; Ahmed and Kilic, 2019; Yu and Feng, 2008). Besides, due to the professional characteristics of inspectors, the focus of evaluation may also be different and leading to one-sided evaluation results (Irina et al., 2021). Fuzzy analytic hierarchy process (FAHP) settles the matter of uncertainty modelling and group decision-making (Wang et al., 2021; Zhu et al., 2021; Tavana et al., 2019), and has outstanding performance on dealing with local problems of qualitative and quantitative combination and interdependence criteria (Keckler et al., 2019; Mosadeghi et al., 2015; Zhao and Shao, 2003).

Consequently, as the comprehensive evaluation of laboratory safety is a problem with characteristics of multi-criteria decision-making, this paper uses FAHP to determine the weight of evaluation index. Furthermore, in order to quantitatively and intuitively evaluate the risk degree of lab operation and bring evaluation process more intelligent, back propagation (BP) neural network, which has the ability of highly self-learning, self-organisation, self-reasoning and self-adaptation (Yang et al., 2018; Wang et al., 2019; Maier et al., 2010), is used to overcome the defects of slow reasoning and manual intervention (Du, 2015; Chen, 2014; Fan et al., 2014). According to research of Wang et al. (2012), BP neural network, which was proposed by Rumelhart et al. (1986), is most widely used in various evaluation fields. Liu (2017) applied optimised BP neural network to put forward a novel model of commercial real estate cost evaluation; Lin (2021) established an evaluation model based on BP neural network and grey model to evaluate the health and sustainability of each country's higher education system; Tseng et al. (2021) applied BP neural network to evaluate the company employee quality; Feng et al. (2021) applied optimised BP neural network to the evaluation on risks of sustainable supply chain in fresh grape industry; Shao et al. (2021) employed BP neural network to evaluate the soil quality in the arid area in northwest China; Yang et al. (2021) applied optimised BP neural network to the teaching management evaluation, etc. Therefore in this reported work, in order to better evaluate university laboratory safety, the BP neural network was employed to gain rules by the existing data analysis and mining, and provide a forceful guarantee for the efficient and safe operation of laboratory use and supervision.

## 2 Methodology

### *2.1 Construction of safety evaluation index system of university laboratory*

Based on the 'University laboratory safety inspection item list (2019)' (Wang, 2019), and considering the principles of practicality and universality, a three-layer safety evaluation indicator system of university laboratory is constructed from the target layer, the criterion layer and the index layer. The system is also established on the basis of field investigation of several laboratories, communication with laboratory managers, questionnaire survey and statistical analysis on the opinions of laboratory users (teachers and students).

### *2.2 Definition of the weight of each index and construction of the fuzzy judgment matrix*

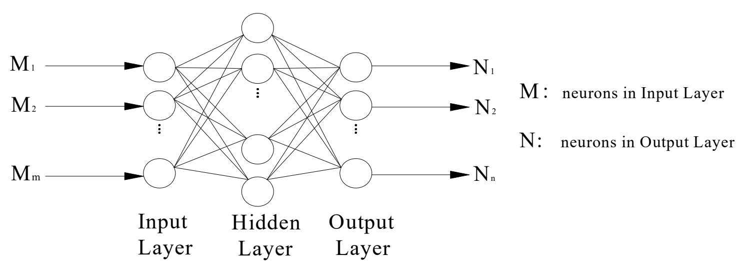
Combining the advantages of analytic hierarchy process and fuzzy mathematics, several experts in the field of laboratory safety and representative teachers and students are invited to construct a judgment matrix A. Hence, the maximum eigenvalue $\lambda_{max}$ is calculated, and the consistency test is carried out according to the following formula to obtain the weight of each index in the criterion layer and index layer in the index system defined by FAHP.

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

where n is the number of indicators, CI is the consistency index, CR is the consistency ratio, and RI is the average consistency index, respectively. Especially, when n takes 4, RI is 0.90, and when n takes 5, RI is 1.12.

**Figure 1** Neural network structure of three layer perceptron




Then, according to the principle of maximum membership degree, comprehensive fuzzy evaluation is carried out to determine the evaluation level.

### *2.3 Construction of BP neural network evaluation model*

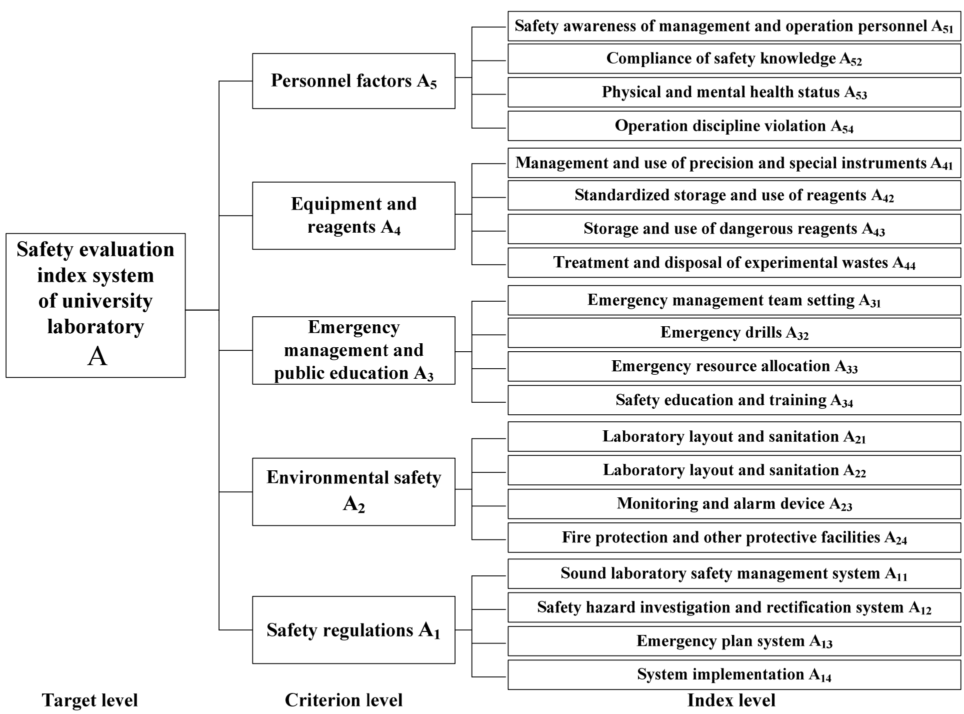
A three-layer BP neural network topology model of input layer-hidden layer-output layer is established, as shown in Figure 1. First, the indexes of the safety evaluation index system of university laboratory determined above are regarded as the input layer, while the target level is regarded as the output layer. Second, the model data samples are obtained based on FAHP method. Finally, the BP neural network evaluation results and grades are obtained through network learning and simulation prediction.

## 3 Results and discussion

### *3.1 Safety evaluation index system of university laboratory*

The rationality and accuracy of university laboratory safety evaluation results are directly related to the evaluation index system. According to the analysis, the target level in the university laboratory safety evaluation index system is the university laboratory safety, and the criterion level is divided into five elements shown in Figure 2, that are safety regulations, environmental safety, emergency management and public education, equipment and reagents, and personnel factors, respectively. Among them, the index level corresponding to the safety regulations is divided into a sound laboratory safety management system, a safety hazard investigation and rectification system, an emergency plan system and system implementation. The index level corresponding to the environmental safety is divided into laboratory layout and sanitation, laboratory ventilation system, monitoring and alarm device, fire protection and other protective facilities. The corresponding index layer of emergency management and public education includes emergency management team setting, emergency drills, emergency resource allocation and safety education and training. The corresponding index layer of equipment and reagents is divided into the management and use of precision and special instruments, the standardised storage and use of reagents, the storage and use of dangerous reagents, and the treatment and disposal of experimental wastes. And the index level corresponding to the personnel factors includes the safety awareness of management and operation personnel, the compliance of safety knowledge, physical and mental health status and operation discipline violation.

**Figure 2** Evaluation index system of university laboratory safety



## 3.2 Application of FAHP

### 3.2.1 Determination of evaluation index weight

According to the safety evaluation index system of university laboratory determined in Figure 2, experts in the field of laboratory safety and representative experimental teachers and students are invited to compare the importance of each factor to a certain factor in the upper layer in the criterion level and the index level respectively. Thereby six judgment matrices are constructed, namely A – ($A_1$–A5), $A_1$ – ($A_{11}$–$A_{14}$), $A_2$ – ($A_{21}$–$A_{24}$), $A_3$ – ($A_{31}$–$A_{34}$), $A_4$ – ($A_{41}$–$A_{44}$) and $A_5$ – ($A_{51}$–$A_{54}$). Taking the five factors of the criterion level as an example, the judgment matrix of A – ($A_1$–$A_5$) is established as follows:

$$A = \begin{bmatrix} 1 & 2 & 3 & 1/2 & 1/3 \\ 1/2 & 1 & 2 & 1/4 & 1/5 \\ 1/3 & 1/2 & 1 & 1/4 & 1/4 \\ 2 & 4 & 4 & 1 & 1/2 \\ 3 & 5 & 4 & 2 & 1 \end{bmatrix}$$

Through MATLAB mathematical software, the maximum eigenvalue $\lambda_{max}$ of the above matrix is 5.126, and the consistency index CI is 0.032, then the consistency ratio CR is <0.1 (CR = CI / RI = 0.029). It is suggested the judgment matrix meets the consistency test, and the eigenvector W corresponding to the maximum eigenvalue is obtained, that is $W = (0.158\ 0.089\ 0.066\ 0.274\ 0.413)^T$, which is the weight value of the criterion level to the target level. Similarly, the weight value of each index level to the criterion level can be obtained and expressed as followed in Table 1.

**Table 1** Weight status of evaluation index system of university laboratory safety

| *Criterion level* | *Weight of criterion level to target level* | *Index level* | *Weight of index level to criterion level* | *Final weight of each index* |
|---|---|---|---|---|
| $A_1$ | 0.158 | $A_{11}$ | 0.355 | 0.056 |
| | | $A_{12}$ | 0.239 | 0.038 |
| | | $A_{13}$ | 0.168 | 0.026 |
| | | $A_{14}$ | 0.238 | 0.038 |
| $A_2$ | 0.089 | $A_{21}$ | 0.154 | 0.014 |
| | | $A_{22}$ | 0.256 | 0.023 |
| | | $A_{23}$ | 0.115 | 0.010 |
| | | $A_{24}$ | 0.475 | 0.042 |
| $A_3$ | 0.066 | $A_{31}$ | 0.282 | 0.019 |
| | | $A_{32}$ | 0.126 | 0.008 |
| | | $A_{33}$ | 0.223 | 0.015 |
| | | $A_{34}$ | 0.369 | 0.024 |
| $A_4$ | 0.274 | $A_{41}$ | 0.189 | 0.052 |
| | | $A_{42}$ | 0.278 | 0.076 |
| | | $A_{43}$ | 0.435 | 0.119 |
| | | $A_{44}$ | 0.098 | 0.027 |

**Table 1** Weight status of evaluation index system of university laboratory safety (continued)

| *Criterion level* | *Weight of criterion level to target level* | *Index level* | *Weight of index level to criterion level* | *Final weight of each index* |
|---|---|---|---|---|
| $A_5$ | 0.413 | $A_{51}$ | 0.272 | 0.112 |
| | | $A_{52}$ | 0.383 | 0.158 |
| | | $A_{53}$ | 0.084 | 0.035 |
| | | $A_{54}$ | 0.261 | 0.108 |

It can be seen from Table 1 that the final weights of $A_{52}$, $A_{43}$ and $A_{51}$ are the largest. Within the three indicators, $A_{52}$ and $A_{51}$ are all aimed at the direct use and operation subjects of the laboratory, which indicates that the safety awareness and safety knowledge of the laboratory personnel are very important and directly affect the safety of the laboratory. And the index $A_{43}$ is the most substantial index in the laboratories of chemical engineering, biomedicine, materials, food, and environmental protection and so on. It is also the most common direct cause of frequent laboratory safety accidents in colleges and universities in recent years.

### *3.2.2 Fuzzy comprehensive evaluation*

Taking 25 laboratories and training bases in the field of science and engineering as an example, the fuzzy comprehensive evaluation of laboratory safety management is carried out. According to the evaluation requirements, the evaluation set V was installed by inviting the experts in the field of laboratory safety with five-level setting method, which is expressed as V = [excellent, good, medium, qualified, poor]. In conformity with $T = W \times R$ and the principle of maximum membership degree, the fuzzy judgment matrix and evaluation dataset were obtained.

60 members of the leading group of laboratory safety management, experimental teacher and student representatives were invited to score the safety level of the index layer for the selected 25 laboratories and training bases. The corresponding scores of each safety level were given as followed: excellent: [1, 0.9], good: [0.8, 0.9], medium: [0.7, 0.8], qualified: [0.6, 0.7], and poor: [0, 0.6]. The data are sorted in the light of the percentage statistical method, and the calculated results are taken as the membership degree of the index. Hence, the fuzzy judgment matrices $R_i$ and R, which are reflecting the criterion level and the target level respectively, are constructed. Taking the environmental monitoring and analysis laboratory of our university as an example, the fuzzy evaluation results are as follows.

The evaluation matrix of safety regulations is expressed by:

$$R_1 = \begin{bmatrix} 0.72 & 0.17 & 0.11 & 0 & 0 \\ 0.45 & 0.28 & 0.19 & 0.08 & 0 \\ 0.10 & 0.23 & 0.50 & 0.10 & 0.07 \\ 0.18 & 0.30 & 0.32 & 0.10 & 0.10 \end{bmatrix}$$

$$T_1 = W_1 \times R_1 = \begin{bmatrix} 0.423 & 0.237 & 0.245 & 0.059 & 0.036 \end{bmatrix}$$

The evaluation matrix of environmental safety is given as:

$$R_2 = \begin{bmatrix} 0.67 & 0.25 & 0.08 & 0 & 0 \\ 0.45 & 0.42 & 0.10 & 0.03 & 0 \\ 0 & 0 & 0.20 & 0.27 & 0.53 \\ 0.70 & 0.15 & 0.15 & 0 & 0 \end{bmatrix}$$

$$T_2 = W_2 \times R_2 = [0.551 \quad 0.217 \quad 0.132 \quad 0.039 \quad 0.061]$$

The evaluation matrix of emergency management and public education is shown as below:

$$R_3 = \begin{bmatrix} 0.30 & 0.20 & 0.28 & 0.22 & 0 \\ 0 & 0 & 0.22 & 0.32 & 0.46 \\ 0 & 0.17 & 0.28 & 0.50 & 0.05 \\ 0.15 & 0.35 & 0.32 & 0.17 & 0.01 \end{bmatrix}$$

$$T_3 = W_3 \times R_3 = [0.140 \quad 0.224 \quad 0.287 \quad 0.276 \quad 0.073]$$

The evaluation matrix of equipment and reagents gives:

$$R_4 = \begin{bmatrix} 0.40 & 0.52 & 0.08 & 0 & 0 \\ 0.22 & 0.30 & 0.37 & 0.11 & 0 \\ 0.10 & 0.20 & 0.22 & 0.28 & 0.20 \\ 0 & 0.13 & 0.19 & 0.20 & 0.48 \end{bmatrix}$$

$$T_4 = W_4 \times R_4 = [0.180 \quad 0.282 \quad 0.232 \quad 0.172 \quad 0.134]$$

The evaluation matrix of personnel factors is expressed as follows:

$$R_5 = \begin{bmatrix} 0.38 & 0.32 & 0.17 & 0.12 & 0.01 \\ 0.10 & 0.35 & 0.28 & 0.22 & 0.05 \\ 0.35 & 0.43 & 0.22 & 0 & 0 \\ 0.13 & 0.27 & 0.45 & 0.12 & 0.03 \end{bmatrix}$$

$$T_5 = W_5 \times R_5 = [0.205 \quad 0.328 \quad 0.289 \quad 0.148 \quad 0.030]$$

Consequently, the comprehensive evaluation matrix is given by :

$$R = \begin{bmatrix} 0.423 & 0.237 & 0.245 & 0.059 & 0.036 \\ 0.551 & 0.217 & 0.132 & 0.039 & 0.061 \\ 0.140 & 0.224 & 0.287 & 0.276 & 0.073 \\ 0.180 & 0.282 & 0.232 & 0.172 & 0.134 \\ 0.205 & 0.328 & 0.289 & 0.148 & 0.030 \end{bmatrix}$$

$$T = W \times R = [0.259 \quad 0.285 \quad 0.252 \quad 0.139 \quad 0.065]$$

In accordance with the calculation results and the principle of maximum membership degree, the maximum safety evaluation grade of the environmental monitoring and analysis laboratory is 0.285, which suggests that the comprehensive evaluation of the laboratory is ‘good’, and there are still some shortcomings to be improved, especially in the emergency management and public education. And for the same reason, the comprehensive evaluation safety levels of other 24 laboratories and training bases can be gained through FAHP method. The evaluated results are 8 ‘excellent’, 11 ‘good’ and 5 ‘medium’. Based on the comprehensive evaluation process and results, safety awareness and knowledge of personnel factors, public education, and the use of dangerous reagents and other indicators need to focus on. And strengthen management and supervision are demanded in order to improve the level of laboratory safety management.

## *3.3 Construction and application of BP neural network*

### *3.3.1 Determination of the number of neurons and dataset*

In the light of the established efficient system of safety evaluation index of university laboratory, the input layer neurons for BP neural network model are 20 evaluation indexes of index level in Figure 2, and the data is the arithmetic mean of the above 60 representatives’ scores. The neuron in the output layer for the network model is the grade score of laboratory safety evaluation, corresponding to the weighted average values of the indexes. And if the grade scores of the data are different from the above FAHP conclusions, they are adjusted to the nearest grade scores of the FAHP evaluation results. Therefore, the number of neurons is 20 for input layer and 1 for output layer, and the constructed 25 datasets are displayed in Table 2. Furthermore, 25 groups of data are separated into two sets, namely 20 groups are randomly chosen as a training dataset, while the remaining five groups are selected as a prediction dataset. Data of each group include 20 evaluation index values in Figure 2 and grade score of the laboratory safety evaluation, which is expected output value. Studies (Yang et al., 2020; Ding et al., 2011) have shown that if the raw data is transformed into the scope of [0, 1], the network learning accuracy can be enhanced, that is conducive to network simulation. As a result, 25 sets of data are unified and standardised in the aforementioned manner before learning and forecasting, thus the standardised data are all in the range of [0, 1] and there is no loss of their original quantitative relationship. Besides, the number of neurons for the hidden layer is decided by the learning error of BP neural network (Guan and Yang, 2020). Nevertheless, the mature theoretical formula has not yet been established at present. So it is generally determined through the operator's experiments and experience (Yang et al., 2020). This work employs empirical formula given as follows:

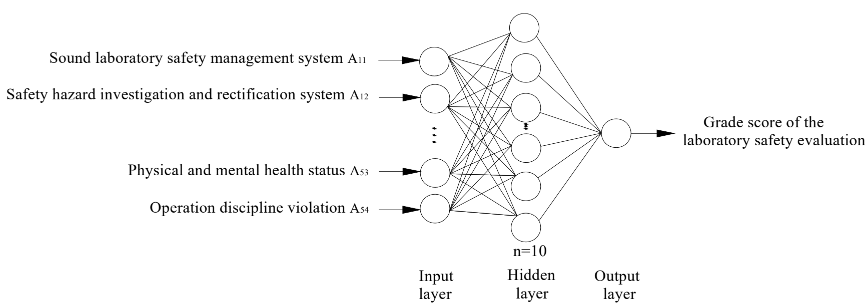
$$n = \sqrt{n_i + n_o} + a, \; 0 \le a \le 10$$

where n, $n_i$ and no are the number of neurons for the hidden layer, input layer and output layer, respectively; and a is the number of sample data for the training of network with the value range of [0, 10]. On the basis of empirical formula combined with model drilling, n = 10 is gained. Accordingly, model structure of the established BP neural network is exhibited in Figure 3.

**Table 2** Evaluation data

| *No.* | $A_{11}$ | $A_{12}$ | $A_{13}$ | $A_{14}$ | $A_{21}$ | … | $A_{44}$ | $A_{51}$ | $A_{52}$ | $A_{53}$ | $A_{54}$ | *Target output* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.91 | 0.87 | 0.76 | 0.78 | 0.90 | … | 0.65 | 0.82 | 0.75 | 0.85 | 0.71 | 0.81 |
| 2 | 0.94 | 0.84 | 0.90 | 0.79 | 0.85 | … | 0.73 | 0.86 | 0.81 | 0.90 | 0.83 | 0.92 |
| 3 | 0.90 | 0.85 | 0.73 | 0.81 | 0.89 | … | 0.68 | 0.83 | 0.76 | 0.91 | 0.80 | 0.84 |
| 4 | 0.92 | 0.86 | 0.71 | 0.69 | 0.87 | … | 0.62 | 0.80 | 0.70 | 0.81 | 0.79 | 0.78 |
| 5 | 0.90 | 0.83 | 0.79 | 0.80 | 0.90 | … | 0.72 | 0.81 | 0.75 | 0.88 | 0.82 | 0.85 |
| … | … | … | … | … | … | … | … | … | … | … | … | … |
| 21 | 0.95 | 0.86 | 0.78 | 0.81 | 0.84 | … | 0.76 | 0.87 | 0.80 | 0.89 | 0.78 | 0.90 |
| 22 | 0.86 | 0.85 | 0.75 | 0.78 | 0.80 | … | 0.75 | 0.80 | 0.72 | 0.83 | 0.75 | 0.73 |
| 23 | 0.90 | 0.85 | 0.89 | 0.80 | 0.92 | … | 0.77 | 0.78 | 0.70 | 0.80 | 0.76 | 0.83 |
| 24 | 0.93 | 0.88 | 0.76 | 0.81 | 0.92 | … | 0.78 | 0.85 | 0.81 | 0.93 | 0.78 | 0.91 |
| 25 | 0.91 | 0.83 | 0.82 | 0.85 | 0.89 | … | 0.77 | 0.80 | 0.79 | 0.90 | 0.73 | 0.88 |

**Figure 3** Model structure of BP neural network




### *3.3.2 Learning and forecasting of BP neural network*

The BP neural network is designed through using the artificial neural network toolbox of MATLAB with its graphical user interface, and the control frame graphic object is adopted for operation. In this model, tansig is taken for the transfer function in the hidden layer, pureline for the transfer function in the output layer, trainlm for the training function, learngd for the learning function, and mse for the performance function, respectively. Besides, the error between actual output and target output is less than 0.001, while the upper limit of iterations is 1,000. Then run the network, and train the network with 20 sets of learning data in Table 2. The training process and result are expressed in Figure 4. And the details of training results $a_n$ compared with target values $a_e$ are shown in Table 3.

As seen in Figure 4, the BP neural network evaluation system of university laboratory safety has a fast convergence speed. After only three iterations of training, system error has gotten to 0.000373044, and the error between actual output and target output conforms to the set value, that is ≤0.001. Moreover, system output value is close to target output value, and the mean square error of 20 sets of training data is basically within [–1%, + 4%] according to Table 3, which indicates BP neural network model constructed can better approximate safety evaluation rule of training data. For the sake of further testing the prediction ability of the model, evaluation index values of the five sets of data in Table 2 are taken into the corresponding items for prediction samples for examination. Then prediction results are displayed in Table 4 and Figure 5.

**Figure 4** Training process and result of BP neural network (see online version for colours)

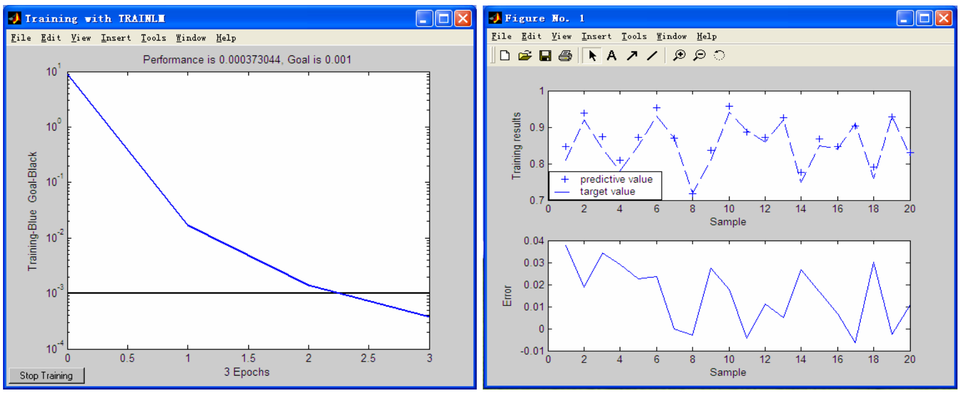


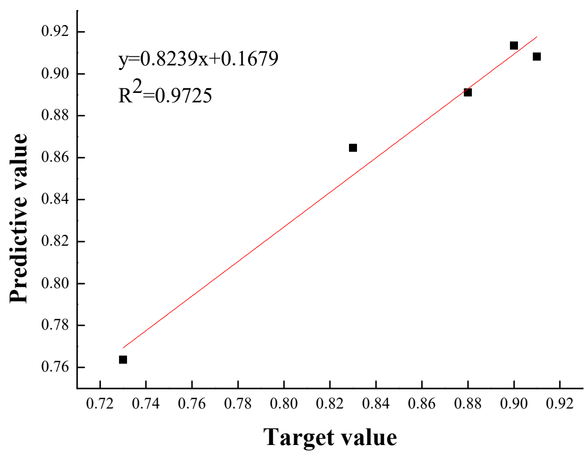

**Table 3** Comparison of experimental tests and training results of BP neural network

| *No.* | $a_e$ | $a_n$ | *Error, %* |
|---|---|---|---|
| 1 | 0.8112 | 0.8498 | 3.86 |
| 2 | 0.9167 | 0.9333 | 1.66 |
| 3 | 0.8418 | 0.8752 | 3.34 |
| 4 | 0.7735 | 0.8033 | 2.98 |
| 5 | 0.8524 | 0.8749 | 2.25 |
| 6 | 0.9242 | 0.9469 | 2.27 |
| 7 | 0.8747 | 0.8746 | –0.01 |
| 8 | 0.7191 | 0.7166 | –0.25 |
| 9 | 0.8058 | 0.8335 | 2.76 |
| 10 | 0.9308 | 0.9501 | 1.93 |
| 11 | 0.8898 | 0.8852 | –0.46 |
| 12 | 0.8645 | 0.8746 | 1.01 |
| 13 | 0.9183 | 0.9234 | 0.51 |
| 14 | 0.7501 | 0.7773 | 2.72 |
| 15 | 0.8511 | 0.8716 | 2.05 |
| 16 | 0.8453 | 0.8496 | 0.43 |
| 17 | 0.9067 | 0.9005 | –0.62 |
| 18 | 0.7484 | 0.7785 | 3.01 |
| 19 | 0.9290 | 0.9267 | –0.23 |
| 20 | 0.8223 | 0.8321 | 0.98 |

**Table 4** The prediction results of simulation

| *No.* | *Evaluation target value* | *Evaluation target result* | *Network predictive value* | *Network evaluation result* | *Error* |
|---|---|---|---|---|---|
| 21 | 0.90 | Excellent | 0.91346 | Excellent | –0.01496 |
| 22 | 0.73 | Middle | 0.76363 | Middle | –0.04607 |
| 23 | 0.83 | Good | 0.86468 | Good | –0.04178 |
| 24 | 0.91 | Excellent | 0.90811 | Excellent | +0.00208 |
| 25 | 0.88 | Good | 0.89102 | Good | –0.01252 |

**Figure 5** The prediction results of simulation (see online version for colours)




It is clear that the evaluation target value is in good agreement with the prediction value of the BP neural network for university laboratory safety, and the error is small. And the correlation coefficient between evaluation target value and network prediction value reaches 0.9725, close to 1. Additionally, it is consistent with the evaluation result obtained by FAHP. It is illustrated the neural network has good performance of prediction and simulation. And it could simulate and predict the untrained data well too, thus it can be employed to predict the safety evaluation system of university laboratory.

## 4 Conclusions

The safety evaluation index system of university laboratory was established based on 5 aspects and 20 indicators. The weight of each index in the evaluation system was determined by using the chromatography analysis method, and then the safety level of 25 laboratories and training bases was defined by employing the fuzzy comprehensive evaluation method. The evaluation results of 8 'excellent', 12 'good' and 5 'middle' were obtained. It indicated that the laboratory safety management of our university was fairly good, but the safety awareness and knowledge of laboratory personnel, public education, and the use of dangerous reagents could be properly strengthened. Furthermore, BP neural network is constructed and adopted to test and evaluate the unknown data by using the existing evaluation results, and the results are consistent with the conclusion of FAHP, which shows that the model has good applicability. And the network is run based on MATLAB mathematical software, which is simple and convenient to use with high intelligent level, so that it is worth promoting.

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