Evaluation of teaching quality of computing method course based on improved BP neural network

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Abstract. Calculation method is a very important basic course of engineering, in the environment of engineering education, a large number of colleges and universities bring calculation methods into the category of professional compulsory courses. This course is not only theoretical, but also practical. Therefore, teachers are required to combine the two organically. The evaluation of teaching quality is of great practical significance to the cultivation of students and the optimization of curriculum. This paper establishes a more convenient and efficient teaching quality evaluation model of calculation method course by making corresponding evaluation index of calculation method course, and proves its excellence through experiments.

1. Introduction

With the rapid development of China's economy and the scale of higher education continues to expand, according to the report on “China's higher education quality issued” by the press conference held by the Ministry of education in 2018, the report comprehensively analyzes the current development of higher education in China. The analysis of the report shows that China's higher education has been in the forefront of the world in terms of scale. In 2018, the total number of college students in China reached 37 million, ranking first in the world; there were 2852 colleges and universities of all kinds in China, ranking second in the world [2]. Under the background of the continuous expansion of China's education scale and the structural transformation of China's market economy, the teaching quality of higher education is widely concerned by the society.

In the environment of engineering education professional certification, many colleges and universities have brought the calculation method into the category of professional compulsory courses. As a representative professional course of engineering discipline, calculation method takes the numerical solution of mathematical problems as the research object, which is the theoretical basis of scientific calculation and a practical course closely combined with engineering projects [1]. The course quality of calculation method plays a very important role in shaping the thinking mode of engineering talents and cultivating their ability to abstract specific problems, Therefore, the teaching methods of computational methods need to keep pace with the times, and the accurate, objective, efficient and convenient evaluation calculation method plays an active and important role in guiding
the curriculum reform. Teaching quality is the lifeline of colleges and universities, and teaching quality evaluation is an effective means to promote teaching quality. In 2013, Luo Juchuan, Qing Yanmei and others proposed to use BP neural network to evaluate the teaching quality of Computer Graphics Course. Through the comparison between the evaluation value of the model and the expert score value, the excellent test effect is obtained, which proves the feasibility and accuracy of the application of BP neural network in course teaching quality evaluation.[3] In 2019, Zhang Yaqing proposed a curriculum teaching quality evaluation model based on active learning support vector machine (AL-SVM). Based on the active learning support vector machine, the final teaching quality evaluation results are obtained by integrating the evaluation results of experts, peers and students.[2] However, in this evaluation model, it is difficult to collect the evaluation data of experts and peers on a large scale, and the data collection has a long period, so the generalization ability is low. In 2020, Jia Juan proposed a method for evaluating mathematical teaching model based on cognitive load theory. The weights of various parameters of this method are set artificially and have certain subjectivity. Moreover, the judgment indexes selected by this evaluation system only adopt two indexes: classroom efficiency and learning consumption time, which cannot fully prove the accuracy of the model[4]. Also in 2020, Li Yuyang proposed a teaching quality evaluation model of data mining algorithm in Colleges and universities. The BP neural network method was used to data mining the collected statistical data, and the adaptive genetic algorithm was used to determine the initial value, learning rate and momentum factor values of the weights of the implicit layer and output layer. Although the results were more accurate, the evaluation process was cumbersome[5].

Therefore, this paper proposes a BP neural network algorithm using adaptive learning rate optimizer to evaluate the teaching quality of computational method courses. Batch Normalization (BN) layer is added to the neural network to improve the generalization ability and robustness of the model. Statistical data were collected in the form of questionnaires, and the feasibility of the model was verified by comparing with expert evaluation values.

2. Experiment principle

BP neural network is composed of input layer, output layer and hidden layer. It is a layer feed-forward network trained according to error back-propagation. The network training includes two processes of signal forward propagation layer by layer and error layer by layer backward propagation. In other words, the input data passes through the hidden layer from the input layer and acts on the corresponding output node, and then the output data is generated after linear or nonlinear transformation by the set activation function, If the output data does not match the expected data, it is converted to the error back-propagation process. The input error propagates to the input layer through the hidden layer. The error is allocated to all the connection points in each layer to update the weight value and threshold value of each node. By repeating the training process, the minimum error value and the corresponding neural network weight value and threshold value are finally obtained to end the training. Then the trained model can be used to complete specific tasks. The structure of BP neural network is shown in Figure 1:
Suppose there are k samples in the input layer, then the input data vector is:

$$x_k = (x_{k1}, x_{k2}, \ldots, x_{km}), \ k = 1, 2, \ldots, k$$  \hspace{1cm} (1)

The output tag values corresponding to the input data vector in turn are:

$$y_k = (y_{k1}, y_{k2}, \ldots, y_{kn}), \ k = 1, 2, \ldots, k$$  \hspace{1cm} (2)

The actual output vector through the network is:

$$o_k = (o_{k1}, o_{k2}, \ldots, o_{kp}), \ k = 1, 2, \ldots, k$$  \hspace{1cm} (3)

According to BP neural network algorithm, the relationship between input and output is as follows:

$$M = f(\sum_j w_j x_j - \sigma)$$  \hspace{1cm} (4)

In formula (4), $f(x)$ is the corresponding activation function used in the network. The input is transformed by linear or nonlinear activation function, and $\sigma$ is the threshold value. However, there are always errors between the actual output value and the output label value in the network. The loss function is minimized by minimizing the error (the common loss functions include mean square error loss function, cross entropy loss function, etc.), and the loss function is obtained by the difference between the actual output vector value and the output label value through specific functions. The process of error minimization is to modify the weight value $w_j$ to minimize the sum of squares of errors:

$$\theta_k = \frac{1}{2} \sum_{i=1}^{n} (y_{ki} - o_{ki})^2, \ k = 1, 2, \ldots, k$$  \hspace{1cm} (5)

The total error of input data vector is as follows:

$$\delta = \sum_{i=1}^{k} \theta_i$$  \hspace{1cm} (6)
The weight value $w_{ij}$ is modified by error $\delta$, and the change amount of weight value $\Delta w_{ij}$ is obtained by Adam optimization algorithm [6]. Adam is a random optimization algorithm based on a ladder degree, and its learning rate is adaptive (the initial value needs to be determined by oneself). It has the advantages of simple and easy to use, small memory demand and relatively economic computing power.

The weight value $w_{ij}$ of BP neural network can be initialized by Gaussian distribution between 0 and 1:

$$f(w | \mu, h^2) = \frac{1}{\sqrt{2\pi h^2}} e^{-\frac{(w-\mu)^2}{2h^2}}$$  

(7)

Where $\mu$ is the mean value of the weight value and $h$ is the standard deviation of the weight value.

BN layer is added after each full connection in the hidden layer[7]. The advantage of BN layer is that it can choose a large initial learning rate to make the training converge rapidly. At the same time, it is no longer necessary to use the regular drop out layer and L2 regularization method to prevent the over fitting problem, because the algorithm principle of BN layer can improve the generalization ability of the network, and can carry out batch normalization to prevent local response.

### 3. Experiment design

#### 3.1. Questionnaire investigation

**3.1.1. Establishment of evaluation index.** In order to better evaluate the teaching quality of computer method course, the selection of teaching quality evaluation index must be scientific, objective and representative. The selection of evaluation index directly affects the effectiveness and fairness of the evaluation results. The course of computational methods is generally divided into two parts: theoretical course and experimental course. In the experimental class, programming teaching is usually carried out, and the algorithm is written with code. Therefore, there are certain requirements for teaching hardware equipment.

The evaluation index should be formulated according to experts and students, and should be timely, intuitive and oriented. Experts have high assessment ability and more mature assessment knowledge system. Therefore, the assessment index of experts should focus on hardware equipment, teaching materials of teachers, assessment method preparation, etc. Because students have a more intuitive feeling of the course, the evaluation index for students should focus on the expression ability of teachers in class, the construction of class atmosphere and the inspiration of class. Therefore, three first level evaluation indexes and 15 second level evaluation indexes in Table 1 are designated.

For each index, four score options are given: 3, 2, 1 and 0 to represent the achievement degree of the evaluation index. The final score of teaching quality evaluation is in the range of 0 to 100.

**Table 1. Teaching quality evaluation index.**

| The first level evaluation indexes | Serial number | The second level evaluation indexes |
|-----------------------------------|---------------|-------------------------------------|
| Assessment of pre class preparation | X1            | Preparation of teaching plan before class |
|                                    | X2            | The course is conducted in accordance with the syllabus |
|                                    | X3            | The completeness of computer and other hardware equipment in experimental class |
|                                    | X4            | The teaching materials selected for the course are updated in real time |
3.1.2. Data collection and processing of questionnaire survey.

Table 2 shows the data collected, a total of 43 copies.

Table 2. Data were collected by questionnaire survey.

| X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 | Y     |
|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|------|
| 3  | 3  | 1  | 2  | 3  | 1  | 1  | 1  | 2  | 1   | 3   | 2   | 2   | 83  | 97   | 68.79 |
| 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1   | 1   | 1   | 1   | 95  | 95   | 44.49 |
| 2  | 2  | 1  | 2  | 2  | 1  | 1  | 1  | 1  | 1   | 1   | 2   | 2   | 2   | 98  | 95   | 59.46 |
| 3  | 3  | 1  | 2  | 3  | 1  | 1  | 1  | 2  | 1   | 2   | 2   | 3   | 3   | 82  | 80   | 69.26 |
| 3  | 2  | 2  | 1  | 3  | 2  | 2  | 1  | 2  | 3   | 2   | 2   | 2   | 82  | 84   | 71.72 |
| 3  | 2  | 1  | 3  | 3  | 2  | 2  | 1  | 2  | 3   | 3   | 3   | 3   | 83  | 89   | 78.85 |
| ...|    |    |    |    |    |    |    |    |    |     |     |     |     |     |      |
| 3  | 2  | 1  | 1  | 3  | 1  | 2  | 0  | 1  | 2   | 1   | 2   | 3   | 83  | 88   | 61.67 |
| 2  | 2  | 0  | 2  | 1  | 1  | 2  | 2  | 2   | 3   | 1   | 3   | 1   | 75  | 84   | 60.58 |
| 3  | 1  | 1  | 1  | 0  | 1  | 0  | 1  | 3   | 2   | 2   | 2   | 78  | 85   | 52.55 |
In order to speed up the training speed of neural network and prevent over fitting caused by excessive local weight, the data in Table 2 are processed by "Maximum-Minimum Normalization":

$$X_{kn}' = \frac{X_{kn} - X_{\min}}{X_{\max} - X_{\min}}, \quad k = 1, 2, \ldots, 10, \quad m = 1, 2, \ldots, 15$$

(8)

$X_{kn}'$——Processed data; $X_{kn}$——original data; $X_{\max}$——The maximum value of the secondary index before processing; $X_{\min}$——The minimum value of the secondary index before processing.

3.2. Construction of BP neural network

Because it is difficult to collect data, the amount of data collected is not much, so as to prevent the situation of over fitting caused by the depth of the network. At the same time, BN layer is connected behind every fully connected layer of hidden layer to reduce the possibility of over fitting. Compared with the traditional stochastic gradient descent optimizer, Adam optimizer has faster convergence speed and stronger ability to prevent falling into local optimal value, and its learning rate is adaptive and the training process is simpler. The training of BP neural network adopts keras based on tensorflow background and the network structure is as follows:

Model: “sequential_7”

| Layer (type)         | Output Shape | Param # |
|----------------------|--------------|---------|
| dense_25 (Dense)     | (None, 256)  | 4096    |
| batch_normalization_16 (Batch) | (None, 256) | 1024    |
| dense_26 (Dense)     | (None, 128)  | 32896   |
| batch_normalization_17 (Batch) | (None, 128) | 512     |
| dense_27 (Dense)     | (None, 1)    | 129     |

Total params: 38,657
Trainable params: 37,889
Non-trainable params: 768

Figure 2. BP neural network model diagram constructed by training.

Then the collected questionnaire data is imported by using Python pandas library, and the questionnaire data is normalized according to formula (8). The last 33 samples were used as training set and the first 10 as test set. Then 20% of the training set was randomly divided into verification set and trained for 400 rounds. The loss function adopts mean square error:

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (real - pred)^2$$

(9)

‘n’ is the number of samples, ‘real’ is the real evaluation value calculated by experts, and ‘pred’ is the network prediction value. The activation function uses the relu function:

$$\text{Relu}(x) = \begin{cases} 
    x & \text{if } x > 0 \\
    0 & \text{if } x \leq 0 
\end{cases}$$

(10)

Relu function can reduce the amount of calculation in the process of back-propagation. When the network is deep, it can also reduce the probability of gradient disappearance. At the same time, it can
make the network sparse and reduce the interdependence between parameters, so as to alleviate the over fitting phenomenon.

4. Experiment result analysis

Network training duration is 23.65 seconds. MSE is 1.194 from the training set, in other words:

\[ real = \text{pred} \pm 1.194 \]  \hspace{1cm} (11)

Table 3. Network prediction value and expert calculation evaluation value of teaching quality evaluation.

|                  | Prediction value (pred) | Calculation value (real) |
|------------------|-------------------------|--------------------------|
|                  | 67.65                   | 68.79                    |
|                  | 44.80                   | 44.49                    |
|                  | 58.86                   | 59.46                    |
|                  | 69.31                   | 69.26                    |
|                  | 71.93                   | 71.72                    |
|                  | 77.85                   | 78.85                    |
|                  | 73.40                   | 74.36                    |
|                  | 66.36                   | 67.05                    |
|                  | 65.87                   | 68.42                    |
|                  | 79.36                   | 80.66                    |
| Average relative error |                         | 1.289%                   |

![Figure 3](image1.png)  \hspace{1cm} ![Figure 3](image2.png)

Figure 3. (a) Training set loss function curve, (b) Test set loss function curve.

The BP neural network is tested by using test set, and get the results in Table 3. The average relative error between network prediction value and expert calculation value is only 1.289%. It can be seen that the BP neural network using Adam algorithm and adding BN layer has higher prediction accuracy and stronger generalization ability in teaching quality evaluation. It can be seen from Figure 3 that the convergence speed is very fast, the training time of the model is very short, and the use is more convenient. Therefore, for the teaching quality evaluation of calculation method course, BP neural network can greatly reduce the time cost and labor cost, and obtain high accuracy. This provides an accurate, objective, efficient and convenient practical guidance for the optimization of calculation methods.

In addition, according to the results of the questionnaire, the mean scores of the indices X₁~X₁₃ are as follows:
The following problems can be seen from Figure 4:

(1) The mean score of index $X_6$ was the lowest. Therefore, the teacher did not introduce engineering examples to explain the theoretical knowledge of calculation method in the course of teaching, which will lead to the theoretical knowledge learned by students can not be used in practice. Therefore, the teacher should explain the simple application of the algorithm in engineering projects in the course of class, so that students can have a more in-depth understanding and application of theoretical knowledge.

(2) The average score of $X_3$ is low, so the course is not complete in terms of hardware equipment. The course of calculation method needs to be programmed on the computer, which can exercise the students' practical ability. However, the incomplete hardware equipment will cause great inconvenience to the students' programming course, which will reduce the teaching effect of the experimental course. Therefore, the school should improve the hardware facilities as soon as possible, so that students can have the conditions to practice on the computer.

(3) Index $X_8$ shows that the allocation of class hours between experimental and theoretical courses is not reasonable. For different majors, different emphasis should be placed on the adjustment of the class hours of theoretical and experimental courses. Unreasonable allocation of class hours will lead to students' inability to learn knowledge efficiently. Therefore, the reallocation of class hours should be considered in time.
Figure 5. Correlation analysis between each index and expert score.

Through the correlation analysis of Figure 5, it was found that the correlation between $X_8$, $x_{14}$, $x_{15}$ indexes and experts value was relatively low, that is, experts' consideration of teaching quality is not particularly focused on the examination results, but on the cultivation of students' thinking, ability and other aspects in the teaching process, as well as whether the learning direction is correct. The core value of the course lies in the cultivation of students' thinking mode and learning ability.

5. Conclusions
The teaching quality evaluation of computational method course in Colleges and universities is related to a variety of influencing factors. Through the BP neural network algorithm added to Adam algorithm and BN layer, the questionnaire data can be deeply mined, and the teaching quality evaluation model of efficient computing method course can be established. The experimental results show that the model proposed in this paper has the advantages of high accuracy, fast training speed and high prediction efficiency, so the performance of the model is excellent. It can be seen that this method has a very wide range of application value, and can be transferred to the teaching quality evaluation of more courses, which plays a positive practical guiding significance for the optimization of efficient curriculum teaching.

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