Application of BP neural network in cross-border e-commerce web pages quality evaluation

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Abstract. E-commerce companies have been already using their website to increase company popularity, advertise products, do online marketing and receive orders online. However, how a company web pages serves its function as a communication window with their customers always concerns trading companies. This paper, based on the experts consultation and customer opinions, combined with the literature review, establishes an evaluation indicator system of e-commerce web page quality. Also, an evaluation model is created to analyze the factors that will influence web page quality of trading company on the basis of BP neural network. Test results show that the BP neural network model is precise, stable and practical.

1. Introduction
China’s cross-border e-commerce transaction scale has shown an increasing trend year by year. In 2019, the total cross-border e-commerce transactions in China reached 10.8 trillion yuan, accounting for 32.1% of the total amount of import and export trade. And the data provided by the General Administration of Customs indicated that China’s total cross-border e-commerce retail imports and exports showed a year-on-year growth from 2015 to 2019. Among them, in 2019, there were more than 6,000 cross-border e-commerce companies nationwide, and the amount of cross-border e-commerce import and export retail transaction was 186.21 billion yuan, increase by 38.2% compared to last year [1].

Cross-border E-commerce industry has seen great prosperity and development potential, and E-commerce web sites serves as an important interface to transmit business information to customers and conduct transactions. Nowadays, many companies are establishing their own web sites to increase company influence and obtain overseas orders. However, many e-commerce web pages interfaces are poorly designed and their contents are badly edited, which resulted in poor readability, appeal and low order conversion rate [2]. Based on the fact mentioned above, it is vital to develop a reasonable and comprehensive evaluating system which can effectively evaluate web pages quality and identify unqualified ones.
2. The evaluation index system of cross-border web pages quality

2.1. Indicators selection

A field research and interviews were conducted to find out the possible factors that will influence the effectivity of a web page, interviewees include senior managers and junior staffs in sales department and marketing department, as well as consumers who are constantly shopping online.

The survey showed that the web page design and web page contents are related to the engaging and efficiency of a company’s website. And these two categories can be further divided in ten lower level indicators.

Consequently, based on the experts consultation and customer opinions, combined with the literature review, an evaluation indicator system of e-commerce web page quality evaluation, which include 2 first-grade indicators and 10 second-grade indicators was established, see Table 1 for details [3].

Table 1. The evaluation index system.

| First-level evaluation index          | Second-level evaluation index                              | Index code |
|--------------------------------------|-----------------------------------------------------------|------------|
| Web page design                      | Ease of access to web page with search engine              | X 1        |
| Web page design                      | Web page is interesting and appealing                      | X 2        |
| Web page design                      | Presence and efficacy of web page search engine            | X 3        |
| Web page design                      | Frequency of web page update                               | X 4        |
| Web page design                      | Web page is logically structured                           | X 5        |
| Web page content                     | Company information about suppliers                        | X 6        |
| Web page content                     | Information about distributors and their locations         | X 7        |
| Web page content                     | Amount and accuracy of product information                | X 8        |
| Web page content                     | Presence of frequently asked questions                    | X 9        |
| Web page content                     | Tips for product use and right product choice              | X 10       |

2.2. Data collection and analysis

30 e-commerce self-built web pages are selected for examination, and 100 consumers aged from 16 to 57 were invited to use and experience these 30 web pages and give feedback concerning these 10 indicators. Then, a total of 100 evaluation results were obtained which the authors ignored 5% of the highest scores and 5% of the lowest, and averaged the rest 90 ones to get a final result, which after normalization processing are shown as Table 2 for partial results. Among these 30 samples, randomly select 20 samples as training data, and the rest as test data.

Table 2. Web page evaluation sample data after processing (partial).

| Sample | Evaluation index | The goal |
|--------|------------------|----------|
|        | X1   | X2   | X3   | X4   | X5   | X6   | X7   | X8   | X9   | X10  |       |
| 1      | 0.70 | 0.70 | 0.75 | 0.80 | 0.75 | 0.70 | 0.90 | 0.80 | 0.80 | 0.85 | 0.78  |
| 2      | 0.60 | 0.60 | 0.70 | 0.70 | 0.75 | 0.75 | 0.75 | 0.70 | 0.70 | 0.70 | 0.72  |
| 3      | 0.60 | 0.67 | 0.78 | 0.78 | 0.78 | 0.82 | 0.84 | 0.76 | 0.78 | 0.80 | 0.75  |
| 4      | 0.62 | 0.65 | 0.78 | 0.78 | 0.78 | 0.79 | 0.80 | 0.65 | 0.70 | 0.70 | 0.70  |
3. Application of BP neural network in Cross-border web pages quality evaluation

3.1. Applicability of BP neural network to the e-commerce web pages quality evaluation

There are many factors that would influence trading companies web pages quality, and the influences of those factors are diversified and complex, therefore, it is difficult to obtain the quality evaluation result with a mathematical formula. Instead, it's a non-linear mathematical problem.

Back Propagation (BP) neural network is a type of nonlinear uncertain mathematical model which can provide a new way for the e-commerce company web pages quality evaluation. Through continuous learning and training, it is able to identify the regularity among huge quantities of complicated data of unknown mode, and even process data of any type [4].

Hence, the application of artificial neural network to the E-commerce web pages quality evaluation system can solve the problems of qualitative indicators and quantitative indicators in comprehensive evaluation indicator system, and conquers the problems of establishing complicated mathematical formula and mathematical model. Therefore, it is an effective method to evaluate web pages quality with BP mathematical model.

3.2. Model structure

Back Propagation (BP) neural network will continually correct the weight value and valve until the mean square error is minimized and the fitting data with high precision is obtained [5].

In this research, the three-layer BP neural network, which has excellent nonlinear mapping capabilities, is used for modeling. In this model, there are ten index indicators that will influence the e-commerce web pages evaluation, therefore, there are 10 neurons in the input layer. And there is only 1 neuron in the output layer as it contains only one index indicator which shows an overall evaluation of web page quality. As the number of neurons in the hidden layer will directly affect how well a neural network can map complicated problems, the number of hidden layer nodes is calculated with the following empirical formula [9]:

$$M = \sqrt{n + m + a} \quad 1 \leq a \leq 10$$

Among them, $M$ refers to the number of neuron nodes in the hidden layer, $n$ the input layer, and $m$ the output layer. From the above formula, $M$ is determined to be 4-14.

3.3. Model construction

Select 30 groups of evaluation figures as the input values of the model, that is $X_i^{(30)} = (x_{i1}, x_{i2}, ..., x_{i30})$, expected output value is $M^{(30)} = (m_1, m_2, ..., m^{30})$. Input 20 sets of samples into the neural network to conduct random training, and calculate the hidden layer output value set $Y_j^{(20)}$ by formula (2).

$$Y_j^{(20)} = f\left(\sum_{i=1}^{10} w_{ij}^{(y)} X_i^{(20)} + b_j^{(y)}\right) = \frac{1}{1 + e^{-\sum_{i=1}^{10} w_{ij}^{(y)} x_i^{(y)} - b_j^{(y)}}}, (j = 1, 2, ..., M)$$

In the formula (2): $w_{ij}^{(y)}$ is the connection weight between the input layer and the hidden layer, $b_j^{(y)}$ is the threshold, the activation function $f(x)$ of the hidden layer uses the $logsig$ function $f(x) = 1/(1+$

|   |   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 0.90 | 0.94 | 0.95 | 0.92 | 0.93 | 0.93 | 0.94 | 0.89 | 0.90 | 0.90 | 0.92 |
| 6 | 0.88 | 0.87 | 0.80 | 0.80 | 0.80 | 0.90 | 0.90 | 0.85 | 0.85 | 0.85 | 0.88 |
| 7 | 0.88 | 0.80 | 0.80 | 0.81 | 0.81 | 0.91 | 0.90 | 0.86 | 0.86 | 0.84 | 0.85 |
| 8 | 0.88 | 0.80 | 0.81 | 0.81 | 0.81 | 0.90 | 0.90 | 0.90 | 0.90 | 0.88 | 0.88 |
| 9 | 0.88 | 0.70 | 0.81 | 0.81 | 0.80 | 0.90 | 0.90 | 0.87 | 0.88 | 0.83 | 0.81 |
| 10 | 0.60 | 0.60 | 0.60 | 0.55 | 0.60 | 0.60 | 0.60 | 0.55 | 0.55 | 0.55 | 0.58 |
exp\((-\alpha)\). The excitation function of the output layer is set as a linear function. When the input variable propagates forward to the output layer, the output value set \(Z^{(20)}\) is calculated by formula (3).

\[
Z^{(20)} = \sum_{j=1}^{M} w_j z_j^{(20)} + b^{(z)}
\]  

(3)

In the formula (3): \(w_j^{(z)}\) is the connection weight, \(b^{(z)}\) is the threshold. After obtaining the output value of all training samples in the output layer, the mean square error is used to judge the training accuracy of the model, and the mean square error can be obtained by formula (4).

\[
MES = \frac{1}{20} \sum_{k=1}^{20} (m_k - z_k^k)
\]  

(4)

In the formula (4): \(m_k^k\) is the measured value of equivalent linear over-excavation of the \(k\)-th training sample, \(z_k^k\) is the output value of the \(k\)-th training sample in the BP neural network output layer. When the error between the training output value and the measured value is big and the target accuracy cannot be reached, the gradient descent algorithm is used to back-propagate the error until the target accuracy is reached, then the training process ends, and the formula is:

\[
w_{(N+1)} = w_{(N)} - \alpha \frac{\partial \text{MSE}}{\partial w} \\
b_{(N+1)} = b_{(N)} - \alpha \frac{\partial \text{MSE}}{\partial b}
\]  

(5) \hspace{1cm} (6)

In the formula (5) & (6): \(w_{(N)}\) is the weight between each connection layer, \(b_{(N)}\) is the threshold between each connection layer, \(w_{(N+1)}\) is the modified weight, \(b_{(N+1)}\) is the modified threshold, \(\alpha\) is the network learning rate, \(N\) is the times of modifications.

After finishing the training, remain the weights and thresholds between the connected layers the same, input the remaining 10 sets of test samples, variables \(X^{(10)}\), and the output value in the output layer can be obtained as set \(Z^{(10)}\).

### 3.4. Model testing and results

In order to ensure the validity of this model, the target error in the sample data training process is set to be \(10^{-4}\), the network learning rate is 0.01, and the maximum number of training steps is 1000. Mean square error MSE and determination coefficient \(R^2\) are used to evaluate prediction accuracy. The smaller the mean square error MSE and the closer the \(R^2\) is to 1, the higher the degree of correlation between the predicted value and the measured value, and the better the fitting of this model. The calculation formula of \(R^2\) is:

\[
R^2 = \frac{\left(10 \sum_{k=1}^{10} m_k^k z_k^k - \left(\sum_{k=1}^{10} m_k^k\right) \left(\sum_{k=1}^{10} z_k^k\right)\right)^2}{\left[10 \sum_{k=1}^{10} (m_k^k)^2 - \left(\sum_{k=1}^{10} m_k^k\right)^2\right] \left[10 \sum_{k=1}^{10} (z_k^k)^2 - \left(\sum_{k=1}^{10} z_k^k\right)^2\right]}
\]  

(7)

In the above formula: \(m_k^k\) is the measured value of the \(k\)-th group of test sample; and \(z_k^k\) is the predicted value of the \(k\)-th group of test sample.

Change the number of neurons in the hidden layer and train the data, and the corresponding prediction performance evaluation indexes can be obtained as shown in Table 3.

| the number of neuron nodes in the hidden layer \(M\) | \(P^2\) | MSE |
|---|---|---|
| 4 | 0.9431 | 0.0208 |
The value of $M$, number of neuron nodes in the hidden layer, is determined to be 8. Because, as is shown in Table 3, when there are 8 neurons in the hidden layer, the value of $R^2$ is 0.9926, and $MSE$ is $4.8 \times 10^{-3}$, which indicates the best prediction performance of the BP neural network model. Also, as is shown in Figure 1, the BP neural network has reached the target requirement after 105 iterations. The final calculation result of the simulation has a square error of $1 \times 10^{-4}$, which is small and can prove that the BP neural network modeled in this research can satisfy the operating requirements.

The predicted value and actual measured value of the test sample are shown in Figure 2. The model prediction value of the test sample is not much different from the actual value, the average relative error is 0.6%. And the relative error of each test sample fluctuates within a range which is less than 2.4%, such a training and testing result is satisfied. And we can safely come to the conclusion that BP neural network prediction model has good accuracy and stability.

|   | $R^2$  | $MSE$  |
|---|--------|--------|
| 5 | 0.9548 | 0.0160 |
| 6 | 0.9704 | 0.0140 |
| 7 | 0.9723 | 0.0151 |
| 8 | 0.9926 | 0.0048 |
| 9 | 0.9804 | 0.0120 |
| 10| 0.9799 | 0.0123 |
| 11| 0.9723 | 0.0151 |
| 12| 0.9741 | 0.0178 |
| 13| 0.9871 | 0.0084 |
| 14| 0.9801 | 0.0118 |

Figure 1. Training curve.
4. Conclusions
E-commerce web page quality evaluation system has many uncertain and complex factors. BP neural network model, with the function of highly nonlinear Mapping function, has practical significance in web page quality evaluation. And experimental results prove that the accuracy of evaluation can be increased and the speed of calculation can also be improved. It can be safely concluded that the BP neural network model is precise, stable and practical.

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