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The Early Warning Research of Enterprise Financial Crisis Based on BP Neural Network

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Abstract

Compared with previous studies on artificial neural network, this paper expounds the artificial neural network theory, and gives information transfer function and mathematical models of BP neural network. This paper has selected 100 financial crisis companies and 100 non-financial companies as samples crisis, which are in line with the definition of the financial crisis. They has established the enterprise financial crisis model by using BP neural network algorithm, also made a sample test, and the accuracy rate is up to 80%.

Keywords*: BP Neural Network; Financial Crisis; Financial Crisis Early Warning Model*

1. Introduction

The most common methods of financial early warning include traditional statistics and artificial intelligence. Artificial neural network, on behalf of artificial intelligence method, although it is more complex and abstract, and has no specific formula, but it overcomes the shortcomings of traditional statistics. Through continuous in-depth study, it can be in good agreement with the actual data. It is widely used in many fields, such as agriculture, energy and detection.

Wu Shunhui [1] uses the neural network model in the research of company financial risk warning. In the study, for the first aspect, he proposes a hybrid model to make financial risk warning which combines BP neural network and particle swarm optimization together. For the second aspect, he selects eighteen indicators from the five types of financial indicators to construct neurons of the BP neural network. Experiments demonstrate that the proposed approach can effectively estimates the company financial risk, and the financial risk estimated by our algorithm is very close to the experts' evaluation. The artificial neural network is widely used by Guofu Zhang and Jitian Wang [2], they use financial risk prediction analysis as a diagnostic tool on the base of dependable accounting information with the evaluation system enterprise financial management. Jun Tang and Lei He [3] use BP neural network to excavate the pattern and rule of customer transaction behavior, and isolate suspicious financial transactions. Xiangguang Shen and Xiaozhong Song [4] build a business financial crisis prewarning model based on BP neural network to conduct empirical analysis of the financial situation in Chinese enterprises

Hong Shen [5] researches the financial data of listed 71 medicine companies in order to establish a more accurate financial pre-warning model with the analysis of BP (Back Propagation)-neural network. Zhibin Liu and Shaomei Yang [6] propose the improved BP neural network imports the adjustable activation function and Levenberg -Marquardt optimization algorithm to forecast the financial risk of the power enterprises scientifically and accurately. Shuang Pan, Weikang Yu and Meiling Gao [7] improve the BP algorithm with the simulation annealing algorithm, effectively overcomes the shortcoming of the

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BP algorithm to easily fall into the local minimum, enhances the BP network performance, and fuse the algorithm to apply forewarns in the financial crisis, the findings indicated that the fusion algorithm's performance is highly effective, the forecast is precise. Yanhong Wang [8] noticed that financial risk predictive accuracy of optimized model is higher than traditional predictive accuracy and efficiency of BP neural network model. Xin Zhao [9] constructs a BP neural network model to predict the financial crisis of companies with the samples from Shanghai stock exchange and Shenzhen stock exchange. And it is proved that the model is appropriate. Dawei Liu [10] Uses the dynamic cluster method to classify enterprise's standardized data and get enterprise's pre-warning model through training the BP neural network using classified data. Discuss its implementation on computer in J2EE platform. Through taking test on the panel data, this method can provide accurate forecast information to the enterprise. Zhihong Lin, Hong Qiao and Xuecheng Dong [11] Combine reality financial data of electric power listed corporation and using rough set theory to select financial indexes, which are as modeling variables, then establishing financial risk estimation model based on Back-propagation neural network. Through training for the financial data, it shows that this model has a high accuracy to the results of financial risks evaluation, and it offers effective technical support to financial risk evading of electric power enterprise. Zhibin Xiong [12] proposes a hybrid system combining feed-forward neural network and MAGBPA-multi-population adaptive genetic back-propagation neural network (MAGBPNN) to overcome the drawbacks of neural networks. Furthermore, the new model has been applied to financial distress analysis based on the data collected from a set of Chinese listed corporations, and the results indicate that the performance of MAGBPNN model is much better than the ones of common neural network model. Yang Yang [13] using the analytic hierarchy process (AHP), entropy value method, BP artificial neural network to build, train and test the Kunming financial risk early warning model; meanwhile, combining the secondary exponential smoothing method to forecast the future financial risks over the next two years; The study predicted results showing that, Kunming's financial risk degrees are 0.1039 and 0.0877 in 2012 and 2013 respectively, indicating that over the next two years Kunming's financial operation in a safe range.

2. Artificial Neural Network Theory

2.1 Artificial Neural Network Structure and Learning Ways

Artificial neural networks is a new subject on the basis of the development of biological neural networks formation mechanism, which mimics the biological neural network structure and learning ways. It is an information processing system formed by a number of basic indicators, which were abstracted, simplified and simulated. Artificial neural networks are divided into feed-forward and feed-back network [14]. In feed-forward network, neurons are in hierarchical arrangement, and each neuron is connected with the former layer. The topmost is input layer, the lowest is the output layer, and the intermediate layer is called the hidden layer. In network, the information transfer is unidirectional, and the connection forms between layers are different, which can be divided into feed-forward network, feed-forward network and the inner-layer network. Also, BP neural network is one of the typical feed-forward network.

Artificial neural network learning mainly divided into three kinds, they are supervised learning, unsupervised learning and reinforcement learning [15]. When neural network deals with some problems, it needs the setting. People need to set output relatively to the input. That is, you should set the desired output while you give a set of inputs simultaneously, and set the known data of input and output as training sample. The neural network can automatically adjust the error between the desired output and actual

output, and adjust the system parameters. BP neural network algorithm is a typical supervised learning [8], shown in Figure 1.

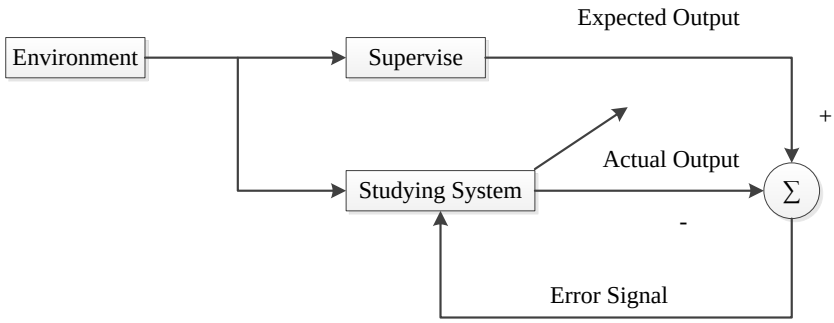

Figure 1. Supervised Learning

The advantages of artificial neural network mainly reflect in learning and information processing. According to the changes of environment, it can turn the complex data into different functions to self-learn. Combining the different network structures and learning methods can build an artificial neural network model to achieve different research purposes.

2.2. BP Neural Network Information Transfer Function

BP neural network is short for feed-forward neural network, which is the most mature and the most widely used neural network model currently. The learning process of BP neural network is divided into forward propagation and reverse propagation. In the process of forward propagation, the input sample passes from the input layer to the output layer through the hidden layer, and the neurons in each layer can only affect to the next layer neurons. BP neural network model turn the input variable and output results to nonlinear problems. It can regard as a reflection from input to output, and a highly nonlinear. BP neural network algorithm structure shown in Figure 2.

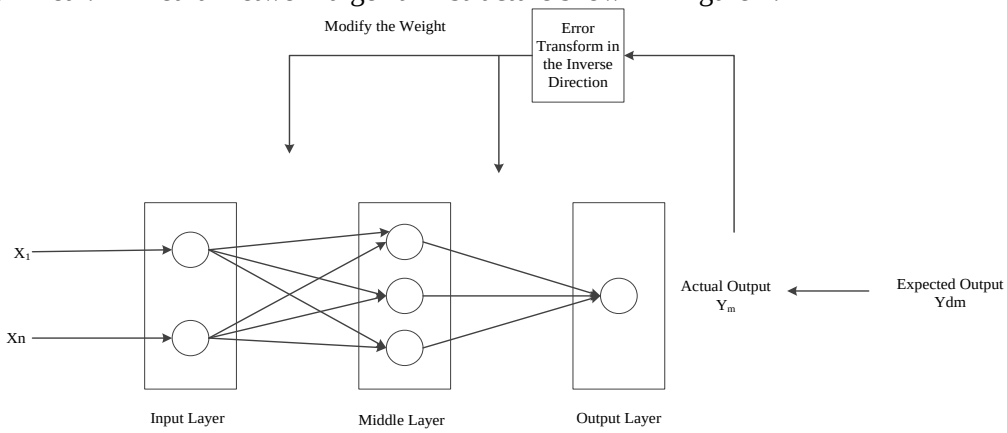

Figure 2. BP Neural Network Algorithm Structure

Shown in Figure 3, BP neural model structure, which has two inputs, has given a certain value to each input. After deviation summation, the input of neural network transfer function has formed.

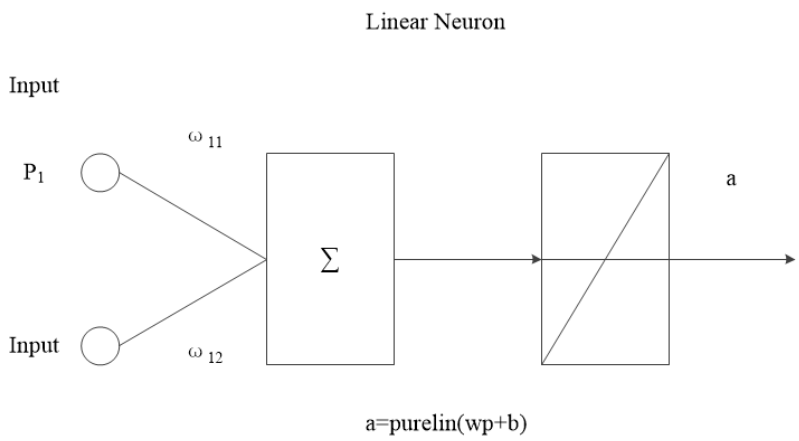

Figure 3. The Typical Structure of Neurons

BP neural network belongs to a multi-layer network. The usual transfer functions include, log-sigmoid function: logsig, hard limit function: hardlim, as well as a line function: purelin. Shown in Figure 4

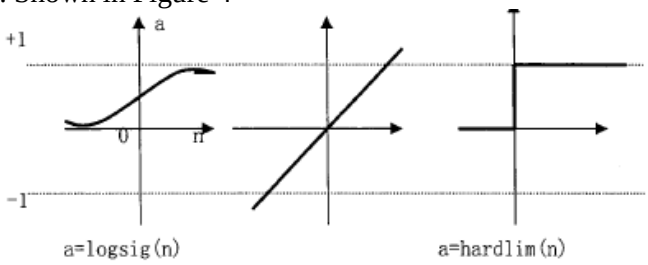

Figure 4. Neural Network Transfer Function

The output layer of BP neural network generally uses sigmoid transfer function, which makes the output of the network within the range of [-1, +1]. By purelin line transfer function, the output can take any value. BP neural network passes the intermediate results by using sigmoid function, meanwhile, it uses purelin function expand output range, so that the network can get the output value beyond [-1, +1].

2.3. BP Neural Network Mathematical Model

The supervised BP neural network needs to set the input value and desired output value in the learning and training process. In training, weight and deviation of network can adjust according to the network errors, and achieve the desired result ultimately .

It has M neural networks, and inputs the arguments in a specific manner P. The sum of input information of I nerve cells, which locates in the K layer of the neural network， is U_i^k .We regard U_i^k as the output of I nerve cell units. Wij represents the continuous output value between I neurons within the layer and the J neuron cells in upper layer. F denotes the relationship function between the input information and output information, then we can get the connection between input and output.

$$V_i^k = f(U_i^k) \tag{1}$$

$$U_i^k = \sum_j W_{ij} V_j^{k-1} \tag{2}$$

R refers to the function deviation.

We can get the square sum of discrepancy between actual output and expected results.

$$r = \frac{1}{2}\sum_j (V_j^m - y_j)^2 \tag{3}$$

In (3), y_j represents the desired output of neural network model. V_j^m is the actual output results of the system through the neural network. By (3), we can get the minimum value of the error, and reduce the error constantly; also the result will be close between the actual output and the desired output.

The update ΔW_{ij} of W_{ij} can be represented as follows:

$$\Delta W_{ij} \infty - \varepsilon \frac{\partial r}{\partial W_{ij}} \tag{4}$$

Want to get the $\frac{\partial r}{\partial W_{ij}}$, because that

$$\frac{\partial U_i^k}{\partial W_{ij}} = \frac{\partial}{\partial W_{ij}}(\sum_j W_{ij} V_j^{k-1}) = V_j^{k-1} \tag{5}$$

Then：

$$\frac{\partial r}{\partial W_{ij}} = \frac{\partial r}{\partial U_j^k}\frac{\partial U_j^k}{\partial W_{ij}} = \frac{\partial r}{\partial U_j^k} V_j^{k-1} \tag{6}$$

So,

$$\Delta W_{ij} = -\varepsilon \frac{\partial r}{\partial U_j^k} V_j^{k-1} \tag{7}$$

$$d_j^k = \frac{\partial r}{\partial U_j^k} \tag{8}$$

If

$$\Delta W_{ij} = -\varepsilon d_j^k V_j^{k-1} \tag{9}$$

ε represents the parameter of learning rate，and it is bigger than zero.

$$d_j^k = \frac{\partial r}{\partial U_j^k} = \frac{\partial r}{\partial V_j^k} \cdot \frac{\partial V_j^k}{\partial U_j^k} \tag{10}$$

In (10), at the right of the equal sign, the second is:

$$\frac{\partial V_j^k}{\partial U_j^k} = f'(U_j^k)$$

$f'(U_j^k)$ is nonlinear sigmoid function:

$$f(U_j^k) = \frac{1}{1+\exp(-U_j^k)} \tag{11}$$

$$f'(U_j^k) = V_j^k (1 - V_j^k) \tag{12}$$

If we want to get $\frac{\partial r}{\partial U_j^k}$, which is the first at the right of equal sign, there are two

possibilities. If I is the nerve cell unit in output layer, so K = M. At this time, y_j is the desired output, which is advanced set by the system, and it is a sure value.

$\frac{\partial r}{\partial U_j^k} = (V_j^m - y_j)$, So:

$$d_j^m = V_j^m(1-V_j^m)(V_j^m - y_j) \tag{13}$$

If I isn't the nerve cell unit in output layer, it is in the hidden layer, so:

$$\frac{\partial r}{\partial U_j^k} = \sum_i \frac{\partial r}{\partial U_i^{k+1}} \cdot \frac{\partial U_i^{k+1}}{\partial V_j^k} = \sum W_{ji} \cdot d_i^{k+1},$$

we can get:

$$d_j^k = V_j^k(1-V_j^K) \cdot \sum_i W_{ji} d_i^{k+1} \tag{14}$$

After calculation, we can conclude that the error signal d_j^k between k layer and K-1 layer is proportional, and adjust in the same direction. We can draw the conclusion from above, the signal transfer principle of neural network is to get the actual output V_j^m, and compare to the expected output, and then we can get the deviation function. After a series of parameter adjustment, then we can minimum the error between actual output and expected output.

It comes true as follows:

$$\Delta W_{ij} = -\varepsilon d_j^k V_j^{k-1} \tag{15}$$

Where:

$$d_j^m = V_j^m(1-V_j^m)(V_j^m - y_j)$$
$$d_j^k = V_j^K(1-V_j^k) \cdot \sum_i W_{ji} d_i^{k+1}$$

We can see clearly that the error signal d_j^k in this layer and d_i^{k+1} in K+1 layer are closely related. It also shows that error signal passes reversed from output layer to the input layer. When modifying the neural network system parameters, if it achieves the expected target output, it will stop learning automatically and finish the construction of application system.

3. Financial Early Warning Indicators Selection

In the past, we evaluate the financial crisis early warning mainly from profitability, debt and operational capacity. The different researchers or same researchers in different studies select different indicators. This article consider mainly from the following aspects: (1) Using frequent indicators in the financial crisis early warning model established in the past; (2) Although most indicators are frequently used in previous studies, they can't get an uniform standards, so we can choose these indicators and make a further examination to the obtained conclusions in the literature; (3) It can improve the efficiency of research in-depth study on the basis of previous studies.

The financial early warning indicators include: profitability capacity indicators, cash flow capacity indicators, solvency capacity indicators, development capacity indicators, shareholder profitability capacity indicators and operational capacity indicators. It is shown in Table 1.

Table 1. Financial Early Warning Indicators

profitability capacity indicators	net sales	development capacity indicators	capital maintenance and appreciation ratio
	return on assets		asset growth ratio
	ROA		revenue growth ratio
	ROE	shareholder profitability capacity indicators	EPS
cash flow capacity indicators	cash flow ratio		Net assets
	net cash flow of per operating activities		sales income
solvency capacity indicators	current ratio	*operation capacity indicators*	Receivable accounts turnover
	Ratio of working capital to total assets		inventory turnover
	assets and liabilities ratio		Current assets and sales revenue account
	equity ratio		total assets turnover
	ratio of proportion in liabilities		
	long-term debt ratio		

4. Financial Crisis Early Warning Model Construction and Simulation

4.1. Financial Crisis Early Warning Model Construction

In this article, we choose 100 companies as samples from the 115 companies, which are consistent with the definition of financial crisis that belongs to ST and *ST firstly from 2007 to 2009 in A-share market.

The construction of these 100 sample companies is as follows:

(1) It continued losses in the last two fiscal years. There exist significant accounting errors or false records in the annual financial statement. The companies correct financial report consciously or demanded to correct by China Securities Regulatory Commission. Accounting errors or false records previous are traced and adjusted. The results show that there are 95 companies that the net profit is negative in current two years.

(2) The audit opinion of its most recent fiscal year shows that there are 2 companies that their ownership interest are negative.

(3)Only 1 company takes special treatment according to the CPA's opinions.

(4) There only 1 company is specially treated according to poor management. There are 52 companies in 2007,21 companies in 2008 and 27 companies in 2009.But the following is not included:(1) 424 companies can't obtain the property data;(2)Only 1 companies has been specially treated after entering the market 2 years. The reason to remove is that the financial data is too less and it has some suspicion in entering the market. It is different from other sample companies. (3)There are 3 companies has been specially treated, or warned, or bankrupt according to huge guarantees. The reason to remove is that the financial guarantee belongs to infrequent events, and it isn't caused by normal operation. It is different from other sample companies. (4) There 1 company is specially treated by natural disasters and big accidents. The reason is the same as (3).

(5) Six companies have been specially dealt with because of the accounting firm gives some denial suggestions or is unable to give suggestions. We selects 100 normal listed companies randomly as the sample companies. That means, it has 100 financial crisis companies and 100 non-financial companies crisis.

Using Matlab program to test repeatedly, and in this study, it adapts the training algorithm of optimization theory, which means Levenberg-Marqurad algorithm.

The setting of parameters is as follows: The number of cycle interval is 100, and a target error is 0.0001; Maximum number of the cycle times is 2000. The detailed procedures are as follows, which was wrote by Matlab-built financial crisis early warning system.

```
P= [];
T= [];
Net=newff (minmax (p), [6, 1], ('logsig','purlin'),'traninlm');
Net.trainparam.show=100;
Net. Net.trainparam.epochs=2000;
Net.trainparam.goal=0.0001;
[net,tr]=train (net,p,t);
Y=sim (net,p);
Ptest= [];
Result-test=sim (net,ptest);
W1=net.iw (1, 1);
Thetal=net.b (1);
W2=net.1w (2, 1);
Theta2=net.b (2)
```

By Matlab training, it shows that the error of financial crisis warning system converges to the target error. In the process of network training and error approach, the final adjustment results of weight value and threshold value are as follows:

ω1 is the weight value from input layer to hidden layer:

$$W_1 = \begin{bmatrix} 34.577 & -4.6799 & 93.639 & 39.905 & 46.633 & -19.637 & -55.04 & 12.122 & -416.692 & -28.393 & -49.247 & -14.635 \\ -218.34 & 18.05 & 6.4975 & 61.687 & -62.342 & -31.363 & 81.057 & 41.216 & -8.2382 & 20.512 & 18.693 & 79.935 \\ 234.03 & 8.3706 & -60.248 & -55.977 & 71.027 & 30.507 & -76.668 & -42.04 & 32.97 & -20.689 & -32.555 & -79.315 \\ -124.06 & -35.086 & -27.64 & -28.223 & -88.555 & 111.51 & 94.299 & 130.84 & -233.32 & 83.085 & 3.3879 & 40.487 \\ -212.75 & 8.2708 & -34.51 & 71.933 & -63.59 & -32.982 & 93.636 & 44.576 & 10.76 & 23.167 & 4.922 & 86.273 \\ 1.298 & 0.07229 & -8.2739 & 12.2 & -56.576 & -3.4345 & -58.806 & 85.537 & 31.05 & -32.832 & 16.797 & 36.117 \end{bmatrix}$$

ω2 Is the weight value from hidden layer to output layer:

$$W_2 = \begin{bmatrix} 1.006 & 93.423 & 48.772 & 1.0084 & -44.657 & 0.004699 \end{bmatrix}$$

θ1 Is the threshold value in hidden layer:

$$\theta_1 = \begin{bmatrix} 10.857 \\ -6.566 \\ 5.0262 \\ -71.913 \\ -9.1459 \\ 35.818 \end{bmatrix}$$

θ2 Is the value of output layer: θ2=[-48.783]

4.2. Financial Crisis Early Warning Model Simulation

Using Matlab to simulate the financial crisis warning model, and the results are shown in Table 2.

Table 2.The Simulation Results of Test Samples

FDC Code	Expected Output	Actual Output	NFDC Code	Expected Output	Actual Output
000720	1	2.7445	000158	0	0.003889
000751	1	0.99777	000159	0	-0.0027
000856	1	0.99768	000301	0	-0.00692
000955	1	1.001	000400	0	-0.00273
000995	1	1.001	000402	0	-0.05962
600115	1	1.0027	000404	0	3.5155
600130	1	0.99767	600162	0	0.14751
600149	1	44.653	600163	0	0.93396
600185	1	1.0016	600165	0	0.59123
600253	1	1.0175	600167	0	-0.00312
600313	1	0.98499	600185	0	1.0016
600340	1	1.0013	600200	0	-0.0065
600506	1	1.0028	600211	0	0.069184
600591	1	1.0024	600222	0	-0.00274
600617	1	0.84005	600231	0	-0.00269
600633	1	0.59904	600282	0	-0.0026
600701	1	0.99692	600305	0	-0.09393
600727	1	1.0025	600309	0	-0.00166
600887	1	1.0056	600321	0	-0.00113
600898	1	0.16213	600480	0	-0.00233

In previous studies, if the output value is bigger than 0.9, then the output is 1. If the output value is less than 0.1, then the output is 0. If the output value is between 0.1 and 0.9, then the output is regarded as model prediction failure. In this study, the output layer adapts a linear transfer function (purelin), so the output value of the network will be expanded in some extent. The output scope in this study will expand to [-0.2, 0.2]. If it exceeds the scope, then the output is regarded as model prediction failure. In the eight listed companies，which are misjudged，a financial crisis company has been misjudged as non-financial crisis companies, and the probability is 12.5%. Two non-financial crisis companies have been misjudged as financial crisis companies，and the probability is 25%. The probability of model prediction failure is 62.5%. The results show that in the 20 group samples, there 8 listed companies that the actual output isn't match to real situation, and the rate of right prediction is 80%. The results show that the use of financial indicators of t-2 in building financial crisis early warning model based on neural network is effective.

The financial crisis early warning model, which is built based on artificial neural network, is quite convenient in actual management. In fact, using samples to test the early warning model, it means to have an actual application to the model. We only need to select 12 financial indicators as input matrix, and input the following instruction in Matlab built model interface.

```
Ptest= [];
Result-test=sim (net,ptest);
```

Then it can realize the prediction of company financial position, and predict the crisis advance. Then we can find out the reasons and take appropriate and effective measures in time to defuse the crisis.

5. Conclusion

In the article, the effective conclusions are mainly based three aspects. On the one hand, in order to meet the needs of sample size, they broaden the objects to all the A-share listed companies in the stock market, without strictly limited to some specific industries. The financial situation exist difference in the same index of different industries, which may cause error to the model. On the other hand, the accuracy of this model is based on the accuracy of training sample data. For example, the scientific fairness, objectivity of financial reports and other public disclosure of the listed company. Although the annual report of listed company is audited by certified accountants, there exist defects in confirming information in accounting standards, which can affect the accuracy of financial crisis early warning model based on neural network. At last, in previous study of financial crisis early warning based on neural network, although the accuracy was up to 90%, they didn't give a strict limit to the training results. Under the whole real financial data of listed companies, if the accuracy can get to 80%, that is enough to prove the reliability of this model. Previous research simply regards 0.5 as the limit of output result, but in this research, the limit to output result is more stringent. Also it proves that financial crisis early warning model based on neural network is effective and persuaded.

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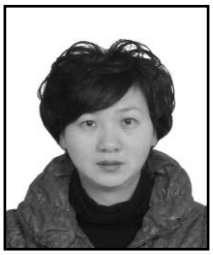

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