Automotive Customer Service Evaluation Based on BP Neural Network

Juan LIU
Shangdong Women's University, Ji'nan, China

Jichen Fang
Weichai Holdings Group Co., Ltd, Weifang, China

ABSTRACT: It is very important to evaluate the automotive customer service for people, but do not have a unified standard to it. Through the research of BP network, we established automotive service satisfaction evaluation model based on BP neural network. Then, evaluated the performance of service satisfaction in the area where the object of 14 service stations in the fourth quarter 2013, analysed the evaluation examples using matlab. Evaluation study results showed that: the model evaluation results are basically consistent with the actual situation, this model is suitable for the evaluation of automotive service. Proved that the comprehensive evaluation of BP neural network have speed computation, high efficiency, strong self-learning and wide adaptability.

KEYWORD: Automotive Service; Customer Satisfaction; BP Neural Network

1 INTRODUCTION

The idea of customer satisfaction originated in Europe, and American scholars cardozo reference it into commercial sector in 1965. Since 1977, the American scholar Hunt[1], Oliver[2] have been published many articles on customer satisfaction problem. Paolo Gaiardelli et[3] analyse from the point of service chain that it include component manufacturers, vehicle manufacturers, customers and assistance centers. Yu guoxin[4],[5] established a multi-level car service supply chain performance evaluation model based the core of service provider. Pei Cunqiang[6] 2008 drawed on The balanced scorecard, applied of the theory of customer satisfaction, service management, supply chain management theory comprehensively, constructed a comprehensive auto service performance evaluation system.

In summary, it can be seen that the research of automotive supply chain, car saled service and customer satisfaction measurement has been very mature, but few studies involve in customer satisfaction, and has not yet put forward automotive service satisfaction evaluation model for China's current stage. So, the researched BP neural network based saled service satisfaction in this paper have some theoretical significance and practical value to the automotive supply chain performance evaluation.

2 THE EVALUATION MODEL BASED ON BP NEURAL NETWORK

2.1 *BP Neural Network*

The neural network is simplification and simulation of biological neural network, It consists of input layer, hidden layer and output layer. There is no coupling between network nodes of same layer and layers take a fully connected. The output of inside neural each layer are transferred to the next layer, to achieve enhanced, reduced or inhibit these outbut by the coupling weights. Figure 1 shows a basic BP neurons, it has n inputs, each input is connected to the neuron node by a appropriate weight value wi, i=1,2,…n.

The output function is: $y = f(W \times X, \theta), a = \sum_{i=1}^{n_0} w_i x_i$

a is the input of activation function. Another input of activation function is threshold of neurons.

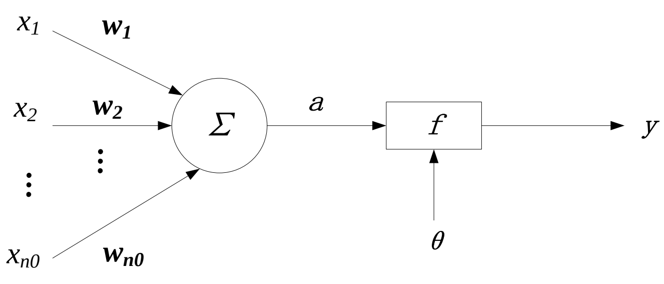

Fig.1 single neural model of BP Neural Network

BP network can be seen as a highly nonlinear mapping from input to output, ie, $F: R^n \to R^m$, *f(X)=Y*. For sample collection, input $x_i (\in R^n)$ and output $g(x_i) = y_i$, may think there is a mapping g for $g(x_i) = y_i$, i=1,2…n. The neural network does several complex by simple nonlinear function and can be approximated by a complex function, then, get the best approximation of f is g. The structure of BP network is showen as Figure 2.

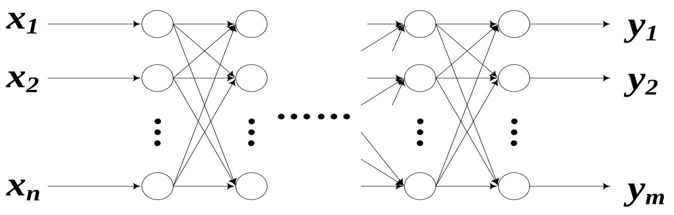

Fig.2 The structure of BP Neural Network

Studies have shown that, if given any $\varepsilon > 0$ and any L_2 function $f:[0,1]^n \to R^m$. there is a three-layer BP network, it can approximate f in an arbitrary precision squared error (BP Theorem). Although the BP theorem shows that as long as the BP network of three layers can be used to realize the L2 function, but in fact if you use three networks often requires a lot of hidden nodes, and the use of multi-layer network can reduce the number of nodes in hidden layer.

2.2 *The Mathematical Description of BP Neural Network*

The structure of multilayer feedforward networks based on BP algorithm is showed in Figure 3. This network has not only an input node, an output node, but also one or more hidden nodes. For input information, spread forward to the nodes of hidden layer, operate by Sigmoid type active function of each unit, spread output information of hidden node to output node and give results. The network learning process include forward and backward two parts, minimum the error signal through repeated use of the process. When the error achieve demand, learning process end.

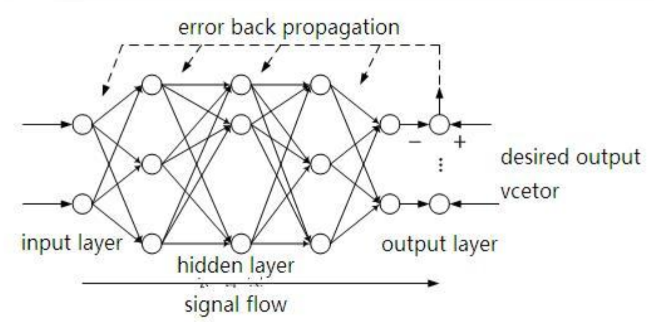

Fig. 3 the neural network structure based BP agorithm

Suppose any network has L layers and n nodes. If give N samples(x_k,y_k)(k=1-N), the output of either node i is O_i, the output is y_k of input x_k ,the output of node i is O_{ik}. In the I layer j unit of network, if input k-th sample, the input of node j is:

$$net_{jk}^{l} = \sum_{j} w_{ij}^{l} O_{jk}^{l-1} \tag{1}$$

O_{jk}^{l-1} represent layer l-1, the output of node is:

$$O_{jk}^{l} = f(net_{jk}^{l}) \tag{2}$$

f(x) is the active function of node j, use squared error function:

$$E_k = \frac{1}{2} \sum_{i} (y_{jk} - \dot{y}_{jk})^2 \tag{3}$$

y_{jk}, $\dot{y}_{jk}$ are the expect and real output of uint j. the total error is:

$$E = \frac{1}{2N} \sum_{k=1}^{N} E_k \tag{4}$$

N is the number of neural about output layer, $\delta_{jk}^{l} = \frac{\partial E_k}{\partial net_{jk}^{l}}$ then:

$$\frac{\partial E_k}{\partial w_{ij}^{l}} = \frac{\partial E_k}{\partial net_{jk}^{l}} \frac{\partial net_{jk}^{l}}{\partial w_{ij}^{l}} = \frac{\partial E_k}{\partial net_{jk}^{l}} O_{jk}^{l-1} \tag{5}$$

Node j is output uint, then $O_{jk}^{l} = \dot{y}_{jk}$,

$$\delta_{jk}^{l} = \frac{\partial E_k}{\partial net_{jk}^{k}} = \frac{\partial E_k}{\partial \dot{y}_{jk}} \frac{\partial \dot{y}_{jk}}{\partial net_{jk}^{k}} = -(y_k - \dot{y}_k) f'(net_{jk}^{l}) \tag{6}$$

J is not output uint, then:

$$\delta_{jk}^{l} = \frac{\partial E_k}{\partial net_{jk}^{k}} = \frac{\partial E_k}{\partial O_{jk}^{l}} \frac{\partial O_{jk}^{l}}{\partial net_{jk}^{k}} = \frac{\partial E_k}{\partial O_{jk}^{l}} f'(net_{jk}^{l}) \tag{7}$$

O_{jk}^{l} is the input of next layer (l+1), calculate $\frac{\partial E_k}{\partial O_{jk}^{l}}$, then:

$$\frac{\partial E_k}{\partial O_{jk}^{l}} = \sum_{m} \frac{\partial E_k}{\partial net_{jk}^{l}} \frac{\partial net_{jk}^{l}}{\partial O_{jk}^{l}} = \sum_{m} \frac{\partial E_k}{\partial net_{jk}^{l+1}} w_{mj}^{l+1} = \sum_{m} \delta_{mk}^{l+1} w_{mj}^{l+1} \tag{8}$$

Obtained from (7) and (8):

$$\delta_{jk}^{l} = \sum_{m} \delta_{mk}^{l+1} w_{mj}^{l+1} f'(net_{jk}^{l}) \tag{9}$$

The steps of this back-propagation algorithm can be summarized as follows:

(1) Selected initial weights;
(2) The following procedure is repeated until convergence;
①For k=1-N

Forward process:calculate O_{jk}^{l-1} , net_{jk}^{l} and $\dot{y}_k$ of each layer each uint, k=2-N

Backward process: for each layer(l=L-1 to 2), calculate δ_{jk}^{l}

②Correction weights

$$w_{ij} = w_{ij} - \mu \frac{\partial E}{\partial w_{ij}}; \mu > 0 \qquad (10)$$

μ is step size, where $\frac{\partial E}{\partial w_{ij}} = \sum_{k=1}^{N} \frac{\partial E_k}{\partial w_{ij}}$

3 CASE STUDY

According to car saled customer satisfaction index(CSI) in the 2013 fourth quarter of one car brand, using the BP neural network established, evaluate the 14 service stations of this brand in a region.

Table 1 shows after-sale service satisfaction index of 12 car brand service stations in 2013 fourth quarter which are selected randomly nationwide. The after-sale service satisfaction take seven measure indicators, the overall evaluation, preparing and maintenance, reception staff, environmental facilities, the process of taking car, repair and maintenance quality, tracking service, they are represented by the letters a-g in table 1.

Table 2 shows after-sale service satisfaction index score of 14 this car brand service stations in 2013 fourth quarter. The total score is 1000 points and the higher scores indicate higher customer satisfaction with car services.

According to part of the sample data in table 1, train the BP neural network, evaluate the 14 service stations in table 2 by established BP neural network evaluation model.

(1) Data normalization

Process the data between [-1,1],transfer the score into a percentage number.

Table 1 after-sale service satisfaction index

	a	b	c	d	e	f	g	CSI
1	935	949	956	934	923	944	930	940
2	955	962	961	948	943	956	962	955
3	936	944	954	945	924	943	938	941
4	961	974	988	969	968	980	954	974
5	907	927	943	829	876	923	904	903
6	911	909	947	887	912	935	938	923
7	897	947	959	891	903	922	891	920
8	906	922	939	924	895	933	878	919
9	935	939	944	910	920	931	906	927
10	881	919	928	875	883	925	906	909
11	956	960	966	975	931	956	943	955
12	977	976	982	952	952	966	967	965

Table 2 the score of after-sale service satisfaction index

	a	b	c	d	e	f	g
1	927	935	946	945	913	937	943
2	953	980	971	968	925	949	943
3	924	952	950	951	915	933	895
4	982	984	989	989	965	986	987
5	860	911	900	847	852	895	778
6	902	958	936	942	897	927	896
7	993	998	992	989	990	992	988
8	922	947	975	924	950	958	919
9	935	957	961	975	929	938	911
10	859	882	903	914	846	878	820
11	962	969	977	973	939	952	928
12	960	957	972	967	931	952	927
13	929	952	950	924	940	943	920
14	986	990	991	984	985	990	985

(2) Network design

①Set the input and output nodes. Take 7 index values of sample as input vector of input node, take the satisfaction value as the expectation of the network output node.

②Compare and choose the number of hidden nodes. Establish BP neural network evaluation model of 7 input nodes, 17 hidden nodes and 1 output node.

③Select the transfer function. Select tansig function as the transfer function of the hidden layer neuron, select purelin function as transfer function of the output layer neuron.

④Select the training function. Consider the convergence speed and training precision, by comparison and testing, choose the Levenberg-Marquardt algorithm to train the model network, the training function is trainlm.

(3) Anti-normalization.

Convert the network output into numerical scores.

4 TRAINNING RESULTS

Use the following statement, doing multiple network training in matlab tool. The process of network training is shown in Fig. 4.

```
net=newff(minmax(P),[17,1],{'tansig','purelin'},'trainlm');
net.trainParam.epochs=1000;
net.trainParam.lr=0.001;
net.trainParam.goal=1e-10;
[net,tr]=train(net,P,T);
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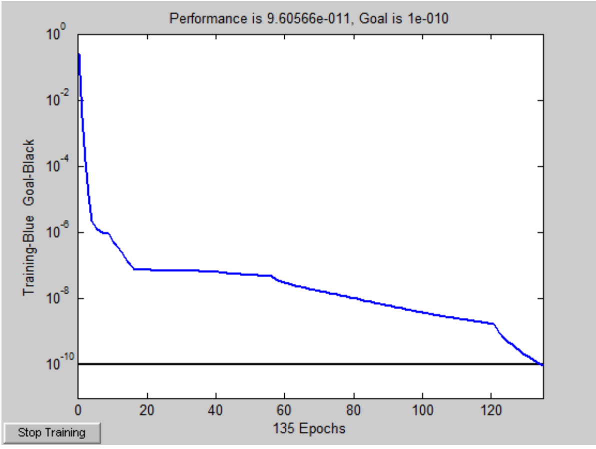

Fig. 4 The process of network training

RAINLM, Epoch 0/1000, MSE 3.74511/1e-010, Gradient 289.368/1e-010
TRAINLM, Epoch 25/1000, MSE 2.67629e-007/1e-010, Gradient 0.000288916/1e-010
TRAINLM, Epoch 50/1000, MSE 8.10641e-008/1e-010, Gradient 0.000745514/1e-010
TRAINLM, Epoch 75/1000, MSE 4.67815e-008/1e-010, Gradient 0.000717933/1e-010
TRAINLM, Epoch 100/1000, MSE 1.13976e-008/1e-010, Gradient 0.000128943/1e-010
TRAINLM, Epoch 125/1000, MSE 3.82084e-009/1e-010, Gradient 0.000107533/1e-010
TRAINLM, Epoch 150/1000, MSE 2.20368e-009/1e-010, Gradient 0.000610212/1e-010
TRAINLM, Epoch 175/1000, MSE 1.33049e-010/1e-010, Gradient 2.86924e-005/1e-010
TRAINLM, Epoch 181/1000, MSE 9.83276e-011/1e-010, Gradient 1.62932e-005/1e-010
TRAINLM, Performance goal met.

The setting target is 1e-010, after running the program, the approximation error curve is shown in Figure 4. We can see from it, after iterating of 135 times and the error value has less than the target. Then, the iteration is terminated, the system display “Performance goal met”, the error of network training is down to the target and the network stop training. All indicate the rate of convergence is faster.

5 EVALUATION RESULTS AND ANALYSIS

After the network training, normalize the data in Figure 2 samely and input the model, Then, take inverse normalization. Compare the obtained results with the original evaluation results as shown in Figure 3, it consistent with the original. So, It can reflect the ranking of service performance about the service station in service area, the model can be used for evaluation of car service performance.

Fig. 3 the comparison of evaluation results

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
BP-CSI	935	953	933	983	883	933	990	950	943	886	955	952	941	988
CSI	935	954	933	983	872	926	992	949	944	875	956	951	940	988

6 CONCLUSION

This paper established a car saled service evaluation model based on BP neural network, detailed the model structure, algorithm theory and algorithm steps. For car saled service satisfaction index of one brand, using the model evaluate the after-sales service satisfaction in the fourth quarter 2013 about 14 service stations in a region. Analyze the evaluation results and The result show that: the evaluation results of the model is basically the same situation, this model is suitable for the evaluation of automotive service performance.

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