Forecasting the Demand of Emergency Supplies: Based on the CBR Theory and BP Neural Network*

Fu Deqiang, Liu Yun, Li Changbing
School of economics and Management, Chongqing University of Post and Telecommunication, Chongqing, China, 400065
(E-mail: fudq@cqupt.edu.cn, liuyun0622@sina.com, lcbss@126.com)

Abstract: In recent years, the unconventional emergence incidents occurred frequently, which are seriously harmful to people's lives and property. So how to predict resource requirements after disasters timely becomes an important issue. This paper presents an accurate prediction method based on CBR and BP neural network. Firstly, a set of base cases of the emergency demand should be found out. Then the law of emergency supplies base cases can be obtained according to BP neural network, at last, to prove the value of the forecast method, the demand of goal case can be predicted by using the law.
Key words: Emergency supplies; Forecast; Case-based reasoning; BP neural network

1 Introduction

Recently, the unconventional emergence incident occurred frequently which is seriously harmful to people's lives and property. The researches of emergency supplies demand forecasting play an important role in improving the emergency response effectiveness and minimizing the disaster losses.

Emergency supplies means once emergence incident occurs, the similar or alternative resources which can be mobilized. Currently, many scholars have conducted studies to forecast the demand of emergency supplies. Guo Ruipeng[1]combined the fuzzy reasoning with the case-based reasoning and established the emergency supplies demand model according to the characteristics of the material requirement. Lin Jianxin[2], who established the mathematical model to forecast the emergency transport demand distribution problem, proposed an improved emergency transport demand curve function. Fu Zhiyan[3] predicted the demand of emergency supplies using case-based reasoning model. Certain contributions have been made from their studies.

In conclusion, now many scholars have done relevant researches of emergency supplies demand forecasting from different angles. The emergency events are characteristic of non-routine, sudden, and uncertainty; however, the previous research did not highlight these characters, so these methods are of low practicality. This paper presents an accurate prediction method based on CBR and BP neural network, and selects emergency supplies samples which are used in BP neural network training. Because similar emergency supplies demand processes are bound to have similar demand law, first, putting forward a set of based cases which are similar with the goal emergency supplies demand, then finding out the demand law of based cases by using BP neural network, and finally apply the law to predict the goal case of emergency demand.

2 Modeling

2.1 The framework of model

The framework of emergency supplies demand forecasting mainly consists of 3 modules:

1）Similar case retrieval module

2）Access to the law of demand module

3）Emergency supplies demand forecasting module

The function of module 1） is to identify one case which is similar to the goal case in the case database; the function of module 2）is to gain the projective reconstruction between the characters of emergency supplies and the demand; the function of module 3）is apply the law from module2） to predict the demand of the goal case emergency supplies by entering the goal case character message into the law.

2.2 Fundamentals Used in the Forecasting of Emergency Supplies Demand

2.2.1 CBR (Case-based reasoning)

* This work is supported by key Laboratory of Electronic commerce and Modern Logistics, Chongqing Education Commission

CBR is kind of methodology which not only can imitate human reasoning and thought process, but also can build intelligent computer systems. It can simulate thought processes of experts, such as association, intuition, analogy, induction, learning and memory and so on, the core idea is that when solving problem, previous experience and acquired knowledge of similar problems can be used to reason the new case, and adjust the solution according to the differences of old and new, then the new solution of the problem will become a new case. The new case can be added into the case database. As the growth of the case database, the experience of the system will be more abundant.

This paper considers the emergency supplies demand as dependent variables. First of all, case database of emergency supplies should be established. There are n cases, and suppose the number i case is denoted by C_i, $(i = 1, 2, ...n)$,namely, the base case set is C, $C=\{C_1,C_2,...,C_n\}$. Therefore, assuming that there are m characters, and they are highly associated with the demand of emergency supplies. The character set is denoted by X, $X=\{x_1,x_2,...,x_m\}$.

According to the different needs of emergency resources, demand for emergency supplies can be divided into 3 categories, manpower needs, material needs, and financial needs. The demand of the goal case is denoted by D.

Because similar emergency supplies demand always be based on the similar demand law, n similar cases can be chose as training sample.

2.3 BP Neural Network

2.3.1 Network structure

BP neural network is a kind of error back propagation learning algorithm. It is composed of the input layer, the hidden layer, output layer and the connections between different neurons, the layers of neurons is connected by weights and thresholds.

BP neural network is used to create the mapping between emergency supplies demand and the character parameters, thereby emergency supplies demand forecasting process can be solved by BP neural network. The process of emergency supplies demand forecasting of BP neural network mainly consists of 3 parts:

(1) Data collection, enter the historical demand data into case database

(2) Use emergency supplies character data and the corresponding demand data to train network.

(3) Apply the network training results to forecasting the demand of emergency supplies according to the character parameters.

2.3.2 Mathematical Expression

BP neural network can be seen as a kind of nonlinear mapping from input to output, that is:

$$D : F^n = F^m,\ f(x) = Y,$$

For a sample set: input $X_i \in R^n$, output $Y_i \in R^m$, then there exists a mapping.

$$g(x_i) = y_i\ (i = 1, 2, ...n),$$

Now map f is requested, so in some sense (usually the number of least squares), f is the best approximation of g. BP neural network is similar to complex function through several complex of simple function.

BP learning algorithm is a very important and classical learning algorithm, which can be used to achieve multilayer feed forward BP neural network weights adjustment[4]. The guiding ideology of the network learning formula is that for the amendment of the network weights (w_{ij}, t_{li}) and the threshold θ, the error function E fall along the gradient direction. 3-BP network node is expressed as: input node x_j, hidden node y_i, output node O_l, the network weight of input nodes and hidden nodes are w_{ij}, and hidden nodes and output nodes are T_{li}. When the expected output of output nodes is T_l, the BP model formula and its derivation is as follows:

(1)The formula of output O_l of output nodes

Input of input nodes: x_j

Output of hidden nodes:

$$y = f(\sum_j w_{ij} - \theta_i) \tag{1}$$

Among them, the connection weights w_{ij}, the nodes thresholds θ_i,

Output of output nodes:

$$O_i = f(\sum_i T_{ij} y_i - \theta_i) \tag{2}$$

Among them, the connection weights T_{ij}, the nodes thresholds θ_l

（2）The correction formula of output layer (hidden nodes to output nodes) is the expected output of output nodes T_l;

All of the sample error:

$$E = \sum_{k-1}^{n} e_k < \varepsilon \tag{3}$$

Among them, one sample error:

$$e_k = \sum_{k-1}^{n} \sum_{i-1}^{n} \left| t_1^{(k)} - o_1^{(k)} \right| \tag{4}$$

Among them, k is sample number; n is output nodes number.

Error formula:

$$\delta_l = (T_l - O_l)O(l - O_l) \tag{5}$$

Weights correction:

$$T_{li}(k+l) = T_{li}(k) + \eta \delta_l y_i \tag{6}$$

Which, k is the iteration number; η is the learning rate, η decides the changes which are produced in each training cycle. And it is generally ranging from 0.01 to 0.8;

（3）Thresholds correction:

$$\theta_l(k+l) = \theta_l(k) + \eta' \delta_l' \tag{7}$$

The correction formula of the hidden layer(input nodes to hidden nodes)

Error formula:

$$\delta_i' = y_i(1 - y_i) \sum_l \delta_i T_{li} \tag{8}$$

Weights correction:

$$w_{ij}(k+l) = w_{ij}(k) + \eta' \delta_i' x_j \tag{9}$$

Thresholds correction:

$$\theta_i(k+1) = \theta_j(k) + \eta' \delta_i' \tag{10}$$

This algorithm is an iterative process, each round will adjust the weight again until the error of expected output and calculated output is less than an allowable value. Then end the learning training, build the model shown as Figure 1.

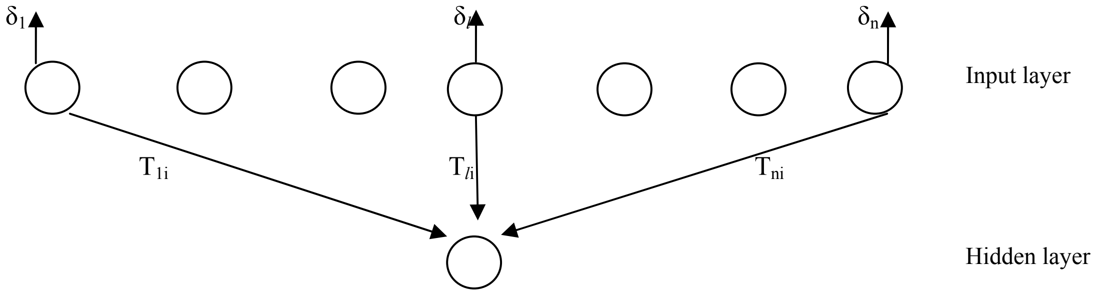

Figure 1 Back-propagation Diagram

3 Examples

3.1 Index Select

Taking the earthquake emergency supplies demand forecasting for example, there are 30 cases in the case database shown as the Table 1, $C_i, i=(1,2,...,30)$. Selecting the follow 4 chief characters of the earthquake emergency supplies as the neurons of input layer, X=｛x_1, x_2, x_3, x_4｝=｛Magnitude, depth, density of population, Number of affected people｝, and output is the demand of earthquake emergency supplies. Taking Ci(i=1,2...,15) as learning sample set, and use X as simulation input of network to learning and train. Takeing Ci(i=16,17,...,30) as the test sample to examine the accuracy of neural network learning, and compair the predicted values with the actual values until the errors are adjusted to a certain range, then forecast the demand of earthquake emergency supplies using the trained network. 3 categories emergency resources demand are all converted by yuan.

Table 1 Case Database

	x_1 (richter scale)	x_2 (Km)	x_3 (one person per Sq.Km)	x_4 (10 thousand)	demand (10 thousand yuan)
C_1	6.0	10	76.11	20	77
C_2	6.1	18	81.43	13.7	3843
C_3	5.5	6	240.97	18	1970
C_4	5.0	6	166.7	41	318
C_5	5.0	6	48.18	3.9	1268
…	…	…	…	…	…
C_{30}	5.2	10	414	2.2	1209

Selecting sigmoid function as the transfer function between the input layer and the hidden layer ,and linear function between the hidden layer and output layer. There is only 1 hidden layer, and the experiential number of hidden nodes is 7. Ficture 2 is the diagram of the 3-layer BP neural network structure.

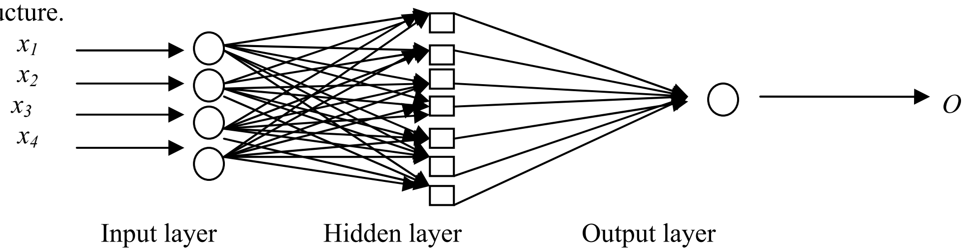

Figure 2 3-layer BP Neural Network Structure Diagram

3.2 Training and Result Analysis

Using Matlab 7.0 to do BP neural network emulate training, and the max learning ratio is 0.3, the minimum is 0.0. After 10000 iterative processes, the average error comes to the reasonable range, less than 5%. Figure 3 is the network training parameter diagram.

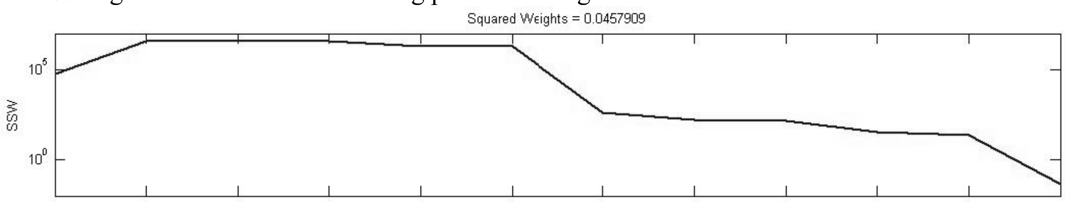

Figure 3 Network Training Parameter SSW Diagram

Under this circumstance, Suppose D, X_D= (7.3, 8, 24, 100). Emergency supplies demand of D can be predicted. The predicted value is 3429, and the actual value is 3290, the error is 4.2%.

4 Conclusions

According to above analysis, the method of Forecasting Emergency Supplies Demand Based on the CBR Theory and BP Neural Network is feasible; the error between the predicted value and the actual value is under reasonable control. However, in order to make the forecasting more accuracy, the number of the case should be greater, and then a more well law can be obtained.

Reference

[1] Guo Ruipeng. Research on the Methods and of Emergency Material Mobilization Decision-making [D]. Beijing: Beijing Institute of Technology, 2006:34-40 (In Chinese)

[2] Lin Jianxin, Wei Xianlan, Wu Haiyan. Time-variation Demand Forecast of Emergent Traffic Evacuation Based on S-curve[J]. Journal of Transport Information and Safety,2009,27(3):92-96 (In Chinese)

[3] Fu Zhiyan, Chen Jian. Research on Emergency Material Demand Forecast Model in Disaster [J].

Logistics Sci-Tech, 2009:11-13 (In Chinese)

[4] Yin Chao, Qian Shengsan,Zeng Yonggang, ZhouYuan. Research for the Estimation of Capacity Demand of Knowledge-production Based on the CBR Theory and BP Neural Network [J]. Science-Technology and Management, 2010:45-48 (In Chinese)