IOP Conf. Series: Materials Science and Engineering **392** (2018) 062087 doi:10.1088/1757-899X/392/6/062087

The prediction of horizontal displacement of retaining and protection structure based on BP neural network

Xueling Liu[1], Jie Gao[2], Nan Li[1], Guangping Chen[1], Ou Gao[1] and Jian Li[1]

[1] School of Geology Engineering and Geomatics, Chang'an University, Xi'an, Shaanxi 710054, China

[2] Electronic integrated research institute, Ministry of Information Industry, Xi'an, Shaanxi 710054, China

Abstract. The horizontal deformation and displacement of retaining and protection structure is one of the most significant deformations and failure types of deep excavations. The artificial neural network technology is introduced into the deep excavations system due to its complexity and nonlinear deformation characteristic. Based on the function of Matlab neural network toolbox, an artificial neural network prediction model, instead of a real model, was established to predict the horizontal displacement of retaining and protection structure of a project in Guangdong Province, in order to provide guidance for the excavation of deep foundation and the design of retaining and protection structure. The results reveal that the predicted value is consistent with that from the actual monitoring, which shows that the displacement prediction on the deep excavations through BP artificial neural network is feasible and reliable.

1. Introduction

In the process of urban development, the continuous emergence of high and super high buildings and underground structures has made the scale, depth and complexity of the deep excavations increasing. In order to ensure the safe construction of the deep excavations, the prediction of deformation has become an important link in the excavation process [1]. For construction of excavations, the horizontal deformation and displacement of retaining and protection structure is an important physical quantity that could reflect the stability of the excavations and their surrounding environment [2-4]. Therefore, it is crucial to achieve a more accurate prediction for the horizontal displacement of retaining and protection structure. As a result, many prediction models have been established by researchers. Shipeng Li [5] used a space-time autoregressive model to establish a spatial-temporal relationship between elevation value of pipes around the excavation for temporal analysis and short-term forecasts, for temporal analysis and short-term forecasts. Proved the model in foundation settlement data pipeline and forecasting short-term feasibility by comparing the results with time series modeling, spatial and temporal analysis of temporal sequences. In the paper written by Chuansheng Huang [6], finite element method was used to analyze the deformation caused by deep excavation construction, constructed a predicting model by based on gray system, markov chain to analyze various defamation forecast model. The applicability of various models is made through actual test and verifies check. Xiaoqiang Liu [7] through established the self-regression model to study the settlement of surrounding buildings of foundation pit for timely prediction.

However, as the excavation system is a complex and fuzzy gray system, its deformation and displacement are affected by many factors, such as ground load, weather, temperature, humidity, stratum properties, supporting structures and methods [8]. Since the degree of influence of various

IOP Conf. Series: Materials Science and Engineering **392** (2018) 062087 doi:10.1088/1757-899X/392/6/062087

factors is difficult to accurately express with quantitative indicators, which leads to the characteristics of fuzzy, non-linear of the excavation deformation, making it difficult to establish the input and output relationships using traditional mathematical methods. However, the nonlinearity, good generalization ability, and fuzzy inference ability of BP neural network could solve many problems of traditional mathematical methods, such as the multicollinearity of multivariate regression analysis methods. It is suitable to predict the horizontal displacement of retaining and protection structure [9]. This paper use BP neural network model and takes the actual monitoring data as a sample. With the help of the Matlab neural network toolbox, a prediction model of the horizontal displacement of the deep foundation pit supporting structure is established. The BP neural network prediction model replaces the actual model, so as to provide guidance for excavation and support design of deep excavations.

2. BP neural network prediction model

BP neural network, also known as error back propagation neural network, was published by Rumelhart in 1986[10]. It is an adjusting artificial neural network with themselves toward potential relationship between input and output including input layer, hidden layer and output layer, Using fully connected. While there does not exist interconnection unit in the same layer. The structure is shown in Figure 1.

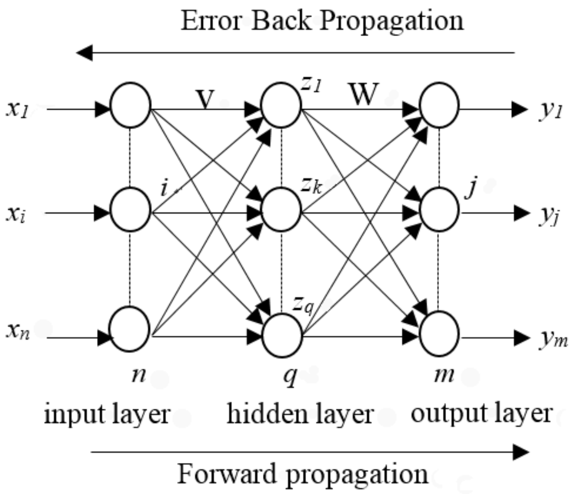


Figure 1. Three layers of network structure diagrams

BP neural network simulates the learning process of human brain and learns adaptively through external stimuli information, achieving the goal of outputting the desired result finally. The main progress is divided into two stages [11-12]: the first stage is the positive learning process, that is, input signal and the single is adjusted by weights and thresholds and transform calculation through the transfer function and output the response value; the second stage is the error back propagation process that is calculating the error between the expected value and the response value. If the error range is beyond the specified error range, the errors caused by each layer are calculated inversely from the hidden layer to the input layer using the recursive algorithm, and the weights are adjusted accordingly. Repeat the two processes above until the expected value and the response error is less than the specified value, the learning process ends automatically. The model establishment process includes the construction of input layer, hidden layer and output layer.

3. Application of BP neural network in deep excavation engineering

In order to verify the feasibility of the established model, this paper takes a deep foundation pit project in Guangdong Province as an example. Based on real-time monitoring the horizontal deformation and displacement of the supporting structure during the construction of the foundation pit, a BP artificial neural network model was established.

IOP Conf. Series: Materials Science and Engineering **392** (2018) 062087 doi:10.1088/1757-899X/392/6/062087

3.1. Project overview
The project is located on the southwest of Kaichuang Road and the west of Lanyue Road in Guangdong Province, with a total floor area of 340,000 square meters. The safety level of foundation pit of the project is Level 2. According to the design and specification requirements and the specific conditions of this project, it sets up the monitoring of the horizontal displacement of the support structure. According to the design requirements, 31 monitoring points are laid out, numbered W1 to W31.Using the Topcon GTS-102N total station with the measuring accuracy of 2 "and the ranging accuracy of 2mm + 2ppm for the horizontal displacement observation. The horizontal displacement markers embedded in the retaining structures are observed by free station method or polar coordinate method. Comparing the coordinate of each monitoring point obtained from each observation and the initial observation before excavation, and the coordinate difference is accumulated displacements value of the monitoring point in this observation period. Monitoring points and control points are used special observation signs, marking the establishment of mandatory signs on the signs to ensure that each observation is at the same point.

3.2. Establish training samples
The training samples used in this paper includes the displacement monitoring data from the beginning of excavation to the end of excavation. During this period, 46 deformation observations were made, and the data of horizontal displacement of 30 times, 35 times, 40 times and 45 times were used as training data. After repeated checking, it is found about 30 days of training samples to meet the accuracy requirements of the neural network. The 46th test is used as a test sample in this paper.

3.3. Establish a prediction model
After checking and testing, the three-layer BP network with 5 input nodes, 8 middle nodes and 1 output nodes (which represents the predicted value of the corresponding position at the 46th time) is constructed, given the control error (ε=0.0001). After about 6,000 training sessions, we can get the knowledge base structure of the neural network. The figure 2(a is the training target and b is the target curve) is the training chart of BP neural network by using the software Matlab2016.

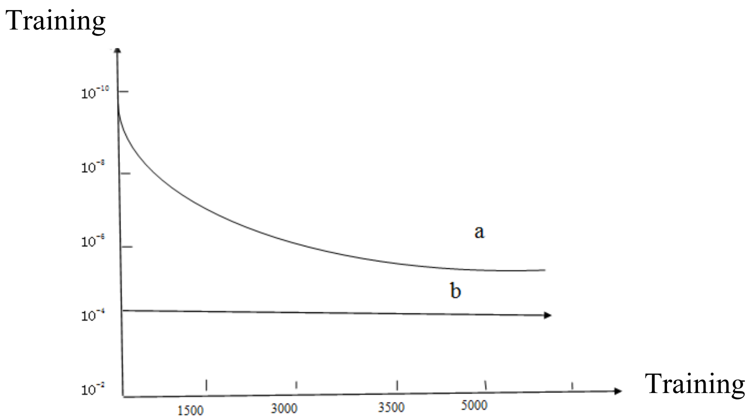
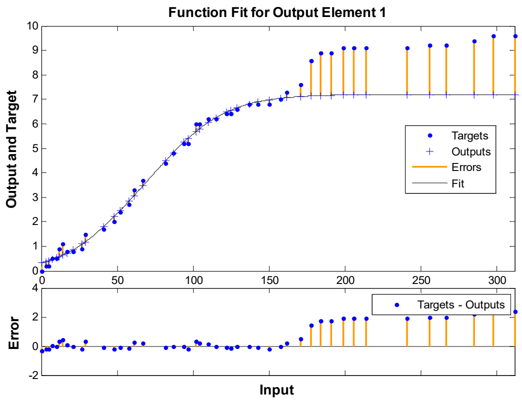


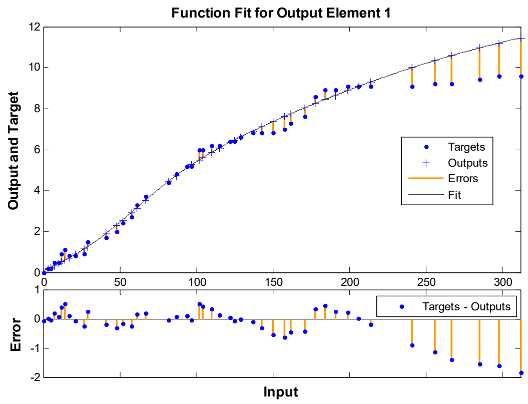
Figure 2. Neural network training curve

3.4. Prediction results and analysis
In this paper, forecasting he horizontal displacement of the 46th deep foundation pit supporting structure at each measuring point by the data of horizontal displacement of 30 times, 35 times, 40 times and 45 times. The monitoring data of the four most reasonable monitoring points from the total monitoring points were selected as the original data for prediction. The following prediction graph is a

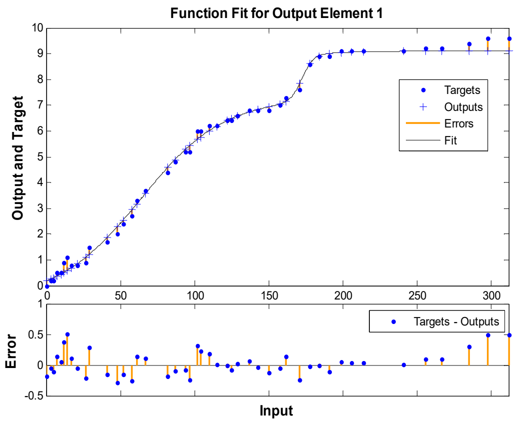
four-point BP neural network, shown in Figure 3 (Due to space limitations, the first and second monitoring point were selected).



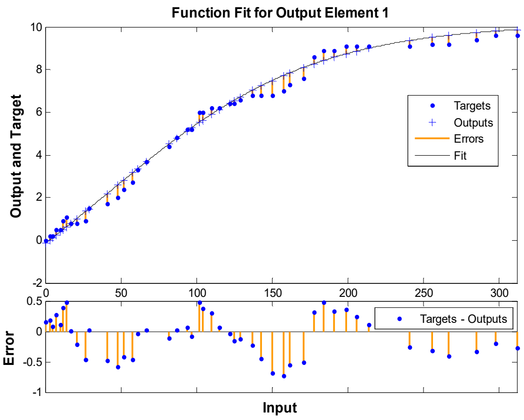
(a)The 30-day curve prediction of the first monitoring point



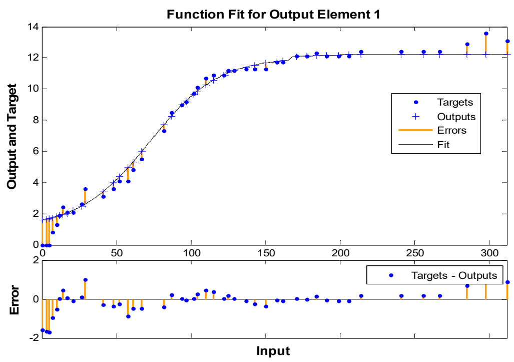
(b)The 35-day curve prediction of the first monitoring point



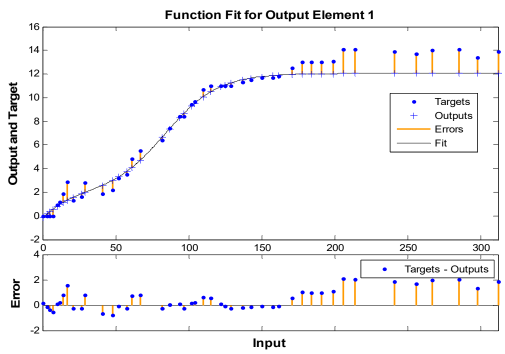
(c)The 40-day curve prediction of the first monitoring point



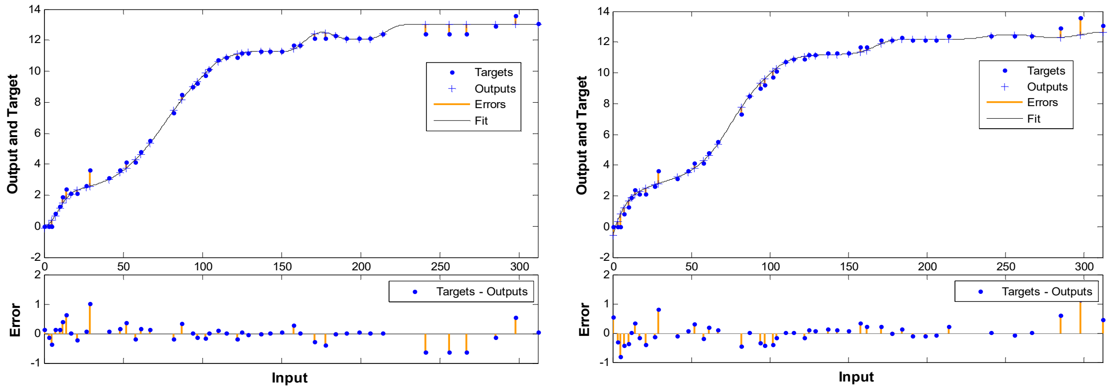
(d)The 45-day curve prediction of the first monitoring point



(e)The 30-day curve prediction of the second monitoring point



(f) The 35-day curve prediction of the second monitoring point



(g)The 40-day curve prediction of the second monitoring point

(h) The 45-day curve prediction of the second monitoring point

Figure 3. Prediction graph of the points

As can be seen from the above figure, the error of the prediction value of the horizontal deformation and displacement of the deep excavation retaining and protection structure obtained by the BP neural network method is small compared with actual value and is within the control range of 0.001. Although a small number of curves slightly deviate from the measured ones in the initial and final period of prediction, the coincidence of the predicted curve and the measured curve is over 90% overall, indicating that it achieved the desired results. This shows that BP neural network prediction method is reasonable, scientific and the prediction effective.

4. Conclusions

BP artificial neural network has a good ability of self-organization and generalization. After learning and training, it can reach high precision. Therefore, BP artificial neural network can be used to predict the deformation of pit excavation. It can be seen that BP artificial neural network has broad application prospects for many nonlinear problems in geotechnical engineering.

When using neural network to predict the deformation of foundation pit engineering, as long as the monitoring personnel input the measured displacement of the day into the network, the network could predict the displacement of the next day according to the data inputted into the computer a few days ago. The system is also suitable for the deformation prediction of the support structure and could take appropriate reinforcement measures according to the predicted results.

The BP artificial neural network is used to predict, the accuracy of the prediction results increases with training data, so in order to ensure the accuracy of the prediction results for the deep foundation pit project, it is necessary to provide a large amount of actual monitoring dates.

Although the predicted value of this example is in good agreement with the actual predicted value, it indicates that the BP artificial neural network prediction model has a high prediction accuracy, the frequency of training and the weight can be determined after many trials and comparison, This is also where BP artificial neural networks need improvement.

Acknowledgments

This study is financially supported by the Science and Technology Innovation Team Project of Shaanxi (Grants No.2015KTZDSF03-03-01) and the Fundamental Research Funds for the Central Universities (Grant No. 310826175029)

References

[1] ZL.Zhang,QY.Huang ,2008 Analysis and forecast of deformation monitoring of engineering by the Surveying and Mapping Publishing House, p6-38.

[2] GW.Clough,JM.Duncan,1971,Finite element ananlyses of retaining wall behavior,ASCE,97(12)
[3] Andrew J.Wang,1993,MA Youssерf,Analysis of deep excavation in Boston,Journal of Geotechnical Engineering,119(1),p69-89.
[4] TA.Haliburten,1968,Numerical analysis of lexible retaining styucture. Proc ASCE,94(6),P1233.
[5] SP.Li,2014 Deformation analysis based on space-time series model,Chang'an University.
[6] CS.Huang,2011,Research on excavation deformation forecasting methods of subway Foundation pit and its application,Zhong Nan University.
[7] XQ.Li,2015,Settlement Prediction Analysis of Foundation Pit Surrounding Buildings based on Self-Regressive Model, Journal of Henan Science and Technology, Vol.572，p86-87.
[8] CH.Wu,CY.Ou,2010,Corner effects in deep excavation-establishment of a forecast model for taipei basin T2 zone.Journal of Marine Science and Technology,18(1):p1-11
[9] Z. Jia,QJ. Guo,QW.Hao,2018, Deformation prediction of the diaphragm wall based on the finite Element-BP Neural Network, HeNan Science Vol.36,p431-434
[10] C. Zhang, J. Yan, Z Guo. 2013, Neural network-based prediction model for deep foundation pit settlement prediction, Chinese Journal of Underground Space and Engineering, 9(6):1315
[11] YJ.Li,YD.Xue,L.Yue,B.Chen,2015,Displacement prediction of deep foundation pit deformation based on genetic algorithm-BP Neural Network.Chinese Journal of Underground Space and Engineering, 11(S2):p741-749.
[12] SB.Li., X.Pei.2011,Prediction of deep foundation pit deformation based on keating Neural Network. Surveying and Mapping Information, 36(5):p41-45