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A TRACING IDENTIFICATION METHOD BASED ON BP NEURAL NETWORKs

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ABSTRACT: In this paper, a tracing identification method based on BP Neural Networks is suggested in order to solve the existing problems in structural identification using ANNs(Artificial Neural Networks), which divides the actual structure into a mechanism model part and a time-varying error adjusting model part. The former is created off line on the basis of a computing model, which is in accordance with the actual situation of the structural system, the latter is identified on line by using a small-scale BP Neural Networks, which employs the system identification ability of the dynamic recurrent network. Through analysis of computer simulation, it indicates that this method can minish effectively the identification error caused by the action of different earthquake loads, and improves prominently the precision and reliability for Artificial Neural Network to identify the structural system.

KEYWORDS: Tracing Identification; BP Neural Networks; Earthquake Loads; Time-Varying Error

1. INTRODUCTION

The more precisely a structural system is identified; the more effectively structural vibration is controlled. Therefore, it is very important for structural vibration control to identify the dynamic characteristic of the structural system.

It is the conventional identification method of structural response to model the structural system by mathematical formula (such as lumped model by differential equation), and get the response of the structure using numerical integral. However, most of the real structures do not satisfy linear parameter and other conditions, which are basic presumptions to model them. Moreover, parameter variation is more complex for complicated structure. It is quite difficult for conventional mathematical model to identify the actual response of the structure. Because Artificial Neural Network has self-learning, adaptive, self-organized and association memory ability which make it provided with the capability of nonlinear mapping, it has pioneered a right approach to resolve the problems above. At present, the development of BP Neural Network has been rather mature, which has been widely applied in many scientific fields. While there exist some defects such as slow constringency speed, distinct identification error, worse robustness and so on when BP Neural Network is applied to identify the dynamic characteristic[1][5]. In order to overcome the shortcomings above, this paper puts forward a tracing identification method based on BP Neural Network, which divides the actual structure into a mechanism model part and a time-varying error model part. The former which is called as status gauge made of single BP Neural Network is created off line on the basis of a computing model, which is in accordance with the actual situation of the structural system, the latter which is called as error emendation is identified on line by using a small-scale BP Neural Network, which employs the system identification ability of the dynamic recurrent network. This method can minish effectively the identification error caused by the action of different earthquake loads by tracing real-timely identification error of identified system, which improves prominently the precision and reliability for Artificial Neural Network to identify the structural system.

2. BP NEURAL NETWORK

BP Neural Network is a typical feedforward network of various Artificial Neural Networks. Because of intelligent characteristic and ability of function approach and parallel handling cosmically of Artificial Neural Network, it has great potency applied to intelligent structural control system, especially compatible to tackle the problems about nonlinear speciality of system, uncertainty and approach to identification function of the system or structural characteristic.

Structural model of BP Neural Network with hidden layers is shown in Figure 1.

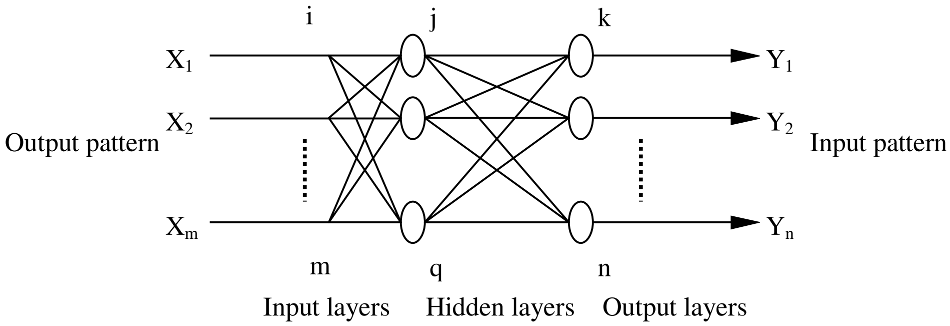

Figure 1. Structural model of BP Neural Network

In Figure 1, there are m input nodes X_1， X_2， …， X_m, n output nodes Y_1， Y_2， …， Y_n, the hidden layers have q nerve cells. W_{ij}、 W_{jk} are the connecting weighted coefficients among input layers, hidden layers and output layers respectively.

3. AN IMPROVED IDENTIFICATION METHOD

Structural system is identified using BP Neural Network, it means that BP Neural Network is trained via sample data of input and output that have existed, whose weight is modified according to BP learning rules, and make BP Neural Network provided with the dynamic characteristic of structural system. When the structure is under action of different earthquake loads, structural response of output of network trained and theoretic result of computing should be coincident, which embodies identification ability of BP Neural Network. Consequently BP Neural Network can be applied in structural vibration control and diagnosis [6][7][8]. However, there exist slow constringency speed, worse robustness, easily plunging into local least and other defects in conventional single BP Neural Network, which produce rather obvious identification error when the structure is under action of different outside loads.

In order to deal with such a problem, An improved method based on BP Neural Network is suggested, namely the single BP Neural Network identification system is in parallel with another BP Neural Network which is called as error adjusting neural network. By learning and training of the network, the author can adjust real-timely weight of error adjusting neural network, make the square of error between identification network's output and theoretic result of computing be the least when training finishes, accordingly minish effectively the identification error caused under action of different earthquake loads, and improve prominently the precision and reliability for Artificial Neural Network to identify the structural system, enlarge remarkably BP Neural Network's applied area, which have great significance for BP Neural Network applied in the fields of structural vibration control, structural mar diagnosis, parameter identification and so on.

The tracing identification structure's sketch map based on BP Neural Network is shown in Figure 2.

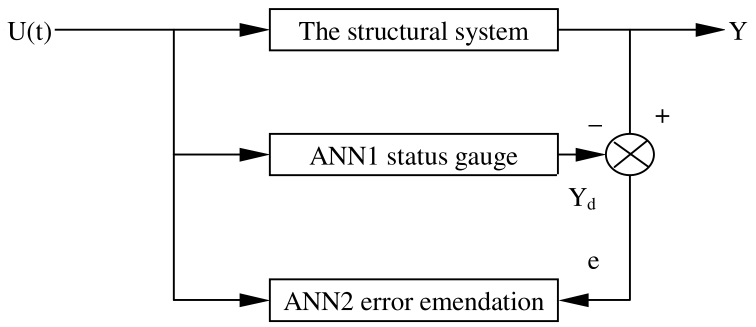

Figure 2. The tracing identification structure's sketch map

Where, Y is theoretic response of computing; Y_d is output response of a single BP Neural Network when inputs are different earthquake loads; e is identification error, $e=Y-Y_d$; ANN1 is the single BP Neural Network which has been trained off line, regarded as status gauge; ANN2 is regarded as error adjusting which can be trained off line or on line.

4. NUMERICAL EXAMPLES

For numerical simulation analysis and comparison to system identifying ability of the tracing identification method based on BP Neural Network, the author takes an 11-floor shear frame structure for example, whose anti-seismic intensity is 8 degree near the earthquake source, whose gravitation load standard magnitude and shearing rigidity of each floor are shown in Table 1.

Table 1

No. of floor	1	2	3	4	5	6	7	8	9	10	11
Rigidity (10^5kn/m)	6. 43	8. 11	8. 11	8. 11	8. 11	8. 11	6. 51	6. 51	6. 51	6. 51	6. 51
Gravitation load (kn)	9633	8631	8631	8631	8631	8413	8413	8413	8413	8413	6218

Firstly, the top floor displacements under action of EL_CENTRO (NS) wave, TIANJIN wave and QIANAN wave whose magnitude has been adjusted respectively are computed by means of structural time-history response analysis[2]. Secondly, the old BP Neural Network of system identification is trained off line, considering the past continuous displacements, velocities and accelerations of the top floor at sampling points of time as input and displacements of the top floor of sampling points of time temporality as output. And the data trained are the responses of elasticity time history, accounting to 1000 data, subsequently the data of the following 20 seconds as input is used to testify the old single BP Neural Network that has been trained well. Compared with theoretic result of computing, simulation result is shown in Figure 3.

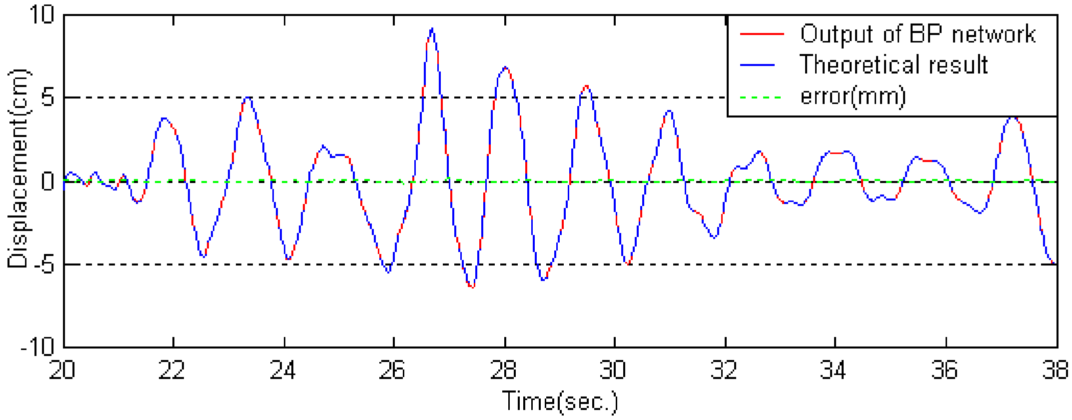

Figure 3. Simulation curves of the old single system identification network

From the analysis above, the maximum of the error between BP network output displacements of the top floor and the theoretic result of computing is 0.1347mm, moreover, the minimum identification efficiency even amounts to 99.92%. Therefore, the BP Neural Network can identify well the responses under action of the earthquake wave that is used to train the network. It may reflect well dynamic characteristic of the structural system. But how about is it when the system is under action of another earthquake wave? So the response information under action of TIANJIN wave whose magnitude has been adjusted is considered as input to testify the single BP Neural Network. And the simulation curves are shown in Figure 4.

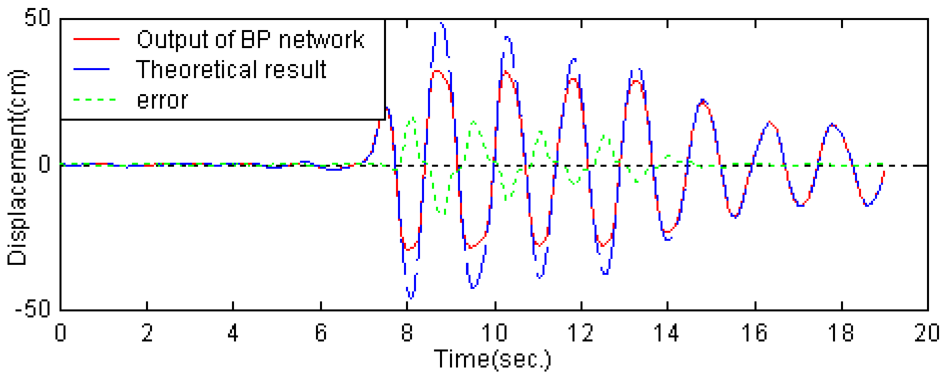

Figure 4. Simulation curves of the single BP network under action of another earthquake load

Conclusion is made that the maximum of the error between BP network output displacements of the top floor and the theoretic result of computing is 17.9479cm, moreover, the minimum identification efficiency only amounts to 63.6%. From the simulation curves, the BP network still has perfect identification effect during beginning phase and attenuation phase, while the error between BP network output displacements of the top floor and the theoretic result of computing is rather obvious in the phase of lasting strong earthquake.

Therefore, both of the identification methods discussed above can be compared with each other to see whose identification effect is better. The improved system identification network is also trained first, and then taken into application. However, the trained method used by ANN1 status gauge is the same as that of the single BP network, ANN2 error emendation is trained by the first-19-second responses under action of TIANJIN wave, regarding the past continuous displacements, velocities, accelerations of the top floor and the error between ANN1 output displacements of the top floor and the theoretic result of computing at sampling points of time as input and displacements of the top floor of sampling points of time temporality as output, accounting to 1900 data. At the same time, the response information computed theoretically under action of QIANAN wave whose magnitude has been adjusted is considered as input to testify the tracing identification based on BP Neural Network, and the identification result is shown in Figure 5 and Figure 6.

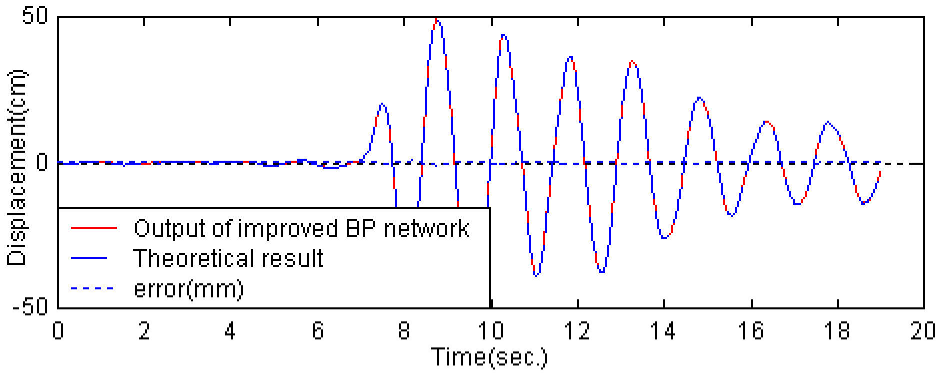

Figure 5. Simulation curves of the improved BP network under action of TIANJIN wave

From the analysis above, the maximum of the error between the improved BP network output displacements of the top floor and the theoretic result of computing is 1.7681mm, moreover, the minimum identification efficiency even amounts to 99.64%. Therefore, the improved BP Neural Network can identify well the responses under action of the earthquake wave that is used to train the network. It may reflect well dynamic characteristic of the structural system under this kind of condition.

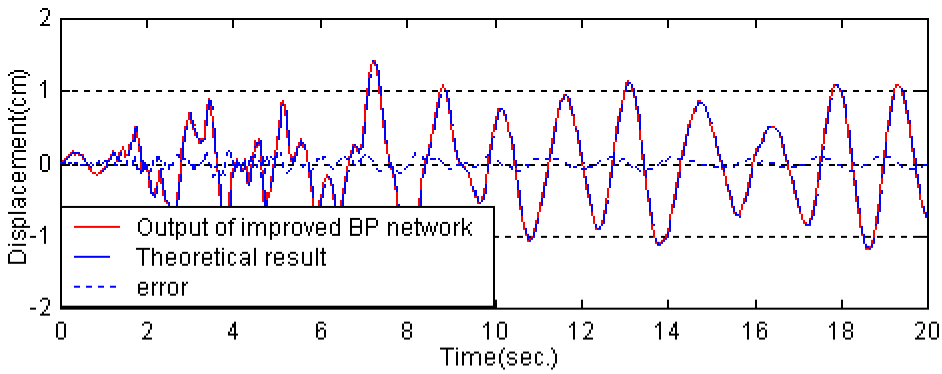

Figure 6. Simulation curves of the improved BP network under action of QIANAN wave

Conclusion is made that the maximum of the error between the improved BP network output displacements of the top floor and the theoretic result of computing is 0.2970cm, moreover, the minimum identification efficiency even amounts to 98.26%. It indicates that the improved identification method based on BP Neural Network is able to identify well the responses of the structural system not only under action of the earthquake wave used to train the network, but also under action of other different earthquake loads from the simulation analysis and comparison above.

5. CONCLUSIONS

In conclusion, the tracing identification method based on BP Neural Network given in this paper can really embody the dynamic characteristic of the structure, extend its applicable spectrum widely, constringe rapidly. And the effect of identification is more precise than the old; further, the improved identification system has a better robustness. But this method needs the status information of the identified system, so it is more appropriate to be applied to forecast and estimate the responses of the system. In a word, the tracing identification method can realize the identification of linear and nonlinear characteristic, static and dynamic system off line or on line, moreover, which has perfect precision and reliability.

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