USE OF NEURAL NETWORKS FOR ACTIVE CONTROL OF SEISMIC RESPONSE OF BUILDING FRAMES

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Submitted

in fulfilment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

HAUZ KHAS, NEW DELHI - 110016, INDIA

June, 2001

DEDICATED TO

MY MOTHER...

CERTIFICATE

This is to certify that the thesis entitled, **"Use Of Neural Networks For Active Control Of Seismic Response Of Building Frames",** being submitted by Mr. Manepalli Mallikharjuna Rao, to the Indian Institute of Technology, Delhi, for the award of 'DOCTOR OF PHILOSOPHY' in Civil Engineering is a record of the bonafide research work carried out by him under my supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of my knowledge has reached the requisite standard.

The material contained in this thesis has not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

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June, 2001.

ACKNOWLEDGEMENTS

!! *Even thousands of lives are short to acknowledge this environment*

I express my deep sense of gratitude to Prof. T. K. Datta for his untiring motivation, valuable guidance and constant encouragement throughout this study. Anyone, who works with him, can not be untouched by feel him as an *IDEAL GURU* as he has two images in one personality and these are, a *Teacher* with one image and a true *Friend* with the other.

I express my deep gratitude to my parents for their blessings and encouragement that helped me to head start my research and reach my target. I do PRANAAM to all my teachers in my life who are directing me to reach the goal.

I want to acknowledge to all my friends, relatives and colleagues inwardly through my deep feelings for them and without them I cannot feel natural smiles on my face.

My sincere thanks are due to my wife Radhika and my children Sowmya Siri and Ratna Sri for their love, affection and continuous encouragement throughout my course of study. My sincere thanks are also due to Dr. (Mrs) S. Karunes for giving me the homely and motherly feelings when I needed most.

On the facility ground, I am very grateful to the IIT Delhi for allowing me to do part time research.

MANEPALLI MALLIKHARJUNA RAO

ABSTRACT

The thesis deals with the development and testing of artificial neural network (ANN) based control schemes for the response reduction of building frames subjected to earthquake excitation. Unlike other ANN based control schemes, the reduction in response is achieved here by controlling the modal response of the structure. For this purpose, both single mode and multi mode response control schemes are developed. Single mode control is equivalent to the control of the response of the single degree of freedom (SDOF) system subjected to support excitation. Three different types of control schemes are presented in which the neurocontrollers i.e., the ANNs are trained to provide the time history of the required control force for a predetermined percentage reduction in response (target control) with inputs as (!) feedbacks from structural displacement, velocity and acceleration, (ii) feedbacks from structural displacement, velocity, acceleration and ground acceleration, and (iii) feedbacks from structural acceleration and ground acceleration. The neurocontrollers are trained with the help of synthetically generated earthquake data having different frequency compositions. Each neural net is trained with the help of a set of is 7500 input-output data sets. For training the neural net SNNS (Stuttgart Neural Network Simulator) package is used.

SNNS is a simulator for neural networks developed at the Institute for Parallel and Distributed High Performance Systems at the Stuttgart University since 1989. SNNS is distributed by the University of Stuttgart as

'Free Software' in a licensing agreement. The SNNS simulator consists of two main components - simulator kernel and graphical user interface. The simulator kernel operates on the internal network data structures of the neural nets and performs all operations on them. The graphical user interface XGUI, built on top of the kernel, gives a graphical representation of the neural networks and controls the kernel during the simulation run. In addition, the user interface can be used to directly create, manipulate and visualise neural nets in various ways. A fully connected feedforward neural net architecture with input nodes, hidden nodes and output nodes (in input layer, hidden layer and in output layer respectively) is used for supervised training of neural net. 'Act_TanH' activation function, 'BackpropMomentum' learning function and 'Topological_order' update function along with 'Randomize_weights' initialising function are used for training the neural nets. All the three control schemes can handle time delay that exists between the measurement of the response and the application of the control force. Efficiency of the neural nets is tested for the El Centro and Treasure Island earthquake data. Further, the control schemes are applied for the response reduction of a ten storey shear building frame whose response is predominantly governed by the single mode response (the first time period of the building frame is about the three times the second time period). The results of the study show that the control schemes are not only very efficient in controlling the displacement response of the structure close to the target level, but also they control the acceleration of the structure substantially. Further, performance of the control scheme with structural acceleration and ground acceleration as feedbacks is quite comparable to those of the other schemes. Therefore, this control scheme, which requires much less feedback information, has been extended to control the response of any building frame whose fundamental period lies between 0.5 s to 1.5 s.

The same three types of control schemes are developed for the reduction of the nonlinear response of SDOF system subjected to support excitation. The nonlinearity of the system is produced due to the elastoplastic behaviour of the SDOF, In the development of the control schemes, it is assumed that the controlled responses remain within the elastic range. For the synthetic generation of the training data pairs, uncontrolled responses of the system are obtained by specifying the permissible yield stress of the system such that it is exceeded by the artificially generated earthquake excitation. The neurocontrollers are trained for a predetermined target reduction of response. The control schemes are tested for El Centro and Treasure Island earthquake data and are also applied to a ten storey building frame for controlling the nonlinear response of the frame, which undergoes nonlinear excursion under these two earthquakes. The results of the study have shown that the ANN based control schemes are equally efficient in controlling the nonlinear response of the building frame and the performance of the control scheme with structural acceleration and ground acceleration as feedbacks is highly satisfactory.

A control scheme is then developed for the reduction of multi mode response of building frame. Two sets of neural nets are trained for the development of the control scheme. The first set of ANNs provide generalised acceleration with input as feedback structural acceleration from a selected number of points on the structure and ground acceleration. The second set of neural net provides the time histories of the required control force with inputs as the generalised acceleration and the ground acceleration. The number and size of the ANNs to be trained depend upon the number of modal responses to be controlled. The theoretical development of the control scheme for finding the required time history of control force for a predetermined target reduction of response is based on the modal analysis technique in which generalised control forces in each mode are matched to provide requisite generalised accelerations. The control scheme can efficiently handle the time delay effect. The neural nets are trained for controlling the response of a ten storey shear building frame with control forces applied at the top storey and by using the same set of synthetically generated earthquake data used for training the SDOF system. Performance of the control scheme is tested for El Centro and Treasure Island earthquake records. The results of the study show that the control scheme provides a reduction in displacement reduction very close to the target level and is also able to substantially control the acceleration response. The performance of the control scheme deteriorates with time delay. However, for a time delay of 0.04 s (twice the sampling interval of data) the performance of the control scheme is quite satisfactory.

The performance of the ANN based multi mode response control scheme is compared with the sliding mode control scheme for the El Centro earthquake record. Using three mode response control, the time history of control force is obtained from the neurocontroller is applied at the top of the building frame. Then the responses are obtained by considering contribution of all modes. These responses are compared with those obtained by sliding mode control for comparable control effort. In the sliding mode control displacement and velocity responses of all the degrees of freedom and the ground motions (displacement and velocity) are taken as feedbacks. For the ANN based control scheme, structural acceleration and ground accelerations are only taken as feedbacks from five selected points on the structure. The results of the study show that the ANN based control scheme performs quite well in the higher range of peak control force. In general, the performance of the ANN based control schemes is quite comparable with that of the sliding mode control scheme.

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