CHAPTER 1

INTRODUCTION

1.1 General

Problems involving the identification of damaged / unknown structural systems are widely encountered in the engineering field. Exact analytical solutions for these types of system are limited, due to the nature of nonlinearity and limited amount of informative data. Consequently, much effort have been devoted by numerous investigators to develop models based on their own priori knowledge.

Method of system identification can be classified into parametric and non-parametric approaches. In the parametric method, a mathematical form of model, or a model structure, must be first chosen based on mechanism of the physical phenomena. Therefore, the parametric approach requires some knowledge of exist system. Under the situation of complicated physical characteristics and limited amount of informative data, the appropriate mathematical form may not be readily determined. The use of inappropriate mathematical forms can make the predicted behavior deviate from the real one. The results from the analysis with the erroneous model are thus evidently unreliable.

Non-parametric approach is another alternative method in the case of unknown or complex system. There is very significant advantage over physical based-model, parametric approach, because a system may not behave within the class of models initially assumed. Among non-parametric models, the artificial neural networks (ANNs) prove to be a powerful tool in satisfactorily emulating complex mapping functions between relevant inputs and outputs (Hornik 1991). The application of ANNs can be found in function mapping, image processing, pattern recognition, Classification, etc. In addition, ANNs have favorable attributes for their application to realistic problems, adaptability, robustness, and high capability of handling non-linear systems (Chen 1995). It is these attributes and their applicability for function mapping that ANNs is suitable for modeling of dynamical system.

1.2 Problem Statement

In the identification procedure, the selection of the representative model for a dynamical system is based on the criterion of goodness-of-fit between the output from real measurement. The output in the first case is obtained by passing a priori known input into the trial models. In other words, the trial models behave as mapping functions. Thus, it is possible to replace the unknown models by structure-known ANNs. Since a good or representative model is the model that emulates closely to the real dynamical system, a suitable ANNs has to yield the same consequence. As will be shown in the following literature, there are many types of ANNs but the so-called multi-layer feed forward neural network is one of the most widely used ANNs. On one hand, based on those previous works, it is reasonable to employ the multi-layer feed-forward neural network as an emulator of the unknown / nonlinear dynamical system with degradation characteristic. On the other, there is still a remaining question on selecting suitable structure of an ANNs for its efficiency and effectiveness of ANNs, it is, therefore, necessary to investigate this basic issue.

1.3 Objectives of Study

The Objectives of this Study is:

1) To apply the ANNs to model the unknown nonlinear behavior.

2) To develop a numerical methodology for dynamic analysis of discretized systems with the inclusion of ANNs-identified models (hybrid discrete-ANNs model).

1.4 Scope of Study

The scopes of this study are:

1) Dynamical systems are of small dimensionalities.

2) Only Multi Layer Perceptron (MLP) network using backpropagation training algorithm is studies here.

1.5 Literature Review

1.5.1 Research on artificial neural networks (ANNs)

Since 1990s, Artificial Neural Networks (ANNs) has received interested to use in many fields of engineering due to numerous ability of ANN. e.g. classification, clustering, pattern association, system identification, and control application. The history of ANNs has been documented by various authors (Anderson and Rosenfeld 1989), and will not be repeated here. However, Short Introduction on ANNs will be given.

ANNs has been developed as generalization of mathematical models of human cognition or neural biology. The origin of the neural network field was done by (McCulloch and Pitts 1943), who showed that networks of artificial neurons could compute any arithmetic or logical function. From the origin, the work in ANNs has been carried and developed by many researchers.

Some important works, however, did continue during the 1970s. In 1972, Kohonen (1972), Anderson (1972) independently and separately developed new neural networks that could act as memories.

The second key development of the 1980s was the backpropagation algorithm for training multilayer perceptron netwoks which was discovered independently by several different researchers. The most influential publication of the backpropagation algorithm was by Rumelhart and McClelland (1986).

Many of the advanced in neural networks have had to do with new concepts, such as innovative architectures and training rules. Equally important have been the availability of powerful new computers on which these new concepts can be test.

1.5.2 Research on identification and control using ANNs

Recently, The application of Artificial Neural Networks (ANNs) in the field of Identification and Control of both static and dynamical system has been grown considerably. Some important basic concepts about application of ANNs have been done by many researches. In non-parametric identification methods, ANNs prove to be a powerful tool in satisfactory emulating complex mapping functions between relevant inputs and outputs (Hornik et al. 1989, Hornik, 1991). A number of neural network techniques, such as the Hopfield Network, the Kohonen network, the Cerebellar model articulation controller (CMAC), and the Backpropagation network have been used in system identification (Albus 1975, Bhat and McAvoy 1989, Billings and Chen 1992, Hopfield 1979, Werbos 1988,1990).

In 1990, Narendra and Parthasarathy demonstrated that neural network can be used effectively for the identification and control of nonlinear dynamical systems.

The neural networks have been applied to many fields of works, also in civil engineering work. The identification and modeling of linear and nonlinear dynamic systems through the use of measured experimental data is problem of considerable importance in engineering. Among the identification methods, the artificial neural network is a newly developed technique. For examples, the work by Chen et al. (1995) referred in this project. Their neural network is trained, tested, and verified by using the responses obtained from structural dynamic model during earthquakes. The results also indicate the great potential of using neural networks in the identification structural dynamic model.

In 1993, Masri et al. (1993) use ANNs to identify the internal forces of structures unknown nonlinear dynamic systems and applied to the damped Duffing oscillator under deterministic excitation. The generalization ability of ANNs is invoked to predict the response of the same nonlinear oscillator under stochastic excitations of differing magnitude. It's shown that ANNs provide high-fidelity mathematical models of structure-unknown nonlinear system encountered in the applied mechanics field.

Kirkegaard (1995) proposed the use of ANNs as modeling of non-linear structures. It's found that the two Neural Network methods can act as actual systems identification, prediction, and simulator.

Yun and Bahng (2000) used Neural Network to estimate stiffness parameters of a complex sub-structural system, which shows the applicability of the present method for the identification of large structural system.

Following by Kosmatopoulos et al. (2001) proposed new approach to solve the problem of estimating / identifying the restoring forces without assuming any model of the restoring forces dynamics. The new approach uses the *Volterra/Wiener neural networks* (VWNN) which are capable of learning input/output nonlinear dynamics, in combination with adaptive filtering and estimation techniques.

Recently, Chang and Zhou (2002) used Recurrent neural network models to emulate the inverse dynamics of the magnetorheological (MR) damper. Because the dynamic behavior of MR damper is well portrayed using a Bouc-Wen hysteretic model.

The Pioneer studies of the application of ANNs for structural control by Ghaboussi and Joghataie (1995) that presented a structural control method using ANNs, in which a neurocontroller was developed and applied for linear structural control when the response of the structure remained within the linearly elastic range. Results of this initial study indicate that the ANNs based control algorithm have the promise of evolving into powerful adaptive controllers after further research.

In 1998, Bani-Hani and Ghaboussi (1998) showed that the vibration of nonlinear structure showing hysteric behavior was also controlled via nonlinearly trained neural networks.