Damage Identification of Multimember Structure using Improved Neural Networks

M. Rajendra, Mechanical Engineering Department, IIT Madras, Chennai, Tamil Nadu, India

K. Shankar, Mechanical Engineering Department, IIT Madras, Chennai, Tamil Nadu, India

ABSTRACT

A novel two stage Improved Radial Basis Function (IRBF) neural network for the damage identification of a multimember structure in the frequency domain is presented. The improvement of the proposed IRBF network is carried out in two stages. Conventional RBF network is used in the first stage for preliminary damage prediction and in the second stage reduced search space moving technique is used to minimize the prediction error. The network is trained with fractional frequency change ratios (FFCs) and damage signature indices (DSIs) as effective input patterns and the corresponding damage severity values as output patterns. The patterns are searched at different damage levels by Latin hypercube sampling (LHS) technique. The performance of the novel IRBF method is compared with the conventional RBF and Genetic algorithm (GA) methods and it is found to be a good multiple member damage identification strategy in terms of accuracy and precision with less computational effort.

Keywords: Damage Identification, Damage Signature Indices (DSIs), Fractional Frequency Change (FFCs), Frequency Domain, Improved Radial Basis Function (IRBF) Neural Networks, Latin Hypercube Sampling (LHS) Technique

INTRODUCTION

System identification is a process of determining parameters of a dynamic system based on numerical analysis of measurement of input (excitation) and the corresponding output (response). In addition to updating numerical models for better response prediction, it is in principle possible to monitor the state of the structure and even detect damages based on changes in identified parameters (Koh *et al.*,

2003). Damage detection is a challenging problem that is under vigorous investigation by numerous research groups using a variety of analytical and experimental techniques. Most of them are computationally expensive and tend to be numerically unstable for the case with a multi-degrees-of-freedom (MDOF) system. However, intelligent systems can address these issues. One such intelligent system is the Artificial Neural Network (ANN). Neural networks (NNs) are computing systems with the ability

to learn from trainings, and are developed to imitate the way humans manage and process information. Based on trained neural networks, the behavior of complex systems may be modeled and predicted, even without a priori information about the structural or mathematical model (Wu *et al.,* 1992; Elkordy *et al.,* 1993; Hagan *et al.,* 1996).

The multilayer feed forward neural networks with back propagation training algorithm commonly called the back propagation neural (BPN) networks are one of the most popularly used neural network architectures for damage prediction. The increase in the number of hidden layers and the network inputs from the experimental investigations showed the good accuracy of the network for the prediction of single and multiple member damage cases (Wu *et al.,* 1992; Elkordy *et al.,* 1993; Pandey & Barai, 1995; Adeli & Park, 1995). Another class of neural networks which have been used for structural damage assessment are counter propagation networks (CPNs). The CPN is marked by its quick training speed and ability to give good results for structural damage of beams and frames using various inputs like static displacements, natural frequencies, mode shapes and other parameters based on mode shapes (Szewczyk & Hajela, 1994; Zhao *et al.*, 1998; Alok Madan, 2005). Both BPNs and CPNs have their own limitations and abilities for identification of structural damage. Most of these strategies involved identification of damage in a single stage scheme that required the network to be trained with large number of data for multiple member damage identification thereby affect the training efficiency and accuracy of the network. Very few studies have been conducted to improve training efficiency and accuracy of NNs by hybridizing (combining CPNs and BPNs) (Prashanth & Shankar, 2008), by selecting effective inputs (Ni *et al.*, 2002; Prashanth & Shankar, 2008) and by generating efficient patterns (Yun & Bahng, 2000). Genetic

algorithm (GA) is also used in detecting the structural damage by formulating the inverse problem into an optimization problem with error minimization between predicted and actual response of the structure (Mares & Surace, 1996; Friswell *et al.*, 1998; Chou & Ghaboussi, 2001; Hao & Xia, 2002; Koh *et al.*, 2003). In recent years a special class of artificial neural networks, the radial basis function (RBF) networks have received considerable attention because of their generalization ability. However, their use in applications for detecting structural damage has been limited. Some of the studies reported using RBFs on damage detection are structural identification of a helicopter rotor (Reddy & Ganguli, 2003), comparison of RBFs with multilayer perceptron (MLP) NNs for identifying creep deformation (EI-Shafie *et al.*, 2010) and application of hybrid method of RBFs combined with genetic algorithm (GA) and fuzzy logic to locate the delamination in composite beams (Zheng *et al.*, 2011). The minimum prediction error for damage detection by NNs reported is 3% in the reviewed literature, but because of the hybridization of NNs with other methods like GA and fuzzy systems more computation effort is consumed for good accuracy (Ni *et al.*, 2002). Thus there is a need of further investigation on the improvement and simplification of RBF neural networks on the multi-member damage identification to get good accuracy with less effort.

A novel two-stage Improved Radial Basis Function (IRBF) neural network is proposed in the present investigation to predict the multiple member damage of a nine-member frame structure (Zhao & Wang, 2007) in the frequency domain. The fractional frequency change ratios (FFCs) and damage signature indices (DSIs) are simulated numerically as effective input patterns from finite element analysis (FEA) with different damage severity levels as output patterns using Latin Hypercube Sampling (LHS) technique to train the IRBF

Related Content

Implementation of Thermal and Energy Improvements in Domestic Refrigeration: Case Studies
Juan Manuel Belman and Armando Gallegos (2015). *Handbook of Research on Advances and Applications in Refrigeration Systems and Technologies (pp. 641-659).*
www.igi-global.com/chapter/implementation-of-thermal-and-energy-improvements-in-domestic-refrigeration/136761?camid=4v1a

Aerodynamic Isolation of Open Refrigerated Vertical Display Cases using Air Curtains
Mazyar Amin, Dana Dabiri and Homayun K. Navaz (2015). *Handbook of Research on Advances and Applications in Refrigeration Systems and Technologies (pp. 543-589).*
www.igi-global.com/chapter/aerodynamic-isolation-of-open-refrigerated-vertical-display-cases-using-air-curtains/136759?camid=4v1a

Characterization of Mechanical Properties and the Abrasive Wear of Thermal Spray Coatings
Salim Barbhuiya and Ikbal Choudhury (2015). *Thermal Sprayed Coatings and their Tribological Performances (pp. 328-359).*
www.igi-global.com/chapter/characterization-of-mechanical-properties-and-the-abrasive-wear-of-thermal-spray-coatings/128079?camid=4v1a

A Novel System for Analysis of Surface Profiles from 3-D Components Using the Dickinson Rotating Ring Contact Profiler