Structural Damage Detection Using Randomized Trained Neural Networks

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Abstract. A computational method on damage detection problems in structures was developed using neural networks. The problem considered in this work consists of estimating the existence, location and extent of stiffness reduction in structure which is indicated by the changes of the structural static parameters such as deflection and strain. The neural network was trained to recognize the behaviour of static parameter of the undamaged structure as well as of the structure with various possible damage extent and location which were modeled as random states. The proposed techniques were applied to detect damage in a cantilever beam. The structure was analyzed using finite-element-method (FEM) and the damage identification was conducted by a back-propagation neural network using the change of the structural strain and displacement. The results showed that using proposed method the strain is more efficient for identification of damage than the displacement.

Keywords: back-propagation, damage detection, finite element method, neural network.

1 Introduction

Structural systems or machinery components tend to accumulate damage during their operation life. Therefore, an effective and reliable damage assessment methodology of the structural system is a very valuable tool. A determination of safety level of a structural system during its operational life is essential not only for safe operation but also maintenance cost reduction and failure prevention.

Occurrence of damage in a structural element reduces stiffness of the structure and generates a small perturbation in its static or dynamic responses. A perturbation on static responses can be identified by the behaviour of displacements or strains. Meanwhile, the behaviour of natural frequencies and mode shapes can be used to identify the perturbation on dynamic responses of the structure. A combination of measured response and finite-element-methods (FEM) then can be developed in order to identify these response perturbations which can be used to determine the size and location of the damage of the structure.

Response of damaged structure will follow the pattern of the size and location of the damage on its structure. Bishop has shown that this pattern can be generalized

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using Artificial Neural Network/NN [1]. Therefore, the damage detection on a structural system or a machinery component can be conducted using NN which was trained to identify the pattern of response characteristic of the structure.

Maity and Saha have developed a damage assessment in structure from changes in static parameter using NN approach [7]. Unfortunately, this assessment was only focused on single element damage and multiple element damage which consists only of two damaged elements. In practical point of view this methodology is inadequate. Therefore, a more general damage assessment methodology has to be developed.

The objective of this research is to develop a structural damaged detection methodology from changes in static parameter, i.e.: displacement and strain of a simple cantilever beam using neural network combined with FEM. In the present work a random state is proposed to simulate stiffness reduction factor and damage location of the structure such that values of the stiffness reduction factor and the damage location are random. Using this random state the proposed method of structural damage assessment may be able to be applied in more general condition.

2 Problem Formulation

First step in damage detection of a structure using neural network is modelling of the structure to obtain data set which is used as input in the network training. This structural modelling has to be able to represent all possibilities of damage condition on the structure. The damage of the structure is modelled by stiffness reduction and consists of size and location on the structure. In order to obtain the data set as input for network training, values of the stiffness reduction are assumed to be random number between 0 and 1. The number and the location of damaged structural element are also assumed to be random and it may be multiple element damage. In this present work, structural response of strain and displacement due to specific loading obtained by FEM were chosen as data set used for training the network.

When the structural responses as input data set was obtained then training of the network is conducted until outputs of the networks satisfy the desired target or until the network reach desired performance which is indicated by error level (difference between output and desired target of network). Usually this error is formulated as mean square error (MSE). The above principle of neural network is illustrated by a simple schematic in Fig. 1 below.

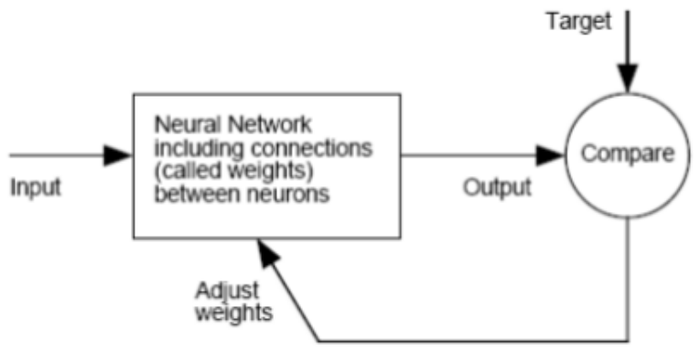

Fig. 1. A schematic of an artificial neural network [2]

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