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Structural damage alarming using auto-associative neural network technique: Exploration of environment-tolerant capacity and setup of alarming threshold

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ABSTRACT

With the intention of avoiding false-positive and false-negative alarms in structural damage alarming using the auto-associative neural network (AANN) technique, two issues pertaining to this technique are addressed in this study. The first issue explored is the environment-tolerant capacity of the AANN. Efforts have been made to seek a generalization technique to enhance the environment-tolerant capacity. First, a baseline AANN model is formulated using the conventional training algorithm. Generalization techniques including AIC and FPE, early stopping, and Bayesian regularization are then investigated, resulting in three new AANN models. Their environment-tolerant capacity is evaluated as per their capability to avoid false-positive and false-negative alarms. The other issue addressed is the setup of alarming threshold, with intent to reduce the uncertainty in AANN-based structural damage alarming. A procedure based on the probability analysis of the novelty index is proposed for this purpose. First, the novelty index characterizing the intact structure is analyzed by the Kolmogorov–Smirnov goodness-of-fit test to obtain its best-fit continuous probability distribution. A confidence interval is then defined in consideration of the compromise between type I and type II errors. The alarming threshold of the novelty index is consequently set at the upper limit of the confidence interval. The above explorations are examined by using the long-term monitoring data on modal properties of the cable-stayed Ting Kau Bridge. The capability to eliminate false-positive alarm is verified by using unseen testing data which were not used in formulating the AANN models, while the capability to alleviate false-negative alarm is examined by using simulated data from the 'damaged' bridge with the help of a precise finite element model. The study indicates that the early stopping technique performs best in improving the environment-tolerant capacity of the AANN, and the alarming threshold set by the proposed procedure helps to reduce the uncertainty in AANN-based structural damage alarming.

1. Introduction

Alarming the presence of structural damage at the earliest possible stage is the most primary objective of structural damage detection. To this end, varieties of damage detection methods have been developed in the past decades [1,2].

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