Mechanical Systems and Signal Processing 25 (2011) 2976–2989

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/ymssp

Distinguishing between sensor fault, structural damage, and environmental or operational effects in structural health monitoring

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ARTICLE INFO

Article history:
Received 12 May 2010
Received in revised form
24 March 2011
Accepted 28 May 2011
Available online 21 June 2011

Keywords:
Environmental or operational effects
Sensor fault
Damage detection
Gaussian process
Likelihood ratio test
Structural health monitoring

ABSTRACT

Discrimination between three different sources of variability in a vibration-based structural health monitoring system is investigated: environmental or operational effects, sensor faults, and structural damage. Separating the environmental or operational effects from the other two is based on the assumption that measurements under different environmental or operational conditions are included in the training data. Distinguishing between sensor fault and structural damage utilizes the fact that the sensor faults are local, while structural damage is global. By localizing the change to a sensor which is then removed from the network, the two different influences can be separated. The sensor network is modelled as a Gaussian process and the generalized likelihood ratio test (GLRT) is then used to detect and localize a change in the system. A numerical and an experimental study are performed to validate the proposed method.

1. Introduction

New sensor technology makes it possible to monitor structures with a dense array of sensors. The objective of structural health monitoring (SHM) is to detect and identify damage in the structure utilizing the sensor data. Damage can be detected from a change in features extracted from the measured time series. Many features are global giving little information about the damage location, e.g. changes in the natural frequencies of the structure. The advantage of global features is that damage can be detected remote from a sensor. Other features such as mode shape vectors can also give information about the damage location. The problem is that the sensitivity of mode shapes to damage may be insufficient for SHM.

Damage identification can be done using analytical or hardware redundancy [1]. Analytical redundancy can be obtained by physics-based methods. The advantage is that the number of sensors can be minimized. The disadvantage is that an accurate mathematical model of the structure is needed, which is often difficult to achieve. On the other hand, hardware redundancy is solely based on measurement data without a mathematical model of the structure. For hardware redundancy in vibration measurements, the number of sensors must be greater than the number of excited natural modes of the structure. Due to the evolving sensor technology, hardware redundancy can be considered as an attractive alternative to analytical redundancy in structural health monitoring. It is utilized in this study to distinguish between different sources of changes in the system.

In a dense sensor network with low-cost sensor nodes, it is quite probable that some nodes fail resulting in unreliable data for inference and decision. More specifically, a sensor fault also causes a change in the system, which can be incorrectly interpreted as structural damage.

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0888-3270/$ - see front matter
doi:10.1016/j.ymssp.2011.05.017