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Experimental validation of a new statistical process control feature for damage detection

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ABSTRACT

A novel statistical process control-based method for damage detection in cantilever-like structures is presented in this paper . It is based on time-domain data obtained from the free vibrations of the first mode of the structure, measured at only one point. The concept of signal length is introduced here as a feature for statistical process control. A statistical model consistent with extreme value theory is fitted to the operational data and used to establish control limits. A strategy based on controlling runs is adopted to increase the sensitivity of the detection. The procedure was applied to a four-storey steel frame, which was subjected in turn to mass and stiffness modifications by adding masses or loosening bolts in a beam–column connection. The results were successful; the proposed procedure was able to detect an increase of 0.04% of the total mass of the frame and loosening of one out of 152 bolts.

1. Introduction

The early detection of damage is a necessity for many structures and mechanical systems for reasons of safety and economy. To this end, numerous vibration-based methodologies have been developed. These methods allow the global damage state of a structure to be continuously or periodically monitored on the basis of measured vibration data. The methods have evolved during the last decades, and they constitute a mature body of research nowadays.

Currently, most methods of structural health monitoring (SHM) are focussed on the problem of determining whether any damage is present throughout the whole structure; these methodologies are often referred to as *global health monitoring*. The majority of these require a comparison between two different stages of the system and the problem is then considered to be a two-class pattern recognition issue. (It is argued in [1] that any SHM problem requires a comparison between two states.) A major advantage of reducing the damage identification issue to detection only is that the problem can be addressed by using *unsupervised learning* (in the terminology of pattern recognition). This means that only data from the normal or undamaged condition of the structure is used to build or *train* the classifier of interest. This problem is often referred to as *novelty detection* in the machine learning community. There are many methods of novelty detection which have been applied in various contexts; an excellent survey of the various methods, encompassing both statistical and neural approaches can be found in [2,3].

One advantage of unsupervised learning which proves critical in the SHM context, is that one does not need measurements from the system in any damage conditions. For very expensive structures, it is inconceivable that one could introduce damage in order to accumulate training data. If the structures are complex—and in very many cases this is the

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