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Structural health assessment at a local level using minimum information

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ABSTRACT

A novel structural health assessment (SHA) technique is presented in this paper. It is a finite element-based time-domain nonlinear system identification technique. It can assess structural health at the element level using only a limited number of noise-contaminated responses and without using information on input excitation. It assesses the location and severity of defect(s) by tracking the changes in the stiffness properties of individual elements from their expected values. The procedure integrates an iterative least squares technique and the unscented Kalman filter (UKF) concept. The integrated procedure significantly improves the basic UKF concept. To demonstrate the effectiveness of the procedure, the health of a relatively large structural system under single and multiple excitations is assessed. Small and relatively large defects are introduced at different locations in the structure and the capability of the method to detect the health of the structure is examined. The optimum number and location of measured responses are investigated. It is demonstrated that the method is capable of identifying defect-free and defective states of the structures using minimum information. Furthermore, it can locate defect spot within a defective element. It is also demonstrated that the proposed method, denoted as UKF-UI-WGI, is superior to the extended Kalman filter-based procedures for SHA developed by the team earlier.

1. Introduction

Civil infrastructure systems, such as buildings and bridges, begin to deteriorate once they are built and used. They also suffer different levels of damage when exposed to severe events, like strong earthquakes, high winds, etc. Even well designed structures can suffer damage due to faulty construction or when exposed to unexpected loadings. Some of the civil infrastructures built conforming to old design standards or guidelines are currently in operation and over their design life. They are especially susceptible to damage because of natural degradation with age and may not satisfy the current design and construction standards. If damages go undetected for an extensive period of time, even a minor defect can become severe causing catastrophic failure leading to loss of life or the repair cost can be prohibitive and replacement will be the only option. However, resources available to the world communities are very limited at present and replacement is not a desirable option. The most attractive option is to extend the life of current infrastructures by identifying the location, type, and severity of defects and then repairing them using the appropriate methods.

Visual inspection is routinely used to assess structural health at present. However, visual inspections may not be conclusive. They are expected to be dependent on the expertise of the inspector. In some cases, defects may be hidden behind obstructions like fire proofing materials, false ceiling, etc. or inaccessible. If the location and type of defects are known, we have technological sophistication to study them further by conducting localized experimental investigations using radiographs, magnetic, ultrasonic, etc. methods. To implement these types of inspection requires that the approximate location and type of damages are known a *priori*. Obviously, they are expected to be unknown for large infrastructures in most cases.

The necessity of cost-effective damage detection techniques suitable for large complex infrastructures has led to the development of several multi-disciplinary methods for structural health assessment (SHA). For the health assessment of civil infrastructures, both static and dynamic response information can be used. When dynamic response information was used, both modal and time domain approaches were pursued. Because of its numerous superiorities, time domain SHA has received significant attention by the researchers recently. Many techniques also have been developed to identify structural systems specifically for SHA [1–3].

To identify defect locations accurately, it would be efficient to represent the structure by finite elements. By tracking the stiffness of the elements, the location and severity of the defects can be assessed. It will also be very desirable if a structure can be

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