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Health Assessment of Nonlinear Structural Systems

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Abstract

A novel structural health assessment procedure for nonlinear structural systems is presented. It is developed by integrating the unscented Kalman filter concept with the weighted global iteration procedure with an objective function. It is denoted as unscented Kalman filter with weighted global iteration (UKF-WGI). It is a finite elements-based time-domain system-identification technique. It can be used to assess structural health at the element level using only a limited number of noise-contaminated responses. The efficiency and accuracy of the procedure are demonstrated by identifying a realistic frame. Defect(s) with different level of severity is simulated in single and multiple member(s) and then the capabilities of the procedure are examined. The examples confirmed that the method is capable of identifying defect-free and defective states of structures. The proposed method is compared with the extended Kalman filter with weighted global iteration (EKF-WGI) procedure. The proposed UKF-WGI is superior to EKF-WGI in all aspects, particularly when the level of nonlinearity is severe. Since the level of nonlinearity is expected to be unknown at the initiation of the inspection, to be on the safe side, the proposed UKF-based procedure should be used to assess structural health in the future.

Keywords: ***Unscented Kalman filter, nonlinear structural system, structural heath assessment, damage detection, parameter identification***

1. Introduction

Structures deteriorate with time during their normal use. They also suffer damages when exposed to natural events like large earthquakes or high winds. Man-made events like impacts or explosions can also cause different levels of damages to them. To maintain the intended use of the structures and economic activities of the region, it is important to detect the location and severity of defects as early as possible to that required remedial actions can be promptly initiated. All defects are not equally important in maintaining the use of the structure. It is also important to decide whether the structure is beyond repair; it needs to be replaced. The topic has recently attracted serious multi-disciplinary research interests. This is generally known as structural health assessment (SHA) in the literature. Due to lack of available resources, developing objective SHA techniques is now one of the very active research areas in the profession. It has many different components including the study of structural behavior, development of sensors, presence of uncertainty in every phase of the investigations, and integrating all available information to objectively assess the current health of a structure. The authors and their team members are active in developing inspection-based SHA techniques. Some of their recent work is presented in this paper.

The most common technique used for SHA is the visual inspection or assessment. By tapping a structure and listening to the generated sound to assess its health was used over centuries. Obviously, its success will depend on the experience of the inspector. A structure consisting of numerous structural elements, SHA can be very challenging using visual inspections. If defects are hidden behind walls, fire proofing material, facades, etc., they cannot be visually inspected. Sometimes, some parts of the structure can be inaccessible. If visual inspection indicates the location and type of defects, and if they are accessible, we have technological sophistication to inspect them more thoroughly using many techniques including radiographs, magnetic, ultrasonic, etc. However, their success will depend on the knowledge of locations and types of defects a *priori*. For real civil engineering structures, this type of information will be unavailable in most cases. These are generally known as non-model approaches. Alternatives to visual or