Computational Intelligence for Structural Identifications

Abdullah Al-Hussein, Achintya Haldar
Department of Civil Engineering and Engineering Mechanics
University of Arizona
Tucson, Arizona
abdullaa@email.arizona.edu; haldar@u.arizona.edu

***Abstract*— Structural health assessment using the structural identification concept using measured dynamic response information in time domain was considered to be not possible in the late seventies. With the help of comprehensive analytical and laboratory investigations, the research team at the University of Arizona conclusively documented that the above statement is not correct. In fact, they showed that the concept has several advantages over other available methods. Considering the implementation potential, the concept appeared to be very desirable. The team proposed several intelligent schemes to address many challenges. They used mathematical concepts used in other disciplines, extensively modified them and proposed few novel concepts. Some of them are briefly presented in this paper and their novelties are described with the help of several informative examples. The concepts presented in the paper cross the disciplinary boundaries and showcase benefits of computational intelligence.**

I. Introduction

Structural health assessment (SHA) using structural identification (SI) technique has recently become an important research item. In 1979, Maybeck [1] concluded that the SI-based concept cannot be used for SHA using measured response information. There are several reasons for his comments including: (i) no mathematical model to represent a system is perfect, (ii) dynamic systems are not only driven by control inputs, but there are always disturbances that cannot be controlled and modeled deterministically, and (iii) responses observed by sensors do not exhibit the actual perfect system responses, since sensors always introduce their own system dynamics and distortion into measured data. The authors and their team members had to overcome several challenges and proposed several computational intelligence schemes and documented that SI is an ideal option to assess structural health at the local element level. Some of these intelligent schemes are presented in this paper.

Structural identification has three essential components: (1) excitation information, (2) the system to be identified, which can be represented by a series of equations or represented in algorithmic form, e.g., in a finite element (FE) formulation in terms of mass, stiffness, and damping characteristics of each element, and (3) response information. Using input excitation and output response information, the dynamic properties of all the elements can be evaluated using the inverse SI algorithm. Using the information on the identified element properties, it will be straightforward to evaluate the amount or rate of degradation of a particular element with respect to the "as built" or expected properties, or the changes from the previous values if periodic inspections are used or deviations from other similar structural elements for the health assessment purpose.

The SI-based concept appears to be simple. However, to increase its implementation potential, several advanced computational techniques need to be used. It is to be noted that the SI concept has evolved over time from non-model based visual inspections to model-based using static and dynamic response measurements. The most desirable outcomes of an inspection are locating defects at the local element level, their number and severity. To obtain such information, it will be advantageous to represent the structure by finite elements. By tracking the changes in the stiffness properties of all the elements as they age or after a natural and man-made event, the health of a structure can be assessed. Most recently, measured time-domain response information instead of modal properties has attracted a considerable amount of attention and it is emphasized in this paper.

II. CHALLENGES IN SI FOR SHA

A. *Measurement of input excitations*

One of the challenges in implementing the SI concept using time-domain response information is measuring the input excitation. Outside the control laboratory environment, the measurements of excitation information could be very expensive and so error-prone that the SI concept may not be applicable as observed by Maybeck [1]; thus SHA without excitation information will be very desirable. The team initially proposed a procedure, known as Iterative Least-Squares with Unknown Input (ILS-UI) [2]. They used viscous-type structural damping. The efficiency of the numerical algorithm was improved later by introducing Rayleigh-type proportional damping, known as Modified ILS-UI or MILS-UI [3]. Katkhuda et al. [4] improved the concept further and called it Generalized ILS-UI or GILS-UI. Later, Das and Haldar [5] extended the procedure for three dimensional (3D) large structural systems and denoted as 3D GILS-UI.

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