STRUCTURAL HEALTH MONITORING THROUGH MODEL UPDATATION TECHNIQUE: A FULL CONCEPT

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ABSTRACT

The process of implementing a damage detection and character strategy for engineering structures is referred to as **Structural Health Monitoring** (SHM). Damage is defined as changes to the material and/or geometric properties of a structural system, including changes to the boundary conditions and system connectivity, which adversely affect the system's performance. The SHM process involves the observation of a system over time using periodically sampled dynamic response measurements from an array of sensors, the extraction of damage-sensitive features from these measurements, and the statistical analysis of these features to determine the current state of system health. For long term SHM, the output of this process is periodically updated information regarding the ability of the structure to perform its intended function in light of the inevitable aging and degradation resulting from operational environments. After extreme events, such as earthquakes or blast loading, SHM is used for rapid condition screening and aims to provide, in near real time, reliable information regarding the integrity of the structure.

Most structural health monitoring and damage detection strategies utilize dynamic response information to identify the existence, location, and magnitude of damage. Traditional model-based techniques seek to identify parametric changes in a linear dynamic model, while non-model-based techniques focus on changes in the temporal and frequency characteristics of the system response.
1. INTRODUCTION TO SHM

Civil structures, particularly those subject to seismic excitation, are prone to damage and deterioration during their service lives. To ensure structural integrity it is desirable to monitor these structures to detect the existence, location, and severity of any damage in real time. Common health monitoring and damage detection practices involve systematic visual inspections by experienced engineers who determine the location and extent of damaged zones.

2. CONCEPT

Commonly known as Structural Health Assessment (SHA) or SHM, this concept is widely applied to various forms of infrastructures. Especially so when damages to structures are concerned, it is important to note that there are stages of increasing difficulty that require the knowledge of previous stages, namely:

- Detecting the existence of the damage on the infrastructure
- Locating the damage
- Identifying the types of damage
- Quantifying the severity of the damage

The process is conducted by first choosing the domain in which data is presented. The domains used include time domain, frequency domain, modal domain, and time-
frequency domain. The second step is to determine which parts of the initial models are thought to have been modeled incorrectly. The third task is to formulate a function which has the parameters that are expected to be design variables, and which represents the distance between the measured data and the finite element model predicted data. The fourth step is to implement the optimization method to identify parameters that minimize this function. In most cases, a gradient-based optimization strategy will be used. For nonlinear analysis, more specific methods like response surface modeling, particle swarm optimization, Monte Carlo optimization, and genetic algorithms can be used.

3. TWO TECHNIQUES IN THE FIELD OF SHM

- Wave propagation based techniques Raghavan and Cesnik
- Vibration based techniques

4. VIBRATION BASED SHM

- Models are proposed for the damage to determine the dynamic characteristics, also known as the direct problem.
- Dynamic characteristics are used to determine damage characteristics, also known as the inverse problem

5. SHM COMPONENTS

- Structure
- Sensors
- Data acquisition systems
- Data transfer and storage mechanism
- Data management
- Data interpretation and diagnosis

Data Interpretation and Diagnosis
Steps for Data Interpretation and Diagnosis

- System Identification
  Generally refers to the type of structural member its areas of damage by using different types of sensors. Damage pattern is identified.

- Structural condition assessment.
  Structural condition of the structure of the bridge, building etc is accessed and problems identified
  - Prediction of remaining service life.
  - Structural model update.

6. MODEL UPDATION

What is Model Updating?
Model updating refers to the methodology that determines the most plausible structural model for an instrumented structural system given its measured response and, possibly, its excitation.
7. AN OVERVIEW
Bayesian updating is particularly important in the dynamic analysis of a sequence of data. Bayesian inference has found application in a wide range of activities, including science, engineering, philosophy, medicine, and law. A new Bayesian model updating approach is presented for linear structural models. It is based on the Gibbs sampler, a stochastic simulation method that decomposes the uncertain model parameters into three groups, so that the direct sampling from any one group is possible when conditional on the other groups and the incomplete modal data. This means that even if the number of uncertain parameters is large, the effective dimension for the Gibbs sampler is always three and so high-dimensional parameter spaces that are fatal to most sampling techniques are handled by the method, making it more practical for health monitoring of real structures. The approach also inherits the advantages of Bayesian techniques: it not only updates the optimal estimate of the structural parameters but also updates the associated uncertainties.

Types of stimulations causing damage to structures
- Vibration
- Earthquake
- Explosion

8. MODEL UPDATING TECHNIQUES
- Among the structural model updating techniques, Bayesian model updating techniques is preferred.
- Due to their ability to consider more than one structural model, Bayesian model updating techniques are robust and are suitable to characterize modelling uncertainties of structural systems.
- Also, linear structural models are often used for model updating
- The GS approach (Gibbs sampler) is robust to the dimension of uncertain model parameters, so it may be applied to real structures.

9. EVALUATION OF DAMAGE PROBABILITY
For the purpose of structural health monitoring, it is essential to locate possible damage and provide an index indicating the severity of the damage. This is achieved by estimating the probability that any stiffness parameter has decreased more than a fraction $d$.

The procedure can be summarized as the following sequence of steps:
- A numerical model of the system is built from an initial guess of the physical properties of the system.
- The solution of the initial model estimates the dynamic response $e_N(x)$ at the sensors location $x$.
- The numerical and measured responses are compared and the error vector $e = e_E - e_N$ is calculated.
- Corrections for the mass and/or stiffness matrices are calculated based on $e$ through a formulation of the problem in the modal domain.
- A modified set of dynamic properties is found from the solution to the new eigen value problem with the updated mass and stiffness matrices.
10. APPLICATION OF MODEL UPDATION TECHNIQUE

Model updating technique is nowadays used in various fields in structural development of the old structure, either it be in civil engineering field or aerospace carrier improvement.

APPLICATION TO THE MULTI-SPAN BRIDGE IN KAVALA, GREECE
11. OTHER LARGE EXAMPLES
The following projects are currently known as some of the biggest on-going bridge monitoring

- The Rio–Antirrio bridge, Greece: has more than 100 sensors monitoring the structure and the traffic in real time.
- Millau Viaduc, France: has one of the largest systems with fiber optics in the world which is considered state of the art.
- The Huey P Long bridge, USA: Have over 800 static and dynamic strain gauges designed to measure axial and bending load effects.
- The Fatih Sultan Mehmet Bridge, Turkey: also known as the Second Bosphorus Bridge. It has been monitored using an innovative wireless sensor network with normal traffic condition.
- Masjid al-Haram, Current expansion project, Mecca, Saudi Arabia: has more than 600 sensors (Concrete pressure cell, Embedment type strain gauge, Sister bar strain gauge, etc.) installed at foundation and concrete columns. This project is under construction.
- The Sydney Harbour Bridge in Australia is currently implementing a monitoring system involving over 2,400 sensors. Asset managers and bridge inspectors have mobile and web browser decision support tools based on analysis of sensor data.

12. CONCLUSION
Model updating can be used in many places like framed structures, airplanes which needs often updating and also in machines. Hence this model updating topic is increasingly important to industry and there is a genuine interest to improve. Structural health monitoring and model updation is interlinked because a proper study on the materials would help us to improve its health and also its efficiency in damage condition.
REFERENCES


