Note Title 4/2/2018

Module 1

Lecture 6 : Components of SHM process

(4) stages in SHM process

(1) operational evaluation

(2) Data acquisition

(3) Extraction of information & condensation of extracted information (Data processing)

(4) Development of statistical model for feature discrimination

(1) Operational evaluation

consists of various factors

i) Economic consideration
ii) Life safety issues
iii) definition of damage
iv) Environmental constraints
v) operational constraint
vi) Data collection & management

(2) Data acquisition depends on the following

1) Excitation methods
   - forced excitation
   - Ambient excitation
   - local excitation

(2) Data transmission
   - wired
   - wireless

(3) sensing the structural response
   - strain
   - displacement
   - acceleration
   - temperature variation
   - wind force, wave force

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- MEMS technology for sensing
  - Fiber-optic sensors (FOS)
  - sensor layout, location of sensors
    - scalability
    - power management

(3) Feature extraction & condensation of information (data management & processing)

- various parameters & methods which are used to extract the vital information required to assess the present health of the structure

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- Resonant frequency band
- Frequency - response function
- Mode shape
- Mode shape curvature
- Modal strain energy
- Dynamic flexibility
- Damping (due to defect)
- Anti - resonance characteristics
- Ritz vector
- Canonical Variate Analysis
- Nonlinear features
- Time - frequency analysis

- empirical mode decomposition
- Hilbert Transform
- wave propagation
- Auto-correlation function

IX Development of statistical model

learning under supervision

unmonitored learning

a) Learning under supervision

- Response surface analysis
- Fisher's discriminant
- Neural Network
- Genetic Algorithm

b) Learning under unmanned condition

- Control chart analysis
- outlier detection
- Neutral Network
- Hypothesis testing

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SHM - State of Art application

Montalvao J, N.M.M Maia et al. 2006.

Review of vibration-based SHM with special emphasis on composites, Shock & Vibration Digest 38 (4) : 295 - 324.

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Many methods - available for damage detection

SHM process - damage detection ?

identification & location of damage

but No single method of SHM can address these problems, can be commonly applied to all types of structures

- Different technique of SHM are practices

- damage - related dependency

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(2) <u>Sensitivity</u>

$\left\{ \begin{array}{l} \text{highly sensitive technique} \\ \quad \text{may show false - positions? damage locations} \\ \qquad\qquad\qquad\qquad\qquad - \text{false - positive} \\ \text{low sensitive techniques} \\ \qquad\qquad \text{may show false - negative positions} \end{array} \right.$

sensitivity of the sensors — problem specific

— life-time prediction of service life, based on damage modeling is very difficult

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- most of techniques are based on reduction in rigidity of the member

but, reduction in rigidity must be related to strength

otherwise, they are not useful for reliability estimates — expected outcome of SHM evaluation

Common Axioms used in SHM process

Ref: Worden K, C.R. Farrar et al. 2007. Fundamental axioms of SHM. Proc. of Royal Soc. of London, Series A, 463 (2082): 1639–1664.

Axiom I All materials have a few inherent flaws or defects

Axiom II Assessment of damage requires comparison of 2 system
— always relative (wrt another system)

Axiom III Unsupervised learning mode can be helpful in identification & location of damage

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Axiom IV

- **sensors** cannot measure damage
- data collected/acquired is to be process to extract featured values
  - which then can be used to detect/quantify damage
- signal processing of the collected data
- statistical classification of the data to convert the sensor data into damage information

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Axiom V

The more sensitive a measurement is to damage, the more sensitive it is to change in environmental & operational conditions

- There is a high possibility of noise mixture with the damage data
- Intelligently extract the featured information from the recorded/acquired data

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<u>Axiom VI</u> -

SHM sensing system strongly depends on

- length (period)
- time scale associated with the damage initiation & evolution
    - if damage is long-term phenomenon, then the damage propagation in terms of its time scale can be <u>lost</u> if not handled with appropriate sensing system

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Axiom VII

There is a strong correlation b/w sensitivity to the damage

- Algorithm used to extract featured information based on which damage will be quantified
  - should be carefully chosen
  - it should be free from noise rejection capability

Axiom VIII

size of the damage, that can be detected from a
static system
- changes into the dynamics of
structural system

It is inversely proportional to the frequency
range of the exciting forces

Example applications of SHM system

(1) Real-time monitoring of buildings under seismic excitation

Celebi, M, A. Sanli et al. 2004. Real time seismic monitoring needs of a building owner and solution: A cooperative effort. Earthquake Spectra. 20(2): 333-346.

Case study

applied set of buildings post-earthquake @ San Francisco

- San Andreas Eq
- M 6.0 Eq
- peak ground acc > 0.25g

Objective

owner wanted to asses safety of occupancy after Earthquake

- A real-time monitoring scheme was deployed

- **Requirements**

  - System must facilitate a rapid assessment of building Integrity following an Earthquake
  - System must provide data like drift ratio, relates to earthquake damage
  - System must deliver data within few minutes after EQ occurred

SHM system recorded the following

- waits for an event
- on occurrence of an event, it produces a low amplitude data is real-time analysis & assessment
- data provided is useful for post-seismic assessment
- Based on the type of the structure and the damage assessments conditions of occupancy (post-EQ) was to be declared (FEMA)

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Summary

- SHM process. – its components
  - influence of each component on the SHM process
- application of a typical monitoring system
  - health condition of public building after EQ.
- Different actions - in SHM scheme
  - planning, designing SHM layout
    - problem - specific
    - data dependent
    - statistical tools