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Module 2

Lecture 11:

(i) Long-term STM

(ii) Statistical pattern Recognition (SPR)

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SPR

Ahmed S. Noman, Farah Deeba, Ashutosh Bagchi. 2009.
Structural Health Monitoring using vibration-based methods and statistical pattern Recognition Technique,
Proc. Int'l workshop on Smart Materials & Structures,
Montreal, Canada.

Vibration-based damage identification is useful in interpreting local damage

But, due to complexities of the real structure under working conditions,
it is very difficult to input the accurate mode shapes/frequencies to VB methods for damage detection

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This may result a large human error in damage identification

- Remedy

If the analysis is supported by semi analytical methods such as
- Statistical pattern Recognition,

then a better accuracy can be seen.

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What is pattern recognition Technique?

- Sensors, which are used to measure strain and vibration of a structural member produce SIGNALS
- These signals are very sensitive to any change in strain/vibration measured
- They respond sensitively to the Environmental changes and operational conditions

Group these changes, associated with the Environmental conditions into a seperate group of data

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Data base { Changes in measurements (strain, frequency) are grouped (identified) as a pair to those environmental changes and operating conditions

→ a group

→ various groups → each group will have a unique pair combinations which is related to change in strain & the corresponding operating conditions

— pattern

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A pattern - arises from signature of the measured signal is identified and this is now compared with the new pattern, which is being recorded

- once the recorded signal, change is liner pattern matches with the existing patterns of data bank,

then these changes are then mapped to the corresponding damage location

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Pattern recognition is a machine-learning process

The ability of the computer to identify and classify whether the observed data matches (belongs) to a specific pattern (that is already existing) in the data base

- This can now expedite the decision-making process
- This feature is very useful in case of automated STM processes.

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Recognition patterns are of (2) types

(1) Supervised learning

- where input pattern of vibration are compared with pre-defined groups in the data base

(2) Unsupervised learning

- pattern is compared with undefined group
- it may become a new group in the data base

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SPR method is a good simplification of SHM

SHM deals with experimental data — lot of uncertainties

- In statistical model, algorithms are used to analyze the distribution of extracted features (strain, frequencies etc) to determine damage location

- These algorithms depend on availability of data of damaged states

If data are not available for damaged states to compare then one can use Outlier Analysis (Fugate et al. 2000)

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one common application of Outlier Analysis for SHM is

X- bar control chart

1) Procedure for damage identification by Statistical Model development

   i) Measure a typical type of data
      - steady state strain
      - live load strain
      - acceleration under live load
      - temperature effects on strain

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(i) When the structure undergoes damage,
mean (or variance) of the extracted features
change significantly (accordingly)

(ii) Auto-regression analysis will be carried out on the measured data
preferably, first few AR coeffs (say, upto 3) are
considered to obtain damage indicators

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Procedure for Damage Identification by pattern Recognition

To apply this method, there is a pre-requisite

- several sample data on the damaged model, like strain, acc should be measured & pattern (group) should be formed

- first set of data on the damaged section - reference data
  rest of them - test data

- when new data is collected, it is compared to match the pattern with the reference data

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Statistical pattern Recognition is useful to expedite the decision-making process in SHM.

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Long-Term SHM (static process)

- long-term refers to maintaining a structure over a large period of time (10 – 15 yrs)

- Fibre-optic sensors
  GPS
  Corrosion sensors

  | most commonly used sensors for long-term maintaining

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Long-term SHM – is a (7) stage process

1st stage Identify the structures that need long-term maintain

- New structures, including those have innovative aspects in design, construction, material etc
- New structures associated with unusual level of risk
  - Geotechnical conditions of the soil
  - seismic risk conditions (near-fault)
  - aggressive corrosive environment

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- Structures of strategic importance (offices of st, Nuclear reactors etc)
- Existing structures whose disruption will affect the critical network
  - important Railway / highway bridges
  - Reservoir
  - -
- New structures in which their features represent a large unit of sub-set of structures
- Existing structures with known deficiencies
- Existing structure, which are recommended for rebuilding.

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2nd stage — Risk Analysis

- Carry out Risk Analysis on the identified structures
  - to list out possible events & degradations that can affect the structure

Example

corrosion
loss of pre-stress
creep
settlement of foundation
Earthquake shake
Impact load

poor execution of public structure

3rd stage : Response

- For the type of structures identified for each risk identified, one has to identify the corresponding consequence

for example,

If corrosion is identified as a risk to coastal structure (which needs long-term study) then expected consequence could be

- chemical change
- loss/degradation of section → strength, durability

At this stage, based on identified risk, approximate response of the identified structure is to be carried out

For example, if corrosion is the risk associated, then corrosion sensor should be chosen

If foundation settlement is the risk associated then inclinometer should be chosen as sensor type

At this stage, it is very important to choose the sensor requirements to measure the expected consequences

desired output @ this stage is

- List of Quantities that need to be measured (monitored)
- their likely magnitude
- their likely location

stage 4 Design of SHM & sensor layout

If an inexperienced Engineer carries out SHM he will start from this stage

objective @ this stage is

to select appropriate type / sensor,

- specifications of sensor (operational range)
- installation requirements (embedded or surface-mounted)
- technical constraints of the sensor
- Budget constraints

- It is always a good practice to include sensors based on different technology
  - do not choose sensor of same technology
  - better to have a mixture

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- Too many data acquisitions will become costlier, complex

- A simple design/layout is advised

Layout of sensors

- Different sensors can be connected to the same data logger
- Several data loggers can be connected to the same data Management system

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Data Management system

should integrate all data loggers to translate incoming data into a SINGLE FORMAT, which can be forwarded

- Most importantly, all vendors of sensors & data acquisition system provide own software for data management

- It is very important to have a SINGLE, INTEGRATED INTERFACE

A detailed design document should be prepared containing the following:

1) List of sensors/type of sensors
2) Layout Architecture
3) Installation plan & Cable Layout
4) Installation procedure for every type of sensor
5) Budget details etc

Stage 5 Installation & Calibration

- one should follow the manufacturer instructions to install sensors
- once they are installed and interconnected, then they need to be tested & calibrated
  - Site Acceptance Test (SAT)
- one need also fix the threshold values, in case of automated Alarming systems
  - Check this Output for its successful working

At this stage, a complete manual, and calibration report should be generated

Stage #6 Data acquisition & Management

Data should be acquired and stored in the database
- appropriate backup
- access authorization

need to be checked

- major outcome of this stage's
  A complete document of project management of Data acq. & Nav, log of events

Stage # 7 Data Assessment

At this stage, Engineer should be able to identify a foreseen risk & expected outcome of the risk

- A set of procedure to respond to any type of damage is to be created

for example,

- If the outcome is simple degradation, then procedure called as maintenance

- If the outcome of recorded data is capacity reduction, then closure of the services.

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Summary

- SPR method
  - decision making process of study
- long-term study
- stages in long-term study
  - each stage is effect study