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Module 4 : Applications of SHM in Infrastructure Engg

- offshore structures
- coastal structures ||

Lecture 1 : Machine Learning in SHM

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What is machine learning?

- a task of generating knowledge from the past experiences
- data base (sensed data) collected from different sensors in the past (on the same or similar type of structure)
- focus is prediction of new data based on the collected (existing) sensor data

M/c learning is stm - recent application
- past 10 yrs

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machine learning is common

i) robot control
ii) Human-computer interaction
iii) speech recognition

more details

@ Worden & Manson

- identified the usefulness of m/c learning to detect damage

- Neutral network is very successful, and makes Stm more competent & reliable

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- m/c learning have also been attempted to complex problems in Health maintaining
  - for example, changes set in the structure due to operational and varying Environmental conditions

(i) Application of m/c learning - embedded sensors

aim: decentralizing the sensor fault detection and making it completely autonomous

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Computer science & Engg, Data mining

process of detecting patterns and structures within the data

- broader concept of pattern recognition - necessary in STM

  - continuous, automatic systems

- Data mining can enable pattern of future predictions
- useful in decision making processes
- facilitate/expedite feature extraction
  - to lead useful/meaningful conclusions on the patterns

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In data mining, techniques employed to detect patterns within the data set $\Rightarrow$ machine learning

- Physics-based approaches is SHM. causes computational overload to the SHM process.

- researchers recommended data-driven approach
  - machine learning

- SHM is concerned, machine learning is seen as a task of generating knowledge about the structural behavior from previously collected sensor data

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Basic requirement

- Structural responses under operational, environmental, accidental loads are well understood, theoretically
- They are also documented well

- Detection of such responses, on the full-scale structure is non-trivial
  - complex nature of combination of various forces acting on the structure.
  - mostly unknown
  - high level of uncertainity in their prediction

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ii) Output of SHM system

may be challenged to be wrong/faulty

as they can affect

i) sensor calibrations
ii) interpretation of threshold values
iii) wrong pattern recognition

very difficult to check from the observed data

The observed data - should be put to self-diagnosis to reveal useful/meaningful output

⟹ machine learning

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classifications of machine learning : SVM

3 categories

(1) Supervised learning

(2) Unsupervised learning

(3) semi-supervised learning

Supervised learning – leads a meaningful out – "labeled data"

- specific pattern of output (pair of output-input)

- using labeled data, it is easy to classify new set of datas

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Unsupervised learning - deals with pattern recognition within the data set

- 'unlabeled data

- data set with unspecified output and not paired with any specific input

- They comprise to form a general group

In SHM, Unsupervised learning - unlabeled data can be useful to detect the existing damage

- labeled data - can be useful to detect the type of damage & its severity as well

mk learning process, required labelled data
to predict new data

- Hence, supervised learning is very appropriate to handle
  STM of complex systems.

- In supervised learning: i) logic-based algorithms
  (decision Tree
  Rule-based classifier)
  (ii) perception-based algorithm
  (iii) Neural networks (single-layer perceptrons -
  multi layers)
  (iv) Statistical learning (Bayesian networks etc

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(v) instance-based learning (k-nearest neighbor algorithm)

- application to stm

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Complexities of implementing the machine learning approach

Aim: to create a decentralized, autonomous sensor-fault detection

principle: Analytical redundancy

- Instead of physically installing multiple sensors for measuring one single parameter,

  analytical redundancy utilizes the coherence of relationship b/w the sensors installed in the structure

Example

measurement of peak amplitudes of frequency spectrum

a) obtained from Fourier Transformation of acceleration response

b) response peak amplitude, obtained from different sensors of the same structure

Both the above set of data are correlated to arrive @ the analytical redundancy

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- This correlation is used to predict the modal peak amplitude of selected sensor locations

- Deviation b/w the expected amplitude & actual amplitude will now become indicators of sensor faults which can be concluded to be miscalibrations of those sensors locations

(decision? ignore those fault values)

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In this whole process, there is an important advantage

- No prior knowledge about the sensor locations, instrumentation (or) structure details are required.

- This is purely a completely Data-driven approach

Sensor-fault is identified based on the sensor data collected previously.

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Wireless SHM

Comprised of wireless nodes

- triaxial accelerometer
- a base station
- host computer

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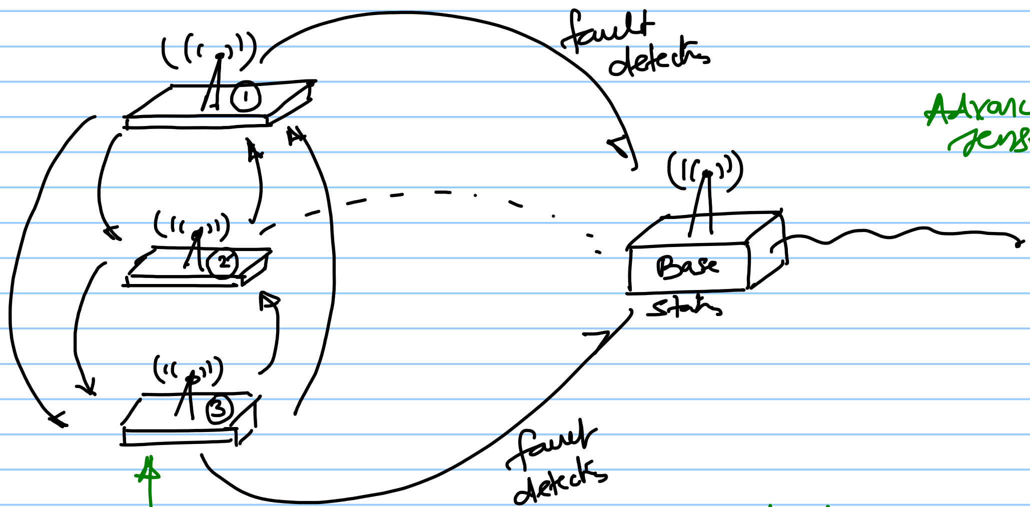
Sensors

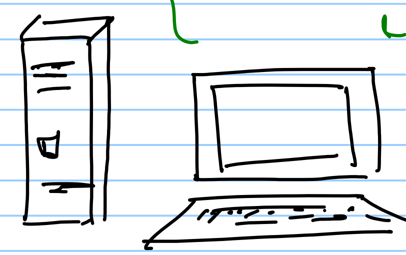
- no max, simply measuring agents

Advanced sensing - { They measure, process, diagnose, decide, detect & control

↑ m/c learning stg



i) acquisition of data (acceleration)
ii) Fourier Transform (FFT)
(iii) detects the highest peak
(iv) communicates the modal peak amplitude
(v) uses modal peaks of correlation sensor data



(i) storage of fault diagnosis
(ii) used in decision making

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Additional readi

(1) K. H. Law, K. Smarsly, Y. Wang. 2014

. Sensor data management Technologies for Infrastructure Asset Mgmt,

chapter in book titled

'Sensor Technologies for civil infrastruct'

Edited by M.L Wang, J.P. Lynch & H. Sohn

Woodhead publishi, UK

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Summary

- importance of m/c learning
- supervised learning (labelled data) is enhancing the system output
- sensors are advanced to perform multiple tasking