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Module 3

Lecture 10 :

Artificial Intelligence in Structural Health monitoring

Smart structures
- advanced level of sensors
- offshore structures

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SHM is a large & complex field

- many aspects, scientific
  practical
  Environmental

SHM system - heterogeneity of various engg technologies

Major aim/objective of SHM

- To accurately identify the current state of health and behavior of the structure

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This can be achieved by

- automatically analyzing the measured data (monitored data) which are received from various monitoring devices

- There will be anomalies
  - Should be detected and eliminated to obtain the state of health of the structure in real-time

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- It is also necessary to evaluate the structural deteriorations and damages precisely.

- Main advantage is that
  - maintenance cost of the structure can be greatly reduced
  - preventive maintenance
  - ↓ time cost & reduce the duration of shut-down for repair
  - service life of the structure can be enhanced

AI plays an important role

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- Artificial Intelligence (AI) has a strong genesis in computer science
  - It provides a variety of methods for mainly problems
    - would be difficult to solve otherwise
  - It is computationally capable to solve complex problems

AI incorporates 'human-like' intelligence, covering
  i) thought-process
  ii) consciousness
  iii) self-awareness

- It replicates the biological models, which lead to definition of intelligence

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- AI enhances
  - special computational capabilities
  - some mechanisms & algorithms

    which simulate the intelligence of human behavior

    without including any direct relationship to human abilities

- Totally, a mechanically-set, automated procedure which
  - thinks
  - acts
  - decides
  - controls

  the situation similar to human intelligence

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Conventional AI

- (i) symbolic school of thought
(ii) represents human knowledge explicitly, in a declared form
(iii) They implement procedural knowledge & expertise, which are transferred to them through training & data symbolics generated by symbols & symbolic structures

Ex Expert systems, Case-based reasoning, Bayesian

Basis for comparison : human intelligence

Computational Intelligence

(i) sub-symbolic school of thought (Neural Networks)
(ii) incorporates human thinking @ sub-symbolic level.
(iii) By modeling the mental phenomena, elementary units are interconnected in the networks & knowledge is implicitly represented

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Ex: Neural Networks

Fuzzy logic systems

Evolutionary computation

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AI in Structural Health Monitoring

SHM - - decision-making
- complexities of wrong/incorrect data

Latency problems

Latency problems in SHM can be handled by AI, effectively.

The process of SHM will be seperated from the overall software system to

- individual micro-controller units
- Intelligent sensing units onsite in the sensing systems

AI transfers decentralizes the complexities from

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Main purpose of sensing units is

to automatically control the acquisition of data

- sensors are not simply recording the data
- They are now meant to control the acquisition of data || AI

through smart sensors

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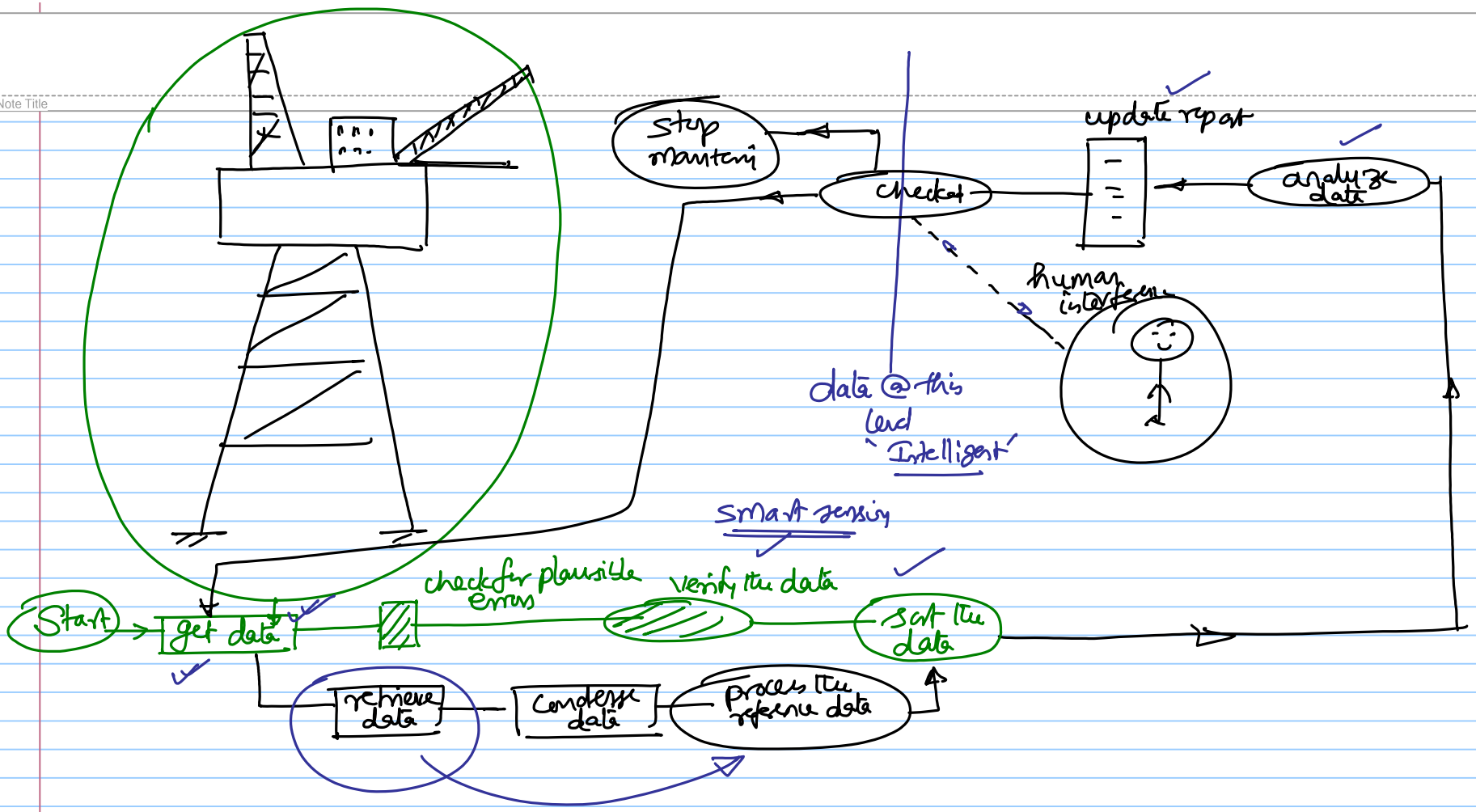

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Plausibility of Errors

- The acquired (measured) data may have inconsistency
- They may not be compatible with the pre-set threshold values.

It is necessary to assess the Errors in the data using micro-controller-based sensing units

Special task:

compare the acquired data with the previous set of data

- If no significant change (no move) is seen for a long period of observation, then sensor will interpret this as WRONG

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- If equal values are reported from a particular sensor location repeatedly for n times, then this is marked as inconsistency
- Further, errors of this nature can also be identified by performing regression analysis (sensor level)
- This detects plausible errors in the acquired data

Important step (AI) different from (STM, conventional)

Is it expensive? It is feasible!
- Simple micro-controller with limited computational power

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- If the response measurement (y) of a structure @ a particular sensor location is recorded as (y) i.e predicted values lead to (y_p)

- By comparing the predicted values (y_p) with acquired values (y) plausible errors can be detected

If $|y - y_p| > \delta y_p$, then

permissible range $\delta y_p = \delta y_p(y, y_p)$

- depends on the project & Stds.

$y_p = \beta_0 + \beta_1 + \epsilon$

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where t = time index to compare (y & y_p)

β_i - regression coefs

ϵ - unpredicted or unexplained variation in the predicted value (y_p).

- Since type, the ϵ fn can be automatically considered to give the correct output (y_p).
  - mean value, for example
- unexplained errors are eliminated

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Data Analysis
- short - term
- Long - term

short term - (2) steps
(i) prognosis
(ii) evaluation

Prognosis value (Y_{PS}) is computed using simple multiple regression model.

$$Y_{PS} = \beta_0 + x_1\beta_1 + x_2\beta_2 \cdots x_k\beta_k + \epsilon$$

Where the parameter x_i - corresponding variables independently measured from different sensor to Gateway

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Based on the properties (Ys),

measured variable (Ys) can be evaluated by Fuzzy logic approach

long-term data analysis

- dealt with Data Mining & Machine Learning (DMML) technique.

- Both the analysis can lead to successful pattern-recognition which makes site more a close-form problem.

- Data trends, can be handled Mann-Kendall test, to check any possible pattern

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Addl reading

Smarsly K. 2003. Development of knowledge-based system for analysis of measured data

15th forum, 2003, Hannover, Germany

Hartmann D, Smarsly K. 2005. Development of Autonomous monitoring system for safety-relevant bridge structures

Research project

Dept of computational Eng,

Ruhr-University Bochum

Germany

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Summary

AI - basis

- AI can modify / better SDM process
- plausible errors in data acquisition can eliminated
- sensors - pattern recognition

AI - add-on to SDM process
- more efficient