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Module 3

Lecture 11

Artificial Neural Network is

STM process

AI is STM, ④ Axioms - directly applicable

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Axiom III - Identifying the existence and location of damage can be done in unsupervising learning model

- But identifying the type of damage, present in a structural system and severity of the damage can be done only by supervised learning mode

Axiom IV (a). Sensors cannot measure damage. feature extraction done through signal processing and statistical analysis classifies the damage. from the sensor data

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Axiom IV b. Without intelligent feature extraction, changing operational conditions & environmental data makes the measured data of damage more sensitive

Axiom V. lengths and time scales associated with damage initiation & evolution of the system decide the properties/characteristics

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Intelligence in SHM can be useful in composite structures.

aim/ using Robust type signal processing protocol

Glass - fibre reinforced plastic (GFRP) laminates are widely used as st materials
- high streng to wt ratio
- Corrosion resistance
- military applications like minimize electromagnetic radar signature of underwater vehicle

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Modes of failure of GFRP

- under static and dynamic loads
- mainly due to cracking as delamination
  - more severe is delamination
    - it causes stiffness reduction
    - leads to catastrophic failure of the structure

- It is vital to detect delamination in GFRP.
  - a few delaminations, may be invisible but still they can cause severe damage to the mechanical properties & load capacity.

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Various techniques

(1) X-ray
(2) Ultrasonic C-scan
(3) laser shearography

- It takes much time to inspect the GFRP structure by these techniques

- Desired option is online detection of damage

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ANN, combined with pre-processing tools such as

Damage Relativity Analysis Technique (DRAT)

can be used for damage diagnosis

- This can predict

  locations
  size
  presence
  extent

  } the damage precisely

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ANN

- a large nl distributed processes
  - comprising of simple processing units (Neurons)
    - which have multiple interconnection paths

ANN are capable of mapping the relationship b/w measurable features of structural damage to their physical parameters

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- Classification & Identification of str damage can be sucessfully done using ANN.

  - uses a set of known damage features and their corresponding physical parameters
  - employs multi-layer feed-forward back propagation network to perform data segmentation
    data compression
    - pattern recognition if present to identify repeating data

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ANN — useful in SHM, in general

- These applications are largely seen in Bridge structures
- Railway bridge - SHM is required to be done

- Data should be collected from the dynamic response of the bridge (through simulation) under passage of trains
  - It is assumed that bridge is in undamaged state and
  - it is healthy

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This can be done in (2) different damaged scenarios

1st stage, ANN - are trained, with an unsupervised learning approach
- Input comprises of accelerations of the deck under healthy state
- Based on the acceleration values @ the previous instant of time. ANN predicts the future accelerations

2nd stage, the predicted errors are statistically characterized by a Gaussian process, which supports the choice of damage detection decision from a known threshold value

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By comparing the damage indices, with the known threshold value, we can differentiate the health condition of the bridge

- damaged
- (or)
- healthy

For each damage case scenario, operating characteristic values, is form of curve are obtained

- Using Bayes theorem, we can also estimate the total cost of the proposed methodology.

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Damage – detection < model-based / model-free

1st case if FRW used, one need to have an accurate finite-element model of the sample structure (Rly bridge)

- damage detection, through 1st scenario has direct physical interpretation

- But, it will be difficult to develop a high-accurate numerical model of a complex structure

on the contrary, 2nd case – deals with model-free approach

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- by means of AI, the damage is classified/identified and tried to relate to the physical characteristics of the bridge

- Model-free approach consists training an algorithm, on some sample acquired data, usually it is done in an unsupervised manner

- without a detailed Numerical model using AI, damage is identified & correlated to physical characteristics based on the algorithm & sample data

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ANN

one of the vital issue is
placement of sensors

- look for optimal sensor placement
  - deciding factor of damage detection
- genetic algorithms to choose sensor type & location

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Alternatively, Li et al recommended

Dual-structure coding and Mutation particle swarm optimization (DSCMPSO) algorithm

- The convergence speed of the algorithm is highly improved
- optimal location is also ↑ (Yi et al)

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Next challenge of ANN is SHM

- seperation of changes in structural characteristics that are caused by vibration-induced damage & changes in operational & Environmental conditions.

- Jin et al, Kalman filter - applied to ANN for damage detection.
  - temperature changes.

In this method, kalman filter is used to estimate the weights of neural network and the confidence intervals of the WTs, used for damage detection

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ADN - can be sucessfully used in STs dependent on "Machine Learning Algorithms"

- MLA - implemented to detect structural abnormalities from the monitoring data

- They use Outlier principle to detect these abnormalities

- based on training data, exclusive to the problem being solved.

Addl reading Kay Smarsly, Kosmas Dragos, Jens Wiggenbrock. 2016. Machine learning techniques for structural health monitoring in STs, 8th European Workshop on SHM, Spain

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ANN

- uses Data-driven approaches for decision-making

They are successful in Civil Engg. as

(i) Large quantity of past data available for Civil Engg. st

(ii) physical characteristics of the st are complex to model

(iii) Computational efforts of ANN- need to be reduced.

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ophas - decentralized ANN

- follows embedded, m/c learning approach to perform the autonomous detection of sensor failure (fault)

Data analysis is / has is related to transforming the useful, compact sensor data into useful information
- probably in the knowledge // physical characteristics format

- life-cycle prediction
- life-cycle management //

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Data driven / Physics-based // AOW as applied to SHM system

physics-based approach - establish the principle model
- map the physical characteristics
- compare the output of the physical model
- then decide damage

Data-driven - Unsupervised, untrained data systems
- computationally intensive

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Data-driven approach - depends on comparison of observed data with the previously collected sensor data

- then decide the damage scenario

- useful -

(i) large-sensor data are available
(ii) physical characteristics of the structure is known
(iii) reduction in computational effort

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Summary

ANN — is sthm system

AI — integrated with ANN

sthm easy
simple
- cost-eff
- less computes

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