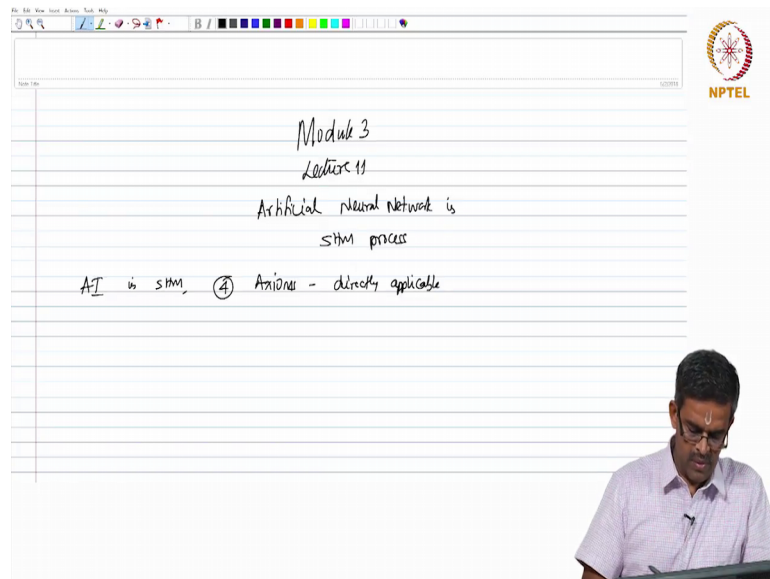


Structural Health Monitoring (SHM)
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Lecture - 63
Part - 1: Artificial Neural Network (ANN) in SHM process

Friends, welcome to the 11th lecture in module 3.

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In this lecture we will talk about the use of artificial neural network in structural health monitoring processes. In the last lecture we discussed about the use of artificial intelligence in general compared to the computation intelligence, and how the interference helps us to improve upon the intelligent sensing, and decision making processes which are very vital and important in structural health monitoring scheme or a network.

So, in this lecture we will extend that artificial intelligence source of information to a neural network. And see how this can be useful in simple applications as far as SHM is concerned, when we talk about use of artificial intelligence in structural health monitoring. There are about four axioms which are very useful and directly applicable axiom one.

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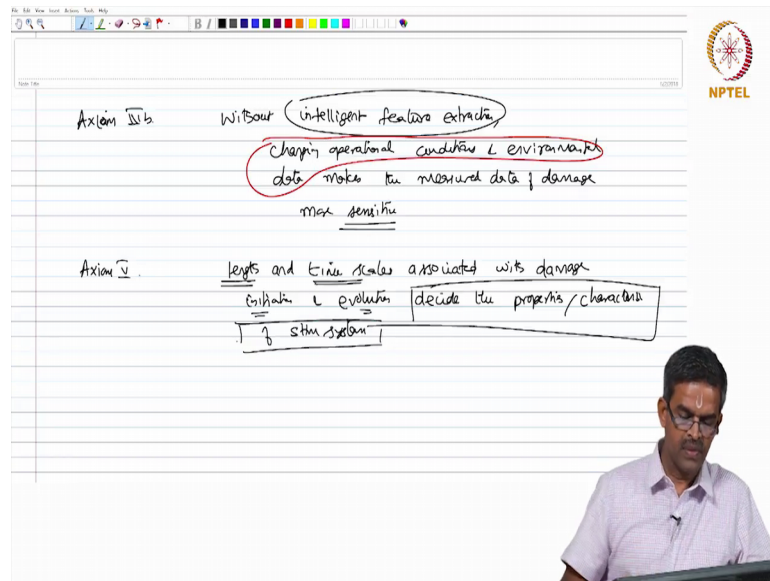
Axiom III - Identifying the existence and location of damage
Can be done in unsupervised learning mode
- But identifying the type of damage, present in a structural system and severity of the damage can be done only by supervised learning mode

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

In that case we should name this as per the order explained in the literature. So, we should say axiom three, which says identifying the existence and location of damage can be done in unsupervised learning mode, identifying the damage or to be very precise identifying the type of damage, present in a system severity of the damage. Only by supervised learning mode, axiom of four a it says that sensors cannot measure damage.

They only record the data they do not know really, whether the data recorded the tentative damage or not sensors cannot measure the damage. It is only through the feature extraction done through signal processing and statistical analysis, classifies the damage from the sensor data it is very important axiom.

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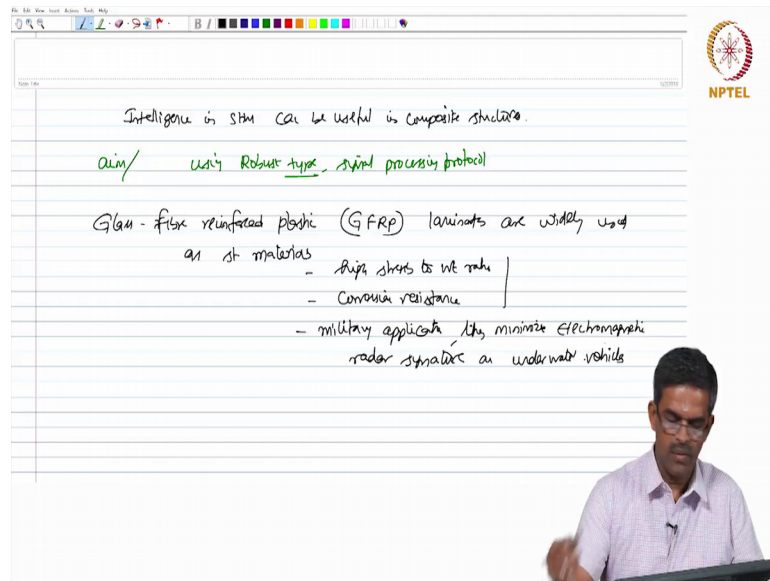


The next axiom is an subset of this so I call this as axiom four b, without intelligent feature extraction, changing operational conditions and environmental data, makes the measure data of damage more sensitive.

It means any change in data related to operational condition or environmental conditions may always give a false implication that it is relevant to a damage, you have to confirm that it is a damage only through intelligent feature extraction. So, without feature intelligent feature extraction the sensitivity of these two parameters will become very dominant. Axiom five the length and time scales associated, with damage initiation and evolution, decide the properties and characteristics of the health monitoring system they govern ok. How long you want to and how and what interval you want to measure the damage parameters.

To really identify the damage initiation and evolution it decides, what is your characteristic of a health monitoring system ok?

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The image shows a digital whiteboard interface with a toolbar at the top and an NPTEL logo in the top right corner. The whiteboard contains the following handwritten text:

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 structural materials

- High strength to wt ratio
- Corrosion resistance
- military applications like minimize electromagnetic radar signature on underwater vehicles

In the bottom right corner, a man in a light purple shirt is visible, looking at a laptop screen.

That is very important the intelligence in structural health monitoring can be useful in composite structures. So, the main aim or the hidden agenda here is using robust type signal processing protocol. Let us take an example where the composites are subjected to damage very often, one classical example is glass fiber reinforced plastic.

What is GFRP laminates or generally or let us say widely used as structural materials, because they have high strength to weight ratio and good corrosion resistance, they are also useful in military applications, because they minimize electromagnetic radar signature or underwater vehicles of GFRP.

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The slide shows handwritten notes on a whiteboard. The title is "Modes of failure of GFRP". The notes are as follows:

- Under static and dynamic loads
- mainly due to cracking or 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 delamination, may be invisible but still they can cause severe damage to the mechanical properties & load capacity.

The NPTEL logo is visible in the top right corner. A presenter is visible in the bottom right corner of the slide frame.

They fail mainly due to cracking or delamination, delamination is more severe because it causes stiffness reduction and leads to catastrophic failure of the structure. So therefore friends, it is vital to detect delamination in GFRP. The more vital part is a few delamination's maybe, but still they can cause severe damage to the mechanical properties and load carrying capacity of the structure.

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The slide shows handwritten notes on a whiteboard. The title is "Various techniques". The notes are as follows:

- 1) X-ray
- 2) Ultrasonic C-scan
- 3) Laser shearography

There is a circled smiley face icon next to the list. To the right of the list, it says: "- It takes much time to inspect the GFRP structure by these techniques".

Below the list, it says: "- desired option is online detection of damage".

The NPTEL logo is visible in the top right corner. A presenter is visible in the bottom right corner of the slide frame.

There are various techniques which are applied to check this delamination, one is X-ray, two is ultrasonic C scan, third could be laser shearography.

Now, with these methods there are some difficulties the difficulties are it takes much time to inspect the laminate or the GFRP structure, by these techniques. Therefore, what is desired the desired option could be online detection of damage, what is online detection how it is done artificial neural networks.

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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

location	} the damage precisely
size	
presence	
extent	

pre processing tools such as damaged, relativity, analysis, technique, which is damage diagnosis. Now, the advantages this can predict the location, size, presence and extent of the damage precisely.

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ANN

- a large set of distributed processes
- emphasis of simple processing units (neurons)
- which have multiple interconnection paths

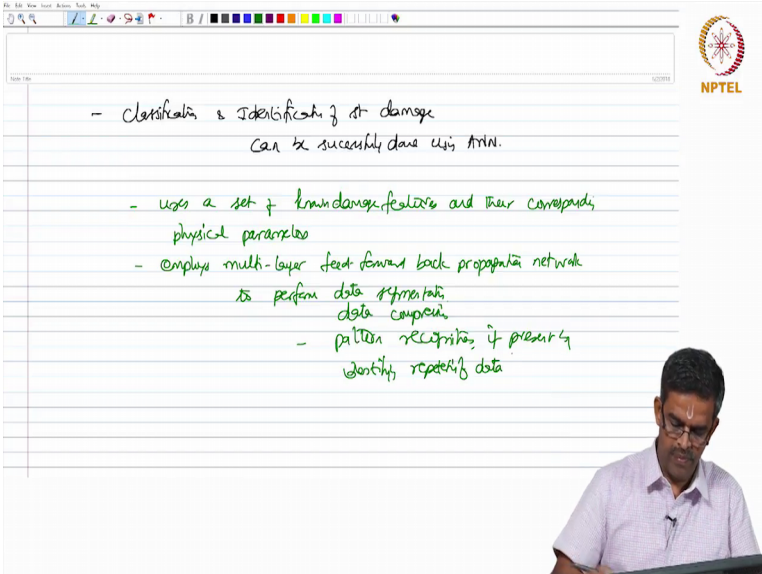
ANN are capable of mapping the relationship b/w

measurable features of structural damage to
their physical parameters

Now let us see more detail about this artificial neural networks, they are actually large, parallel, distributed, processes comprising of simple processing units. These units are called neurons which has multiple interconnection paths, mapping the relationship between measurable features of structural damage to the physical parameters.

For example what kind of damage would cause what change in the physical parameter of property. This can be identified and established using an artificial neural network.

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- Classification & Identification of str damage
Can be successfully 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 by identify repetition of data

Classification and identification of structural damage can be successfully done using artificial neural network. How does it do it, it uses a set of known damage features and their corresponding physical parameters. It also employs multi layer feed forward back propagation network to perform, data segmentation, data compression and above all most importantly the pattern recognition if present by identifying the repetition of data.

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ANN - useful in STM, in general

- These applications are largely seen in Bridge-structures
- Railway bridge - STM is required to be done
- Data should be collected from the dynamic response of the bridge (through simulation) under passage of train
 - It is assumed that bridge is in undamaged state and
 - it is healthy

The image shows a whiteboard with handwritten notes in green ink. The notes discuss the application of Artificial Neural Networks (ANN) in structural health monitoring, specifically for bridge structures. The text is written on a whiteboard with a grid pattern. The NPTEL logo is visible in the top right corner of the whiteboard area.

Let us see how ANN can be useful in structural health monitoring in general are largely seen in bridge structures. For example, let us take a railway bridge whose health monitoring is required to be done ok. So, the steps could be very simple data should be collected from the dynamic response of the bridge, through simulation under passage of train. When this is done, it is assumed that bridge is healthy bridge is in undamaged state and it is therefore considered to be 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

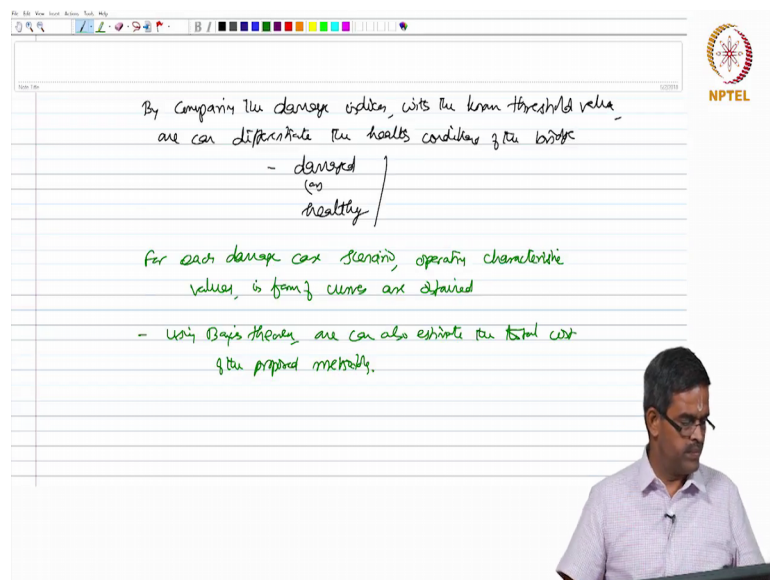
2nd stage, the prediction errors are statistically characterized by a Gaussian process, which supports the choice of damage detector decision from a known threshold value.

The image shows a whiteboard with handwritten notes in green ink. The notes describe a two-stage process for bridge health monitoring using ANN. The text is written on a whiteboard with a grid pattern. The NPTEL logo is visible in the top right corner of the whiteboard area.

Which are different damage scenarios in the first stage, I can use artificial neural network which are essentially trained with an unsupervised learning, approach the input comprises of accelerations of the deck under healthy state. Now based on the acceleration values at the previous instant of time, the neural network predicts; the future acceleration in the second stage of damage prediction in the second stage of damage scenario.

The prediction errors are statistically characterized by a Gaussian process which supports, the choice of damage decision 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, one can differentiate the health conditions of the bridge

- damaged
 or
 healthy

for each damage case scenario, operating characteristic values, in form of curves are obtained

- using Bayes theorem one can also estimate the total cost of the proposed methodology.

By comparing the damage indices, with the threshold value one can differentiate the health conditions of the bridge whether it is damaged or healthy ok. One can do decide this for each damage case scenario as seen above, operating characteristic values, in form of curves are obtained then using Bayes theorem one can also estimate the total cost of the proposed methodology.