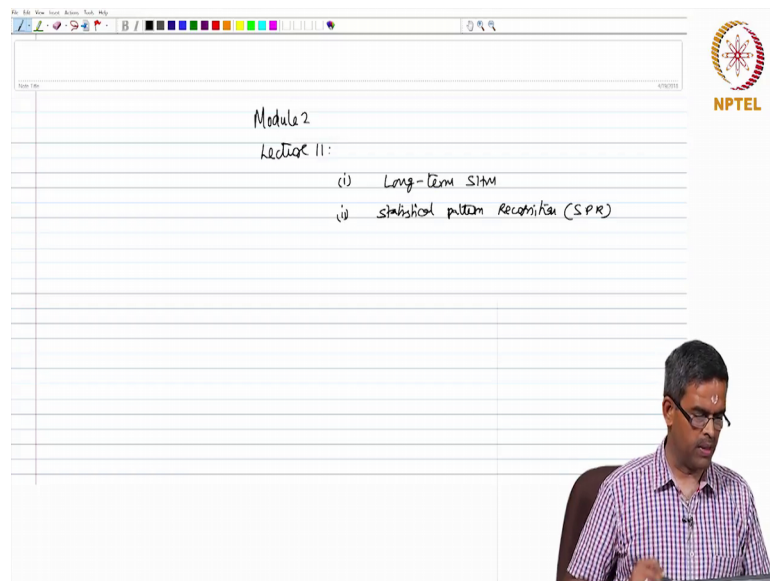


Structural Health Monitoring (SHM)
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Lecture - 37

Part - 1: Structural Health Monitoring (SHM) & Statistical Pattern Recognition (SPR)

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Friends welcome to the next Lecture in Module 2, which is the 11th lecture in this we will talk about 2 things one is long term Structural Health Monitoring, we will also talk about Statistical Pattern Recognition which is abbreviated as SPR.

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SPR

Ahmed S. Noman, Farah Deeba, Ashutosh Baschi. 2009.
Structural Health Monitoring using Vibration-based methods
and Statistical Pattern Recognition Technique,
Proc. Intl Workshop on Smart Materials & Structures,
Montreal, Canada.

Vibration-based damage identification is useful in interpreting local damage

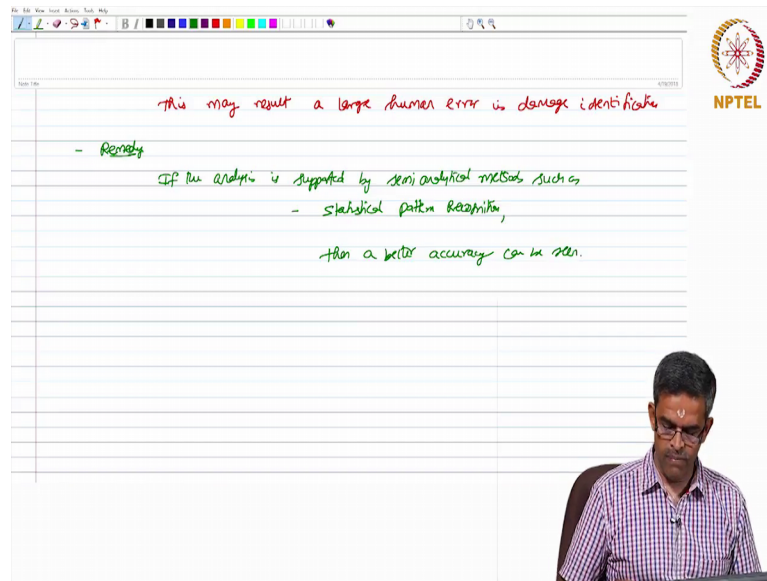
But, due to complexities of the real structure under working conditions
it is very difficult to input the accurate mode shapes &
frequencies to VB methods for damage detection.

To start with let us discuss about SPR one can see more details about SPR in this paper, this is actually proceedings of an international workshop on smart materials and structures held in Montreal Canada in the year 2009. We will talk about the brief introduction to statistical pattern recognition test and its application to vibration based methods in structural health monitoring in this lecture, along with that we will discuss details about what are the implications of long term structural health monitoring? Ok.

We have already seen and accepted a fact that vibration based damage identification is useful in interpreting the local damage. Let me emphasize this fact repeatedly in different lectures, local damage detection is very easily and conveniently done using vibration based methods, but unfortunately due to the high complexities of the real structure under working conditions, it is very difficult to input the accurate mode shapes and frequencies, to vibration based methods for damage detection.

Because, we know these methods want or demand input of mode shape and frequency to obtain the mode shape and frequency of a real structure under working condition is very complex.

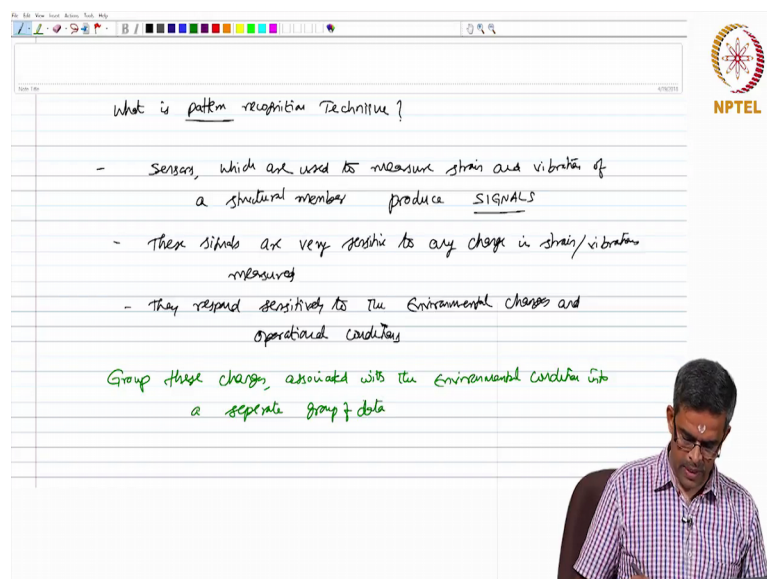
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The screenshot shows a presentation slide with a white background and a blue border. The slide contains handwritten text in red and green. The red text reads: "this may result a large human error in damage identification". Below it, a green heading reads: "- Remedy". The green text continues: "If the analysis is supported by semi analytical methods such as", followed by a bulleted list: "- statistical pattern Recognition,". The final green text reads: "then a better accuracy can be seen." In the bottom right corner, there is a small inset video of a man with glasses and a checkered shirt, looking down. The NPTEL logo is visible in the top right corner of the slide.

So, this may result this may result a large human error in damage identification, but there is a remedy for this the remedy is 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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The screenshot shows a presentation slide with a white background and a blue border. The slide contains handwritten text in black and green. The black text reads: "What is pattern recognition Technique?". Below it, there is a bulleted list: "- 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", and "- They respond sensitively to the Environmental changes and operational conditions". The green text reads: "Group these changes, associated with the Environmental conditions into a separate group of data". In the bottom right corner, there is a small inset video of the same man from the previous slide, looking down. The NPTEL logo is visible in the top right corner of the slide.

So, the question asked is what is pattern recognition testing more technique. So, the basis is sensors, which are used to measure strain and vibrations of a structural member ok, produce signals. These signals are very sensitive to any change in strain or vibrations

measured, they respond sensitively to the environmental changes and operational conditions.

So, what do we actually do is we try to group these changes, associated with the environmental conditions into a separate group of data.

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

Data base

→ a group

→ various groups

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

— pattern

That is changes in measurements what are the measurements used for example, strain, frequency, etcetera are grouped that is identified as a pair to those environmental changes and operating conditions.

So, we a we create a database which is actually a group like this we create various groups, each group will have a unique pair combination, which is related to change in strain and the corresponding operating conditions we call this as a pattern.

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

- once the recorded signal, change in their pattern
matches with the existing patterns of data
base,
then these changes are then mapped to the
corresponding damage locations

So, now a pattern which essentially arises from signature of the measured signals is identified and this is now compared with the new pattern, which is being recorded. Once the recorded signal, change in their pattern matches with the existing patterns of database. Then these changes are then mapped to the corresponding damaged locations.

So, it is very simple that we do not compare every signal to identify the damage. We try to compare the measured signal signatures with the existing patterns, which are saved, which are grouped in the given database.

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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 system processes.

So, we call this as pattern recognition. Therefore, pattern recognition is a machine learning process that is it is the ability of the computer to identify and classify, whether the observed data matches or belongs to a specific pattern that is already existing in the database. So, what is the advantage of this? This can now expedite the decision making process. This feature is very useful in case of automated SHM processes.

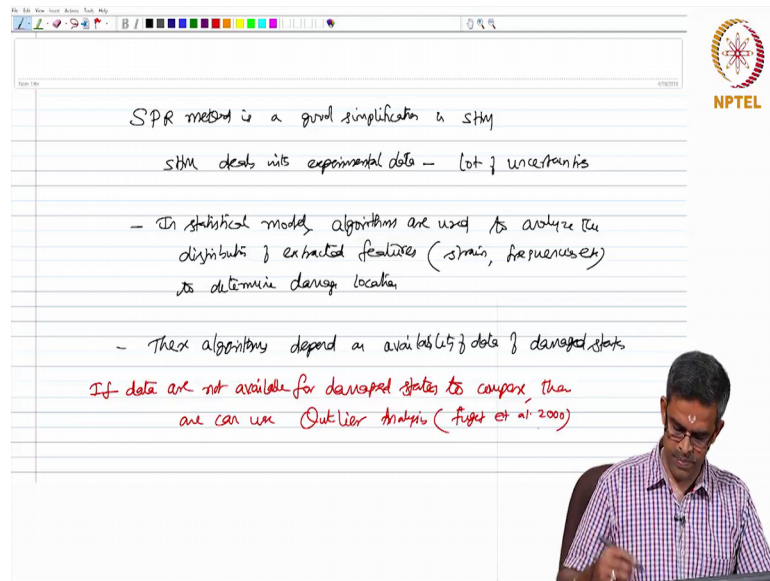
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Recognition patterns are of 2 types

- (1) Supervised learning
 - where input pattern of vibration are compared with pre-defined groups in the database
- (2) Unsupervised learning
 - pattern is compared with undefined group
 - it may become a new group in the database

Now, recognition patterns one of 2 types; namely supervised learning which means that where the input patterns of vibration are compared with predefined groups in the database. Alternatively you can also have unsupervised learning. This means that pattern is compared with undefined group possibly it may become a new group in the database.

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SPR method is a good simplification in SHM

SHM deals with experimental data - lot of uncertainties

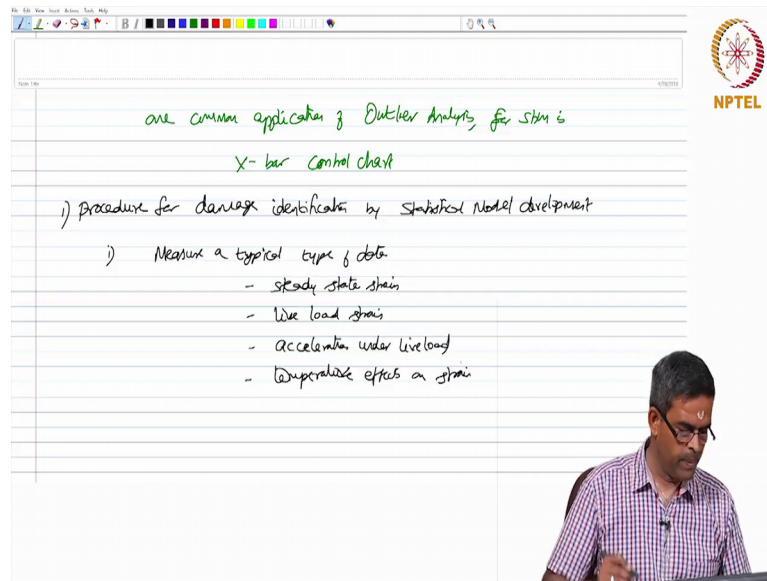
- In statistical model, algorithms are used to analyze the distribution of extracted features (strain, frequencies, etc) to determine damage location.
- These algorithms depend on availability of data of damaged states

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

Now, statistical pattern recognition method is a good simplification in structural health monitoring. We know structural health monitoring deals with experimental data, which anyway has lot of uncertainties. These uncertainties can be handled in statistical model; different algorithms are used to analyze the distribution of extracted features. What are the normal extracted features? Maybe the strain measurements may be frequencies, etcetera to determine the damage location. However, these algorithms depend on availability of data of damaged states.

Now, if the damaged states are not available for damaged states to compare, then one can use outlier analysis. You can see more details about this and Fuget et al 2000.

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one common application of Outlier Analysis for strain is
X-bar control chart

i) procedure for damage identification by statistical model development

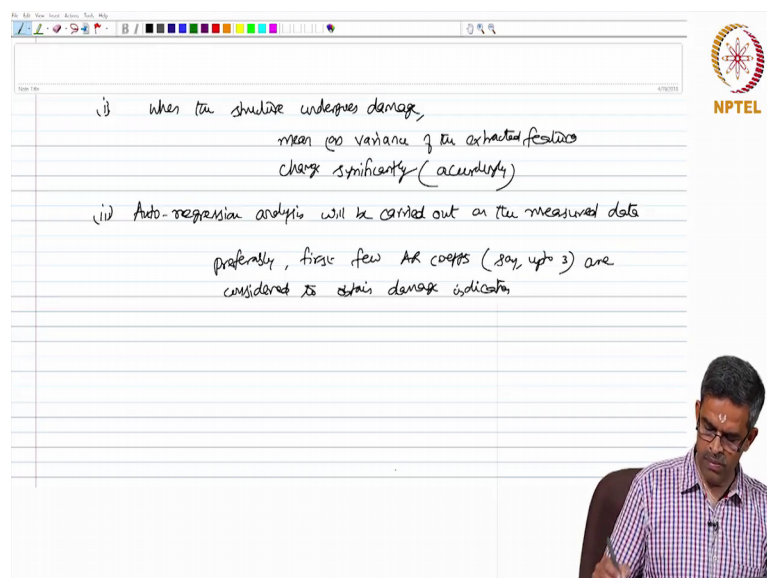
ii) Measure a typical type of data

- steady state strain
- live load strain
- acceleration under live load
- temperature effects on strain

One common application of outlier analysis recommended for structural health monitoring is X-bar control chart. We will not be able to discuss more detail about the specific application (Refer Time: 18:47) Fuget et al 2000 to learn more about the X-bar control chart and its application as far as SPM is concerned. Now let us look into the procedure for damage identification by statistical model development.

So, first step will be measure a typical set of data. Namely steady state strain live load strain, acceleration under live load, one can also measure temperature effects on strain.

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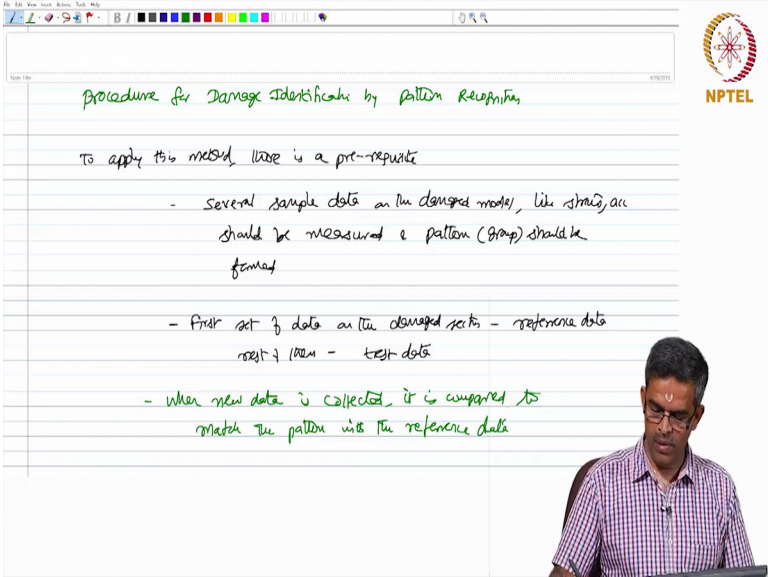


iii) When the structure undergoes damage,
mean & variance of the extracted features
change significantly (accidentally)

iv) 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

Once they are measured when the structure undergoes damage mean on variance of the extracted features change significantly. In fact, they change accordingly subsequently auto regression analysis will be carried out on the measured data preferably, first few auto correlated regression coefficients. Say up to 3 or considered to obtain damage indications.

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Procedure for Damage Identification by Pattern Recognition

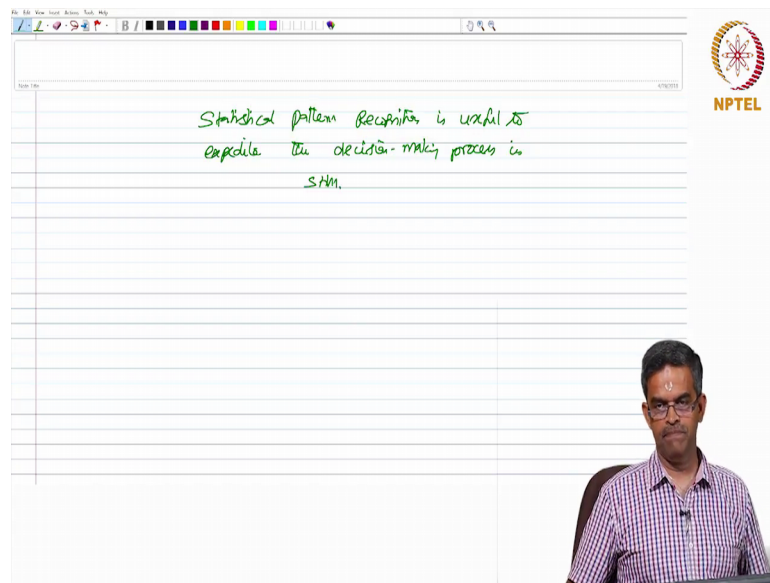
To apply this method there is a prerequisite

- 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

Let us now see the procedure for damage identification by pattern recognition to apply this method there is a prerequisite. The prerequisite is several sample data on the damaged model, like strain acceleration should be measured and pattern let us say group should be formed.

The first set of damaged data that is first set of data on the damaged section can be considered as the reference data. The rest of the data can be considered as the test data. Now, when new data is collected it is compared to identify or let us say to match the pattern with the reference data.

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The image shows a digital whiteboard interface. At the top, there is a menu bar with options like 'File', 'View', 'Insert', 'Format', 'Tools', and 'Help'. Below the menu bar is a toolbar with various drawing tools. The main area of the whiteboard is filled with horizontal lines. In the center, the following text is written in green: "Statistical pattern recognition is useful to expedite the decision-making process in SHM." In the top right corner, there is a circular logo with a star-like pattern and the text "NPTEL" below it. In the bottom right corner, a man with glasses and a checkered shirt is visible, looking towards the camera.

So, friend's statistical pattern recognition is useful to expedite the decision making process in Structural Health Monitoring.