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Module 1

Lecture 8 : Uncertainties in SHM process

- Insitu monitoring, which is a continuous monitoring system is capable of identifying major differences b/w vibration-based measurements and environmental-based changes

- Continuous monitoring is expensive
  - It handles a big volume of data
    - communication
    - analysis
    - retrieval

- other alternative
  - Numerical simulation
  - Numerical structural analysis
  - structural health

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- It can also avoid complexities that arise from continuous monitoring

For example,

continuous monitoring of a bridge is considered

- blocking of traffic
- conducting expensive static and dynamic load tests

cumbersome procedures

Alternatively,

damage status of deck slabs of the bridge can also be detected by analyzing eigen frequency (or) stiffness (degradation)

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one of the important demerit of this alternate method is that

Effects caused by local damage cannot be detected by this method.

other specific issues are

(1) Difficult to capture time-dependent change in material properties

(2) time-dependent change in structural geometry and the loading pattern

These are the actual sources of uncertainties

Sources of uncertainties in SHM

(1) Exact modelling of external load events, including its time and space dependency is approximated by a set of independent events

(2) Strength & stiffness degradation with space & time dependence are disregarded

(3) Measurements of geometric data such as
- maxm deflection of the deck slab
- displacement under dynamic load tests

are subjected to large human errors & inaccuracies

(b) Modelling Uncertainties

(1) structural modifications such as

- construction errors
- changes in structural geometry (marine growth, crack propagation)
- change in material characteristics due to ageing, physical, chemical & mechanical degradation

cannot be captured completely

(c) uncertainties from load variations

space & time dependency characteristics of load variations - is also not captured completely

Solution to handle the above uncertainties

3 ways, by which these can be handled

(1) Using Random Variables

(2) Fuzziness

(3) fuzzy randomness

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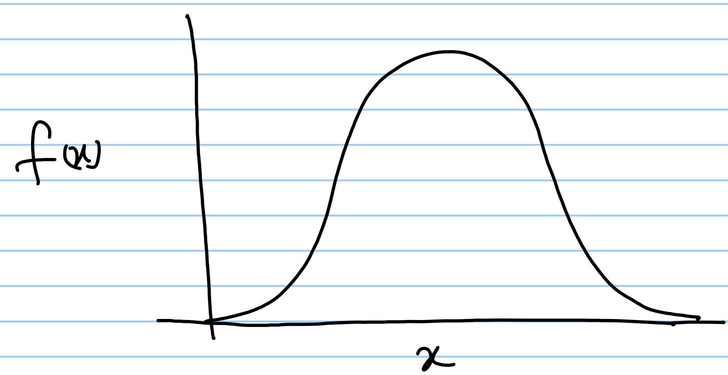
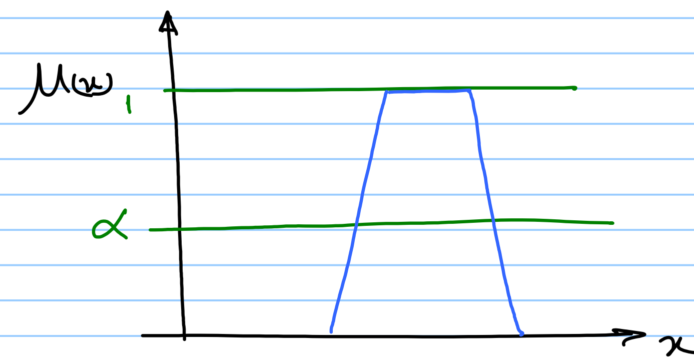
(1) Randomness   (2) Fuzziness



(1) Randomness



(2) Fuzziness

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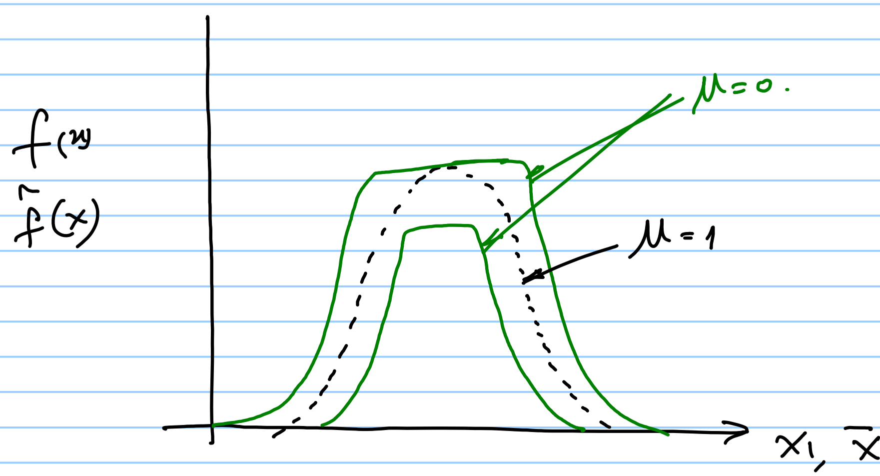

(c) Fuzzy randomness

selection of the model, depends on the availability of data

- Quantum & Quality of data available to represent uncertainty - decide? model

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For example,

if the data is statistically sound then
are parameter can be described stochastically.

But, choice of probability distribution will affect
the results of simulation, significantly.

If data of parameters are frequently fragmented
and not precise,
then fuzzy- randomness model is more
effective to model this uncertainty

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Other class of uncertainties - study

(1) Uncertainties present in the observational data

- experimental
- Numerical

Analysis

<u>solution:</u>

To characterize the effects caused by the uncertainties on the output of the Analysis

- statistical sampling
- hypothesis testing
- Input/output effect analysis

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Issues - related to Advancements is SHM

- SHM process, in the present context is highly advanced
- Wireless, decentralized sensors, which are recent advancements in semi-conductor devices & MEMS technology
    - very useful to collect in-situ data, efficiently
- They are also capable of establishing communication requirements between the sensors
    - This makes decision process much faster

However,

investigation of the collected data is an issue

- This needs a faster investigation process
- even though the data is huge, statistical tools should be able to handle this volume without any residual error

Solution: statistical pattern Recognition (SPR)

- when the data is analyzed for a set of observations they follow a specific pattern

Identify this statistical pattern

- It becomes easy and simple to perform data condensation & feature extraction, from the observed data

(SPR) — major solution to address uncertainties related to volume of data

- continuous monitoring structure

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The most critical issue
is Data Normalization

- Qualitative separation of data &
vibration-based results from that of
environmental conditions

Statistical prognosis

In the data analysis, uncertainty assessment, therefore
becomes very critical

one does structural prognosis

- Identification of future operation conditions & loading

Here also, uncertainity plays a role

- service life prediction based on time & space dependency characteristics of material is very complex
- load variations, which are time-space dependent add to this complexity

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Critical issues of uncertainties in SHM (Summary)

- Can arise from parametric data, which arise from physical experiment and Numerical simulation output

- Imperfect knowledge of control parameters of the physical experiment & numerical simulations
    - imperfect knowledge on the input to Numerical model

- It can also arise from
    - Stochastic Equations of motion
    - environmental variations
    - measurement errors
    - discretization & Numerical errors

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- from the pdf of specific probability distributions

pdf - can handle problems related to uncertainties using random theory

- one can choose a specific type of distribution to include all possible values of the variable

Other methods

(1) Dempster - Shafer theory of possibility & belief
(2) Theory of fuzzy sets
(3) Information gap theory
(4) Convex models of uncertainty

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The most simpler way to address this uncertainty is Monte-Carlo technique

- idea - to randomly pick values of a parameter such that histogram of the chosen values approximates the PDF

  - The computational model is analyzed (or evaluated) @ each point sampled in the input parameter space

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summary

SHM - advanced

- advantages

- critical issues -

most important issue is the uncertainties

- physical exp
- Numerical simulation

- Data collect
- Data processing
- structural prognosis

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Future reading

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Note Title 4/5/2018

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SHM under consideration of uncertain data

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