CEE 6511 – Random Vibrations

3 Credits

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Course Description: This course introduces concepts of random processes for modeling dynamic structural behavior under time-dependent excitations. Numerical tools will be provided for assessing the reliability of structural systems subject to uncertain dynamic loads. Both single and multiple degree-of-freedom structures will be studied. The course also presents experimental modal analysis of structures with random vibration data.

Prerequisites:

- CEE 6510 – Structural Dynamics or equivalence
- Undergraduate degree in civil, mechanical or aerospace engineering
- Experience with MATLAB is recommended

Course References

Complete course notes will be handed out. Although no formal textbook is required, following books are good references.

- *Random Vibrations: Analysis of Structural and Mechanical Systems*, by L.D. Lutes and S. Sarkani (full text available through GT library).
- *Random Vibrations, Theory and Practice*, by P. H. Wirsching, T. L. Paez, and K. Ortiz.
- *Probability, Statistics, and Random Processes for Electrical Engineering*, by Alberto Leon-Garcia.

Course Requirements:

- Homework assignments (approximately 6 assignments): you are allowed to work in groups on all homework and out of class assignments, but any work you turn in must be completed by yourself.
- Midterm exam
- Final project: modal analysis and model updating of a four-story shear-frame structure.

Grading: Five homework assignments (30%), midterm (40%), final project (30%)

Outline

Week 1	Introduction; review of basic probability theory – sample space, probability axioms and basic laws, conditional probability and Bayes rule
Week 2	Independence, discrete and continuous random variables, functions of a random variable **Homework 1** assigned
Week 3	Two random variables, joint, marginal, and conditional distributions; functions of two random variables, expectation, moments **Homework 1** due, **Homework 2** assigned
Week 4	Covariance, correlation, conditional expectation, iterated expectation
Week 5	Mean square error estimation, linear estimation, jointly Gaussian random variables **Homework 2** due, **Homework 3** assigned
Week 6	Random vectors, joint, marginal, and conditional CDF, PDF, PMF, mean and covariance matrix, Gaussian random vectors
Week 7	Random processes, IID processes, random walk, Markov processes, Gauss-Markov process **Homework 3** due, **Homework 4** assigned
Week 8	Mean and autocorrelation functions, Gaussian random processes, stationary random processes, strong and weak stationarity **Lab Demo** - Acceleration measurement of a laboratory MDOF structure using wireless sensors
Week 9	**Midterm** Autocorrelation functions, power spectral density
Week 10	Response of LTI system to WSS process input, output mean, autocorrelation, and PSD **Homework 4** due, **Homework 5** assigned
Week 11	Random vibrations of SDOF systems, white noise excitations
Week 12	Random vibrations of MDOF systems, proportional and non-proportional damping **Homework 5** due, **Homework 6** assigned
Week 13	Threshold crossings, reliability by first passage time, envelop process, distribution of extrema
Week 14	Experimental modal analysis: natural excitation technique (NExT) and eigen-system realization (ERA) **Homework 6** due
Week 15	Recursive estimation, posterior PDF, condition PDFs for Gaussians, information interpretation
Week 16	Kalman filter, LTI system with sensor noise, Lyapunov recursion, measurement update, time update, steady-state Kalman filter **Final project** due