CES 5010

Probabilistic and Stochastic Methods in Civil Engineering

Instructor: Professor Gurley, 475-I Weil hall, office hours to be determined.

Reference Texts:
"Reliability of Structures", A.S. Nowak and K.R. Collins, McGraw-Hill, ISBN: 0-07-048163-6
"An Introduction to Random Vibrations, Spectral and Wavelet Analysis", third edition, D. E. Newland ISBN: 0582 21584 6, Addison, Wesley, Longman
"Engineering Application of Correlation and Spectral Analysis", second edition, J. S. Bendat & A. G. Piersol, Wiley Interscience, ISBN: 0-471-57055-9
"Random Data Analysis and Measurement Techniques", third edition, J. S. Bendat & A. G. Piersol, Wiley Interscience, ISBN: 0-471-31733-0
"Probability Concepts in Engineering Planning and Design: Volume I – Basic Principals", A. Ang and W. Tang, John Wiley & Sons, ISBN: 0-471-03200-X

Required Software: MATLAB

Course Description: Uncertainty is inherent to the process of structural design. Parameters describing loads and the load carrying capacities of structural members and systems cannot be perfectly known, and thus absolute safety cannot be guaranteed. Traditionally uncertainties have been accounted for in the design process by the use of safety factors, which do not explicitly account for specific knowledge of the uncertain quantities. This approach is being replaced with methods that describe uncertainty in a probabilistic sense, offering a more realistic framework with which to approximate the likelihood of system failure. These so-called *reliability* methods are currently being incorporated into design codes, and are based on concepts of probability theory and stochastic (random) variables.

Goals: Introduce beginning graduate students and advanced undergraduate students to the concepts of uncertainty in structural analysis.

Course Objectives: The purpose of this class is to provide students with exposure to several fundamental aspects of uncertainty, and the roles they play in the determination of system reliability. The specific topics include probability and statistics, stochastic processes, random data analysis, and reliability methods. Fundamental theory is provided, however the emphasis will be on application and examples. The course is intended as a complement to advanced analysis and structural dynamics courses, though neither is a prerequisite.

Topic Details: The topics listed above are described in more detail below:

Probability, Statistics and Stochastic Processes: Quantities that are not exactly known (e.g., material properties, dead and live loads), or quantities that change in time in a random manner (e.g., wind loads, seismic ground motions, stiffness degradation due to corrosion) can be described as a relative likelihood of values. These quantities are known as stochastic processes. While such quantities are not precisely known (what will the wind speed be in 5 seconds?), their behavior can be characterized within defined bounds of uncertainty. The mathematics of statistics, probability and stochastic processes will be covered along with practical applications.

Random Data Analysis: The characterization of stochastic processes is often conducted through the analysis of data measured in-field or in experimental facilities. Examples include wind tunnel experiments, breaking concrete cylinders, measuring strains on structural components, etc. This section of the class will cover basic methods to classify the behavior of random processes, including statistical analysis, probability modeling, spectral (frequency domain) analysis via Fourier transforms, and digital simulation of random data. Emphasis will be on the analysis of full-scale hurricane wind field velocity data.

Reliability Analysis: The fundamentals of probability, statistics, stochastic processes, and random data analysis provide the groundwork for reliability analysis. This section will cover the theory and application of methods to determine the likelihood of system failure based upon a probabilistic description of random loads, uncertain material properties, and uncertain structural capacity. Limit states (defining failure modes), and determining the reliability index through analytical, computational, and Monte Carlo simulation methods will be covered.

Grading: The final grade will be determined from homework (100 %). I reserve the possibility of trading homework weight for project weight.

Homework: Homework will be assigned regularly. A project may be assigned midterm to be counted with the homework grade.

Honesty Policy: All students admitted to the University of Florida have signed a statement of academic honesty committing themselves to be honest in all academic work and understanding that failure to comply with this commitment will result in disciplinary action. This statement is a reminder to uphold your obligation as a UF student and to be honest in all work submitted and exams taken in this course and all others. The University Student Code of Conduct may be found at www.dso.ufl.edu/sccr/process/student-conduct-honor-code

Students with Disabilities Students Requesting classroom accommodation must first register with the Dean of Students Office. That office will provide the student with documentation that he/she must provide to the course instructor when requesting accommodation. www.dso.ufl.edu/drc

Counseling Services Resources are available on-campus for students having personal problems or lacking clear career and academic goals. The resources include:

- UF Counseling & Wellness Center, www.counseling.ufl.edu/cwc
- Career Resource Center, Reitz Union, 392-1601, www.crc.ufl.edu/

Software Use All faculty, staff and student of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Reading list

1: Introduction and set theory
2: Counting rules
3: Discrete random variables
4: Continuous random variables, probability models, multiple random variables
5: Summary of probability theory
6: Random variable simulation for Monte Carlo
7: Monte Carlo simulation and variance reduction methods
8: Importance Sampling
9: Correlation, Fourier analysis and spectral density estimation
10: Probability modeling from empirical data – goodness of fit
11: Goodness of fit pt. 2
12: Stochastic Process Theory: correlation functions, spectral density, coherence, data analysis
13: Linear systems, random vibration
14: Statistics of narrow banded processes
15: Probability in Design Codes

Course Schedule: subjects and dates subject to change

Class #	Date	Topic	HW due date	Reading
1 - 2	January 8, 10	Introduction to course, begin set theory, venn diagrams		1
3– 4	January 15, 17	Conditional probability, baye's theorem, total probability, independence		2
5 – 6	January 22, 24	Counting rules, discrete distributions, using Matlab	HW#1 1/24	3
7 – 8	January 29, 31	Discrete distributions, glass breakage experiment, Continuous random variables and distributions	HW #2 1/31	4, 5
9 – 10	February 5, 7	Continuous random variables and distributions		
11 – 12	February 12, 14	Multiple correlated random variables Functions of random variables: moments and transformations	HW #3 2/14	6, 7
13 – 14	February 19, 21	Reliability problems: analytical approximations, Monte Carlo simulation Monte Carlo simulation: errors, sample size and univariate distributions	HW #4 2/21	
15 – 16	February 26, 28	Simulating multivariate correlated random variables Correlation distortion simulation	HW #5 2/28	
17 – 18	March 12, 14	Importance sampling, variance reduction methods Stochastic process theory	HW #6 3/14	8, 9
19 – 20	March 19, 21	Stochastic Processes: autocorrelation, frequency domain concepts Fast Fourier Transform		10, 11
21 – 22	March 26, 28	Power spectral density (PSD), cross correlation, coherence	HW #7 3/28	12
23 – 24	April 2, 4	Simulating random variables with memory (PSD)		
25 – 26	April 9, 11	FFT filtering, goodness of fit for PDF modeling Data analysis: gust factors, length scales	HW #8 4/11	13, 14, 15
27 – 28	April 16, 18	Linear vibration: system response	HW #9 4/18	
29	April 23	Linear vibration: system response	HW #10 4/26 @ noon	