CE 229: STRUCTURAL AND SYSTEM RELIABILITY

SPRING 2013
Tue/Thu 12:30-2PM, 544 Davis Hall

Units: 3

Prerequisites: Graduate Standing.

Course Description:

Review of probability theory. Multivariate distribution models. Review of classical methods for characterization of systems and assessment of system reliability. Formulation of structural reliability for components and systems. Exact solutions for special cases. Computational reliability methods, including first- and second-order reliability methods (FORM and SORM), response surface, Monte Carlo simulation and importance sampling. Bounds on system reliability. Reliability sensitivity and importance measures. Bayesian updating and reliability analysis under statistical and model uncertainties. Introductions to reliability-based optimal design, time- and space-variant reliability analysis, finite-element reliability methods.

Course Objectives:

To offer a comprehensive and in-depth coverage of modern methods for structural and system reliability assessment, analysis of uncertainty propagation, component/variable importance measures, and probabilistic bases for performance-based design and decision-making. Students will use computer codes to apply the concepts learned to example problems and a term project. Students completing this course will be able to read and understand the large and rapidly growing literature in the field of structural and system reliability and risk analysis. They will also understand the techniques employed in educational, research and commercial reliability analysis codes, such as CalREL, FERUM, OpenSees, NESSUS, PROBAN and STRUREL. Methods discussed in this course have broad applicability and can be used in many disciplines where probabilistic analysis is needed.

bSpace:
All material for this course will be posted at https://bspace.berkeley.edu/.

Required Reading:

Class notes. Selected readings from a list of references will be posted.

Reference Text:

Ditlevsen, O., and H. O. Madsen (1996). *Structural reliability methods*. J. Wiley & Sons, New York, NY. Freely downloadable at:
http://www.web.mek.dtu.dk/staff/od/books.htm

Computer Programs:

Work in this class will require the use of one of the reliability codes CalREL, FERUM or OpenSees. CalREL is a general-purpose reliability analysis program written in FORTRAN. Instructions for access to and use of this program will be given in the class. FERUM is a Matlab toolbox for finite element reliability analysis developed by Terje

Haukaas and other Berkeley students and scholars. The code and a User's Guide can be downloaded from http://www.ce.berkeley.edu/FERUM/. OpenSees is a general-purpose finite element code under development by a multi-university group with the sponsorship of PEER. Reliability modules for this code have been developed by Terje Haukaas and Kazuya Fujimura among others. Additional information about this code can be obtained at http://OpenSees.Berkeley.edu.

Use of all three programs for reliability analysis will be demonstrated in this class. Among the three, CalREL is the most powerful and general code for reliability analysis, but it requires explicit definition of limit-state functions and a rudimentary knowledge of FORTRAN. FERUM, which includes a linear finite element code for simple structural systems, is easy to use and adapt if you know MATLAB. OpenSees allows you to define the reliability problem in terms of a general nonlinear finite element model. However, using OpenSees requires more experience than the other two codes. Introductory information about all three codes is given in

Der Kiureghian, A., T. Haukaas and K. Fujimura (2006). Structural reliability software at the University of California, Berkeley. *Structural Safety*, **28**(1-2):44-67.

You can find a copy of this paper at the course website.

Homework:

Weekly assignments, including due dates, will be posted on the course website on most Thursdays. Solutions will be posted after the due date. Students are encouraged to use programs such as Matlab or MathCAD to solve these problems. For some assignments, the use of CalREL or FERUM will be required. The homework will count 20% of the course grade.

Exams:

An examination is tentatively scheduled for Thursday April 11. This exam will count 40% towards the course grade.

Term Project:

Each student is required to submit a term project, either individually or in a team consisting of no more than 2 students. The topic can be one of the following:

a) A comprehensive reliability analysis or probabilistic design of a selected structural component or system. The word "structural" is used here to denote a reliability method that employs limit-state functions (as opposed to purely empirical methods). Geotechnical, mechanical, electrical, environmental and other components and systems can be studied, as long as the methods discussed in the course are used. Use of the programs CalREL, FERUM or OpenSees is strongly encouraged.

b) Critical review of selected papers in the area of structural reliability. One or more papers may be selected depending on the content. The review must be in-depth and go beyond what we have covered in the class in that area. Reproducing the results in the paper and their extension may be considered.

c) New analytical or computational work that advances the state of the art of structural reliability theory.

d) Development of a computer code or module to implement a specific reliability algorithm or formulation and its implementation in CalREL, FERUM or OpenSees.

e) Any other idea that you may think is worthwhile and cannot be classified as above. Prior approval from the instructor is necessary.

The project can be conducted by groups of 1 or 2 students. The amount of work, however, must be proportional to the number of contributors. I allow teamwork because I think advanced concepts are better understood when two students interact. Therefore, if you are a group of two, do not divide the work in two separate parts. Instead, work interactively on the whole project together.

A one-page abstract of the Term Project is due by March 19. The abstract should state the title of the project, the name(s) of the investigator(s), and a 500-word description of the proposed work, including the main objectives, the technical approach to be used, and the expected results. You should receive my approval before proceeding with the work. Submit the project abstract as a Word document so I can make tracked edits and comments and return to you.

The Term Paper describing the results of your project is due on Thursday May 16. It should be in a typed form and in sufficient detail to allow evaluation of its merit. Each student will make a 20-minute oral presentation of his/her term project at a "Reliability Symposium" organized the same day.

Grading:

Homework:	20%
Midterm examination:	40%
Term project and presentation:	40%

Instructor:

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Office Hours: Tuesdays 2:30-3:30PM, Thursdays 9:30-11AM.

CE229 – Structural Reliability

Topical Outline

	Topic	No. of lectures
1.	Introduction. Review of essential elements of probability theory	5
2.	Multivariate distribution models	2
3.	Structural component reliability Exact solutions for special cases General formulation, approximate solution methods: MVFOSM, FOSM, FORM, SORM	6
4.	Reliability sensitivities, importance measures, updating	2
5.	System reliability analysis System definition and characterization System reliability analysis Component importance measures	5
6.	Monte Carlo simulation and importance sampling methods	2
7.	Reliability analysis under statistical and model uncertainties	2
8.	Introduction to Bayesian networks and application to infrastructure risk assessment	2
9.	Time- and space-variant reliability analysis	1