M E 591X: Probabilistic Engineering Analysis and Design

(Spring 2018 Schedule: M W F 10 – 10:50 am, Black 1026)

This is an experimental graduate-level course on engineering design for reliability and failure prevention. The course will be offered in the Spring 2018 semester.

Motivation

Since the 1980s, major industries and government agencies worldwide have faced increasing challenges in ensuring the reliability of engineered systems. Examples of failures in attaining high reliability include the Chernobyl disaster in Russia (1986), the collapse of the I-35W Mississippi River Bridge in the U.S. (2007), the lithium-ion (Li-ion) battery fire/smoke issues on Boeing 787 Dreamliners in the U.S. and Japan (2013), and the Li-ion battery exploding/smoke issues on Samsung Galaxy Note 7 (2016). The rapidly increasing costs associated with these failures, along with stringent reliability requirements, have resulted in considerable research attention directed towards developing probabilistic analysis and design methods for anticipating and avoiding catastrophic failures. The existing curriculum at ISU does not adequately address reliability and uncertainty in engineering system design and post-design failure prognostics. There is a need to introduce this knowledge to students so that they can directly apply it to their own research studies where uncertainty and/or reliability may play an important role. This course will meet this need by exploring statistical/probabilistic methods for engineering design and prognostics and health management. It will provide students with a hands-on experience on the applications of these methods to analyze and improve the reliability of engineered systems.

Description

- Applications of probabilistic and statistical methods to engineering system design and post-design failure prognostics.
- Hands-on learning of various probabilistic and statistical design methods, such as design of experiments, surrogate modeling, uncertainty quantification, reliability-based design, and robust design.
- Real-world examples on use of Bayesian estimation and machine learning methods for post-design failure prognostics.

Prerequisites:

Necessary: Linear algebra (as in MATH 207), probability theory (as in STAT 231).
Optional: optimization theory, information theory.

Textbooks

1. Myers and Montgomery, Response Surface Methodology, Wiley, 1995.
2. Haldar, A., and Mahadevan, S., *Probability, Reliability, and Statistical Methods in Engineering Design*, John Wiley & Sons Inc., 2000.
3. Modarres, M., Risk Analysis in Engineering: Techniques, Tools, and Trends, Taylor & Francis Group, 2006.

4. Adams, D. E., Health Monitoring of Structural Materials and Components, Wiley, 2007.

Course Outcomes

After taking this course, students will be able to:

1. Model uncertainties for engineering analysis and design;
2. Analyze the reliability of engineered systems under uncertainty, and optimize the design of engineered systems given a target reliability;
3. Integrate reliability analysis and design optimization with computer simulation models (CAD/CAE/FEA) for reliability-based design and robust design;
4. Implement model-based and data-driven prognostics for remaining useful life prediction of engineered systems based on physical models and sensor data.

Course Topics

1. Uncertainty modeling: fundamentals of probability and statistics; statistical methods for exploratory data analysis.
2. Basics of reliability analysis: definition of reliability; uncertainty quantification; general reliability analysis (time-independent and time-dependent); Bayesian reliability analysis.
3. Numerical methods for reliability analysis: Monte Carlo simulation; first- or second-order reliability method (FORM/SORM); Design of Experiments (DOE); importance sampling; stochastic response surface methods.
4. Probabilistic design: introduction to design optimization; classical vs. probabilistic approach to engineering design; reliability-based design; robust design; probabilistic sensitivity analysis.
5. Prognostics and health management: extraction of health-relevant features from sensor data; model-based prognostics; data-driven prognostics; uncertainty management in prognostics.

Instructor

Dr. Chao Hu
Office: 2026 Black Eng. Bldg.
Phone: 515-294-0771
Email: chaohu@istate.edu

Grading:		
	Exam (2 sets, each 25%)	50%
	Homework (5 sets, each 5%)	25%
	Design Project (20% project report, 5% peer review)	25%