SE 598 – Data-driven Design Methods

Spring 2021

Department of Industrial and Enterprise Systems Engineering
University of Illinois at Urbana-Champaign

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Office Hours: MW 6:30 ~ 7:50 PM

Course Description: Engineering systems design relies on quantitative and qualitative data to describe design-related engineering phenomena and prescribe improvements for design practice. Data-driven design refers to making engineering design decisions based on data. While using data-driven design framework, data is of primary importance. Moreover, advanced computational methods that create mathematical models and develop computer tools based upon data for engineering design decision making are critical for engineering design. In this course, we will explore advanced computational methods for data-driven design, including engineering design and optimization, system modeling and simulation, probabilistic design, uncertainty quantification, advanced sampling and analysis of physical experiments, physics-informed machine learning, as well as multifidelity approaches for design. Engineering design applications in structures, energy storage systems, power systems, engineering materials, and design for additive manufacturing will be used as design case studies in this course.

Learning Objectives: After completing this course, students can

- Be familiar with the literature on computational methods for data-driven design;
- Develop mathematical models for engineering design and formulate optimization problems for design improvements;
- Solve design problems with time-independent /time-dependent probabilistic design constraints using different optimization methods;
- Apply data-driven techniques such as reduced order modeling and machine learning to address high dimensional design problems;
- Use surrogate modeling techniques (e.g. Gaussian processes) to develop design models with variable fidelities based upon system inputs/outputs data;
- Quantify system output uncertainties with statistical models and estimate the model parameters using uncertainty quantification techniques;
- Apply different sampling techniques to enhance the fidelity of computational models for design;

Textbook:

- Hu, C., Youn, B.D., and Wang, P., Engineering Design under Uncertainty and Health Prognostics, Springer Nature, ISBN 978-3-319-92574-5.

Additional References:

- Introduction to Optimum Design, Arora, J.S., Elsevier Academic Press, 2nd, 3rd or 4th edition.
- Engineering Design: A Materials and Processing Approach, Dieter G. E., 1991, 2000, 2009
- Engineering Optimization: Methods and Applications, Reklaitis, R.R., 2002

Prerequisites: Math 241 and IE 300, or per the instructor's approval.

Evaluation: Students are expected to complete their homework/exams on their own. In addition, one term project will be evaluated based on the project report. Graduate students will have the second term project to account for one additional credit hour. The evaluation of students' work is the instructor's professional judgment and is **not subject to negotiation.** Incomplete "**I**" will not be given out, unless there are very special circumstances.

Grading: The overall grade of the course will be assembled based on

20%: Homework/Quizzes
20%: Exam
20%: Term Project 1
20%: Term Project 2
20%: Term Project 3

A+: 97 – 100%	A: 93 – 96%	A-: 90 – 92%
B+: 87 – 89%	B: 83 – 86%	B-: 80 – 82%
C+: 77 – 79%	C: 73 – 76%	C-: 70 – 72%
D+: 67 – 69%	D: 63 – 66%	D-: 60 – 62%

Academic Integrity: We will follow university regulations for academic integrity: (http://admin.illinois.edu/policy/code/). Students who violate academic integrity will receive a "0" on that exam or assignment and may receive an "F" grade in the course. Discussing a homework assignment in a group is encouraged as long as each student writes the answer in his/her own words. Plagiarism is considered a serious violation of academic integrity and will be dealt with utmost severity.

Topical Outline

- Introduction to engineering design & optimization
- Engineering systems and modeling
- Simulation in product design and optimization
- Probabilistic computing and design under uncertainty
- Reliability-based design and control co-design
- Surrogate modeling and uncertainty quantification
- Data sampling and analysis of physical and computer experiments
- Multifidelity modeling and data fusion