BIOE 498/598 PJ

Experiment Design and Optimization

Spring 2022

http://bioe498.github.io

Course Instructor
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Office Hours: Thursday, 3-4pm, online

Description

All engineers perform experiments. Whether they be “wet-lab” or simulated, experiments test the limits of our hypotheses and drive our understanding. Often engineers want to go beyond validating their theories and models. Engineers want the best designs – the optimal combination of cost, reliability, performance, and usability.

Part I of this course presents *Design of Experiments* and *Response Surface Methodology*, two systematic frameworks for optimizing and understanding real-world systems. Using both experimental data and computer simulations, students will explore methods to efficiently search large design spaces. Upon completion, students will be able to

- Design experiments with maximum statistical power.
- Use sequential experiments to find optimal experimental conditions.
- Tune “black box” models with multiple inputs and parameters.

Part II generalizes the above techniques into *Surrogate Optimization* to tackle larger problems with complex response surfaces. Surrogate optimization emphasizes active learning and sequential experiments that adapt designs based on intermediate results.

Part III introduces *Reinforcement Learning*, a branch of artificial intelligence where agents both design experiment and interpret the results. Reinforcement learning underlies many recent AI breakthroughs in gameplay, logistics, protein folding, self-driving cars, and robotics. Students will learn to build agents that rival human experts when solving multistage decision problems.

The techniques in this course apply to any field of science and engineering. The course will focus on biomedical and bioengineering topics, including

- Bioprocess and metabolic engineering
- Medical device design and testing
- Optimizing molecular biology assays
- Design of synthetic gene circuits

Students will use real-world data and simulation software to optimize designs. As is typical in engineering, many of the projects lack a single “best” answer. Students will learn to balance multiple objectives and constraints when solving problems.

Audience
The course targets upper division undergraduates and graduate students in all engineering fields. Students in BIOE, ABE, and CHBE may connect best with the application areas. Examples will be selected from all undergraduate BIOE tracks. Students from MCB, ACES, and other colleges are welcome provided they meet the course prerequisites.

Prerequisites
- BIOE 210 (Linear Algebra for Biomedical Data Science)
- Graduate students with a background in linear algebra and basic statistics are welcome. These students should review Part I of the following text for background on linear statistical modeling: *Linear Algebra: Foundations of Machine Learning* by P.A. Jensen (available for free online).
- Basic computer programming skills. This course will introduce students to the R programming language – no experience with R is necessary.

Assessments
Five case studies. Students are encouraged to work in teams of two or three. For example, one case study is an assignment from the manager at a fictional company. Teams will receive a budget that can be spent on experiments. The deliverable for each project will be a slide deck detailing the optimization performed and team's recommendations.

Two in-class exams. Exams measure conceptual understanding of experimental design and optimization techniques. Any non-electronic materials are allowed during the exam, including the course textbooks and notes.

Grading
Case studies: 75% (5 × 15% each)
Exams: 25% (2 × 12.5% each)