UTC-IASE
UNIVERSITY OF CONNECTICUT

UCONN
SCHOOL OF ENGINEERING

SE 5102: Uncertainty Analysis, Robust Design, and Optimization, Spring 2018

Course Instructor: Matthew D. Stuber, Ph.D.

Catalog Description. 3 credits. Provides students with a thorough understanding of platform-based and model-driven methods for uncertainty analysis and robust design of cyber-physical systems. Topics include modeling of uncertainties, sensitivity analysis, robust design analysis methodologies (DFSS, IDOV), and critical parameter management (CPM).

Pre-Requisites. A systems modeling course, which includes Foundations of Physical Systems Modeling, Embedded/Networked System Modeling Abstractions, or Model-Based Systems Engineering.

Intended Audience. The course is designed for all graduate students in systems engineering.

Course Delivery Method. The course will be offered online, asynchronously, in small recorded modules according to the course schedule and syllabus. Direct and live communication with the instructor will be available each week, according to the class schedule, for discussion, questions, examples, and quizzes. Attendance at live sessions is required, and you must notify the instructor in advance if you cannot attend. Live sessions will be conducted via WebEx. Students can communicate with the instructor via email with "SE 5102" opening the subject line.
WebEx Address: https://uconn-cmr.webex.com/meet/stuber

Course Objectives. This course is designed to provide students with the foundations of model-based methods for uncertainty analysis and robust design of process systems. Students will develop skills in the areas of numerical analysis and optimization, uncertainty analysis in design, sensitivity analysis in design, and robust design. Topics include modeling of uncertainties, sensitivity analysis, robust design methodologies, and critical parameter management.

Anticipated Student Outcomes. By the end of SE 5102, a student will be able to:

(1) Exhibit proficiency in optimization theory, methods and software application
(2) Develop skills in model-based uncertainty analysis
(3) Formalize mathematically complex problems of robust design in systems engineering
(4) Analyze, solve, and present a model-based design approach for an industry-relevant system
(5) Integrate acquired knowledge in the analysis of physical systems

(6) Communicate rigorously mathematical findings

Background Information Required on the Following Subjects:

(1) Thermodynamic cycles such as chillers or cabin air conditioning systems
(2) Mathematical modeling of physical systems
(3) Modelica, MATLAB and FMI tools for simulation of thermodynamic systems

Course Organization. The course is organized into five learning modules:

(1) Numerical Analysis and Optimization
(2) Uncertainty Analysis and Quantification
(3) Sensitivity Analysis in Design
(4) Robust Design
(5) Flexibility Analysis

Course Outline. The structuring of these five learning modules into 14 lectures of a one semester course, along with the topics and references, is described in the following. An example system model, such as a chiller or cabin air conditioner from earlier pre-requisite courses, must be attained by each student team for use in this course as a project, and coded in MATLAB / Modelica.

----------Module 1: Numerical Analysis and Optimization ----------

Lecture 1: Course Introduction – Jan. 18 Live Session

- Course layout
- Grading

Lecture 2: Optimization Preliminaries – Jan. 25 Live Session

- Introduction to notation
- Standardized formulation concepts
- Intro to Theory

Lecture 3: Optimization – Feb. 1 Live Session

- Convex Analysis
- Unconstrained Programming

Lecture 4: Optimization – Feb. 8 Live Session

- Constrained Programming
- Optimization-based design

----------Module 2: Uncertainty Analysis----------

Lecture 5: Introduction to Uncertainty Analysis – Feb. 15 Live Session

- Types of uncertainty
- Accounting for Uncertainty in Design
- Propagation of Uncertainty

Lecture 6: Uncertainty Quantification – Feb. 22 Live Session

- Modeling Uncertainty
- Estimation of uncertainty distributions
- Operating conditions
- Margin analysis at operating points.

Lecture 7: Model Validation and Parameter Estimation – Mar. 1 Live Session

- Estimation of uncertain parameters in modeling

----------Module 3: Sensitivity Analysis----------

Lecture 8: Introduction to Sensitivity Analysis – Mar. 8 Live Session

- Full Factorial experimentation. Partial factorial designs.
- Linear and quadratic term regression and ANOVA.
- MATLAB implementation of full factorial experiments. Regression regstats().

Lecture 9: Sensitivity Analysis in Systems Designs – Mar. 22 Live Session

- Local Sensitivity Analysis
- Global Sensitivity Analysis
- Marginal costs

----------Module 4: Robust Design----------

Lecture 10: Introduction to Robust Design – Mar. 29 Live Session

- Design under uncertainty
- Operations under uncertainty
- Min-max problem formulation

Lecture 11: Formal Robust Design Methodology – Apr. 5 Live Session

- Worst-case design
- Cutting-plane algorithms
- Marginal costs and the price of robustness

Lecture 12: Traditional Probabilistic Methodology – Apr. 12 Live Session

- Taguchi robust design and signal to noise ratios. Traditional factorial experimental formulation.
- Critical parameter management

----------*Module 5: Flexibility Analysis*----------

Lecture 13: Introduction to Flexibility in Systems Design and Analysis – Apr. 19 Live Session

- Problem formulation
- Flexibility analysis metrics

Lecture 14: Course Summary/Final Project Presentations – Apr. 26 Live Session

USEFUL READING.

Relevant reading materials will be posted to HuskyCT, when available digitally.

References

1. *Applied Interval Analysis*, Jaulin, Kieffer, Didrit, and Walter, Springer-Verlag London, 2001. (eBook, online)
2. *Design for Six Sigma*, Yang and El-Haik, McGraw-Hill, New York, 2003. (eBook, online)
3. *Nonlinear Regression Modeling for Engineering Applications*, Rhinehart, Wiley, New Jersey, 2016. (eBook, online)

Grading. Student grades will be based upon: Homework 70%, In-Class Communication: 10%, Final Project Report: 20%.

Due Dates and Late Policy. All due dates will be identified in blackboard when the work is posted. Deadlines are based on Eastern Standard Time; if you are in a different time zone, please adjust your submittal times accordingly. The instructor reserves the right to change dates accordingly as the semester progresses. All changes will be communicated in an appropriate manner.

Homework. Homework assignments will be posted on HuskyCT. Homework assignment due dates will be given with the assignment. NO late homework will be accepted as the homework will often be discussed in class. Each problem will be graded on a scale of 0-100 with 80% being allocated to the problem solutions, and 20% being allocated to the formatting (e.g., clarity, conciseness, organization, comments and discussion of code (where appropriate), etc.).

Project, Presentations, and Project Report. A project is to be developed by student groups (2, possibly 3 per group), which is expected to evolve during the entirety of the track. The project that is to be executed in this course refers mainly to the design project identification, challenge quantification, significance, and relevance to the model-based design philosophy (with respect to the robust design topics), and plan of attack. The final deliverable (presentation and report) should identify all the aforementioned elements in a quantifiable manner and strategy for solution. The final report should be 10 pages or less and adhere to formal technical writing guidelines and mathematical rigor.

Student Conduct. https://community.uconn.edu/the-student-code-preamble/. Students are responsible for adherence to the University of Connecticut student code of conduct. Pay attention to the section on Student Academic Misconduct, "Academic misconduct is dishonest or unethical academic behavior that includes, but is not limited, to misrepresenting mastery in an academic area (e.g., cheating), intentionally or knowingly failing to properly credit information, research or ideas to their rightful originators or representing such information, research or ideas as your own (e.g., plagiarism)." Examples of academic misconduct in this class include but are not limited to: copying solutions from the solutions manual, using solutions from students who have taken this course in previous years, copying your friend's homework, looking at another student's paper during an exam, lying to the professor or TA and incorrectly filling out the student workbook.

Attendance. Students should make every effort to attend the live sessions and to talk with students in the Slack chat forum to get help and assistance from others. It is practically impossible to follow the class if sessions are missed.

Absences. Make-up of missed exams requires permission from the Dean of Students, see "Academic Regulations." Midterm-exams are treated the same as Final Examinations. Students involved in official University activities that conflict with class time must inform the instructor in writing prior to the anticipated absence and take the initiative to make up missed work in a timely fashion. In addition, students who will miss class for a religious observance must "inform their instructor in writing within the first three weeks of the semester, and prior to the anticipated absence, and should take the initiative to work out with the instructor a schedule for making up missed work."

Adding or Dropping a Course. If you should decide to add or drop a course, there are official procedures to follow:

- Matriculated students should add or drop a course through the Student Administration System.
- Non-degree students should refer to Non-Degree Add/Drop Information located on the registrar's website.

You must officially drop a course to avoid receiving an "F" on your permanent transcript. Simply discontinuing class or informing the instructor you want to drop does not constitute an official drop of the course. For more information, refer to the online Graduate Catalog,

Academic Calendar. The University's Academic Calendar contains important semester dates.

Students with Disabilities. Students needing special accommodations should work with the University's Center for Students with Disabilities (CSD). You may contact CSD by calling (860) 486-2020 or by emailing csd@uconn.edu. If your request for accommodation is approved, CSD will send an accommodation letter directly to your instructor(s) so that special arrangements can be made. (Note: Student requests for accommodation must be filed each semester.)

Course Schedule*

Date[1]	Topic	Module	Details
Jan. 16-Jan. 18	*Course Introduction*		Homework 1, Due Jan. 26
Jan. 18-Jan. 25	*Intro to Optimization*	1	Homework 2, Due Feb. 2
Jan. 25-Feb. 1	*Convex Analysis & Unconstrained Programming*	1	Homework 3, Due Feb. 9
Feb. 1-Feb. 8	*Constrained Programming & Optimal Design*	1	Homework 4, Due Feb. 16
Feb. 8-Feb. 15	*Uncertainty in Design*	2	Homework 5, Due Feb. 23
Feb. 15-Feb. 22	*Uncertainty Analysis*	2	Homework 6, Due Mar. 2
Feb. 22-Mar. 1	*Model Validation & Parameter Estimation*	2	Homework 7, Due Mar. 9
Mar. 1-Mar. 8	*Design of Experiments*	3	Homework 8, Due Mar. 23
Mar. 8-Mar. 22	*Sensitivity Analysis & Marginal Costs*	3	Homework 9, Due Mar. 30
Mar. 22-Mar. 29	*Design & Operations Under Uncertainty*	4	Homework 10, Due Apr. 6
Mar. 29-Apr. 5	*Probabilistic Robust Design*	4	Homework 11, Due Apr. 13
Apr. 5-Apr. 12	*Formal Robust Design*	4	Homework 12, Due. Apr. 20
Apr. 12-Apr. 19	*Flexibility Analysis*	5	Work on Final
Apr. 26	*Course Summary/Final Project Presentations*		

* Schedule is tentative and may change
[1] First Date indicates release of lecture modules

Instructor's Contact Information:

- Matthew Stuber: matthew.stuber@uconn.edu Phone: (860)486-3689
- Office Hours: Live Sessions Thursday, 5-8PM ET

Helpful Links:

- Virtual Computer Lab at UConn: http://skybox.uconn.edu/
- Course Material: https://lms.uconn.edu
- Institute for Advanced Systems Engineering: http://www.utc-iase.uconn.edu/