SYDE 531: Design Optimization Under Probabilistic Uncertainty

Instructor: K. Ponnambalam (*call me "ponnu"*)

Office hours: Email me anytime for a reply and to fix an appointment, if needed.   ponnu@uwaterloo.ca (**Your email subject heading should start with SYDE 531 when emailing me for course help**)

Course URL: Use Tophat (as invited) and Learn

SYDE 531 LEC,TUT 0.50 Course ID: 013383 **Design Optimization Under Probabilistic Uncertainty**

Optimization methods for real world problems have to deal with probabilistic uncertainty either due to data uncertainty or manufacturing uncertainty or both. Maximizing the expected value of the objective function subject to reliability (or risk) constraints is commonly used in such design or decision-making problems. Common methods used are stochastic programming, stochastic dynamic programming, chance-constraints, yield optimization and tolerance design. Example applications are selected from water management, energy systems, financial engineering, and manufacturing. [Offered: F]

Course Objectives: The main goal of this course is to make students familiar with suitable optimization methods for use in design optimization affected by various sources of probabilistic uncertainties. [All CEAB attributes are addressed in some fashion; see the list below].

Evaluation:

Assignments + Class participation (individual)	10%
Computer assignments (in class/tutorial)	20% (Group: 2 individuals)
Midterm Exam (in Class)	25% (individual; max 2 hrs)
Final Exam (Theory part in class)	30% (Individual; max 2.5hrs)
Practical Exam	15% (Group: 2 individuals)

Practical exam is an application of one or more methods from the course to solve a given problem with computational methods and tools (Matlab) learnt in the class for an application

All assignments computer code must be submitted in softcopies.

General Overview of the Course: (More details in Schedule; see in Tophat)

Introduction to SYDE 531 (First class – 1 week)

- General formulation of an optimization problem - Designing systems under uncertainty

A. Review of Optimization (2 Weeks)

- Dynamic Programming - Unconstrained Optimization - Constrained Optimization - Expanded Lagrangian Function (EFL) Optimization - Normalized Expanded Lagrangian Function (NEFL) Optimization

B. Review of Probability Theory and Probability Estimation (2 Weeks)

 - Random Variables and their Moments

 - Functions of Random Variables and their Moments (First Order Second Moment method)

- Chebyshev's inequality [SEP]

- Monte-Carlo Simulation of random variables [SEP]

- Markov Chains [SEP]

C . Robust Design (2 Weeks) [SEP]

D. Stochastic Programming and Chance-Constrained Programming (2 Weeks)

E. Stochastic Dynamic Programming (1 Weeks) [SEP] Final Examination (1 Week) [SEP] Practical Examination (~2 Weeks) [SEP]

The Tophat book of mine is sufficient that presents all the above material. However, there are reference books and articles that could be used in addition if students wish to.

Section A: [SEP] Bertsekas, D.P., Chs 1,3-4 of Nonlinear Programming, Athena Scientific, Mass., 1995 [HARD]

Section B: [SEP] Papoulis, A., Chapters 1-7 of Probability, Random Variables, and Stochastic Processes, 3rd Edition, McGraw-Hill Publ., 1991 [HARD]

Section C: Structural Design Optimization Considering Uncertainties: Structures & Infrastructures Book , Vol. 1, Series, Series Editor: Dan M. Frangopol Hardcover – Mar 24 2008 [HARD]
by Yannis Tsompanakis (Editor), Nikos D. Lagaros (Editor), Manolis Papadrakakis (Editor)
ISBN-10: 0415452600
ISBN-13: 978-0415452601

Hillier, F.S., and G. J. Lieberman, Chs 1-3,5 of Intro. to Stochastic Models in Ope. Res., McGraw-Hill, 1990.

Section D, and E : [SEP] Hillier, F.S., and G. J. Lieberman, Chs 8,11 of Intro. to Stochastic Models in Ope. Res., McGraw-Hill, 1990.

Wagner, H.M., Ch 16 of Principles of Operations Research, 2nd Ed., 1975. Reference Textbooks:

Introduction to Stochastic Programming
Authors: John R. Birge, François Louveaux
ISBN: 978-1-4614-0236-7 (Print) 978-1-4614-0237-4 (Online)

Research Papers and Related Sections in the Course(An asterisk indicates that the author was a student of this course):

*Sadjadi S.J., and K. Ponnambalam, 1997. Advances in trust region algorithms for constrained optimization, Applied Numerical Mathematics, Vol 29., 423-443, 1999. [Section A].

*Shavezipur, M. , K. Ponnambalam, Khajepour, A., and Hashemi, S. M., 2008. Fabrication uncertainties and yield optimization in MEMS tunable capacitors, *Sensors and Actuators A: Physical*, 147, 613-622. [Sections B and C]

*Alvarez, J., K. Ponnambalam, and V. H. Quintana, 2007, Generation and transmission expansion under risk using stochastic programming, *IEEE Transactions on Power Systems*, 22 (3), 1369 – 1378. [Section D]

**Mahootchi, Masoud , K. Ponnambalam, H. Tizhoosh, 2010. Comparison of risk-based optimization models for reservoir management, *Canadian J. of Civil Engineering*, 37, 112-124. [Sections D and E]

Writing and Communication Centre.
The Writing and Communication Centre works with students in all Faculties to help you consider your audience, clarify your ideas, develop your voice, and write in the style appropriate to your discipline. We offer one-on-one support for writing papers, delivering presentations, integrating research, and revising for clarity and coherence. Group appointments for team-based projects, presentations, and papers are also available.
All of our services are available virtually: booked appointments, drop-ins, resources, and writing groups. Check out our website for other ways to interact with us, such as open online forums and online "Question and Answers". Visit us at www.uwaterloo.ca/wcc.
Please note that communication specialists guide you to see your work as readers would. We can teach you revising skills and strategies, but will not change or correct your work for you. Please

bring your assignment instructions and any notes or drafts to your appointment.
[Link **Writing and Communication Centre**]

Course and Departmental Expectations

Guiding Principles for our SYDE-BME Community (faculty, staff, and students):
1) Be compassionate. 2) Be accountable. 3) Be patient. 4) Be safe and healthy.

Compassionate and respectful communication: Most online communication between the Department and students will be done through LEARN and/or email. Students are reminded that they should now use their email account name@uwaterloo.ca. Include an academic signature with your full name, program, student ID. We encourage you to include your preferred pronouns (he/him; she/her; they/them).

SYDE-BME COMMENT ON ACCOMMODATION: We respect that our SYDE-BME students are independent adult decision-makers, with many opportunities to partake in activities that might be in time conflict with academic deadlines and deliverables. Along with the right to make adult decisions comes the responsibility and accountability for those decisions and any outcomes.
The University of Waterloo's policy on accommodation for missed deliverables pertains to verifiable health matters, and highly unfortunate events (for example: family tragedies). The Department of Systems Design Engineering follows University of Waterloo's general policy: students who self-elect to forgo a deliverable receive a "0" for that deliverable. It is preferred practice so that fairness is maintained for members of the same class/course by avoiding preferential treatment, and so that instructors are not burdened with having to create extra quizzes, deliverables, etc. It also reflects professional practice, as failing to show up to work and missing deadlines can be very costly to the company and individual (for example: not submitting a contract proposal, or design review on time). *Please read the policy here:* [Link Accommodation due to illness]

SYDE-BME Academic Priorities over Co-op Interviews: With asynchronous schedules, students should be able to arrange co-op interviews that do not conflict with major deliverables (for example: timed course midterms, final exams). For deliverables with longer time

windows (for example: 24-48 hours or more), students must manage their time for deliverables and co-op interviews accordingly. If a co-op interview conflicts with a short deliverable time window (for example: 1-3 hours), then students MUST follow the CECA procedure for rescheduling the interview: [Link CECA rescheduling co-op interviews]

Compassionate Accommodation: If you are facing challenges that are affecting more than one course contact the Associate Chair Undergraduate (A.C.U.G. email: sydeunde@uwaterloo.ca) or the Director of BME (email: sdbmedir@uwaterloo.ca). They will review your case and coordinate a reasonable and fair plan in consultation with appropriate others (for example: instructors, Department Undergraduate Studies Committee, Chair, AccessAbility Services, Engineering Counselling services, Registrar's Office).

FACULTY OF ENGINEERING – MORE FINE PRINT
Faculty of Engineering website: [Link Academic Support and Policies].

Academic Integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect, and responsibility.
[Check Academic Integrity website for more information. Link Office of Academic Integrity].

Discipline: A student is expected to know what constitutes academic int egrity (see link above) to avoid committing an academic offence, and to take responsibility for their actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (for example: plagiarism, cheating) or about expectations for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. Relevant documents include:
- University of Waterloo Policy 71 [Link Policy 71 Student Discipline].
- Academic Penalty Guidelines [Link Policy 71 Penalty Guidelines].
- Assessment of Unauthorized Collaboration: [Link Assessment of Unauthorized Collaboration].

Grievance: A student who believes that a decision affecting some aspect of their university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4. When in doubt please be certain to contact the **Associate Chair Undergraduate or Academic Advisor** who will provide further assistance.
[Link Policy 70 Petitions & Grievance.]

Appeals: A decision made, or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes they have a ground for an appeal should refer to Policy 72 (Student Appeals)
[Link Policy 72 Student Appeals].

AccessAbility Services: AccessAbility Services (A.A.S.) is the University's centralized office for the provision of academic accommodations for students with a known or unknown disability, illness, or condition. Even if students are unsure of whether they qualify for A.A.S. support, an A.A.S. consultant can talk them through next steps, and refer them elsewhere if appropriate.
[Link AccessAbility Services].

<p style="text-align:center;color:red;font-weight:bold;">CEAB Graduate Attributes (GA)</p>

The numbers in parentheses in the students learning objectives above refer to the CEAB Engineering Graduate Attributes defined by the Canadian Engineering Accreditation Board. These are listed below as a reference:

GA.	Attribute.	Attribute Definition.
1	**Knowledge Base.**	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.
2	**Problem analysis.**	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.
3	**Investigation.**	An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of

		information in order to reach valid conclusions.
4	**Design.**	An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.
5	**Use of Engineering Tools.**	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.
6	**Individual and team work.**	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.
7	**Communication skills.**	An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.
8	**Professionalism.**	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.
9	**Impact of engineering.**	An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.
10	**Ethics and equity.**	An ability to apply professional ethics, accountability, and equity.

11	**Economics and project management.**	An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.
12	**Lifelong learning.**	An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.