IE598 – Optimization Under Uncertainty

General Information

Lectures: 147 Loomis Laboratory, T&Th 2:00-3:20 PM in person (links to lecture material will be available on Canvas `https://canvas.illinois.edu/courses/42570`)

Instructor: Prof. Grani A. Hanasusanto

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Prerequisites: Graduate-level knowledge of linear programming, integer programming, nonlinear programming, probability, and statistics. Knowledge of convex optimization and analysis is beneficial. Students are expected to be comfortable with <u>advanced mathematical formality and reasoning</u>.

Course Description: A wide variety of decision making problems in engineering, science, and economics involve uncertain parameters whose values are unknown to the decision maker when the decisions are made. The underlying uncertainty of these problems may arise from incomplete data, measurement errors or the inherent stochastic nature of the respective problems. Ignoring this uncertainty can lead to inferior solutions that perform poorly in practice.

The goal of this course is to introduce optimization models and methodologies that address uncertainty-affected decision problems. The course will introduce fundamental techniques from stochastic programming, robust optimization, and distributionally robust optimization. The theory will be motivated through concrete examples from production planning, supply chain management, project management, portfolio selection, machine learning, etc.

Didactic Approach: The course will be taught in the <u>classical formal teaching fashion</u>. The material will be presented at a modern research level and the main results will be <u>proved rigorously</u>.

Learning Outcomes: By the end of the course, the student must be able to:

- Formulate uncertainty-affected decision problems as formal mathematical optimization models
- Solve the resulting models using standard off-the-shelf optimization solvers and interpret the results
- Appreciate the benefits and the shortcomings of different paradigms for optimization under uncertainty

Topics Covered:

- **Introduction:** Convex optimization, duality theory, probability theory

- **Three paradigms:** Stochastic optimization, robust optimization, distributionally robust optimization, risk measures

- **One-stage piecewise-linear models**:

    - Stochastic: reformulation for discrete distribution
    - Robust: reformulation via duality
    - Distributionally robust: reformulation for mean-covariance ambiguity sets

- **Two-stage linear models:**

    - Stochastic: reformulation for discrete distribution, approximation via decision rules, Monte Carlo sampling mathods, Benders decomposition
    - Robust: NP hardness, Benders decomposition

- **Multi-stage linear models**: Stochastic dual dynamic programming

Software:
- Python via the Anaconda distribution (`https://www.anaconda.com/`)

- CVXPY

Texts (optional):
1. A. Shapiro and D. Dentcheva, *Lectures on Stochastic Programming: Modeling and Theory*, SIAM, 2014.

2. A. Ben-Tal, L. El Ghaoui, and A. Nemirovski, *Robust Optimization*, Princeton University Press, 2009.

Grading Policy: In this course, there will be several homework assignments, one project and one final exam. The weightings are as follows:

Homework Assignments	40%
Project (groups of 2 or 3)	35%
Final Exam	25%

Homework assignments are due at the beginning of class on designated days. On these assignments, you are allowed and in fact encouraged to discuss the problems with your classmates. However, you *must* write your own solution. Late assignments will not be accepted.

Attendance and Exam Policy: While attendance is not taken, you are expected to attend each lecture on time and take notes to prepare for your homework assignments, project and exam. You are required to take the exam at the scheduled time. Make-up exams will not be given without a valid medical excuse.

Additional Information

- **Sexual Misconduct Reporting Obligation:** The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.
A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: `https://wecare.illinois.edu/resources/students/#confidential`. Other information about resources and reporting is available here: `https://wecare.illinois.edu`.

- **Academic Integrity:** The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: `http://studentcode.illinois.edu/`. Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: `https://studentcode.illinois.edu/article1/part4/1-401/`. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

- **Religious Observance:** Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at `https://odos.illinois.edu/community-of-care/resources/students/religious-observances/` to request appropriate accommodations. This should be done in the first two weeks of classes.

- **Disability-Related Accommodations:** To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, email disability@illinois.edu or go to `https://www.disability.illinois.edu`. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnose a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

- **Family Educational Rights and Privacy Act (FERPA):** Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See `https://registrar.illinois.edu/academic-records/ferpa/` for more information on FERPA.

- **Anti-Racism and Inclusivity Statement:** The intent is to raise student and instructor awareness of the ongoing threat of bias and racism and of the need to take personal responsibility in creating an inclusive learning environment. The Grainger College of Engineering is committed to

the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Bias Assessment and Response Team (BART) (`https://bart.illinois.edu/`). Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.