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

IE411 Optimization of Large-Scale Linear Systems
Fall 2023

Lectures: 101 Transportation Building, T&Th 2:00-3:20 PM (links to lecture material will be available on Canvas)

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Overview: This course is about large-scale linear optimization, which is an important discipline for modeling and solving engineering and business problems. We will cover both the theory and computation of linear optimization and touch upon some relevant applications. Some important topics include: various applications; LP geometry; the simplex method; the interior point method; the decomposition principle and column generation; numerical implementation issues; duality theory and applications; and sensitivity analysis.

Objectives: The main objective is for the student to gain a deeper understanding of the fundamental theory and computation of linear optimization. In particular, an emphasis will be placed on the theoretical and computational aspects related to the simplex method and the interior point method.

Prerequisites: IE310 and MATH415

Textbooks:

1. Bazaraa, Jarvis and Sherali, *Linear Programming and Network Flows (fourth edition)*, John Wiley and Sons (2010). (*ebook free from the library,* required)
2. Bertsimas and Tsitsiklis, *Introduction to Linear Optimization,* Athena Scientific (1997).
3. Vanderbei, *Linear Programming: Foundations and Extensions (fourth edition),* Springer (2014). *(ebook free from the library,* optional*)*

Lecture Notes: Lecture notes will be posted on Canvas before the lectures. Caution: Lecture notes are only used to facilitate your understanding of the lectures and will be supplemented by additional notes/explanations on the blackboard.

Software: Excel Solver and Matlab will be the main tools used for this course.

Grading Policies: There will be individual homework every other week (roughly). Most of the exercises will be from the textbook(s). Some homework assignments will be computational. You are encouraged to discuss homework problems in groups. However, you must write your own solutions **(You are required to follow university policies on student conduct).** Please submit your homework through Canvas. ***No late homework is allowed without the instructor's permission.*** We will selectively grade homework problems.

We will have one project on coding the simplex method and three exams.

The homework will form 40% of the final grade and the project 15%. There will be three midterms, each of which comprises 15%. The details about the exams will be announced later in class.

Additional homework problems will be assigned to students registered for 4 credit hours.

Didactic Approach: The course will be taught in a classical formal teaching fashion. The material will be presented at a modern research level, and the main results will be proved rigorously. Students are expected to be comfortable with advanced mathematical formality and reasoning.

Tentative Schedule (subject to change, Chapters based on BJS10)

Week 1 (August 22 & 24): Chapters 1.1-1.3
Introduction; LP Models; LP Applications I
Homework 1 assigned on August 22

Week 2 (August 29 & 31): Chapters 1.1-1.3
LP applications II

Week 3 (September 5 & 7): Chapter 1.4
Mathematical preliminaries
Homework 1 due on September 7
Homework 2 assigned on September 7

Week 4 (September 12 & 14): Chapters 2.1-2.5
Geometry of LP I

Week 5 (September 19 & 21): Chapter 2.6-2.7, Chapter 3.1-3.2
Geometry of LP II
Homework 2 due September 19
Homework 3 assigned September 19

Week 6 (September 26 & 28): Chapters 3
Simplex method; Revised simplex method
September 26: Midterm I

Week 7 (October 3 & 5): Chapters 4
Starting solution and convergence: the Big-M method/two-phase method; Degeneracy and cycling
Homework 3 due on October 3
Homework 4 assigned on October 3

Week 8 (October 10 & 12): Chapters 5
Special simplex implementations and optimality conditions

Week 9 (October 17 & 19): Chapter 5
Duality theory; Applications of duality theory I
Homework 4 due on October 17
Homework 5 assigned on October 17
Dr. Hanasusanto is away for conference one day

Week 10 (October 24 & 26): Chapter 6
Applications of duality theory II
Homework 5 due on October 26

Week 11 (October 31 & November 2): Chapter 6
Dual simplex method
Homework 6 assigned on November 2
November 2: Midterm II

Week 12 (November 7 & 9): Chapter 6
Sensitivity analysis; Parametric analysis

Week 13 (November 14 & 16): Chapters 7
Column generation method; Lagrangian relaxation
Homework 6 due on November 16
Homework 7 assigned on November 16

Week 14 (November 21 & 23): Thanksgiving break

Week 15 (November 28 & 30): Chapter 8
Computational complexity of the simplex algorithm; Ellipsoid algorithm; Interior point method
Homework 7 due on November 30

Week 16 (December 5):
December 7: Midterm III

December 5: Coding project due

Emergency Planning

In an emergency in this building, we'll have three choices: **RUN** (get out), **HIDE** (find a safe place to stay inside), or **FIGHT** (with anything available to increase our odds for survival).

First, take a few minutes this week and learn the different ways to leave this building. If there's ever a fire alarm or something like that, you'll know how to get out, and you'll be able to help others get out too.

Second, if there's severe weather and leaving isn't a good option, go to a low level in the middle of the building, away from windows.

If there's a security threat, such as an active shooter, we'll **RUN** out of the building if we can do it safely, or we will **HIDE** by finding a safe place where the threat cannot see us. We will lock or barricade the door, and we will be as quiet as possible, which includes placing our cell phones on silent. We will not leave our area of safety until we receive an Illini-Alert that advises us it is safe to do so. If we cannot run out of the building safely or we cannot find a place to hide, we must be prepared to fight with anything we have available in order to survive. **Remember, RUN away or HIDE if you can, FIGHT if you have no other option.**

Finally, if you sign up for emergency text messages atemergency.illinois.edu, you'll receive information from the police and administration during these types of situations.

If you have any questions, go to police.illinois.edu, or call 217-333-1216.

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: wecare.illinois.edu/resources/students/#confidential.

Other information about resources and reporting is available here: 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 Observances

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.