Optimization II (ORIE 3310/5310)

Spring 2024

Instructor:	Oktay Günlük
Email:	ong5@cornell.edu
Office hours:	Rhodes 221, Wed 3-4PM, or by appointment
Head TA	Ishan Bansal (ib332)
PhD TAs	Hannane Yaghoubizade (hy465), Trang Tran (htt27)
MEng TA	Taojie Wang (tw533)
Undergrad TAs	Andrew The (alt73), Jian Kai Ang (ja686) , Saniya Vaidya (ssv33), Francis Bahk (feb47)
Lectures:	Mon and Wed 1:25PM - 2:40PM, Gates Hall G01
Labs:	Tu 10:10AM - 12:05PM, Rhodes Hall 571 Tu 2:30PM - 4:25PM, Rhodes Hall 453 We 10:10AM - 12:05PM, Rhodes Hall 571
Credit Hours:	4

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1 Course Description

In this course we will cover the following topics

Integer programming: Formulation and modeling; Branch and bound, cutting planes, constraint generation for solving large-scale problems

Network optimization: Minimum-cost network flow, maximum flow, Ford-Fulkerson algorithm; the shortest-path problem; the assignment problem, the Hungarian algorithm

Dynamic programming: Bellman equation, principle of optimality; applications to the knapsack problem, the shortest-path problem, inventory planning; stochastic dynamic programming

1.1 Course Objectives and Learning Outcomes

- Learn a breadth of optimization topics: problems and algorithms beyond basic linear programming and simplex method.
- Analyze optimization problems and algorithms.
- Understand the importance of problem assumptions .
- Learn why these algorithms work and how efficient they are.
- Learn how to apply these models and algorithms to actual problems.

1.2 Prerequisites

The prerequisites for this course are comfort with linear algebra and knowledge of ORIE 3300/5300 material, which include: formulating linear programs, the simplex method, and related topics such as linear programming duality.

Jupyter notebooks and OR Tools will be used extensively throughout the course.

2 Class Format

- There will be 75 minute lectures in a classroom 2 times a week.
- In addition, each student will attend a 2 hour lab for recitation exercises.
- There will be weekly homework assignment as well as lab assignments.
- Overall, the students are expected to spend 90 hours of supplemental work during the semester.

2.1 Recitation Exercises

There will be a computing exercise during each recitation which you must complete during the recitation section and submit on Gradescope. Each exercise can be done individually or in pairs and will be graded out of four points, based on attendance and effort. Unless approved by the head TA, you are required to attend the recitation session that you are enrolled in.

3 Course Reading

Lectute notes: We will treat this document, which is available on Canvas, as a textbook.

Additional resources: If you would like to read additional material related to this course, you may consider the textbook by Wayne L. Winston titled *Introduction to mathematical programming : operations research*, which covers most of the topics studied in 3300 and 3310. Note that this is not a requited textbook for this course.

4 Course Websites

The Canvas site will contain all of the information that you need in this course, including staff information and office hours, lecture notes, homework assignments and solutions, exam preparation material, course announcements. Make sure that you are enrolled on the course Canvas site and that you **check the site regularly** for updates, announcements, and new material.

We will use Gradescope for homeworks and exam grades. We will use Ed Discussions as a place to ask and answer questions about the course content and the homework, which can be accessed via Canvas. Please post your questions and feel free to answer other students' questions there. If you email the course staff to ask questions regarding course content and homework, we will redirect you to Discussions site. Participation either in the form of asking or answering questions will be considered for part of a course participation grade.

Canvas: `https://canvas.cornell.edu/courses/59783`

Gradescope: `https://www.gradescope.com/courses/715386`

Ed Discussions: `https://edstem.org/us/courses/54464/discussion/`

5 Assessments and Grades

Course grade will be based on homework sets, two prelim exams, one final exam, recitation exercises, and lecture/recitation/Discussion participation. The final exam will be cumulative, covering all topics studied during the semester. The participation grade also includes filling out a course survey from the Engineering College at the end of the semester.

Homework	20%
Prelim 1	20%
Prelim 2	20%
Final Exam	30%
Recitation Exercises	10%
Lecture/Recitation/Discussions participation	5%
Total	105%

Letter grades will be given based on the total grade using a curve. 80% attendance is required.

5.1 Class Participation and Attendance

Students are strongly encouraged to attend lectures and actively participate by asking for clarifications and answering questions.

5.2 Homework Assignments

Submitting homework: Weekly homework assignments will be posted on Canvas and are due at **9PM on Tuesdays**. They should be submitted through **Gradescope** and emailed homeworks will not be accepted.

Solutions: Homework solutions will be posted on Canvas after 9pm on Thursday.

Late homework: Each student may turn in **two homeworks late** without penalty during the course of the semester. Any late homework must be turned in by **9pm on Thursday the same week**.

The ability to turn in two homeworks late is intended to cover all situations in which you might want to turn in a homework late, including illness, travel, interviews, getting locked out of your room prior to the deadline, nonfunctional laptops and printers, etc. Please use your late homework wisely since once you have turned in two homeworks late no further late homeworks will be accepted.

Dropped homework grade: One lowest homework grade will be dropped. If you don't submit a homework, it will be given a zero and can be the dropped homework.

Regrade requests: If you found that your graders made a grading mistake, clearly describe your request for regrade on **Gradescope**. Regrade request must be submitted **before the next homework is due**. Any regrade request may require us to regrade your entire homework, not just the grading mistake, and so the overall resulting grade could be either higher or lower. Regrade requests will be handled by Grad TAs.

5.3 Exams

Exams will take place on the following dates:

Exam	Date and time	Location
Prelim 1	2/22/2024, 7:30 p.m.	HKMBB11
Prelim 2	4/16/2024, 7:30 p.m.	STL196, STL265
Final Exam (cumulative)	Date TBA	Location TBA

5.4 Additional Requirements for 5310 Students

Graduate students enrolled in ORIE 5310 must demonstrate advanced mastery of the material: assignments and exams may differ from those for the parallel undergraduate course ORIE 3310. Grading curve for 5530 students will be separate from 3310 students.

6 Weekly Lectures

Week 1: Lab 0: Installation/set-up

(a) Course Intro, LP review
(b) Production Planning and Labor Scheduling
(c) Upper/lower bounds and IP intro

Week 2: Lab 1: Transportation problem

(a) B&B
(b) 0-1 Knapsack problem
(c) Integer Knapsack and Comparing Formulation and Facility Location

Week 3: Lab 2: Branch-and-bound

(a) Several formulations for Clustering
(b) Quadratic assignment problem, SVM
(c) Big M for Lot sizing, Subset Sum

Week 4: Lab: 3: Clustering

(a) Valid inequalities, convex hulls, cutting planes
(b) Cutting planes for knapsack problem

Week 5: Lab 4: Gomory Cuts

(a) General IPs: Formulation cuts and Gomory fractional cuts

(b) Cover inequalities

Week 6: No lab

(a) Feb. Break

(b) Cutting stock

Week 7: Lab 5: Column generation

(a) Solving the Gilmore and Gomory LP: Column Generation

(b) Cutting stock example and IP heuristic.

(c) Intro to graphs + Min cost flow

Week 8: Lab PS1: Prelim scheduling (part 1)

(a) Shortest paths – special case

(b) Max flow – special case

(c) Max-flow MCF reduction and Assignment problem MCF reduction

Week 9: Lab PS2: Prelim scheduling (part 2)

(a) Ford-Fulkerson and min cut

(b) Project selection

Week 10: Lab 6: FordFulkerson

(a) Assignment IP/ algorithm

(b) Hungarian Algorithm

Week 11: Spring Break

Week 12: Lab 7: Hungarian Algorithm

(a) DP intro: Shortest paths in layered networks

(b) DP: Critical path analysis

(c) DP: Production planning

Week 13: Lab 8: DP and March Madness

(a) DP: Non-linear Knapsack

(b) DP: Stochastic DP

Week 14: Lab 9: Stochastic DP and March Madness

(a) DP: Stochastic production planning

(b) DP: Hidden Markov models

Week 15: Lab 10: TSP and subtour elimination constraints

(a) TSP part I

(b) TSP part II

Week 16: Other possible topics

(a) Scheduling jobs on machines

(b) Assignment dual LP and Hungarian algorithm

(c) Game theory

(d) Multicommidity flows

7 Academic Integrity

Cornell's Code of Academic Integrity can be found at `https://cuinfo.cornell.edu/aic.cfm/` Violations of the Code of Academic Integrity, especially plagiarism, may result in a failing grade in the course. Students are urged to read and complete the exercises on "Recognizing and Avoiding Plagiarism" at: `http://plagiarism.arts.cornell.edu/tutorial/index.cfm`. Buying, selling, or reposting course materials on external websites will be considered an academic integrity violation.

Your work on the written homework and exams should be your own. For the homework, you may discuss approaches to problems with other students, but as a general guideline, such discussions may not involve taking notes. You must write up solutions on your own independently, and acknowledge anyone with whom you discussed the problem. You may not discuss exam problems with other students.

For the recitation exercises, you may work with a partner, and you and your partner may turn in a single assignment.

If you have any concerns about your learning, grades, or progress in the course, or if you have other difficulties, feel free to talk to me or any of the TAs. Other resources at Cornell are also available (`http://caringcommunity.cornell.edu/`).

8 Personal Conduct

The Program/Department expects students to be respectful and professional in all participation and communication. You are expected to maintain professional conduct and speech in all aspects of this course. Professional behavior demands you have a responsible and mature attitude in person and online. Disrespectful, unethical, and/or unprofessional behaviors will not be tolerated and can result in course failure and/or dismissal from the program.

9 Inclusivity/Diversity Statement

Inclusive Learning Environment: Cornell supports an inclusive learning environment where diversity and individual differences are understood, respected, appreciated, and recognized as a source of strength. It is expected that students in this class will respect differences and demonstrate diligence in understanding how other peoples' perspectives, behaviors, and worldviews may be different from their own. Adapted from the University of Colorado's College of Education and Behavioral Science found at `https://www.unco.edu/education-behavioral-sciences/about-us/diversity-equity/framework.aspx`.

10 Disabilities Statement

If you have a disability-related need for reasonable academic adjustments in this course, provide Professor Gunluk with an accommodation letter from Student Disability Services. Students are expected to give two weeks' notice of the need for accommodations. If you need immediate accommodation, please arrange to meet with Professor Gunluk via Zoom within the first week of classes.

11 Attestation

By registering for this class and accessing course materials through Canvas, students agree to abide by University, College, Department, and Course policies.