IND E 599 Integer Programming

Syllabus for Winter 2022

Class Hours: TR 2:30–3:50pm
Classroom: TBD

Instructor: Chaoyue Zhao
Office Hours: MW 1:30pm-2:30pm, or by appointment
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Catalog Description: Theory, algorithms, and applications of integer programming. Formulation of binary, pure, and mixed integer linear programs, relaxations, preprocessing, branch and bound, cutting plane methods; theory of polyhedra, convex hulls and facets, theory of valid inequalities, lifting and projection.

Course Objectives: Many large-scale problems arising in practice, such as supply chain optimization and communications network design, involve discrete decision variables. In recent years, the integration of theoretical and algorithmic advances in integer programming into optimization software drastically increased our ability to solve large-scale integer programs. In this course we will cover integer programming theory and algorithms, so that at the end of this course you will be able to

1. develop good models for optimization problems that involve discrete variables and combinatorial constraints,
2. apply the theory learned to design effective algorithms to solve large-scale integer programs in practice,
3. implement the algorithms designed using modeling and optimization softwares such as AMPL and CPLEX.

Prerequisite: It is generally expected that students will have taken (or be concurrently enrolled in) IND E 513 Linear Optimization Models In Engineering (specifically: how to formulate LPs and concepts from linear programming).

Texts: Conforti, Cornuéjols, and Zambelli, *Integer Programming*, Springer, 2014. (A modern take on IP)
Free PDF here: http://link.springer.com/book/10.1007%2F978-3-319-11008-0
Jeff Linderoth's slides: http://homepages.cae.wisc.edu/~linderot/classes/ie418/index.html

Other References: Wolsey, *Integer Programming*, Wiley, 1998. (Accessible)
Nemhauser and Wolsey, *Integer and Combinatorial Optimization*, Wiley, 1999. (Comprehensive)
Schrijver, *Theory of Linear and Integer Programming*, Wiley, 1998. (Highly mathematical)

Evaluation Procedure:
⋄ Homework 25%
⋄ Projects 25%
⋄ Midterm 25%
⋄ Final 25%

Class Policies:

1. *Final exam shall be held at the time listed in the official schedule.* It is your responsibility to make sure that you will be available to take the final exam at the said time. No exceptions will be made, and a make-up for the finals will be offered only under *extenuating circumstances* (such as medical reasons), and only if permitted by the university.

2. All tests will be comprehensive up to a specified topic although emphasis will be on newer material. No make-ups will given for the tests unless prior arrangements have been made with the instructor, and a written *authorized* excuse is provided. The validity of the excuse will be determined by the instructor. If a test is missed due to an emergency, inform the instructor as early as possible.

3. Homework assignments and projects are to be completed individually. You are allowed to discuss the class material pertinent to assignment questions with your class mates, but you *should not* share your solution with another person. When in doubt, avoid discussion and contact the instructor for help. Specific instructions will be provided with each assignment.

4. Late homework submissions *will not be accepted* for grading. Contact the instructor at least 2 days in advance if you are not able to meet the deadline, or within 2 days from the deadline if unforeseen circumstances forced the delay. Decision to give full/partial/no credit will be made by the instructor.

5. There will be one project to be completed individually. This will involve computer implementation of the methods described in the class. More details about the project will be provided during the quarter.

6. No disagreement on a score received on any graded material will be entertained 5 working days after the date it was returned.

Academic Misconduct Process: Quoted from the College of Engineering website: "Engineering is a profession demanding a high level of personal honesty, integrity and responsibility. Therefore, it is essential that engineering students, in fulfillment of their academic requirements and in preparation to enter the engineering profession, shall adhere to the University of Washington's Student Code of Conduct. Any student in this course suspected of academic misconduct will be reported to the College of Engineering Dean's Office and the University's Office of Community Standards and Student conduct. Any student found to have committed academic misconduct will receive a 0-grade on impacted academic work." Please also review the syllabus attachments for information on UW Student Academic Responsibility. Information is also available online at: `https://depts.washington.edu/grading/pdf/AcademicResponsibility.pdf`

Religious Accommodations: Quoted from the registrar's website: "Washington state law requires that UW develop a policy for accommodation of student absences or significant hardship due to reasons of faith or conscience, or for organized religious activities. The UW's policy, including more information about how to request an accommodation, is available at `https://registrar.washington.edu/staffandfaculty/religious-accommodations-policy/`
Accommodations must be requested within the first two weeks of this course using `https://registrar.washington.edu/students/religious-accommodations-request/`."

Date	Tentative topic
Week 1	What is an IP? Formulating IPs - Selected problems: Assignment, knapsack, set cover, traveling sales man, facility location, lot sizing, flow-shop scheduling, job-shop scheduling, assembly line balancing, etc
Week 2	Formulating IPs - Continued Branch-and-bound for binary IP - (bounding, pruning, node selection strategies, variable selection strategy)
Week 3	Branch-and-bound for general IP and MIP - (bounding, pruning, node selection strategies, variable selection strategy) Comparing alternative formulations - Uncapacitated facility location problem
Week 4	Comparing alternative formulations - Uncapacitated lot sizing problem Cutting plane method - Definition and generic algorithm
Week 5	"optimization=separation" - Ellipsoid method Gomory Fractional Cuts
Week 6	**MIDTERM** (One page of handwritten notes) Branch-and-cut
Week 7	Preprocessing - Redundant constraints, coefficient tightening, variable fixing Convex hulls and Meyer's Theorem - Chvátal-Gomory (CG) cuts; CG rank; CG closure
Week 8	Mixed Integer Rounding (MIR) cuts & Gomory Mixed Integer (GMI) cuts Minimal descriptions; facets; dimension; aff. independence
Week 9	Direct facet proofs Generating facets by lifting (e.g., knapsack covers)
Week 10	Perfect formulations and their characterizations Total unimodularity and total dual integrality