University of Wisconsin-Madison
ISyE/Math/CS 728: Integer Optimization
Spring 2021 Syllabus

Basic Course Information

Canvas Course URL:	https://canvas.wisc.edu/courses/230933
Credits:	3
Contact hours:	2.5 hrs/week
Instructional mode:	Remote
Lecture and office hours:	See Zoom Link posted on Canvas web site
Grad 50%:	Counts toward 50% graduate coursework requirement
Required or elective:	Elective
Requisites:	Graduate or Professional Standing

UW-Madison Credit Hour Policy

This course meets the *Traditional Carnegie Definition* for how credit hours are met by the course. Students in the course have 2.5 hours/week of direct faculty/instructor instruction during lectures, and are expected to spend a minimum of two hours per credit hour on work related to this course outside of class time.

Instructors And Teaching Assistants

Instructor	Prof. Jim Luedtke
Office hours	Tuesday and Thursday 10:45am–11:45am in Zoom
Instructor Email	jim.luedtke@wisc.edu
Teaching Assistant	Rui Chen
TA Office Hours	Monday 1-2pm, Wednesday 2-3pm in Zoom
TA Email	rchen234@wisc.edu

Official course description

Introduces optimization problems over integers, and surveys the theory behind the algorithms used in state-of-the-art methods for solving such problems. Special attention is given to the polyhedral formulations of these problems, and to their algebraic and geometric properties. Applicability of Integer Optimization is highlighted with applications in combinatorial optimization. Key topics include: formulations, relaxations, polyhedral theory, cutting planes, decomposition, enumeration. Students are strongly encouraged to have knowledge of Linear Programming (e.g., ISyE/Math/CS/Stat 525), including algorithms, duality and polyhedral theory.

Course Learning Outcomes

After taking this course, students should achieve the following outcomes:

1. Learn the basics of polyhedral theory, which consists in the study of systems of linear inequalities both from an algebraic and a geometric point of view.
2. Understand perfect formulations and what properties are desirable in an integer programming formulation of a problem.
3. Understand how valid inequalities can be used as cutting planes to strengthen integer programming formulations.

Tentative List Of Topics To Be Covered

Following is a tentative schedule of the topics of the course. This is subject to change, and if time permits we may cover some topics not explicitly listed here.

Topic
Branch& bound and cutting planes
Integer programming models
Integer programming software
Perfect formulations
Decomposition methods
Polyhedral theory and strong valid inequalities
General purpose valid inequalities

Required Textbook, Software & Other Course Materials

There is no required textbook. The recommended textbook is *Integer Programming* by M. Conforti, G. Cornuéjols, and G. Zambelli. Springer, 2014. ISBN: 978-3-319-11008-0

Some supplemenaty texts are as follows:

Integer Programming, Laurence A. Wolsey. Wiley-Interescience, 1998.
Theory of Linear and Integer Programming, Schrijver. John Wiley & Sons, 1986.
Integer and Combinatorial Optimization, Nemhauser and Wolsey. 1988.

Grading

The course grade will be based on a weighted average of these components.

- 25% Homework
- 35% Midterm exam
- 35% Option: Final exam or final course project
- 5% Participation

Both exams will be take-home exams. Exams may have a computational component. The midterm exam will be posted at March 14 at 1pm, and is due March 16 at 1pm. The final final exam (for students who choose that option) will be posted May 2 at 1pm, and is due May 4 at 1pm. The final project (for students who choose that option) is due May 4 at 1pm.

The course will be graded on a curve, consistent with standards in existing graduate level courses in ISyE, Math, and CS. Specifically:

- A (approximately 45%): Requires consistent high performance across homeworks and exams.
- AB (approximately 25%): Requires solid performance on most class work, not quite at the standard of A.
- B (approximately 20%): Requires moderate performance on most classwork, demonstrating a grasp of most concepts in the curriculum.
- BC (approximately 5%): Requires acceptable performance on most classwork.
- C (typically less than 5%): Requires acceptable performance on a majority of classwork, with some significant gaps in understanding of a minority of concepts and possible several missed homeworks.
- D: (typically less than 5%): Requires marginally satisfactory performance.
- F: (typically less than 5%): Unacceptable performance.

Homework

Homework assignments will be given roughly every two weeks, and are a required part of the course. It may not always be possible to grade the homework assignments in full. If not, a subset of questions will be selected to be graded in detail, and the rest will be checked for the general idea. Examples of correct solutions will be provided, and especially for questions that aren't graded in detail, it is important that the students self-check their solutions and make sure they understand the correct solutions. The assignments should be submitted electronically in pdf format in the Canvas web site. Late submission policy: 20% of total points will be deducted per hour.

Students are encouraged to work in groups of two on homework assignments. Groups must work independently of each other, may not share answers with each other, and solutions must not be copied from the internet or other sources. If improper collaboration on an assignment is detected, *all groups* involved will automatically receive a 0 on the assignment in question. In any assignment, students must properly give credit to any outside resources they use (such as books, papers, etc.). Please note that as the exams must be done independently, it is in each student's best interest to take an active role in all homework exercises.

Optional course project

Students have the option to do a course project in groups of at most two people (individual projects are allowed, but I strongly encourage students to work with a partner). Students who do the course project will not take the final exam. If you do a project with a partner and also do your homework assignments with a partner, your **partners for the homework assignments and the project must be different.**

Project topics must be approved by me. I may be able to provide some suggestions on project topics, or you can choose a topic that is interesting to you, e.g., it may be related to your research. Students must submit to me a proposed project topic by **April 9** at the latest if they choose to do a project, although it is advised to start on the project earlier than this deadline if possible.

For projects that are done in a team, group members will be asked to anonymously describe each team member's contribution.

Other Course Information

Required background

A prerequisite for this course is a good understanding of mathematical arguments. This includes the basic vocabulary for mathematical statements, and the basic principles for proving statements. All these concepts are presented in the document "Introduction to mathematical arguments" by Michael Hutchings, which is available in Canvas. The only way to further develop skills with writing proofs is by experience. We will do formal proofs in the course, and students will be expected to prove things in assignments and on exams.

Students must have working knowledge of linear algebra, including set theory, vectors and matrices, matrix inversion, subspaces and bases, and affine subspaces. An overview of these concepts can be found in Section 1.5 of the 525 recommended textbook: "Introduction to Linear Optimization" by D. Bertsimas, and J.N. Tsitsiklis.

This course requires knowledge of Linear Optimization, including geometry of linear programming, the simplex method, and duality theory. See Chapters 1-4 of the 525 recommended textbook: "Introduction to Linear Optimization" by D. Bertsimas, and J.N. Tsitsiklis.

Some assignments will require implementation of algorithms. Thus, some computer programming experience is strongly encouraged before taking this course. You may use any language you like for the assignments (provided it can interface with an integer programming solver such as Gurobi), but examples will be done in Python and I will only be able to provide (minimal) help with Python.

Course web site

The Canvas web site is where lecture slides, homework assignments, homework solutions, and grades will be posted. Students will use the Canvas web site also to submit the assignments electronically in pdf format and to view the TA's comments.

The Canvas web site contains also two documents that cover some of the prerequisites. For basic proof techniques, see the document "Introduction to mathematical arguments." For mathematical notation, see the document "Math symbols cheat sheet."

The Canvas web site also has a link to a Piazza page for the course. We will use the Q&A Forum within Piazza for all questions related to this course. When students have a question related to this course, they should first check this Q&A forum to see if it has already been answered, and if not, post their question there. This way, all students benefit from the question and the answer. Students are also allowed, and encouraged, to answer questions posted by other students, and doing so will contribute to their participation score. Students are allowed to post questions anonymously so that the class will not know who asked the question.

Classroom participation

Students are expected to attend lectures or view the lecture recordings. Students are encouraged to attend the lectures live when possible, and participate by asking and answering questions. Students are asked to keep themselves muted during lecture, except when they are called on to ask a question. Students wishing to ask a questions should either "raise hand" in zoom, or simply type into the chat.

Related courses

- ISyE/Math/CS 425: Introduction to Combinatorial Optimization
- ISyE/CS 524: Introduction to Optimization
- ISyE/Math/CS/Stat 525: Linear Programming Methods
- ISyE/CS 719: Stochastic Programming
- CS/ISyE/Stat/Math 726: Nonlinear Optimization I

Academic Integrity

By enrolling in this course, each student assumes the responsibilities of an active participant in UW-Madison's community of scholars in which everyone's academic work and behavior are held to the highest academic integrity standards. Academic misconduct compromises the integrity of the university. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these acts are examples of academic misconduct, which can result in disciplinary action. This includes but is not limited to failure on the assignment/course, disciplinary probation, or suspension. Substantial or repeated cases of misconduct will be forwarded to the Office of Student Conduct & Community Standards for additional review. For more information, refer to https://conduct.students.wisc.edu/academic-integrity/

Accommodations For Students With Disabilities

The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities is a shared faculty and student responsibility. Students are expected to inform faculty of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. Faculty, will work either directly with the student or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA.

Diversity & Inclusion

Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals.

The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world.

I encourage students in this class to speak up and participate during class meetings. Because the class represents a diversity of individual beliefs, backgrounds, and experiences, every member of this class must show respect for every other member of this class.

Use of Recorded Materials

Lecture materials and recordings for ISyE728 are protected intellectual property at UW-Madison. Students in this course may use the materials and recordings for their personal use related to participation in this class. Students may also take notes solely for their personal use. If a lecture is not already recorded, you are not authorized to record my lectures without my permission unless you are considered by the university to be a qualified student with a disability requiring accommodation. https://www.wisconsin.edu/regents/policies/recording-of-lectures/ Students may not copy or have lecture materials and recordings outside of class, including posting on internet sites or selling to commercial entities. Students are also prohibited from providing or selling their personal notes to anyone else or being paid for taking notes by any person or commercial firm without the instructor's express written permission. Unauthorized use of these copyrighted lecture materials and recordings constitutes copyright infringement and may be addressed under the university's policies, UWS Chapters 14 and 17, governing student academic and non-academic misconduct.