CS/ECE/ISyE 524 – Introduction to Optimization

Summer 2024

Optional Class Time and Location

When	Where
MW 2:35-4:10pm CT F 8:35-10:10am CT	Online (Canvas: https://canvas.wisc.edu/courses/408204)

Instructor Information

Primary Instructor	Email	Office Hours
Dr. Amanda Smith	amanda.smith@wisc.edu	Class times listed above double as office hours Additional meetings available by appointment

TA	Email	Office Hours
Eric Brandt	eric.l.brandt@gmail.com	Mondays, 8-9pm CT (online – via Canvas) Thursdays, 12-1pm CT (online – via Canvas)

General Information

Course Webpage

https://canvas.wisc.edu/courses/408204

Instructional Modality

Online only

Description

Introduction to mathematical optimization from a modeling and solution perspective. Formulation of applications as discrete and continuous optimization problems and equilibrium models. Survey and appropriate usage of basic algorithms, data and software tools, including modeling languages and subroutine libraries.

The credit standard for this 3-credit course is met by an expectation of a total of 135 hours of student engagement with the courses learning activities (45 hours per credit), which include regularly scheduled lecture times, project work, problem sets, and other student work as described in this syllabus.

Prerequisites: (COMP SCI 200, 220, 300, 301, 302, or 310) and (MATH 320, 340, 341, or 375) or graduate/professional standing

Course Learning Objectives

After successfully completing this course, students will be able to:

- Engage in topics about "optimization in practice"
- Use and analyze the results of state of the art optimization software.

- Use the Julia language and JuMP modeling package
- Design good models for realistic applications in engineering and the sciences.
- Develop a "commercial strength" application of optimization technology.

Distribution of Information

Students are expected to keep up with all class content. You are responsible for assignments or policies that are announced on Canvas and for material covered in lectures. You are responsible for any material distributed electronically via the course webpage.

We will use the Canvas course page for everything, including lecture videos, live sessions (on Zoom), and assignments, as well as more general announcements such as reminders, assignment clarifications, or useful resources. Make sure to check the page regularly! The course page will be very important in the conduct of the course, as we will use it for announcements, posting assignments, turning in assignments, posting lecture notes and other material, and for other purposes.

This term we will be using Piazza for class discussion. The system is highly catered to getting you help fast and efficiently from classmates, the TA, and myself. Rather than emailing questions to the teaching staff, please post your questions on Piazza. If you have any problems or feedback for the developers, email team@piazza.com. Class link: https://piazza.com/class/lwtd0qe2obh5xn.

If you do need to email one of the instructors, be sure to include "ISyE 524" in your subject line. Instructors will do their best to respond to your questions/concerns promptly within normal business hours (8am-5pm M-F). You may post questions or send email outside of business hours but we cannot guarantee an expedient response; we will respond during the subsequent business day. Posting on Piazza (privately if necessary) is preferred to email, and will certainly get a quicker response. Unread email queues get deep quickly, making emails easy to overlook. Piazza posts won't be overlooked, and therefore are your best means for communication regarding 524 topic.

In some cases, religious observances or other events conflict with scheduled class activities. In such situations students will be given an alternative means of meeting the academic requirement. **Students must notify the instructor of any such conflicts, with the specific dates, within the first two weeks of classes** (that is, not later than July 1). Students requiring disability accommodations are also requested to make arrangements with the instructors, within the same period if possible.

Course Materials

Required Materials

There is no required textbook for the class. All course material will be presented in lecture and/or provided online as notes. That being said, several textbooks cover parts of what we will see in class, and you may find it helpful to use them as references. Here are a few:

- S. Boyd and L. Vandenberghe. *Convex Optimization*. Cambridge University Press, 2004. The book is available for free here: http://stanford.edu/~boyd/cvxbook/.

- H.P. Williams. *Model Building in Mathematical Programming*, 5th Edition. Wiley, 2013

- R.L. Rardin. *Optimization in Operations Research*. Prentice Hall, 1998.

Computing

- You will be required to write code in Julia (http://julialang.org/), a free open-source programming language similar to Matlab and Python. We will also use the JuMP modeling language, which is a Julia module (https://jump.dev/). All assignments should be written to run with Julia version 1.10.

  Download Julia and add the JuMP and IJulia packages at https://julialang.org/. ***It's very important that you download version 1.10, NOT older releases such as 1.6.***

Course Grade

Your overall grade in the course will reflect how well you demonstrate mastery of the learning objectives (LOs). Your grade will be based on the final course average across 3 graded components:

Assignment	Weight
Homework	50%
Midterm	20%
Project	30%

To qualify for the following letter grades, the minimum course averages shown after the grades will be needed:

Letter grade	Percent cutoff
A	93
AB	87
B	80
BC	75
C	70
D	60
F	0

The instructor reserves the right to lower the cutoffs. In other words, any changes made to these cutoffs can only cause your letter grade to stay the same or improve.

The homework assignments will be primarily intended for you to practice applying concepts from lecture and will be graded on a rough 4-point scale. Occasionally, you may need to do additional research beyond materials given in class to solve a homework problem.

The midterm exam will include questions to test your ability to identify model components and construct mathematical models, similar to homework problems. The exam will also include more theoretical questions, potentially asking you to make connections between several different concepts or to apply a concept in a new way.

Finally, the course project will give you a chance to find a real-world problem of your own to analyze and turn into a mathematical model that can be solved. You will be asked to describe the limitations of the model, the assumptions you have to make, and the interpretation of the proposed solution to the model. More details regarding each of these components can be found in the following sections.

Midterm Exam (20%)

There will be a written midterm exam on Friday, July 19, at a time TBD. Note there is no final exam. More details about the structure of the exam and how you will access it will be shared in the first couple weeks of class. However, if you believe you will be unable to be online for the exam at any time on July 19 (due to significant difference of time zone, inability to obtain internet access on that date, or other reasonable request), please let the instructor know by the end of the second week of class (no later than July 1) and we will make necessary accommodations.

The exam will be open notes; students can access any lecture notes or assignments to complete the exam. However, you *must complete the exam individually*. If there is evidence of improper collaboration, all students involved will automatically receive a 0 on the exam and will be reported to the Office of Student Conduct & Community Standards.

Students who believe their grades on the exam are in error can request adjustment of the grades during a period of one week after the exam grades are released. The instructor reserves the right to either increase or decrease the exam grade upon review.

Course Project (30%)

You will be required to complete a course project in groups of 1-3 people. This project will give you an opportunity to apply many of the techniques you learn in this course in the context of a real problem. The final products of this project will be: (1) a project proposal (due Friday, July 12), (2) an interim progress report (due Monday, July 29), and (3) a final report (due the last day of class – August 9) in the form of an IJulia notebook and a PDF of the IJulia notebook (so the instructors can run your code). The proposal will be graded on completion, but the instructor may follow up with you if there are any specific concerns about the difficulty level or feasibility of the project.

The interim progress report will be graded on completion and will provide another opportunity for the instructors to provide feedback on your projects. More details will be shared in the first few weeks of class.

The **final** report will be graded as follows:

1. Introduction (16%)
2. Mathematical model (24%)
3. Solution (24%)
4. Results and discussion (24%)
5. Conclusion (8%)
6. Report quality (4%)

Details of the project assignment will be given in the first few weeks of the course.

Homework (50%)

Homework will be assigned in most weeks as a means to help you understand the concepts and to give you practice in applying them. There are (roughly) weekly homework assignments (6-8 total). These will be graded on a coarse 4-point scale. You get 4 points if you attempted all problems and got everything mostly right. The lowest score of these assignments will be dropped, so each of the remaining highest-scoring assignments will be worth about 7% of your grade. Homework will be due on dates/times stated on the course page; it will be graded and the grades returned to you, usually within one week. For most assignments, you will be required to turn in a ***single PDF*** of your IJulia notebook. When you submit an electronic assignment you are responsible for verifying that it uploaded successfully to Canvas. It is a good idea to submit early and often to make sure that technical glitches do not prevent you from turning in your assignment on time.

The points possible on late homework will decay by 25% per day. In other words, assignments will lose one point automatically for each day by which they are late (e.g., the maximum score on an assignment turned in within 24 hours after the original due date will be 3 points). Occasionally, reasonable exceptions may be made, with the instructor's specific approval in each case. If you are requesting an exception, you must communicate with the instructor **before** the original homework due date. Solutions will generally be posted soon after the assignment is due, so we cannot accept assignments more than 4 days late.

You are encouraged to join with other students in discussing the homework. However, homework that you hand in must have been prepared by you alone. It is fine to work with others in deciding how to do something and even in working out the solution, but when you write it up you must do so yourself. For example, you must not use another student's work as a formatting template, even if you fill in the numbers yourself. You must prepare the complete assignment by yourself. If the instructor determines that a group of students have not turned in individual assignments, all students involved will receive 0 on that assignment.

Homework grades will be posted on the course Canvas page. Students who believe their grades on assignments are in error can request adjustment of the grades during a period of one week after the grade of the item in question is posted. After that time, no adjustments will be made. The one-week period will necessarily be shortened for the last one or two assignments of the semester.

Extra Credit (up to 1%)

There is the opportunity to earn up to **1% extra credit** by participating regularly and meaningfully on the Piazza discussion forum. Participation includes asking questions, responding to questions, and sharing useful advice/tips. "Regularly" is defined as (on average) 1 engagement per week (or about 7-8 total this summer). "Meaningfully" is defined as either asking a question about course content, sharing related information/resources, or responding to a content-related question. Note this does not include questions about course logistics (e.g., Where is the midterm? When is this assignment due?) Between 0% and 1% extra credit will be allocated for less participation. This is a good opportunity to figure out what you understand well and what you need clarification on!

Additional Information and Resources

Regular and Substantive Student-Instructor Interaction

Interaction with faculty and instructional staff is a key component of the high-quality education UW-Madison offers and is part of the Wisconsin Experience. This course meets the regular and substantive student-instructor interaction requirement by:

- Offering participation in regularly scheduled learning sessions, where there is an opportunity for direct interaction between the student and the qualified instructor.

- Providing personalized comments for an individual student's assignment or exam.
- Actively facilitating online discussions.
- Posting announcements about academic aspects of the class.
- Identifying students struggling to reach mastery through observation of discussion activity, assessment completion, or even user activity and offer additional opportunities for interaction.

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

McBurney Disability Resource Center syllabus statement: "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 [me] 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 [I], will work either directly with the student [you] 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." http://mcburney.wisc.edu/facstaffother/faculty/syllabus.php

Diversity and 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." **https://diversity.wisc.edu/**

Privacy of Student Records & the Use of Audio Recorded Lectures

See information about privacy of student records and the usage of audio-recorded lectures.

Lecture materials and recordings for this course 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. [Regent Policy Document 4-1] 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.

Undergraduate Students' Rules, Rights & Responsibilities

Please review the Undergraduate Guide

Tentative Class Schedule

Date	Topic	Dates
Week 1	Introduction; Julia; Linear Algebra; LP basics	June 17, 19, 21 Homework 0 due June 21
Week 2	LP basics; LP special cases	June 24, 26, 28 Homework 1 due June 26
Week 3	LP special cases; LP duality; Solving LPs	July 1, 3, 5 Homework 2 due July 3
Week 4	Least squares; Trade-offs; Regularization	July 8, 10, 12 Homework 3 due July 10 Project proposal due July 12
Week 5	Regularization; Convex programming basics	July 15, 17, 19 Homework 4 due July 17 Midterm exam July 19
Week 6	Convex programming basics; Duality in convex programming; Integer programming basics	July 22, 24, 26 No homework due
Week 7	Integer programming basics; Solving integer programs	July 29, 31, Aug 2 Homework 5 due Aug 2 Interim progress report due July 29
Week 8	Solving Integer programs; General nonlinear programming; Stochastic Programming	August 5, 7, 9 Homework 6 due August 9 Project due August 9