CS/ECE/ISyE 524 – Introduction to Optimization

Summer 2020

Class Time and Location

When	Where
MW 2:35-4:10pm F 9:35-11:10am	Online (Canvas: https://canvas.wisc.edu/courses/202205)

Instructor Information

Primary Instructor	Email	Student Hours
Dr. Amanda Smith	amanda.smith@wisc.edu	Additional meetings available by appointment
TA	**Email**	**Student Hours**
Emad Sadeghi	ssadeghi@wisc.edu	

General Information

Course Webpage

https://canvas.wisc.edu/courses/202205

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 or member of Engineering Guest Students

Course Learning Objectives

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

- Extract a sensible mathematical model from a problem description provided in plain text, and solve the problem. Specifically:
    - Identify decision variables, algebraic constraints, and an objective function.

    - Categorize the model type (LP, MIP, QP, NLP, etc.).
    - Simplify the model if possible.
    - Implement and solve the problem in a modeling language (Julia).
    - Interpret the solution and provide an answer in plain text.
- Demonstrate an intuitive understanding for broad classes of optimization models. Specifically:
    - Visualize and illustrate algebraic constraints geometrically.
    - Summarize the general algorithmic techniques used to solve different classes of optimization problems and comment on their efficiency, reliability, and scalability.
    - Perform appropriate sensitivity and trade-off analyses.

ABET Student Outcomes

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

1 Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

2 Communicate effectively with a range of audiences.

10 Apply the techniques, skills, and modern engineering tools necessary for engineering practice, such as quality engineering, optimization, simulation, and project management.

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 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, I encourage you to post your questions on Piazza. If you have any problems or feedback for the developers, email team@piazza.com. Find our class signup link at https://piazza.com/wisc/summer2020/csececeisye524.

If you do need to email one of the instructors, be sure to include “CS 524” in your subject line. Instructors will do their best to respond to your questions/concerns quickly within normal business hours (8am-5pm M-F). Occasionally, instructors will check and respond to emails outside of normal business hours, but we cannot guarantee an expedient response if you contact us outside those hours.

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 June 26). 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 (http://www.juliaopt.org/JuMP.jl/0.21/). All assignments should be written to run with Julia version 1.3.1 and JuMP version 0.21. You can use either of the following two methods to complete assignments:

- *Recommended:* Download Julia and add the JuMP and IJulia packages**:** **https://julialang.org/ .** ***It's very important that you download version 1.3.1, NOT older releases such as 0.6.4.***

- *Not recommended*: Alternatively, you may run Julia in your browser using JuliaBox: https://www.juliabox.com/. Simply log in with any email or Github account and create a new file using "Julia 1.0.3." This method will get you started instantly but is perhaps less reliable in the long run. When the servers are under a heavy load, they can be ***very*** slow.

We will spend part of the first lecture learning how to write and run code using Julia/JuMP.

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: homework assignments, 50%; course project, 35%; midterm exam, 15%.

To qualify for the following letter grades, the minimum course averages shown after the grades will be needed: A (93 – excellent mastery of LOs), AB (87), B (80 – good mastery of LOs), BC (70), C (60 – fair mastery of LOs), D (50 – poor mastery of LOs). 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. The instructor will use homework results to adjust the course content as necessary (e.g., revisiting more challenging concepts). 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 their 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 (15%)

There will be a written midterm exam on Friday, July 17. Note there is no final exam. It is your responsibility to ensure that you are available and present for the midterm exam. 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 graded exams are returned. The instructor reserves the right to either increase or decrease the exam grade upon review.

Course Project (35%)

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 10) and (2) a final report (due the last day of class – August 7) in the form of an IJulia notebook. Specifically, the report will be graded as follows:

1. Introduction (15%)

2. Mathematical model (20%)

3. Solution (25%)

4. Results and discussion (25%)

5. Conclusion (5%)

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.

In general, 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.

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

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/

Tentative Class Schedule

Date	Topic	Dates
Week 1	Introduction; Julia; Linear Algebra; LP basics	June 15, 17, 19
Week 2	LP basics; LP special cases	June 22, 24, 26
Week 3	LP special cases; LP duality; Solving LPs	June 29, July 1, 3
Week 4	Least squares; Trade-offs; Regularization Project proposal due (July 10)	July 6, 8, 10
Week 5	Regularization; Convex programming basics Midterm exam (July 17)	July 13, 15, 17

Date	Topic	Dates
Week 6	Convex programming basics; Duality in convex programming; Integer programming basics	July 20, 22, 24
Week 7	Integer programming basics; Solving integer programs	July 27, 29, 31
Week 8	Solving Integer programs; General nonlinear programming; Stochastic Programming Project due (August 7)	August 3, 5, 7