Department of Industrial and Systems Engineering
Spring 2024

Introduction to Optimization

(CS/ECE/ISyE 524)

Lecture: Monday and Wednesday, 4:00PM-5:15PM 1800 Engineering Hall

---

Jeff Linderoth
Office: 3226 Mech. Engr.
Office hours: 9AM-10AM Tuesdays & 11AM-12PM Fridays (also by appt.)
Public calendar available at `http://tinyurl.com/37upk9dp`
Phone: 608-890-1931
E-mail: `linderoth@wisc.edu`
Web: `https://jlinderoth.github.io/`

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.

Teaching Assistant and Course Support

Teaching Assistant: Eric Brandt
Office Hours: 2:30-3:30PM Mon. & Wed.
Location: 3107 Mechanical Engineering Building
`email`: elbrandt@wisc.edu

Teaching Assistant: Sanjai Pushpa
Office Hours: 2:00-3:00PM Thursday and Friday
Location: 3107 Mechanical Engineering Building
`email`: pushpa@wisc.edu

Instructional Modality, Course Environment & Logistics

The class is intended to be taught face-face in a sychronous manner. Lectures and office hours are all planned to be in-person. All assignments and course interactions will utilize Internet technologies and require regular and active student engagement throughout the course.

Course Credit:

This is a three credit hour course. The credit hours are met with the traditional Carnegie definition—there is an expectation of a total of 135 hours of student engagement with the courses learning activities (45 hours per credit), which include attending and participating in twice-weekly lectures, problem sets, project work, and other student work as described in this syllabus.

Regular and Substantive Student-Instructor Interaction:

Substantive interaction among students and instructors will occur through direct instruction, providing feedback on student work, providing information about course content, facilitating and discussion of course content. The interaction will occur multiple times per week in course meetings and office hours.

Course Materials

Optional Textbooks

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 provide good references for optimization models. You may find it helpful to use them as references. Here are a few:

Wayne Winston. *Operations Research: Applications and Algorithms*, Fourth Ed. (Brooks/Cole, Cengage Learning, 2004). *This is a textbook for a standard course in Operations Research. It has descriptions of many modeling techniques we will learn in this course.*

H. P. Williams. *Model Building in Mathematical Programming*, 4th Edition (John Wiley & Sons, 1999). *This book is a bit outdated, but it is a* classic *reference on the importance of building good models for optimization problems.*

S. Boyd and L. Vandenberghe. *Convex Optimization* (Cambridge University Press, 2004). *This book is a mathematically rigorous introduction to concepts in continuous, convex optimization. It is available for free at* `http://stanford.edu/~boyd/cvxbook/`

Web Sites

The course will make significant use of the `Canvas` system: `https://canvas.wisc.edu/`. I plan to use Canvas primarily for posting materials—such as lecture slides, sample IJulia notebooks, homework problems sets and solutions—and for posting grades. I will also use the Piazza forum `www.piazza.com` for its discussion/chat features.

Required Course Material and Software

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 1.10.0 and JuMP version 1.18. In the course, we will provide instructions for installing Julia and JuMP and IJulia packages at `https://julialang.org/`. It is important that you work with most recent stable release of the software.

Course Overview

This three-credit course introduces students to practical techniques for modeling and optimizing systems. Many companies and research programs are integrating optimization technology into their day to day operations. Manipulating models and optimization software and applying general operations research methodology in various contexts is becoming an increasingly sought after skill. This course is designed to teach students about "optimization in practice." The course involves learning about, using, and analyzing the results of state of the art optimization software. The student will learn how to design good models for realistic applications in engineering and the sciences.

Course Learning Outcomes

After taking this course, my objective is that you will be able to do the following:

1. The ability to write down an algebraic formulation of an optimization model that captures the main decision elements of practical problems.

2. The ability to categorize optimization models, and understand the implications of modeling on algorithm performance
3. To understand the tradeoff between model accuracy and tractability and to consider the feasibility of alternative design solutions
4. The ability to explain, at a non-technical level, how optimization may be applied to decision problems.
5. To become familiar with the operation of state-of-the-art optimization software, including parameters that may significantly affect software performance
6. Use and analyze the results of state of the art optimization software;
7. Use the Julia language and JuMP modeling package;
8. Design good models for realistic applications in engineering and the sciences;

The assessments given in this course are specifically designed to measure your progress in the above areas.

ABET Student Outcomes

a an ability to apply knowledge of mathematics, science, and engineering

e an ability to identify, formulate, and solve engineering problems

g an ability to communicate effectively

k an ability to use the techniques, skills, and modern engr. tools necessary for engr. practice

Requirements and Grading

Lectures

For instruction, the course will contain twice-weekly lectures. Learning is an interactive process. As such, attendance at lectures is strongly encouraged. Lecture recording will not be made available for viewing. Lecture slides will be available before class.

Homework

There will be (roughly) bi-weekly homework assignments. The homework assignments are meant to ensure that you have mastered the material from the weekly lectures and will help you to learn the skills and concepts listed under course objectives. An integral part of the learning process is a rigorous self-assessment of knowledge. Answers to the homework problems will be posted, and students are expected to assess their performance and seek additional help should it be required. Not all homework problems will be rigorously graded. Rather, some portions may be rigorously graded, and the remainder will be checked at a more cursory level. You are responsible for checking your homework against the answer key and asking questions about items you do not understand.

Exams

There will be three in-class exams. Exam dates are February 28, April 8, and May 10.

Grading Scheme

- 30% Homework
- 20% Midterm #1
- 20% Midterm #2
- 30% Final Exam

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

Grade	% Cutoff
A	90
AB	87
B	80
BC	77
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.

(Tentative) Chronological Syllabus

I will do my best to stick to this course coverage, but based on student feedback and how quickly we can cover material, I reserve the right to modify as we move through the course. Regardless, I will try very hard to keep the dates of assignments and exams fixed.

Part I: **Linear and Network Optimization** *January 24-February 28*

Overview of course & Introduction to Julia and JuMP. Basic linear programming modeling—input-output, staffing models, blending models, multiperiod models, and modeling piecewise-linear functions, Network Optimization, LP Duality

Homework #1: February 11
Homework #2: February 25
Midterm Exam #1: February 28

Part II: **Convex Optimization** *March 4-March 20*

Least squares, Tradeoffs and Pareto curves, regularization, quadratic programs, second-order cone programs, semidefinite constraints, interior point methods.

Homework #3: March 17

Part III: **Integer Optimization** *April 1 - April 25*

Rounding and relaxation, fixed costs and vari- able bounds, modeling integer constraints and logic constraints, set cover and the Traveling Salesman Problem, quadratic assignment problems, special ordered sets, cutting plane and branch & bound methods

Homework #4: April 2
Midterm Exam #2: April 8
Homework #5: April 22

Part IV: **Stochastic Optimization** *April 29-May 1*

Introduction to Decision-Making Under Uncertainty. Recourse-Based Stochastic Programming. Modeling Risk Measures. Chance Constraints.

Homework #6: May 6
Final Exam: May 10

Course Statements and Policies

Homework Submission Policy

Learning is a collaborative process, so you are encouraged to verbally discuss the course work, including homework, with other students. However, work that you hand in *must have been prepared by you alone.* It is *imperative* that you understand the material on your own. You (obviously) can't ask your study-partners for help on the quizzes and exams, so it is up to the student to ensure that they have *individually* mastered the material. An effective way of ensuring this is to work on the homework assignments alone before seeking help or collaborating with others.

Unless otherwise specified, all assignments are due on Sundays 11:59pm. Due dates are hard deadlines, and typically late homework is not accepted. You typically will have around two weeks to complete the assignments, which is ample time if you start working on it when it is assigned. Extension requests are granted only for extenuating circumstances and at the discretion of the instructor. Regardless, late assignments are marked down 10% for each day they are late. I typically will post solutions within 1-2 days of the assignment due date. **Late homework is not accepted for grading after solutions have been posted.** So please turn in your homeworks when they are due, and communicate with the instructor should you not be able to meet the deadlines. The lowest homework grade will be dropped before computing the average used in the course grading scheme. Thus, if you have extenuating circumstances that will not allow you to finish one assignment, your grade will not be aversely affected.

Schedule Conflicts

Sometimes students have legitimate conflicts that prevent them from taking an exam at the scheduled time. In accordance with University policy, I request that you notify me of any such conflicts within the first two weeks of class. If for some reason you become aware of such a conflict after the first two weeks of class, I request that you notify me as soon as you become aware of the conflict. In such cases, I will work with you to schedule a make-up exam, provided that you

have made a reasonable effort to give me advance notice of your conflict. Wanting to go home before May 10 is not a legitimate conflict.

Academic Integrity

As exams require you to understand the material, it is not in any student's interest to simply copy the material. You also should realize that if you allow another student to just copy your assignment, you are denying them the opportunity to learn and prepare for exams. I encourage students to work together. **However, you may not share any code, copy solution from another person, or carry out an assignment together. Discussion should only involve verbal communication. All assignments need to be written up entirely separately.** It is always better to turn in an incomplete assignment than to turn in an assignment that is even partially copied, or created by a large-language model such as ChatGPT. Submitting someone else's work, or the output of a large-language model, as your own is academic misconduct. Such cheating and plagiarism will be dealt with in accordance with University procedures (see the Academic Misconduct Guide for Students: `https://conduct.students.wisc.edu/academic-misconduct/`.) Also note—the TA, grader, and I run all of the homework problems through openAI and will compare homework solutions against the ChatGPT output.

Respect for Colleagues

Diversity is a source of strength, creativity, and innovation. All students in this course are expected to value the contributions of each person and respect the ways in which their identity, culture, background, experience, status, abilities, and opinion enrich our learning experience and university community. Disrespectful behavior or comments directed toward any group or individual will be addressed (and dealt with harshly) by the instructor.

Obtaining Help

The TA and I will do our best to answer email questions in a timely fashion. However, it is easy to become overwhelmed handling such requests. Thus, we make two requests of you if you are asking for help via email

1. Please only ask for help if you have given some significant thought about the problem on your own. (This also helps you learn better).
2. Please ask your questions on the Piazza site. We receive immediate notification of all postings, so posting there should receive a response as quickly as an email would. If you e-mail a question, we will probably ask that you post it to the forum, or we may post it to the Piazza forum ourselves.

Drop and Add Dates

If you feel it is necessary to withdraw from the course, communicate with the instructor and your program staff right away. Full deadlines and ramifications of dropping/withdrawing are at the Office of the Registrar `https://registrar.wisc.edu/dates/`.

Communicating about course topics with Instructors and Peers

If you have questions about course logistics or content, consider sharing them in a course-wide communication channel, like the main Piazza discussion forum, so that all students may benefit from the questions and responses. Additionally, students are encouraged to answer questions from

other students when they know the answer, to provide timely assistance and to facilitate peer-to-peer learning and engagement. In this way, students are encouraged to share their challenges, support each other, and learn through teaching others.

Communicating about personal matters with Instructors

If you have questions of a personal nature, relating to a personal emergency, an assignment grade, or other private matter, contact me via email. Please allow up to 24 hours for me to respond.

Course Evaluations

Students will be provided with an opportunity to evaluate this course and learning experience. Student participation is an integral component of this course, and your feedback is important to me. I strongly encourage you to participate in the course evaluation. For additional information, see `https://kb.wisc.edu/81069`

Subject to Change Notice

All material, assignments, and deadlines are subject to change. It is the student's responsibility to be aware of all course timelines, announcements, and communications from her or his instructor pertaining to changes in course assignments and due dates. I will communicate any changes to students well in advance.

Archiving Course Material

Students may desire to keep a record of their work and certain course materials from this course. It is the responsibility of each student to gather and archive their own material. Students should do this before the end of each semester and the online course site is no longer available.

Student Resources

- Community & Support Site `https://community.engr.wisc.edu/`
- Student Handbook `https://uwmadison.app.box.com/s/4qm7k15y0fwwet8bp1x9uvylms8kaua8`
- Office of the Registrar `https://registrar.wisc.edu/`
- Office of the Registrar Dates and Deadlines `https://registrar.wisc.edu/dates/`
- UW–Madison Libraries `https://www.library.wisc.edu/`
- McBurney Disability Resource Center: `https://mcburney.wisc.edu/`