ECE 506 Optimization Theory Fall 2024

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Room ECE 229-A
Department of Electrical and Computer Engineering
MSC01 1100
1 University of New Mexico
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The University of New Mexico

COURSE INTERACTIONS GUIDE

Class Discussion Times (optional and recorded): Saturday mornings 9am to 11am
Class Discussions Zoom Link (updated): https://unm.zoom.us/j/94374314467
Discussions will be recorded and start on August 24th and repeat every Saturday until December 14th. There will not be a discussion on November 30th.

Class Office Hours (optional but may not be recorded): Sunday afternoons 5pm to 6pm.
Class Office Hours Zoom link: https://unm.zoom.us/j/94286333920
Office hours will not be recorded.

Personal Zoom link for setting up appointments with the instructor:
https://unm.zoom.us/j/8307784406

Instructor Cell Phone: (505) 563-0563
Instructor Email: *pattichi@unm.edu*
Department Phone: (505) 277-2436
Department Fax: (505) 277-8298
Instructor office: ECE Room 229A (by appointment only)

Format:
This is a 3 credit hour course. The course is offered online and through the Accelerated Online Program.

Meetings:
There is no requirement for synchronous meetings in the course. The students are expected to setup meeting times with the instructor to discuss their projects.

Class discussions:
Class discussions are optional and will be recorded. Their goal is to focus on problem-solving and homework. Students can expect me to go through each problem in the assignment and pause for questions. By Friday afternoon, the students are encouraged to email questions or post questions on the Discussion group titled "Weekend Discussion Topics Suggestions". To access the discussion group, click on **Discussions** on the left navigation bar and then click on "Weekend Discussion Topics Suggestions".

For questions raised after Saturday morning, I may reply by email or ask the student to come during office hours. Students are expected to watch video lectures before class discussions.

My goal is to post the class discussions by Saturday evening. For each video, I will briefly describe what was covered.

Class discussions will start on Saturday, August 24th. We will not have a class discussion on Saturday, November 30th. The class discussion time on December 14th will be used for student presentations. Also, refer to the schedule for the class.

Office hours:
Class office hours provide the option for one-to-one meetings. A student may request for a private one-to-one meeting or may optionally participate in discussions where many students participate. Office hours may not be recorded except when I get through tutorial material.

A student may also request to setup another time for a one-to-one appointment through my personal zoom link: **https://unm.zoom.us/j/8307784406. Note that this is a different zoom link.**

Office hours will start on Sunday, August 25th. We will not have office hours on Sunday, December 1st, and the last day for office hours will be December 8th. Please refer to the class schedule.

Contact via email or text message:
You can email me at pattichi@unm.edu for any questions related to the course. Please use "ECE 506" in the email title so that I know that it is related to class. If I am late to an appointment or you desperately need to meet me, feel free to text me at my cell phone: (505) 563-0563. In general, avoid a direct phone call since I may mistake your call for a spam call ☹.

Course Description

The course will focus on developing computer-based methods for optimization. We will cover both the theory and the algorithms of optimization theory, with an emphasis on the algorithmic issues. The course will cover mathematical foundations, 1D optimization methods and algorithms, Line-search, trust-region methods, Conjugate Gradient Methods, Large-scale Optimization Methods, Constraint Optimization Theory, Convex Optimization, Multiobjective Optimization, Simulated Annealing, Stochastic Gradient Descent, and Momentum Methods. A project is required.

Course Objectives

The following are the objectives for the course. Each module will have specific learning objectives listed on the Overview Page. The activities in that module (i.e., discussions, assignments, and assessments) are developed so that you can demonstrate you have met these objectives:

C1. Learn and apply algorithms used to optimize.
C2. Demonstrate an understanding of the mathematical concepts associated with numerical optimization.
C3. Demonstrate an application of optimization theory to an appropriate problem.

Prerequisites and Co-requisites

- Graduate standing
- Knowledge of Calculus and basic linear algebra

Specific Course Requirements (If Applicable)

The students should be able to code in Matlab and/or Python. A brief tutorial for Python will be given.

TECHNICAL SKILLS

In order to participate and succeed in this class, you will need to be able to perform the following basic technical tasks:

- Use Canvas (help documentation located in “Help”>”UNM Canvas Help Site” link on left course menu, and also at Online Student Documentation).
- Install, use, and program in Matlab for running the examples in the class.
- Install, use, and program in Python for the last part of the course.
- Use email – including attaching files, opening files, downloading attachments
- Copy and paste within applications including Microsoft Office
- Open a hyperlink (click on a hyperlink to get to a website or online resource)
- Use the in-course web conferencing tool (Zoom)
- Download and install an application or plug in – required for participating in web conferencing sessions

TECHNICAL REQUIREMENTS

Computer

- A high speed Internet connection is highly recommended.
- Supported browsers include: Detailed Supported Browsers and Operating Systems
- Any computer capable of running a recently updated web browser should be sufficient to access your online course. However, bear in mind that processor speed, amount of RAM and Internet connection speed can **greatly** affect performance. Many locations offer free high-speed Internet access including UNM’s Computer Pods.
- Microsoft Office products are available free for all UNM students (more information on the UNM IT Software Distribution and Downloads page)

For UNM Canvas Technical Support: (505) 277-0857 (24/7) or visit the Canvas Info Site

Canvas outages: Unexpected Canvas system outages are rare but, if they occur, I will advise everyone on how to proceed.

Web Conferencing

Web conferencing will be used in this course during the following times and dates:
For the online sessions, you will need:

- *A headset with microphone. Headsets are widely available at stores that sell electronics, at the UNM Bookstore or online.*
- *A high-speed internet connection is highly recommended for these sessions. Please test your wireless Internet connection for audio and/or video quality prior to web conferencing.*
- *For UNM Web Conference Technical Help: (505) 277-0857*

Tracking Course Activity

Canvas automatically records all students' activities including: your first and last access to the course, the pages you have accessed, the number of discussion messages you have read and sent, web conferencing, discussion text, and posted discussion topics. This data can be accessed by the instructor to evaluate class participation and to identify students having difficulty

TEXTBOOK AND SUPPLEMENTAL MATERIALS

Required Textbooks:

The theory and many of the standard optimization algorithms are covered based on:

[N&W] J. Nocedal and S.J. Wright, *Numerical Optimization*, 2nd Edition, Springer Series in Operations Research, 2006.

Convex optimization theory and a guide to their applications will be based on:

[B&V] S. Boyd and L. Vandenberghe, *Convex Optimization*, Cambridge University Press, 2004. Download book and slides from: http://www.stanford.edu/~boyd/books.html. Download Matlab code from: http://cvxr.com/cvx/.

For the last part of the course, we will use:

[ML] Bottou, Léon, Frank E. Curtis, and Jorge Nocedal. "Optimization methods for large-scale machine learning." *SIAM Review* 60.2 (2018): 223-311.

[W&R] S.J. Wright and B. Recht, *Optimization for Data Analysis*, Cambridge University Press, 2022.

An outstanding paper that captures several optimization methods for deep learning is given in:

[Opt-ML] Le, Q. V., Ngiam, J., Coates, A., Lahiri, A., Prochnow, B., & Ng, A. Y. (2011, January). On optimization methods for deep learning. In ICML.

Recommended and/or Optional Textbooks, Journals and Articles:

I will cover the basic concepts of 1D optimization methods from:

[D&S] J.E. Dennis, Jr. and R. B. Schnabel, *Numerical Methods for Unconstrained Optimization and Nonlinear Equations*, SIAM Classics in Applied Mathematics, 1996 republication of the 1983 edition.

I consider this to be the best introductory text ever written on the subject. However, it is somewhat outdated, and only focused on small to medium sized problems. It is primarily focused on Newton's Algorithm. It is also one of SIAM's best sellers!

We will cover stochastic methods from two classic textbooks:

[SR] Sheldon Ross, *Simulation*, (latest is 5th edition).

[BR] Brian Ripley, *Stochastic Simulation*, 2006.

We will not cover Combinatorial Optimization this semester. However, interested students should refer to:
[P&S] C. H. Papadimitriou and K. Steiglitz, Combinatorial Optimization: Algorithms and Complexity, Prentice Hall, 1982 (Dover re-publication).

Required Supplementary Materials:

All students are expected to download and install Matlab. Matlab is freely available for UNM students. Students will also be expected to download and install Python. Python installation instructions will be provided. I am also hoping that we will use parallel computing. I am looking into gnu parallel and mpi4py based on CARC tutorials. The mpi4py should work with PyTorch.

For information with parallel computing options, refer to:
https://carc.unm.edu/education--training/introslidesintermed2022.pdf
However, note that we are not likely to get on Hopper ☹.

COURSEWORK AND PARTICIPATION

Instructor Response Time

I routinely check the course for postings or emails throughout the day and weekends. You can anticipate a 24 to 48 hour response from me, Monday – Thursday. I will try and respond to all weekend (Friday afternoon to Sunday) emails and postings by noon on Monday or earlier. If it takes me more than 72 hours to respond to an email, I may have missed your message. In this case, please email me again.

Procedures for Completing Coursework

- *Late homework is subject to penalties and may not be accepted. You may take a few extra days to complete a homework, provided you inform me before the deadline.*
- *A take-home final will be given in the last week of the course. No extra time will be allowed for the take-home final.*
- *A final project and a final presentation is required to receive credit for the course. The final project presentation will be due on finals week.*
- *All written work needs to be submitted online. If you have a difficulty using a tool to complete work, please reach out to UNM's Canvas Support immediately and notify your instructor as well. This statement does not apply to programming assignments. For programming assignments, notify the instructor.*

Assignments

A detailed list of the assignments, due dates, and points is given in the schedule in the last page of the syllabus. Note that there will graded discussions as well as quizzes to ensure that students watch the lectures. In each assignment, all problems are weighted equally, unless you see the number of points associated with each problem.

Project

For the project, you will be asked to submit:

- Project proposal
- A revision of the project proposal
- Project presentation (including code)
- Final project material

Please see the assignments links within the course for more details.

Discussions

There will be course discussions that will be graded. You are required to participate in these discussions. There will also be a general Q&A discussion board where you can ask questions.

Final Exam

There will be a take home final exam assigned in the last week of classes.

Grading Policy

Exam	25%
Project	25%
Homework	50%

Expectations for Participation

- *time required (9-12 hrs per week). However, please note that programming assignments may take longer, depending on your programming background. Furthermore, programming assignments may be completed over 2 weeks.*
- *students are expected to learn how to navigate in Canvas*
- *students are expected to keep abreast of course announcements*
- *students are expected to keep instructor informed of class related problems, or problems that may prevent the student from full participation*
- *students are expected to address technical problems immediately*
- *students are expected to observe course netiquette at all times*

Netiquette

- *Refer to netiquette link:* https://canvasinfo.unm.edu/students/intro-to-canvas/netiquette.html.

GRADING PROCEDURES

As outlined in the grading policy, the final grade will reflect three sub-areas:

- **Discussions and Homework (50%):**
    - **Discussions:** You are expected to read the discussion prompt and carefully respond to all of the questions provided in the discussion prompt. Discussions help the instructor understand the needs and interests of the students as related to the learning objectives. For example, there will be questions about your background to help the instructor understand how to focus the lectures on your specific interests and needs. Grades reflect completion. In other words, points

will be taken off for not answering all of the questions raised in the discussion prompt. Discussions will be graded within a week after the due date.
    - **Homework:** Homework assignments are directly related to the learning objectives of the course. Pencil and paper problems are specifically designed to help me assess fundamental mathematical concepts. Furthermore, some pencil-and-paper assignments follow a guided tutorial learn-by-doing approach, where a fundamental concept is developed through a sequence of questions. Programming problems are specifically aimed at testing the performance and limitations of the different algorithms. Students will be expected to comment on the performance of each algorithm. Homework grades will be based on completeness, correctness, and adherence to programming guidelines. Students must submit running code so that the results can be reproduced if needed. **It is not acceptable for students to submit results without accompanying code.** Homeworks can be quite involved. Expect the homework to be graded within two weeks.

- **Project material (25%):** Project material includes proposal, presentations, revision document, and final presentation and student paper. The goal of the project is to apply optimization methods developed in class to specific problems that are of interest to the student. The students will be expected to spend significant time on their projects. More specifically, note that projects count about half as much as credit as the homework. Thus, the goal here is to spend about half as much as the total time spent on the homeworks. **You are required to meet with the instructor online to discuss the project proposal and final presentation.** The instructor will provide you with different meeting times to make sure to find times to meet with each student. During the project proposal meeting, we will discuss the different aspects of your project and what will be needed to properly complete the project. You will be provided with templates for completing the project proposal, presentation, and the final paper. Furthermore, you will be provided with writing guides on how to complete the project assignments. Your project assignments will be graded based on effort, adherence to writing guidelines, completeness, and **response to feedback**. Project assignments will be graded in time to provide feedback prior to the next project assignment. Typically, project assignments will be graded within a week after the assignment is due.

- **Take home final exam (25%):** The goal of the final exam is to assess understanding of fundamental concepts developed in class. The final exam will be focused on concepts that were covered during the last part of the class (e.g., optimization for machine learning methods). However, essential concepts that were covered earlier will also be tested. A more detailed guide will be provided on the week prior to the last week of instruction. The final exam will be graded within a week after its due date.

Grading Scale

Final grades will be based on the sum of all possible course points as noted above. Percentage of available points

Grade	
90 -100	A
80 -89	B

70 -79	C
60 -69	D
< 60	F

UNM POLICIES

Title IX: Gender Discrimination

In an effort to meet obligations under Title IX, UNM faculty, Teaching Assistants, and Graduate Assistants are considered "responsible employees" by the Department of Education (see pg. 15). This designation requires that any report of gender discrimination which includes sexual harassment, sexual misconduct and sexual violence made to a faculty member, TA, or GA must be reported to the Title IX Coordinator at the Office of Equal Opportunity.
Read more about campus policy regarding sexual misconduct.

COPYRIGHT ISSUES

All materials in this course fall under copyright laws and should not be downloaded, distributed, or used by students for any purpose outside this course.

The UNM Copyright Guide has additional helpful information on this topic.

Accessibility

The American with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodations of their disabilities. If you have a disability requiring accommodation, please contact the UNM Accessibility Resource Center in 2021 Mesa Vista Hall at 505-277-3506. Information about your disability is confidential.

- Canvas's Accessibility statement
- Microsoft's Accessibility statement
- Matlab accessibility statement is available at:
  https://www.mathworks.com/support/accessibility.html
- Matlab privacy statement is available at:
  https://www.mathworks.com/company/aboutus/policies_statements/privacy-policy.html

Academic Misconduct

You should be familiar with UNM's Policy on Academic Dishonesty and the Student Code of Conduct which outline academic misconduct defined as plagiarism, cheating, fabrication, or facilitating any such act.

Example Drop Policy:

UNM Policies: This course falls under all UNM policies for last day to drop courses, etc. Please see or the UNM Course Catalog for information on UNM services and policies. Please see the UNM academic calendar for course dates, the last day to drop courses without penalty, and for financial disenrollment dates.

Virtual Meeting Recordings and Guest Participant Policy:

Technology will be used for virtual meetings in this course and our use of such technology is governed by the Family Educational Rights and Privacy Act of 1974 (FERPA), the UNM Acceptable Computer Use Policy, UNM Computer Use Guidelines, and UNM's Student Code of Conduct. Sharing Electronic video and/or audio recording of the class with participants outside of the class is not permitted without written consent of the instructor and each participating student individually. The form to obtain written consent is available at https://registrar.unm.edu/forms/ferpa-consent.pdf. If a student in the course is uncomfortable with completing the FERPA consent waiver, then the student should talk with their advisor or instructor to determine whether successful participation in the class is still possible, or whether another course will meet the student's degree requirements.

If permission for electronic video and/or audio recording is granted, any distribution of the recording is prohibited. You may not share class recordings with anyone outside of this course and doing so may result in disciplinary action. Students with specific electronic recording accommodations authorized by the University of New Mexico Accessibility Resources Center do not require instructor permission; however, the instructor must be notified of any such accommodation prior to recording. A record of all meetings and recordings is kept and stored by UNM, in accordance with these policies. Guest instructors and other participants may also attend our class meetings. Your instructor will not share course access in relation to class activities outside of the course participants, which include your fellow students, TAs/GAs, and any guest instructors, guest students, or community-based learning partners that we may engage with to achieve the stated course objectives.

UNM RESOURCES

CTL tutoring services (previously known as CAPS) are free and available to UNM students enrolled in undergraduate classes. Services include tutoring in STEM, writing, and languages, and personalized support with study skills and learning strategies. For asynchronous feedback on your writing, submit assignments to the Online Writing Lab (OWL).

Services are available in person and online. Visit the main office on the 3rd floor of Zimmerman Library or go to the Virtual Front Desk on the CTL website to get connected with a tutor or to schedule an appointment: ctl.unm.edu >undergraduates.

UNM Libraries

Student Health and Counseling (SHAC) at (505) 277-3136. If you are having active respiratory symptoms (e.g., fever, cough, sore throat, etc.) AND need testing for COVID- 19; OR If you recently tested positive and may need oral treatment, call SHAC.

LoboRESPECT Advocacy Center (505) 277-2911 can offer help with contacting faculty and managing challenges that impact your UNM experience.

FOR MILITARY-CONNECTED STUDENTS

There are resources on campus designed to help you succeed. You can approach any faculty or staff for help with any issues you may encounter. Many faculty and staff have completed the GREEN ZONE training to learn about the unique challenges facing military-connected students. If you feel that you need help beyond what faculty and/or staff can give you, please reach out to the Veterans Resource Center on campus at 505-277-3181, or by email at vrc@unm.edu.

LAND ACKNOWLEDGEMENT

Founded in 1889, the University of New Mexico sits on the traditional homelands of the Pueblo of Sandia. The original peoples of New Mexico Pueblo, Navajo, and Apache since time immemorial, have deep connections to the land and have made significant contributions to the broader community statewide. We honor the land itself and those who remain stewards of this land throughout the generations and also acknowledge our committed relationship to Indigenous peoples. We gratefully recognize our history.
Resource: Division for Equity and Inclusion.

CITIZENSHIP AND/OR IMMIGRATION STATUS

All students are welcome in this class regardless of citizenship, residency, or immigration status. Your professor will respect your privacy if you choose to disclose your status. As for all students in the class, family emergency-related absences are normally excused with reasonable notice to the professor, as noted in the attendance guidelines above. UNM as an institution has made a core commitment to the success of all our students, including members of our undocumented community. The Administration's welcome is found on our website.

RESPECTFUL AND RESPONSIBLE LEARNING

We all have shared responsibility for ensuring that learning occurs safely and equitably. UNM has important policies to preserve and protect the academic community, especially policies on student grievances (Faculty Handbook D175 and D176), academic dishonesty (FH D100), and respectful campus (FH CO9). These are in the Student Pathfinder and the Faculty Handbook. Please ask for help in understanding and avoiding plagiarism or academic dishonesty, which can both have very serious consequences.
Support: Center for Academic Program Support (CAPS). Many students have found that time management workshops can help them meet their goals (consult (CAPS) website under "services".

CONNECTING TO CAMPUS AND FINDING SUPPORT

UNM has many resources and centers to help you thrive, including opportunities to get involved, mental health resources, academic support including tutoring, resource centers for people like

you, free food at Lobo Food Pantry, and jobs on campus. Your advisor, staff at the resource centers and Dean of Students, and I can help you find the right opportunities for you.

COURSE SCHEDULE

The full course schedule is given in the following page. All of the homework assignments, discussions, and lecture quizzes add up to 50% of the grade. The project accounts for 25% of the total. The take home final accounts for another 25%.

Please note that we will not be meeting for class during finals week (Dec 12th – Dec 17th). Important Fall 2022 Semester Deadline dates can be found on the registrars website at http://registrar.unm.edu/semester-deadline-dates/fall-2022.html.

Week	Dates	Week Info	Module	Assignment/Exam/Points	Due Dates
1	19-Aug	First week of classes	Intro to Numerical Opt and Python Env	Hwk #0: SW Setup (50 pts) & Discussion (100 pts)	26-Aug
2	26-Aug		An Intro to the Math of Opt Theory	Hwk #1: Basic Optimization Math (300 pts)	3-Sep
3	3-Sep	Monday is labor day.	Fund of Unconstrained Opt	Hwk #2: Fund. Of Unc. Opt (250 pts)	16-Sep
4	9-Sep		Rates of Convergence and Line Search		
5	16-Sep		Line-search and Trust-region Methods	Hwk #3: Line search, Trust Reg, and Conj Grad (500 pts)	7-Oct
6	23-Sep		Conjugate Gradient Methods		
7	30-Sep		Deterministic Methods for Large-scale Optimization	Hwk #4: Convex Optimization (500 pts)	31-Oct
8	7-Oct	Oct 10-11 is Fall Break.	Convex Optimization I		
9	14-Oct		Convex Opt II and Multi-objective Opt		
10	21-Oct		Convex Optimization and its Applications	Project Proposal	Nov. 3
11	28-Oct		Stochastic Optimization	Select meeting time and then meet on 11/9/2024	Nov. 8
12	4-Nov		Stochastic Gradient Descent	Revised Proposal Due	18-Nov
13	11-Nov		Convergence of Stoch Gradient Descent Algorithm	Hwk #5 Opt for Machine Learning (250 points)	2-Dec
14	18-Nov	Thanksgiving week	Optimization for Machine Learning Algorithms		
15	25-Nov		Opt for Deep Learning Methods and Course Review		
16	2-Dec	Last week of courses	Final Exam Review	Take-home final exam (25% of total)	7 to 9-Dec
		Finals week		Final Paper and Presentation (20% of total)	14-Dec

Thanksgiving: November 24-25

Fall Break: October 10-11

Last Day: 12/14/2024