JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Syllabus
Applied Mathematics and Statistics 553.761
Nonlinear Optimization I
Fall 2021

Description: This course considers algorithms for solving various important nonlinear optimization problems and, in parallel, develops the supporting theory. Our primary focus will be on unconstrained optimization. Topics will include: necessary and sufficient optimality conditions; first-order methods (like steepest descent) for smooth and nonsmooth optimization, second-order methods (like Newton, quasi-Newton and trust-region methods); stochastic gradient and coordinate descent methods; linear and nonlinear least squares problems and conjugate gradient methods. If time allows: linear programming, minimax optimization, zeroth-order, higher-order methods.

Lectures
Tues/Thurs 4:30-5:45pm
https://wse.zoom.us/j/92703163526?pwd=ZEx5VWZjNEo2MnQ0ZVJmZDJpLzRGdz09

Instructor
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Teaching Assistants
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(Zoom) Office hours: Wed 3-4pm,
https://zoom.us/j/9922645607?pwd=bk1iVU1kVEtHNjBpNC9zRGk0T0FFQT09

Textbook
We won't be following any particular textbook. Notes will be posted on blackboard after each class. Other potentially useful textbooks as references (but not required):
J. Nocedal and S. Wright, Numerical Optimization, Second Edition, Springer, (2006),
Y. Nesterov, Introductory Lectures on Convex Optimization: A Basic Course, Kluwer Academic Publishers, Norwell, MA, (2004),
A. Ruszcynski, Nonlinear Optimization, Princeton University Press, Princeton, NJ (2006),
D. P. Bertsekas, Nonlinear Programming, Second Edition, Athena Scientific, Belmont, MA, (1999).

Course Goals

(i) Students will learn the basic mechanisms that drive convergence of optimization algorithms.
(ii) Students will learn the basic theory that underpins each algorithm.
(iii) Students will learn to implement optimization algorithms.
(iv) Students will learn the scientific tools that are relevant for different classes of optimization problems and different problem sizes.
(v) Students will gain intuition into the strategies and techniques that drive the most successful methods.

Course Topics

- Necessary and sufficient optimality conditions
- Smooth optimization
  - Steepest Descent and line-search methods
  - Optimal accelerated first-order methods in convex optimization
- Nonsmooth optimization
  - Optimal methods in convex optimization
  - Guarantees in nonconvex settings
- Stochastic and coordinate descent methods
- Newton's Method and Quasi-Newton Methods
- Trust-Region Methods
- Conjugate Gradient Methods/Least Squares

Course Grading & Assessment

Course grades will be based on four components: Homework, Midterm, Final, Participation. These are described individually below. I would like to maximize the course score that I give each of you. To optimize each student's course score, I will solve the following optimization problem:

Denote the student's performance in each of these four components as

$C_H = Homework\ score\ (out\ of\ 100)$,
$C_M = Midterm\ Exam\ score\ (out\ of\ 100)$,
$C_F = Final\ Exam\ score\ (out\ of\ 100)$,
$C_P = Participation\ score\ (out\ of\ 100)$.

Then a rubric for grading this student is given by selecting weights for these four components as

$H = Homework\ weight$,
$M = Midterm\ Exam\ weight$,
$F = Final\ Exam\ weight$,
$P = 100 - H - M - F$,

(Notice the participation weight is determined by the other three since they must sum to 100).

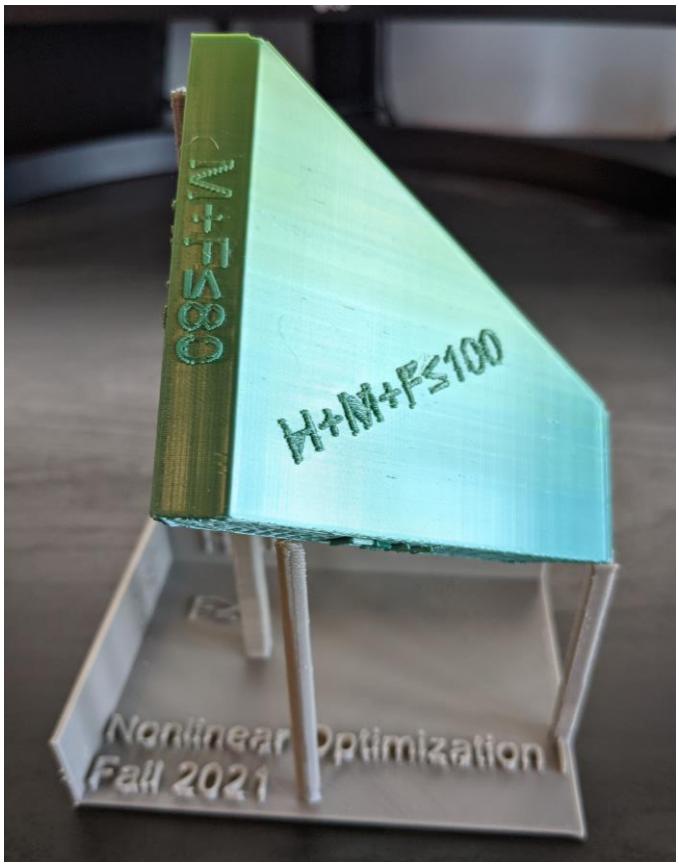
Each student's score is given by maximizing over the set of all reasonable rubrics by solving

$$\max\ (C_H H + C_M M + C_F F + C_P(100 - H - M - F))/100$$
$$over\ all\ triples\ (H, M, F) \in \mathbb{R}^3 \text{ subject to}$$

$H + M + F \leq 100$	(Percentages are at most 100)
$H, M \geq 15$	(Homework and Midterm should matter)
$F \geq M$	(Final is more important than Midterm)
$50 \leq M + F \leq 80$	(Exams are the most, but not all of the class)
$H + M + F \geq 90$	(H M F are the vast majority of the class)

This optimization problem will be solved individually for each student to give them the best rubric and highest course score I can justify.

The 5 constraints above, specify a certain feasible region of triples in 3D space. See to the right for a picture of this region 3d printed. Copies of this polyhedron are available for any student in my office (sadly the pandemic has prevented me from handing them out in person on day one). If you would like one, please come by and get your copy at any point in the semester.



Course Assessment - Homework
Homework assignments (approximately five) will be posted on the course blackboard.

Most homework assignments include at least one question that involves the writing and testing of code. I prefer programming in python and will often give some sample code you may choose to work from. However, you are allowed to use any language you like to complete assignments.

Course Assessment - Exams
Additional assessment will be based on one midterm exam and the final exam, both take home. The dates of the midterm and final exams will be posted on the course website as they become available, although the date of the final exam is determined by the official JHU final exam schedule.

The Midterm will be made available on blackboard on Friday October 15, 2021 and will be due at the beginning of class on Tuesday, October 19, 2021.
The Final Exam will be held from TBD.

Course Assessment - Participation
The grading program described above will assign between 0 and 10 percent of the course to be a participation grade. As a result, you can get full marks in the course without any participation.

Students will receive full points in participation, for moderately doing any of: engaging during or after lectures, engaging in office hours, or asking insightful questions.

Ethics
The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition.

Report any violations you witness to the instructor. You may consult the associate dean of student conduct (or designee) by calling the Office of the Dean of Students at 410-516-8208 or via email at integrity@jhu.edu.

Personal Wellbeing

- If you are sick please notify me by email so that we can make appropriate accommodations should this affect your ability to attend class, complete assignments, or participate in assessments. The Student Health and Wellness Center is open and operational for primary care needs. If you would like to speak with a medical provider, please call 410-516-8270, and staff will determine an appropriate course of action based on your geographic location, presenting symptoms, and insurance needs. Telemedicine visits are available only to people currently in Maryland. See also https://studentaffairs.jhu.edu/student-life/student-outreach-support/absences-from-class/illness-note-policy/
- The Johns Hopkins COVID-19 Call Center (JHCCC), which can be reached at 833-546-7546 seven days a week from 7 a.m. to 7 p.m., supports all JHU students, faculty, and staff experiencing COVID-19 symptoms. Primarily intended for those currently within driving distance of Baltimore, the JHCCC will evaluate your symptoms, order testing if needed, and conduct contact investigation for those affiliates who test positive. More information on the JHCCC and testing is on the coronavirus information website.
- All students with disabilities who require accommodations for this course should contact me at their earliest convenience to discuss their specific needs. If you have a documented disability, you must be registered with the JHU Office for Student Disability Services (385 Garland Hall; 410-516-4720; http://web.jhu.edu/disabilities/) to receive accommodations.
- Students who are struggling with anxiety, stress, depression or other mental health related concerns, please consider connecting with resources through the JHU Counseling Center. The Counseling Center will be providing services remotely to protect the health of students, staff, and communities. Please reach out to get connected and learn about service options based on where you are living this fall at 410-516-8278 and online at http://studentaffairs.jhu.edu/counselingcenter/.
- Student Outreach & Support will be fully operational (virtually) to help support students. Students can self-refer or refer a friend who may need extra support or help getting connected to resources. To connect with SOS, please email deanofstudents@jhu.edu, call 410-516-7857, or students can schedule to meet with a Case Manager by visiting the Student Outreach & Support website and follow "Schedule an Appointment".

Classroom Climate

As your instructor, I am committed to creating a classroom environment that values the diversity of experiences and perspectives that all students bring. Everyone here has the right to be treated with dignity and respect. I believe fostering an inclusive climate is important because research and my experience show that students who interact with peers who are different from themselves learn new things and experience tangible educational outcomes. Please join me in

creating a welcoming and vibrant classroom climate. Note that you should expect to be challenged intellectually by me, the TAs, and your peers, and at times this may feel uncomfortable. Indeed, it can be helpful to be pushed sometimes in order to learn and grow. But at no time in this learning process should someone be singled out or treated unequally on the basis of any seen or unseen part of their identity.

If you ever have concerns in this course about harassment, discrimination, or any unequal treatment, or if you seek accommodations or resources, I invite you to share directly with me or the TAs. I promise that we will take your communication seriously and to seek mutually acceptable resolutions and accommodations. Reporting will never impact your course grade.

Family Accommodations Policy

You are welcome to bring a family member to class on occasional days when your responsibilities require it (for example, if emergency child care is unavailable, or for health needs of a relative). In fact, you may see my children in class on days when their school is closed. Please be sensitive to the classroom environment, and if your family member becomes uncomfortably disruptive, you may leave the classroom and return as needed.