# ORI 391Q.1 (19955) – Nonlinear Programming

# CSE 393 (63170) – Nonlinear Programming

# Spring 2025

# General Information

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| **Instructor:** | Raghu Bollapragada |
| **Time & location:** | Tuesdays and Thursdays, 12:30 PM - 2:00 PM (CST)<br>ETC 7.146 (in - person meetings) |
| **Course Mode:** | All lectures will be live streamed on zoom and will be recorded and posted<br>on Canvas. Zoom link for live lectures is provided on Canvas. |
| **Office:** | ETC 5.118 |
| **Office Hours:** | Tuesday 2:00 PM - 02:45 PM, and Thursdays 11:30 AM - 12:15 PM in my office.<br>Office hours are also available via online Zoom appointments.<br>If you want to see me outside these hours please send me an email. |
| **Email:** | raghu.bollapragada@utexas.edu |
| **Website:** | https://sites.google.com/view/raghub/home |
| **Class Web Page:** | https://utexas.instructure.com/courses/1408053.<br>All class materials will be posted on *Canvas*. |
| **Prerequisites:** | Multivariable Calculus, Linear Algebra and basic programming skills in<br>Matlab or Python. No prior knowledge of optimization is assumed. |
| **Required Text:** | J. Nocedal and S. Wright, *Numerical Optimization,* Springer<br>Newyork, NY, 1999.<br>You are not required to read the textbook but it is recommended. You may be<br>asked to read some topics as part of reading assignments. You are not<br>responsible for textbook material that is not covered in the lecture. |
| **Other Text:** | There are many books on nonlinear optimization methods. The following are<br>a few good references:<br>• D. Bertsekas, *Nonlinear Programming*, Vol. 4., Athena Scientific, 2016.<br>• D. Bertsekas, *Convex Optimization Algorithms*, Athena Scientific, 2015.<br>• S. Boyd and L. Vandenberghe, *Convex Optimization*, Cambridge university<br> press, 2004. |

**Longhorn Textbook Access (LTA):** The materials for this class are available through the Longhorn Textbook Access (LTA) program, an initiative between UT Austin, The University Co-op and textbook publishers to significantly reduce the cost of digital course materials for students. You are automatically opted into the program but can easily opt-out (and back in) via Canvas through the 12th class day (January 29th). To opt out, simply press the "My Textbooks" link in Canvas and then press the "Opt Out" button on the material. You will be billed for your LTA material after the 5th class day through your "What I Owe" page but still have through the 12th class day to opt out. You must pay for your LTA materials through the What I Owe page by the 20th class day (February 10th). If you do not pay by the 20th class day, you will lose access to the materials after the 20th class day and your charge will be removed. More information about the LTA program is available at [https://www.universitycoop.com/longhorn-textbook-access](https://www.universitycoop.com/longhorn-textbook-access)

**Course Description:** Optimization is an important tool in decision science. A wide variety of decision making problems arising in engineering applications are modeled as *nonlinear programming* problems (NLPs). The goal of this course is to introduce basic theoretical principles underlying nonlinear optimization problems and the numerical methods that are available to solve them. We focus on algorithms and theory for smooth unconstrained, and constrained optimization problems.

**Learning Objectives:** By the end of the course, students will learn about the most common numerical optimization algorithms for solving smooth unconstrained and constrained optimization problems. They will understand the theoretical foundation and convergence properties of these methods, and in programming assignments they will learn how to implement the methods.

**Topics Covered:**

1. Introduction to Nonlinear Optimization

    - Examples, Definitions and Background

2. Unconstrained Optimization

    - Fundamentals of unconstrained optimization
    - Line search and trust region methods
    - Steepest descent method
    - Newton's Method
    - Quasi-Newton methods
    - Conjugate Gradient method

3. Constrained Optimization

    - Theory of constrained optimization
    - Quadratic optimization
    - Penalty methods
    - Sequential quadratic programming
    - Interior-point methods

4. Stochastic Optimization[1]

- Stochastic Gradient (SG) method, Variants of SG method

**Grading Policy:**  In this course, there will be several homework assignments, one in-semester exam, one course project, and one final exam. The weightings are as follows:

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| Homework Assignments (groups of 1 or 2) | 25% |
| Project (groups of 2 or 3, due April 25, 2025, tentative) | 20% |
| In-Semester Exam (February 27, tentative) | 25% |
| Final Exam (May 03, cumulative, includes all material discussed in the class) | 30% |

Homework assignments can be done in teams of 1-2 students and are due at the beginning of class on designated days. Late assignments will not be accepted. They will be posted on course website atleast one week before they are due. On these assignments, you are allowed to discuss the problems with your classmates. However, each team *must* write their own solution. Assignments must be submitted electronically on the course website. Please create a zip file with `LastName_FirstName_HW#`.zip with all materials (written, code etc.) You are encouraged to use LaTeX to compile these assignments. Please make sure you mention the name and Eid of all the members of the group on the assignment. Every student in the group should submit the same solution (that consists of all the members' names). Otherwise the solutions will not be graded. Every member of the group will get same grade. Letter grades will be determined according to the following conversion:

A   93% or greater
A-  86% to < 93%
B+  83% to < 86%
B   76% to < 83%
B-  72% to < 76%
C+  68% to < 72%
C   64% to < 68%
C-  60% to < 64%
D+  52% to < 60%
D   46% to < 52%
D-  40% to < 46%
F   < 40%

The instructor reserves the right to increase your total score by "curving" or some other method. However, these changes will never lower your grade.

**Project Policy:**  The course project will entail both software implementation and the creation of a report detailing your software along with the numerical results obtained from test problems. You will have coding assignments distributed throughout the semester, contributing to a significant portion of the project's codebase. All coding activities must be carried out using either Matlab or Python. Course projects should be done in teams of 2-3 students.

**Exam Policy:**  You are required to take the exam at the scheduled time. Make-up exams will not be given without a valid medical excuse.

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[1]If time permits

**Regrade Requests:**  Request for regrading an assignment must be made in writing within one (1) week of the graded assignment being made available to students in the class.

**Sharing of Course Materials is Prohibited:**  No materials used in this class, including, but not limited to, lecture hand-outs, slides videos, assessments (quizzes, exams, papers, homework assignments), in-class materials, review sheets, and additional problem sets, may be shared online or with anyone outside of the class unless you have my explicit, written permission. Unauthorized sharing of materials promotes cheating. It is a violation of the University's Student Honor Code and an act of academic dishonesty.

**Class Recordings:**  Class recordings are reserved only for students in this class for educational purposes and are protected under FERPA. The recordings should not be shared outside the class in any form. Violation of this restriction by a student could lead to Student Misconduct proceedings.

**Honor Code:**  I expect everyone to abide by the UT Honor Code, which states: The core values of the University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the University is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community. All suspected violations of the Honor Code will be referred to the Administration for adjudication. The assignments in this course are all to be completed individually. Stealing ideas or copying text from a classmate, the internet, or other external resources will be treated as a violation of the Honor Code. Plagiarism is a serious offense and is cause for dismissal from the University.

**Tentative Course Schedule:**  The course schedule below is subject to change and will be updated as frequently as possible.

| Lecture | Date | Topics | Assigned | Due |
|---------|------|--------|----------|-----|
| 1 | 01/14 | Introduction, Background & Definitions | | - |
| 2 | 01/16 | Introduction, Background & Definitions | HW1 | - |
| 3 | 01/21 | Fundamentals of Unconstrained Optimization | - | - |
| 4 | 01/23 | Fundamentals of Unconstrained Optimization | - | - |
| 5 | 01/28 | Generic Line Search Methods | HW2 | HW1 |
| 6 | 02/30 | Generic Line Search Methods | - | - |
| 7 | 02/04 | Steepest Descent & Newton Methods | - | - |
| 8 | 02/06 | Modified Newton & Quasi-Newton Methods | - | - |
| 9 | 02/11 | Quasi-Newton and its limited memory variants | HW3 | HW2 |
| 10 | 02/13 | Conjugate Gradient (CG)& Newton - CG Methods | - | - |
| 11 | 02/18 | Trust-Region Methods | - | HW2P |
| 12 | 02/20 | Theory of Constrained Optimization | - | - |
| 13 | 02/25 | Midterm Review | - | HW3 |
| - | 02/27 | Midterm | - | - |
| 14 | 03/04 | Theory of Constrained Optimization | HW4 | - |
| 15 | 03/06 | Theory of Constrained Optimization | - | HW3P |
| 16 | 03/11 | Theory of Constrained Optimization | - | - |
| 17 | 03/13 | Quadratic Programming | - | - |
| - | 03/17-03/22 | Spring Break | - | - |
| 18 | 03/25 | Quadratic Programming | HW5 | HW4 |
| 19 | 03/27 | Quadratic Programming | - | - |
| 20 | 04/01 | Penalty & Augmented Lagrangian Methods | - | - |
| 21 | 04/03 | Penalty & Augmented Lagrangian Methods | - | - |
| 22 | 04/08 | Sequential Quadratic Programming (SQP) | HW6 | HW5 |
| 23 | 04/10 | Sequential Quadratic Programming (SQP) | - | - |
| 24 | 04/15 | Interior Point Methods | - | - |
| 25 | 04/17 | Interior Point Methods | - | - |
| 26 | 04/22 | Stochastic Optimization | - | HW6 |
| 27 | 04/24 | Software & Review & Project Due | - | - |
| - | 05/03 | FINAL (01:00 PM - 03:00PM) | - | - |

## Additional Information

• **Email Communication:** For this class, email will be used as an official form of communication for notifying you of new homework assignments and other class updates. The University of Texas email policy can be found at: http://www.utexas.edu/cio/policies/university-electronic-mail-student-notification-policy.

• **Students with Disabilities:** The University of Texas at Austin provides upon request appropriate academic accommodations for qualified students with disabilities. For more information, contact the Office of the Dean of Students at 471-6259, 471-4641 TTY.

• **Course Evaluation:** Near the end of the course you will have an opportunity to anonymously evaluate the course and instructor using the standard College of Engineering evaluation form.

• **Class Web Site and Privacy:** For this class, web-based, password-protected class sites will be available via the *Canvas* system. The syllabus, handouts, assignments and other resources are types of information that may be available within this site. Site activities could include exchanging e-mail, engaging in class discussions and chats, and exchanging files. In addition, a class e-mail roster will be a component of the site. Students who do not want their names included in this

electronic class roster must restrict their directory information in the Office of the Registrar, Main Building, Room 1. For information on restricting directory information see: http://registrar. utexas.edu/students/records/restrictmyinfo.

• **Behavior Concerns Advice Line (BCAL):** If you are worried about someone who is acting differently, you may use the Behavior Concerns Advice Line to discuss by phone your concerns about another individual's behavior. This service is provided through a partnership among the Office of the Dean of Students, the Counseling and Mental Health Center (CMHC), the Employee Assistance Program (EAP), and The University of Texas Police Department (UTPD). Call 512-232-5050 or visit http://www.utexas.edu/safety/bcal.

• **Religious Holy Days:** By UT Austin policy, you must notify me of your pending absence at least fourteen days prior to the date of observance of a religious holy day. If you must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, you will be given an opportunity to complete the missed work within a reasonable time after the absence.

• **COVID-19 Guidance:** To help keep everyone at UT and in our community safe, it is critical that all students report COVID-19 symptoms and testing, regardless of test results, to University Health Services, and faculty and staff report to the HealthPoint Occupational Health Program (OHP) as soon as possible. Please see this link to understand what needs to be reported. In addition, to help understand what to do if a fellow student in the class (or the instructor or TA) tests positive for COVID, see University Health Services.

• **Title IX Reporting:** Title IX is a federal law that protects against sex and gender-based discrimination, sexual harassment, sexual assault, sexual misconduct, dating/domestic violence and stalking at federally funded educational institutions. UT Austin is committed to fostering a learning and working environment free from discrimination in all its forms where all students, faculty, and staff can learn, work, and thrive. When sexual misconduct occurs in our community, the university can:

- Intervene to prevent harmful behavior from continuing or escalating.

- Provide support and remedies to students and employees who have experienced harm or have become involved in a Title IX investigation.

- Investigate and discipline violations of the university's relevant policies.

Faculty members and certain staff members are considered "Responsible Employees" or "Mandatory Reporters," which means that they are required to report violations of Title IX to the Title IX Coordinator at UT Austin. I am a Responsible Employee and must report any Title IX related incidents that are disclosed in writing, discussion, or one-on-one. Before talking with me, or with any faculty or staff member about a Title IX related incident, be sure to ask whether they are a responsible employee. If you want to speak with someone for support or remedies without making an official report to the university, email advocate@austin.utexas.edu. For more info about reporting options and resources, visit https://titleix.utexas.edu/campus-resources or contact the Title IX Office at titleix@austin.utexas.edu.

• **Campus Carry:** "The University of Texas at Austin is committed to providing a safe environment for students, employees, university affiliates, and visitors, and to respecting the right of individuals who are licensed to carry a handgun as permitted by Texas state law." For more information, please see http://campuscarry.utexas.edu/students.