[AE8803] Syllabus

Title: Convexifying Autonomous Decision-making

[Class Day(s), Time, Location (include lab/recitation locations)]

Instructor Information

Instructor	Email	Drop-in Hours & Location
Sarah Li	sarahli@gatech.edu	Tuesday 11 am – 12 pm and by appointment

Teaching Assistant(s)	Email	Drop-in Hours & Location
TBD	TBD	TBD

General Course Information

Description

This course establishes the theoretical foundations of convex optimization for modeling and solving problems in autonomy and decision-making. First half explores topics including convex geometry and analysis, optimality conditions, Fenchel/Lagrangian duality, linear matrix inequalities, and convergence guarantees from first order gradient methods. In the second half, emphasis is placed on using convexification techniques to address nonconvex subclasses such as: distributionally robust, min-max optimization, and multi-agent features of problems in autonomy and decision-making. Additionally, this course provides a practical introduction to using CVXPy.

Pre- &/or Co-Requisites

Required - AE 6530 – multivariable linear system and control (or equivalent)

Recommended – Undergraduate-level real analysis and probability theory

Optional – AE 6310 - Design and optimization

Course Goals and Learning Outcomes

- Students can follow optimization-based proofs/algorithms in robotics/control/ML publications
- Students gain intuition for limitations/trade-offs of convergence guarantees in control/ML problems
- Students can convexify control/ML problems to derive local/ϵ-optimal guarantees
- Students can use CVXPY to model and solve optimization problems

Core IMPACTS

TBD

Syllabus Portal

Canvas

Course Requirements & Grading

This course will be graded as

- 36% homework
- 40% final

- 24% midterm

Homework: we will have about 6 homework assignments, about one every two weeks.

Exams: we will have an in-class midterm (time TBD) and a final exam during exam season. On the exams, the following tools are allowed.

- Basic, 4-function calculator
- Scientific calculator
- One double-sided U.S. letter or A4 size crib sheet – submitted with your exam

Extra Credit Opportunities

If students experience significant life-related hardship over the course that impacts their grade, they are welcome to come discuss it with me.

Grading Scale

Your final grade will be assigned as a letter grade according to the following scale:

A	90-100%
B	80-89%
C	70-79%
D	60-69%
F	0-59%

Course Materials

Course Text

- **Convex optimization**, 1st edition, Boyd & Vandenberghe (required)
- **Numerical Optimization**, Nocedal & Wright (optional)
- **Linear Matrix Inequalities in System and Control**, Boyd, El Ghaoui, Feron, Balakrishnan (optional)

Additional Materials/Resources

Python + cvxpy installation

Course Website and Other Classroom Management Tools

Canvas

Topics Overview:

- Linear algebra review – LMIs, schur complement, SVD, etc.
- Convex Sets:
  - geometric/algebraic properties
  - classic examples – cones, polytopes, ellipsoids, spectrahedral, Gelbrich sets
  - variational inequalities,
  - separating hyperplane theorem
- Convex Functions:
  - geometric/algebraic convexity conditions
  - convexity preserving operations
  - Jensen's inequality,
  - Extensions: quasi-convex, log-convex
- Minimizing Convex Functions:
  - standard form, feasibility,
  - optimality conditions
  - Quasi-convex optimization, min-max optimization
- Lagrangian and Fenchel duality:
  - KKT Multipliers
  - Dual functions
  - Dual problem – strong vs weak duality

    - Minmax optimization – saddle points
    - Constraint qualifications: Slaters, LICQ, MFCQ
    - Sensitivity analysis
    - Examples problems
- Saddle points
    - minmax optimization
    - Normal form games
- Linear programs (LP)
    - Max flow min cost
    - Dynamic programming
    - Markov decision process
- Quadratic programs
    - Least squares
    - Gradient descent (GD)
    - Regularizations: proximal GD, mirror descent
- QP with constraints:
    - SDPs/LMIs state feedback, H2 control
    - Quadratically constrained QP (QCQP)
    - Second order cone program (SOCP)
    - robust LP,
    - distributionally robust optimization (DRO)
- Non-convex extensions:
    - Difference of convex programs
    - Perron-Frobenius - eigenvalue minimization,
    - Min-max optimization – minimax theorem

Course Policies, Expectations, & Guidelines

- You are welcome to drink during class, but please minimize eating.
- If you arrive late – please quietly find a place to sit and minimize disturbance to the ongoing lecture.
- I will provide course notes uploaded to canvas. I will also annotate them/solve problems in class on the ipad. I encourage you to follow on your own device/print out. My written notes will be uploaded to canvas.
- Students need to have python access and basic knowledge of how to code in python. we will provide tutorial link suggestions, but we will not dedicate time to explaining python usage. We will also not help you with any other language, including MATLAB.
- Some exposure to mathematical proofs is necessary prior to taking this course.
- You are encouraged to collaborate with others on homeworks. Please indicate who you collaborated with.
- Your homework is graded on the correctness and clarity of your proofs/explanations – any correct answer without a derivation will be given zero grade.

Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. Review Georgia Tech's Honor Code and the student Code of Conduct.

Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services (404-894-2563) as soon as possible to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Attendance and/or Participation

I do not mind if you don't show up to classes. However, students who come to class will have priority during office hours.

Collaboration, Group Work, and Use of Generative AI

Students are highly encouraged to discuss problems with each other but should write up solutions on their own. Homework and exams are strictly evaluated on the correctness and clarity of the proofs – we will not dig through unclear proofs to grant extra grades.

Extensions, Late Assignments, & Re-Scheduled/Missed Exams

With advanced notice (at least 1 week is possible), we are happy to make scheduling arrangements for any required travels, personal hardships, unexpected events. Sickness related issues must have doctor notes to be valid.

Inclement Weather and Digital Learning Days

In the event of inclement weather/campus shutdown, we will provide prior notice about class cancellation or digital learning days.

Student-Faculty Expectations Agreement

At Georgia Tech, we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. The Student-Faculty Expectations articulate some basic expectations that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Student Use of Mobile Devices in the Classroom

You are welcome to use devices on SILENT. If I hear your phone's audio/vibration, I will ask you to turn it off. Absolutely no devices beyond a simple calculator are allowed during exams.