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Syllabus

Course Syllabus

ISYE 6669

Deterministic Optimization

Professors: Dr. Andy Sun and Dr. Shabbir Ahmed

Course Description

The course will teach basic concepts, models, and algorithms in linear optimization, integer optimization, and convex optimization. The first module of the course is a general overview of key concepts in optimization and associated mathematical background. The second module of the course is on linear optimization, covering modeling techniques, basic polyhedral theory, simplex method, and duality theory. The third module is on nonlinear optimization and convex conic optimization, which is a significant generalization of linear optimization. The fourth and final module is on integer optimization, which augments the previously covered optimization models with the flexibility of integer decision variables. The course blends optimization theory and computation with various applications to modern data analytics.

Prerequisite

- Linear algebra
- Multivariate Calculus
- Basic Probability
- Familiarity with programming in Python

Course Goals

Student who take this course can expect to achieve the following goals:

- Learn modeling skills for formulating various analytics problems as linear, convex nonlinear, and integer optimization problems
- Learn basic optimization theory including duality theory and convexity theory, which will give the students a deeper understanding of not only how to formulate an optimization model, but also why.
- Learn fundamental algorithmic schemes for solving linear, nonlinear, and integer optimization problems.
- Learn computational skills for implementing and solving an optimization problem using modern optimization modeling language and solvers.

Grading Policy

- There will be one midterm quiz and one final quiz. The midterm will be 35% of your overall grade and the final will be 40% of your overall grade.
- There will be homework assignments most weeks of the semester. Your two lowest homework grades will be dropped, and the remaining ones will add up to 25% of the course grade. Your homework assignments will be peer-graded (based on the median score assigned by your peer graders). You will also need to peer-grade others' homeworks; you will not receive a final grade for your homework submission if you do not complete your peer assessments.
- Audit and Verified/MicroMasters learners must achieve an overall weighted average of 60% to pass the course. For OMS Analytics degree students, we will keep a separate gradebook outside of edX; quizzes will be scaled to letter grades based on their difficulty, and combined with the homeworks to determine an overall letter grade scale at the end of the semester.

Homework and Quizzes Due Dates

All homework and quizzes will be due at the times in the table at the end of this syllabus. These times are subject to change so please check back often. Please convert from UTC to your local time zone using a Time Zone Converter.

Timing Policy

- The Modules follow a logical sequence
- Assignments should be completed by their due dates.

- Quizzes must be completed during the time allotted on the schedule.
- You will have access to the course content for the scheduled duration of the course.

Quiz Policy

- For midterm and final quizzes, you are allowed to use one sheet of paper, either 8.5”x11” or A4, with handwritten notes (both sides of the sheet, 2 sides total).
- For midterm and final quizzes, you are allowed a blank sheet of paper for scratch work (Verified/MicroMasters learners and OMS Analytics degree students will be proctored; you will have to show the front and back of the blank sheet while you are being proctored. Audit learners will not be proctored).

Attendance Policy

- This is a fully online course.
- Login on a regular basis to complete your work, so that you do not have to spend a lot of time reviewing and refreshing yourself regarding the content.

Plagiarism Policy

- Plagiarism is considered a serious offense. You are not allowed to copy and paste or submit materials created or published by others, as if you created the materials. All materials submitted and posted must be your own.

Student Honor Code

All Audit and Verified course participants are expected and required to abide by the letter and the spirit of the edX honor code.

- Review the edXHonor Code: https://www.edx.org/edx-terms-service
- You are responsible for completing your own work.
- Any learner found in violation of the edX Honor Code will be subject to any/all of the actions listed in the edX Honor Code.

All OMS Analytics degree students should abide by the Georgia Tech Student Honor Code

- Review the Georgia Tech Student Honor Code: www.honor.gatech.edu.
- Any OMS Analytics degree student suspected of behavior in violation of the Georgia Tech Honor Code will be referred to Georgia Tech’s Office of Student Integrity.

Communication

- All learners should ask questions, and answer their fellow learners' questions, on the course discussion forums. Often, discussions with fellow learners are the sources of key pieces of learning.
- Verified learners and OMS Analytics degree students can also ask questions of the instructor and teaching assistants via the course discussion forums. For special cases such as failed submissions due to system errors, missing grades, failed file uploads, emergencies that prevent you from submitting, personal issues, etc., a special email address will be provided in a discussion forum for you to directly contact the instructor and teaching assistants.

Netiquette

- Netiquette refers to etiquette that is used when communicating on the Internet. Review the Core Rules of Netiquette. When you are communicating via email, discussion forums or synchronously (real-time), please use correct spelling, punctuation and grammar consistent with the academic environment and scholarship1.
- In Georgia Tech's MS in Analytics program, we expect all participants (learners, faculty, teaching assistants, staff) to interact respectfully. Learners who do not adhere to this guideline may be removed from the course.

1. Conner, P. (2006-2014). Ground Rules for Online Discussions, Retrieved 4/21/2014 from http://teaching.colostate.edu/tips/tip.cfm?tipid=128

Course Topics and Sample Pacing Schedule

- The table below contains a course topic outline and homework due dates.

Weeks	Course Topics	Release Dates

Week 1	Module 1: Introduction • Lesson 1: Introduction to Optimization Models • Lesson 2: Mathematical ingredients • Lesson 3: Classification of optimization problems Module 2: Illustration of the optimization process • Lesson 1: A portfolio optimization problem • Lesson 2: Formulating a portfolio optimization model • Lesson 3: Solving the portfolio optimization model • Lesson 4: Summary of the optimization process	Aug 20, 2018 at 13:00 UTC
Week 1 Homework	Homework 1	Aug 20
Week 2	Module 3: Review of Mathematical Concepts • Lesson 1: Linear Algebra • Lesson 2: Properties of Functions • Lesson 3: Properties of Sets Module 4: Convexity • Lesson 1: Convex Functions • Lesson 2: Convex Sets • Lesson 3: Convex Optimization Problems	Aug 27, 2018 at 13:00 UTC
Week 2 Homework	Homework 2	Aug 30

Week 3	Module 5: Outcomes of Optimization • Lesson 1: Possible Outcomes of Optimization • Lesson 2: Existence of Optimal Solutions • Lesson 3: Local and Global Optimal Solutions • Lesson 4: Idea of Improving Search Module 6: Optimality Certificates • Lesson 1: Optimality Certificates and Relaxations • Lesson 2: Lagrangian Relaxation and Duality	Sept 3, 2018 at 13: 00 UTC
Week 3 Homework	Homework 3	Sept 6
Week 4	Module 7: Unconstrained Optimization: Derivative Based • Lesson 1: Optimality Conditions • Lesson 2: Gradient Descent • Lesson 3: Newton's Method Module 8: Unconstrained Optimization: Derivative Free • Lesson 1: Methods for Univariate Functions • Lesson 2: Methods for Multivariate Function	Sept 10, 2018 at 13: 00 UTC
Week 4 Homework	Homework 4	Sept 13

Week 5	Module 9: Linear Optimization Modeling - Network Flow Problems • Lesson 1: Introduction to LP Modeling • Lesson 2: Optimal Transportation Problem • Lesson 3: Maximum Flow Problem • Lesson 4: Shortest Path Problem Module 10: Linear Optimization Modeling - Electricity Market • Lesson 1: How Electricity Markets Work • Lesson 2: Modeling Power plant Scheduling Using LP • Lesson 3: Market Clearing Mechanism • Lesson 4: A Real-World Example	Sept 17, 2018 at 13:00 UTC
Week 5 Homework	Homework 5	Sept 20
Week 6	Module 11: Linear Optimization Modeling - Decision-Making Under Uncertainty • Lesson 1: the Need to Make Decisions Under Uncertainty • Lesson 2: Two-Stage Stochastic Linear Programming • Lesson 3: An Example Using Stochastic LP • Lesson 4: How to Solve Stochastic Programs Module 12: Linear Optimization Modeling - Handling Nonlinearity • Lesson 1: The Power of Piecewise Linear Functions • Lesson 2: Robust Regression Using LP • Lesson 3: Radiation Therapy • Lesson 4: LP Models for Radiation Therapy	Sept 24, 2018 at 13:00 UTC

Week 6 Homework	Homework 6	Sept 27
Week 7	Module 13: Geometric Aspects of Linear Optimization • Lesson 1: Basic Geometric Objects in LP • Lesson 2: Extreme Points and Convex Hull • Lesson 3: Extreme Rays and Unbounded Polyhedron • Lesson 4: Representation of Polyhedrons Module 14: Algebraic Aspects of Linear Optimization • Lesson 1: Basic Feasible Solution • Lesson 2: Polyhedron in Standard Form • Lesson 3: Basic Feasible Solution in Standard Form LP • Lesson 4: Why We Care So Much About BFS	Oct 1, 2018 at 13:00 UTC
Week 7 Homework	Homework 7	Oct 4
Week 8	Module 15: Simplex Method in a Nutshell • Lesson 1: Local Search - The General Idea • Lesson 2: Local Search - Specialized to LP • Lesson 3: How to Walk on the Edge • Lesson 4: When to Stop and Declare Victory Module 16: Further Development of Simplex Method • Lesson 1: Summarize Simplex Method • Lesson 2: Handling Degeneracy • Lesson 3: Phase I/Phase II Simplex Method • Lesson 4: An Example	Oct 8, 2018 at 13:00 UTC
Week 8 Homework	Homework 8	Oct 11

Midterm	Midterm Exam	Oct 15, 2018
Week 9	Module 17: Linear Programming Duality • Lesson 1: A Simple But Fundamental Trick for Deriving LP Dual • Lesson 2: Relation to Lagrangian Duality • Lesson 3: Weak and Strong Duality and Complementary Slackness • Lesson 4: Two-Person Zero-Sum Game Module 18: Robust Optimization • Lesson 1: Robustness and Its Wide Applications • Lesson 2: Robust Linear Program • Lesson 3: Two-Stage Robust Linear Program	Oct 15, 2018 at 13:00 UTC
Week 9 Homework	Homework 9	Oct 18
Week 10	Module 19: Nonlinear Optimization Modeling - Approximation and Fitting • Lesson 1: Gauss, Geodesy, and Linear Least-Squares Problem • Lesson 2: SVD, Matrix Approximation, and Image Compression • Lesson 3: Sparsity, Regularization, and Basis Pursuit • Lesson 4: Robust Approximation Module 20: Nonlinear Optimization Modeling - Statistical Estimation • Lesson 1: Parametric Distribution Estimation • Lesson 2: Nonparametric Distribution Estimation • Lesson 3: Computing Probability Bounds	Oct 22, 2018 at 12:00 UTC

Week 10 Homework	Homework 10	Oct 25
Week 11	Module 21: Convex Conic Programming - Introduction • Lesson 1: Convex Cones and Generalized Inequality • Lesson 2: From LP Duality to Conic Duality • Lesson 3: Second-Order Conic Programming • Lesson 4: Semi-Definite Programming Module 22: Second-Order Conic Programming - Examples • Lesson 1: Projection and Separation • Lesson 2: Optimal Placement Problem • Lesson 3: Support Vector Machine • Lesson 4: Nonlinear Discrimination	Oct 29, 2018 at 12:00 UTC
Week 11 Homework	Homework 11	Nov 1
Week 12	Module 23: Second-Order Conic Programming - Advanced Modeling • Lesson 1: Conic Quadratic Representable Functions and Sets • Lesson 2: More "Exotic" CQr Functions • Lesson 3: Robust Linear Programming Revisited Module 24: Semi-Definite Programming - Advanced Modeling • Lesson 1: Eigenvalue Optimization as SDP • Lesson 2: Polynomial Optimization as SDP • Lesson 3: Optimal Power Flow and SDP Relaxation • Lesson 4: Structural Design	Nov 5, 2018 at 12:00 UTC

Week 12 Homework	Homework 12	Nov 8
Week 13	Module 25: Discrete Optimization - Introduction • Lesson 1: Why Discrete Variables • Lesson 2: Discrete Optimization Challenges • Lesson 3: Computational Complexity Module 26: Discrete Optimization - Modeling With Binary Variables 1 • Lesson 1: Nonconvex Functions • Lesson 2: Nonconvex Sets and Logical Relations • Lesson 3: Logical Relations	Nov 12, 2018 at 12:00 UTC
Week 13 Homework	Homework 13	Nov 15
Week 14	Module 27: Discrete Optimization - Modeling With Binary Variables 2 • Lesson 1: Set Packing, Covering, Partitioning • Lesson 2: Graph and Network Problems Module 28: Discrete Optimization - Modeling Exercises • Lesson 1: Modeling Exercises - 1 • Lesson 2: Modeling Exercises - 2 • Lesson 3: Modeling Exercises - 3	Nov 19, 2018 at 12:00 UTC
Week 14 Homework	Homework 14	Nov 22

Week 15	Module 29: Discrete Optimization - Linear Programming Relaxation • Lesson 1: Linear Programming Relaxation • Lesson 2: Ideal Formulations Module 30: Discrete Optimization - Solution Methods • Lesson 1: Enumeration • Lesson 2: Cutting Plane Methods • Lesson 3: Branch-and-Bound Algorithm • Lesson 4: Heuristics	Nov 26 at 12: 00 UTC
Week 15 Homework	BONUS: Homework 15	Nov 29
Final	Final Exam	Dec 3, 2018

Course Materials

- All content and course materials can be accessed online
- There is no textbook for this course
- Reference books:
  - R. Rardin. "Optimization in Operations Research", Prentice Hall, 1998.
  - S. Boyd and L. Vandenberghe, "Convex Optimization," Cambridge University Press, 2004. Online: https://web.stanford.edu/~boyd/cvxbook/
  - A. Ben-Tal and A. Nemirovski, "Lectures on Modern Convex Optimization," SIAM, 2001.

Technology/Software Requirements

- Internet connection (DSL, LAN, or cable connection desirable)
- PuLP optimization software (free download; see http://www.coin-or.org/PuLP/ -- Windows version and (for Mac users) a Linux version)
- CVX in Python: CVXOPT, CVXPY software (available at http://cvxopt.org and http://www.cvxpy.org/en/latest/)

- CVX in MATLAB: CVX software (available at http://cvxr.com/cvx/)
- Python programming language (free download; see http://www.python.org). Preferably use the Anaconda distribution (http://www.anaconda.com) with Python 2.7.
- Adobe Acrobat PDF reader (free download; see https://get.adobe.com/reader/)