

Course Syllabus

ISYE 6669

Deterministic Optimization

Spring 2025

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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 that will be graded by faculty. The midterm will be 40% and the final will be 40% of the 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 20% of the course grade. Some of the assignments will be faculty graded, and others will be peer-graded (based on the median score assigned by your peer graders). You will also need to peer-grade others' homework; you will not receive a final grade for your homework submission if you do not complete your peer assessments.
- For OMS Analytics degree students, quizzes will be scaled to letter grades based on their difficulty and combined with the homework to determine an overall letter grade scale at the end of the semester.
- Grade Breakdown
 - Homework 20%
 - Midterm 40%
 - Final Exam 40%

Total	100%
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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 EST 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

- No notes (apart from what is stated below), books, or calculator/computers are allowed in the midterm and final quizzes.
- For midterm and final quizzes, you are allowed two blank sheets of paper for scratch work (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). For midterm you are allowed to use one sheet of paper with notes. For final you are allowed two sheets of paper with notes. Each student must prepare their own notes.

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 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.
- OMS Analytics degree students can also ask questions of the instructor and teaching assistants via Piazza.

Netiquette

- Netiquette refers to etiquette that is used when communicating on the Internet. 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.

¹Conner, P. (2006–2014). Ground Rules for Online Discussions, Retrieved 8/14/2020 from <https://tilt.colostate.edu/TipsAndGuides/Tip/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	<p>Module 1: Introduction</p> <ul style="list-style-type: none"> • Lesson 1: Introduction to Optimization Models • Lesson 2: Mathematical ingredients • Lesson 3: Classification of optimization problems <p>Module 2: Illustration of the optimization process</p> <ul style="list-style-type: none"> ○ 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 	Jan 6, 2025 at 8:00 a.m. Eastern
Week 1 Homework	Homework 1	Jan 6 at 8: 00 a.m. Eastern – Jan 16 at 11:59 p.m.

		Peer Assmt: Jan 16 at 11:59 Eastern – Jan 20 at 11:59 Eastern
Week 2	<p>Module 3: Review of Mathematical Concepts</p> <ul style="list-style-type: none"> Lesson 1: Linear Algebra Lesson 2: Properties of Functions Lesson 3: Properties of Sets <p>Module 4: Convexity</p> <ul style="list-style-type: none"> Lesson 1: Convex Functions Lesson 2: Convex Sets Lesson 3: Convex Optimization Problems 	Jan 13, 2025 at 8:00 a.m. Eastern
Week 2 Homework	Homework 2	Jan 13 at 8: 00 a.m. Eastern – Jan 23 at 11:59 p.m. Peer Assmt: Jan 23 at 11:59 Eastern – Jan 27 at 11:59 Eastern
Week 3	<p>Module 5: Outcomes of Optimization</p> <ul style="list-style-type: none"> 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 <p>Module 6: Optimality Certificates</p> <ul style="list-style-type: none"> Lesson 1: Optimality Certificates and Relaxations Lesson 2: Lagrangian Relaxation and Duality 	Jan 20, 2025 at 8:00 a.m. Eastern
Week 3 Homework	Homework 3	Jan 20 at 8: 00 a.m. Eastern – Jan 30 1 at 11:59 p.m. Peer Assmt: Jan 30 at 11:59 Eastern – Feb 3 at 11:59 Eastern

Week 4	<p>Module 7: Unconstrained Optimization: Derivative Based</p> <ul style="list-style-type: none"> Lesson 1: Optimality Conditions Lesson 2: Gradient Descent Lesson 3: Newton's Method <p>Module 8: Unconstrained Optimization: Derivative Free</p> <ul style="list-style-type: none"> Lesson 1: Methods for Univariate Functions Lesson 2: Methods for Multivariate Function 	Jan 27, 2025 at 8:00 a.m. Eastern
Week 4 Homework	Homework 4	Jan 27 at 8: 00 a.m. Eastern – Feb 6 at 11:59 p.m. Peer Assmt: Feb 6 at 11:59 Eastern – Feb 10 at 11:59 Eastern
Week 5	<p>Module 9: Linear Optimization Modeling - Network Flow Problems</p> <ul style="list-style-type: none"> Lesson 1: Introduction to LP Modeling Lesson 2: Optimal Transportation Problem Lesson 3: Maximum Flow Problem Lesson 4: Shortest Path Problem <p>Module 10: Linear Optimization Modeling - Electricity Market</p> <ul style="list-style-type: none"> 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 	Feb 3, 2025 at 8:00 a.m. Eastern
Week 5 Homework	Homework 5	Feb 3 at 8: 00 a.m. Eastern – Feb 13 at 11:59 p.m.

		Peer Assmt: Feb 13 at 11:59 Eastern – Feb 17 at 11:59 Eastern
Week 6	<p>Module 11: Linear Optimization Modeling - Decision-Making Under Uncertainty</p> <ul style="list-style-type: none"> • 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 <p>Module 12: Linear Optimization Modeling - Handling Nonlinearity</p> <ul style="list-style-type: none"> • 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 	Feb 10, 2025 at 8:00 a.m. Eastern
Week 6 Homework	Homework 6	Feb 102 at 8: 00 a.m. Eastern – Feb 20, at 11:59 p.m. Peer Assmt: Feb 20 at 11:59 Eastern – Feb 24 at 11:59 Eastern
Week 7	<p>Module 13: Geometric Aspects of Linear Optimization</p> <ul style="list-style-type: none"> • 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 	Feb 17, 2025 at 8:00 a.m. Eastern

	<p>Module 14: Algebraic Aspects of Linear Optimization</p> <ul style="list-style-type: none"> • 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 	
Week 7 Homework	Homework 7	<p>Feb 17 at 8: 00 a.m. Eastern – Feb 27 at 11:59 p.m. Peer Assmt: Feb 27 at 11:59 Eastern – Mar 3 at 11:59 Eastern</p>
Week 8	<p>Module 15: Simplex Method in a Nutshell</p> <ul style="list-style-type: none"> • 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 <p>Module 16: Further Development of Simplex Method</p> <ul style="list-style-type: none"> • Lesson 1: Summarize Simplex Method • Lesson 2: Handling Degeneracy • Lesson 3: Phase I/Phase II Simplex Method • Lesson 4: An Example 	<p>Feb 24, 2025 at 8:00 a.m. Eastern</p>
Week 8 Homework	Homework 8	<p>Feb 24 at 8: 00 a.m. Eastern – Mar 6 at 11:59 p.m. Peer Assmt: Mar 6 at 11:59 Eastern – Mar 10 at 11:59 Eastern</p>

Midterm	Midterm Exam	Mar 3, 2025 at 8: 00 a.m. Eastern – Mar 10 at 11:59 p.m. Eastern
Week 9	<p>Module 17: Linear Programming Duality</p> <ul style="list-style-type: none"> • Lesson 1: Introduction to Duality Theory • Lesson 2: Lagrangian Relaxation and LP Duality • Lesson 3: Weak Duality and Strong Duality • Lesson 4: Table of Possibles and Impossibles • Lesson 5: Complementary Slackness <p>Module 18: Robust Optimization</p> <ul style="list-style-type: none"> • Lesson 1: Concept of Robustness • Lesson 2: Concept of Robustness in Example • Lesson 3: Robust Linear Program • Lesson 4: More Examples of Robust 	Mar 3, 2025 at 8: 00 a.m. Eastern
Week 9 Homework	Homework 9	Mar 3 at 8: 00 a.m. Eastern – Mar 13 at 11:59 p.m. Eastern Peer Assmt: Mar 13 at 11:59 Eastern – Mar 17 at 11:59 Eastern
Week 10	<p>Module 19: Large-Scale Optimization Cutting Stock Problem</p> <ul style="list-style-type: none"> • Lesson 1: Cutting Stock Problem • Lesson 2: Gilmore-Gomory Formulation • Lesson 3: Column Generation • Lesson 4: Column Generation for Cutting Stock Problem <p>Module 20: Large-Scale Optimization</p> <ul style="list-style-type: none"> • Lesson 1: Example for Column Generation 	Mar 10, 2025 at 8: 00 a.m. Eastern

	<ul style="list-style-type: none"> • Lesson 2: Primal-Dual Relationship: Constraint Generation • Lesson 3: Primal-Dual Relationship: Pricing Problem and Separation Problem 	
Week 10 Homework	Homework 10	Mar 10 at 8: 00 a.m. Eastern – Mar 20 at 11:59 p.m. Peer Assmt: Mar 20 at 11:59 Eastern – Mar 24 at 11:59 Eastern
Week 11	<p>Module 21: Large-Scale Optimization Dantzig-Wolfe Decomposition</p> <ul style="list-style-type: none"> • Lesson 1: Exploiting Special Structures of Large-Scale Optimization • Lesson 2: Dantzig-Wolfe Decomposition 1 • Lesson 3: Dantzig-Wolfe Decomposition 2 • Lesson 4: Dantzig-Wolfe Decomposition 3 • Lesson 5: Example <p>Module 22: Nonlinear Optimization Modeling - Approximation and Fitting</p> <ul style="list-style-type: none"> • Lesson 1: Linear Equations, Norm, and Least Square • Lesson 2: Function Fitting • Lesson 3: Normal Equation and Singular Value Decomposition • Lesson 4: Image Compression, Constrained Least Squares, and SVD • Lesson 3: Support Vector Machine 	Mar 17, 2025 at 8: 00 a.m. Eastern
Spring break		Mar 17-Mar 21, 2025
Week 11 Homework	Homework 11	Mar 17 at 8: 00 a.m. Eastern – Mar 27 at 11:59 p.m. Peer Assmt: Mar 27 at 11:59 Eastern – Mar 31 at 11:59 Eastern
Week 12	Module 23: Convex Conic Programming Introduction	Mar 24, 2025 at 8: 00 a.m. Eastern

	<ul style="list-style-type: none"> Lesson 1: Convex Cones, Order, and Linear Conic Programming Lesson 2: Second-Order Cone and SOCP Lesson 3: PSD Cone and SDP <p>Module 24: SOCP, SDP Examples</p> <ul style="list-style-type: none"> Lesson 1: Statistical Classification Problem Lesson 2: Experimental Design Lesson 3: Extremal Ellipsoid Problem 	
Week 12 Homework	Homework 12	<p>Mar 24 at 8: 00 a.m. Eastern – Apr 3 at 11:59 p.m.</p> <p>Peer Assmt: Apr 3 at 11:59 Eastern – Apr 7 at 11:59 Eastern</p>
Week 13	<p>Module 25: Discrete Optimization - Introduction</p> <ul style="list-style-type: none"> Lesson 1: Why Discrete Variables Lesson 2: Discrete Optimization Challenges Lesson 3: Computational Complexity <p>Module 26: Discrete Optimization - Modeling With Binary Variables 1</p> <ul style="list-style-type: none"> Lesson 1: Nonconvex Functions Lesson 2: Nonconvex Sets and Logical Relations Lesson 3: Logical Relations 	<p>Mar 31, 2025 at 8: 00 a.m. Eastern</p>
Week 13 Homework	Homework 13	<p>Mar 31 at 8: 00 a.m. Eastern – April 10 at 11:59 p.m.</p> <p>Peer Assmt: Apr 10 at 11:59 Eastern – Apr 14 at 11:59 Eastern</p>

<p>Week 14</p>	<p>Module 27: Discrete Optimization - Modeling With Binary Variables 2</p> <ul style="list-style-type: none"> Lesson 1: Set Packing, Covering, Partitioning Lesson 2: Graph and Network Problems <p>Module 28: Discrete Optimization - Modeling Exercises</p> <ul style="list-style-type: none"> Lesson 1: Modeling Exercises - 1 Lesson 2: Modeling Exercises - 2 Lesson 3: Modeling Exercises - 3 	<p>Apr 7, 2025 at 8: 00 a.m. Eastern</p>
<p>Week 14 Homework</p>	<p>Homework 14</p>	<p>Apr 7 at 8: 00 a.m. Eastern – Apr 17 at 11:59 p.m. Peer Assmt: Apr 17 at 11:59 Eastern – Apr 21 at 11:59 Eastern</p>
<p>Week 15</p>	<p>Module 29: Discrete Optimization - Linear Programming Relaxation</p> <ul style="list-style-type: none"> Lesson 1: Linear Programming Relaxation Lesson 2: Ideal Formulations <p>Module 30: Discrete Optimization - Solution Methods</p> <ul style="list-style-type: none"> Lesson 1: Enumeration Lesson 2: Cutting Plane Methods Lesson 3: Branch-and-Bound Algorithm Lesson 4: Heuristics 	<p>Apr 14, 2025 at 8:00 a.m. Eastern</p>
<p>Week 15 Homework</p>	<p>Homework 15</p>	<p>Apr 14 at 8: 00 a.m. Eastern – Apr 20 at 11:59 p.m. Peer Assmt: Apr 20 at 11:59 Eastern – Apr 24 at 11:59 Eastern</p>
<p>Final</p>	<p>Final Exam</p>	<p>Apr 24, 2025 at 8:00 a.m. Eastern – May 1, 2025 at 11:59 p.m. Eastern</p>

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 <https://www.cvxpy.org/>)
- 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>)
- Adobe Acrobat PDF reader (free download; see <https://get.adobe.com/reader/>)