

ISYE 4135 OPTIMIZATION FOUNDATIONS FOR MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE

Concentration elective

Prepared Profs. Scheinberg and Lan, Spring 2026

Credit: 3-0-3

Prerequisite(s): MATH 1553 or MATH 1554 and MATH 2550 or MATH 2551 and CS 1301 or CS 1371

Texts:

None

Referenced

Course slides, reading and data available on Canvas

Catalog Description:

This course provides an overview of health systems and public health to explore their positive impact on well-being of individuals and effectiveness of health systems.

Course Description

Continuous optimization models and algorithms are at the heart of many problems of Data Science, Machine Learning, AI, signal processing, economics and other modern contexts. This course introduces foundations of optimization models and algorithms as applied in these settings. Topics include unconstrained optimization, gradient descent and its variants, Newton method, convergence of algorithms, parameter tuning, line-search, stochastic gradient descent and its variants, empirical risk minimization, constrained optimization, duality, convexity, Lagrange duality. We will use examples from linear regression, Lasso regression, logistic regression, support vector machines and neural networks.

Topical Outline

The topical outline is shown in the table below. The table has 2 columns. The first column lists the topics to be covered. The second column lists the week number these topics will be covered.

Topics	Week
Introduction, optimization problems, constrained and unconstrained problems, local global optima. Convex and nonconvex functions, level sets	1
Hessian, gradients, linear algebra, optimality conditions. Least squares	2
Gradient descent, examples, Line search. Convergence of gradient descent	3
Newton and Quasi-Newton methods. Accelerated gradient descent, coordinate descent.	4
Binary classification and Logistic regression, large scale data sets, stochastic gradient descent	5
Convergence of stochastic gradient descent. Extensions and Neural Networks	6
Review. Midterm	7
Linear and Integer programs, relaxations. LP examples in signal processing	8
Linear programming, graphical method. Duality, Intro	9
Duality properties. Complementary slackness	10
Lagrangian, KKT conditions. Convex QP, duality	11
Portfolio Optimization. Support Vector Machines and Lasso regression	12
Other convex problems and their optimality. Methods for constrained problems	13
Other topics of interest. Review	14

Course Learning Outcomes

By the end of this course, students will be able to:

1. apply gradient and stochastic descent algorithms in correct settings with correct parameters, recognize if the algorithm attains desirable solution.
2. recognize and model linear optimization problems and some other constrained optimization problems,
3. solve them using software packages and recognize when the output is correct.
4. understand capabilities and limitations of the algorithms that are covered in this course.

The Mapping from the Course Outcomes to ABET Student Learning Outcomes

The table below shows the relationship between course outcomes and ABET student learning outcomes. The table has 8 columns. The first column lists the course learning outcomes listed above. The next 7 columns list the abbreviated ABET Student Learning Outcomes. The entry of H in a row with specific course learning outcome and column with specific ABET Student Learning Outcomes indicate the importance of attaining this outcome is high and will be assessed.

Course outcome \ Program Outcomes	1. identify, formulate solve engg prob by engg, sci & Math	2. produce solutions consider public health, safety, welfare, global, cultural, social, environ & economic	3 communicate with a range of audience	4 recognize ethical & professional responsibilities, make informed judgement consider resolutions in global, economic, environ and societal context.	5. effective on a team provide leadership, collaborative and inclusive envirm, plan tasks & meet objectives	6. develop and conduct experiment, analyze and interpret data & use engineering judgement to draw conclusions.	7. acquire and apply new knowledge using appropriate learning strategies
1. Apply gradient and stochastic descent algorithms in correct settings with correct parameters, recognize if the algorithm attains desirable solution							
2. Recognize and model linear optimization problems and some other constrained optimization problems		H					
3. Solve them using software packages and recognize when the output is correct							
4. Understand capabilities and limitations of the algorithms that are covered in this course		H			H		

Evaluation of the important outcomes

Course outcomes 6 will be assessed on project or specific question on final exam