School of Computing and Information Science

Course Title: Optimization Methods for Computing: Theory and Applications **Date:** 09/03/2019

Course Number: COT 5443

Number of Credits: 3

Subject Area: Data Science	**Subject Area Coordinator:** **email:**
Catalog Description: Optimization for CS graduate students, including algorithms, applications to widely used methods including efficient computing, machine learning and data science, and real-world problems. Basic calculus and programming skills are needed.	
Textbook: 1) Borwein, Jonathan, and Adrian S. Lewis. ***Convex analysis and nonlinear optimization: theory and examples***. Springer Science & Business Media, 2010. 2) Boyd, Stephen, and Lieven Vandenberghe. *Convex optimization*. Cambridge university press, 2004.	
References: None	
Prerequisite Courses: ((MAC 2311 Calculus I or equivalent) and (MAS 3105 Linear Algebra or equivalent)) or instructor's permission	
Corequisite Courses: None	

Type: **Elective**

Prerequisite Topics:

- Calculus, Basic Programming (e.g., Python or MATLAB)

Course Outcomes:

Students who successfully complete this course will be able to:

1. Explain the general concepts of optimization theory, linear/nonlinear optimization, convex/nonconvex problems;
2. Formulate an optimization problem from scratch, and utilize the most efficient algorithm to solve the formulated problem;
3. Describe decomposition techniques, their step by step implementation, and advantages for large-sclae computational problems;
4. Identify computing and decision making problems, e.g., data analytics and machine learning, and the theoretical optimization problems behind each notion
5. Explain and discuss emerging real-world applications of optimization for learning and data science, e.g., energy demand forecasting, traffic flow optimization, and community analysis in social networks.

Outline:

Topic	Number of Lecture Hours (Total: 37.5 hours = 15 weeks * 2 lectures/week * 1.25 hrs/lecture)	Outcome
Introduction to Optimization • What are the main roles of optimization in computing? • How to formulate an optimization based on a real-world computing problem? • What are the applications of optimization in learning and data sciences?	5	1,2
Preliminaries • Linear algebra and matrix calculus preliminaries • Eigen value decomposition, singular value decomposition, matrix inversion • Overview of related Python libraries/ MATLAB functions	2.5	1,2,4
Centralized algorithm for general optimization problems • How to formulate and solve unconstrained optimization • How to formulate and solve constrained optimization • Karush–Kuhn–Tucker (first order necessary) conditions • Example: Optimal energy management in data centers	3.75	1,2
Convexity • What is the definition of convex optimization? • How can we solve convex optimization problems? • Duality theorem	2.5	1,2,3
Decomposition techniques for nonlinear optimization • Lagrangian decomposition • Augmented Lagrangian decomposition • Optimality condition decomposition • Examples: Data fitting, optimal pricing in financial systems	10	1,3,4
Decomposition techniques for linear optimization • Dantzig-Wolfe decomposition • Benders decomposition for linear problems • Examples: Resource allocation in manufacturing	6.25	1,3,4,5
Optimization for decision making and computing • Understanding the role pf optimization theory in computer science tools and problems • How to leverage optimization algorithms for more efficient data analytics? • How can we formulate a learning problem as an optimization problem? How to use the skills from this course to solve the formulated problem? •	6.25	4,5
Real-world examples of optimization	1.25	4,5