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Bulletin # : 1
Academic Year : 2019-20

FLORIDA INTERNATIONAL UNIVERSITY
UNIVERSITY CURRICULUM COMMITTEE
Proposal for a New Course

1. **School/College** Engineering and Computing
   Div./Dept. in Which Taught School of Computing and Information Sciences
2. | COT | 5 | | | 3 |
   |---|---|---|---|---|
   | Alpha Prefix | 1st Digit | Last 3 Digits | "C"-lec-lab "L"-Lab | Cr. Hrs. |

   CIP Code *(Leave this blank)*: ______
3. **Grading Method (select one):** ☒ Graded ☐ Pass/Fail

4a. **Course Title** Optimization Methods for Computing: Theory and Applications

b. **Abbreviated course Title** *(for computer class schedules, transcripts)* Opt. Com. Thr. & Appl.
LIMITED TO 25 Characters *(including spaces)*

5. **Statewide Course Numbering Subject Matter Area** COT (Computing Theory)
6. **Catalog Description/Major Topics** *(not to exceed 200 characters including spaces)*
   College of Medicine and College of Law: Attach description not exceeding 1,000 characters including spaces.

   Optimization for CS students, including introduction to optimization algorithms, applications in CS, efficient computing, and real-world problems. Basic calculus and programming skills are needed.

7. **Attach detailed syllabus course outline and course justification on separate page(s).**
8. **Prerequisite(s):** MAC 2311 Calculus I or equivalent; MAS 3105 Linear Algebra or quivalent (instructor's permission is acceptable)
9. **Corequisite(s):** None
10. **Objective(s) of Course:**

    Provide students with a solid and comprehensive understanding of optimization algorithms, focusing on their pivotal role in computing/decision making tools as well as real-world applications.

11. **Does this course duplicate/overlap other courses at FIU?** ☐ No ☒ Yes
    If yes, please explain: There is about 20% of overlap with two existing math/mechanical engineering courses. Please see details in the justification.
12. **What other closely related department(s) have been consulted about this course?**
    None
13. **Is this course used for the assessment of a program or a certificate (if yes, then send a notification to assessment@fiu.edu)?** [No] Yes

PROPOSAL REQUESTED BY:

	(Type name)	(Signature)	Date
Faculty Contact	Mohammadhadi Amini	[signature]	09 / 26 / 2019
	moamini@fiu.edu (Email address)	412-626-4064 (Phone number)	
Chairperson (Dept./Div.)	Ram Iyengar	[signature]	09 / 27 / 2019
Chairperson (Curr. Comm.)	Wei-Chiang Lin	[signature]	09 / 29 / 2019
College/School Dean	John Volakis	[signature]	/ / 20

Submit one original form. Attach one copy of the course justification and course syllabus, course description, objectives, major topics and textbooks.

Optimization Methods for Computing: Theory and Applications
Instructor: Mohammadhadi Amini

Course Justification

Ever-increasing integration of sensing and measurement technologies in the Internet-of-Things (IoT) environment enabled real-time computing for monitoring and control of different networks, including communication networks, power grids, and transportation networks. Wireless sensors networks, smart meters, and intelligent road side units are examples of emerging technologies that help sensing the system states and leverage this data to optimize the operation of networks. This further leads to a crucial need to develop theoretical algorithms to analyze enormous amount of collected data in a computationally-efficient fashion. It is crucial for computer science (CS) students, specifically those who are interested in real-time computing, decision making, and learning methods, as well as data analytics, to understand the theoretical aspects of the tools that they deploy in research, fundamental notions of optimization, and applying optimization tools and algorithms to computing problems.

There are courses on data science and machine learning at FIU, including Principles of Data Mining, Introduction to Data Science, Introduction to Machine Learning, and Capstone in Data Science classes. Aforementioned courses mainly investigate the data science and machine learning algorithms and tools. It is imperative to develop a course that provides the introduction to optimization algorithms from computing perspective, and prepare students to understand the theoretical foundations of computing and decision making tools, including data science and machine learning tools from an optimization perspective. This graduate-level course (Optimization Methods for Computing: Theory and Applications) will thoroughly describe optimization theory as a foundation for several areas in CS, including but not limited to learning and data science, as well as engineering, including but not limited to system engineering, electrical engineering, and civil engineering. Students will be equipped with strong theoretical tools that can be applied to a wide spectrum of applications. This course will also strengthens their vision and understanding of the complexity behind these tools in terms of various optimization techniques for efficient computing.

There are courses on optimization from mathematical perspective at Math and Statistics departments at FIU, including Numerical Optimization, and Optimization and Linear Algebra. These courses provide solid theoretical foundations for optimization and require some prerequisites which are not mainly taken by CS students. The first part of proposed course covers the required concepts for numerical optimization, including an overview of linear algebra. Although the mentioned two courses focus on the theoretical concepts, proofs, and fundamental linear algebra, the proposed course focuses on deploying optimization in computer science, especially this course focuses on efficient computing, learning, and data science. There are two additional components in the proposed course: 1) decomposition techniques for efficient computing and large-scale optimization, 2) introducing applications in data science, machine learning, and real-world problems. The proposed course is self-explanatory and provides essential required background for CS students before introducing each optimization algorithm. Further, there is a course at Mechanical Engineering on Optimization Algorithms. The optimization course offered by Mechanical Engineering department is mainly focused on commercial tools for solving optimization problems. In the proposed course, however, the main emphasize is on optimization algorithms, decomposition techniques to solve them efficiently, and their application in machine learning and data science. The only overlap in the proposed syllabus is providing a quick overview of related Python libraries/ MATLAB functions. Hence, proposed course will not spend time on detailed introduction of commercial optimization tools. The focus is more the algorithm side and computer science applications. Further, proposed course will not teach evolutionary and nature-inspired algorithms.

In order to bridge the gap between optimization theory and its application to learning and data science, this course provides comprehensive understanding of optimization theory and its pivotal role in learning and data science. It covers a wide spectrum of problems from the foundations of optimization, different classes of problems (constrained/unconstrained, linear/nonlinear), solution methods and algorithms, and duality theory, towards the role of optimization in CS and Engineering areas, including learning and data science. In order to expose student to real-world problems, practical use-cases from different application domains will be introduced during the semester. Students will be engaged in the learning process by solving hands-on problems during the class. This new course will provide CS students with a thorough understanding of theory behind several tools. Several senior positions in industry as well as national labs require such solid background as a complement to numerous data science tools. As the required preliminaries and mathematical concepts are covered in the class, it also can benefit non-CS students in the College of Engineering and Computing who are interested in applying optimization methods to their research for several computing and engineering applications.

School of Computing and Information Science

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

Course Number: COT 5XXX

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; MAS 3105 Linear Algebra or equivalent (instructor's permission is acceptable)	
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-scale 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