جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Course Syllabus: Numerical Optimization - AMCS 211

Division	Computer, Electrical and Mathematical Sciences & Engineering
Course Number	AMCS 211
Course Title	Numerical Optimization
Academic Semester	Spring
Academic Year	2018/2019
Semester Start Date	01/27/2019
Semester End Date	05/23/2019
Class Schedule (Days & Time)	01:00 PM - 02:30 PM | Mon Wed

Instructor(s)

Name	Email	Phone	Office Location	Office Hours
Bernard Semaan Ghanem	Bernard.Ghanem@kaust.edu.sa	+966128080261	2125, 1, Al-Khawarizmi (bldg. 1)	TBD

Teaching Assistant(s)

Name	Email
TBD	TBD

Course Information

Comprehensive Course Description	This course studies fundamental concepts of optimization from two viewpoints: theory and algorithms. It will cover ways to formulate optimization problems (e.g. in the primal and dual domains), study feasibility, assess optimality conditions for unconstrained and constrained optimization, and describe convergence. Moreover, it will cover numerical methods for analyzing and solving linear programs (e.g. simplex), general smooth unconstrained problems (e.g. first-order and second-order methods), quadratic programs (e.g. linear least squares), general smooth constrained problems (e.g. interior-point methods), as well as, a family of non-smooth problems (e.g. ADMM).
Course Description from Program Guide	Solution of nonlinear equations. Optimality conditions for smooth optimization problems. Theory and algorithms to solve unconstrained optimization; linear programming; quadratic programming; global optimization; general linearly and nonlinearly constrained optimization problems.

Goals and Objectives	At the end of this course, students should: -be able to formulate problems in their fields of research as optimization problems by defining the underlying independent variables, the proper cost function, and the governing constraint functions. -be able to transform an optimization problem into its standard form as outlined in the course. -understand how to assess and check the feasiblity and optimality of a particular solution to a general constrained optimization problem. -be able to evaluate whether the cost function and the constraints are convex, thus defining a convex problem with strong guarantees on optimality and convergence. -be able to use the optimality conditions to search for a local or global solution from a starting point. -be able to formulate the dual problem of some general optimization types and assess their duality gap using concepts of strong and weak duality. -understand the computational details behind the numerical methods discussed in class, when they apply, and what their convergence rates are. -be able to implement the numerical methods discussed in class and verify their theoretical properties in practice. -be able to apply the learned techniques and analysis tools to problems arising in their own research.
Required Knowledge	Prerequisites include multivariate calculus, elementary real analysis, and linear algebra.
Reference Texts	Required Textbook: -*Numerical Optimization*, J. Nocedal and S. Wright, Springer Series in Operations Research and Financial Engineering, 2006 Reference Books: -*Linear Programming with MATLAB*, M. Ferris, O. Mangasarian, and S. Wright, MPS-SIAM Series on Optimization, 2007 -*Convex Optimization*, S. Boyd and L. Vandenberghe, Cambridge University Press, 2004
Method of evaluation	**5.00**% - Quiz(zes) **30.00**% - Midterm exam **30.00**% - Homework /Assignments **30.00**% - Final exam **5.00**% - Course Project(s)
Nature of the assignments	**Homework and Quizes** There will be homework assignments every two weeks, which include programming problems. The handed-in assignment will be corrected in a timely manner and solutions will be provided by the instructor thereafter. Drop quizzes will be administered at the beginning of some classes at the discretion of the instructor to make sure the students are following the course material. Therefore, student attendance and pre-class preparation is very important. It is expected that each student does his/her own assignment individually. Copying homeworks is not tolerated and will be dealt with accordingly. **Exams** Two exams are scheduled during the semester, outside of class hours. The date and time of the midterm exam will be agreed upon via a unanimous vote. The exams are closed book, but each student is allowed one A4 hand-written “cheat sheet” for the midterm exam and two such sheets for the final. The content of these sheets is at the discretion of the student. **Project** The end of semester project gives each student to opportunity to apply the concepts and methods taught in class to optimization problems they encounter in their own research. Each student will propose their own project, upon the consent of the instructor. If a student cannot come up with a feasible topic for their project, the instructor will propose one for him/her.
Course Policies	All homework assignments, quizzes, and exams are required. Students who do not show up for a quiz or an exam should expect a grade of zero. If you dispute your grade on any homework, quiz, or exam, you may request a re-grade (from the TA for the homeworks and quizzes or from the instructor for the exams) only within 48 hours of receiving the graded exam. Incomplete (I) grade for the course will only be given under extraordinary circumstances such as sickness, and these extraordinary circumstances must be verifiable. The assignment of an (I) requires first an approval of the dean and then a written agreement between the instructor and student specifying the time and manner in which the student will complete the course requirements.

Additional Information	Optimization is at the core of many fields in applied mathematics, engineering, and computer science. For example, engineers want to design the "best" system that has a certain desirable behavior, while remaining faithful to the design specifications. This inherently describes an optimization problem. Once formulated and modeled, knowledge of feasibility, optimality, and numerical methods to achieve both is needed. As such, this course teaches students the building blocks to find the "best" solutions they are seeking. Although this course highlights fundamental points that are needed for a deeper study of the field of optimization, it obviously cannot cover all aspects of this topic. Therefore, it is the student's responsibility to take initiative and pursue external readings and exercises (self-study) to better understand the rich material being conveyed and to appreciate its impact on the research process more.

Tentative Course Schedule

(Time, topic/emphasis & resources)

Week	Lectures	Topic
1	Mon 01/28/2019 Wed 01/30/2019	Background review
2	Mon 02/04/2019 Wed 02/06/2019	Background review Introduction to optimization (general formulations, optimality, and feasibility)
3	Mon 02/11/2019 Wed 02/13/2019	Unconstrained optimization theory (optimality conditions)
4	Mon 02/18/2019 Wed 02/20/2019	Convex functions and convex sets
5	Mon 02/25/2019 Wed 02/27/2019	Line search optimization
6	Mon 03/04/2019 Wed 03/06/2019	Trust region optimization
7	Mon 03/11/2019 Wed 03/13/2019	Popular methods: gradient and conjugate gradient descent
8	Mon 03/18/2019 Wed 03/20/2019	Popular methods: Newton and quadi-Newton methods
9	Mon 03/25/2019 Wed 03/27/2019	Least squares optimization (linear and nonlinear)
10	Mon 04/01/2019 Wed 04/03/2019	Constrained optimization theory (optimality conditions)
11	Mon 04/08/2019 Wed 04/10/2019	Lagrangian formulation, duality, and dual problems
12	Mon 04/15/2019 Wed 04/17/2019	Interior point methods
13	Mon 04/22/2019 Wed 04/24/2019	Linear programming
14	Mon 04/29/2019 Wed 05/01/2019	Linear programming
15	Mon 05/06/2019 Wed 05/08/2019	Quadratic programming
16	Mon 05/13/2019 Wed 05/15/2019	Augmented Lagrangian methods
17	Mon 05/20/2019 Wed 05/22/2019	Augmented Lagrangian methods Majorization Minimization

Note

The instructor reserves the right to make changes to this syllabus as necessary.