EE 505: Optimization Theory

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| **Lecture Schedule** | Monday-Wednesday  16:30 am – 18:00 am | **Semester** | Fall 2018 | | |
| **Credit Hours** | Three | **Pre-requisite** | Linear Algebra | | |
| **Instructor** | Muhammad Tahir | **Contact** | [mtahir@uet.edu.pk](mailto:mtahir@uet.edu.pk) | | |
| **Office** | Office of the Director ORIC, UET Lahore | **Office Hours** | Monday 14:00 – 15:00,  Wednesday 10  :00 – 11:00 | | |
| **Teaching Assistant** | None | **Lab Schedule** | N/A | | |
| **Office** | N/A | **Office Hours** | N/A | | |
| **Course Description** | This course will cover nonlinear optimization, techniques, including linear optimization as a special case. The following topics will be covered:   * Introduction to optimization problems and their types * Convex sets * Introduction to convex functions * Quadratic and convex programming * Duality theory * Gradient method for solving optimization problems * Interior point methods for solving optimization problems | | | | |
| **Expected Outcomes** | The objective of this course is to make students acquire a systematic understanding of optimization techniques. The course will give an introduction to optimization problem types and applications. After completion, the students will be able to formulate nonlinear optimization problems where the optimal solution is also globally optimal, i.e. convex nonlinear optimization and its variants. They will become equipped with different tools that are useful in solving and analyzing optimization problems, including duality theory, sensitivity analysis etc.  In the discussion of different optimization techniques, some well known research problems in the domain of electrical engineering will also be discussed. In addition, the students are expected to learn the use of different optimization solvers including MATLAB optimization tool box, Mosek etc. | | | | |
| **CLOs** | **Description** | | | **PLOs** | **Level** |
| CLO1 | Usage of tools to model optimization problems that arise in engineering. Fundamentals of matrix theory, real analysis and multivariable calculus. | | | PLO1 | Medium |
| CLO2 | Recognize and characterize convex functions and sets and describe basic concepts of convex analysis. Also,  characterize and formulate linear, quadratic, geometric, second-order cone, and semidefinite programming problems. | | | PLO2 | Medium |
| CLO3 | Good understanding of Lagrange duality theory, certificates of or distance to optimality via dual solutions, and sensitivity of solutions to constraints with interpretation in terms of prices. Know how to solve KKT conditions. | | | PLO3 | High |
| CLO4 | Numerical methods for solving convex optimization problems, focusing on Newton’s algorithm and interior-point methods. | | | PLO5 | High |
| CLO5 | Develop effective communication and presentation skills | | | PLO10 | High |
| **Textbooks** | **Required**: *Convex Optimization* by S. Boyd & L. Vandenberghe Cambridge Univ. Press, 2004.  **References**: *Engineering Optimization: Theory and Practice* by S. S. Rao , John Wiley & Sons 2009. | | | | |
| **Grading Policy** | * Assignments: 20% (CLO1, CLO2) * Presentations: 10% (CLO 5) * Midterm: 30% (CLO1, CLO2) * Final: 40% (CLO3, CLO4) | | | | |

**Lecture Plan**

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| **Weeks** | Topics | **Readings** |
| **1\*** | **Introduction to Optimization**  Statement of optimization, objective function, problem constraints and constraint surface, classification of optimization problems | **Class notes**  **CLO1** |
| **2\*** | **Convex Sets**  Affine and convex sets, cones and convex cones, hyperplanes and half spaces, polyhedral, Euclidean and norm balls, norm cones,  convexity preserving operations, separating and supporting hyper-planes | **Chapter 2**  **CLO1, CLO2** |
| **3\*** | **Convex Functions**  Basic properties, example convex functions, operations preserving convexity, conjugate function, quasi-convex functions, log-concave and log-convex functions | **Chapter 3**  **CLO2** |
| **2\*** | **Convex Optimization**  Convex optimization problems, linear optimization, quadratic optimization, geometric optimization, geometric interpretation, vector optimization, research problem formulation | **Chapter 4**  **CLO2** |
| **1** | **M I D T E R M** |  |
| **2\*** | **Duality Theory**  Duality, Lagrange dual function, dual problem, duality in linear optimization, optimality conditions, duality gap, research problem solution discussions | **Chapter 5**  **CLO3** |
| **1\*** | **Sensitivity Analysis**  Perturbation and sensitivity analysis, relaxing or tightening of constraints | **Chapter 5**  **CLO3, CLO4** |
| **1\*** | **Unconstrained Minimization**  Gradient based first order algorithms, second order algorithms, line search method, | **Chapter 9**  **CLO3, CLO 4** |
| **1\*** | **Equality Constrained Minimization**  Newton’s method extension for equality constrained problems | **Chapter 10**  **CLO3 CLO4** |
| **1\*** | **Interior-Point Methods**  Concept of barrier function and its characterization, Primal-dual based algorithms | **Chapter 11**  **CLO4** |
| **1\*** | **Controlling the Trajectory of Optimization Convergence**  Augmented Lagrangians, ADMM method, Introduction of PID control for optimization convergence trajectory control | **Research papers**  **CLO3** |
| **1\*** | **Research paper presentations** | **CLO5** |

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