ECE 174

Intro to Linear & Nonlinear Optimization

Ken Kreutz-Delgado

ECE Department, UCSD
Contact Information

► Course Website
  • Accessible from http://dsp.ucsd.edu/~kreutz

► Instructor
  • Ken Kreutz-Delgado
    kreutz@ece.ucsd.edu
    Office Hour: Monday, 1-2pm, EBU-I 5605

► Teaching Assistant
  • Tasha Vanesian
    tcvanesian@ucsd.edu
    Office Hour: Tuesday, 10-11am, EBU-I 5706

► Administrative Assistant
  • Travis Spackman
    tspackman@ece.ucsd.edu
    (858) 822-4697, EBU-I 5600
Textbook

- **Matrix Analysis & Applied Linear Algebra**
  Carl D. Meyer, SIAM, 2000
  3rd printing is latest

- **Recommended Texts**
  - *Linear Algebra*, 4th Edition
    S. Lipschutz & M Lipson
    Schaum’s Outlines, McGraw-Hill, 2009
  - *Linear Algebra and its Applications*, 4th Edition
    G. Strang, Brooks Cole, 2005
Course Objectives

▶ How to think geometrically in signal and data spaces, and apply high-level abstract geometric thinking when solving linear and nonlinear inverse problems in such spaces.

▶ How to solve linear and nonlinear inverse problems using basic optimization techniques.

▶ Make students comfortable with the process of moving back-and-forth between abstract mathematical solution techniques and practical engineering problems.
  • At the end of the quarter students will be able to apply very abstract mathematical concepts to very practical engineering problems.
Assumed Course Background

It is assumed that students know the material from linear algebra very well.

For this reason, readings and homework can, and will, be assigned from sections in the textbook not in the order of presentation used by the author.

The goal of this course is not to teach the fundamental concepts of linear algebra (which you are presumed to already know from Math 20F).

The goal is to ensure that students are comfortable with the underlying abstract geometric concepts associated with linear mappings between inner-product vector spaces and linear inverse problems encountered in many different application domains in engineering and science.
Assumed Programming Background

- It is assumed that students know Matlab or an equivalent high-level design-oriented programming language well.
- Proficiency in Matlab or the equivalent is needed to perform the mandatory computer assignments which will comprise 15% of your total, overall grade.
Course Performance Evaluation

15% Homework. 15% Computer Projects. 30% Midterm Exam. 40% Final Exam. This breakdown is non-negotiable.

- Homework (15%) is graded “A for Actual Effort”. You get full credit merely for turning it in and it is evident that you worked on it. You get partial credit if you are missing problems or it is clear that no real good faith effort was expended. You get no credit if you don’t turn in the homework.

- Computer assignments (15%) are rigorously graded for correctness of content and results.

- Midterm (30%) and Final (40%) are rigorously graded for correctness of derivations and results.

- Final exam is scheduled for Tuesday June 9, 2009. This date is firm and non-negotiable.
Student Collaboration & Cheating

▶ Students are allowed to discuss homework problems.
  • Individual write-ups must be turned in.
  • Not understanding homework problems and solutions will hurt you on the exams which together comprise 70% of the overall course grade.

▶ Computer projects must be done individually.
  • Code and written reports must be turned in.
  • Identical, or unreasonably similar, overlap of code between two students will be perceived as cheating and aggressive administrative action will be taken.

▶ Exams are closed notes and closed book.
  • Aggressive administrative action will be taken against students caught cheating.
Course Topics - I

► Overview of (constrained and unconstrained) linear least squares and nonlinear optimization.
  • Discussion of real-world linear and non-linear inverse problems encountered in engineering drawn from circuit analysis, robotics, communications, and signal processing.

► Signal spaces as abstract vector spaces and matrices as representing linear mappings between signal spaces.

► Under- and over-constrained linear systems of equations and linear inverse problems.
  • Well-posed and ill-posed linear inverse problems.

► Constrained and unconstrained quadratic optimization of linear systems (the "linear least squares" problem).
Course Topics - II

- Solutions to the linear least squares problem.
  - Relationship to the four fundamental subspaces of linear algebra.
  - The projection theorem, adjoint operators, the normal equation, generalized inverses, & the Moore-Penrose pseudoinverse.

- The Singular Value Decomposition (SVD).
  - SVD and the four fundamental subspaces of linear algebra.
  - Use of the SVD to solve linear inverse problems and to obtain the Moore-Penrose pseudoinverse.

- Quadratic forms and weighted least-squares
  - Use in modeling energy, power, and uncertainty quantities encountered in engineering applications.
  - The weighted least squares problem and its relationship to the problem of maximum likelihood (MLE) estimation.
Course Topics - III

- Nonlinear least squares theory.
  - Vector differentiation and Hessians.
  - Necessary & sufficient conditions for an optimum to exist.

- Linearization-based nonlinear optimization techniques.
  - Iterative optimization techniques, including steepest descent, Gauss's method, and Newton's method.
  - Constrained nonlinear optimization and the method of Lagrange multipliers (time permitting).
Computer Programming Assignments (minimum of two projects)

For each assignment students will turn in an “Engineering Technical” report.

- You should write these up assuming that you will show them to prospective employers during job interviews.
- Students have had positive responses in interviews.

Linear least-squares project.
- Speech compression via differential coding.

Nonlinear least-squares project.
- GPS positioning.

Other possible assignments.
- Anti-jamming notch filter via constrained weighted least-squares.
- Understanding the Google search engine.