SPRING 2006

ECE 174. Introduction to Linear and Nonlinear Optimization with Applications (4 Units)

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Class Website: http://dsp.ucsd.edu/~kreutz/Classes.htm

2005-2006 Catalog Description:

The linear least squares problem, including constrained and unconstrained quadratic optimization and the relationship to the geometry of linear transformations. Introduction to nonlinear optimization. Applications to signal processing, system identification, robotics, and circuit design. Four hours of lecture. (Spring)

Prerequisite:
Math 20F (Linear Algebra) with a grade of C- or better.

Text Books:


Course Objectives:

The primary goal is to teach students how to think geometrically in signal spaces, and to apply high-level abstract geometric thinking when solving linear and nonlinear inverse problems in such spaces. A second goal is to understand how to solve linear and nonlinear inverse problems using basic optimization techniques. Another goal is to 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.

It is assumed that students know the material from linear algebra *very well*. For this reason, reading 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), but rather 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 problem domains in engineering and science.
After taking this course, students should be well prepared for further courses in nonlinear optimization; numerical linear algebra; signal processing; and state-space control theory. Students who know probability, random variables, and the material in this course should be well prepared for subsequent courses in statistical learning theory and statistical signal processing (such as ECE275AB). Feedback from students who have gone on to graduate school indicates that this material has been very useful for them in their graduate courses.

Course Topics:

1) 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) which can be solved using these techniques.


4) Solutions to the linear least squares problem and their relationships to the four fundamental subspaces of linear algebra. Discussion of the projection theorem, the adjoint operator, the normal equations, the adjoint equations, generalized inverses, and the Moore-Penrose pseudoinverse.

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

6) Quadratic forms as 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.

7) Nonlinear least squares theory. Vector differentiation, hessians, and necessary sufficient conditions for an optimization to exist.


Course Implementation:

Three hours of classroom lecture by the professor. The professor provides two hours of regularly scheduled office hour per week. Students are encouraged to work in groups or teams, but all computer projects and homework turned in must be individually analyzed and written up.

Evaluation Method:

As described in further detail below, the overall course grade is broken down as follows: Homework and Matlab Projects 30%, Midterm 30%, Final 40%. This breakdown is nonnegotiable.

1) Students are given homework, which is graded “A for Effort”. This means that all honest attempts at solving the problems (successful or unsuccessful) are given full credit. Lack of effort results in no credit. Ambiguous effort gets half credit. Homework solutions are provided and students are informed that a selected few of the problems from the homework will be chosen at random and put on the exams unaltered.

3) The computer projects are graded “for real” and are based on submitted written reports. Homework plus Matlab programming projects account for 30% of the total grade.

2) There are two exams: a midterm, which is worth 30% of the grade, and a final, which is worth 40% of the grade. Please bring paper, pencils, and a nonprogrammable calculator to all exams. All tests are closed book and notes.
The final exam date and time for this course is Wednesday, June 14, 3-6pm. The final exam date and time is nonnegotiable.

3) As already mentioned, 30% of the course grade is based on the homework (see above) and two written reports which students must turn in based on two computer projects. The projects are based on an application of linear and nonlinear least squares solutions techniques. The topics are the following:

- Linear predictive coding: data compression via the use of minimum least squares predictive coding.
- GPA location and receive-clock calibration via Gauss-Newton optimization using only range and timing information provided by (at least) four line-of-sight satellites.

Students are free to use a different programming language than Matlab (e.g., Mathematica or Maple) if they so desire, but they will not be able to benefit from discussions with the TA which will be solely Matlab-based. Additional information on the project and report requirements will be placed on the class website.

POLICY ON ACADEMIC DISHONESTY:

All UCSD, School of Engineering, and ECE Department policies on academic dishonesty will be vigorously enforced. Aggressive administrative action will be taken against any student caught cheating, even for a first-time incident. There will be no "second chance." In addition, some matters can be grounds for criminal charges made through the police department.