Math 6370-24240 (Fall 2010): Numerical Analysis *

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Texts

Numerical Linear Algebra, Lloyd N . Trefethen and David Bau, SIAM, 1997, ISBN: 0898713619.

Objectives

The purposes of this course are to provide the mathematical foundation of numerical methods, to analyze their basic theoretical properties (stability, accuracy, and computational complexity), and to demonstrate their performances on examples.

Remarks

This is the first semester of a two-semester course. The focus in this semester will be on numerical linear algebra. A short introduction to iterative solution of nonlinear systems and numerical optimization will also be given.

Prerequisites

Graduate standing or consent of instructor. Students should have had a course in Linear Algebra and an introductory course in analysis. Familiarity with Matlab is also required.

*This syllabus contains important information about this course to which you will need to refer from time to time.

Course Policies and Procedures

Grades: Homework (40 percent), Reading (20 percent), Exams (40 percent)

Exams: All three Exams will be given in class (one hour and half) and will be open-book, open-note. Students with a valid excuse for missing up to one exam must provide written documentation to that effect, e.g., a medical certificate. No make-up exams will be given.

Homework: There are total six homework assignments. You may, with impunity, submit up to two assignments up to one class period (not one week) beyond their due date. Subsequent submissions will incur penalties in increments of 10%. Homework submitted later than one class period beyond its due date will not be accepted without a written excuse. Matlab program source code must be turned in and must adhere to the programming standards. Homework scores can not be changed one week after they have been returned.

Reading: There are total six reading papers, among which you may choose three papers to write your reports. Your reports shall contain information about the historical context of the paper, including biographical information about the author(s) and a plot of citations as a function of time. You shall outline some of the central ideas of the paper and conduct Matlab experiments to illustrate some of the properties of the algorithm under discussion. Reading report submitted beyond its due date will not be accepted without a written excuse.

Honor Code Policy: On homework and reading, you are encouraged to discuss homework with your classmates. However, you are expected to individually write up your solutions and reports.

Course Outline, Homework, Reading, and Exam Dates[1]

- **Part I Fundamentals**
  - Lecture 1 (Aug. 24) Matrix-Vector Multiplication, Orthogonal Vectors and Matrices, Norms
  - Lecture 2 (Aug. 26) The Singular Value Decomposition, More on the SVD
- Assignment I (Aug. 31) 1.3, 2.3, 3.5, 4.3, 4.5, 5.3
- Reading I (Sept. 2) Trefethen (1992) - Definition of Numerical Analysis: Appendix of the Textbook.
- **Part II QR Factorization and Least Squares**
  - Lecture 3 (Aug. 31) Projectors, QR Factorization
  - Lecture 4 (Sept. 2) Gram-Schmidt Orthogonalization, MATLAB
  - Lecture 5 (Sept. 7) Householder Triangularization
  - Lecture 6 (Sept. 9) Least Squares Problems
- Assignment II (Sept. 14) 6.1, 6.5, 7.5, 8.1, 9.3, 10.1, 11.1, 11.3
- Reading II (Sept. 16) Householder (1958) - QR Decomposition: A. S. Householder, "Unitary triangularization of a nonsymmetric matrix," Journal of the Association of Computing Machinery 5 (1958), 339-342.
- **Part III Conditioning and Stability**
  - Lecture 7 (Sept. 14) Conditioning and Condition Numbers, Floating Point Arithmetic
  - Lecture 8 (Sept. 16) Stability, More on Stability
  - Lecture 9 (Sept. 21) Stability of Householder Triangularization, Stability of Back Substitution
  - Lecture 10 (Sept. 23) Conditioning of Least Squares Problems, Stability of Least Squares Algorithms
- Assignment III (Sept. 28) 12.3, 13.3, 14.1, 15.1, 16.2, 17.1, 18.3, 19.2
- Reading III (Sept. 30) Wilkinson (1961) - Error Analysis for Systems of Eqs.: J.H. Wilkinson, "Error analysis of direct methods of matrix inversion," J. Assoc. Comput. Mach. 8 (1961), 281-330

[1]This schedule, including dates of exams, is subject to change. Changes will be announced in class.

- **EXAM I (Sept. 28)**
- **Part IV Systems of Equations**
  - Lecture 11 (Sept. 30) Gaussian Elimination, Pivoting
  - Lecture 12 (Oct. 5) Stability of Gaussian Elimination
  - Lecture 13 (Oct. 7) Cholesky Factorization
- Assignment IV (Oct. 12) 20.1, 20.3, 21.3, 22.2, 22.3, 23.3
- Reading IV (Oct. 14) Strassen (1969) - Gaussian Elimination is Not Optimal: V. Strassen, "Gaussian elimination is not optimal," Numer. Math. 13 (1969) 354-356.
- **Part V Eigenvalues**
  - Lecture 14 (Oct. 12) Eigenvalue Problems, Overview of Eigenvalue Algorithms
  - Lecture 15 (Oct. 14) Reduction to Hessenberg or Tridiagonal Form
  - Lecture 16 (Oct. 19) Rayleigh Quotient, Inverse Iteration
  - Lecture 17 (Oct. 21) QR Algorithm without Shifts
  - Lecture 18 (Oct. 26) QR Algorithm with Shifts
- Assignment V (Oct. 28) 24.3, 25.1, 26.2, 27.1, 28.2, 29.1, 30.5, 31.3
- Reading V (Nov. 2) Golub & Kahan (1965)- The Singular Value Decomposition: G. Golub and W. Kahan, "Calculating the singular values and pseudo-inverse of a matrix," SIAM Journal on Numerical Analysis 2 (1965), 205-224.
- **EXAM II (Oct. 28)**
- **Part VI Iterative Methods**
  - Lecture 19 (Nov. 2) Overview of Iterative Methods
  - Lecture 20 (Nov. 4) The Arnoldi Iteration
  - Lecture 21 (Nov. 9) How Arnoldi Locates Eigenvalues
  - Lecture 22 (Nov. 11) GMRES
  - Lecture 23 (Nov. 16) The Lanczos Iteration
  - Lecture 24 (Nov. 18) From Lanczos to Gauss Quadrature
  - Lecture 25 (Nov. 23) Conjugate Gradients
  - Lecture 26 (Nov. 30) Biorthogonalization Methods

- Assignment VI (Dec. 2) 33.1, 34.1, 35.3, 36.3, 37.1, 38.3, 38.6, 39.1
- Reading VI (Dec. 2) Hestenes & Stiefel (1952) - The Conjugate Gradient Iteration: Magnus R. Hestenes and Eduard Stiefel, "Methods of conjugate gradients for solving linear systems," Journal of Research of the National Bureau of Standards 49 (1952), 409-436.
- **EXAM III (Dec. 2)**