The University of Connecticut **Fall 2008**
Dept. of ESE **KRP**

ECE 6435 : Advanced Numerical Methods for Scientific Computation

General Information

Instructor:

Prof. Krishna R. Pattipati
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Office Hours: Tuesday-Thursday: 11:00 AM – 12:00 Noon

Classes: Time: Wednesday, 6PM-9PM, Location: ITE 125

Text: **(Course Notes)** K. R. Pattipati and D.L. Kleinman, *Computational Methods for Linear Systems*, 1993, 2008 (Updated)
(Text) G. H. Golub and C. F. Van Loan, *Matrix Computations*, Johns Hopkins Press, Third Edition, 1996.
(Optional) M. T. Heath, *Scientific Computing: An Introductory Survey*, McGraw-Hill, 2002.
(Optional) B. N. Datta, *Numerical Methods for Linear Control Systems*, Elsevier, 2004.

Course Objective

This course is designed to provide students with a thorough understanding of the mathematical underpinnings of computational methods for linear systems, as well as the implementation and testing of various algorithms in software.

Course Outline

Lecture 1: **Course Overview :**
- *Course Objectives*
- *Round-off Errors*
- *Background on Matrix Algebra*

Lecture 2: **Computing e^{At}**
- *Motivation for computing* e^{At}
- *Polynomial Approximation of Functions*
- *Horner's Rule to Evaluate Polynomials*
- *Computation of* e^{At} *by Chebyshev Polynomials*
- *Concepts of Shifting, Scaling and Doubling*
- *Computation of* e^{At} *by Pade Approximation*
- *Computation of* e^{At} *via Upper Schur Form*
- *Uniformization Method when A is stochastic*
- *Bad (Dubious) Methods for Computing* e^{At}

Lecture 3: **Computing Integrals Involving e^{At}**
- *Motivation for computing integrals involving* e^{At}
- *Computation of* $e^{A\delta}$ *and* $\int e^{A\sigma} d\sigma$
- *Concept of Doubling*
- *Computation of* $S = \int e^{A\sigma} Q e^{A^T\sigma} d\sigma$

- *Application to system stabilization*

Lecture 4: **Solving System of Equations $A\underline{x} = \underline{b}$**
- *Motivation for solving $A\underline{x} = \underline{b}$*
- *Overview of Decomposition Methods*
- *LU Decomposition*
- *Sensitivity of Linear Systems*
- *Some Difficult Test Problems*
- *Improvements on LU Decomposition*
- *Rank One Updates*

Lecture 5: **System of Equations $A\underline{x} = \underline{b}$ Involving Positive Definite (PD) Matrices**
- *Motivation for Decomposition Methods for PD Matrices*
- *Algorithm Cholesky (Column Version)*
- *Pivoting for Positive Semi-definite Matrices*
- *LDL^T Decomposition (Factorization)*
- *Toeplitz System of Equations*
- *Levinson-Durbin Algorithm*
- *Generalized Levinson's Algorithm*
- *Sparse Matrix Methods for PD Systems*

Lectures 6 & 7: **Orthogonalization Methods**
- *Motivation behind Orthogonalization*
- *Least Squares Problem and its Properties*
- *Householder Transformation*
- *Serial and Parallel Gram-Schmidt Orthogonalization*
- *Givens Transformation*
- *Weighted Least Squares Problems and its Solution*
- *Computation of Pseudo Inverse*
- *Total Least Squares*
- *Partial Least Squares*

Lecture 8: **Recursive (Sequential) Methods**
- *Recursive Least Squares (RLS)*
- *Sequential LDL^T Factorization Updates*
- *Sequential QR Updates*
- *Application to Kalman Filtering*

Lecture 9: **Linear Programming**
- *What is Linear Programming (LP)?*
- *Revised Simplex Method*
- *Interior Point Methods*
- *Comparison of Revised Simplex and Interior Point Methods*

Lecture 10: **Unsymmetric Eigen Value Problem**
- *What is the Eigen Value Problem?*
- *Properties of Eigen Values and Eigen Vectors*
- *Eigen Value Conditioning Problem*
- *Power Method for finding the Maximum Eigen Value and its Eigen Vector*
- *Inverse Power Method*
- *QR Method*
- *Eigen Value Assignment Problem for Stabilizing Linear Systems*

Lectures 11: **Symmetric Eigen Value Problem**

- Symmetric QR Method
- Lanczos Method for Sparse Symmetric Matrices

Lecture 12: **Singular Value Decomposition**

- *What is Singular Value Decomposition (SVD)?*
- *Properties of SVD*
- *Computation of SVD*
- *Applications*

Lecture 13: **Discrete and Continuous Lyapunov Equations**

- *What is a Lyapunov Equation?*
- *Application of Lyapunov Equation*
- *Computational Methods for Solving the Lyapunov Equation (Direct, Itertaive and Semi-iterative Methods)*

Lecture 14: **Discrete and Continuous Riccati Equations**

- *Continuous-time Linear Quadratic Regulator (LQR) Problem*
- *Kleinman's Algorithm for the Algebraic Riccati Equation (ARE)*
- *Discrete-time LQR Problem*
- *Schur Method for Solving the ARE*

Grading:

Homework/Project Assignments	60%
Review Paper Presentation	10%
Term Project	30%
Total	100%

Additional Information:

- Starting with **October 17** Lecture, each lecture will be divided into two parts. The first 2.5 hours will be used to present course materials, and the remaining 0.5-hour will be used for students to present reviews of recent journal publications.

- Paper reviews should be based on relevant and recent (2002 and up) journal articles from, e.g., IEEE Trans. On Automatic Control, IEEE Trans. On Signal Processing, SIAM Journal of Scientific and Statistical Computing, SIAM Journal on Numerical Analysis, Mathematics of Computation, IMA Journal of Numerical Analysis, Linear Algebra and its Applications, SIAM Journal of Matrix Analysis and its Applications, BIT, Numerische Mathematik, JACM,…

- Term projects can be performed in teams of two students on relevant computational topics. Topics could be related to research, or based on at least two recent journal articles. **Numerical implementation** and **testing** are a must.

- Term project **proposals** are due on **Wednesday October 22**, presentations are scheduled on **Wednesday December 3** from 6 PM to 9 PM, and final reports are due on **Friday December 11**.

- Programming can be done in any language.