Advanced Computational Techniques in Engineering

Course Details
Course Code: 15M1WCI432
Level: M Tech CSE
Semester: Semester 4
Instructor: Prof Dr S P Ghrera

Outline Course Description:
Data Distributions, Data Transforms, Fourier, Wavelet and Anamorhpic transforms, Gaussian Elimination and Its Variants, Sensitivity of Linear Systems ,Vector and Matrix Norms , A Posteriori Error Analysis Using the Residual, Roundoff Errors; Backward Stability, Propagation of Roundoff Errors , Backward Error Analysis of Gaussian Elimination , The Least Squares Problem, The Discrete Least Squares Problem, Orthogonal Matrices, Rotators, and Reflectors, Solution of the Least Squares Problem, The Gram-Schmidt Process, Geometric Approach, Updating the QR Decomposition, The Singular Value Decomposition, Eigenvalues and Eigenvectors, Systems of Differential Equations, The Power Method and Some Simple Extensions, Similarity Transforms, Reduction to Hessenberg and Tridiagonal Forms, The QR Algorithm, Implementation of the QR algorithm, Use of the QR Algorithm to Calculate Eigenvectors, Eigenspaces and Invariant Subspaces, Subspace Iteration, Simultaneous Iteration, Methods for the Symmetric Eigenvalue Problem, The Generalized Eigenvalue Problem; Iterative Methods for Linear Systems, A Model Problem , The Classical Iterative Methods, Convergence of Iterative Methods , Descent Methods; Steepest Descent, Preconditioners, The Conjugate-Gradient Method, Derivation of the CG Algorithm, Convergence of the CG Algorithm, Indefinite and Nonsymmetric Problems,

Assumed Background:
A basic undergraduate-level background in engineering mathematics and computational techniques is assumed. In particular, it is assumed that the student has a basic understanding of linear algebra, probability & statistics and optimisation, on which the more advanced material in this course will build.

Course Aims
An advanced course designed to deepen student knowledge and capability in computational techniques in areas of particular importance to engineering. The course aims to give students the computational tools and theory needed for further research work of engineering. Specifically, the aim is ensure the student has excellent skills in numerical implementation of advanced methods in linear algebra. The students will be required to use MATLAB as an tool for their work during the course.

Detailed Description

15M1WCI432: Advanced Computational Techniques in Engineering

1 Gaussian Elimination and Its Variants 1	L1-5
1.1 Data Distributions, Data Transforms	
1.2 Matrix Multiplication, Systems of Linear Equations	
1.3 Triangular Systems	

6.1 Eigenspaces and Invariant Subspaces	
6.2 Subspace Iteration, Simultaneous Iteration, and the QR Algorithm	
6.3 Eigenvalues of Large, Sparse Matrices,	
6.4 Sensitivity of Eigenvalues and Eigenvectors	
6.5 Methods for the Symmetric Eigenvalue Problem	
6.6 The Generalized Eigenvalue Problem	
7 Iterative Methods for Linear Systems	L36-42
7.1 A Model Problem	
7.2 The Classical Iterative Methods	
7.3 Convergence of Iterative Methods	
7.4 Descent Methods; Steepest Descent	
7.5 Preconditioners	
7.6 The Conjugate-Gradient Method	
7.7 Derivation of the CG Algorithm	
7.8 Convergence of the CG Algorithm	
7.9 Indefinite and Nonsymmetric Problems	

Text Book

Fundamentals of Matrix Computations, DAVID S. WATKINS
Linear Algebra Done Right, by Sheldon Axler

References

The following is an excellent text for reviewing fundamental concepts and some applications of linear algebra.

- Gilbert Strang, Linear Algebra and Its Applications, 4th Edition, Brooks Cole, 2006.
- Gene H. Golub and Charles F. Van Loan, Matrix Computations, 3rd edition, John Hopkins University Press, 1996, ISBN 0-8018-5414-8.
- Lloyd N. Trefethen and D. Bau III, Numerical Linear Algebra, SIAM, 1997.
- James W. Demmel, Applied Numerical Linear Algebra, SIAM, 1997.

References on Iterative Methods and Multigrid Methods

The following books are for additional readings on iterative methods and multigrid methods, which are increasingly important but not covered in this course due to time constraint.

- Anne Greenbaum, Iterative Methods for Solving Linear Systems, SIAM, 1997.
- Yousef Saad, Iterative Methods for Sparse Linear Systems, SIAM, 2003.
- William L. Briggs, Van Emden Henson, Steve F. McCormick, A Multigrid Tutorial, 2nd edition, SIAM, 2000.

References on C Programming

If you want to purchase a C book, a classical one is

- B.W. Kernighan, D.M. Ritchie, C Programming Language (2nd edition). Prentice Hall, 1988.

- M. Banahan, D. Brady and M. Doran, The C Book, second edition, Addison Wesley, 1991.
- C Programming, Wikibooks

Learning Objectives
After successfully completing this course you should be able to:

1 Identify applications in Engineering where computational techniques in linear algebra, can be applied.
2 Grasp the theoretical foundations of matrix algebra,
3 Understand and explain a number of key algorithms in linear algebra
4 Implement computational techniques in MATLAB with a high level of proficiency.

Graduate Attributes
Successfully completing this course will contribute to the recognition of your attainment of the following **UQ (Postgrad Coursework)** graduate attributes:

GRADUATE ATTRIBUTE	LEARNING OBJECTIVES
A. IN-DEPTH KNOWLEDGE OF THE FIELD OF STUDY	
A2. A **broad understanding** of the field of study, including **how other disciplines relate** to the field of study.	**1**
A3. A **comprehensive** and **in-depth knowledge** in the field of study.	**2, 3, 4**
A5. An **international perspective** on the field of study.	
A7. An appreciation of the **link** between **theory** and **practice**.	
B. EFFECTIVE COMMUNICATION	
B1. The ability to **collect**, **analyse** and **organise information** and **ideas** and to **convey** those **ideas clearly** and **fluently**, in both **written** and **spoken forms**.	**3**
B2. The ability to **interact effectively with others** in order to work towards a common outcome.	
B3. The ability to **select** and **use** the **appropriate level**, **style** and **means of communication**.	**3**
B4. The ability to **engage effectively** and **appropriately with information and communication technologies**.	**4**
B5. The ability to **practise** as part of an **interdisciplinary team**.	
C. INDEPENDENCE AND CREATIVITY	
C2. The ability to **work** and **learn independently** and	**2**

effectively.	
C3. The ability to **generate ideas** and **adapt innovatively** to changing environments.	
C5. The ability to **formulate** and **investigate problems**, **create solutions**, **innovate** and **improve** current **practices**.	**1**
C6. The **abilities** and **skills** that provide a foundation for **future leadership** roles.	
D. CRITICAL JUDGEMENT	
D2. The ability to **apply critical reasoning** to issues through **independent thought** and **informed judgement**.	**4**
D4. The ability to **process material** and to **critically analyse** and **integrate information** from a wide range of sources.	**1**
D5. The ability to **evaluate opinions**, **make decisions** and to **reflect critically** on the justifications for decisions using an **evidence-based approach**.	
E. ETHICAL AND SOCIAL UNDERSTANDING	
E1. An **understanding** of **social** and **civic responsibility**.	
E3. An **appreciation** of the **philosophical** and **social contexts** of a discipline.	
E4. A **knowledge** and **respect** of **ethics** and **ethical standards** in relation to a major area of study.	
E5. A **knowledge** of other **cultures** and **times** and an **appreciation** of **cultural diversity**.	
E7. The ability to **work effectively** and **sensitively** across all areas of **society**.	
E8. An **understanding** of and **respect** for the **roles** and **expertise** of **associated disciplines**.	

Academic Integrity

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Dirctor/HOD.