DS284: Numerical Linear Algebra

Department of Computational and Data Sciences

Indian Institute of Science, Bangalore

Aug 2025 - Nov 2025

Faculty:	Dr. Phani Motamarri	**Time:**	Tue and Thu (14:00 PM – 15:30 PM)
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Office Hours by TAs:	Saturday 3 PM - 5 PM	**Venue:**	CDS 309

What will I learn in this course?: DS284 is a course on computational linear algebra. The course lies at the intersection of applied mathematics and computing and is fundamental to computational science research conducted in many emerging scientific disciplines, including Artificial Intelligence/Machine learning and Quantum Computing. We will broadly deal with five types of problems arising in many scientific disciplines — (1) Linear system of equations ($Ax = b$), (2) Orthogonalization of vectors, (3) Singular Value Decomposition, (4) Eigenvalues and Eigenvectors ($Ax = \lambda x$), and (5) Least squares problems (Regression) ($min_x||Ax - b||^2$). The accuracy, efficiency and stability of the computational algorithms for solving the above problems on a computer will be discussed throughout the course.

How to access class material?

1. Join Teams Course Page

Course Outline:

- *Preliminaries:* Matrix-vector multiplication, Matrix-matrix multiplication, Review of rank, column-space, null-space and invertibility of matrices, Matrix and vector norms, Orthogonal vectors and matrices, arithmetic complexity, floating point arithmetic, Conditioning and stability of a problem, Forward and Backward stability.
- *Matrix decompositions and applications:* Singular value decomposition (SVD), Applications of SVD (low rank approximations, data compression, PCA), Projectors, QR decomposition (Gram-Schmidt approach, Householder triangularization), Least squares problems, Pseudoinverse, Normal equations, Cholesky decomposition
- *Eigenvalue problems:* Greshgorin theorem, Similarity transformation, normal matrices, eigenvalue and eigenvector computations, eigendecomposition, Rayleigh quotients, Hessenberg transformation, Schur decomposition, real symmetric eigenvalue problems, power method, Rayleigh quotient iteration, inverse iteration, QR algorithm, Subspace iteration
- *Iterative methods:* Krylov subspaces, Approximating eigenvalues and eigenvectors using Krylov subspaces (Arnoldi approach), Iterative solution of linear systems using Krylov methods (GMRES, Conjugate gradient)

Prerequisites:

- An undergraduate-level understanding of linear algebra, multivariate calculus is assumed.
- Familiarity with a programming environment (Matlab or Octave or Python)

Main References: This is a restricted list of various interesting and useful books.

- Numerical linear algebra by Lloyd Nicholas Trefethen, David Bau
- Linear Algebra and Learning from Data – Gibert Strang
- Matrix Computations by G. Golub and C. Van Loan, Johns Hopkins, third edition, 1996.
- Linear Algebra and its Applications – David C Lay (Addison-Wesley Publishers)
- Linear Algebra and its Applications – Gilbert Strang
- Iterative Methods for Sparse Linear Systems by Y. Saad, PWS, 1997
- Applied Numerical Linear Algebra by J. Demmel, published by SIAM, 1997
- Numerical Linear Algebra by Grégoire Allaire, Sidi Mahmoud Kaber

Grading Policy: Two quizzes and few graded assignments (50%), Midterm (20%), Final (30%).

How do I clear my doubts: (i) Immediately after class hours, (ii) Post your questions on the Course page on Microsoft Teams, (iii) TA office hours on Saturdays from 3 PM to 5 PM.

Important Information:

- A total of four quizzes will be conducted in addition to midterm and final exam.
- Approximately 6-7 assignments will be posted online on Teams for your practice, and some of the questions will be graded. This will be informed when the assignment is posted.
- Quizzes are short one-hour written tests comprising multiple-choice and/or subjective questions testing your conceptual understanding of the topics.
- Students are strongly encouraged to work out the problems in assignments as the underlying concepts can help you understand the subject better and help you answer the tests better (quizzes, midterm or finals). A few quiz questions can also be directly from assignments.
- Assignment problems can include programming questions designed to develop a conceptual understanding of some of the algorithms discussed in the class, and students are strongly encouraged to do these tasks in a programming environment convenient to them (Matlab, Octave or Python). Be mindful that the algorithmic ideas learned in the programming tasks can appear in any form in quizzes, midterm, or finals.

Important Timelines:

- Assignments: Evenly spaced throughout the semester.
- Quizzes: To be decided in the Class (no open book but one A4 reference sheet allowed)
- Midterm: Tentatively first week of October (no open book but one A4 reference sheet allowed)
- Final Exam: As per the institute schedule (no open book but one A4 reference sheet allowed)