CSci 5304 Fall 2022
Computational Aspects of Matrix Theory

General Information

PLease note: 1) additional information provided online (canvas and instructor's class pages); 2) This syllabus may still undergo small changes. It will be more or less finalized in the second week of classes.

This course introduces the basic numerical techniques of linear algebra. It covers basic tools (e.g., norms), design of matrix algorithms, their analysis, and related applications. Students taking this class should have a good background in linear algebra (prerequisite is csci 2033 or equivalent) and be familiar with Matlab. New this year: we will discuss the option of using Python+numpy as an alternative to matlab for assignments.

- **Class Schedule:** TTh 08:15 AM - 09:30 AM — Keller Hall 3-125
- **Lectures:** *This course is scheduled as an in-person course. I intend to hold all class sessions in-person except if situational factors arise, such as personal illness of the instructor, when the class may be held synchronously via Zoom or recorded for later viewing.*

  Note from UNITE: *Those students enrolled in the on-campus sections of courses will have access to the streaming video archives on a ten-day delay. UNITE will lift the delay seven days prior to any scheduled exams and one week prior to the University's Last Day of Instruction for the semester, to prepare for Finals Week. Access ends on the last day of Finals Week.* You should get a detailed message from UNITE about access and how to contact them for technical support. Also note that UNITE indicates that it will consider lifting the delay in some circumstances.
- **Instructor:** Yousef Saad ≪ saad@umn.edu ≫ `http://www.cs.umn.edu/~saad`
- **Teaching Assistant:** Zechen Zhang ≪ zhan5260@umn.edu ≫
- **Office hours:** The office hours are posted online.

  The Instructor's office hours will use a blended mode. By default meetings will be online via Zoom. In-person meetings can be set up with appointments for the 2nd half of the Office hour. Walk-ins (no appointments) are OK in the second half of the office hour– but may receive a lower priority.

  The TA's office hours will be via Zoom for Monday and in person for Friday - see class web-site for details.
- **Class Website:** Basic information and lecture notes will be posted here:

  `www-users.cse.umn.edu/~saad/csci5304/`

  Detailed schedule, Homeworks, quizzes, grades, will be posted on canvas. Homeworks and quizzes will be submitted via canvas.

  It is your responsability to check both Canvas (especially for homeworks) and the instructor's class website (for lecture notes) on a regular basis.

Textbook

There is no *required* textbook for this class. However, you will need a good reference for an in-depth coverage of the material that will be seen. Here are a few listed in order of preference.

- Main reference: *Matrix Computations* 4th edition, G. Golub and C. Van Loan. John Hopkins, 2015. This is a rather comprehensive book and it is especially recommended as a reference for those of you who will do research involving numerical linear algebra. A PDF version of the older edition of the book can be obtained online – and it is sufficient.
- *Fundamentals of Matrix Computations* by David S. Watkins. John Wiley & Sons, 2002, ISBN-13: 978-0470528334, ISBN-10: 0470528338.
- *Numerical linear algebra*, Lloyd N. Trefethen and David Bau, III. SIAM, 1997 (pbk). Very well written, easy to understand and insightful presentation of most topic to be covered. Not as detailed (or complete) as the ones above.

Matlab references: Matlab will often be used for writing short programs (in particular for homeworks). Matlab has extensive online documentation and there are many resources posted on the web, so a manual is not really needed unless you have never used matlab before in which case it is recommended to get a reference manual. Here are a couple that I found quite good:

- *" Matlab, Third Edition: A Practical Introduction to Programming and Problem Solving 3rd Edition"* by Stormy Attaway. (2013) Publisher: Elsevier, ISBN-13: 978-0124058767 ISBN-10: 0124058760
- *"Mastering Matlab"* by Duane Hanselman and Bruce Littlefield. Prentice Hall (2011) ISBN-13: 978-0136013303 ISBN-10: 0136013309.

Python/Numpy: We will discuss the option of using Python+numpy as an alternative to matlab for assignments. This will be an added option - not a replacement to Matlab.

Lecture Notes

Lecture notes will be posted regularly on the class web-site (see above – not on canvas). (Icon "Lect. Notes" in menu). These notes will be posted by topic rather than lecture by lecture, and they are usually posted prior to the lectures.

Evaluation

Your evaluation for this class will be based on *5 homeworks (HW), 3 short tests (quizzes) and 3 mid-terms (Exams)* as listed in the schedule. *There will be no final exam* The final score will consist of the following:

- Homework total: 32.5 % for a total of 5 homeworks (6.5 % each).
- Quizzes total: $24\% = 3 \times 8\%$,
- Exams: $43.5\% = 3 \times 14.5\%$,

There will be no make-up quizzes or exams. If you have to miss an exam due to an emergency, a 'neutral' grade will be assigned by replacing the missing grade entry by the mean of the other two – (this amounts to dropping the lowest grade which is zero). A justification will be required in such cases, e.g. note from doctor in case of sickness. The same procedure will be applied for any missed quizzes.
The quizzes will be short in duration (Up to 25mn each - to be specified each time). These will be either on paper or directly taken online on Canvas. Each of the 3 exams will take only about half of a lecture (40mn) and will be on paper – they will be closed books with a formula sheet allowed (instructions on this will be provided). There will also be in-class exercises with the goal of improving class participation and discussions. These will not be graded.
Your final grade for this class will be decided based on the following scale, where T is the total score (out of 100) you achieved in the class.

A : $100 \geq T \geq 93$	**A-** : $93 > T \geq 87$	**B+** : $87 > T \geq 82$
B : $82 > T \geq 77$	**B-** : $77 > T \geq 72$	**C+** : $72 > T \geq 65$
C : $65 > T \geq 60$	**C-** : $60 > T \geq 55$	**D+** : $55 > T \geq 50$
D : $50 > T \geq 40$	**F** : $40 > T$	

If you are taking the class on an S-N basis your total score must be at least 60% in order to get an S grade.

Grading

Grades will be posted immediatly after each homework or quiz is graded. This will usually take up to one week. It is important that you check your grades regularly. If you see a discrepancy between your grades and the grades posted, you need to alert the TA immediatly. You have one week after the homework/ quiz is returned for requesting a change. Details on this can be found in the general **policy on homeworks and tests** – posted in the schedule of the instructor's class web-site.

Cheating

All homeworks and quizzes must represent your own individual effort. Please read the course policy on homeworks and tests.
Cheating cases will be dealt with in a very strict manner. At a minimum, violators of this policy will fail the course and will have their names recorded. For additional information please consult the student code of conduct which can be found here: `https://regents.umn.edu/policies/index`

Overview of topics to be covered

[Tentative and the order of coverage may be different]

- Background: Subspaces, Bases, Orthogonality, Matrices, Projectors, Norms. Floating point arithmetic. Introduction to Matlab and Python/Numpy

- Systems of linear equations. Solution of Systems of Linear Equations: matrix LU factorization. Special matrices: symmetric positive definite, banded.
- Error analysis, condition numbers, operation counts, estimating accuracy.
- Orthogonality, the Gram-Schmidt process. Classical and modified Gram-Schmidt. Householder QR factorization. Givens rotations. Least-squares systems. Rank deficient LS problem.
- More on least squares problems. Regularization, Least squares problems with constraints.
- Eigenvalues, singular values. The Singular Value Decomposition. Applications of the SVD.
- Eigenvalue problems: Background, Schur decomposition, perturbation analysis, power and inverse power methods, subspace iteration; the QR algorithm.
- The Symmetric Eigenvalue Problem: special properties and perturbation theory, Law of inertia, Min-Max theorem, symmetric QR algorithm, Jacobi method. Applications.
- Sparse matrix techniques. The Lanczos algorithm. Lanczos bidiagonalization. Sparse direct solution methods (overview). Krylov subspace methods for linear systems (overview).