CSci 5304 Fall 2020
Computational Aspects of Matrix Theory

General Information

PLease note: 1) additional information provided online (canvas and cse 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 will be taught online - with synchronous lectures [Mon-We 8:15-9:30] via zoom. All office hours will be online. All lectures will be recorded and posted.

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.

- **Class Schedule:** MW 08:15 AM - 09:30 AM — Online
- **Instructor:** Yousef Saad ≪ saad@umn.edu ≫ `http://www.umn.edu/~saad`
- **Teaching Assistant:** Ziyuan Tang ≪ tang0389@umn.edu ≫
- **Office hours:** Posted online.
- **Class Website:** Basic information and lecture notes will be posted here:

  `www-users.cselabs.umn.edu/classes/Fall-2020/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 cselabs website (for lecture notes) on a regular basis.
- **Policies related to Zoom recording:** This course will include video and audio recordings of class lectures and classroom activities. These recordings will be used for educational purposes and the instructor will make these available to all students currently enrolled in csci5304. Students must seek instructor permission in order to share either course recordings or course content/materials. Similarly, instructors who wish to share zoom recordings with other classes must seek and document permission from students whose image or voice are in these recordings.
- **Academic conduct and policies related to online learning:** Please read the Office for Community Standards memo on virtual learning expectations. The rules stipulated in it apply to all participants in csci5304.

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 book can be obtained online.
- *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.

Lecture Notes

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

Evaluation

Your evaluation for this class will be based on 6 homeworks, and 7 short tests (quizzes). The final score will consist of the following:

- Homework total: 36 % for a total of 6 homeworks (6% each).
- Quizzes total: $55\% = 5 \times 11\%$, from the 5 best scores out of the 7 quizzes.
- Participation : 9%.

There will be no make-up quizzes but note that your two lowest scores for the quizzes will be dropped.
There will 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 about 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 cse 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.
- 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).