CSci 5304 Fall 2021
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 in person, with an attempt to stream the lectures online synchronously [Mon-We 4:00-5:30] via zoom. All office hours will be online. We plan to record and post all lecture videos, but the logistics to do this are yet to be determined.

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 4:00-5:15 PM in Keller 3-230.
- **Instructor:** Daniel Boley `<boley@umn.edu>` `https://www-users.cs.umn.edu/~boley`
- **Teaching Assistant:** Calvin Roth `<rothx195@umn.edu>`
- **Office hours:** To Be Posted online.
- **Class Website:** Basic information and lecture notes will be posted here:
  `https://www-users.cselabs.umn.edu/classes/Fall-2021/csci5304/`
- **Class Canvas Page:** Detailed schedule, Homeworks, quizzes, will be posted on the above web site or on the Canvas site. All materials (homeworks and quizzes) will be submitted via Canvas. Zoom links for lectures and office hours will be posted on Canvas.
  `https://canvas.umn.edu/courses/268080`

  If you attend a class in person, in-class exercises should be handed in on paper during class (the old-fashioned way). Those not present in class should hand in their in-class exercises via Canvas by the following morning, or the stated due date, if any.

  It is your responsability to check both Canvas (especially for homeworks) and the class website on CSELABS (for lecture notes) on a regular basis.
- **Policies related to Zoom recording:** All materials and recordings for this class will be used for educational purposes and the instructor will make these available to all students currently enrolled in csci5304. Permission from the instructor must be obtained before sharing any course materials with anyone not enrolled in this class. This applies to all handouts, recordings, homeworks, tests, except that the syllabus for the class may be

freely shared. Similarly, instructors who wish to share zoom recordings outside of this class must seek and document permission from students whose images appear in these recordings (unless they are cropped out).

- **Academic conduct and policies related to online and in-class learning:** Please read the Office for Community Standards memo on virtual learning expectations. The rules stipulated in it apply to all participants in csci5304. Students are expected to follow University guidelines to prevent the spread of Covid, like wearing a mask while on campus. Failure to do so will be a disruption to the class and may result in the class going entirely on-line and/or the disruptor failing the class outright, among other consequences.

- **Other Policies (including late penalties):** See https://www-users.cselabs.umn.edu/classes/Fall-2021/csci5304/index.php?page=policy.

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. *Note:* The third edition will be more than adequate for this class, but the fourth edition is an excellent reference resource who will continue working in any field where computational linear algebra play a major role.
- *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.
- *Matrix Analysis and Applied Linear Algebra*, Cark D. Meyer. SIAM, 2000. An excellent text of fundamentals of linear algebra theory.

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 website (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 5 to 6 homeworks, and 3 exams. The exams may be in-class or take-home, depending on the logistics for the electronic delivery of lectures. There will also be 7 to 10 in-class exercises which will occur from time to time. You will receive full credit for in-class exercises if you make a good faith attempt to answer the questions and hand them in on time. The final score will consist of the following:

- Homework total: 45 % for a total of 5-6 homeworks (7.5% to 9% each).
- Exams total: 45% $= 3 \times 15\%$.
- In-class exercises : 10% for handing in in-class exercises (also called quizzes).

You may be asked to discuss answers for a few homeworks or exams either in person or by providing a short video explaining the reasoning behind your answers.
There will be in-class exercises (also called quizzes) with the goal of improving class participation and discussions. These will be tracked, and full credit will be provided if you make a good-faith attempt to find an answer (i.e. no credit for handing in an empty answer). There will be no make-up in-class exercises but note that your two lowest scores for the quizzes will be dropped.
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. However, to pass the class you must get at least a passing score on the homeworks alone and on the exams alone.

A : $100 \geq T \geq 94$	**A-** : $94 > T \geq 90$	**B+** : $90 > T \geq 87$
B : $87 > T \geq 83$	**B-** : $83 > T \geq 80$	**C+** : $80 > T \geq 75$
C : $75 > T \geq 70$	**C-** : $70 > T \geq 60$	**D+** : $60 > T \geq 55$
D : $55 > T \geq 50$	**F** : $50 > T$	

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 immediately 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 to request 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]

Week	Topics
01	Background: Subspaces, Bases, Orthogonality, Matrices, Projectors, Norms. Floating point arithmetic. Introduction to Matlab.
02	... *continued*
	HW1 due Friday 09/13
03	Systems of linear equations. Solution of Systems of Linear Equations: matrix LU factorization. Special matrices: symmetric positive definite, banded.
	HW2 due Friday 10/01
04	Error analysis, perturbation theory for linear systems, condition numbers, operation counts, estimating accuracy.
	Test1 on wed 10/06
05	... *continued*
06	... *continued*
	HW3 due Fri 10/22
07	Orthogonality, the Gram-Schmidt process. Classical and modified Gram-Schmidt. Householder QR factorization. Givens rotations. Least-squares systems. Rank deficient LS problem.
08	... *continued*
	HW4 due Fri 11/05
09	4 Fundamental orthogonal subspaces. Singular values. The Singular Value Decomposition. Applications of the SVD. Regularization, Least squares problems with constraints.
	Test2 on Wed 11/10
10	... *continued*
11	Eigenvalue problems: Background, Schur decomposition, perturbation analysis, power and inverse power methods, subspace iteration; the QR algorithm.
	short week (Thanksgiving)
12	... *continued*
	HW5 due Fri 12/03

13 The Symmetric Eigenvalue Problem: special properties and perturbation theory, Law of inertia, Min-Max theorem, symmetric QR algorithm, Jacobi method. Applications.

Test3 on Wed 12/08

14 Sparse matrix techniques. The Lanczos algorithm. Lanczos bidiagonalization. Sparse direct solution methods (overview). Krylov subspace methods for linear systems (overview).

HW6 due Wed 12/15