MATH547: Linear Algebra for Applications

Course Info

This course is an introduction to the many applications of linear algebra. Basic theoretical concepts are discussed, but the focus is on expressing these concepts in algorithms, and use of linear algebra algorithms to solve practical problems.

Course goals: Students will acquire an understanding of the fundamental role linear algebra has in mathematical modeling, become familiar with ways to formulate applications of interest as linear algebra problems, and proficient in using available computational tools to solve these problems.

Title	**MATH547: Linear Algebra for Applications**
Times	MoWeFr 1:25-2:15 PM, Greenlaw 101
Office hours	MoWeFr 11:00AM-12:00 PM, Chapman 451
Instructor	Sorin Mitran
Assistants	Wyatt Bridgman, Yunyan He

Honor Code:

- All work is individual. You may discuss various approaches to homework problems with students, instructors, but must draft your answers by yourself
- All exams are closed book

Grading

Required work

- Homework - 8 assignments x (4 1-point exercises + a 4-point computer application) = 64 points
- Midterm - 3 problems x 4 points = 12 points
- Final - 6 problems x 4 points = 24 points
- You will be given the opportunity during the Final Examination to answer one 4-point question from the midterm material (the question will be different from those given during the Midterm Examination). The score from this question will replace your worst score on a problem from the Midterm Examination.

Homework is designed such that each grade point requires 0.5 hours to complete, once basic concepts have been understood.

Examinations will test *understanding* of course concepts, as tested by problems that require insight rather than rote repetition of homework exercises.

Extra credit

You may use these extra credit questions to make up for missed homework or points lost on the examinations.

Turn in any of these before Fall break to receive extra credit points:

- EC1 (2 points) (to be posted)
- EC2 (2 points) (to be posted)
- EC3 (2 points) (to be posted)

Turn in any of these before last day of class to receive extra credit points:

- EC4 (2 points) (to be posted)
- EC5 (2 points) (to be posted)
- EC6 (2 points) (to be posted)

Extra credit is designed such that each grade point requires 1 hour to complete, double the effort required for homework grade points.

Mapping of point scores to letter grades

Grade	Points	Grade	Points	Grade	Points	Grade	Points
A *cum laude*	101-112	B+	86-90	C+	71-75	D+	56-60
A	96-100	B	81-85	C	66-70	D	50-55
A-	91-95	B-	76-80	C-	61-65	F	0-49

Note: Students can obtain a grade of C- (64 points) by correct solution of the homework problems. Higher undergraduate grades require either doing some of the extra credit or dedicating effort to *understanding* the theoretical concepts of the course, as tested during the midterm and final examinations.

Course policies

- Students are free to establish their own schedule; there is no need to inform instructor of absences. Course attendance is highly recommended to gain insight into course topics.
- Students are required to read posted lecture notes, sections from textbook, and complete exercises prior to class attendance. These assignments are posted at least one week in advance of class meeting time starting with Week 2.
- Late homework is not accepted.
- Homework and extra credits are submitted in electronic form through Sakai. Submission by email is not accepted.

Bibliography

Course textbook: *Applied Linear Algebra* by Peter Olver and Chehrzad Shakiban. Additional recommendations:

- *Linear Algebra and Its Applications* by David Lay, Steven Lay, and Judi McDonald, Pearson publishers
- *Linear Algebra and Its Applications* by Gilbert Strang.

Lectures, reading and exercise assignments

The following lecture notes are meant as a synopsis of class discussions. For more details consult the corresponding sections within the textbook.

Week	Monday	Wednesday	Friday
1	1/11 Linear combinations Lesson01.pdf Discussion01.pdf	1/13 Matrices Lesson02.pdf Discussion02.pdf	1/15 Matrix products, transpose Lesson03.pdf Discussion03.pdf
2	(MLK holiday, no class)	1/20 Measuring vectors: scalar products, norms Lesson04.pdf Discussion04.pdf	(No class, snowstorm)
3	1/25 1/22 Measuring vectors: angles & Intro to linear systems Lesson05.pdf Discussion05.pdf	1/27 Vector set span, matrix range, linear dependence Lesson06.pdf Discussion06.pdf	1/29 Vector spaces and subspaces, left null space Lesson07.pdf Discussion07.pdf
4	2/1 Fundamental theorem of linear algebra Lesson08.pdf Discussion08.pdf	2/3 Homework1 preparation Homework1SolutionClassDiscussion.pdf Homework1SolutionClassDiscussion.tm	2/5 Fundamental theorem linear algebra proof (part 1) Lesson09.pdf Discussion09.pdf
5	2/8 Fundamental theorem linear algebra proof (part 2), General solution of Ax=b Lesson10.pdf Discussion10.pdf	2/10 Homework2 preparation	2/12 Bases for fundamental spaces (examples) Lesson11.pdf Discussion11.pdf
6	2/15 (University closed, snow day)	Homework2 in class preparation	Homework2 in class preparation
7	2/22 Solution of Ax=b (square matrix	2/24 LU factorization and solving Ax=b	2/26 Gram-Schmidt algorithm,

	case) Lesson12.pdf Discussion12.pdf	Lesson13.pdf Discussion13.pdf	QR factorization Lesson14.pdf Discussion14.pdf
8	2/29 Projection Lesson15.pdf	3/2 Data fitting, interpolation Lesson16.pdf Discussion16.pdf	10/5 Projection solution of least squares problem Lesson17.pdf
9	3/7 Determinants Lesson18.pdf Lesson19.pdf	3/9 Cramer's rule Lesson20.pdf	3/11 Midterm examination
10	3/21 Midterm review	3/23 Eigenvalues Lesson21.pdf Discussion21.pdf	3/25 (No class)
11	3/28 Algebraic, geometric multiplicities Lesson22.pdf Discussion22.pdf	3/30 Eigensystem computation (direct methods) Lesson23.pdf Discussion23.pdf	4/1 Eigensytem computation (iterative methods) Lesson24.pdf Discussion24.pdf
12	4/4 Eigensystem applications Lesson25.pdf Discussion25.pdf	4/6 Eigensystems for (skew-)symmetric matrices. Applications Lesson26.pdf Discussion26.pdf	4/8 Schurr decomposition. SVD Lesson27.pdf Discussion27.pdf
13	4/11 SVD computation Lesson28.pdf Discussion28.pdf	4/13 SVD applications. Model reduction for (skew-)symmetric matrices. Applications Lesson29.pdf Discussion29.pdf	4/15 Practice final exam FinalPrep.pdf (becomes active at class time)
14	4/18 Practice final exam review FinalPrepSolution.pdf	4/20 Case study 1: Cellular motility Lesson30.pdf Discussion30.pdf	4/22 Case study 2: Markov chains Lesson31.pdf Discussion31.pdf
15	4/25 Case study 3: Astrophysical spectroscopy Lesson32.pdf Discussion32.pdf	4/27 Course concept review FinalDiscussion.pdf	

Homework

Homework should be started within 24 hours of it being posted. You should attempt upload of your completed assignment well ahead of the deadline, preferably to allow enough time for office hours consultation. The submission deadline and electronic submission procedure of typeset homework are strictly enforced.

(Note: the Jan 13 class lockout has delayed the homework schedule by a week from initial plans. First homework to be posted on Jan 22. Homework 0 is a test of submission procedures, and not included in course grade.)

Nr.	Issue Date	Due Date	Topic	Problems	HowTo	Solutions
0	1/19	1/22	Test of homework submission procedure	Homework0.tm Homework0.pdf		
1	1/29	2/5	Vector spaces	Homework1.tm Homework1.pdf	Problem1a video	Homework1Solution.tm Homework1Solution.pdf
2	2/6	2/22	Fundamental matrix subspaces and applications to face recognition	Homework2.tm Homework2.pdf	OctaveImageIO.tm OctaveImageIO.pdf	
3	2/22	2/29	LU, QR factorizations	Homework3.tm Homework3.pdf		
4	2/29	3/7	Projections, permutations, least squares applied to analysis of electroenchephalograms (EEGs)	Homework4.tm Homework4.pdf	EEG.tm EEG.pdf	Homework4Solution.tm Homework4Solution.pdf
5	3/23	4/1	Eigenvalue and eigenvector computation	Homework5.tm Homework5.pdf		Homework5Solution.tm Homework5Solution.pdf
6	4/4	4/11	Eigensystem applications	Homework6.tm		

				Homework6.pdf
7	4/13	4/20	SVD computation	Homework7.tm Homework7.pdf
8	4/20	4/27	Final preparation	Homework8.tm Homework8.pdf

Examinations

- Midterm examination: 1:25-2:15 PM, Fr. Mar. 11
- Final examination: 12:00-3:00 PM, Mo. May 2

- Midterm.SP.2016.pdf, MidtermSolution.SP.2016.pdf
- Final.pdf, FinalSolution.pdf

Course materials

Software

The utility of linear algebra can only be understood through practical applications on problems of realistic complexity. This requires use of computers and relevant software. Two options are available for students:

- For future users of linear algebra: install TeXmacs and use Octave-online
- For future developers of computational applications: install Virtual Box and the SciComp@UNC Linux environment

Course examples will use both environments.

Users: TeXmacs and Octave

- TeXmacs is a freely available editor with excellent support for mathematical editing. Under OS/X and Linux TeXmacs supports interspersing computation and text editing
- Octave is a freely available system oriented towards linear algebra computations. The language is almost identical to the commercial Matlab system. Octave may be installed locally , or used online, and there are many tutorials available online, e.g. on YouTube .

Developers: SciComp@UNC Linux environment

Scientific computation is typically carried out in a Un*x environment (e.g. OS/X, various Linux versions). This course uses a customized Linux environment named SciComp@UNC that is installed as a virtual machine on your laptop (assumed to satisfy UNC laptop requirements. See SciComp@UNC.

Here are some basic operations we carry out within the environment, as relates to Homework1:

- Navigating to Homework 1
- Basic editing within Homework 1

If you have difficulties with using the SciComp@UNC virtual machineon your laptop you can try to install the main programs (Octave and TeXmacs used in the course directly on your base operating system. You can also try to use the online version of Octave

If you experience a hardware failure during the course, a temporary solution is to use the machine outside the Chapman 451 office.

Lecture notes, homework texts and solutions

Course materials (lecture notes, homework, quizzes) are distributed through Sakai and also through the subversion utility, available on all major operating systems. In the SciComp@UNC Linux environment the following will check out an initial copy of course materials:

- mkdir ~/courses
- cd ~/courses
- svn co http://mitran-lab.amath.unc.edu:8082/subversion/courses/MATH547/

Under Windows use Tortoise SVN or SmartSVN. Under OS/X use SmartSVN. Refer to the particular product for instructions on how to carry out the initial checkout of course materials.

In SciComp@UNC Linux you update the course materials before each lecture by:

- cd ~/courses/MATH547
- svn update

Similar procedures exist for svn under Windows or OS/X.