

Syllabus for CSCI 2830-002

Linear Algebra for Computer Scientists

23 August 1999

1 Specs

Class Meetings: M, W 4:00–5:15pm in ECCR 108.

Textbook: G. Strang, *Introduction to Linear Algebra*, available at the UMC bookstore.

Instructor: Prof. Liz Jessup, jessup@cs.colorado.edu, 492-0211, ECOT 625. Office hours TBD.

2 Objectives

This is an introductory course in linear algebra. The goal of this course is to teach you the mathematical fundamentals of linear algebra in a way that illustrates their relevance to computer science. A second goal is to prepare you for study of numerical methods for solving linear algebra problems. Such methods are the subject of CSCI 3656 Numerical Computation, for which a course in linear algebra is a prerequisite.

3 About our approach

This is a course in mathematics. But, in it, you will use the mathematical concepts to illustrate facts about computers, and you will use computers to help you improve your understanding of the mathematics. You will also see how linear algebra is applied in various areas of computer science.

This course includes computer applications in three different contexts: programming exercises, textbook examples, and guest lectures. The application programming exercises will be included as part of the weekly homework assignments. The guest talks will be delivered by a variety of computer scientists who have in common the use of linear algebra in their research areas. The applications may include problems in such areas as computer game development, numerical analysis, parallel computing, artificial intelligence, computer performance, and systems analysis.

4 The nature of the material

Introductory linear algebra is a cumulative subject. Please make sure that you understand each concept well before moving on to study the next.

5 About language

As our primary language, we will use Matlab. It is an interpreted language designed explicitly for linear algebra applications. It has substantial graphics capabilities as well.

Matlab is available in the CSEL for the following three operating systems: linux (on the machines named after the letters of the alphabet m-z), sparc solaris (on the fast new ultra 10s named after Mayan months), and hp-ux (on nag, nagina, taussky, etc). It is best to use the version installed as /tools/edu/matlab_5.3/bin/matlab. You may also find it convenient to purchase the student edition of Matlab and install it on your personal PC.

There is a limit of 21 simultaneous Matlab users. Please plan your time accordingly. Unavailability of the tool the night before an assignment is due is not an excuse for late homework.

6 Requirements and Grading

Grades will be based on homework assignments (40%) and hour exams (60%). Good class participation is strongly encouraged.

There will be approximately ten homework assignments. Assignments will generally be due at the beginning of class one week after they are handed out. Some of the homework problems will involve programming. Some will include more detailed looks at specific computer science applications.

You are encouraged to work together to figure out the homework problems, but writeups must be your own, individual work. You may write any program together with one partner.

There will be four hour exams. You will be given the full 75 minutes to work on these exams. The fourth hour exam will be held during the final exam period. An optional fifth exam covering the material of the first two exams will also be offered during the final exam period. You may elect to replace one of your first three exam grades with your grade on the fifth exam.

7 Course Critique

As this is only the third offering of this course (and the first with this text), your opinions on the materials and their presentation are particularly important. You will have formal opportunities to speak your mind about the course, but the instructors also invite your informal comments (anonymous or otherwise) at any time and in any form.

8 CSCI 2830 CALENDAR

The course is organized into four parts roughly delineated by the four hour exams.

In the first part of the course, you will learn the collection of basic tools from linear algebra that you will need to do the more advanced work later in the semester. These include the fundamental vector and matrix operations and methods for solving systems of equations when you have as many equations as unknowns.

In the second part, you will begin to study the geometry of vectors. Understanding how vectors are related to each other in space is the key to understanding when matrix problems can be solved.

In the third part, you will focus on the special case of orthogonal vectors and the matrices and spaces defined by such vectors. Manipulation of orthogonal matrices is a fundamental part of methods for solving problems where there are more equations than unknowns, and such problems are common in the analysis of experimental data.

The final part of the course concerns eigenvalue problems. Eigenvalues are used (in a very general sense) to characterize the energy of a system modelled by a matrix. Eigenvalue problems present the most complex mathematics of any of the problems studied in this course, and so they will provide a good test of your understanding of the first two parts of the course!

What follows is a tentative outline of the course. This calendar is subject to change according to the needs and pace of the class. Guest speakers will be scheduled as they are available, and the schedule will slide to accommodate their visits.

Week 1, 8/23-8/25 Introduction to vectors and matrices. The geometry of linear equations. Gaussian elimination for solving square systems of linear equations ($Ax = b$).

Reading: sections 1.1-2.3 of the textbook

Week 2, 8/30-9/01 Matrix operations and inverses. Matrix factorization. Operation counts.

Reading: section 2.4-2.6

Week 3, 9/08 (No class Monday, September 6–Labor Day.) Transposes and permutations.

Reading: section 2.7

Week 4, 9/13-9/15 Performance programming of matrix operations. Review.

Hour exam 1

Reading: Elements of Matlab (handout)

Application 1: The Secret Agent Man meets linear algebra (2 weeks)

Week 5, 9/20-9/22 An introduction to vector spaces. The nullspace. Solving $Ax = 0$. Matrix rank.

Reading: sections 3.1-3.3, the definition of a vector space on p.107.

Week 6, 9/27-9/29 The complete solution of $Ax = b$. Linear independence. Bases.

Reading: section 3.4-3.5

Week 7, 10/04-10/06 The four fundamental subspaces.

Reading: section 3.6, 4.1

Week 8, 10/11-10/13 Review.

Hour exam 2

Week 9, 10/18-10/20 Projections. Least squares approximations.

Reading: sections 4.2-4.3

Application 2: a linear algebra puzzle—avoiding trigonometry in a graphics problem (2 weeks)

Week 10, 10/25-10/27 The QR factorization.

Reading: sections 4.4

Week 11, 11/01-11/03 Properties of determinants. Formulas for determinants.

Reading: sections 5.1-5.2

Week 12, 11/08-11/10 Uses of determinants. Review.

Reading: chapter 5.3

Hour exam 3

Week 13, 11/15-11/17 The basics of eigenvalues and eigenvectors. What they mean.

Reading: sections 6.1-6.2

Application 3: graphics (2 weeks)

Week 14, 11/22 (No class Wednesday, Nov.24.) Symmetric and symmetric positive definite matrices. What they are and why they are worth a close look. The power method.

Reading: sections 6.4-6.5, pp.415-416

Week 15, 11/29-12/01 Matrix norms, condition numbers, and the ill-conditioned problem.

Reading: section 9.2, pp.395-400

Week 16, 12/06-12/08 The conclusion.

Hour Exam 4 (and optional exam): Monday, December 13 7:30-10:30pm.