EAS596 Introduction to Numerical Mathematics for Data Scientists - Fall 2019 - Lecture 1

Sunday, August 25, 2019 9:50 PM

Overview of Course

Syllabus

Topics

Introduction to Matlab

History

Basic commands

m-files (Scripts and functions)

Editor and debugger

Loops and logical statements

First examples

- x-y plot
- Taylor series approximations

EAS 596 Course Syllabus
Introduction to Numerical Mathematics for Data Scientists
Fall 2019

Instructors

Dr. Gary Dargush	Dr. David Salac
Bell 223	Jarvis 326
gdargush@buffalo.edu	davidsal@buffalo.edu
716-645-2315	716-645-1460
Office Hours: W 4:00-6:00 PM	Office Hours: MW 2:15-3:30 PM

Teaching Assistants

@buffalo.edu	@buffalo.edu
Office Hours: Bell 250	Bell 250

Course Meeting Times
MW, 11:00 AM – 12:30 PM (Dargush), Bell 250
MW, 12:30 PM – 2:00 PM (Salac), Norton 218

Course Description

- To develop the ability to formulate and solve problems using mathematical methods and tools
- To apply knowledge gained in lower level mathematics courses
- To introduce concepts and methods of linear algebra
- To introduce a broad range of numerical methods
- To develop the ability to identify, understand, and solve algebraic equations
- To develop the ability to identify, understand, and solve differential equations
- To develop experience with numerical and symbolic mathematical software and their use in problem solving

Prerequisites Calculus

Textbooks & Other Course Materials There are three required texts:

- G. Strang, Introduction to Linear Algebra, 5th ed., Wellesley-Cambridge Press, 2016.
- L. N. Trefethen, D. Bau, Numerical Linear Algebra, SIAM, 2017.
- L. V. Fausett, Applied Numerical Analysis Using MATLAB, 2nd Ed., Prentice Hall, 2008.

You may find the following other references useful, but they will not be used in the course and you are not required to purchase them.

- S. C. Chapra, Applied Numerical Methods with Matlab for Engineers & Scientists, 4rd Ed., McGraw-Hill, 2018.
- S. S. Rao, Applied Numerical Methods for Engineers and Scientists, Prentice Hall, 2002.

- H. Moore, MATLAB for Engineers, 4th Ed., Pearson, 2015. This book is recommended to enhance your MATLAB programming skills.
- S. J. Chapman, Essentials of MATLAB Programming, Cengage Learning, 2009.
- W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery, Numerical Recipes: The Art of Scientific Computing, Cambridge University Press, 2007.

Important Dates

- Last Day to Add/Drop — Tuesday, September 3, 2019
- Last Day to Resign — Friday, November 8, 2019
- Midterm Exam — TBD
- Final Exam — 11:45 AM – 2:45 PM, Wednesday, December 11, 2019

Grading Policy Grades will be based on points accumulated from the course requirements.

Course Requirement	**Percent of Final Grade**
Exams (2)	60% (25/35% Each)
Homework Assignments (Approx. 10)	40% (4% Each)

You will be able to drop 1 homework assignment.

Exact cutoffs for specific grades will depend on the level of difficulty of exams and assignments. These cutoffs will be determined once the final exam has been graded. **All sections of EAS 596 will be assigned the same cutoffs.** However, the cutoffs will not exceed the following:

Percentage	**Final Grade**
92	A
82	B
72	C
62	D

In certain cases, students may be eligible to receive a temporary incomplete ("I") grade. Students may only be given an "I" grade if they have a passing average in coursework that has been completed and establish well-defined parameters to complete course requirements. Prior to the end of the semester, students must initiate the request for an "I" grade and receive the instructor's approval. Detailed information is available from the Undergraduate Course Catalog: http://undergrad-catalog.buffalo.edu/policies/grading/explanation.shtml#incomplete.

Computing/MATLAB Most assignments will have a computing component. MATLAB will be used throughout the course. MATLAB is available on all PCs in the SENS labs and is available through the "My Virtual Computing Lab" available to all students.

Course Requirements The following table summarizes the requirements of the course.

Requirement	Quantity	Material Covered	Date
Exams	2	(1) Through numerical linear algebra (2) Through Integration/Comprehensive	(1) Week 8 (2) Finals Week
Homework	≈ 10	Variable; related to material covered in lecture	Submitted in-class

Expectations of Students

- Students are expected to act in a professional manner. A student's grade may be reduced due to unprofessional or disruptive behavior. Examples include coming to class late, texting (or otherwise using your cell phone) during class, your cell phone ringing during class and/or exams, etc.
- Homework assignments will be assigned approximately weekly. Homework assignments are due **at the assigned date and time**.
- Homework assignments will be graded and returned to students.
- **Late submission of assignments will receive a grade of zero.**
- Students are encouraged to discuss assignments and share ideas, but each student must independently write and submit their own solution.
- Makeup exams will be given in the following circumstances only:
  1. You contact the instructor prior to the exam
  2. You have a valid and documented reason to miss the exam
     - Serious illness or family emergency are acceptable reasons
     - Sleeping in, lack of preparation, ennui, grogginess, etc. are not acceptable excuses

Accessibility Services and Special Needs If you have a disability and may require some type of instructional and/or examination accommodation, please inform me early in the semester so that we can coordinate the accommodations you may need. If you have not already done so, please contact the Office of Accessibility Services (formerly the Office of Disability Services) University at Buffalo, 25 Capen Hall, Buffalo, NY 14260-1632; email: stu-accessibility@buffalo.edu Phone: 716-645-2608 (voice); 716-645-2616 (TTY); Fax: 716-645-3116; and on the web at http://www.buffalo.edu/accessibility/. All information and documentation is confidential. The University at Buffalo and the School of Engineering and Applied Sciences are committed to ensuring equal opportunity for persons with special needs to participate in and benefit from all of its programs, services and activities.

Academic Integrity This course will operate with a zero-tolerance policy regarding cheating and other forms of academic dishonesty. Any act of academic dishonesty will subject the student to penalty, including the high probability of failure of the course (i.e., assignment of a grade of "F"). It is expected that you will behave in an honorable and respectful way as you learn and share ideas. Therefore, recycled papers, work submitted to other courses, and major assistance in preparation of assignments without identifying and acknowledging such assistance are not acceptable. All work for this course must be original for this course. Please be familiar with the University and the School policies regarding plagiarism. Read the Academic Integrity Policy and Procedure for more information: http://undergrad-catalog.buffalo.edu/policies/

course/integrity.shtml Visit the Senior Vice Provost for Academic Affairs web page for the latest information at http://vpue.buffalo.edu/policies/

EAS 596 Topics List
Introduction to Numerical Mathematics for Data Scientists
Fall 2019

The following is the planned list and ordering of topics. This list is subject to change.

Lecture	Topic	Trefethen	Strang	Fausett
1	Introduction			
1	Introduction to Matlab	9		1.4
1	Matlab – Functions and Scripts			1.4
1	Matlab – IDE			1.4
1	Matlab – Loops and logical statements			
1	Matlab – Example, Fibonacci sequence			
2	Approximation & Round-off Errors	Appendix		1.3
2	Significant Figures			1.2
2	Numbering Systems			
2	Finite Precision Arithmetic	13		
2	Floating Point Representations	13		
3	Vectors – Introduction	1	1.1	
3	Vector Operations	1	1.1	
3	Dot Product		1.2	
3	Schwartz Inequality		1.2	
4	Triangle Inequality		1.2	
4	Linear Combination of Vectors		1.1	
4	Matrix – Introduction	1	1.3	
4	Matrix Operations	1	2.4	
4	Matrix – Vector	1	1.3	
4	Matrix Properties, Determinant, Trace		5.1	
4	Matrix Inverses – Introduction	1	2.5	
5	Linear Systems of Equations – Introduction		2.1	
5	Solution Existence and Uniqueness		2.2	
6	Elimination & RREF		2.2	
6	Use of Matrices: Graphs and Graph Theory		10.1	
6	Use of Matrices: Markov Chains		10.3	
7	Vector Spaces & Subspaces		3.1	
7	Rules of a Vector Space		3.1	
7	Span		3.1	
7	Vector Independence		2.7	
7	Linear Independence & Dependence		3.4	
7	Basis		3.4	
7	Vector Space Dimension		3.4	
8	Functions			
8	Function Composition, Inverse			
8	Linear Transformations		8.1, 8.2	
8	Sample Geometric Linear Operators in R3			

Lecture	Topic	Trefethen	Strang	Fausett
9	Column Space	1	3.1, 3.5	
9	Nullspace	1	3.2, 3.5	
9	Row Space	1	3.4, 3.5	
9	Left Nullspace		3.5	
9	Rank-Nullity (Dimension) Theorem		3.5	
9	Orthogonality		4.1	
9	Orthogonality of the Four Matrix Subspaces		4.1	
10	Numerical Solutions – Introduction		11.1	
10	Matrix & Vector Norms	3	11.2	
10	Condition Number	12	11.2	
10	LU Decomposition & Gaussian Elimination	20, 21	2.6	4.1
10	Operation Count of LU	20	11.1	
10	Failure of LU due to Finite Precision	20	11.1	
11	Projections on Subspaces	6	4.2	
11	Least Squares Approximation	11	4.3	
12	Normal Equations		4.2	
12	Orthogonal & Orthonormal Basis		4.4	
12	QR	7	4.4	
12	Classical Gram-Schmidt	8	4.4	
13	Modified Gram-Schmidt	8	4.4	
13	Householder Triangularization	10	11.1	4.2
13-14	Eigensystems	24	6.1	5
14	Normal Matrix			
14	Matrix Diagonalization		6.2	
14-15	Iterative Eigensolvers	25-30		5.1-5.3
15	SVD	4, 5, 31	7.1, 7.2, 7.4	5.4
16	Scalar Differential Equations			
16-17	Solution of Linear ODEs			
17-18	PDEs			
18-19	Systems of ODEs		6.3	
19	Finite Difference			14.2
19	IVPs			12
20	Multistage Methods			12.2
20-21	Runge-Kutta Schemes			12.2
21	Multi-Step Methods			13.3
21	BVPs			15.3
22	IVP + BVP			15
22	Root Finding			2
23	Systems of Nonlinear Equations			7
23	Minimization			2.5
24	Multidimensional Minimization			7.2
25	Nonlinear Regression			
25	Interpolation			8
26	Integration			11.2

Matlab - History & Overview

Sunday, August 25, 2019 10:03 PM

Matlab: Matrix laboratory

LINPACK & EISPACK from 1970s

evolved into initial versions of Matlab

in Fortran

Matlab is an interpreted language, rather than

a compiled language, such as Fortran, C, C++

First commercial Matlab in 1980s

Added functionality (ODEs, Sparse matrices)

From terminal to desktop version in 2000

More functionality (Parallel computing, toolboxes)

```
% clear workspace
clc
clear
format long

alpha = 1/2;
x = 2.;

y = x^alpha;

x
y


n = 64;
x = (1:n)';
x = 2*x/n;
b = 4.;
x

for j=1:4
    alpha = j/2;
    % for i=1:n
    %     y(i) = x(i)^alpha + b;
    % end
    [y] = power_law(n,alpha,x);
    j
    alpha
    y'
end

figure(1)
plot(x,y)

figure(2)
loglog(x,y)
```

```
function [y] = power_law(n,alpha,x)

y = x.^alpha;
% y'
```

Taylor Series

Monday, August 26, 2019 10:39 AM

$$f(x) = f(a) + \frac{f'(a)}{1!}(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \ldots$$

$$f(x) \cong \cancel{f(a) +} \sum_{n=0}^{N} \frac{f^{(n)}(a)}{n!}(x-a)^n$$

```
% clear workspace
clc
clear
format long

a = 0;
x = 2;
N = 20;
eps = 1e-6;

expx = exp(x);
% expx

fts = 0;

for n=0:N

    fts = fts + exp(a)*(x-a)^n/factorial(n);
    err = fts - expx;

    if abs(err) < eps

        % convergence
        n
        expx
        fts
        err
        break

    end
end
```