The Professor
The Class — Overview
The Class...
Introduction

Numerical Matrix Analysis
Lecture Notes #1 — Introduction

Peter Blomgren,
⟨blomgren.peter@gmail.com⟩
Department of Mathematics and Statistics
Dynamical Systems Group
Computational Sciences Research Center
San Diego State University
San Diego, CA 92182-7720
http://terminus.sdsu.edu/

Spring 2016

Outline

1 The Professor
   • Academic Life
   • Contact Information, Office Hours
   • Non-Academic Life

2 The Class — Overview
   • Literature & Syllabus
   • Grading
   • Expectations and Procedures

3 The Class...
   • Resources
   • Formal Prerequisites

4 Introduction
   • The “Why?” the “What?” and the “How?”

Academic Life
MSc

MSc. Engineering Physics, Royal Institute of Technology (KTH), Stockholm, Sweden. Thesis Advisers: Michael Benedicks, Department of Mathematics KTH, and Erik Aurell, Stockholm University, Department of Mathematics. Thesis Topic: “A Renormalization Technique for Families with Flat Maxima.”

Figure: Bifurcation diagram for the family $f_{a_1,2}$ [BLOMGREN-1994]

PhD


Figure: The noisy (SNR = 4.62 dB), and recovered space curves. Notice how the edges are recovered. [BLOMGREN-1998]
Research Associate. Stanford University, Department of Mathematics. Main Focus: Time Reversal and Imaging in Random Media (with George Papanicolaou, et. al.)

Figure: Comparison of the theoretical formula for a medium with $L = 600\, m$, $a_e = 195\, m$, $\gamma = 2.12 \times 10^{-4}\, m^{-1}$. [Left] shows a homogeneous medium, $\gamma = 0$, with $a = 40\, m$ TRM (in red / wide Fresnel zone), and a random medium with $\gamma = 2.12 \times 10^{-5}$ (in blue). [Right] shows $\gamma = 0$, with $a = a_e = 195\, m$ (in red), and $\gamma = 2.12 \times 10^{-5}$, with $a = 40\, m$ (in blue). The match confirms the validity of [the theory]. [Blomgren-Papanicolaou-Zhao-2002]

Peter Blomgren, ⟨blomgren.peter@gmail.com⟩ Lecture Notes #1 — Introduction — (5/20)

Fun Times... ⇒ Endurance Sports

- Triathlons:
  - (12) Ironman distance $(2.4 + 112 + 26.2)$ — 11:48:57 [PR]
  - (16) Half Ironman distance — 5:14:20

- Running
  - (1) Trail Double-marathon (52 miles) — 10:59:00
  - (4) Trail 50-mile races — 9:08:46
  - (6) Trail 50k (31 mile) races — 5:20:57
  - (13) Road Marathons — 3:26:19 (7:52/mi)
  - (23) Road/Trail Half Marathons — 1:36:25 (7:21/mi)
Math 543: Literature

“Required” —  

“Required” — (Supplemental)
Class notes and class web-page.

“Optional” — (Classic, Comprehensive Reference)

Expectations and Procedures, I

- Most class attendance is "OPTIONAL" — Homework and announcements will be posted on the class web page. If/when you attend class:
  - Please be on time.
  - Please pay attention.
  - Please turn off mobile phones.
  - Please be courteous to other students and the instructor.
  - Abide by university statutes, and all applicable local, state, and federal laws.

Expectations and Procedures, II

- Please, turn in assignments on time. (The instructor reserves the right not to accept late assignments.)
- The instructor will make special arrangements for students with documented learning disabilities and will try to make accommodations for other unforeseen circumstances, e.g. illness, personal/family crises, etc. in a way that is fair to all students enrolled in the class. **Please contact the instructor EARLY regarding special circumstances.**
- Students are expected and **encouraged** to ask questions in class!
- Students are expected and **encouraged** to to make use of office hours! If you cannot make it to the scheduled office hours: contact the instructor to schedule an appointment!
Expectations and Procedures, III

- Missed midterm exams: Don’t miss exams! The instructor reserves the right to schedule make-up exams, make such exams oral presentation, and/or base the grade solely on other work (including the final exam).

- Missed final exam: Don’t miss the final! Contact the instructor ASAP or a grade of incomplete or F will be assigned.

- Academic honesty: submit your own work — but feel free to discuss homework with other students in the class!

Honesty Pledges, I

- The following Honesty Pledge must be included in all programs you submit (as part of homework and/or projects):
  
  I, (your name), pledge that this program is completely my own work, and that I did not take, borrow or steal code from any other person, and that I did not allow any other person to use, have, borrow or steal portions of my code. I understand that if I violate this honesty pledge, I am subject to disciplinary action pursuant to the appropriate sections of the San Diego State University Policies.

- Work missing the honesty pledge may not be graded!

Honesty Pledges, II

- Larger reports must contain the following text:
  
  I, (your name), pledge that this report is completely my own work, and that I did not take, borrow or steal any portions from any other person. Any and all references I used are clearly cited in the text. I understand that if I violate this honesty pledge, I am subject to disciplinary action pursuant to the appropriate sections of the San Diego State University Policies. Your signature.

- Work missing the honesty pledge may not be graded!

Math 543: Computer Resources

You need access to a computing environment in which to write your code; — you may want to use a combination of Matlab (for quick prototyping and short homework assignments) and C/C++ or Fortran (or something completely different, like Java or $\text{M}^\text{S}-\text{D}^\text{♭}$).

Class accounts for the computer lab(s) will be available.

You can also use the Rohan Sun Enterprise system or another capable system. [http://www-rohan.sdsu.edu/raccts.html]

Free C/C++ (gcc) and Fortran (f77) compilers are available for Linux/UNIX.

You may also want to consider buying the student version of Matlab: http://www.mathworks.com/

SDSU students can download a copy of matlab from http://www-rohan.sdsu.edu/~download/matlab.html

[Licensing Subject to Change With Minimal Notice]
Math 543: Introduction — What you should know already

Prerequisite: Math 541
541 \Rightarrow \text{Intro to Numerical Analysis and Computing}
- Solution of equations of one variable, direct methods in numerical linear algebra, least squares approximation, interpolation and uniform approximation, quadrature.

Pre-Prerequisite: Math 254 or Math 342A
254 \cap 342A \Rightarrow \text{Basic Linear Algebra}
- Vectors, Matrices, Eigenvalues and Eigenvectors.

\begin{align*}
\bar{x} &= \begin{bmatrix}
x_1 \\
x_2 \\
\vdots \\
x_n 
\end{bmatrix}, \\
A &= \begin{bmatrix}
a_{11} & a_{12} & \cdots & a_{1n} \\
a_{21} & a_{22} & \cdots & a_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
a_{n1} & a_{n2} & \cdots & a_{nn}
\end{bmatrix} = \begin{bmatrix}
\bar{a}_1 \\
\bar{a}_2 \\
\vdots \\
\bar{a}_n
\end{bmatrix}
\end{align*}

Math 543: Introduction — Why???

Solution of linear systems and eigenvalue problems show up in many applications in applied & computational mathematics / sciences / engineering.

Although we probably know about Gaussian Elimination for solving for

\( \bar{x} = A^{-1}\bar{b} \)

in infinite precision, finding this solution (or at least a good approximation thereof) in finite precision (i.e. on a computer) is sometimes a challenge — especially if we need the solution fast.

Math 543: Introduction — What we will learn

\begin{align*}
A\bar{x} &= \bar{b}, & A\bar{x} &= \lambda\bar{x}, & Q^T AQ &= \Lambda = \text{diag}(\lambda_1, \lambda_2, \ldots, \lambda_n)
\end{align*}

- QR-Factorization / Least Squares
- The SVD
- Conditioning and Stability
- Gaussian Elimination, Pivoting
- LU- and Cholesky-factorization
- Eigenvalue Problems
- Iterative Methods
- Arnoldi, GMRES, Lanczos, Conjugate Gradients

Applications (sources of Numerical Linear Algebra problems):
- Solution of partial differential equations (PDEs)
- Optimization (Operations Research)
- Model Analysis and Fitting (Least Squares)
- Image Processing
- Protein Folding
- DNA sequencing, etc. etc. etc.