1. Introduction — (1/26)
Outline

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

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?”
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 $f_{a, \frac{1}{2}}$ [BLOMGREN-1994]

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 $L = 600 \text{ m}$, $a_e = 195 \text{ m}$, $\gamma = 2.12 \times 10^{-5} \text{ m}^{-1}$. [LEFT] shows a homogeneous medium, $\gamma = 0$, with $a = 40 \text{ m}$ TRM (in red / wide Fresnel zone), and a random medium with $\gamma = 2.12 \times 10^{-5}$ (in blue). [RIGHT] shows $\gamma = 0$, with $a = a_e = 195 \text{ m}$ (in red), and $\gamma = 2.12 \times 10^{-5}$, with $a = 40 \text{ m}$ (in blue). The match confirms the validity of [the theory]. [Blomgren-Papanicolaou-Zhao-2002]
San Diego State University

Professor, SDSU, Department of Mathematics and Statistics. Projects: Computational Combustion, Biomedical Imaging (Mitochondrial Structures, Heartcell Contractility, Skin/Prostate Cancer Classification), carbon sequestration, compressed sensing.

Figure: [LEFT] Phase-space projections produced by the time coefficients of the POD decomposition of the rotating pattern shown in [RIGHT]. [Blomgren-Gasner-Palacios-2005]
Development of algorithms achieving near-optimal GPU utilization, with applications to Computational PDEs, Computational Linear Algebra, and Computational Optimization.

**Project #1**: *Fast Multipole Method for Waves over Vortices*, w/Chris Curtis & Daniel Matteson. (S’21)

**Project #2**: *StarPU + ScalFMM Implementation for the Fast Multipole Method*, w/Susana Munguia Hernandez. (in progress)

**Threadripper 3990X** ~ $4,475
64 Cores, 128 Threads.

**RTX 4090** ~ $1,599
16,384 CUDA Cores
Fun Times... ⇔ Endurance Sports

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

Running
- (1) 100k Race (62.1 miles) 15:37:46 (15:05/mi)
- (1) Trail Double-marathon (52 miles) 10:59:00 (12:32/mi)
- (5) Trail 50-mile races 9:08:46 (10:59/mi)
- (8) Trail 50k (31 mile) races 5:20:57 (10:20/mi)
- (16) Road/Trail Marathons 3:26:19 (7:52/mi)
- (30) Road/Trail Half Marathons 1:35:00 (7:15/mi)
Contact Information

<table>
<thead>
<tr>
<th>Office</th>
<th>GMCS-415 and zoom - zoom - zoom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email</td>
<td><a href="mailto:blomgren@sdsu.edu">blomgren@sdsu.edu</a></td>
</tr>
<tr>
<td>Web</td>
<td><a href="https://canvas.sdsu.edu/">https://canvas.sdsu.edu/</a></td>
</tr>
<tr>
<td></td>
<td><a href="https://www.gradescope.com">https://www.gradescope.com</a></td>
</tr>
<tr>
<td></td>
<td><a href="http://terminus.sdsu.edu/SDSU/Math543">http://terminus.sdsu.edu/SDSU/Math543</a></td>
</tr>
<tr>
<td>Office Hours</td>
<td><a href="https://calendly.com/blomgren_sdsu/">https://calendly.com/blomgren_sdsu/</a></td>
</tr>
<tr>
<td></td>
<td>(see Canvas / Calendly for Hours)</td>
</tr>
</tbody>
</table>
Spring 2020: We went online part-way thru the semester

Spring 2021: Zoom-U

Spring 2022: Masked-U — not a good semester (many reasons)

Spring 2023: The New Normal™... some modifications.

During COVID we all de-socialized to some extent; and there is definitely a “learning gap.”

There is sometimes a tendency to see all this silly learning and class work as unnecessary obstacles to getting a degree.

... of least resistance and have Uncle Google, Aunt Wiki, Scuzzy Cousin Chegg, Skynet, or ChatGPT do all the heavy lifting...
We need to remind ourselves that education is about developing skills and processes, definitely not just about “having The Answer.” Understanding

- how to get The Answer;
- how to validate The Answer;
- what The Answer means; and
- how The Answer potentially is useful;

are often the bigger and more important lessons.

It is “unlikely” that you, in real life, will be asked to differentiate cos(sin(tan(ln(x)))), or write the 55,000,001st analysis of Fyodor Dostoevsky’s “Crime and Punishment,” or single-handedly implement the Singular Value Decomposition... but acquiring the skills to perform these tasks are arguable useful.
“Required” —  


“Required” — *(Supplemental)*

Class notes and class web-page.

* SIAM members receive special pricing (30% off). SIAM student membership is free.
Math 543: Literature

Everything You Ever Wanted to Know, but Were Afraid to Ask...

“Optional” — (Classic, Comprehensive Reference)


“Optional” — (Comprehensive Reference)


* SIAM members receive special pricing (30% off). SIAM student membership is free.
Math 543: Literature

“Inspiration for the Road Ahead” —


“Considered... but, no.” —


* SIAM members receive special pricing (30% off). SIAM student membership is free.
Math 543: Introduction — Grading etc.

50% Homework: both theoretical, and implementation (programming) — Recommended languages: Python, Matlab, C/C++, or Fortran; however anything goes: 6510 assembler, Java, M$-D^b$, Haskell...

25% Midterm: $\left[ \frac{1}{2} \text{ Take-Home, and } \frac{1}{2} \text{ In-Class} \right]$.

25% Final: $\left[ \frac{1}{2} \text{ Take-Home, and } \frac{1}{2} \text{ In-Class} \right]$. 
Most class attendance is “OPTIONAL” — Homework and announcements will be posted on the class web page. If/when you attend class:
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.
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.
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.
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.
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.
Please, turn in assignments on time. (The instructor reserves the right not to accept late assignments.)
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.**
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!
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 make use of office hours! If you cannot make it to the scheduled office hours: contact the instructor to schedule an appointment!
Late HW Policy

- Assignments accepted up to 24 hours after original deadline, with a 10% penalty.
- Further extensions will only be granted in extreme, well-documented, circumstances.
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).
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.
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, 1

The following **Honesty Pledge** must be included in all programs you submit (as part of homework and/or projects):
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 — real or artificial — 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.
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 — real or artificial — 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!**
Larger reports must contain the following text:
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 — real or artificial — and that I did not allow any other person to use, have, borrow or steal portions of my report. 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].
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 — real or artificial — and that I did not allow any other person to use, have, borrow or steal portions of my report. 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!
You need access to a computing environment in which to write your code; — you may want to use any combination of Matlab (for quick prototyping and short homework assignments) and other languages; e.g. Python, C/C++ or Fortran (or something completely different, like Java or M$\text{-D}$.)

Free C/C++ and Fortran compilers are available for Linux/UNIX.

SDSU students can download a copy of matlab from


[LICENSING SUBJECT TO CHANGE WITH MINIMAL NOTICE]
**Prerequisite:** Math 340

340 $\Rightarrow$ **Programming in Mathematics**
- Introduction to programming in mathematics. Modelling, problem solving, visualization..

**Prerequisite:** Math 254 or Math 342A or AE 280

254 $\cap$ 342A $\cap$ AE 280 $\Rightarrow$ **Basic Linear Algebra**
- Vectors, Matrices, Eigenvalues and Eigenvectors

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

$$\tilde{x} = A^{-1}\tilde{b}, \quad \text{where} \ A \in \mathbb{R}^{n \times n}, \ \tilde{x}, \tilde{b} \in \mathbb{R}^n$$

in infinite precision (by hand), 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 — Why???

The computational complexity (number of operations needed) for Gaussian Elimination is $O(n^3)$, which is quite slow as $n$ grows “large.”

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.
- Data Science, Machine Learning, AI, etc...
Math 543: Introduction — What We Will Discuss

\[ A\tilde{x} = \tilde{b}, \quad A\tilde{x} = \lambda\tilde{x}, \quad Q^T AQ = \Lambda = \text{diag}(\lambda_1, \lambda_2, \ldots, \lambda_n), \quad A = U\Sigma V^* \]

- QR-Factorization / Least Squares
- The Singular Value Decomposition
- Conditioning and Stability
- Gaussian Elimination, Pivoting
  \[ \Rightarrow \] LU- and Cholesky-factorization
- Eigenvalue Problems
- Iterative Methods
  \[ \Rightarrow \] Arnoldi, GMRES, Lanczos, Conjugate Gradients