18-647

Computational Problem Solving for Engineers

Course Mechanics

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Instructor

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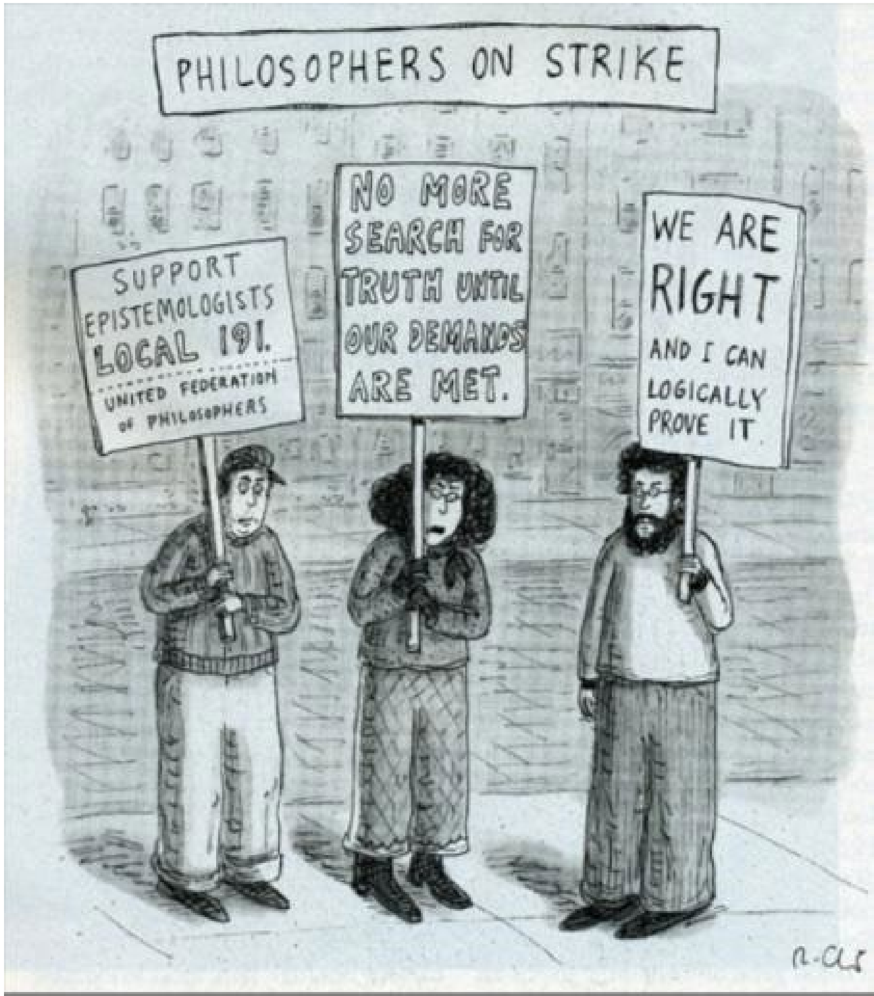
Teaching Assistant

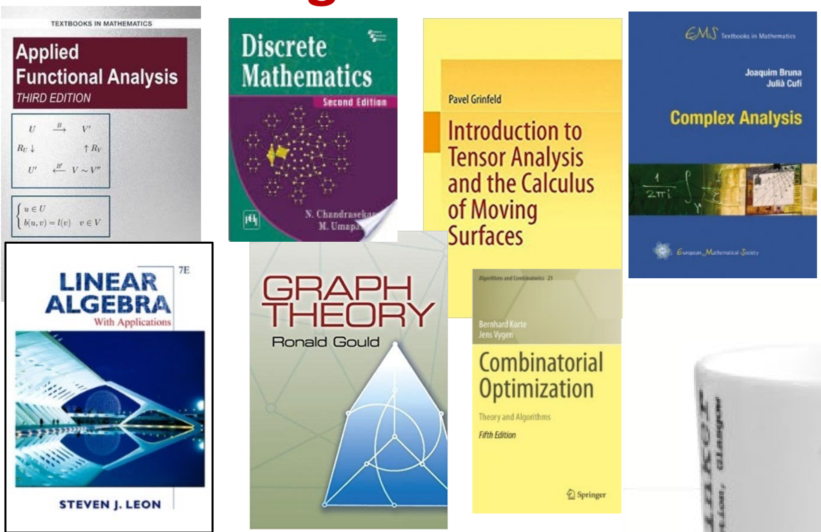
Course Philosophy

- **Learn how to solve real engineering problems including AI/ML with large(r) computers**
- **Your productivity is key: shortest time to solution**
- **Learn how to scale from laptop to large machines and the cloud productively**
- **No need to become a performance engineer, but know your computer stuff**



18-647: 10,000 Foot View

Scalable Algorithms



Larger-Scale Hardware

Languages and Libraries

C++
Intel Math Kernel Library
LAPACK Users' Guide
nag
FFTW
cuBLAS
OpenACC Directives for Accelerators
OpenMP
IMSL
RogueWave SOFTWARE
SuiteSparse: GraphBLAS
Graph algorithms in the language of linear algebra

Performance vs. Productivity

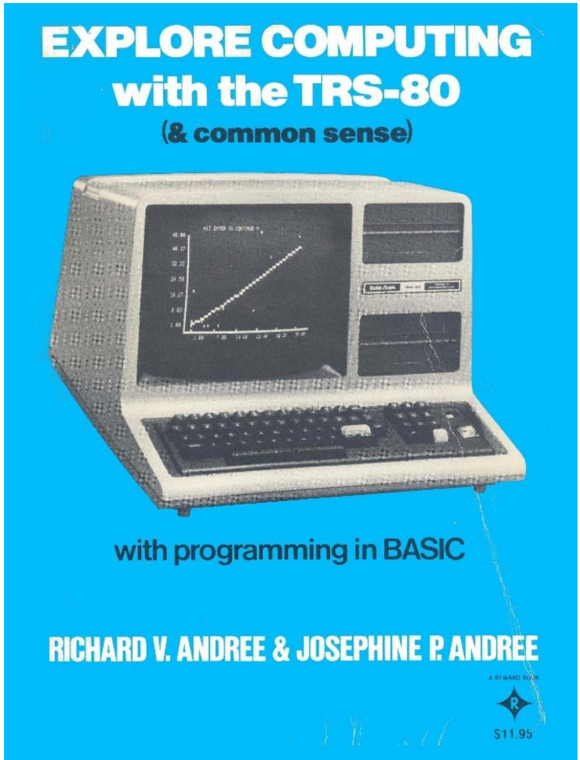
TensorFlow
NumPy
python
SciPy
PyTorch
Wolfram Mathematica
MATLAB
SWI Prolog

Course Mechanics

- **Lectures:** 80 minutes, Tues/Thurs 9:30am – 10:50am
- **Recitation:** 50 minutes, Fri 10:00am – 10:50am
- **Homeworks:** Solve 5 smaller homeworks that give a tour through the cross-section of the course material
- **Blog post:** Pick interesting result from the homeworks and write a blog post explaining what you learned

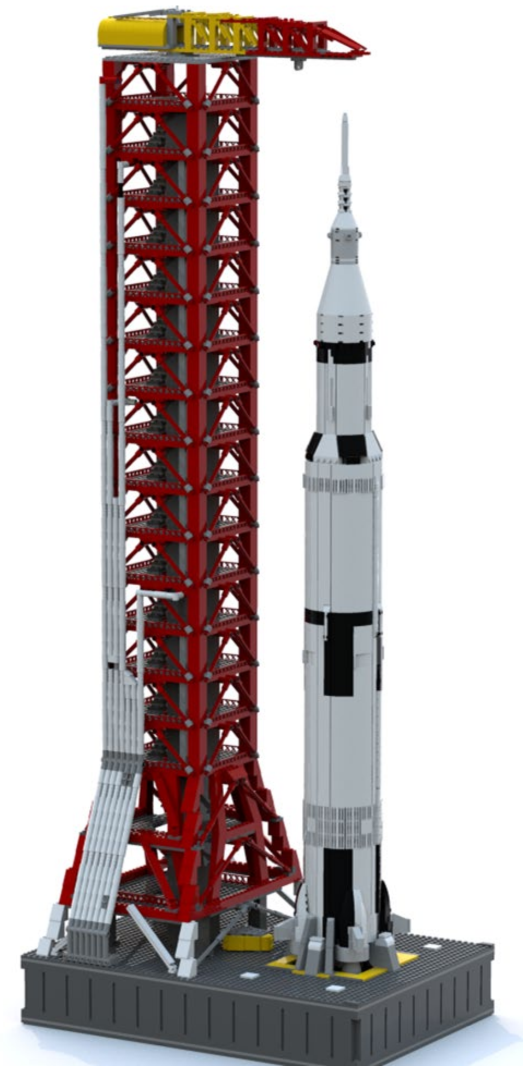
5 Homeworks: Explore Computing

- **Deeper-dive into algorithm families**
  Algorithms underlying CSE, AI and ML
- **Explore performance vs. productivity**
  High level/scripting vs. high performance languages
- **Explore range of computer systems**
  Linux servers, cloud, HPC, high throughput
- **High productivity through specialization**
  Frameworks and problem solving environments
- **Assess how good is your solution**
  Profiling, timing, modeling, assessing results



Blog Post: For An Interesting HW Problem

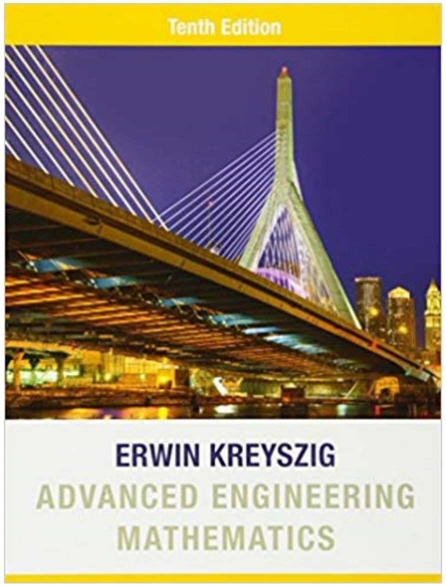
- Problem specification
- Algorithm
- Hardware and software
- Outcome
- Scalability and complexity
- Quality of the result
- Performance analysis

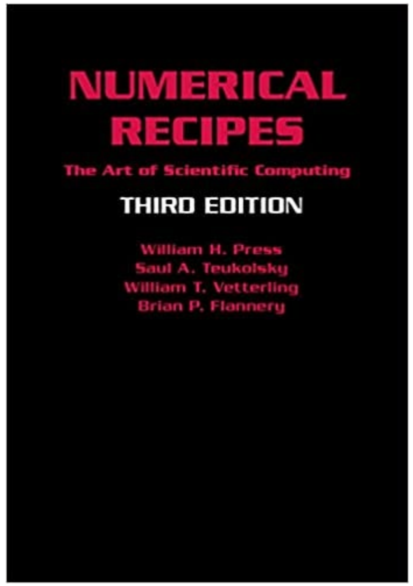


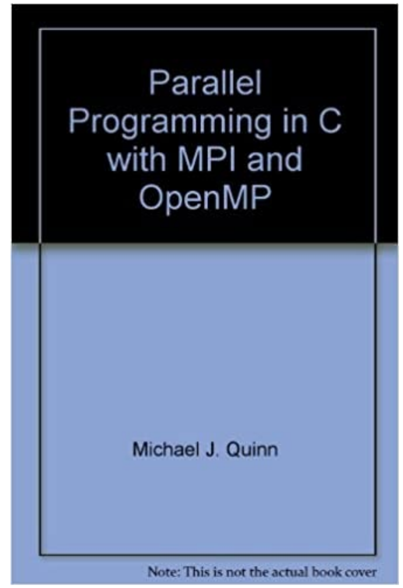
Grading

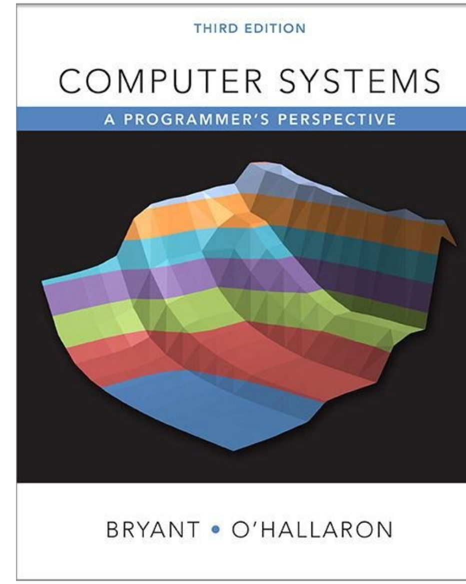
- In-class participation: 20%
- Blog post: 20%
- 5 Homeworks: 60%

18-647 Additional Material









Advanced Engineering Mathematics, 10th Edition
Edward J. Norminton, Herbert Kreyszig, Erwin Kreyszig

Computer Systems: A Programmer's Perspective, Third Edition
Randal E. Bryant and David R. O'Hallaron, Carnegie Mellon University

Numerical Recipes: The Art of Scientific Computing
William H. Press, Saul A. Teukolsky, William T. Vetterling and Brian P. Flannery

Parallel Programming In C with MPI and OpenMP
Michael Quinn

There is no course text book but these books cover the space

Tentative Schedule (Guest Lectures may move)

Dates	Topic
January 16	**State of computing:** What is the current state of the art from embedded devices through desktops, servers, and consumer system all the way to cloud, HPC, and supercomputing
January 18	**Computer architecture:** Relevant computer architecture concepts
January 23	**Software stack:** ISA, operating system, virtualization, messaging, containers
January 25	**Mathematics for Engineers:** The central role of numerical linear algebra
January 30	**The ECE Computing Environment:** number cluster, Andrew systems, capability machines, GPU access, cloud access, Pittsburgh Supercomputing Center and XSEDE
February 1	**Algorithm analysis, scalability, complexity:** Getting answers in time
February 6	**Guest Lecture:** Quantum Computing and Quantum Algorithms
February 8	**Parallelization:** Sequential vs. parallel algorithms, scalability vs. performance
February 13	**Need for speed:** Principles of code optimization, when and how to optimize code
February 15	**Cloud computing and HPC:** Amazon EC2/Windows Azure/Google Cloud, Computational Grids, Scientific Workflows, Computing Centers
February 20	**Numerical Analysis:** How good are your answers? How to make them better?
February 22	**Scalable algorithms:** Dense numerical linear algebra, CNNs/DNNs, FFTs

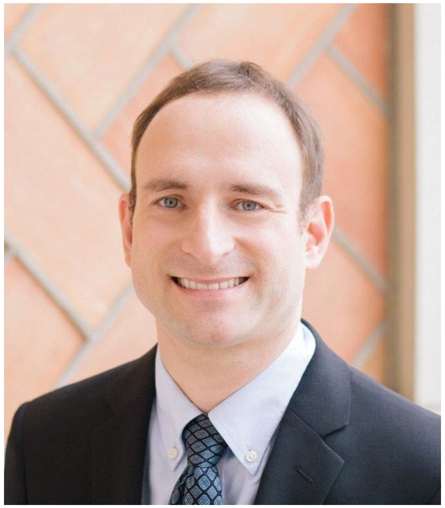
Schedule (Cont'd)

Dates	Topic
February 27	**Scalable algorithms:** Graph algorithms and sparse numerical linear algebra
February 29	**Scalable algorithms:** ODE and PDE solvers, stencils, filters, discretization
March 12	**Scalable algorithms:** Discrete and continuous optimization, ML training
March 14	**Scalable algorithms:** Informatics, symbolic computing, higher level AI
March 19	**Scalable algorithms:** Statistics: Monte Carlo, MCMC, statistical ML
March 21	**Data:** Obtaining real data sets, data visualization, data bases, data stores, file systems
March 26	**Modern CPUs I:** Super-Scalar Out-of-order, multicore
March 28	**Modern CPUs II:** vector extensions
April 2	**Hardware Acceleration:** GPUs, FPGAs, TPU, Tensor Cores,...
April 4	**From productivity to performance:** C++, OpenMP, MPI, CUDA, Autotuning
April 9	**Guest Lecture:** Software Engineering vs. Performance Engineering
April 16	**Guest Lecture:** Pittsburgh Supercomputing Center and Usable HPC and High Performance AI/ML
April 18	**Research Talk:** SPIRAL: Formal Software Synthesis of Computational Kernels
April 23	**Student Blog Presentations and Homework Lessons Learned**
April 25	**Summary and Beyond**

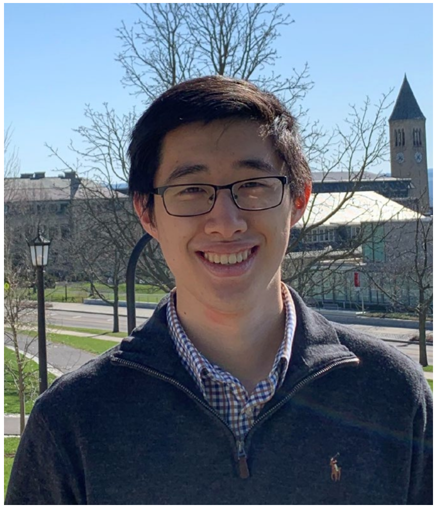
Homework and Blog Post Schedule

Dates	Topic
January 25	**Release homework 1**
February 6	**Homework 1 due, release homework 2**
February 20	**Homework 2 due, release homework 3**
March 14	**Homework 3 due, release homework 4**
April 2	**Homework 4 due, release homework 5**
April 18	**Homework 5 due**
April 23	**In class: Blog Presentations and Homework Lessons Learned**
April 25	**Blog post due**

Teaching Staff



Instructor
Franz Franchetti
Office Hours: Mon 2pm—3pm
HH A312
http://www.ece.cmu.edu/~franzf



Teaching Assistant
Eric Tang
Office Hours: TBD

Canvas:
https://canvas.cmu.edu/courses/39200

TAs, Recitation, and Office Hours

- TAs are mentors for your blog post and give advise regarding homeworks and system issues
- Weekly recitation to help with homework issues that may be prevalent across entire class
- Weekly faculty office hours to discuss homeworks and general course related topics
- Faculty and TA one-on-ones if needed, schedule via email


Other Logistics

- **ECE IT Helpdesk**
  email: help@ece.cmu.edu

- **ECE Course Support: HH 1113**
  email: ece-asc@andrew.cmu.edu

- **Accounts: ACCESS, ECE, Amazon EC2,…**

- **Software access/licenses**

- **ECE ITS and Pittsburgh Supercomputing Center (PSC)**

Enjoy