Computational Modeling in Engineering and the Sciences

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Description

In this beginner-friendly group, we will broadly explore the field of computational modeling: the kind of work done at the Oden Institute (https://oden.utexas.edu). We will practice both reading papers and coding simple projects. Each meeting will consist of a discussion, lecture, and self-guided coding demo. Relevant literature will be assigned for reading between each session.

We will start with learning how to build and solve ordinary differential equations, then partial differential equations. Emphasis will be on applications in storm surge modeling, my area of research, but other groups and topics will be considered on the way. The semester will culminate in a mini-project solving the nonlinear Shallow Water Equations.

Goals

- **Learn about computational modeling.** We will explore at the surface level common modeling techniques and solution schemes used by engineers and scientists to model real-world problems.
- **Explore research and academia.** We will explore the work at the Oden Institute and resources available to students like the Texas Advanced Computing Center (https://tacc.utexas.edu).
- **Mentorship.** I am happy to be a resource for anyone interested in research and academia, whether that means an undergraduate job for a couple of semesters, or aspirations for professorships and tenure.
- **Build up math and coding skills.** Although participants are not expected to pursue hydraulics or even computational science, the techniques covered are broadly applicable. They should be useful exposure for any engineer, mathematician, or computer scientist.
  - Math skills: ODEs, PDEs, numerical solution techniques
  - Programming skills: Python, Jupyter, Conda, NumPy, control sequences, data structures, vectorization, visualization, file I/O
- **"Leave things better than we found them."** If anything, this is a chance to try new things, discover your interests, and grow as a person.

Prerequisites

- Required
  - Programming fundamentals
  - Calculus

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  - Understanding of basic matrix operations
  - Willingness to learn new things
- Recommended
  - Python
  - Vector calculus
  - Linear algebra
  - Differential equations
  - Interest in domain outside of computer science, e.g. physics

Format

This group is intended to be a hybrid between a reading group and a project group. This means students can get light exposure to the world of research, but still apply concepts and gain practical skills. The exact format will be adjusted based on mentee needs.

- **Readings.** Expect to spend half an hour every week on a reading assignment. It is fine to not understand everything, just focus on overarching ideas. Research literature often requires high-level knowledge, so I may also assign non-technical news articles.
- **Discussions.** At the start of each meeting, everyone will share their main takeaways. I might prompt a question or two.
- **Lectures.** Sufficient mathematical content from high-level undergraduate classses will be covered to inform coding demos and mini-projects.
- **Demos.** Jupyter notebooks and Python skeletons will be provided to build simple models and simulations.

Schedule

A tentative schedule is provided below, subject to change based on need and mentee feedback. Fewer sessions than weeks are scheduled in anticipation of conflicts and end-of-semester chaos.

	Date	Reading	Lecture	Demo
1		N/A	Overview of DiRP	Setup of Python, conda, Jupyter, NumPy
2		Konstantinovsky - Mastering the SEIR Model	Scalar ODEs, integration techniques, error analysis	1D ODEs, error analysis
3		Baigent - Lotke-Volterra Dynamics (Chapter 1)	General ODEs and examples	SEIR and population dynamics
4		Jah - Multiple-Opject Space Surveilance	Formulating n-body problem	Astrodynamics
5		[TBD: Something HPC?]	HPC and TACC	TACC "tour"
6		[TBD: Something quantum, oncology, cardiology?]	PDEs and solution techniques	Scalar advection equation
7		Dawson - hp DG for Advection	Transport equations	Fun PDEs I
8		Dawson - DG for Storm Surge	Computational hydraulics and Shallow Water Equations	Fun PDEs II
9		Pachev - ADCIRC NN	Constructing a simulation	SWE I
10		Cerrone - ADCIRC Transformer	Postprocessing	SWE II