Fundamentals of Computational Biomedical Engineering: 42-675

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Term: Fall 2025

1 Meeting Times

Lecture: Mondays/Wednesdays, 12:30 - 1:50 PM (Wean Hall 5421)

Office Hours (Instructor): Tuesday, 8:30 - 9:30 AM (Scott Hall, 4N300A) and Thursday, 3:00 - 4:00 PM (Scott Hall, 4N300A)

Office Hours (TA): TBA

2 Course Description

The primary objective of the course is to explore coding for biomedical computing. It is intended for students without a strong background in coding to serve as a bridge to more advanced modeling and computing courses. This course will enable students to use computational tools for solving biomedical engineering problems, in preparation for other graduate courses and for their future career. Students will gain solid skills in programming MATLAB and Simulink to organize, analyze, model, and visualize biomedical problems. Areas to cover include linear algebra and principal component analysis, non-linear equations, calculus, ordinary differential equations, and machine learning, with examples drawn from cancer diagnosis, glucose monitoring, immunotherapy, bioelectrical activities, cardiac simulation, kidney dialysis, and infectious disease modeling, etc. The course will end by transitioning to Python programming, taking advantage of the similarities between Python and MATLAB.

3 Learning Objectives

At the conclusion of this class, you should be able to:

- Identify basic concepts related to computing and coding

- Understand how biomedical engineers utilize numerical tools to address real world problems.
- Use MATLAB as a computing tool, through data in/output, data organization, data analysis and visualization, and implementation of functions.
- Understand differences in MATLAB and Python and feel comfortable in identifying key features of coding languages.
- Recall concepts and applications of linear algebra, nonlinear equations, and differential equations.
- Gain a basic understanding of of machine learning and its implementation.
- Understand how computer models of physiological systems and medical conditions are built.
- Understanding the limitations of computation and potential sources of error.

4 Pre-requisites

There are no formal pre-reqs for this course. A general understanding of concepts from calculus, such as derivatives and integration, is assumed.

5 Course Website

We will use Canvas as our website for the course. All materials (syllabus, lecture notes, reading materials, homework assignments, etc) will be posted. Homeworks will also be turned in and graded using Gradescope there.

6 Communication

I will make regular announcements through Canvas about availability of class materials, modifications to assignments, clarifications from class notes, materials to supplement class discussion, etc. To reach me, you are welcome to email me (jszafron@andrew.cmu.edu) for a response within a few days. For more urgent requests, there is a course Slack where you can message me directly and ask general questions in the shared channel.

7 Grading

Grades for the course are weighted by:

- **Attendance/Quizzes - 20%**
- **Homework Assignments - 25%**

- **Programming Assignments - 20%**
- **Mid-term - 10%**
- **Final Project - 25%**

Grade ranges: A (93-100%), A- (90-93%), B+ (86-90%), B (83-86%), B- (80-83%), C+ (76-80%) , C (73-76%), C- (70-73%), D+ (66-70), D (63-66%), D- (60-63%).

The average for the class will be curved up to 85% (B), if needed. Requests for re-grades should be accompanied by a written statement with detailed technical justifications for why the answer was mistakenly marked incorrect or incomplete and must come within 1 week of the assignment being returned. No re-grades will be allowed for the Final Project.

8 Course Materials

Our primary resource will be the online exercises offered by Mathworks (`https://matlabacademy.mathworks.com/`). As part of your homework assignments, you will work through selected modules and include a copy of the certificate. Lectures will be a mix of slides and programming activities.

Focusing on the class will enhance your learning and that of your peers. Please close all applications that are not actively being used for note taking or problem solving.

9 Homework

Homework assignments are generally given on Wednesdays and due 1 week later. They will include a combination of written questions and coding problems for numerical solution of more complex equations. **HW assignments should be turned in as a PDF before midnight (11:59:59 PM ET) the day they are due.**

For coding questions, output plots as well as source code should be provided. Ensure that you include comments so that the graders can understand your thought processes, use short but descriptive variable names, and generate neat, readable plots.

For late homeworks, you will be allowed a grace period of **3 days for 2 homework assignments** with no consequence. Otherwise, late homeworks (those turned in after 11:59 PM on the due date) will lose 15% points per day. Please talk to me if you have an illness or family issue that delay your ability to do the work.

10 Exams

Both exams are take-home and not cumulative. Exam 1 will cover classes 1-9 and HWs 1-4 (more fluids), and exam 2 will cover classes 15-22 and HWs 6-8 (more solids). Knowing how to do the homework questions and in class examples will prepare you for answering the questions on the exam.

11 Project

We will spend the last week of class working on a computational modeling project. You will choose an application of interest and develop a modeling framework for that problem. Grades for the project will be based on the presentation and a report (∼1000 words and 2 Figures) detailing your approach. Presentations will be during the final exam period and reports are due by midnight on Dec 14th.

12 Class Environment

This class will have an open and welcoming environment for all participants. Treat other members of the class, myself, and the teaching assistants with respect in every interaction. Engaging with diverse identities is critical to ensure we close longstanding gaps in both research and healthcare. If issues arise with unfair or hostile treatment, they can be discussed with me or shared with the following resources:

Center for Student Diversity and Inclusion: csdi@andrew.cmu.edu, (412) 268-2150
Ethics Reporting Hotline. Students, faculty, and staff can anonymously file a report by calling 844-587-0793 or visiting cmu.ethicspoint.com.

13 Accommodations

If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at access@andrew.cmu.edu.

14 Attendance

Attendance is not required. However, there are periodic in-class assignments that contribute to 10% of your grade, as explained above. I highly recommend coming to all classes, unless you are ill or have a family emergency (unavoidable reasons). If you miss class, you are welcome to come to office hours to go over the lecture notes or schedule another time to meet with me individually.

15 Academic Integrity

For a clear description of what counts as plagiarism, cheating, and\or the use of unauthorized sources and tools, please see the University's Policy on Academic Integrity (revised in April 2013): `https://www.cmu.edu/policies/student-and-student-life/academic-integrity.html`

There are a couple caveats to this for our class. For homeworks, you are welcome to talk to your classmates and get help from them if you are stuck, but you must write your own answers and code. For example, it is cheating to directly copy another student's code and then change the variable names. It is not cheating for them to explain the general steps they took, show you useful information from their notes, or to help you debug after you've written your own code. Projects are individual assignments and are graded on the presentation and report. However, you may assist each other with technical aspects of modeling for the project.

The use of generative AI is prohibited in this class for any material that is turned in, unless explicitly allowed. Therefore, you can use it to brainstorm project ideas, create outlines, and plan algorithms, but all things that are graded should be generated by you.

16 Class Recording

I will record audio from class and post to Canvas after lecture, usually within 1 day. I may post extended derivations of equations for use in the homework assignments.

17 Well-being

Your health is important, and I encourage you to take the time to maintain your health. Talk to me if stress from this course, or from events in your life, is overwhelming you. There are resources on campus that can help with mental health: `http://www.cmu.edu/counseling/`. Support is also always available (24/7) from Counseling and Psychological Services: 412-268-2922.

Part of maintaining health is eating well. If you are worried about affording food or feeling insecure about food, there are resources on campus that can help. Any undergraduate or graduate student can visit the CMU Pantry and receive food for free. Follow the directions on the CMU Pantry website to schedule your visit: `https://www.cmu.edu/student-affairs/resources/cmu-pantry/`

18 Course Schedule

Date	Topic	Assigned/Due
1: Aug 25	Class Intro, Getting started w/ MATLAB, Computer architecture basics	HW1
2: Aug 27	Plotting, data arrays	
3: Sep 3	Array operations, data visualation, conditional data selection	HW1 due, HW2
4: Sep 8	Data organization, tables	
5: Sep 10	Data pre-processing and analysis, program constructs	HW2 due, HW3
6: Sep 15	Functions, program debugging	PA1
7: Sep 17	Datastores, data groups	HW3 due, HW4
8: Sep 22	2D and 3D data graphics	
9: Sep 24	Histograms, Curve Fitting, Interpolation	HW4 due, HW5
10: Sep 29	Nonlinear equations, systems of nonlinear equations	
11: Oct 1	Linear equations, linear transformations, eigenvalues/eigenvectors	HW5 due, HW6
12: Oct 6	Singular value decomposition, principal component analysis	
13: Oct 8	Principal component analysis	HW6 due, HW7
Oct 13	(-)	(-)
Oct 15	(-)	(-)
14: Oct 20	Ordinary differential equations	
15: Oct 22	Midterm Exam	HW7 due, PA1 due, HW 8
16: Oct 27	Exam review, systems of ODEs	
17: Oct 29	Higher order ODEs	HW8 due, HW9
18: Nov 3	Simulink	
19: Nov 5	Overview of AI/traditional machine learning	HW9 due, HW10
20: Nov 10	Deep learning	
21: Nov 12	Transition to Python	HW10 due, HW11, PA2
22: Nov 17	Python Programming	
23: Nov 19	Python Programming	HW11 due, HW12
24: Nov 24	Python Programming	
25: Dec 1	Work on projects	
26: Dec 3	Work on projects	HW12 due, PA2 due
27: Dec XXX	Project presentations (during final exam)	