JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Hopkins Engineering Applications & Research Tutorials EN.500.111
Mathematical Cardiology: Modeling, Simulation & Artificial Intelligence - Fall, 2023

Course Title
Mathematical Cardiology: Modeling, Simulation and Artificial Intelligence

Instructor Information
Zan Ahmad
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Office: Wyman Park Building S413 and Hackerman Hall 219
Office hours: TBD, and by appointment.

Meetings
Monday, 04:30 – 05:45pm, Bloomberg 176
Wednesday, 04:30 – 05:45pm, Hodson 303.

28 August 2023 – 10 November 2023.

Description
In cardiovascular engineering / computational cardiology, having a strong intuition of the underlying mathematical and physiological concepts is crucial for making advancements in research. This course will introduce students to the basics of mathematical modeling and computer simulations for describing physical processes and provide a high-level understanding of how these tools can be leveraged for understanding the heart and treating adverse cardiac events. Additionally, machine learning (ML) and its applications in cardiovascular medicine will be approached with the intention of demystifying what goes into the "black box". The beginning of the course will explain the importance and history of the field. The first half of most lectures will provide a general overview of physiological processes and relevant modeling techniques to simulate them. In the second half, the instructor will provide students with sample code which can be easily modified to simulate and graphically visualize results. In-class coding workshops and demonstrations will provide students with a hands-on learning opportunity to interact with the visual graphics produced by the mathematical descriptions and formalisms discussed in the lecture component.

Course Topics
- What is "mathematical cardiology"? Resources for learning MATLAB, GitHub, LaTeX, Python
- Numerical methods for blood flow modeling (0D, 1D, and 3D models: the pros and cons of each).
- Cardiovascular mechanics and the mathematics of muscle dynamics.
- Cardiac electrophysiology: simulating action potential propagation with 3D visual graphics
- Modeling congenital heart defects: single ventricle disorders, pulmonary hypertension, etc.
- Feedback control: circulation during dynamic maneuvers (i.e., exercise, hypergravity, etc.)
- The fetal heart circulation
- Basics of ML and the Integration of Data for Model Calibrations and Development
- Patient-Specific Modeling: 3D Computational Fluid Dynamics (CFD) on Image Data
- Machine Learning based Image Analysis (e.g., Convolutional Neural Networks)

Textbook
The following textbook is freely available to you as a reference to help develop your projects:

- Charles S. Peskin, Frank C. Hoppensteadt, *Modeling and Simulation in Medicine and Life Sciences*, Second Edition, Springer Link, (2002). Textbook-PDF

Course Expectations
Lectures will be held weekly for 10 weeks during the semester. Attendance to lectures is mandatory and active class participation is highly encouraged. There will be frequent coding workshops to engage with the course material. Final projects may develop into research projects continued with the instructor's advisement after the course ends.

Course Objectives
Throughout the duration of the course, students will learn to conduct literature review, formulate their own ideas, and execute a small research project of their choice over the semester. They will also learn about common challenges in the field related to clinical translation and strategies to overcome said challenges. It is intended that students learn real-world problem-solving skills which they can generalize and apply to their own educational, professional or research career. The concepts that are presented in this course are accessible to a student population of varying backgrounds, lectures will be brief and serve as grounds for more advanced investigations depending on interest. The mathematical and biological prerequisite knowledge required is that of a typical high school curriculum and any advanced concepts will be developed or reviewed during the course. Each of the ten course topics has a research project associated with it that interested students can work on. More on that on the first day.

Ethics
The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition. Report any violations you witness to the instructor. You can find more information about university misconduct policies on the web at these sites: e-catalog.jhu.edu/undergrad-students/student-life-policies/

Students with Disabilities
Any student with a disability who may need accommodations in this class must obtain an accommodation letter from Student Disability Services, 385 Garland, (410) 516–4720, studentdisabilityservices@jhu.edu.