JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Hopkins Engineering Research-Opened Investigation Course EN.500.111
Advanced Topics in Computational Cardiology: 3D Heart Modeling, Shape Analysis and AI - Fall 2024

Course Title
Advanced Topics in Computational Cardiology: 3D Heart Modeling, Shape Analysis and AI

Instructor Information
Zan Ahmad
zahmad6@jhu.edu
Office: Wyman Park Building S413 and Hackerman Hall 219
Office hours: TBD, and by appointment.

Meetings
Monday, Wednesday 04:30 – 05:45pm.
Location: Kroft Hall B32 26 August 2024 – 6 November 2024.

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 state-of-the-art research in mathematical modeling, computer simulations, and machine learning for studying the cardiovascular system and provide a high-level understanding of how these tools can be leveraged for understanding the heart and treating adverse cardiac events. Each week will have a lecture component and a computer workshop component where students can engage with the material learned in lecture. For the computer workshops, the instructor will provide the sample code and sample data (deanonymized and approved for educational purposes). This will allow for students to interact with models, modify them to conduct experiments and visualize their results on real patient anatomies. Lecture content will be directly related to the ongoing research in the Trayanova Computational Cardiology Lab.

Course Topics
- Introduction to Cardiovascular Modeling
- Hemodynamic Modeling: 0D, 1D, 3D Cardiac Fluid Dynamics Simulations
- Cardiac Electrophysiology Modeling and Simulation
- Machine Learning for Medical Data
- Anatomical Shape Analysis
- Neural Operators for Learning Large-Scale PDEs

Prerequisites or Taking Simultaneously:
- Multivariable Calculus OR Differential Equations OR Linear Algebra OR Computational Medicine: Cardiology OR Numerical Analysis
- Some basic programming experience (Introductory Python, MATLAB, etc.)
- Knowledge in one or more of the following areas: Probability Theory, Mathematical Statistics, Machine Learning/AI, Real Analysis, Functional Analysis

These prerequisites are not strict, and if you are unsure about whether you meet the prerequisites for the class, you are encouraged to reach out to the me to discuss. Most of the mathematical and computational principles will be developed either in the course or through assigned readings. There are no biological prerequisites for the same reasons.

Textbook
No textbook is required for the class. Useful references to papers and books will be added to the course Canvas page.

Course Expectations

- This course is recommended for engineering and mathematics focused students with an interest in learning about the applications of their knowledge in cardiovascular medicine, and for premedical, biomedical engineering or life science students with sufficient mathematical background who wish to gain detailed intuition for how computational tools can improve patient outcomes in cardiology and further our physiological understanding.
- Lectures will be held twice a week (Mondays and Wednesdays) for 10 weeks during the semester. There will be no quizzes or exams. Attendance to lectures is mandatory and active class participation is highly encouraged. There will be frequent coding workshops to engage with the course material.

Assignments & Grading
The class is graded on a letter grade basis unless otherwise specified by the student when registering. Short problem sets and coding assignments will be due every two weeks (4-5 total). Your cumulative grade will be based on your effort on these assignments. Assignments may include assigned paper readings and presentations. There will be no exam and there will be a final project for extra credit.

Course Objectives Throughout the duration of the course, students will learn to conduct literature review, formulate their own ideas, and learn important tools that are useful in the Computational Cardiology research field. They will also learn about common challenges related to methodology development and clinical translation along with 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 advanced but focused on big-picture concepts regarding how to formulate complete research ideas to answer important mathematical, biological and clinical questions. The course has a flexible list of prerequisites because I will attempt to develop the required mathematical and biological concepts as needed.

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.