Computational Modeling of Physiological Systems
BMEN 601

Spring 2021

Course Description (3 credits):

This course introduces students to the fundamental principles underlying computational modeling of complex physiological systems. A major focus of the course will be on the process by which a model of a biological system is developed. Students will be introduced to the mathematical methods required for the modeling of complex systems as well as to tools for computational simulation. Roughly one half of the material will introduce the physiological system under study and the second half will focus on models for the general cellular physiology and the development of higher-level models of a particular physiological system.

Professor: Dr. Arij Daou

Lecture: TR 2:00 – 3:15 pm
Virtual office hours: TWR 11:00 – 12:00, or by appointment
Virtual office: https://aub.webex.com/meet/ad75
Office: Raymond Ghosn Building, RGB 405 – Extension: 3412
Email: arij.daou@aub.edu.lb

Prerequisites: Math 201 – Math 202

Textbook(s) and/or required materials
Textbook: Notes provided by instructor

References

1- Introduction to Modeling in Physiology and Medicine, by *Claudio Cobelli* and *Ewart Carson* (ISBN: 978-0-12-160240-6)
2- Nonlinear Dynamics And Chaos: With Applications To Physics, Biology, Chemistry, And Engineering, by *Steven Strogatz* (ISBN: 978-0738204536)
3- Mathematical Modeling in Systems Biology, by *Brian Ingalls* (ISBN: p780262315623)
4- Physiology, by *Linda Costanzo* (ISBN: 9781455708475)

Course Objectives

- Build on a basic understanding of physiology to develop a more in depth level of understanding that will enable engineering analysis of selected physiological systems: (1) nervous system, (2) cardiovascular system, (3) pulmonary gas transport system, (4) action potential generating system in excitable cells.
- Be able to translate the understanding of physiological function into an engineering model based on block-diagram analysis of a dynamic system whose function is based on a differential equation.
- Be able to apply engineering models of physiological systems to answer questions relevant to the design of biomedical engineering devices or processes.
- Be able to break down a complex physiological system into the function of its component subsystems, and then build an engineering model based on subsystems.
- Be able to apply basic principles of steady-state and dynamic negative feedback control to physiological systems.
- Be able to recognize the difference between the roles of variables and parameters in a model.

Course Topics

A- Introduction

- Introduction to Modeling in Physiology
- Overview of Differential Equations in Physiological Systems
- Nonlinear Dynamics and Bifurcation Theory

B- Cellular Physiology

- Biochemical Reactions (Thermodynamics, enzyme kinetics, glycolytic oscillations).
- Cellular Homeostasis (Cell membrane, diffusion, active transport, osmosis).
- Electrophysiology: The Hodgkin-Huxley Model and Excitability.
- Wave Propagation in Excitable Systems: Calcium Dynamics.

C- Systems Physiology (selected topics)

- The Circulatory System (Blood flow, cardiac output, circulation, arterial pulse).
- The Heart (ECG, cardiac cells, cellular coupling, cardiac arrhythmias).
- Blood (Plasma, blood cell production, erythrocytes, clotting).
- Respiration (Capillary-alveoli gas exchange, ventilation, perfusion).
- Muscle (Hill model, smooth muscle, molecular motors).
- The Endocrine System (Pituitary gland, ovulation, insulin and glucose).
- The Retina and Vision (Light adaptation, photoreceptor physiology, light reflex).
- The Inner Ear (Frequency tuning, models of the cochlea, resonance in hair cells).

Software
MATLAB/Python, but you can code with your preferred programming language.

Evaluation methods

1- Assignments (30%)
2- Two Quizzes (40%)
3- Final Exam (30%)

AUB strives to make learning experiences accessible for all. If you anticipate or experience academic barriers due to a disability (such as ADHD, learning difficulties, mental health conditions, chronic or temporary medical conditions), please do not hesitate to inform the Accessible Education Office. In order to ensure that you receive the support you need and to facilitate a smooth accommodations process, you must register with the Accessible Education Office (AEO) as soon as possible: accessibility@aub.edu.lb; +961-1-350000, extension 3246; West Hall 314.

You are encouraged to make use of the Interdisciplinary Design Practice Program at MSFEA. IDPP can help students develop stronger course projects through brainstorming ideas for projects, experimenting with low-resolution prototyping to turn ideas into reality, brushing up presentation skills, and developing real-world, human-centered perspectives of course outcomes. IDPP aims to foster a generation of breakthrough innovators who can take on world challenges. The IDPP team also facilitates design activities for students. They are assisted and empowered to use design methodologies to achieve remarkable outcomes. Students can book one-on-one sessions with Peer Design Advisors by emailing idesign@aub.edu.lb or by visiting the IDPP office (and playground) in Bechtel Design Hall.
Check us out on the AUB website: https://www.aub.edu.lb/msfea/Pages/idpp.aspx