BIEN 223/223V: Engineering Analysis of Physiological Systems
Fall 2016

COURSE OUTLINE

Course Time: Lecture TR 8:10 a.m. - 9:30 a.m. MSE011

Instructor: V. G. J. Rodgers (215 MSE) victor.rodgers@ucr.edu Office Hours: W 1:00-3:00 p.m. and by appointment

TA: Junchao Wang (A120 Bourns Hall) jwang071@ucr.edu Office Hours:TBD

Textbooks: *Systems Biology: Mathematical Modeling and Model Analysis*, Andreas Kremling, Chapman & Hall/CRC Press, ISBN: 978-1-4665-6789-4.

References:

Guyton and Hall Textbook of Medical Physiology, 13e (Guyton Physiology) 13th Edition, John E. Hall, ISBN-13: 978-1455770052.

Process Control. A First Course with MATLAB, P. C. Chau, Cambridge University Press, ISBN: 0-521-00255-9, 2002

Advanced Engineering Mathematics, Alan Jeffrey, Harcourt Academic Press, San Diego, 0-12-382592-X (2002)

Process Dynamics & Control, D.E. Seborg, T. F. Edgar, and D. A. Mellichamp, John Wiley & Sons, Inc., ISBN: 0-471-86389-0

Transport Phenomena in Biological Systems, G. Truskey, F. Yuan, D.F. Katz, Pearson Prentice Hall, New Jersey, 2004, ISBN: 0-13-042204-5

MathWorks Videos and Webinars, www.mathworks.com

Other Material: Class notes; MATLAB and SIMULINK

Topic Description:
It is the goal of this course to provide basic engineering analytical tools for quantifying physiological systems behavior. This is critical in helping to move forward our understanding of biological processes for development of new ways to combat disease and The number of physiological systems is vast and reviewing all of them in detail is not realistic in this short course. Therefore, we will address several keys systems and then use engineering methodology to evaluate the system of interest for solving particular problems. The students will apply these principles to other processes through the quarter-long project.

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The body is an extremely complex system. Any attempt to model the system behavior completely would be a formidable task at best. However, in addressing specific problems in the body, often we can model a portion of the overall system that can provide insight to the solution of our problem. Even though these subsystems remain complex, the appropriate simplification of the process may result in satisfactory results.

To begin such modeling, we usually start with the conservation laws and build a steady-state or transient lumped parameter model. This approach recognizes the limitations of a more detailed analysis but provides the structure for realistic outputs. Overall, these mathematical modeling efforts can lead to systems of equations. For the transient processes, these are systems of ordinary differential equations.

For the dynamic process, the well-developed systems dynamics approach is used. Often, when within a region of validity, linear systems analysis is preferred. This is because the tools in linear systems analysis are well-developed and easy to analyze. This is especially true when the physiological process is controlling process behavior. Thus, classical process identification and control will be used in this course to evaluate physiological systems.

However, regardless of the approach, system validation is paramount for determining whether the model or its parameters have any real meaning.

Since this course will address the analysis of time-dependent (transient) processes and how to control them, both practical and mathematical tools will both be incorporated. The course will begin with developing solutions of time-dependent differential equations for real processes and recognizing particular behavior of real processes. An appreciation of solvable algebraic and differential equations (specifically linear) and development of methods for solving linear ordinary differential equations will also be discussed. In particular the Laplace transform method will be used when necessary. The course will cover aspects in control theory pertaining to model development, analysis of system behavior for identification, feedback, feedforward, cascade and other control schemes, single input/output systems and an introduction to multiple input/multiple output systems. Because this course takes on the content from a number of modeling methods and applies them to physiological systems, a substantial part of the material will be obtained from the class notes.

Prerequisites

A background in engineering analysis would be ideal. In addition, a first course in ordinary differential equations is essential. Finally, since solutions will be obtained using numerical methods, working knowledge of computer manipulation and programming is helpful. However, commercial computing tools such as Matlab will be used extensively in the homework, labs and projects. Therefore, students must obtain a computing account.

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Grading

The grading will consist primarily of two closed-book exams (Confidence Builders), two evaluations of one quarter-long continuous individual projects and homework. The homework will be reviewed with the primary concern being effort and professionalism. Therefore, it is essential to the student that they are responsible for their individual understanding of the problems and their assigned purpose. To this end, I will have an open-door policy for help and support with any aspect of this course. Answers to the homework will be made available through iLearn. No homework will be accepted late. The closed-book exams will be on the fundamentals of systems dynamics and control as applied to physiological systems. The project will be based on a physiological topic where the student (with approval) choices independent topics to solve a particular problem. The topic should be spawned from the textbook but the student is expected to do significant literature reviews to strengthen the project. It is expected that the students will be resourceful with projects using tools outside of those presented in this class if necessary. Written presentations of the results will be an essential parts of the grade.

Tentative Topics

Introduction

- Purpose for Modeling
- Conservation Laws
- Steady-State Analysis
- Dynamic Systems Control Schemes: Feedback, Feedforward & Inferential
- System Identification
- System Validation
- Computational Methods

Some Systems of Interest

- The Cell
- Endocrine System
- Metabolism
- The Circulation
- Arterial Pressure and Control
- Kidney
- Nervous System

Process Dynamics

- Mathematical Modeling
- Linear Systems and Linearization
- Static Analysis of Physiological Systems

Process Control

- Analysis of Transient Linear Control Systems
- Frequency-Domain Analysis of Linear Control Systems
- Stability Analysis
- Identification of Physiological Control Systems

System Validation

- Experimental Design

Parameter Estimation
Model Validation

Exam Schedule and Grading (Tentative):

EXAM	POINT	DATE and TIME
Project Assigned		September 27, 2016
Homework	100	Weekly
1st Project Report	100	October 20, 2016
1st Confidence Builder	200	October 27, 2016
2nd Confidence Builder	300	December 1, 2016
Final Project Report	300	December 8, 2016
TOTAL	**1000**	

Basic Format for Project Reports

The reports should be typed and typically include:

1. Introduction and Purpose
2. Theory
3. Method of Approach
4. Results
5. Discussion and Analysis
6. Conclusions and Recommendations
7. Bibliography
8. Appendices

- Raw Data
- Sample Calculations

Collaboration Policy

Any questions about homework problems or laboratories should be addressed to Professor Rodgers. Discussion of homework problems and laboratories with other students in the class is acceptable but direct copying of complete or part of an assignment is not allowed. Violation of this policy will result in a zero given for the homework set. Cheating on exams may result in an F grade given for the course.