BME 511: Physiological Control Systems

Fall 2022, Units: 4
Lecture: Mon & Wed, 3:30 – 5:20PM, OHE 132 (on-campus); DEN@Viterbi (D2L) (off-campus)
Discussion: Mon, 2 – 2:50PM, OHE 100D (on-campus); DEN@Viterbi (D2L) (off-campus)

Instructor: Dr. Nathan Cho
Office Hours: Tues 9 – 10AM, Wed 1 – 2PM @ BHE B7 or by appointment
Contact Info: chonatha@usc.edu

Teaching Assistant: Tara Cornwell
Office Hours: Thurs 1:30 – 2:30PM @ Zoom (Meeting ID: 92472773334, Passcode: 703630)
Contact Info: tara.cornwell@usc.edu

Course Description
Application of control theory to physiological systems; static and dynamic analysis of closed-loop systems; time domain analysis of linear control identification methods; nonlinear control.

Learning Objectives
(1) Develop simple mathematical models of physiological control systems.
(2) Apply the basic analytical techniques in control theory to determine the dynamic characteristics of linear closed-loop systems.
(3) Implement basic system identification methods to estimate the parameters of models of physiological systems.
(4) Analyze and simulate the dynamics of simple nonlinear oscillators, neuronal models, and closed-loop nonlinear systems with delayed feedback.
(5) Use MATLAB and Simulink software to analyze and simulate models of physiological systems.

Course Outcomes
(1) Describe and apply the basic analytical techniques employed in control theory, systems analysis, and model identification.
(2) Evaluate the quantitative principles underlying the dynamic processes in physiological regulation.
(3) Interpret and critique data from research articles related to physiological control systems.
(4) Collaborate with classmates to communicate important findings from research articles and connect with the principles and techniques learned in class.

Course Preparation
Pre-/Co-Requisites: None
Knowledge of ordinary differentiation equations (ODEs), linear systems, and MATLAB/Simulink programming recommended

Course Notes
Lecture slides are posted on DEN@Viterbi (D2L) **at least 24 hours before each lecture**. All other course materials (syllabus, assignment descriptions, etc.) will also be posted on D2L.

Technological Proficiency and Hardware/Software Required
All students have real-time access to the course lectures (slides and video recordings) through the DEN@Viterbi (D2L) website (https://courses.uscden.net). A key objective of this course is for students to learn how to develop computational models of physiological regulation using MATLAB/Simulink. To accomplish this objective, in addition to material covered in the lectures, hands-on exploration sessions focused on physiological modeling will be held during the latter part of some of the lecture periods. Students are highly recommended to have had previous experience using MATLAB/Simulink, but the Discussion sessions can be used to help those who are not so familiar with MATLAB/Simulink programming. MATLAB/Simulink is available to students from the university without charge:

https://www.mathworks.com/academia/tah-portal/university-of-southern-california-623588.html

Online resources for MATLAB/Simulink include the following sites:

MATLAB tutorials:
1. https://www.mathworks.com/support/learn-with-matlab-tutorials.html
2. https://matlabacademy.mathworks.com/

Simulink tutorials:
1. https://www.mathworks.com/learn/tutorials/simulink-onramp.html
2. https://www.mathworks.com/products/simulink.html?s_tid=hp_products_simulink

In general, the MathWorks website will provide the most helpful information. MATLAB/Simulink tutorials are also available on YouTube for those who find videos more helpful than text.

Recommended Reading and Supplementary Materials
The primary textbook used for this course is:
Khoo: Physiological Control Systems – Analysis, Simulation and Estimation 2nd Ed., Wiley/IEEE Press, 2018 (ISBN: 978-1-119-05533-4).

https://www.amazon.com/gp/product/1119055334/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1

Other useful references include:
Dorf and Bishop: Modern Control Systems, 13th Ed., Pearson Education Pub., 2016.
Lathi and Green: Linear Systems and Signals, 3rd Ed., Oxford University Press, 2017.

Description and Assessment of Assignments
Homework Assignments: Homework assignments will consist of quantitative problems related to the topics covered in the lectures and are aimed at solidifying the students' understanding of the concepts introduced in the lectures. Students are allowed to discuss and work on these assignments in collaboration with their peers. Homework groups can consist of **1 to 3 people**.

Exams: There will be three exams throughout the semester, spaced roughly a month apart. These will be open-book tests consisting of quantitative problems and short essay questions.

Students who are not able to take any of these exams due to medical or other emergency must notify Dr. Cho **BEFORE the exam via email**. Make-up exams may be administered in cases where a valid excuse (e.g., medical/emergency) is given.

Project: To provide a stronger appreciation and hands-on experience of how the concepts and methodologies covered in this course can be applied to solve problems in physiology, students will work on one project. The project may be considered as an additional homework assignment that is more open-ended and requires solutions employing MATLAB/Simulink programming. Submission of the project report will be done through the same groups established for homework assignments.

Presentation: At the end of the semester, students will work in the same groups to present the findings of scientific articles that revolve around various artificial biomedical control systems during regular class time. More details regarding the presentation and rubric will be distributed in a separate document.

Discussion Sessions
A 50-min discussion section is held every week on Monday (except 8/22 & 9/5), led by the TA, to answer questions related to the assigned homework and lecture contents presented the week before. This session is meant to be interactive, and students are encouraged to ask questions that would help enhance their understanding of the class material.

Assignment Submission Policy
Homework assignments, project report, and presentation files are to be submitted via DEN@Viterbi (D2L) **before the indicated due date and time** (stated at the beginning of each assignment). Homework assignments will be accepted late, but **25% of the total possible points will be subtracted every 24 hours (including holidays and weekends)**, starting immediately after the due date and time. Late projects and presentation files will **NOT be accepted**.

Grading Timeline
Homework assignment and exam grades will be posted on DEN@Viterbi (D2L) within **one week of the due date**. Project and presentation grades may take longer than a week, but no longer than two weeks.

Regrade Policy
Regrade requests for homework assignments and exams are due within **one week of the date they are returned to the students**. The regrade request must total at least 10% of the total grade for the assignment. Students must **type a justification for their request and email both the original assignment and justification to Dr. Cho**. For group assignments, all group members must be copied in the email. Each student is limited to **two regrade requests** for any type of assignment throughout the semester. This does not include administrative errors (incorrect point additions, etc.), which should be brought to the attention of the TA immediately for correction without penalty.

Grading Breakdown

Assessment	% of Grade
Homework Assignments (5)	10
Exams (3)	60*
Project	15
Presentation	15
TOTAL	**100**

*Lowest score exam is weighted 15%, the highest 25%, and the intermediate 20%.

Course Grading
Final grades will be determined based on the statistics of the course (mean, median, and standard deviation). Statistics for each assignment will be announced after grading, which will provide students an idea of how they are performing throughout the course. An absolute grading scale is not utilized because final grade distribution varies year-to-year, which makes it difficult to generate a representative grading scale. Final grade distribution from the past year will be shown on the first day of lecture for transparency but may not be the actual distribution of this semester.

Collaboration Policy
Students are expected to work together on homework, project, and presentation assignments **within their groups**. Although different group members may help each other, any identical (or nearly identical) assignments will be given zero points. Students may not work together for exams. Plagiarism or other forms of academic misconduct will result in a zero grade for the assignment/exam and will be reported to USC's Office of Student Judicial Affairs and Community Standards, as detailed at the end of the syllabus.

Communication Policy
If there is a question, students should ask during class time or follow these steps in order: (1) consult the syllabus; (2) ask a classmate; (3) review lecture slides and reading material; (4) ask the TA at office hours; (5) ask the instructor at office hours; (6) email the TA; (7) email the instructor. Emails that require short responses (at the discretion of the instructor or TA) will be answered within 24 hours between 9AM – 5PM on business days. Responses received on weekends or holidays will be delayed to the next business day. Emails that require a long response (at the discretion of the instructor or TA) will not be answered over email. Instead, the student will be directed to office hours.

Attendance Policy
Attendance for presentations and exam periods is mandatory and will only be excused in case of an emergency, at the discretion of the instructor. If students knows in advance that they will be absent on the day of an exam or presentation for an important occasion (at the discretion of the instructor), **notify the instructor as soon as possible or at least two weeks in advance such that arrangements can be made**.

Course Schedule
Lecture Schedule

Date	Topics and Deliverables
8/22 (M)	**Lecture 0: Course Introduction**
8/24 (W)	**Lecture 1: Static Analysis of Closed-Loop Systems Pt. 1** Reading: Khoo, PCS Ch. 3 HW 0 Assigned (Not Graded)
8/29 (M)	**Lecture 2: Static Analysis of Closed-Loop Systems Pt. 2** Reading: Khoo, PCS Ch. 3 HW 1 Assigned (Due Mon, 9/12 @ 12PM)
8/31 (W)	**Lecture 3: Review of Linear Systems** Reading: Khoo, PCS Ch. 1
9/5 (M)	**NO CLASS** (Labor Day)
9/7 (W)	**Lecture 4: Computational Modeling and Simulation Pt. 1** Reading: Khoo, PCS Ch. 4
9/12 (M)	**Lecture 5: Computational Modeling and Simulation Pt. 2** Reading: Khoo, PCS Ch. 4 HW 1 Due @ 12PM HW 2 Assigned (Due Mon, 9/26 @ 12PM)
9/14 (W)	**Lecture 6: Modeling Dynamic Systems Pt. 1** Reading: PCS Ch. 2
9/19 (M)	**Lecture 7: Modeling Dynamic Systems Pt. 2** Reading: Khoo, PCS Ch. 2 HW 3 Assigned (Due Mon, 10/10 @ 12PM)
9/21 (W)	**Lecture 8: Modeling Dynamic Systems Pt. 3** Reading: Khoo, PCS Ch. 2
9/26 (M)	**Review for Exam 1** HW 2 Due @ 12PM
9/28 (W)	**Exam 1**
10/3 (M)	**Lecture 9: Time-Domain Analysis** Reading: Khoo, PCS Ch. 4
10/5 (W)	**Lecture 10: Frequency-Domain Analysis** Reading: Khoo, PCS Ch. 5
10/10 (M)	**Lecture 11: Stability Analysis of Linear Systems Pt. 1** Reading: Khoo, PCS Ch. 6 HW 3 Due @ 12PM Group Presentation Assigned (PPT Due Mon, 11/16 OR Wed, 11/18 @ 2PM)
10/12 (W)	**Lecture 12: Stability Analysis of Linear Systems Pt. 2** Reading: Khoo, PCS Ch. 6 HW 4 Assigned (Due Mon, 10/24 @ 12PM)
10/17 (M)	**Lecture 13: Stability Analysis of Linear Systems Pt. 3** Reading: Khoo, PCS Ch. 6

10/19 (W)	**Lecture 14: Nonlinear Analysis Pt. 1** Reading: Khoo, PCS Ch. 10
10/24 (M)	**Lecture 15: Nonlinear Analysis Pt. 2** Reading: Khoo, PCS Ch. 10 HW 4 Due @ 12PM
10/26 (W)	**Review for Exam 2**
10/31 (M)	**Exam 2**
11/2 (W)	**Lecture 16: System Identification Pt. 1** Reading: Khoo, PCS Ch. 8 HW 5 Assigned (Due Mon, 11/28 @ 12PM)
11/7 (M)	**Lecture 17: System Identification Pt. 2** Reading: Khoo, PCS Ch. 8 Project Assigned (Due Mon, 12/5 @ 12PM)
11/9 (W)	**Guest Lecture** (Dr. Patjanaporn "Sang" Chalacheva, Assistant Teaching Professor at Carnegie Mellon University)
11/14 (M)	**Guest Lecture** (Dr. Leonardo Nava-Guerra, Medtronic)
11/16 (W)	**Presentations Day 1** Session 1 PPTs Due @ 2PM
11/21 (M)	**Presentations Day 2** Session 2 PPTs Due @ 2PM
11/23 (W)	**NO CLASS** (Thanksgiving Break)
11/28 (M)	**Review for Exam 3** HW 5 Due @ 12PM
11/30 (W)	**Exam 3**
12/5 (M)	Project Due @ 2PM

Discussion Schedule (Every Mondays from 2 – 2:50PM)

8/22	**NO DISCUSSION**	10/17	**Review on Domains & Stability Analysis**
8/29	**HW 0 Discussion**	10/24	**HW 4 Discussion**
9/5	**NO DISCUSSION** (Labor Day)	10/31	**Q&A for Exam 2**
9/12	**HW 1 Discussion**	11/7	**Exam 2 Discussion**
9/19	**Review on Static Analysis & Dynamic Systems**	11/14	**NO DISCUSSION** (Tara at Conference)
9/26	**HW 2 Discussion**	11/21	**Review on System Identification**
10/3	**Exam 1 Discussion**	11/28	**HW 5 Discussion**
10/10	**HW 3 Discussion**		

Statement on Academic Conduct and Support Systems

Academic Conduct: Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention and Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free & confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED)- (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following *protected characteristics*: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations. The university also prohibits sexual assault, non-consensual sexual contact, sexual misconduct, intimate partner violence, stalking, malicious dissuasion, retaliation, and violation of interim measures.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy - (213) 821-4710

uscsa.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.