MAE 263E: Bionic Systems Engineering

Lecture: TBD TBD **Classroom:** TBD
Zoom Link: https://ucla.zoom.us/j/93441564055 **Password:** MAE298W22

Course Staff

Instructor:
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Office Hours: TBD
Zoom: TBD
I sincerely encourage you to attend my office hours, as well as those of the TAs. Especially as we return from remote learning, it is essential that we take advantage of opportunities to connect as much as possible. If it would be helpful to meet outside of office hours, please email me directly – we will work together to find a time that works for you.

General Course Information

Welcome to MAE 298! I'm thrilled to have you here, and look forward to the quarter ahead. This syllabus contains a ton of information that will give you a leg up on the coming term. Please read it and keep it around for future reference.

There are a couple of important things I want you to know before you read this document. First and foremost, know that I care about you and want to help you learn in a way that will inform the whole of your engineering career. I recognize that this course is a small part of each of your lives, and that all of you are dealing with a lot right now. Although my lived experiences are likely different than yours, I'm always willing to listen to you and be a resource for you. Second, there is nothing academic in this world that I think is cooler than the topics we'll cover in this course. You don't have to feel that way to be successful, but I do hope that you share in my excitement for the material by the end of the quarter. This stuff can change the world.

Course Description: This course is an introduction to design principles for bionic systems, including wearable robotics and implantable devices. Our goals in the course are to i) understand the biological systems that enable human movement, and ii) learn to manipulate those systems via robotic devices and surgical techniques. Topics include neural control of movement, neuromusculoskeletal modeling, actuator design, sensor integration, robotic control, neural interfacing, surgical techniques for amputation, and fundamentals of orthopaedic implants. The course builds towards a final project in which students will design and simulate wearable devices for real-life musculoskeletal pathologies, such as amputation, stroke, or paralysis.

Course Website: Announcements, lecture recordings, lecture notes, assignments, and other course materials will be posted on the UCLA CCLE course website (https://bruinlearn.ucla.edu/courses/108956). Students are responsible for checking the site often and ensuring that they receive mass e-mail announcements sent via the CCLE website. *The CCLE Discussion Forum will not be regularly monitored by course staff.*

Prerequisites: MECH&AE 82, MECH&AE M20 or equivalent. This course is intended for graduate students in Mechanical Engineering, and assumes a basic understanding of second-order dynamics, as well as significant experience coding in MATLAB. Third and fourth year undergraduate students may be granted enrollment at the instructor's discretion, on a case-by-case basis. Please email Prof. Clites if you are an undergraduate student interested in enrolling this year.

Textbook: There is no required textbook for this course. Readings will be provided from the scientific literature. The following texts may be helpful in reinforcing course material:

- Winter, David A. *Biomechanics and motor control of human movement*. John Wiley & Sons, 2009
- Pons, José L. *Wearable robots: biomechatronic exoskeletons.* John Wiley & Sons, 2008
- Aström, Karl Johan, and Richard M. Murray. *Feedback systems: an introduction for scientists and engineers*. Princeton University Press, 2010

Required Software:

- **MATLAB** will be used throughout the course. MATLAB can be downloaded by following the instructions at https://softwarecentral.ucla.edu/matlab-getmatlab. MATLAB can also be accessed via SEASnet. If

you do not already have a SEASnet account, you can create one at this link: http://www.seas.ucla.edu/acctapp.

- **OpenSim** will be used for the first 1/3 of the course, and for the final project. OpenSim can be downloaded for free at https://simtk.org/frs/?group_id=91. Please be sure to download the latest version (OpenSim 4.3), which is available for both Windows and Mac.

Learning Objectives

Throughout the course, we will cover many topics. If it ever becomes difficult to identify what's most important, you can refer back to these learning objectives. By the end of the course, you should be able to:

1. **Describe the biological systems that enable human movement.** Humans are complex bio-electro-mechanical systems. The first portion of this course will be dedicated to learning how electrical signals in the brain and spinal cord are converted to high-fidelity movement and locomotion.
2. **Design the core components of wearable robotic devices.** Robotic devices that are intended to be worn on (or implanted in) the human body require special consideration. You will learn to design actuators, sensors, and control systems that are specifically tailored to the unique needs of human movement.
3. **Understand how invasive surgical approaches can be used to engineer the human body.** By manipulating the body, we aim to create bionic systems in which body and machine are optimized to interact with each other. You will see how others have done this in the past, and think about how invasive surgical approaches can be applied to new problems in human rehabilitation and augmentation.

Homework

Frequency and Due Dates: I will assign 6 problem sets over the quarter (approximately 1 per week for the first 6 weeks, see *Key Dates* in schedule below). Problem sets will contain both analytical problems and MATLAB-based computation. Unless otherwise specified, homework is to be uploaded by **11:59pm every Friday**.

- Unless you have obtained special permission from me for extraordinary circumstances, in advance of the assigned due date, late homework will not be accepted.
- Special emergency extensions may be given if assignments are late due to COVID-related health issues. Please reach out to me directly, prior to the assignment's due date, to request such an extension.
- Give yourself plenty of time to do these assignments, especially if the software is new to you. We will be available in office hours to help troubleshoot; take advantage of the resources we are offering.

Submission using Gradescope: We will be using Gradescope (https://gradescope.com/) to manage submission of problem sets and possibly the midterm exam. This free, secure system enables early submission, automated rejection of late submissions, faster access to grades, and a transparent grading rubric.

General Gradescope Information

- Use a single email address for your profile.
- Gradescope will be set with a hard deadline that disallows late submissions. I encourage you to upload your work early, in case you have technical difficulties. In the unlikely event that you do encounter technical difficulties with Gradescope, reach out to me prior to the assignment due date.
- When your submission is completed successfully, you will be automatically redirected to a webpage for viewing your submission and will be shown a confirmation message. If you do not wait until you see this confirmation message before switching to another browser tab or page, your submission will not be uploaded correctly.
- You may continue to overwrite your uploaded files until the submission deadline has passed.

Homework Collaboration Policy: Discussing homework problems with classmates will help you digest course information, and plays an essential role in the learning process. However, each student must write up and turn in their own solutions to all assigned problems. It is important that you are able to independently reproduce any work you turn in. You are not allowed to copy solutions or code directly from another student, nor may you copy online solutions. The purpose of the homework is to help you learn course material and prepare for the

quizzes and exams; it is therefore in your interest to thoroughly understand the homework solutions. Note that collaboration is not allowed in any form on the midterm (see policies below).

Exams

Exam Frequency and Logistics: One midterm exam will be given during the quarter. In the exam, I will ask you to apply what you've learned in the homework to engineering problems. Exam questions will be a mix of analytical problems, numerical problems, and concept questions. Exams will be given either in person or asynchronously over a 24-hour window, with automatically-enforced time limits for completion.

Exam Collaboration Policy: Collaboration is not allowed on exams. The purpose of the exams is to assess your ability to apply what you've learned in the course to real-world engineering problems. Like quizzes, exams will be open book and open note. However, seeking help from anyone else, including peers or tutors, is not allowed.

Final Project

The course will culminate in a final project, in which you will simulate a movement pathology and design a wearable robotic system to improve human function. Successful completion of this project will draw from material covered throughout the entire course. You will have initial opportunities to develop project elements as part of the regular homework assignments. More information is contained in the Final Project Information document. Note that the format and contents of this project are subject to change, if we end up remote for much of the term.

Grading Policies

Regrade Requests: Course staff will update Gradebook as frequently as possible. If you feel that there is an error in the grading of a specific homework assignment, quiz, or exam, please use the regrade request on Gradebook within one week from the day grades are posted.

Grade Breakdown: Your overall grade in the course will be a weighted average of your assignments, according to the following breakdown:

Problem Sets - 30%
Midterm Exam - 30%
Final Project - 40%

Course Grade Allocation: Overall course grades will be calculated as a weighted average of component grades, as shown in *Grade Breakdown*. Course letter grades will be assigned according to a traditional numerical grading scheme, as follows:

A+: ≥ 97.5
A: ≥ 92.5 and < 97.5
A-: ≥ 90 and < 92.5
B+: ≥ 87.5 and < 90
B: ≥ 82.5 and < 87.5
B-: ≥ 80 and < 82.5
C+: ≥ 77.5 and < 80
C: ≥ 72.5 and < 77.5
C-: ≥ 70 and < 72.5
D+: ≥ 67.5 and < 70
D: ≥ 62.5 and < 67.5
D-: ≥ 60 and < 62.5
F: < 60

Academic Integrity

I trust you, as an adult and a person of integrity. You do not have to earn that trust – it is yours by default unless and until you give me a reason to reconsider. Because I care about you, I have worked hard to design this course so that you can successfully learn the material. Please take advantage of the resources available to you. If you find yourself tempted to bend the rules, or to do something dishonest, please pause think about why that is the case, and then reach out to me instead. If you contact me *before* you cheat, I can work with you to find an alternative solution. There is always a better way.

All of that being said, it is important to recognize that UCLA expects and requires all of its students to act with honesty and integrity, and to respect the rights of others in carrying out all academic assignments, quizzes, and exams. As such, any and all suspected cases of academic dishonesty will be reported to the Office of Academic and Student Affairs. This is the worst part of my job; please don't let things get this far. Sanctions may include zero scores, reduction of the letter grade, or an automatic failing grade. If warranted, a student may be disqualified, suspended, or expelled from the School of Engineering. It is your responsibility to know and understand the University Academic Integrity Policy and the UCLA Student Code of Conduct (https://www.deanofstudents.ucla.edu/studentconductcode).

CAE Accommodations

I am happy to support any accommodations from the Center for Accessible Education (CAE). If you are already registered with the CAE, please request your Letter of Accommodation in the Student Portal. If you are seeking registration with the CAE, please submit your request for accommodations via the CAE website. Students with disabilities requiring academic accommodations should submit their request for accommodations as soon as possible, as it may take up to two weeks to review the request. For more information, please visit the CAE website, visit the CAE at A255 Murphy Hall, or contact us by phone at (310) 825-1501.

Tentative Calendar

WEEK	KEY DATES	DATE	LECTURE	TOPIC	PAPERS
1	HW1 assigned 1/04	Tu 1/04	1	Course overview, intro to human movement, basic neuromuscular physiology	Zajac, 1989
		Th 1/06	2	Cutaneous sensation, proprioception, motor planning, reflexes	Proske, 2012
2	**HW1 due 1/10** HW2 assigned 1/11	Tu 1/11	3	Neuromusculoskeletal modeling: EMG, activation, Hill Type models	Buchanan, 2006
		Th 1/13	4	Neuromusculoskeletal modeling: tendons, moments arms, pennation angles	Millard, 2013
3	**HW2 due 1/17** HW3 assigned 1/18	Tu 1/18	5	Neuromusculoskeletal modeling: Forward dynamics, inverse dynamics, parameter ID	Markowitz, 2016
		Th 1/20	6	Using neuromusculoskeletal models in robotic control	Eilenberg, 2010
4	**HW3 due 1/24** HW4 assigned 1/25	Tu 1/25	7	Using neuromusculoskeletal models in robotic control (cont.)	
		Th 1/27	8	Motors, series elastic actuators	Pratt, 1995
5	**HW4 due 1/31** HW5 assigned 2/01	Tu 2/01	9	Transmissions, thermal principles, motor/transmission selection	Carney, 2021
		Th 2/03	10	Comms and Control	Young, 2014
6	**HW5 due 2/07** **Project proposals due 2/07** HW6 assigned 2/08	Tu 2/08	11	Current Prosthetic Tech Journal Club or Ethics Discussion	
		Th 2/10	12	Exoskeleton Control (Guest Lecture)*	Mooney, 2014
7	**HW6 due 2/14**	Tu 2/15	13	Sensors, Evaluation and Validation: Motion capture, metabolic cost, human-in-the-loop	Zhang, 2017
		Th 2/17		**Midterm exam**	
8		Tu 2/22	14	Neural interfacing: conventional direct-nerve strategies	Tan, 2014
		Th 2/24	15	Neural interfacing: TMR, RPNI, AMI	Clites, 2018
9		Tu 3/01	16	Mechanical interfacing: sockets, osseointegration, surgical procedures	Ortiz-Catalan, 2014
		Th 3/03	17	Endoprostheses and joint replacement	
10	**Project papers due 3/14**	Tu 3/08	18	Project working day	
		Th 3/10	19	Project presentations	

*likely to be shuffled/rescheduled