MCEN 4228/5228 Modeling of Human Movement (Fall 2021)

Human movement analysis is used in a wide range of applications, from physical rehabilitation to sport training, human-robot interaction and animation. The course objective is to provide a systematic overview of human movement on multiple levels of analysis, with an emphasis on the phenomenology amenable to computational modeling. Topics will include muscle physiology, movement-related brain areas, musculoskeletal mechanics, forward and inverse dynamics, optimal control and Bayesian inference, learning and adaptation.

More generally, the goal of this course is to inspire students to 'see' and appreciate the complexities of movement control in all aspects of daily life, to be motivated to learn more, and to provide them with the skills to do so. By the end of this course, students will be able to:

1. Understand the process of movement generation.
2. Analyze and simulate computational models of movement control at multiple levels of analysis.
3. Have experience with engineering tools used to study movement.
4. Read and critique scholarly articles related to biomechanics and movement control.
5. Appreciate the current challenges in the field of movement biomechanics.
6. Apply this understanding and experience to an important real-world problem.

Instructor:	Prof. Alaa Ahmed
	alaa@colorado.edu
	Office hours: MW after class 11:10-12:10
Lecture Times:	MWF 10:20-11:10 am
Lecture Location:	ECCR 135
Web page:	www.canvas.colorado.edu

Recommended Reading (Optional):

T.K. Uchida and S.L. Delp (2020) *Biomechanics of Movement: The Science of Sports, Robotics, and Rehabilitation*, The MIT Press.

R. Shadmehr and S. Mussa-Ivaldi (2012) *Biological Learning, and Control: How the Brain Builds Representations, Predicts Events, and Makes Decisions*, The MIT Press.

R. Shadmehr and A. A. Ahmed (2020) *Vigor: Neuroeconomics of Movement Control*, The MIT Press.

Course Grading: Student grades will be based upon performance in in-class presentations and participation, homework assignments, and a final project. The final grade will be calculated based on the following breakdown (4228/5228):

Homework Assignments	60%/50%
Journal Article Presentation	0%/10%
Project	35%/35%
Class Participation	5%/5%

Homework Assignments: There will be ~10 homework assignments. Assignments are to be submitted on Canvas by the beginning of class on the date due. No late HW will be accepted. Lowest grade will be dropped.

Journal Article Presentations: We will read and discuss 8 journal articles in class throughout the semester on an almost weekly basis. Graduate students are to sign up in groups to present each article in-class. A weekly homework question will be based on the reading.

Project: A final project consisting of developing an NIH R21 style grant proposal on a topic related to the course material is the cornerstone of the class. Deliverables include an in-class presentation, project report, and peer review.

Class Participation: Points for class participation will be awarded based on class attendance, in-class participation and problem-solving, and response to in-class iClicker-style questions and polls.

Grading of Homework: For undergraduates, homework problems will be designated as 'knowledge' or 'challenge' problems. 'Knowledge' problems will be graded based on correctness of the solution. 'Challenge' problems will be graded based on effort. For graduate students, all homework problems will be graded based on correctness.

TENTATIVE CLASS SCHEDULE

Week	Session	Date	Topic	HW
1	1	23-Aug	Introduction	
	2	25-Aug	Functional Anatomy	
	3	27-Aug	Walking	
2	4	30-Aug	Walking and Running	
	5	1-Sep	Running	
	6	3-Sep	Muscle Physiology	HW 0 Due
3	7	6-Sep	Labor Day	
	8	8-Sep	Muscle Force Generation	
	9	10-Sep	Muscle Architecture	HW 1 Due
4	10	13-Sep	Tendon Mechanics	
	11	15-Sep	Musculoskeletal Geometry	
	12	17-Sep	Musculoskeletal Geometry	HW 2 Due
5	13	20-Sep	Quantifying Movement	
	14	22-Sep	Inverse Kinematics	
	15	24-Sep	Journal Article Presentation #1	HW 3 Due
6	16	27-Sep	Inverse Kinematics	
	17	29-Sep	Inverse Dynamics	
	18	1-Oct	Journal Article Presentation #2	HW 4 Due
7	19	4-Oct	No Class - Dr. Ahmed at NIH Review Panel	
	20	6-Oct	Inverse Dynamics	
	21	8-Oct	Journal Article Presentation #3	Project Proposal
8	22	11-Oct	Inverse Dynamics	
	23	13-Oct	Movement Simulation	
	24	15-Oct	Journal Article Presentation #4	HW 5 IK Due
9	25	18-Oct	Neural Control of Movement	
	26	20-Oct	Motor Prediction	
	27	22-Oct	Journal Article Presentation #5	HW 6 ID Due
10	28	25-Oct	Motor Prediction	
	29	27-Oct	Sensorimotor Integration & Estimation	
	30	29-Oct	Journal Article Presentation #6	HW 7 Simulation
11	31	1-Nov	Sensorimotor Integration & Estimation	
	32	3-Nov	Motor Learning	

	33	5-Nov	MLMC Conference	HW 8 Learning
12	34	8-Nov	Motor Learning	
	35	10-Nov	Movement Costs and Rewards	
	36	12-Nov	Journal Article Presentation #7	HW 9 Estimation
13	37	15-Nov	No Class – Dr. Ahmed at SfN	
	38	17-Nov	Movement and Decision Making	
	39	19-Nov	Journal Article Presentation #8	
14	40	22-Nov	Fall Break - No Classes	
	41	24-Nov	Fall Break - No Classes	
	42	26-Nov	Fall Break - No Classes	
15	43	29-Nov	Presentations	
	44	1-Dec	Presentations	
	45	3-Dec	Presentations	HW 10 Utility
16	46	6-Dec	Mock NIH Review Panel	
	47	8-Dec	Mock NIH Review Panel	

Department Policies

A primary objective of the Mechanical Engineering Department is to prepare each of our students for careers in the engineering profession. As professionals, engineers must meet high standards of technical competence and ethical behavior. According to the Accreditation Board of Engineering and Technology (ABET) code of ethics, engineers uphold and advance the integrity, honor and dignity of the engineering profession by:

1. Using their knowledge and skill for the enhancement of human welfare;
2. Being honest and impartial, and serving with fidelity the public, their employers and clients;
3. Striving to increase the competence and prestige of the engineering profession.

The Department of Mechanical Engineering (ME) believes that it is essential for each of you to learn the professional behavior that will prepare you for your career after college. Therefore, in each mechanical engineering course you will be required to practice the professional behavior that will be expected by your future employers. This syllabus clearly outlines the ME policy regarding academic integrity and academic climate. These policies will be upheld in each of your courses throughout the mechanical engineering curriculum. However, we also expect that this culture of professionalism will pervade all of your University of Colorado experiences.

Homework Format

It is your responsibility to make your solutions clear and legible. The graders have the discretion to deduct points (up to and including full credit) for solutions that are hard to read or unprofessional in appearance. . Problems may be written by hand and subsequently scanned and converted to an electronic format. No hard copies, only electronic submission will be accepted.

Unless the problem requires a written response, short answer, or figures, the following format is *required*. This will facilitate grading and will assist you to approach problems in a consistent, organized way that will lead to the correct solutionSchematic/sketch (unless it is obviously not needed). List relevant information on the figure.

1. List of assumptions.
2. Governing equations. Label the equations.
3. List of known values, with units, including properties obtained from a table. Indicate the source, if applicable.
4. List of unknowns. Make sure they correspond to a sketch if applicable.
5. Solution: If applicable, present the answer with a box around it.
6. Verification. Check the answer against what common sense tells you. Do the units make sense? Do the results compare reasonably to a related known quantity?

Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on classroom behavior and the Student Conduct & Conflict Resolution policies.

Requirements for COVID-19

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to

Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

As of Aug. 13, 2021, CU Boulder has returned to requiring masks in classrooms and laboratories regardless of vaccination status. This requirement is a temporary precaution during the delta surge to supplement CU Boulder's COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home. In this class, if you are sick or quarantined, please let me know immediately and I will do my best to make accommodations to allow you to continue to make progress in the course.

Accommodation for Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the Honor Code website.

Discrimination and Harassment

Discriminatory and harassing behavior **will not** be tolerated in the Department of Mechanical Engineering. A safe and inclusive environment will be created and maintained by the students and instructing faculty

member. Students with concerns about discrimination or harassment actions should immediately contact the instructor, the Department Chair, their academic advisor, or the Office of Institutional Equity and Compliance. Some examples that may be considered harassment:

- A teaching assistant or instructor asking a student for a date.
- Displaying sexually explicit material in an academic setting (including laptop or handheld computer wallpaper, desktop, et. al.)
- Persisting in asking a classmate for a date after being turned down.
- Using degrading terminology in referring to others, including peers.
- Making identity-based jokes or comments that create a hostile environment.

The University of Colorado policy is stated below:

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or email cureport@colorado.edu. Information about OIEC, university policies, reporting options, and the campus resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options.

Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. If you have a conflict with attending class or assignment deadlines, please notify me of the schedule conflicts as early in the semester as possible so that there is adequate time to make necessary arrangements. See the campus policy regarding religious observances for full details.