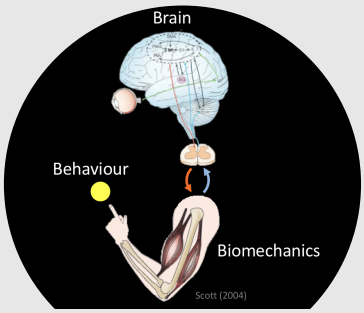

Neuromechanics

BMEG 446/646 (S-2025)

Credits: 3 hours

Description

The field of Neuromechanics investigates how our neural circuitry (Brain) and physics (Biomechanics) dictate how we move (Behaviour). This course will explore the interactions between our sensory system, central processing and biomechanics. We will also discuss emerging applications related to this new and exciting field of research.

Instructor Info

Dr. Joshua Cashaback

By Appointment

201J

STAR Campus

joshcash@udel.edu

Course Info

Lecture: M & W, 8:30-9:50am

FinTech 414

NA

NA

TA Info

NA

NA

NA

NA

Overview

Our ability to interact with our environment is truly remarkable given the complex neural circuitry and physics that underlie our movements. Even a small child can outperform state-of-the-art robotics across a range of seemingly simple tasks, such as walking and object manipulation. Module 1, Sensory Processing: We will first discuss how the nervous system integrates multiple streams of sensory information. Module 2, Muscle and Limb Dynamics: Next, we will learn about how muscles contract to move our limbs. Module 3, Control Policies (Brain, Biomechanics, Behaviour): Next we will bring together what we have learned up to this point, and cover what objectives that the nervous system may consider (e.g. minimize energy) and how this leads to stereotypical features of movement. Module 4, Application: Finally, we will discuss the role of Neuromechanics in several emerging fields.

- Prerequisites: None

Learning Objectives

- Understand fundamental principles and current theories of Neuromechanics.
- Learn how our senses, central nervous system and muscles interact to produce movement
- Identify, formulate, and solve complex computational and engineering problems fundamental to the field of Neuromechanics:
- Improve ability to communicate effectively with a range of audiences through written reports and collaborative presentations.
- Analyze and interpret data, and use engineering judgment to draw conclusions
- Enhance self-directed learning skills for graduate school and industry
- Learn about the role of Neuromechanics in several emerging technologies.

Grading Scheme

90%	Biweekly Assignments (6 x 15% each)
10%	Group Presentation

Material

There is no required textbook for this course. Since a major aim of this course is to cover current topics in Neuromechanics, course content (and therefore the required readings) will vary from year to year. However, there will be a core set of articles associated with this course (see list below).

1. Leib R, Howard IS, Millard M, & Franklin DW. (2024). Behavioral Motor Performance. Comprehensive Physiology, 14, 5179-5224.
2. Ekeberg O, et al. (1991). A computer based model for realistic simulations of neural networks. I. The single neuron and synaptic interaction *Biol Cybern*, 65, 81-90.
3. Deneve S, Pouget A (2004). Bayesian multisensory integration and cross-modal spatial links. *J. Physiol-Paris*, 98(1-3), 249-258.
4. Zajac, FE (1989). Muscle and tendon properties models scaling and application to biomechanics and motor. *Crit Rev Biomed Eng*, 17(4), 359-411.
5. Gribble PL, Ostry DJ (1999). Compensation for interaction torques during single-and multijoint limb movement. *J Neurophys*, 82(5), 2310-2326.
6. Scott (2004). Optimal feedback control and the neural basis of volitional motor control. *Nat Rev Neurosci.*, 5, 534-546.
7. Cisek P, Puskas GA, & El-Murr S (2009). Decisions in changing conditions: the urgency-gating model. *Jneurosci*, 29(37), 11560-11571.

Assignments

The assignments are designed so that you will learn how to perform calculations that are fundamental to the field of Neuromechanics. To carry out these calculations you will use a high-level programming language of your choice (e.g., Python or Matlab). Note that all sample code will be provided in Python. The theme of each assignment are listed directly below. Late assignments will have 10% deduction for each day that the assignment is late. Note that you can work in groups, but each student needs to submit his/her own version of the assignment. Please upload all assignments to Canvas with your name on the file (e.g., Cashaback_assign1).

1. Ordinary Differential Equations (ODEs) and Sensory Feedback.
2. Action Potentials and Multisensory Integration.
3. Muscle Dynamics.
4. Limb Kinematics and Dynamics.
5. Optimal Feedback Control.
6. Decision-Making and Motor Adaptation.

Group Presentations

Students will form groups of 2-4 people. Each group will give a 10 minute presentation on an emerging and applied area in the field of Neuromechanics. The presentations are worth 10% of the course grade. Students should emphasize: a) what the question / issue is, b) how the approach / technology attempts to address that issue, c) what is the role of neuromechanics, d) how does it work, e) what are the advantages and disadvantages of the approach / technology, and f) possible future directions. To avoid redundancy, the same topic cannot be examined by different groups. Topic assignment will be on a first-come, first serve basis. Groups can choose a topic of their preference, with some possible topics listed below.

1. Neuroprosthetics.
2. Brain-machine interfaces.
3. Human-in-the-loop.
4. Exoskeletons in the workplace.
5. Soft robotics.
6. Robot-guided surgery.
7. Biologically inspired robots
8. Rehabilitation

Schedule

MODULE 1: Multisensory Integration (Inputs)

Feb 3, 5

- •Course Introduction
- •Primer on ODEs
- •Assignment 1: ODEs and Sensory Feedback

- Leib R et al. (2024). *Comprehensive Physiology*, 14, 5179-5224.

Feb 10, 12

- •Sensory Systems
- •Action Potentials
- •Assignment 2: Action Potentials and Bayes

- Ekeberg O, et al. (1991). *Biol Cybern*, 65, 81-90.
- Assignment 1 report due Feb. 12th before class.

Feb 17, 19

- •Lab
- •(Multi)Sensory Illusions
- •Assignment 2: Action Potentials and Bayes

Feb 24, 26

- •Bayesian Integration
- •LAB (John B)
- •Assignment 2: Action Potentials and Bayes

- Deneve S, Pouget A (2004). *J. Physiol-Paris*, 98(1-3), 249-258.

MODULE 2: Muscle and Limb Dynamics (Outputs)

Mar 3, 5

- •Muscle Properties (self-directed learning)
- •Muscle Dynamics
- •Assignment 3: Muscle Model

- Zajac, FE (1989). *Crit Rev Biomed Eng*, 17(4), 359-411.
- Zahalak, GI (1981). *Mathematical Biosciences*, 55(1-2), 89-114.
- Assignment 2 report due Mar. 3 before class.

6: Mar 10, 12

- •LAB
- •Limb Kinematics (2-link) (Rucha)
- •Assignment 4: Limb Kinematics / Dynamics

- Assignment 3 report due Mar. 12 before class.

Mar 17, 19

- •Limb Dynamics (2-link) (Seth S)
- •LAB
- •Assignment 4: Limb Kinematics / Dynamics

- Gribble PL, Ostry DJ (1999). *J Neurophys*, 82(5), 2310-2326.

Mar 24, 26

- •NO CLASS (Spring Break)
- •NO CLASS (Spring Break)

MODULE 3: Control Policies (Brain, Biomechanics, Behaviour)

May 31, April 2

- •Neural Basis of Movement I
  Cerebellum and Internal Models
  (self-directed learning)
- •Neural Basis of Movement II
  Basal Ganglia, Dopamine, Reinforcement
- •No Assignment

- Wolpert et al. (1998). *Trends in cognitive sciences*, 2(9), 338-347.
- Assignment 4 report due April 2 before class.

Apr 7, 9

- •Human Behaviour
- •Optimal Feedback Control:
  Stereotypical Movement
- •Assignment 5: OFC model (John B.)

- Scholz, JP, Schoner, G. (1999). *Exp. Brain Res.*, 126(3), 289-306.
- Scott (2004). *Nat Rev Neurosci.*, 5, 534-546.

Apr 14, 16

- •Optimal Feedback Control: A Theoretical Framework
- •LAB
- •Assignment 5: OFC model (Truc)

- Todorov, E, & Jordan, MI (2002). *Nat. Neurosci.*, 5(11), 1226.

April 21, 23

- •Decision-Making & Action Selection
- •LAB
- •Assignment 6: Decision and Adaptation

- Cisek et al. (2009). *Jneurosci.*, 29(37), 11560-11571.
- Assignment 5 report due April 21 before class.

April 28, 30

- •NO CLASS (conference)
- •NO CLASS (conference)

May 5, 7

- •Error-Based Learning (John B)
- •Objectives of the Nervous System (e.g., minimize force, energy, or error)
- •Assignment 6: Decision and Adaptation

- Smith, M. A., et al. (2006). *PLoS Bio.*, 4(6), e179.

MODULE 4: Emerging Applications

May 12, 14

- •Presentations
- •Presentations

- Assignment 6 report due May 14 before class.

Grading Scale

Letter Grade	Percent Grade
A	93-100%
A-	90-92.99%
B+	87-89.99%
B	83-86.99%
B-	80-82.99%
C+	77-79.99%
C	73-76.99%
C-	70-72.99%
D+	67-69.99%
D	63-66.99%
D-	60-62.99%

CANVAS

The syllabus, lectures and assignments will all be posted on CANVAS. I will attempt to have all lectures posted the day before the corresponding class.

Attendance

You are highly encouraged to attend class to maximize your educational experience. That being said, attendance is not mandatory.

Absences on religious holidays listed in university calendars are recognized as an excused absence. Nevertheless, students are urged to remind the instructor of their intention to be absent on a particular upcoming holiday. Absences on religious holidays not listed in university calendars, as well as absences due to athletic participation or other extracurricular activities in which students are official representatives of the university, shall be recognized as excused absences when the student informs the instructor in writing during the first two weeks of the semester of these planned absences for the semester.

Communication

If you have to get in touch with me via email, use the address listed above and put NEUROMECH-667 as the subject. *Note, I will NOT be answering homework or assignment questions via email, so please be proactive by utilizing class time (including prior to and following class) and LAB days. Office hours are appointment only.*

Use of Advanced Automated Tools

The use of artificial intelligence or machine learning tools such as ChatGPT are not permitted for any graded material.

Student Mental Health & Wellbeing

College students often experience things that may interfere with academic success such as academic stress, sleep problems, juggling responsibilities, life events, relationship concerns, or feelings of anxiety, hopelessness, or depression. If you are experiencing any of the above in a way that is negatively impacting your ability to participate fully in the learning activities for this class, I strongly encourage you to get in touch with me. Additionally, I have provided information from other campus-wide units below. Contact me if you are struggling with this class, please check-in with me before or after class. Check-in with your academic advisor or the Assistant Dean for Student Services in your college. If you are struggling in multiple classes, unsure whether you are making the most of your time at UD, or unsure what academic resources are available at UD. For a complete list of advisors, check out https://www.advising.udel.edu/academic-advisor-directory/. UD's Center for Counseling & Student Development (CCSD), TimelyCare, and UD Helpline UD's Center for Counseling & Student Development (CCSD) provides cost-free and confidential mental health services promoting psychological well-being so that students can be more successful in their academic, personal, and career pursuits. CCSD provides in-person services including walk-in urgent visits, scheduled individual and group counseling, and consultation for students, parents, and faculty. CCSD partners with TimelyCare to provide scheduled counseling and health coaching via telehealth. For 24/7 mental health support, students have the option of calling the UD Helpline at 302-831-1001 or accessing TimelyCare's Talk Now service through the TimelyCare app or online. Visit CCSD's website for additional information and resources. Student Well-being- Division of Student Life. Our three wellbeing units—Student Health Services (SHS), Student Wellness and Health Promotion (SWHP) and the Center for Counseling and Student Development (CCSS)—are here to help you thrive both mentally and physically in your time as a Blue Hen and beyond. Come visit us on the South Green for all of your wellness needs! Explore the Student Life's Wellbeing webpage for a comprehensive listing of well-being resources, activities, and services available to all students.

The Safety of Our Learning Environment

Student learning can only occur when students and their instructors feel safe, respected, and supported by each other.

Academic Honesty

Please familiarize yourself with UD policies regarding academic dishonesty. The Academic Honesty Policy states: "Students must be honest and forthright in their academic studies. Students are expected to do their own work and must give proper credit for any work not their own. Students may neither give nor receive unauthorized assistance. Engaging in academic dishonesty, or allowing other students to do the same, corrupts the educational process and diminishes the quality of a University of Delaware degree." View the university's procedures for resolving academic dishonesty concerns. Contact Community Standards & Conflict Resolution at communitystandards@udel.edu or (302) 831-2117.

Harassment and Discrimination

The University of Delaware works to promote an academic and work environment that is free from all forms of discrimination, including harassment and sexual misconduct. As a member of the community, your rights, resources and responsibilities are reflected in the Non-Discrimination, Sexual Misconduct, and Title IX policy. Please familiarize yourself with this policy at the University's Office of Equity & Inclusion's website. You can report any concerns to the University's Office of Equity & Inclusion (302) 831-8063 or at titleixcoordinator@udel.edu. You can report anonymously through UD Police (302) 831-2222 or the EthicsPoint Compliance Hotline. Read the full policy. File a report.

Faculty Statement on Disclosures of Instances of Sexual Misconduct

If, at any time during this course, I happen to be made aware that a student may have been the victim of sexual misconduct (including sexual harassment, sexual violence, domestic/dating violence, or stalking), I am a responsible employee, which means I am directed to report any incident of sexual harassment or misconduct to the University's Title IX Coordinator. The Title IX Coordinator will then meet with the student to discuss how the University will respond to the report and the student's rights and options, to offer resources, and to ensure that the student and the campus community are safe. If such a situation is disclosed to me in class, in a paper assignment, or in office hours, I promise to protect your privacy–I will not disclose the incident to anyone but the Title IX Coordinator in a confidential manner. For more information on Sexual Misconduct policies, where to get help, and reporting information, please refer to www.udel.edu/sexualmisconduct. You can also send an email to the Title IX Coordinator at titleixcoordinator@udel.edu. At UD, we provide 24/7/365 crisis assistance and victim advocacy and counseling. Contact 302-831-1001 to get in touch with a sexual offense support advocate, as well as confidential and anonymous counseling services for other concerns.

Accommodations for Students with Disabilities

Any student who may need disability-related accommodations should contact the Office of Disability Support Services (DSS) office as soon as possible. For more information, please visit Getting Registered at DSS. Contact DSS by phone: 302-831-4643; fax: 302-831-3261; website: www.udel.edu/dss; email: dssoffice@udel.edu; or visit 240 Academy Street, Alison Hall Suite 130 during business hours (8-5 M-F).

Non-Discrimination

Any student who may need disability-related accommodations should contact the Office of Disability Support Services (DSS) office as soon as possible. For more information, please visit Getting Registered at DSS. Contact DSS by phone: 302-831-4643; fax: 302-831-3261; website: www.udel.edu/dss; email: dssoffice@udel.edu; or visit 240 Academy Street, Alison Hall Suite 130 during business hours (8-5 M-F). Non-Discrimination. The University of Delaware does not discriminate against any person on the basis of race, color, national origin, sex, gender identity or expression, sexual orientation, genetic information, marital status, disability, religion, age, veteran status or any other characteristic protected by applicable law in its employment, educational programs and activities, admissions policies, and scholarship and loan programs as required by Title IX of the Educational Amendments of 1972, the Americans with Disabilities Act of 1990, Section 504 of the Rehabilitation Act of 1973, Title VII of the Civil Rights Act of 1964, and other applicable statutes and University policies. The University of Delaware also prohibits unlawful harassment including sexual harassment and sexual violence. For inquiries or complaints related to non-discrimination policies, please contact: Office of Equity & Inclusion- oei@udel.edu, (302) 831-8063. For complaints related to Section 504 of the Rehabilitation Act of 1973 and/or the Americans with Disabilities Act, please contact: Office of Disability Support Services, dssoffice@udel.edu, Alison Hall, Suite 130, Newark, DE 19716 (302) 831-4643 OR contact the U.S. Department of Education - Office for Civil Rights.