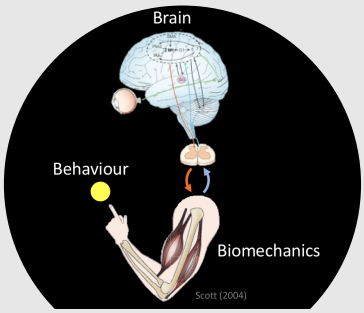

Neuromechanics
BMEG 467/667 (S-2020)

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
Friday, 3-5pm
201J
STAR Complex
joshcash@udel.edu

Course Info

Lecture: M & W, 8:40-9:55am
ISE 322
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: MATH305 or permission of instructor

Learning Objectives

- Understand fundamental principles and current theories of Neuromechanics.
- Learn how our senses, central nervous system and muscles interact to produce movement
- Learn computational models fundamental to the field of Neuromechanics
- Improve ability to write reports and deliver presentations.
- Learn about the role of Neuromechanics in several emerging technologies.

Grading Scheme

60%	Biweekly Assignments (6 x 10% each)
15%	Midterm
10%	Individual Presentation
15%	Final Exam

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). *Students are responsible for all material as it will appear on exams.*

1. Nishikawa K, et al. (2007). Neuromechanics: an integrative approach for understanding motor control. *Integr Comp Biol*, 47(1), 16-54.
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. Handford ML, Srinivasan M (2016). Robotic lower limb prosthesis design through simultaneous computer optimizations of human and prosthesis costs. *Sci. Rep.*, 6, 19983.

Assignments

The assignments are designed so that you will a) learn how to perform calculations that are fundamental to the field of Neuromechanics, and b) build confidence before the midterm and exam. 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.

1. Primer on Ordinary Differential Equations (ODEs).
2. Action Potentials (Hodgkin-Huxley Model).
3. Muscle Dynamics (Hill-type and Cross-Bridge Model).
4. Limb Kinematics and Dynamics.
5. Optimal Feedback Control.
6. Adaptation Models (Smith Two-State Model).

Midterm

There will be a midterm exam worth 15% of the course grade. This will occur in-class on [March 25]. The format will be a combination of multiple choice and short-answer questions. Calculators will be permitted.

Individual Presentations

Each student 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 individuals. Topic assignment will be on a first-come, first serve basis. Students 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

Final Exam

The final exam will occur during the final exam period and therefore the date, time and location will be scheduled by the University [May 21, ISE 322, 8-10am]. The format will be a combination of multiple choice and short-answer questions that will cover the entire content of the course. The value of the exam will be 15% of your grade.

Schedule

MODULE 1: Multisensory Integration (Inputs)

Week 1: Feb 10, 12

- •Course Introduction
- •Primer on ODEs
- •Assignment 1: Solving Dynamical Systems

- Nishikawa K, et al. (2007). *Integr Comp Biol*, 47(1), 16-54.

Week 2: Feb 17, 19

- •Sensory Systems
- •Action Potentials
- •Assignment 2: Hodgkin-Huxley Model

- Ekeberg O, et al. (1991). *Biol Cybern*, 65, 81-90.
- Assignment 1 report due Feb.19th before class.

Week 3: Feb 24, 26

- •(Multi)Sensory Illusions
- •Bayesian Integration
  - Deneve S, Pouget A (2004). *J. Physiol-Paris*, 98(1-3), 249-258.
- •Bayes Homework
  - Assignment 2 report due Feb.26th before class.

MODULE 2: Muscle and Limb Dynamics (Outputs)

Week 4: Mar 2, 4

- •Muscle Properties
  - Zajac, FE (1989). *Crit Rev Biomed Eng*, 17(4), 359-411.
- •Muscle Dynamics
  - Zahalak, GI (1981). *Mathematical Biosciences*, 55(1-2), 89-114.
- •Assignment 3: Muscle Model

Week 5: Mar 9, 11

- •LAB
- •Limb Kinematics (2-link)
  - Gribble PL, Ostry DJ (1999). *J Neurophys*, 82(5), 2310-2326.
- •Assignment 4: Limb Kinematics / Dynamics
  - Assignment 3 report due Mar. 11th before class.

Week 6: Mar 16, 18

- •Limb Dynamics (2-link)
- •LAB

Week 7: Mar 23, 25

- •Midterm Review
- •Midterm
  - Based on Module 1 and 2 material only.
- •No Assignment
  - Assignment 4 report due Mar. 23rd before class.

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

Week 8: Mar 30, Apr 1

- •SPRING BREAK

Week 9: Apr 6, 8

- •Neural Basis of Movement I
  Cerebellum and Internal Models
  - Wolpert et al. (1998). *Trends in cognitive sciences*, 2(9), 338-347.
- •Neural Basis of Movement II
  Basal Ganglia, Dopamine, Reinforcement
- •No Assignment

Week 10: Apr 13, 15

- •Human Behaviour
  - Scholz, JP, Schöner, G. (1999). *Exp. Brain Res.*, 126(3), 289-306.
- •Optimal Feedback Control:
  Stereotypical Movement
  - Scott (2004). *Nat Rev Neurosci.*, 5, 534-546.
- •No Assignment

Week 11: Apr 20, 22

- •Optimal Feedback Control: A Theoretical Framework
  - Todorov, E, & Jordan, MI (2002). *Nat. Neurosci.*, 5(11), 1226.
- •LAB
- •Assignment 5: OFC model

Week 12: Apr 27, 29

- •NO CLASS (NCM Conference)

Week 13: May 4, 6

Objectives of the Nervous System (e.g., minimize force, energy, or error)

- •Error-Based Learning
  - Smith, M. A., et al. (2006). *PLoS Bio.*, 4(6), e179.
- •Assignment 6: Adaptation Model
  - Assignment 5 report due May 4th before class.

MODULE 4: Emerging Applications

Week 14: May 11, 13

- •Presentations
- •Presentations
  - Assignment 6 report due May 13th before class.

Week 15: May 18

- •Final Exam Review
  - Based on Module 3 and 4 material only

Grading Scale

Letter Grade	Percent Grade
A	93-100%
A-	90-92%
B+	87-89%
B	83-86%
B-	80-82%
C+	77-79%
C	73-76%
C-	70-72%
D+	67-69%
D	63-66%
D-	60-62%

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 except for the midterm, final, presentation, and handing in assignments.

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 utilize class time (including prior to and following class), LAB days, and office hours.*

Academic integrity

Please familiarize yourself with UD policies regarding academic dishonesty. To falsify the results of one's research, to steal the words or ideas of another, to cheat on an assignment, to re-submit the same assignment for different classes, or to allow or assist another to commit these acts corrupts the educational process. Students are expected to do their own work and neither give nor receive unauthorized assistance. Complete details of the university's academic integrity policies and procedures can be found at sites.udel.edu/studentconduct/sgup/ Office of Student Conduct, 218 Hullihen Hall, (302) 831-2117. E-mail: student-conduct@udel.edu

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. As a member of the community, your rights, resource and responsibilities are reflected in the non-discrimination and sexual misconduct policies. Please familiarize yourself with these policies at www.udel.edu/oei . You can report any concerns to the University?s Office of Equity & Inclusion, at 305 Hullihen Hall, (302) 831-8063 or you can report anonymously through UD Police (302) 831-2222 or the EthicsPoint Compliance Hotline at www1.udel.edu/compliance. You can also report any violation of UD policy on harassment, discrimination, or abuse of any person at this site: sites.udel.edu/sexualmisc to-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 obligated to inform the university?s Title IX Coordinator. The university needs to know information about such incidents in order to offer resources to victims and to ensure a safe campus environment for everyone. The Title IX Coordinator will decide if the incident should be examined further. 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. For more information on Sexual Misconduct policies, where to get help, and how to reporting information, please refer to www.udel.edu/sexualmisconduct. At UD, we provide 24-hour crisis assistance and victim advocacy and counseling. Contact 302-831-1001, UD Helpline 24/7/365, to get in touch with a sexual offense support advocate.

For information on various places you can turn for help, more information on Sexual Misconduct policies, where to get help, and reporting information please refer to www.udel.edu/sexualmisconduct.

Accommodations for Students with Disabilities

Any student who thinks he/she may need an accommodation based on a disability should contact the Office of Disability Support Services (DSS) office as soon as possible. Students who have documentation of their need for accommodation should register via the SAM platform: andes.accessiblelearning.com/UDEL/. Reach DSS in the following ways: Visit at 240 Academy Street, Alison Hall Suite 130, Phone: 302-831-4643, fax: 302-831-3261, DSS website. Email: dssoffice@udel.edu

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: Interim Director, Institutional Equity & Title IX Coordinator - Fatimah Stone titleixcoordinator@udel.edu, 305 Hullihen Hall Newark, DE 19716 (302) 831-8063

For complaints related to Section 504 of the Rehabilitation Act of 1973 and/or the Americans with Disabilities Act, please contact: Elizabeth Reed, Interim Director Office of Disability Support Services and University ADA Compliance Coordinator - ecreed@udel.edu, Alison Hall, Suite 130, Newark, DE 19716 (302) 831-4643 OR contact the U.S. Department of Education - Office for Civil Rights.