Neuromechanics of Human Motion

Introduction

Joshua Cashaback, PhD

Welcome!

BMEG 667 — Neuromechanics in Human Motion

Prerequisites:

a) none
b) should have some basic math background

Monday & Wednesday, 8:40-9:55am

(lectures with vary in length to some extent)

Instructor

Joshua Cashaback, Ph.D.

1. Ph.D. — Biomechanics
2. Postdoctoral Fellowship — Computational Neuroscience
3. Postdoctoral Fellowship — Neuromechanics

Contact Information

1. (ZOOM) Office Hours: Friday afternoon 3:00pm - 5:00pm
2. Office: STAR Complex, rm. 201J
3. Answer questions before and after class (time permitting)
4. Email: joshcash@udel.edu

Class and Zoom

1. Lectures are inclass
2. Can watch in synchronously or asynchronously from home
3. Recurrent zoom link: https://udel.zoom.us/j/97388159044
4. Used for class, lab, office hours

Course Objectives

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

Major Course Components

1. Learn fundamental aspects of human biology
2. Learn computational models that **complement** biology.
3. Some lectures will be more biology, some more computational, and some a mix

Mathematics Background

This course is aimed at Engineering & Physics, Kinesiology, and Physical Therapy students that have some familiarity with mathematics (i.e., introductory level calculus or linear algebra). Lectures have been designed to walk through each problem and often provide sample code so that everyone can follow along.

1. What you should know:
   a. basic trigonometry
   b. matrix multiplication
   c. introductory calculus
   d. lacking any of these? Come chat with me after class.
2. What would be a bonus:
   a. basic probability (e.g., normal distribution)
   b. ODEs

Modules

1. Sensory INPUTS (Module 1)
    a. Sensory Organs and Action Potentials (Hodgkin-Huxley model)
    b. Multisensory Integration and Illusions (Bayesian Statistics)
2. Motor OUTPUTS (Module 2)
    1. Muscle Dynamics (Hill-type vs Crossbridge)
    2. Limb Kinematics and Dynamics (Lagrange-Euler)
3. Central Processing (Module 3)
    a. Neural Basis of Human Movement
    b. Features of Human Behaviour
    c. Optimal Feedback Control (LQG)
4. Other
    a. Adaptation (State-space models)
    b. Emerging Technologies

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Grading Scheme

- 60% Biweekly Assignments (6 x 10% each)
- 15% Midterm (Modules 1 and 2)
- 10% Presentation
- 15% Final Exam (Module 3 and 4)

When emailing assignment and take-home exams, write your last name on the pdf (e.g., Cashaback_assign1). For all email correspondance in the class, write NEUROMECH667 in the subject line.

I will not be answering assignment questions via email, so utilize office hours, lab time, before and after 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%

My Goals for You

1. Understand Material (Visual examples, demonstrations, simulations)
2. Learner-Centered Environment (Practical Components, In-class coding)
3. Actively Engage and Interact (Both sides, ‘connect-the-dots’)
4. Improve Communication Skills
5. Set you up for SUCCESS!

On your end...

1. Please, be respectful of others
   a. e.g., don't be disruptive during lectures, understand people have different perspectives and approaches.
2. Submit assignments on time (10% deductions per day)
3. Use office hours, Labs, and class for questions. Don't wait until last minute to ask questions.
4. Academic Integrity (see syllabus)
5. Disputing marks (legitimate reasons only)
6. HAVE FUN LEARNING!

Programming

1. Use any language you please (Python, Matlab, C++, LabView, R, etc.)
2. All coding examples will be done in Python
3. https://www.anaconda.com/distribution/
4. Written assignments (Latex or Word)
5. https://pages.uoregon.edu/koch/texshop/obtaining.html
6. Bring a laptop to lecture if you have one or pair up with someone that does

MODELLING

Why Make Models?

1. Test validity of a functional hypothesis from an observed phenomenon
2. Theory-driven predictions (e.g., astrophysics)
   gravitational waves (Einstein - 100 yrs.)
   Higgs boson (Peter Higgs - 48 yrs)
3. Ethical considerations (thoughts?)
   simulate surgery, disease, effect of drugs
4. Formalize thinking
5. Fun!

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Limitations

1. All Models are wrong
2. Your model is only as good as it's assumptions
3. simple models may not capture reality or be misleading
4. complex models may be confusing (high dimensionality) and overfit the data.
5. "With four parameters I can fit an elephant, and with five I can make him wiggle his trunk (John von Neumann)"

Other Modelling Considerations

1. Tradeoffs with model complexity (depends on goal. e.g., control or joint loading)
2. Simple as possible but as complex as needed.
3. Does your model explain phenomenon?
4. Does your model reproduce other data sets?
5. Can your model make predictions (currently testable or not)?
6. phenomenological vs. mechanistic

Relavance

1. Neuroprosthetics
2. Brain-Machine Interface.
3. Human-in-the-loop
4. Exoskeletons in the workplace
5. Soft Robotics
6. Robot-guided Surgery
7. Rehabilitation

QUESTIONS???

In-Class (or Homework) Assignment

1. Open Python (or other language)
2. https://www.anaconda.com/distribution/
3. Use a for loop and evaluate $y = x^2$ for a range of values (e.g., [-5,5] with 100 values)
4. store x and y values in an array
5. plot $y = x^2$
6. try changing range and increments

A Solution

```python
import numpy as np
from pylab import *

max, min, n = 5, -5, 100 #max range value, min range value, number of values
X, Y = np.zeros(n), np.zeros(n)

for i in range(n):
        x = i * (max - min)/n + min #calculates each incrementally increasing x value
        y = x**2
        X[i], Y[i] = x, y


fig, ax = plt.subplots(figsize=(9,8))
plt.title('Ta-Da!', fontsize = 24)
plt.xlabel('X (a.u.)', fontsize = 21)
plt.ylabel('Y (a.u.)',fontsize = 21)
d0 = errorbar(X, Y, linestyle = '-', linewidth = 2.0, color = 'blue')
legend([d0], ['$x^2$'], fontsize = 18)
show()
```

Next Class

1. Introduction to Dynamical Systems
2. Solving dynamical systems with ODEs
3. Briefly discuss the relevance of ODEs to model biological processes