BME 504/BKN 504: Neuromuscular Systems Fall 2014

Course Information v1.0

Professor: Francisco Valero-Cuevas
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Office hours: TBD

or by appointment

Class: M & W 11:00 AM to 12:20 PM
Location: TBD
Course for graduate students or by permission from the instructor to advanced undergraduates.
3-units

Web Page: http://bbdl.usc.edu/BMEBKN504.php

TA: Cassie Nguyen cassieng@usc.edu.

Purpose**:** To introduce basic and advanced engineering and neuroscience tools for analysis and simulation of motion and force production of vertebrate limbs. These are very broad fields at the interface of biology, physiology, medicine and engineering. Thus, the course emphasizes collaborative learning driven by carefully selected homework, readings, attendance of seminars, hands-on laboratory experiences, and in-class exams. This will enable students to use an engineering analysis and simulation approach to complete a semester-long project related to a tendon-driven neuromuscular system of their choice.

Topics:

At the end of the semester, students should be able to define and explain *Neuromechanics* as the evolutionary co-adaptation of the nervous system and the body in the context of mechanical function by:

- Considering the basic organization of the sensorimotor neural system
- Considering the organization of tendon-driven multi-joint systems
- Outlining the link between the neural signal and muscle contraction
- Defining the mechanical characteristics of muscles as force-generating units
- Analyzing musculoskeletal forces that occur within the body
- Understanding the concepts of muscle and kinematic redundancy
- Appreciating the role of biomechanics in the clinical evaluation of disabilities
- Describing the options used by the nervous system to control muscle force
- Modeling, simulating, optimizing and animating a neuromuscular system
- Designing experiments to evaluate the severity of a neuromuscular pathology

Grading:

	Homework	15% (~bi-weekly)
	Reading quizzes & seminars	15% (~weekly)
	Midterm exam I	20% (in-class, closed notes)
	Midterm exam II	20% (in-class, closed notes)
	Project	30% (semester-long, by groups assigned by Prof.)

The project will be a computational exploration of a musculoskeletal system and will be assigned by week 5. The final project is in lieu of final exam.

Textbook:
• Course notes ("*Neuromechanics of Tendon-Driven Systems*") and articles from the literature will be distributed.
• Selected readings from Principles of Neural Science by Eric R. Kandel, James H. Schwartz, Thomas M. Jessell, McGraw-Hill/Appleton & Lange; 5th edition (2013). (**Purchase only if you are using in other courses)

Homework: To be handed in and graded individually, although I encourage and expect you to work in groups. Homework sets are due at the beginning of class on the date listed in the syllabus. Homework will be accepted late with a 10% penalty per day after the due date and before solutions are posted, and 50% penalty thereafter. I strongly encourage you to do, and hand in, all homework even if with a penalty for delay. Some exam questions will be directly related to homework assignments, and the homework is designed to teach you the tools needed for the individual projects.

Reading quizzes & seminars:
• There will be a 10-point quiz at the beginning of the lecture most weeks towards the beginning of the semester. The purpose of the quizzes is to keep you on track with critical reading and seminars that are background or related material to the lectures, lab, homework and project. The quizzes will often cover the background reading material to supplement lectures.
• Of the 15% of the grade for this category, one third (5% of total grade) will require students to attend and hand in a one-page summary for the Engineering, Neuroscience and Health seminar series held on several Mondays (http://bbdl.usc.edu/ENH). Attendance will be taken and credit prorated by number of lectures attended. If your schedule does not permit attending in person, you can view as web archive, but must show proof of time conflict to use this option.

Special Needs**:** Any student requesting academic adjustments or accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me no later than 2 weeks after the first class. DSP is located in the Center for Academic Support, STU 301, Tel. (213) 740-0776.

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Course Syllabus v1.0

Lecture			*Topic*	*Readings/HW/Project/Quizzes/Tests/Notes*
1.	M	8/25	**Introduction** Overview of forward and inverse biomechanical models. Overview of musculoskeletal modeling	• Lecture based on Valero-Cuevas et al. Computational models for neuromuscular function. IEEE Reviews in Biomedical Engineering, 2: p. 110-35, 2009 • Ch 1 of *Neuromechanics* handed out
2.	W	8/27	**Muscle:** Organization of muscle tissue The sarcomere as a position actuator The force length curve The action potential Sarcoplasmic reticulum Ca+ release and uptake Cross-bridge cycle Excitation contraction dynamics	• Reading Quiz #1 Ch 1 of *Neuromechanics* • Assign K&S Chapters** 33 The organization of movement 34 The motor unit and muscle action **See me if you do not have K&S book
	M	9/1	**Labor day, University Holiday**	**No class** • HW 1 handed out, due on 9/8. See MATLAB book
3.	W	9/3	**Muscle:** Simple Hill-Type model of muscle Dynamic twitch response from this model The motor unit, muscle fiber types The size principle, muscle recruitment and rate coding The regulation of isometric force.	• Reading Quiz #2 (K&S Chapters**) 33 The organization of movement 34 The motor unit and muscle action
4.	M	9/8	**MATLAB tutorial:**	• HW 1 due at beginning of class • HW 2 handed out, due on 9/17
5.	W	9/10	**MATLAB tutorial:**	• Ch 2 of *Neuromechanics* handed out
6.	M	9/15	**Fundamentals of limb mechanics:** Frames of reference and Homogeneous transformations	Reading Quiz #3 Sections 2.1-2.3 of *Neuromechanics*
7.	W	9/17	**Fundamentals of limb mechanics:** Kinematic descriptions of limbs, Kinematics of open linkage chains	• HW 2 due at beginning of class
8.	M	9/22	**Fundamentals of limb mechanics:** The Jacobian for limb kinematics	Reading Quiz #4 Sections 2.4-2.7 of *Neuromechanics* • HW 3 handed out, due on 10/6
9.	W	9/24	**Fundamentals of limb mechanics:** The Jacobian for limb kinetics	
10.	M	9/29	**Class time used to discuss projects**	• Ch 3 of *Neuromechanics* handed out
11.	W	10/1	**Fundamentals of tendon actuation:** Moment arms, modeling moment arms Activation, torque and force spaces Muscle redundancy Muscle co-contraction	Reading Quiz #5 Sections 3.1-3.6 of *Neuromechanics*
12.	M	10/6	**Fundamentals of tendon actuation:** **Midterm Exam I Review**	• HW 3 due at beginning of class
13.	W	10/8	**Midterm Exam I (In-class)**.	
14.	M	10/13	**Optimization:** Linear Programming Application of linear programming to muscle coordination	• Reading Quiz #6 Sections 3.7-3.10 of *Neuromechanics* • HW 4 handed out, due on 10/22

Lecture			*Topic*	***Readings/HW/Project/Quizzes/Tests/Notes***
15.	W	10/15	**Optimization:** Introduction to Sage, an alternative computational environment	• Ch 4 of *Neuromechanics* handed out
16.	M	10/20	**Class time used to discuss projects**	
17.	W	10/22	**Optimization:** Graphical interpretation of Linear Programming Introduction to input and output spaces and feasible force sets	Reading Quiz #7 Ch 4 of *Neuromechanics* • HW 4 due at beginning of class
18.	M	10/27	**Feasible and versatile function:** Muscle redundancy, revisited Muscle co-contraction, revisited Computational Geometry	• HW 5 handed out, due on 11/5. HW 5 is the project review
19.	W	10/29	**Feasible and versatile function:** Singular value decomposition Manipulability and manipulating force ellipsoid	
20.	M	11/3	**Analysis:** Monte Carlos Methods Hypothesis testing with Monte Carlo methods Examples from the literature	
21.	W	11/5	**Project review presentations**	
22.	M	11/10	**Midterm Exam II Review**	• HW 6 handed out, due on 11/19
23.	W	11/12	**Midterm Exam II (In-class)**	
24.	M	11/17	**Class time used to discuss projects**	
25.	W	11/19	**Open topics**	• HW 6 due at beginning of class • Ch 5 of *Neuromechanics* handed out
26.	M	11/24	**Open topics**	
		11/26-11/30	**Thanksgiving Holiday**	**No class**
27.	M	12/1	**Neuromechanics topics**	Reading Quiz #8 Ch 5 of *Neuromechanics*
28.	W	12/3	**Student project presentations**	**Project Reports Due December 10**