BME 504/BKN 504: Neuromuscular Systems Fall 2013

Course Information v1.0

Professor: Francisco Valero-Cuevas
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213.821-2084

Office hours: TBA

or by appointment

Class: M & W 11:00 AM to 12:20 PM
Location: OHE100D
Course for graduate students or by permission from the instructor to advanced undergraduates.
3-units

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

TA: Sarine Babikian <sbabikia@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 signals, muscle contraction, and biomechanical output
- 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. Final project 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 Mondays 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 Mondays (http://bbdl.usc.edu/ENH) from 4 to 5 PM in HNB 100. 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,open 8:30 a.m. - 5:00 p.m. Monday through Friday, (213) 740-0776.

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Course Syllabus v1.0

Color code: Black is for general course content and material. Red is for Reading Quizzes and HW. Blue is for special dates. Green is for Seminars and other activities.

Lecture			*Topic*	*Reading/HW Assignments*	*Notes*
1.	M	8/26	**Introduction** Course logistics Neuromechanics Overview of forward and inverse biomechanical models The stretch reflex	Ch1 of McMahon "*Muscles, Reflexes, and Locomotion*" handed out	
2.	W	8/28	**MATLAB tutorial:** Simulation of limbs Introduction of ode45	• Ch 1 of *Neuromechanics* handed out • Read Ch1 of McMahon "*Muscles, Reflexes, and Locomotion*"	By Sarine Babikian. If not familiar with MATLAB see this book
		9/ 2	**Labor day, University Holiday**		**No class**
3.	W	9/4	**Muscle:** Simple Hill-Type model of muscle Dynamic twitch response from this model	Reading Quiz #1 • Ch 1 of *Neuromechanics* • Ch1 of McMahon "*Muscles, Reflexes, and Locomotion*" HW 1 handed out	
4.	M	9/9	**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 #2 (K&S Chapters**) 33 The organization of movement 34 The motor unit and muscle action	
5.	W	9/11	**Motor units:** The motor unit, muscle fiber types The size principle, muscle recruitment and rate coding The regulation of isometric force	HW 1 due at beginning of class Other HW TBA.	
6.	M	9/16	**Fundamentals of limb mechanics:** Frames of reference and Homogeneous transformations. Homework description	Reading Quiz #3 Ch 2 of *Neuromechanics*	ENH Seminar: Madhusudhan Venkadesan
7.	W	9/18	**Fundamentals of limb mechanics:** Kinematic descriptions of limbs Kinematics of open linkage chains		
8.	M	9/23	**Fundamentals of limb mechanics:** The Jacobian for limb kinematics.		
9.	W	9/25	**Fundamentals of limb mechanics:** The Jacobian for limb kinetics		
10.	M	**9/30**	**Class time used to discuss projects**		ENH Seminar: James Finley

Lecture			*Topic*	*Reading/HW Assignments*	*Notes*
11.	W	10/2	**Fundamentals of tendon actuation:** Moment arms, modeling moment arms. Activation, torque and force spaces	Reading Quiz #4 Ch 3 of *Neuromechanics*	
12.	M	10/7	**Fundamentals of tendon actuation:** Introduction to feasible force sets Muscle redundancy Muscle co-contraction **Midterm Exam I Review**		ENH Seminar: Eugene Izhikevich
13.	W	**10/9**	**Midterm Exam I (In-class)**.		
14.	M	10/14	**Optimization:** Linear Programming Graphical interpretation of Linear Programming.	Reading Quiz #5 Ch 4 of *Neuromechanics*	ENH Seminar: Stacey Finley
15.	W	10/16	**Optimization:** Application of linear programming to muscle coordination.		
16.	M	**10/21**	**Class time used to discuss projects**		
17.	W	10/23	**Feasible and versatile function:** Singular value decomposition. Manipulability and manipulating force ellipsoid.	Reading Quiz #6 Ch 5 of *Neuromechanics*	
18.	M	10/28	**Feasible and versatile function:** Computational Geometry		
19.	W	10/30	**Feasible and versatile function:** Computational Geometry		
20.	M	11/4	**Analysis:** Monte Carlos Methods.	Reading Quiz #7 Ch 6 of *Neuromechanics*	ENH Seminar: Stefan Schaal
21.	W	11/6	**Analysis:** Hypothesis testing with Monte Carlo methods **Midterm Exam II Review**		
22.	M	**11/11**	**Class time used to discuss projects**		
23.	W	**11/13**	**Midterm Exam II (In-class)**		
24.	M	11/18	**Dynamics of tendon-driven systems:** Quasi-static function	Reading Quiz #8 Ch 7 of *Neuromechanics*	ENH Seminar: Tim Carroll
25.	W	11/20	**Dynamics of limbs:** Equations of motion for a double pendulum		
26.	M	11/25	**Dynamics of limbs:** Simulation of a double pendulum		ENH Seminar: Ranulfo Romo
		11/27-11/30	**Thanksgiving Holiday**		**No class**
27.	M	**12/2**	**Student project presentations**		
28.	W	**12/4**	**Student project presentations**		**Project Reports Due December 10**