BME 504/BKN 504: Neuromuscular Systems Fall 2015

USC University of Southern California

USC Viterbi School of Engineering — *The Viterbi iPodia (ViP) Program*

Course Information v3.1

Pilot iPodia course among The University of Southern California, Tecnológico De Monterrey (Guadalajara), and UNAM (Mexico City)

Professor: Francisco Valero-Cuevas
404 RTH
valero@usc.edu
Skype: bme504

Office hours: Mondays 5-6 PM, RTH 404

Skype Office hours: Tuesdays 5-6 PM (most weeks)

Class: M & W 11:00 AM to 12:20 PM
Location: RTH 217
Course for graduate students or by permission from the instructor to advanced undergraduates.
3-units

Web Page: https://courses.uscden.net USC's Distance Education Network

TA: Chunji Wang <chunjiw@gmail.com>
Skype: bme504

Office hours: Tuesdays 4-5 PM, DRB 145
Skype Office hours: Tuesdays 3-4 PM

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, 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 nervous system
- Considering the structure and function 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
- Understanding the concepts of muscle and kinematic redundancy
- Appreciating the role of biomechanics in the clinical evaluation of disabilities
- Describing the set of feasible commands used by the nervous system to control limb function
- Modeling, simulating, optimizing and animating a neuromuscular limb
- Designing experiments to evaluate the severity of a neuromuscular pathology

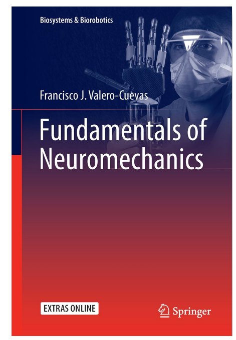
Academic Conduct:
Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism at http://www.usc.edu/student-affairs/student-conduct/grad_ai.htm. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct/.

Grading:

Homework	15% (~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:
- Fundamentals of Neuromechanics by FJ Valero-Cuevas, *Springer-Verlag London. Series on Biosystems and Biorobotics, Vol 8 (2016)* *http://www.springer.com/us/book/9781447167464*
- Articles from the literature to 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)
- Numerical Computing with MATLAB (free online book) *http://www.mathworks.com/moler/index_ncm.html*



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**:** Students requesting academic adjustments based on a disability must contact Disability Services and Programs (DSP) to obtain a letter of verification each semester. 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 v3.1

Lecture		*Date*	*Topic*	*Readings/HW/Project/Quizzes/Tests/Notes*	*Chapter*
1.	M	8/24	**Course 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	**1**
2.	W	8/26	**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	
3.	M	8/31*	**Python/Sage tutorial:** PhD Student Brian Cohn	• HW 1 handed out, due on 9/9. Also, see MATLAB book if needed	
4.	W	9/2*	**Muscle:** Post-doctoral Fellow Dr. Kian Jalaleddini 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 • Appendix A of *Neuromechanics* handed out	
	M	9/7	**Labor day, University Holiday**	**No class**	
5.	W	9/9	**Linear Algebra and Kinematics of Rigid Bodies**	Reading Quiz #3 Appendix A of *Neuromechanics* • HW 1 due at beginning of class	**Appendix A**
6.	M	9/14	**Fundamentals of limb kinematics:** Frames of reference and homogeneous transformations	Reading Quiz #4 Ch.2 of *Neuromechanics* • HW2 handed out, due on 9/23	**2**
7.	W	9/16	**Fundamentals of limb mechanics:** Kinematic descriptions of limbs, Kinematics of open linkage chains		**3**
8.	M	9/21	**Fundamentals of limb mechanics:** The Jacobian for limb kinematics	Reading Quiz #5 Ch. 3 of *Neuromechanics*	**3**
9.	W	9/23	**Class time to discuss projects**	• HW 2 due at beginning of class • HW3 handed out, due on 9/30	
10.	M	9/28	**Fundamentals of tendon actuation:** Moment arms, modeling moment arms Activation, torque and force spaces The control of joint torques is underdetermined	Reading Quiz #6 Ch. 4 of *Neuromechanics*	**4**
11.	W	9/30	**Fundamentals of tendon actuation:** Muscle redundancy and co-contraction Muscle excursions The control of tendon excursions is overdetermined	• HW 3 due at beginning of class • HW4 handed out, due on 10/5	**4**
12.	M	10/5	**Midterm Exam I Review**	• HW 4 due at beginning of class	

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13.	W	10/7*	**Midterm Exam I (In-class)**		
14.	M	10/12	**Numerical optimization for underdetermined systems** Linear Programming Application of linear programming to muscle coordination	• Reading Quiz #7 Ch. 5 of *Neuromechanics*	**5**
15.	W	10/14	**Numerical approaches limb and musculotendon kinematics:** Joint vs. musculotendon velocities Neural control of eccentric vs. concentric contractions	• HW 5 handed out, due on 10/21 Reading Quiz #8 Ch. 6 of *Neuromechanics*	**6**
16.	M	10/19	**Feasible and versatile function:** Introduction to input and output spaces and feasible force sets Zonotopes, polytopes, Minkowsky sums, oh my!		**7**
17.	W	10/21	**Feasible function with task constraints:** Muscle redundancy, revisited Muscle co-contraction, revisited Computational Geometry	• HW 5 due at beginning of class • HW 6 (project review) handed out, due on 11/4	**7, 8**
18.	M	10/26	**Class time used to discuss projects**	Reading Quiz #9 Ch 7 of *Neuromechanics*	
19.	W	10/28	**Numerical approaches to feasible function:** Vertex enumeration		**8**
20.	M	11/2	**Analysis tools:** Singular value decomposition Manipulability and manipulating force ellipsoids Monte Carlos Methods Hypothesis testing with Monte Carlo methods	Reading Quiz #10 Ch. 8 of *Neuromechanics*	
21.	W	11/4	**Project review presentations**	• HW 6 (project review) due in class • HW 7 handed out, due on 11/18	
22.	M	11/9	**Midterm Exam II Review**		
23.	W	11/11	**Midterm Exam II (In-class)**		
24.	M	11/16	**Class time used to discuss projects**		
25.	W	11/18	**Guest Lecture by Prof. Art Kuo**	• HW 7 due at beginning of class Reading Quiz #11 Ch. 9 of *Neuromechanics*	**9**
26.	M	11/23	**The nature and structure of feasible sets** **Implications**		**9, 10**
		11/25- 11/29	**Thanksgiving Holiday**	**No class**	
27.	M	11/30	**Implications and examples from the literature**	Reading Quiz #11 Ch. 10 of *Neuromechanics*	**10**
28.	W	12/2	**Student project presentations**	**Project Reports Due December 13th**	