DEPARTMENT OF MECHANICAL ENGINEERING
GEORGE R. BROWN SCHOOL OF ENGINEERING
RICE UNIVERSITY

MECH 497/597: NEUROMUSCULOSKELETAL MODELING (3 Credits)

Fall 2024

SECTION I. CONTACT INFORMATION

- Instructor: B.J. Fregly, Ph.D.
- Office: Mechanical Engineering Building 234
- Email: fregly@rice.edu
- Office Hours (MEB 234):

  Tuesdays: 12:05 PM - 1:00 PM

  Wednesdays: 10:30 PM - 11:30 PM

  Thursdays: 12:05 PM - 1:00 PM
- Grader: Rob Salati
- Office: Ryon Engineering Lab 101
- Email: rob.salati@rice.edu

SECTION II. COURSE INFORMATION

- Pre-requisites: MECH 310 and CAAM 210 (or by permission of instructor)
- Lecture Schedule:

  Thursdays and Thursdays: 10:50 AM – 12:05 PM
- Location:

  Herman Brown Hall 227
- Optional Textbook:

  Thomas K. Uchida and Scott L. Delp. Biomechanics of Movement – The Science of Sports, Robotics, and Rehabilitation. The MIT Press, Cambridge, MA, 2021. Available from Amazon.com.
- Required Software:

  OpenSim version 4.5 (Windows and Mac) musculoskeletal modeling software. Available for free online at:

  https://simtk.org/projects/opensim

  Notepad++ (Windows) or BBEdit (Mac) text editor. Available for free online at:

  https://notepad-plus-plus.org/

  https://www.barebones.com/products/bbedit/

  Matlab R2023a or newer (Windows or Mac). Available for free from Rice.

  Neuromusculoskeletal Modeling (NMSM) Pipeline software that adds Model Personalization and Treatment Optimization functionality to OpenSim (https://nmsm.rice.edu/). Developed by the instructor's lab and available for free online at:

  https://simtk.org/projects/nmsm

- Web-based Teaching Materials:
  Dr. Scott Delp's lab at Stanford University has developed a wealth of teaching materials on musculoskeletal computer modeling and simulation using the OpenSim software developed by his research group. Available for free online at:
  https://opensimconfluence.atlassian.net/wiki/spaces/OpenSim/overview
- Teaching Philosophy:
  If interested, you can read the instructor's teaching philosophy on his lab website:
  http://rcnl.rice.edu/PDFs/teaching_philosophy.pdf
- Teaching Methodology:
  The instructor will utilize PowerPoint presentations, the blackboard, and interactive software demonstrations to facilitate learning in this course. Students are strongly encouraged to ask questions during class. The only dumb question is the question that you don't ask! Each lecture, the instructor will provide an outline of the concepts to be covered so that students will know where they are in the course material. Class notes (and possibly lecture video recordings) will be posted on Canvas after each lecture. We will also have periodic "Simulation Session" lectures where students will bring their laptops to class and work with the instructor on various modeling and simulation exercises. If you do not have a laptop, you will need to work with another student in class who has one.
- Course Description:
  Introduction to computer modeling and simulation of the human neuromusculoskeletal system. Topics include measurement of human movement, 3D kinematic modeling, inverse and forward dynamic simulations, muscle-tendon modeling, muscle and joint contact force estimation, neural control modeling, personalization of neuromusculoskeletal models, and optimization of orthopedic surgery and neurorehabilitation treatments for individuals with movement impairments (e.g., caused by osteoarthritis, stroke, cerebral palsy, cancer). Programming proficiency in Matlab is required. Graduate/Undergraduate Equivalency: MECH 597. Mutually Exclusive: Credit cannot be earned for MECH 497 and MECH 597.
- Course Design:
  This course is modeled after the graduate course ME 382 "Modeling and Simulation of Human Movement" developed by Dr. Scott Delp at Stanford University. Variations of this course are also taught at the University of Texas at Austin, the University of Wisconsin, Wake Forest University/Virgnia Tech, and the University of Tennessee. The instructors from each of these courses (including the present course at the Rice University) have agreed to share all course materials to create a world-class instructional opportunity. Consequently, you will be benefiting from extensive work done by instructors at six institutions while taking this course.
- Course Purpose:
  The goal of this course is to teach you how to develop dynamic models, analyses, and simulations of the human neuromusculoskeletal system for different types of movement. Learning will be achieved through a series of traditional lectures, interactive modeling and simulation lectures, simulation laboratories, and simulation projects. The focus will be on the system involved in producing voluntary movement - the human neuromusculoskeletal system. Mathematical models will be developed for each component of the system and implemented in the OpenSim musculoskeletal modeling software, with some models also implemented in the NMSM Pipeline software developed in the instructor's lab. Students will create models, perform computer simulations, and analyze the results to gain insight into movement biomechanics and control.

- Course Objectives:

  By the end of the course, you should be able to do the following:

  - *Neuromusculoskeletal modeling*. Develop complex three-dimensional musculoskeletal models, develop muscle-tendon models possessing force-length-velocity properties, develop neural control models that emulate the characteristics of the human motor control system, and develop personalized neuromusculoskeletal models that represent the unique characteristics of a specific subject.
  - *Neurousculoskeletal analyses*. Calculate joint motions and muscle moment arms from experimental surface marker data using musculoskeletal geometry principles, calculate joint moments from experimental force and motion data using inverse dynamics principles, predict muscle activations and forces during movement using optimization principles, and analyze the inter-dependence of muscle activations using muscle synergy analyses.
  - *Neuromusculoskeletal simulations*. Create three-dimensional forward and inverse dynamic simulations of musculoskeletal motion that reproduce experimentally measured movements and predict new movements for which no experimental data are available (e.g., following a clinical treatment).

- Absence Policy:

  The instructor is aware that the students participating in **university-sponsored** extracurricular activities may, on rare occasions, need to miss a lecture during the semester. In such cases, it is the student's responsibility to obtain the missed material from the instructor or another student in the course.

- Topics Covered:

  The course will be divided into six parts:

  1) Background
  2) Skeletal modeling
  3) Muscle-tendon modeling
  4) Neural control modeling
  5) Model personalization
  6) Treatment optimization

  By the end of the course, you should be able to put the six parts together and be well prepared to pursue future projects involving neuromusculoskeletal modeling, simulation, and optimization.

SECTION III. GRADING POLICY

- Grading:

  Since this course is built around computer simulations, grading will involve primarily simulation labs and simulation projects. Students enrolled in MECH 497 and MECH 597 will be graded as follows:

Class Participation/Attendance	10%
Simulation Labs (minimum of 5)	40%
Simulation Projects (3)	45%
Share Your Life Story in 5 Minutes	5%

  Students enrolled in MECH 597 will complete a more extensive third simulation project containing additional items not required for students enrolled in MECH 497.

- Collaboration

  Students are encouraged to collaborate with and learn from others in the course on simulation labs and simulation projects. HOWEVER, direct copying of another student's work is not permitted, and students must complete each assignment either individually or with one partner (selected by mutual agreement).

  Late assignments will not be accepted. However, since difficult weeks will arise during the semester, each student will be permitted two late assignments (excluding the third simulation project) turned in not more than one week after the original due date. No prior notice need be given to the instructor when you choose to cash in a late assignment. Hardship cases will be considered on an individual basis only if the instructor has been contacted *before* the due date of the assignment.

- Attendance

  Students are expected to attend all lectures. Since most of the course material is not available in any textbook, it will be critical for students to attend lectures regularly.

- Grading

  Course Grades:

A+	98-100
A	93-97
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
F	below 59

SECTION IV. HOLIDAYS - NO SCHEDULED CLASSES

1. Midterm Recess (Tuesday) 10/15/2024
2. Election Day (Tuesday) 11/5/2024
3. Thanksgiving Day (Thursday) 11/28/2024

SECTION V. UNIVERSITY POLICIES

- Rice Honor Code:

  All student conduct associated with this course must comply with the Rice Honor System. While participation in study groups is strongly recommended, the work that you submit for grading must be your own. This policy applies to homework assignments and exams.

- Rice Disability Support:

  Any student with a disability requiring accommodations is encouraged to contact the instructor outside of class. Information regarding disability accommodations and other support can be obtained at http://www.dss.rice.edu/.

- Syllabus Policy:

  Information contained in the course syllabus, other than the Absence Policy, may be subject to change with reasonable advance notice, as deemed appropriate.

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