Master Course Description for *Wearable Robotics*

Title: Wearable Robotics

Credits: 3

Course Description: This course serves as an introduction to the field of wearable robotics, concentrating primarily on lower-limb exoskeletons and prostheses. The course material draws heavily from primary scientific literature, and students will gain fundamental knowledge of modern approaches used for the design, control, and evaluation of wearable robotic systems for human locomotion. Topics of discussion include neural control of movement, neuromusculoskeletal modeling, robotic control architectures, applications of machine learning, neural interfacing, and tools for real-world physiological evaluation of wearable robots. The course will present background material in a lecture/open discussion format, with students' assignments covering independent reading, analytical questions and computer simulations. The course builds to a final team project on a sub-topic of wearable robotics.

Prerequisite: None

Coordinator: Kim Ingraham, Assistant Professor, Electrical & Computer Engineering

Goals: The goal of this course is to expose students to modern concepts for designing and evaluating wearable robotics systems for human locomotion. Students will leave this course with a greater understanding of the fundamental neuromotor control principles that govern human locomotion, the key design principles for the mechanical design of wearable robots, and the strategies for effectively controlling wearable robotic systems to meet a variety of physiological objectives. Through the course assignments, students will learn to engage with and parse primary scientific literature, use field-standard open-source neuromusculoskeletal modeling software, and work with real open-source datasets to process and analyze biomechanical data. Students will demonstrate their knowledge in a final project where they perform a comprehensive literature review on the sub-topic of their choosing, formulate a relevant hypothesis, and identify and analyze a relevant open-source dataset to test this hypothesis.

Learning Objectives: By the end of the course, students will be able to:

1. Explain the neuromusculoskeletal systems that enable human locomotion.
2. Describe the principles of developing physiologically inspired controller architectures for wearable robots.
3. Critically discuss state-of-the-art approaches and future directions for evaluating the impact of assistive robotic devices in the real world.

Textbook: There is no textbook required for this course. All reading material drawn from the scientific literature will be made available through the course Canvas website. The following textbooks may be useful to reinforce course concepts:

- Uchida, Thomas K. and Delp, Scott L. *Biomechanics of Movement: The Science of Sports, Robotics, and Rehabilitation.* MIT Press, 2020 (eBook available for check-out from UW Library)
- Winter, David A. *Biomechanics and motor control of human movement.* John Wiley & Sons, 2009 (PDF available on Canvas)
- Pons, José L. *Wearable robots: biomechatronic exoskeletons.* John Wiley & Sons, 2008 (PDF available on Canvas)

Prerequisite by Topic: Students must have experience or proficiency using MATLAB (or similar) programming.

Topics:

- Overview of human locomotion, simple models of gait
- Basic neuromusculoskeletal physiology and properties
- Sensing, proprioception, neural motor control
- Neuromusculoskeletal modeling and its applications in prosthetic and exoskeleton control
- Passive exoskeletons
- Tools for the experimental measurement of gait
- *Field trip:* Real experimental data collection session in the AMP lab
- Design principles for wearable robots
- Wearable robotic control (low level, mid level, and high level controller architecture)
- Machine learning applications in wearable robotics
- Human-in-the-loop optimization
- Studying preference and perception with wearable robotic systems
- Neuromodulation: spinal stimulation and functional electrical stimulation
- Neural interfacing and advanced surgical techniques

Course Structure: The class meets for two 80-minute class periods per week that are dedicated to lecture and interactive discussion. Weekly quizzes and/or interactive polls will be used to assess learning and promote attendance. Weekly homework assignments are each two parts: (i) a reading assignment with critical review and (ii) a programming assignment (either MATLAB or OpenSim). Homework is assigned weekly for the first six weeks of the class, and then students should shift their focus to working on the project for the remainder of the term. The course culminates in one small team project (2-3 students), in which teams perform a literature review on a relevant topic of their choosing, identify and critically evaluate an open-source dataset, and process/analyze this dataset to answer a scientific question of interest. Teams will present their projects to the class.

Computer Resources: Weekly, interactive polls/quizzes will be administered, and students require a smartphone or laptop. Course assignments require a modern PC or Mac capable of running the following programs:

- **MATLAB** will be used throughout this course. Students enrolled at UW can download MATLAB and Simulink free of charge using their UW credentials.
- **OpenSim** is an open-source musculoskeletal modeling and simulation software that will be used on some assignments. OpenSim (version 4.4) can be downloaded for free at https://simtk.org/frs/index.php?group_id=91 for both Windows and Mac.

Grading: Overall Participation and Quizzes (10%), Homework (45%), Final Project (Paper) (25%), Final Project (Presentation) (20%)

Prepared by: Kim Ingraham

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