University of Utah

ME EN 7960-001

Wearable Robotics

Meeting Time: Monday & Wednesday 11:50 AM-01:10 PM
Location: WEB 2460
Office Hours: Monday and Wednesday, 01:10 PM -2:00 PM

Instructor:

Dr. Tommaso Lenzi, PhD
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Course Objective:
This course will give students a broad overview of Wearable Robotics by focusing on design, modeling, and control of powered exoskeletons and robotic limb prostheses. The course is organized into lectures, readings, and discussions on fundamental areas of wearable robotics such as robot morphology, advanced actuation systems (e.g., SEA, VIA, CVT), sensing, and related control strategies. Emerging applications areas in the medical and industry sectors will also be discussed through the analysis of specific case studies. Students will learn how to design and control wearable robotics system through homework, projects, and lab exercises. Students will have the opportunity to work on an open-source robotic leg prosthesis previously developed at the Bionic Engineering Lab. This device will be used by students as a tool to apply the knowledge acquired during the course.

Prerequisite:
Students should have taken: (1) Intro to Robotics (ME EN 5220/6220) or equivalent, (2) Classical Control Systems (ME EN 6200) or equivalent. Students not meeting the prerequisites should speak with the instructor.

Text: Readings (research papers and book chapters) will be provided be the instructor.

Course Webpage: Canvas: https://utah.instructure.com/courses/796584/

Grading:

Participation and Quizzes	:	50%
Homework:		30%
Final Project:		20%

Detailed Schedule:

Week	Date	Topic	Reading
1	08/22 M	Introductions	Syllabus How to read for grad school
	08/24 W	Overview	Herr JNER 2009 Dollar TRO 2009 Open-source Leg - Hackster.io
		Robot Morphology	
2	08/29 M	(1) Kinematic Design	Zoss et al. TMECH 2006 Accoto et al RAM 2014
	08/31 W	(2) Cable based	Walsh et al ICRA 2011 Asbeck et al. RAM 2014 Mao et al TRO 2012
3	**09/05**	**Labor Day**	**NO CLASS**
	09/07 W	(3) Kinematic Compatibility	Schiele and van der Helm TNSRE 2006 Cempini et al TMECH 2015
		Actuation Systems	
4	09/12 M	(1) DC motors - 1	Principles and Properties of high dynamic DC Miniature Motors
	09/14 W	(2) DC motors - 2	Principles and Properties of high dynamic DC Miniature Motors
5	09/19 M	(3) Series and Parallel Elastic Actuators	Veneman et al. IJRR 2006.pdf Rouse et al IJRR 2014.pdf
	09/21 W	(4) Parallel and Parallel Elastic Actuators	Au and Herr RAM 2008 Beckerle et al TMECH 2017
6	09/26 M	(5) Variable Stiffness Actuators	Wolf et al. TMECH 2016 Shepherd et al TNSRE 2017
	09/28 W	(6) Variable Transmission Actuators	Everarts et al IROS 2017 Ingvast et al IJRR 2006 Tran et al RAL 2019
7	10/03 M	(7) Hydraulic/Pneumatic Actuators	Pillai et al ICRA 2011 Lambrecht et al ICRA 2009 Gordon et al JBiomech 2006
	10/05 W	**Work on the Open-Source Leg Project**	**Work on the Open-Source Leg Project**
	10/10	**Fall Break**	**NO CLASS**
	10/12	**Fall Break**	**NO CLASS**
		Biosignals	

8	10/17 M	(1) Gait Kinematics	Kuo Movement Science 2007.pdf
	10/19 W	(2) Electromyography	De Luca, Practicum on sEMG v1.5
9	10/24 M	(3) Indirect Calorimetry	Instructor's notes
	10/26 W	(4) Pressure sensing and comfort	Schiele et al ICRA 2011 Donati et al Sensors 2013
10	10/31 M	**Work on the Open-Source Leg Project**	**Work on the Open-Source Leg Project**
		Control Systems	
	11/02 W	(1) Low-level Control	Vallery et al. IROS 2007 Paine et al TMECH 2014
11	11/07 M	(2) Mid-level Control *Impedance*	Nagarajan et al RAS 2016 Karavas et al RAS 2015
	11/09 W	(3) Mid-level Control *Kinematic*	Martınez et al. TRO 2017 Lenzi et al. TNSRE 2013
12	11/14 M	(4) Mid-level Control *Electromyography*	Hoover et al TMECH 2013 Kigouchi et al TNSRE 2012
	11/16 W	(5) High-level Control *Finite-state Machine*	Varol TBME 2015 Simon TNSRE 2017
13	11/21 M	(6) High-level Control *Phase-based*	Quintero IROS 2016 Sugar JMechRob 2015
	11/23 W	**Work on the Open-Source Leg Project**	**Work on the Open-Source Leg Project**
		Application Areas	
14	11/28 M	Robotic Arm Prosthesis	Lenzi et al. TMECH 2016 Controzzi et al. TNSRE 2017
	11/30 W	Robotic Leg Prosthesis	Lawson et al RAM 2014 Goldfarb et al. Science TrMed 2015
15	12/05 M	Medical Exoskeletons	Esquenazi et al PMR 2017 Wang et al TNSRE 2015
	12/07 W	Military Exoskeleton	Quinlivan SciRo 2017 Ding SciRo 2018
16	**12/14**	**FINAL EXAM**	**12:30AM – 12:30PM**

Homework

Homework assignments are related to the conceptual design/control/analysis of wearable robots and will be based on Matlab/Simulink.

HW 1 – Conceptual Design of Advanced Actuation Systems

Based on considerations on Human Biomechanics students will dimension an advanced actuation system such as the one seen in class. (e.g., Dimension a series elastic actuator to minimize the energy consumption of a powered ankle prosthesis)

HW 2 – Biosignal Processing for Human Intention Detection

Starting from a dataset of bio-signals provided by the instructor students will develop algorithm for user intention detection and/or effort assessment (e.g., Analysis of electromyography EMG activation under different exoskeleton-mediated assistance)

HW 3– Closed-loop Control of Advanced Actuation Systems

Based on the dynamic models of advanced actuation system students will develop and simulate a low-level closed-loop control system for a wearable robot

Project

We will develop a new generation of an open-source robotic leg prosthesis previously developed at the Bionic Engineering Lab. You can find more information on the current generation of the open-source robotic leg at this link:

https://www.hackster.io/open-source-bionics/open-source-powered-prosthetic-leg-56be8e

The project will be supported by the following teaching assistants, who they will meet

Lukas Gabert, PhD (lukas.gabert@utah.edu)

Sergei Sarkisian (sergei.sarkisian@utah.edu)

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