University of Utah

ME EN 7240
Haptics for Virtual Reality, Teleoperation, and Physical Human-Robot Interaction
Spring 2019

Meeting time: Tuesday & Thursday 10:45-12:05, FASB 101
Office Hours: By appointment

Instructor:
Dr. Jake Abbott, office: MEK 2016, e-mail: jake.abbott@utah.edu, phone: (801) 585-6672

Course Objectives:
This course will give students a broad overview of the topic of haptics applied to virtual reality, teleoperation, and physical human-robot interaction. Haptics is the study of touch: touch sensing, perception, cognition, and feedback. The course is organized into lectures, readings and discussions on classical and current topics in haptics, and a hands-on programming project. Through the lectures, readings, and discussion, students will learn to think critically about prior work presented in the haptics literature as well as their own work. Through the project, students will create/recreate an advanced haptic system.

Prerequisites:
Students should have taken: (1) Intro to Robotics (ME EN 5220/6220) or equivalent, (2) Classical Controls (ME EN 5200/6200) or equivalent, (3) any C++ programming course. Any student not meeting ALL THREE of these prerequisites should speak with the instructor.

Text:
There is no required textbook. All readings are provided as pdf documents on the course web page.

Course Web Page:
Canvas: http://utah.instructure.com

Grading:

Attendance:	35%
Daily quizzes on reading:	35%
Final Project:	15%
Comprehensive Exam:	15%

Readings and Attendance:
A significant portion of this course involves reading classical and current papers on a wide variety of topics in the field of haptics, and discussing those important works together. As a consequence, reading in this course is more important than it typically is in engineering courses. Students are expected to do the reading for a given day before coming to class. This is not a suggestion; it is mandatory. There is not enough time in the lectures to cover all of the required material, so reading is crucial for a complete understanding of the material. The homework component of the course is diminished to provide more time each week for reading.

It is advised that students take notes on key points and contributions of the papers that they read, and also make note of questions and confusing elements for further discussion. These notes will also help students study for the comprehensive final exam. During the reading, students should adopt a strategy that lives somewhere in between skimming and a deep knowledge; don't let yourself get bogged down in anything for too long because it can be discussed in class. Students should understand the key contributions and methods used, but need not have a deep understanding of the analytical development.

To account for the importance of doing the readings and participating in the discussions, attendance will be mandatory. Students will have two free dropped days (intend for them to be used only in the event of sickness and family emergencies), but any missed day beyond that will count against the attendance grade, regardless of the reason.

In addition, there will be quizzes each day at the beginning of class to test reading comprehension. The quizzes will be designed to be fairly easy for students who have done the reading in the spirit described above. Students will have two free dropped quizzes that will not count against the quiz grade; in many cases these will correspond to the two dropped attendance days, but regardless, the two lowest quiz scores will be dropped.

Project:
There will be a project during (approximately) the final month of the course. Projects will be done in teams of two. Projects will not involve building any hardware. Rather, they will take the form of (1) implementing methods that were covered in the readings on actual haptic interfaces, so that the entire class can haptically experience things they have only read about, or (2) conducting a new experiment that advances the state-of-the-art in haptics. More details about the project will be provided at the appropriate time. We have a variety of haptic devices, and a number of working software examples, which students can use to quickly begin a new project.

Comprehensive Exam:
There will be a comprehensive final exam to test the knowledge that is retained by the students. The comprehensive exam will be similar in spirit to the quizzes and the discussions of the readings.

Cheating and Plagiarism:
Anyone found to be cheating on a quiz or plagiarizing reports or papers of any kind, will receive some form of punishment, up to and including receiving an E for the class. Keep your eyes on your own work during quizzes and exams to avoid the appearance of cheating. Anyone who helps another student cheat is just as guilty as the person receiving the help. This is a very serious topic.

Posting any material from this course online, including both your own work and solutions provided by the Instructor, is considered a serious ethics violation that will be treated like any other cheating violation, including potential reversal of grades (and even degrees) retroactively.

In graduate school, your reputation among your professors is much more important than your GPA (considering how you will get your next job). It is always better to take the ethical high road than to unethically try to improve your grade.

You must complete the Academic Integrity module on Canvas within the first two weeks of this course, of you will be asked to leave the course.

Further Reading:
I will try to provide a broad overview of the field of haptics, but my background is Mechanical Engineering and Robotics, so the course and my knowledge certainly skews that way.

In Canvas, I have provided the chapter *Haptics*, by Hannaford and Okamura, from the *Springer Handbook of Robotics* (2008). This is a good reference with a broad overview of the field.

CHAI3d is a platform-agnostic C++ simulation framework to interface commercial (and custom) haptic devices with real-time haptic and graphical simulations: http://www.chai3d.org/

We will read a number of chapters from the edited book *Haptic Rendering* by Lin and Otaduy (Eds.). For a deeper treatment of some of the more "computer science" elements of haptic rendering, students should look at the other chapters of that book. It also has other good haptics overview chapters.

For a broad overview of the field of haptics from a neuroscience perspective, see the edited book *Human Haptic Perception* by Grunwald (Ed.).

For a complete introduction to the field of psychophysics, see *Psychophysics: The Fundamentals, Third Edition*, by Gescheider.

The instructor reserves the right to make changes to any course policies. Students will be notified of any changes.

Wk	Date	Topic	Reading
1	8-Jan	Introduction and Overview	
	10-Jan	Physiology of Haptic Perception	Lederman and Klatzky, 2009
2	15-Jan	Design of Haptic Interfaces	Hayward and Maclean, 2007
	17-Jan	Methods of Haptic Rendering	Lin and Otuduy, Chapters 8 and 15
3	22-Jan	Methods of Haptic Rendering	Lin and Otuduy, Chapters 16 and 17
	24-Jan	Virtual Mechanisms and Virtual Fixtures	Clover et al., 1997; Nahvi et al., 1998; Peshkin et al., 2001; Abbott et al., 2007
4	29-Jan	Stability of Haptic Rendering	Colgate and Brown, 1994; Gillespie and Cutkosky, 1996
	31-Jan	Stability of Haptic Rendering	Adams and Hannaford, 1999
5	5-Feb	Stability of Haptic Rendering	Abbott and Okamura, 2005; Diolaiti et al., 2006
	7-Feb	**Class cancelled due to instructor travel**	
6	12-Feb	Teleoperation	Hokayem and Spong, 2006
	14-Feb	Teleoperation	Rodriguez-Seda et al., 2009
7	19-Feb	Rate vs. Position Control	Kim et al., 1987; Zhai, 1993; Zhai and Milgram 1998
	21-Feb	Rate vs. Position Control	Masliah and Milgram 2000; Dominjon et al., 2005
8	26-Feb	Teleoperation with Time Delay	Kim and Bejczy, 1993; Funda et al., 1992; Sayers and Paul, 1994
	28-Feb	Teleoperation with Time Delay	Mitra and Niemeyer, 2008; Xu et al., 2016
9	5-Mar	Event-based Haptics	Okamura et al., 2001; Kuchenbecker et al., 2006
	7-Mar	Event-based Haptics **Discuss class projects**	Lawrence et al., 2000; Gleeson and Johnson, 2010
10	12-Mar	**No class, Spring Break**	
	14-Mar	**No class, Spring Break**	
11	19-Mar	Spatial Reasoning	Jacob et al., 1994; Parsons, 1995; Ware and Arsenault, 2004; Usevitch and Abbott, 2018
	21-Mar	Haptic Illusions	Lederman and Jones, 2011
12	26-Mar	Vibrotactile Displays	Choi and Kuchenbecker, 2012; Romano and Kuchenbecker, 2012; Zhang et al., 2018
	28-Mar	Shear-based Tactile Displays	Chubb et al., 2010; Gleeson et al., 2010
13	2-Apr	Shape and Encountered Displays	Wagner et al., 2002; Yokokohji et al., 2005; Song et al., 2016
	4-Apr	Multifingered Interaction	Cutkosky, 1989; Bullock et al., 2013
14	9-Apr	Multifingered Interaction	Endo et al., 2011; Pacchierotti et al., 2017
	11-Apr	**Class cancelled, instructor available**	
15	16-Apr	5-minute project presentations	
	18-Apr	**Class cancelled for Design Day**	
16	23-Apr	Demo projects	
17	1-May	**Comprehensive Final Exam: 10:30-12:30**	

COLLEGE OF ENGINEERING GUIDELINES

https://www.coe.utah.edu/semester-guidelines **Spring Semester 2019**

Appeals Procedures

See the Code of Student Rights and Responsibilities, located in the Class Schedule or on the UofU Web site for more details

Appeals of Grades and other Academic Actions

If a student believes that an academic action is arbitrary or capricious he/she should discuss the action with the involved faculty member and attempt to resolve. If unable to resolve, the student may appeal the action in accordance with the following procedure:

1. Appeal to Department Chair (in writing) within 40 business days; chair must notify student of a decision within 15 days. If faculty member or student disagrees with decision, then,
2. Appeal to Academic Appeals Committee (see https://www.coe.utah.edu/students/academic-affairs/academics/ for members of committee). See II Section D, Code of Student Rights and Responsibilities for details on Academic Appeals Committee hearings.

Americans with Disabilities Act (ADA)

The University of Utah seeks to provide equal access to its programs, services, and activities for people with disabilities. If you need accommodations in a class, reasonable prior notice needs to be given to the instructor and to the Center for Disability Services, 162 Olpin Union, 581-5020 (V/TDD) to make arrangements for accommodations. All written information in a course can be made available in alternative format with prior notification to the Center for Disability Services.

Adding Classes

Please read carefully: All classes must be added within **10 academic days** of the beginning of the semester (deadline: Friday, January 18). Late adds will be allowed January 19-January 28, requiring only the instructor's signature. Any request to add a class after January 28th will require signatures from the instructor, department, and Dean, and need to be accompanied by a petition letter to the Dean's office.

A $50 FEE WILL BE ASSESSED BY THE REGISTRAR'S OFFICE FOR ADDING CLASSES AFTER January 28, 2019. ***

******Before you elect to take a class CR/NC you should check with your Advisor. Core classes used to compute your Engineering GPA need letter grades.**

Withdrawal Procedures

See the Class Schedule or web for more details ** Please note the difference between the terms "drop" and "withdraw". Drop implies that the student will not be held financially responsible and a "W" will not be listed on the transcript. Withdraw means that a "W" will appear on the student's transcript and tuition will be charged. **

Drop Period – No Penalty

Students may DROP any class without penalty or permission during the FIRST TEN academic days of the term (Friday, January 18).

Withdrawal from Full Term Length Classes

Students may WITHDRAW from classes without professor's permission until **Friday, March 8, 2019.** Beginning January 19 until March 8, a "W" will appear on the transcript AND **tuition will be charged**. Refer to Class Schedule, Tuition and Fees for tuition information.

Withdrawal from Session I & Session II

See the web page for details:
https://registrar.utah.edu/academic-calendars/spring2019.php
Withdrawals after March 8, 2019, will only be granted due to compelling, nonacademic emergencies. A petition and supporting documentation must be submitted to the Dean's Office, 1602 Warnock Engineering Building. Petitions must be received before the last day of classes (**Tuesday, April 23, 2019**).

Repeating Courses

When a College of Engineering class is taken more than once, only the grade for the second attempt is counted. Grades of **W, I, or V** on the student's record count as having taken the class. Departments enforce these guidelines for other courses as well (e.g., math, physics biology, chemistry). Attempts of courses taken at transfer institutions count as one attempt. This means a student may take the course only one time at the University of Utah. Courses taken at the University of Utah may not be taken a second time at another institution. If a second attempt is needed, it must be at the University of Utah. Please work with your department advisor to determine the value of repeating courses. Students should note that anyone who takes a required class twice and does not have a satisfactory grade the second time may not be able to graduate. It is the responsibility of the student to work with the department of their major to determine how this policy applies in extenuating circumstances.