# ME 327: Design and Control of Haptic Systems

Syllabus
Spring Quarter 2020
*Updated May 31, 2020*

## Description

Study of the design and control of haptic systems, which provide touch feedback to human users interacting with virtual environments and teleoperated robots. Focus is on device modeling (kinematics and dynamics), synthesis and analysis of control systems, design and implementation, and human interaction with haptic systems. Coursework includes homework/laboratory assignments and a hands-on project. Directed toward undergraduate and graduate students in engineering and computer science. Prerequisites: dynamic systems, feedback controls, and MATLAB programming.

## Course Times/Locations

Lectures: Approximately 45 minutes of pre-recorded lecture material will be posted on Mondays and Wednesdays, and should be watched before the next interactive session. You'll find these in the Course Videos section on Canvas. *(Note: Any quiz questions in the recorded lectures should be answered before proceeding, although they are not graded.)*

Interactive Sessions: Tuesdays and Thursdays 9:00 am PDT, approximately 30 minutes in duration, although some sessions may go up to 1 hour. You'll find links to the live sessions and recordings in the Zoom section on Canvas. *(Note: Lecture attendance strongly encouraged, but not required to pass the class.)*

Office hours: Held via Zoom, see Canvas syllabus page for the latest schedule

## Teaching Team

Instructor: Allison Okamura (aokamura@stanford.edu)
Teaching Assistants: Brandon Ritter (ritter98@stanford.edu) and Zonghe Chua (chuazh@stanford.edu)

## Course Website

Access to course materials, including pre-recorded lectures, liver and recorded interactive sessions, office hour zoom links, assignments, and quizzes will be done through Canvas: http://canvas.stanford.edu. In addition, Piazza will be used for discussion boards (added after the first few weeks of class based on student feedback): https://piazza.com/stanford/spring2020/me327/. The best way to contact instructors and receive input about assignments and class concepts outside of the live interactive sessions and office hours is through the discussion forum provided on Piazza. There you can post a new question, search through previous posts, answer other student's posts, and receive instructor feedback. This site allows the teaching team to know what questions students have, and we can provide answers in a centralized location. Occasionally we will ask you to submit or access materials through Google; make sure to login to Google with your SUNet ID.

## Prerequisites

You should have a basic understanding of dynamic systems such as that covered in EE 102 or ME 161, and introductory feedback control such as that covered in ENGR 105. You should also be familiar with to MATLAB, which is required for some of the assignments. (MATLAB for this class is available to all students via Canvas.) If you have any questions about whether or not you have the appropriate background for this class, let Allison know.

## Logistics and Organization

Communications for this class will occur via pre-recorded lectures (approximately 45 minutes), live interactive sessions at the scheduled class time (approximately 30 minutes, also recorded), live office hours and meetings, and use of discussion boards on Canvas. You are strongly encouraged to attend the interactive sessions and actively participate. Some of the interactive sessions will require a little preparation on your part, so make sure to watch the pre-recorded lectures in advance.

Learning activities and assessments will include: written assignments, MATLAB assignments integrated with Canvas, hands-on haptic demonstrations, Hapkit labs, presentations, and occasional quizzes. Assignments and labs will typically be distributed weekly and due the following week. The deadlines will be given on Canvas. Assignments will include a variety of activities, including written responses, problem solving, presentations, and building and programming haptic devices. Note: There is *laboratory fee of $50* to partially offset the cost of Hapkit materials, due via Axess by the add/drop deadline. Students registered for this class will see the $50 fee under Finances in Axess. You may keep the Hapkit you construct for this course. You may also need to use household materials for certain assignments.

The Stanford Honor Code applies to this course. ◆ Students who need an academic accommodation based on the impact of a disability must initiate the request with the Office of Accessible Education (OAE). Professional staff will evaluate the request with required documentation, recommend reasonable accommodations, and prepare a current Accommodation Letter for faculty. Students should contact the instructor and the OAE in the first week of classes since timely notice is needed to coordinate accommodations. The OAE is located at 563 Salvatierra Walk; phone: 723-1066; their web site is http://studentaffairs.stanford.edu/oae. ◆ Academic accommodations are also available for students who have experienced sexual violence. If you would like to talk to a confidential resource, you can schedule a meeting with the Confidential Support Team (CST) or call their 24/7 hotline at: 650-725-9955. Non-confidential resources include the Title IX Office, for investigation and accommodations, and the SARA Office, for healing programs. Students can also speak directly with the teaching staff to arrange accommodations. Note that university employees – including professors and CAs – are required to report what they know about incidents of sexual or relationship violence, stalking, and sexual harassment to the Title IX Office. Students can learn more at https://vaden.stanford.edu/sexual-assault. ◆ Academic accommodations are also available for students experiencing acute trauma related to personal or societal challenges, with immediacy that cannot be addressed by OAE. Examples include bereavement, health issues, and stress or fear caused by racial injustice. Students requesting accommodations are urged to contact the teaching team as soon as possible.

**Objectives**

Haptics is a dynamic, multi-disciplinary field that is actively being researched by engineers, computer scientists, product designers, psychologists, and neuroscientists. By the end of the course, you should be able to:

- Identify salient features of a haptic device design
- List a variety of different types of haptic interfaces
- Identify the primary mechanisms of human haptic sensing
- Design psychophysical and perceptual tests
- Understand a number of methods for sensing the position of and actuating haptic interfaces
- Describe the differences between grounded and ungrounded force feedback
- Implement controllers to render various dynamics (stiffness, damping, inertia)
- Describe and implement basic telemanipulation controllers
- Understand the causes of instability in virtual reality and teleoperation systems
- Describe applications of haptic devices
- Develop a new haptic device or application of a haptic device
- Read, evaluate, and critique research papers
- Design and deliver a research presentation
- Create passive haptic demonstrations

**Grading**

Grading in this class is Satisfactory/No Credit (S/NC). Overall, you must receive a 50% or higher score in the class in order to pass. In addition, each class component has a minimum required for passing. We hope that this relatively generous passing requirement will accommodate for the special challenges of this quarter while allowing us to foster intellectual nourishment and social connection. To request an extension in advance of an assignment deadline if needed due to illness, technology issues, or other personal circumstances, email Allison directly at aokamura@stanford.edu.

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| 50% | Assignments | Assignments (including labs) will generally be distributed on a weekly basis and be due one week later. Start on assignments early, and ask for help if you get stuck. Discussing the assignment with your classmates is encouraged, but everyone must turn in his or her own work. Assignments will be submitted via Canvas. Assignments will be graded on a point system as follows: 3 (completely or mostly correct), 2 (completed with strong effort, but with mistakes), 1 (mostly incorrect or missing), 0 (not submitted). Solutions will be distributed so you can check the details of your work. To receive an "S" in the class, you must have no more than one 0 and at least 12 points total. |
| 30% | Quizzes | Three timed online quizzes will be used to assess knowledge of course topics. To receive an "S" in the class, you must submit all 3 quizzes and receive at least 50% score on average. |
| 20% | Presentations and demonstrations | Students will form groups (the size of a group to be determined) will pick a recent research paper to read, understand, and present to the class via a pre-recorded short lecture. In addition, each group will create an interactive demonstration. Your presentation will be evaluated on organization, subject knowledge, slides, and presentation skills. Your demonstration will be graded based on knowledge, relevance, and interactivity. You will |

also assist in evaluating the presentations of your peers. To receive an "S" in the class, you must participate in and receive at least a 50% total score for the group presentations/demonstrations.

**Acknowledgments**
Many individuals have contributed to the development of this course by sharing materials from their own haptics research or courses. These include: Katherine Kuchenbecker (University of Pennsylvania), Will Provancher and Jake Abbott (University of Utah), Karon MacLean (University of British Columbia), and Blake Hannaford (University of Washington). Previous Stanford students and course assistants including Tania Morimoto and Melisa Orta Martinez have also provided many valuable contributions to the course design.

**Schedule (tentative – see details and updates on Canvas)**

| Week | Dates | Lecture Topics | Interactive Sessions | Assignments/Quizzes |
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| 1 | April 6-10 | Introduction to haptics | Haptic design | Assignment 1 |
| 2 | April 13-17 | Human haptics and user studies | Haptics user studies | Assignment 2 |
| 3 | April 20-24 | Tactile haptic devices | Tactile haptics demos | Assignment 3 |
| 4 | April 27-May 1 | Kinesthetic haptic devices: design, sensors, actuators | Basic rendering and design | Assignment 4, Quiz 1 |
| 5 | May 4-8 | Kinesthetic haptic devices: dynamics and control | Dynamics and control | Assignment 5 |
| 6 | May 11-15 | Kinesthetic haptic devices: multi-dof devices | Multi-dof haptic device analysis and demo | Assignment 6 |
| 7 | May 18-22 | Kinesthetic haptic devices: rendering | Hapkit assembly | Assignment 7, Quiz 2 |
| 8 | May 25-29 | Teleoperation | Teleoperation | Assignment 8 |
| 9 | June 1-5 | Student paper presentations | Hands-on demos | Presentations/demos |
| 10 | June 8-10 | N/A | Hapkit rendering demos | Quiz 3 |