CSCI 699: Haptic Interfaces and Virtual Environments

Units: 4

Spring 2022—Time TBD:

Location: TBD

Course Website:
For grades and assignment submission:
https://blackboard.usc.edu
For assignments, announcements, and questions:
http://piazza.com/usc/spring 2021/csci699

Instructor: Heather Culbertson
Office: RTH 403
Office Hours: Wednesdays 1-2:30 pm
Contact Info: hculbert@usc.edu

Course Description

This course provides a graduate-level introduction to the field of haptics, which involves human interaction with real, remote, and virtual objects through the sense of touch. Haptic interfaces employ specialized robotic hardware and unique computer algorithms to enable users to explore and manipulate simulated and distant environments. Topics for the course include human haptic sensing and control, haptic interface design, virtual environment rendering methods, teleoperation control algorithms, and system evaluation. Current applications for these technologies will be highlighted, and important techniques will be demonstrated in a laboratory setting. Coursework includes homework/laboratory assignments and a research-oriented project. This class is appropriate for graduate students in computer science or any related engineering discipline with interest in robotics, dynamic systems, controls, or human-computer interaction.

Learning Objectives and Outcomes

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

- Identify the primary mechanisms of human haptic sensing
- Understand a number of methods for sensing the position of and actuating haptic interfaces
- Describe the differences between grounded and ungrounded force feedback
- Identify salient features of a haptic device design
- List a variety of different types of haptic devices
- Implement controllers to render various dynamics (stiffness, damping, inertia)
- Describe and implement basic teleoperation controllers
- Understand the causes of instability in virtual reality and teleoperation systems
- Design psychophysical and perceptual tests
- 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

Prerequisite(s): Students should have doctoral standing in computer science or engineering, or permission from the instructor. If you have any questions about whether or not you have the appropriate background for this class, please talk with the instructor.

Recommended Preparation: Prior or simultaneous enrollment in CSCI 545 (Robotics) will be useful to you. Students should have experience with progamming (assignments will be in C++). Previous experience with hardware prototyping and/or circuits would be beneficial, but not required.

Logistics and Organization

The class meets two times a week, on Tuesdays and Thursdays. You are expected to attend all class sessions and actively participate in class discussions. If you have to miss a class, notify the instructor in advance. Late arrivals and unexcused absences will reduce learning in the class and negatively affect your participation grade.

The first part of the semester will focus on lectures, readings, and discussions designed to introduce you to the field of haptics and haptic interface design both from a hardware and software perspective. Assignments will be handed out biweekly, and due biweekly. The deadline will be written on the assignment. Assignments will include a variety of activities, including written responses, problem solving, and programming haptic interfaces and virtual environments. All assignment materials will be submitted electronically on Blackboard.

Assignments will include programming the 3D Systems Touch haptic device. For these assignments, you will be given starter code. Two Touch haptic devices and computers will be available for class use in my research lab (RTH 416). You must sign up for timeslots to work on the assignments as the devices must be shared with your classmates.

For the second part of the semester, students will form two- or three-person teams and select a current research problem in the field of haptics to pursue. There will be project discussion and checkpoints along the

way to help guide your endeavors. You will complete most of the work on your project during the last ten weeks of the semester, and the class will conclude with final project demonstrations and a written report. Towards the end of the semester, students will also present published haptics papers (relevant to their projects) to their peers during class periods.

Textbook

Because a comprehensive book on the field of haptics does not yet exist, this class has no textbook. Instead, selected readings will be handed out each week and made available on the course Piazza website. You will learn quite a lot by doing these readings. You will be expected to turn in a short summary (1-2 paragraphs) on each reading to Blackboard before the indicated lecture.

Online Resources

Please log in to Blackboard for grading and submitting assignments for this course. Lecture notes and assignments will be posted on Piazza. This is also the best way to contact instructors and receive student input about assignment problems and class concepts outside of class and office hours. Simply navigate to piazza.com, create an account, and add CSCI 699 to your list of courses (http://piazza.com/usc/spring2021/csci699). There you can post a new question, search through previous posts, answer other student's posts, and receive instructor feedback. This site allows the instructor to know what questions students have, and I can provide answers in a centralized location. Please use this resource.

Grading Breakdown

Your grade in this class will be computed as a weighted average of your scores in the four main course components.

5%	Class Participation	All students are expected to actively engage in lectures and discussions. If you have a question, ask it! It is certain that someone else in the room has the same concern. Such contributions will keep everyone on the same page and will help the professor improve her presentation of the material. Similarly, if you have an observation or an idea, share it with everyone! A great deal of the learning in this class will be facilitated by peer interaction, as we all come from different academic and professional backgrounds.
5%	Readings	Readings will be assigned for each class on that day's topic. It is important to complete these readings in order to understand the material presented in the course. Students should submit a short summary (1-2 paragraphs) of each reading to Blackboard before the beginning of class.
40%	Homework Assignments	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/her own work. Apparent academic integrity violations will be reported to the Office of Student Conduct. Late assignments will be penalized by 20% per day.
10%	Paper Presentation	Each student will pick a recent research paper to read, understand, and present in detail to the class. You will select this paper from the set of papers presented orally at the 2019 World Haptics Conference. Your presentation will be evaluated on organization, subject knowledge, slides, presentation skills, and interactivity. You will also assist in evaluating the presentations of your peers.
40%	Course Project	You will conduct a final team project in teams of two or three. You will work with Dr. C over the course of the semester to select your

		topic and teammates, study the relevant literature, define your problem, and develop a novel technique or device to solve it. Your project will be evaluated by the functionality of your end-of-semester demonstration, the correctness and completeness of your presentation, the technical strength of your contribution, and the organization, style, and clarity of your written report, which will be due approximately one week after the project demonstration.

Grading Scale

Course final grades will be determined using the following scale

A	94-100
A-	90-93
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	59 and below

Assignment Submission Policy

Assignments will be submitted as a single .zip file on Blackboard. Late assignments will be penalized by 20% per day.

Acknowledgments

Many individuals have contributed to the development of this course by sharing materials from their own haptics research or courses. These include: Allison Okamura (Stanford University), Katherine J. Kuchenbecker (Max Planck Institute for Intelligent Systems), J. Edward Colgate (Northwestern University), Will Provancher and Jake Abbott (University of Utah), Karon MacLean (University of British Columbia), Blake Hannaford (University of Washington), and Jeremy Brown (Johns Hopkins University).

Course Schedule (subject to change)

Week	Lec #	Date	Lecture Topics
1	1		Introduction and course overview
	2		Applications of haptic devices
2	3		Human haptic perception
	4		Tactile haptic devices
3	5		Surface haptic devices
	6		Kinesthetic haptic devices: design and kinematics
4	7		Kinesthetic haptic devices: dynamics and control
	8		Multi-DOF kinesthetic devices
5	9		Project discussions
	10		Programming virtual environments
6	11		Programming virtual environments (continued)
	12		Rendering surface haptic properties

7	13		Rendering complex objects
	14		Teleoperation
8	15		Teleoperation (Continued)
	16		Pseudohaptics and haptic illusions
9	17		Psychophysical Methods
	18		User Studies/Experimentation
10	19		Project Checkpoint 1
	20		Data-driven haptics
11	21		Wearable and ungrounded devices
	22		Tactile sensing
12	23		Project Checkpoint 2
	24		Paper presentations
13	25		Paper presentations
	26		Project Checkpoint 3
14	27		Project user studies
	28		Project user studies
15	29		Project demonstrations
	30		Project demonstrations
			Final project presentations

Readings

Week 1 (optional) - MacLean, K. E. (2008). Haptic interaction design for everyday interfaces. Reviews of Human Factors and Ergonomics, 4(1), 149-194.

Week 1 - Johnson, K. O. (2001). The roles and functions of cutaneous mechanoreceptors. Current opinion in neurobiology, 11(4), 455-461.

Week 2 – Pacchierotti, C., Sinclair, S., Solazzi, M., Frisoli, A., Hayward, V., & Prattichizzo, D. (2017). Wearable haptic systems for the fingertip and the hand: taxonomy, review, and perspectives. IEEE transactions on haptics, 10(4), 580-600.

Week 3 – Meyer, David J., Michaël Wiertlewski, Michael A. Peshkin, and J. Edward Colgate. "Dynamics of ultrasonic and electrostatic friction modulation for rendering texture on haptic surfaces." In 2014 IEEE Haptics Symposium (HAPTICS), pp. 63-67. IEEE, 2014.

Week 4 – Massie, Thomas H., and J. Kenneth Salisbury. "The phantom haptic interface: A device for probing virtual objects." In Proceedings of the ASME winter annual meeting, symposium on haptic interfaces for virtual environment and teleoperator systems, vol. 55, no. 1, pp. 295-300. 1994.

Week 5 – Hayward, Vincent, and Karon E. MacLean. "Do it yourself haptics: part I." IEEE Robotics & Automation Magazine 14, no. 4 (2007): 88-104.

Week 6 – Weir, D. W., J. Colgate, M. C. Lin, and M. Otaduy. "Stability of haptic displays." In Haptic Rendering: Foundations, Algorithms, and Applications, pp. 151-189. AK Peters, 2008.

Week 7 – Salisbury, Kenneth, Francois Conti, and Federico Barbagli. "Haptic rendering: introductory concepts." IEEE computer graphics and applications 24, no. 2 (2004): 24-32.

Week 7 – Zilles, Craig B., and J. Kenneth Salisbury. "A constraint-based god-object method for haptic display." In Proceedings 1995 IEEE/RSJ International Conference on Intelligent Robots and Systems. Human Robot Interaction and Cooperative Robots, vol. 3, pp. 146-151. IEEE, 1995.

Week 8 – Minsky, Margaret, Ouh-young Ming, Oliver Steele, Frederick P. Brooks Jr, and Max Behensky. "Feeling and seeing: issues in force display." In ACM SIGGRAPH Computer Graphics, vol. 24, no. 2, pp. 235-241. ACM, 1990.

Week 9 – Hollerbach, John M., and David E. Johnson. "Virtual environment rendering." Human and Machine Haptics 7 (2000): 56-58.

Week 10 – Hashtrudi-Zaad, Keyvan, and Septimiu E. Salcudean. "Analysis of control architectures for teleoperation systems with impedance/admittance master and slave manipulators." The International Journal of Robotics Research 20, no. 6 (2001): 419-445.

Week 11 – Niemeyer, G., Preusche, C., Stramigioli, S., & Lee, D. (2016). "Telerobotics". In Springer handbook of robotics (pp. 1085-1108). Springer, Cham.

Week 12 – Lederman, Susan J., and Lynette A. Jones. "Tactile and haptic illusions." IEEE Transactions on Haptics 4, no. 4 (2011): 273-294.

Week 13 – Jones, Lynette A., and Hong Z. Tan. "Application of psychophysical techniques to haptic research." IEEE transactions on haptics 6, no. 3 (2012): 268-284.

Week 14 – Okamura, Allison M., Katherine J. Kuchenbecker, and Mohsen Mahvash. "Measurement-based modeling for haptic rendering." *Haptic Rendering*. AK Peters/CRC Press, 2008. 440-464.

Week 15 – Cutkosky, Mark R., Robert D. Howe, and William R. Provancher. "Force and tactile sensors." Springer Handbook of Robotics (2008): 455-476.

Statement for Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with the Office of Student Accessibility Services (OSAS) each semester. A letter of verification for approved accommodations can be obtained from OSAS. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. OSAS is located in GFS 120 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for OSAS is (213) 740-0776.

Statement on Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. Scampus, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

Emergency Preparedness/Course Continuity in a Crisis

In case of a declared emergency if travel to campus is not feasible, USC executive leadership will announce an electronic way for instructors to teach students in their residence halls or homes using a combination of Blackboard, teleconferencing, and other technologies.