Haptic Interfaces
Department of Mechanical Engineering and Applied Mechanics
University of Pennsylvania

Description
This class 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. Primary class topics 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 hands-on homework assignments, reading and discussion of research papers, and a final project. This class is appropriate for graduate students in any engineering discipline with interest in robotics, dynamic systems, controls, or human-computer interaction.

Objectives
By the end of the course, you should
- Understand many key ideas in haptics.
- Develop your skills at designing computer-controlled electro-mechanical systems.
- Improve your skills at reading research papers and giving oral presentations.
- Experience the process of defining a current research problem and investigating it.
- Be creative and have fun!

Teaching Team
Katherine J. Kuchenbecker, Ph.D.
(pronounced Kook-en-beck-er)
Skirkanich Assistant Professor of Innovation
Mechanical Engineering and Applied Mechanics

Email: kuchenbe@seas.upenn.edu
Calendar: http://ical.mac.com/uzq/KJK
Office: 224 Towne Building, 215.573.2786
Lab: 144 Towne Building, 215.573.6748
Web: http://haptics.grasp.upenn.edu

My office hours are Monday from 2:00 p.m. to 3:30 p.m., Wednesday from 2:00 p.m. to 3:30 p.m., and by appointment.

Acknowledgments
Many individuals have contributed to the development of MEAM 625 by sharing the materials from their own haptics courses. Most notably, the structure of this class is patterned after Allison M. Okamura’s ME/CS 651 class at Johns Hopkins University. Other materials are inspired by Ed Colgate’s ME 495 at Northwestern University; Blake Hannaford and Ganesh Sankaranarayanan’s EE 589 at the University of Washington; Ken Salisbury, Federico Barbagli, and Francois Conti’s CS 277 at Stanford University; and Will Provancher and Jake Abbott’s ME7960-007 at the University of Utah. Previous MEAM 625 students have also provided many valuable suggestions for the improvement of this class.
Prerequisites
MEAM 625 students should have graduate standing in engineering or permission from the instructor. Prior or simultaneous enrollment in courses such as MEAM 410/510 (Mechatronics), MEAM 420/520 / CSE 390 (Introduction to Robotics), MEAM 535 (Advanced Dynamics), ESE 500 (Linear Systems Theory), or ESE 406/505 / MEAM 513 (Classical Controls) will be useful to you. Programming experience in C, C++, and/or Matlab will be useful but not required.

Logistics
This class is worth one credit unit, and it meets three times a week. Monday and Wednesday lectures will take place from 10:30 to 11:50 a.m. in Towne 321. Friday recitations will take place from 10:00 a.m. to 10:50 a.m. in Towne 309. Note that both these rooms have been changed from their original locations to accommodate a larger class size.

Organization
Monday and Wednesday class meetings will be used for lectures to provide you with a solid foundation for the field of haptics. Friday class meetings will be more interactive, including lab tours, paper discussions, and course project discussions.

For the first part of the semester, assignments will generally be handed out on Wednesdays and due the following Thursday. Assignments will include a variety of activities, including written responses, problem solving, and hands-on haptic interface programming.

The last few weeks of the semester will be used for individual student presentations of current haptics research papers. These papers will be taken from the papers presented orally at the 2010 IEEE Haptics Symposium and the 2010 EuroHaptics Conference.

Over the course of the semester, students will form three-person teams and select a current research problem in the field of haptics to pursue. There will be project discussions and checkpoints along the way to help guide your endeavors. You will complete most of the work on your project during the last four weeks of the semester, and the class will conclude with final project demonstrations, a public open house, and a written report.

Projected List of Topics
Haptics is a dynamic, multi-disciplinary field that is actively being researched by engineers, computer scientists, product designers, psychologists, and neuroscientists. Here is a list of topics that we will probably cover this semester. If there is something else you want to learn about, please tell KJK.

- Types of Haptic Interfaces
- Applications for Haptic Interfaces
- Programming Haptic Virtual Environments
- Rendering Haptic Surface Properties
- Human Haptic Sensing
- Human Subject Experiments
- Psychophysics and Human Factors
- Sensors and Actuators for Haptics
- Kinesthetic Haptic Interface Design
- Signal Processing for Haptic Interfaces
- Haptic System Dynamics
- Telerobotic System Design
- Teleoperation Controllers
- Tactile Feedback Device Design
- Programming Tactile Feedback Systems
- Doing a Literature Search
- Managing a Research Project
- Giving a Good Technical Presentation
Important Dates

- **Friday, September 10**: Tour of the Penn Haptics Lab during recitation
- **Friday, September 24**: Tour of the Penn Clinical Simulation Center during recitation
- **Friday, November 5**: Marcia O’Malley (Rice University) at GRASP Seminar
- **Monday, December 6, and/or Wednesday, December 8**: Final Project Presentations (with hands-on demos)
- **Friday, December 10**: Günter Niemeyer (Willow Garage) at GRASP Seminar
  - Public Open House for Final Projects (with hands-on demos)
- **Wednesday, December 22**: Final Project Report Due

Attendance

You are expected to attend all class sessions and actively participate in the discussions that transpire. If you must miss a class, please notify KJK in advance and arrange to get a summary and written notes from a classmate. Late arrivals and unexcused absences will reduce your learning in this class and negatively affect your participation grade.

You should make a special effort to attend the lectures by visiting haptics experts, even though these talks are outside our regular class time. I invited these individuals to visit Penn to enrich the experience of our class, and I think you will enjoy hearing about their research.

Blackboard Website

This course has a website on Penn’s Blackboard system. KJK will post announcements, handouts, readings, and assignments on this site. You will use it for downloading handouts and viewing your grades. You access Blackboard at this address:

https://courseweb.library.upenn.edu

Log in to Blackboard using your PennKey and password, and then click on the link for MEAM 625 in your course list. Please tell KJK if you have any difficulties with Blackboard.

Email List

The course has an email list that you can use for contacting everyone. It is as follows:

meam625-001-10c@lists.upenn.edu

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 website. Some readings will be covered in lecture, and others will be discussed during a Friday class time. You will learn quite a lot by doing these readings.

Course Reserves

For additional reference, many books relevant to haptics have been placed on reserve at the Penn Engineering Library. These books will be valuable resources for your project. By showing your PennCard at the library’s front desk, you can check any of these books out for two hours at a time. If you arrive at closing time, you can check them out overnight.
**Grading**

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

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<tr>
<th>Component</th>
<th>Weight</th>
<th>Description</th>
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<tr>
<td>Class Participation</td>
<td>10%</td>
<td>As mentioned above, 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.</td>
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<tr>
<td>Homework Assignments</td>
<td>40%</td>
<td>Assignments will generally be distributed on Wednesdays and due the following Thursday by 5:00 p.m. Assignments that pertain to the project will contribute to that portion of your grade instead of this one. You should turn your homework in by delivering it to KJK’s office (224 Towne) on the day it is due. 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. Apparent academic integrity violations will be reported to the Office of Student Conduct. Late assignments will be penalized by 20% per day.</td>
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<tr>
<td>Paper Presentation</td>
<td>10%</td>
<td>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 2010 IEEE Haptics Symposium and the 2010 EuroHaptics 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.</td>
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<td>Project</td>
<td>40%</td>
<td>You will conduct a final team project in teams of three. You will work with KJK 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. If your project yields an accepted conference paper, I will pay for part or all of the team to attend the conference. Such a feat will almost certainly require additional work after completion of the course project; this time commitment will need to be approved by your advisor if you are already involved in other research.</td>
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