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Today’s Class

- Haptics: definition
- Course overview and mechanics
- Introduction to Haptics
  - Haptics overview
  - History
  - High-level taxonomy of haptic devices
  - Applications/Motivations
  - Current challenges
- Readings
hap·tic ('hap-tik)

adj.
Of or relating to the sense of touch; tactile.
[Greek haptikos, from haptesthai, to grasp, touch. (1890)]

Cutaneous
• Temperature
• Texture
• Slip
• Vibration
• Force
• Pain

Kinesthesia
• Location/configuration
• Motion
• Force
• Compliance
Objectives of this course

- Gain broad perspective of haptics
  - Haptic perception
  - Psychophysics
  - Design and control of haptic interfaces
  - Stability
  - Haptic Rendering
  - Teleoperation

- Hands-on experience with haptics
  - Homework/Labs and Project

- Gain some familiarity with current research and literature

- Identify opportunities for research in haptics
Acknowledgments

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Katherine Kuchenbecker, U. Penn

Ken Salisbury, Stanford

Federico Barbagli, Stanford and Hansen Medical

Francois Conti, Stanford

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Administrative Details

- Class time is T Th 10:45-12:05 pm
- Dr. Provancher’s office hours:
  - TBA @ 2136 MEB or 2172 MEB (lab)
- Dr. Abbot’s office hours
  - TBA @ Ken138 or 2172 MEB (lab)?
- Class Location: 3174 MEB
- Lab Location: 2172 MEB
- Readings: To be posted on class website
- Course Website: http://mech.utah.edu/haptics
Course Website: http://mech.utah.edu/haptics

- Readings password protected (to avoid the wrath of publishers)
Grading

- 15% Class participation/contribution
  - Ask questions!
  - Offer opinions, insights, during class and paper discussions
- 35% Homework/Labs
  - 7-10 assignments
- 35% Project
  - 33% of this for the final wiki report
- 15% Project presentations and Demo
  - Each student team gives a 15 minute presentation of their project
Course Structure

- 1st Half
  - Lectures, readings, homework/labs

- 2nd Half
  - Readings/discussions, project
  - Project presentations, demo and wiki report
Content of the Course

- Human haptic sensing, neurophysiology and psychophysics
- Stability analysis
- Fundamentals of teleoperation and control
- Device design - haptic devices and tactile devices
- Issues in device design for humans
- Haptic rendering
- Improvements in haptics
- Modeling humans (limbs and system ID)
- Event-based haptics
Who am I?

- Mechanical Engineering
  - Adjunct appointment in Computer Science
- 4 primary research topics
  - Design of hand-mounted tactile displays
  - Tactile perception
  - Embedded manufacturing (embedded sensing and actuation in multi-material structures)
  - Climbing Robots
- Haptics and Embedded Mechatronics Lab
Who are you?

- Grads/Undergrads
- ME, CS, BME, ECE, ?
- Research interests
- Take and review ungraded background quiz
  - Hand in at end of class
Getting the most out of class

Learning Method % Retention
• What one reads 10%
• What one hears 26%
• What one sees 30%
• What one sees and hears 50%
• What one speaks 70%

Origins of Haptics
Mechanical Teleoperation

• Ray Goertz, Argonne National Lab, 1940s
Modern Teleoperation

JASON, e.g. Sayers (1999)

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Haptic Interaction with Virtual Objects

Information and power flows

Courtesy Mandayam Srinivasan, MIT

© Barbagli, Conti, Salisbury 2008
Some terminology

- “Haptic” refers to the perceptual system that draws information from the skin and kinesthesia.
- “Proprioception” is the unconscious perception of movement and spatial orientation arising from stimuli within the body itself.
- “Kinesthesia” is the sense that detects bodily position, weight, or movement of the muscles, tendons, and joints.
- “Tactual Stereognosis” is the perception of the form of an object by means of touch.
Types of Haptic Sensing

**Kinesthetic / Proprioceptive**
Stems from body movement

**Cutaneous / Tactile**
Stems from skin contact

Illustration by A. M. Okamura.
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Haptic Interfaces

**Kinesthetic (Force Feedback) Displays**
Devices that provide forces or motions

**Hybrid Haptic Displays**
Attempt to combine kinesthetic and tactile feedback

**Tactile Displays**
Devices that stimulate skin to create touch sensation

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Kinesthetic Displays

Devices that provide forces or motions

- Device Taxonomy
  - Grounded devices
  - Body-based devices
  - Inertial reaction devices

- Transmission Types
  - Impedance (Low inertia, backdriveable)
  - Admittance (non-backdriveable)
Grounded kinesthetic devices
Impedance Type

MPB Freedom6S

SensAble Phantom Premiums

SensAble Omni

Magnetic Joystick, Hollis

Novint Falcon

Exoskeleton, Rosen
Quick Falcon Demo

Grounded kinesthetic device – Impedance Type

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Grounded kinesthetic devices
Admittance Type

Cobot Hand Controller
[Faulring/Colgate]
http://lims.mech.northwestern.edu/projects/handcontroller

Haptic Master
(Moog Inc.)

© J. Edward Colgate 2006
Body-based devices

- Cybergrasp
- Rutgers Hand Master
- Arm Exoskeleton
Inertial Reaction Devices

- Game controllers
Tactile Displays

- Devices that stimulate skin to create touch sensation

- Device Taxonomy
  - Pin Arrays
    - Arrays of vertically moving pins
    - Arrays will laterally moving pins (Hayward and others)
  - Slip Display (Colgate, Caldwell, and others)
  - Shear Display
    - Variable friction display (Colgate and others)
    - Shear motion (Provancher and others)
  - Contact Location Display (Provancher)

- Other Technologies
  - Vibrotactile: Pager motors and voice coils
  - Pneumatic
  - Electrotactile
  - Suction
  - Ultrasonic Pressure
  - Etc…
Pin Arrays
with vertically moving pins

Burdea & Coiffet (1994)

Virtual finger
 Virtual edge

Tactile feedback array

3 2 1

3 2 1

Kaczmarek, et al. (1995)

Kontarinis, et al. (1995)

Wagner, et al. (2002)
Pin Arrays
with laterally moving pins

Havward, et al. (2003-7)

Wang, et al. (2006)

Figure 4: Mechanical design of the tactile Shear Force Display
Fritschi, et al. (2006)

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Slip Displays

Hole in outer handle to contact inner rotating mandrel

Salada, et al. (2002-5)

Northwestern Haptic Knob.
Salada, Lipsey, Colgate (early 2000’s)
http://lims.mech.northwestern.edu/projects/rotaryknob/

Combined tactile and kinesthetic display
Variable Friction Shear Display


TPaD: Tactile Pattern Display.

01 Vibration mode of bending element

Winfield & Colgate (2007)
http://lims.mech.northwestern.edu/projects/TPaD/index.htm

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Shear Motion Display

- Fingertip Shear Feedback & Skin Stretch for Haptic (Directional) Guidance
- Currently miniaturizing

Directional Shear Cues

Gleeson, Horschel, Provancher (2009)
Contact Display Prototype
combined tactile and kinesthetic display

2-D Contact Display Concept

1-D Contact Display Concept

Provancher et. al (2005)
Pneumatic and vibrotactile feedback

Sato, et al. (1991)

Burdea (1996)

Immersion CyberTouch Glove

Stone (1992)

Add Moy & Fearing, and Cahn & Fearing

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Tactile Device Challenges

- Stimulation density needs to be high
- Multimodal sensations are hard to overlay
- High complexity and weight diminishes portability, practicality
- Passive touch does not feel real

- Tactile device design is difficult!
Haptics has many applications

- Blind Persons
  - Programmable Braille
  - Access to GUIs
- Training
  - Medical Procedures
  - Astronauts
- Education
- Computer-Aided Design
  - Assembly-Disassembly
  - Human Factors
- Entertainment
  - Arcade (steering wheels)
  - Home (game controllers)
- Automotive
  - BMW “iDrive”
  - Haptic Touchscreens
- Mobile Phones
  - Immersion “Vibetonz”
- Animation/Modeling
- Art
- Material Handling
  - Virtual Surfaces

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Training

- Visual display alone is not sufficient for certain types of virtual environments. To learn physical skills, such as using complicated hand tools, haptic information is a requirement.
Virtual Prototyping

McNeeley et al. (Boeing Corp.)

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Rehabilitation

Applications

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Teleoperation

Applications
Telemedicine

- Future application for tactile sensing/display
  - Telemedicine/Telesurgery

www.intuitivesurgical.com
Computer interface for blind users

- Text-based computers can easily be enhanced to include a speech synthesizer
- Graphical user interfaces are inherently visual
- A haptic display can help a blind computer user interact with graphics-based operating systems
Entertainment

Microsoft Sidewinder Steering Wheel

Applications

Logitech Wingman Joystick

© Colgate, Kuchenbecker, Provancher 2006-2009
Underlying motivations for haptics

- Looking across applications, we find common motivations:
  - *Haptics is required to solve the problem*
    - Interfaces for the blind
    - Phlebotomy training (task is mainly “feel”)
    - Vibetonz – a private communication channel
    - Improve communication (e.g., provide direction cue)
  - *Haptics improves realism and sense of immersion*
    - Entertainment
    - Animation/modeling
    - Diagnosis (e.g., Medical)
  - *Haptics provides constraint*
    - Assembly/disassembly
    - Virtual surfaces
How to design effective haptic interfaces

A simple three-step program...

A. Understand how the human sensory and perceptual systems work
B. Use this information to develop performance metrics
C. Understand how to build/control machines that display haptic percepts and meet performance metrics
Some current challenges in haptics

- Low power, embedded (miniaturize) haptics
  - Mobile electronics
- Exploiting tactual stereognosis (e.g., for automobile instrument panels)
  - Exoskeletal devices haven’t been the answer
- Haptics over the internet (e.g., for telesurgery)
  - Latencies are a big issue
- Haptic feedback for amputees
Haptics for prosthetics

- “Sensory reinnervation” provides a possible means for restoring the sense of touch to amputees

Kinesthetic and tactile sensors
Reading for next time

- Overview of reception and perception (neurophysiology and psychophysics)
  

    - Read first 7 ½ pages and skim the rest