Haptic Feedback

Kevin Cleary
cleary@georgetown.edu
Imaging Science and Information Systems (ISIS) Center
Department of Radiology
Georgetown University
http://simcen.usuhs.mil/miccai2001

Overview

- Definitions
- Human performance characteristics
- Force feedback
  - Example simulator systems
  - Force feedback devices
- Haptic rendering
- Tactile feedback
- Research issues

Definitions

- Tactile (touch) feedback: sensed by receptors close to the skin (high bandwidth)
- Force feedback: sensed by receptors placed deeper in the body (low bandwidth)
- Haptic feedback: technically same as tactile feedback, but often extended to include both tactile and force feedback as in haptics
- Source: Force and Touch Feedback For Virtual Reality, Burdea

Human Sensory Motor Control

- Maximum force exertion
  - Grasping force: 400 N males, 228 N females
  - Finger force: 40 to 50 N
  - Sustained force exertion is substantially lower
- Sensing bandwidth: can be 100's of Hz
  - Depending on grip and other factors
- Force tracking resolution, compliance resolution, etc, also studied
- Source: Burdea 1996

Vibrotactile stimulation

- Vibration of surface of finger(s) through contact with haptic interface
- Sensing bandwidth >= 500 Hz (Boff & Lincoln 1988)
- Can be added to conventional haptic interface through stimulator on handle (Kontarinis & Howe 1995)

Human Tactile Perception

- Specialized receptors in fingertips
- Mechanoreceptors respond to mechanical action (force, vibration, slip)
- SA-I mechanoreceptor characteristics
  - Receptive field diameter of 3-4 mm
  - Frequency range of 2-32 Hz
  - Spatial resolution
    - » Gap detection: 0.87 mm
    - » Grating detection: 1.0 mm
- Sources: Burdea 1996, Moy 2000

Force Feedback

Force Feedback

- Field has a long history: origins in nuclear industry for handling radioactive material
- Recently: commercially devices with sufficient capability at a reasonable cost
- Concentrate on desktop force feedback systems suitable for surgical simulators

Why Use Force Feedback?

Courtesy of National Capital Area Medical Simulation Center

Haptic Catheter/Needle Simulator

Courtesy of National Capital Area Medical Simulation Center

Endoscopy Simulator

- Flexible scope provides tactile sensations
- Physical model
- Computer based simulation
- Commercially available: Immersion Corporation

http://www.immersion.com/products/medical/endoscopy.shtml

PHANTOM Desktop

- 6 DOF position sensing
- 3 DOF force feedback
- Connects to parallel port
- PC or SGI platform
- GHOST software library
- Sensable Techologies: http://www.sensable.com/ (/haptics/products/phantom.html)

PHANTOM 1.5 / 6 DOF

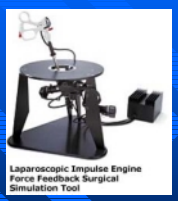
- 6 DOF force feedback
- PC or SGI platform

PHANTOM Premium 3.0

- workspace of 40 x 58 x 84 cm
- About same as arm pivoting at shoulder
- Larger force output

Laparoscopic Impulse Engine

- Force feedback system for laparoscopic surgical simulators
- PCI interface card
- PC/SGI software development kit
- Immersion Corporation



http://www.immersion.com/products/custom/laproimpulse.shtml

Sarcos Dextrous Arm Master

- Human-sized slave and master
- Master like an exoskeleton, but grounded – can be used standalone
- 10 DOF (spherical shoulder, hinge elbow, spherical wrist, and 2 fingered gripper)

http://www.sarcos.com/teleobotics.html

Microsoft Sidewinder Joystick

- Inexpensive force feedback device (about $100)
- Potential applications in simulated "needle" procedures
- Relatively easy to program

http://www.microsoft.com/products/hardware/sidewinder/force-feedback/default.htm

Logitech Wingman Mouse

- Inexpensive force feedback device (about $100)
- Potential applications in surgical simulation
- Relatively easy to program

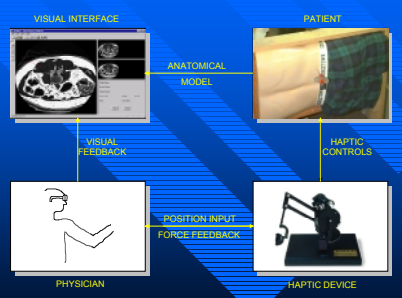
http://www.logitech.com/cf/support/wmffmouse.cfm

Haptic Rendering

Haptics Programming Toolkits

- GHOST® from Sensable Technologies
  - API (application programming interface) for haptics applications
  - Includes force field class, support for VRML
- {Burdea also listed VPS- Voxmap PointShell from Boeing – but not sure this is haptics oriented}

Haptic System Configuration



Computational Issues

- Different update rates required
  - Visual interface: 30 Hz
    - » visual perception threshold
  - Haptic control: 1000 Hz
    - » stability and a responsive interface
    - » difficult to compute complicated models
    - » multirate simulation may be required
      - haptic interface still at a high rate
      - physical model at a lower rate
      - reference: Cavusoglu and Tendick 2000

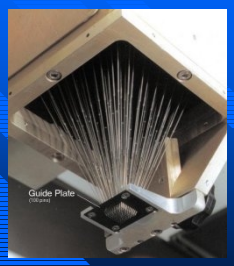
Tactile Feedback

Tactile Feedback

- For presenting information about texture, local compliance, and local shape [Moy 2000]
- Medical applications such as a robotic laparoscopic telesurgery system

400 Pin Tactile Array

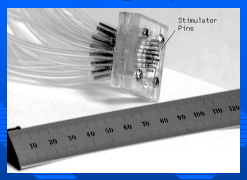
- 400 individually controlled probes
  - 0.5 mm apart
- Control
  - 16 TMS320C50 DSPs
  - Each controls 25 motors
- Reference: Pawluk et al.

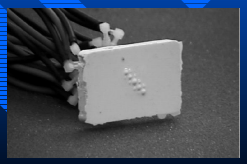


http://www.med.jhu.edu/somlab/lab/research/methods/400pin/

Berkeley Tactile Display

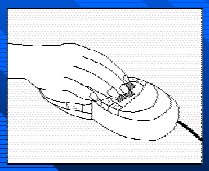
- 5 x 5 pin pneumatic display
  - 0.3N force per element
  - 3 bits of force resolution
- New version: molded display
  - No air leakage
  - Low pin friction
  - Curved displays possible
- Source: http://robotics.eecs.berkeley.edu/~ronf/tactile.html





VirTouch: Virtual Touch System

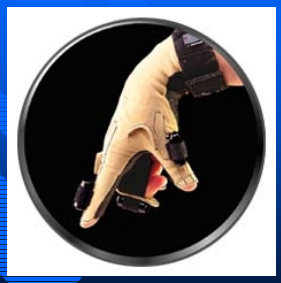
- Designed to allow blind and visually impaired to navigate computer screen
- Provides tactile feedback to fingertips
- Allows user to recognize graphic shapes through touch



http://www.virtouch.co.il/vts.htm

CyberTouch™ Tactile Feedback

- Tactile feedback option for instrumented glove
- Small vibrotactile sensors on each finger and the palm
- RS-232 interface



http://www.immersion.com/products/3d/interaction/cybertouch.shtml

Research Issues

- Human performance characteristics: presentation of haptic feedback to user
- Haptic rendering: computing complex models in real-time
- Low cost haptic feedback devices
- New force feedback and tactile devices
  - Limited workspace, fidelity issues, limited maximum force, etc.

Resources

- Haptics community web page
  - http://haptic.mech.nwu.edu
- Electronic journal of haptics research
  - http://www.haptics-e.org
- Workshop on haptic human-computer interaction
  - http://www.dcs.gla.ac.uk/~stephen/workshops/haptic/
- Eurohaptics 2001: http://www.eurohaptics.org/

Bibliography

- General
  - Force and touch feedback for virtual reality, Burdea, Wiley, 1996
- Tactile feedback
  - Engineering Data Compendium: Human Perception and Performance, K.R. Boff and J.E. Lincoln, 1988.
  - Tactile display of vibratory information in teleoperation and virtual environments, Kontarinis and Howe, *Presence*, 1995
  - Human psychophysics for teletaction system design, Moy et al., www.haptics-e.org, 2000
  - Simulating soft tissue with a tactile shape display, Pawluk et al., http://biorobotics.harvard.edu/research.html
- Haptic rendering
  - Multirate simulation for high fidelity haptic interaction with deformable objects in virtual environments, Cavusoglu and Tendick, *IEEE Robotics and Automation Conference*, 2000

Bibliography (page 2)

- Haptic Interfaces
  - A critical study of the mechanical and electrical properties of the PHANTOM haptic interface and improvements for high performance control, Cavusoglu et al., submitted to *Presence* July 2001 (http://robotics.eecs.berkeley.edu/~mcenk/research/abstracts.html)
  - A touch/force display system for haptic interface, Yoshikawa and Nagura, *Presence*, Vol. 10, No. 2, April 2001, 225-235.
- Tactile arrays
  - Control and pattern specification for a high density tactile display, Pawluk et al., Haptics Symposium, ASME IMECE, 1998.