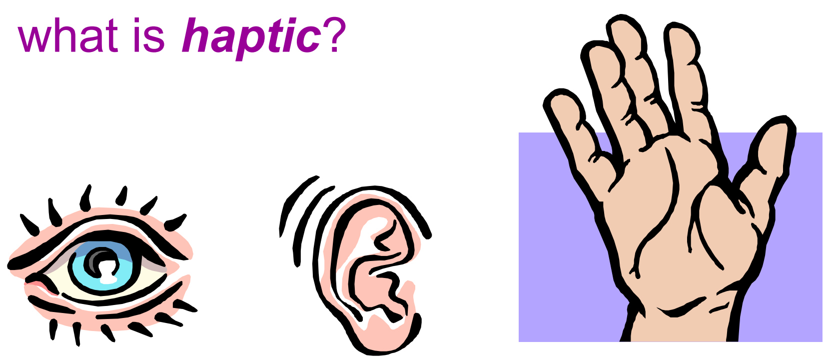
Haptics and the User Interface

based on slides from
Karon MacLean,

original slides available at:

http://www.cs.ubc.ca/~maclean/publics/

what is ***haptic***?



from Greek *haptesthai* : **to touch**

types of human haptic sensing

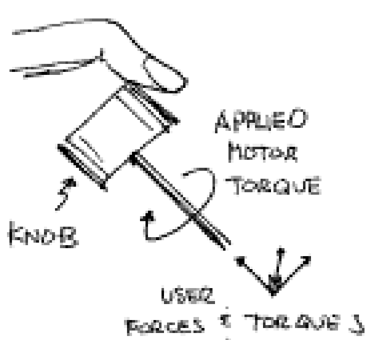
cutaneous / tactile:

- **heat, pressure, vibration, slip, pain**
- sensation arising from stimulus to the skin

kinesthesia / proprioception:

- **limb position, motion, force**
- end organs located in muscles, tendons, and joints
- stimulated by bodily movements

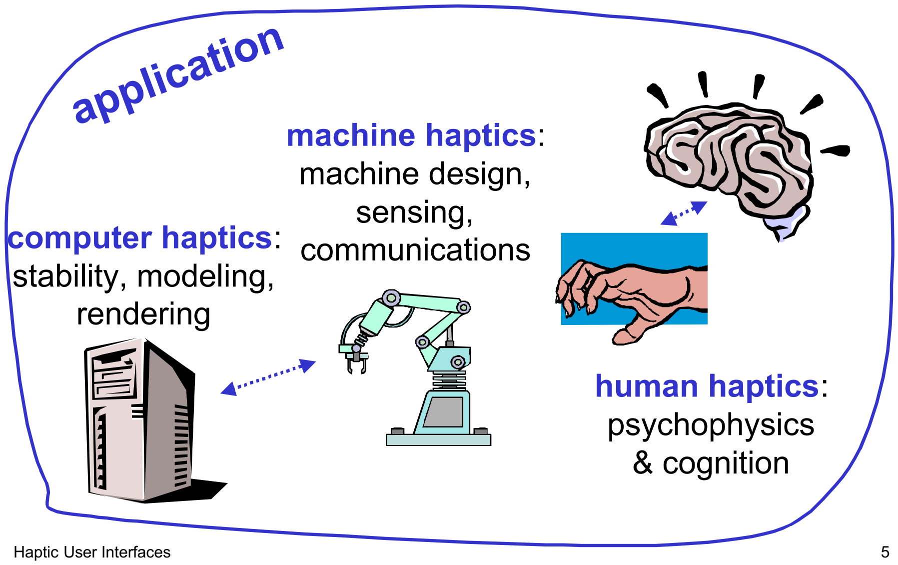
what is “haptic force feedback”?



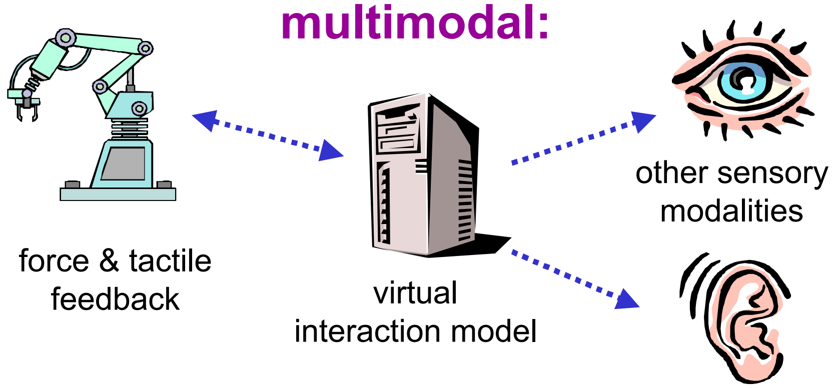
a small personal robot:

- applies computer-controlled forces to user’s hand
- represents a virtual environment
- acts as both an input and output device: user feels & controls at same time.

haptic or “force feedback” interfaces



haptic interfaces are often **multimodal:**



→ psychophysicists have discovered a few things about how stimuli to multiple senses **influence** one another

some **current** application areas
in no particular order

- desktop GUI augmentation
- medical robotics
- physical rehabilitation
- entertainment
- embedded consumer electronics
- telerobotics and virtual environments
- training and education
- CAD tools
- creative & expressive tools

desktop "HUI"

one approach:
- everyone has a haptic mouse
  (force or tactile feedback)
- render GUI is easier with edges, textures, etc

more ambitious:
- redesign GUI's from ground up with haptic feedback in mind

a bit further out still:
it's not a desk any more…

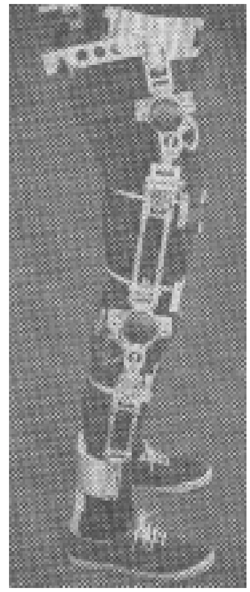
medical applications

- training & simulation, for:
  - diagnosis
  - tissue palpation
  - measures… swelling, bone fracture, pulse, lumps
- Minimally Invasive Surgery (MIS)
  - training through simulation
  - the real thing: “fly by wire” to improve interaction
- telesurgery
  demonstrated on a human in France this semester!

Intuitive Surgical, Inc.
Mountain View, CA

rehabilitation

Durfee & Goldfarb, MIT Biomechanics Lab: controllable brake aids paraplegics in walking



Hogan & Krebs, MIT Biomechanics Lab: retraining stroke patients while measuring their progress.

entertainment: greatest cost pressure

- virtual reality arcades (body-sized systems)
- home-based gaming systems:
  - vibration feedback
  - force feedback joysticks and mice
- coming soon (?):
  - model-based force feedback in synthesizer keys
  - more expressive & creative apps as quality ↑ and cost ↓

military applications

combat simulators: projection with treadmill display

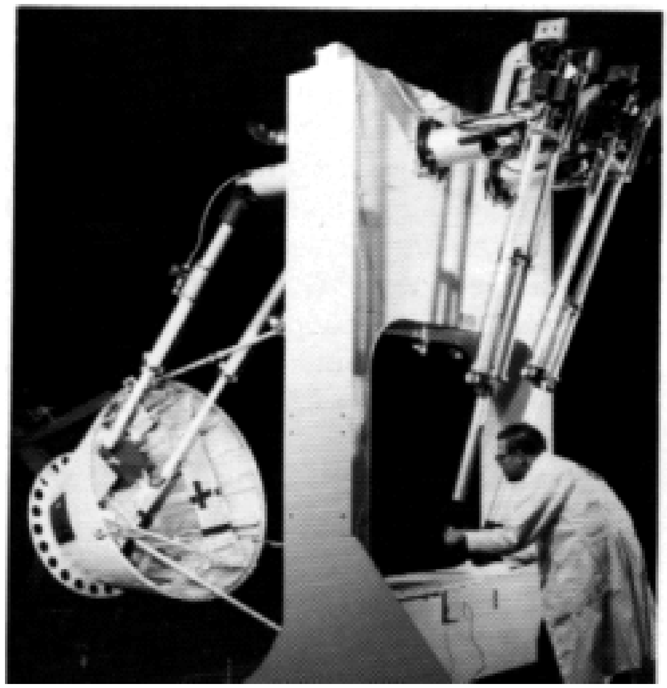
Hollerbach, Univ. of Utah

rest of talk

- historical roots: robotics & teleoperation
- tenets of physical interaction design
- how force feedback works
- rendering haptic models
- areas of basic research
- getting going

60's

General Electric robotics program



powered telerobot: "man magnifier"

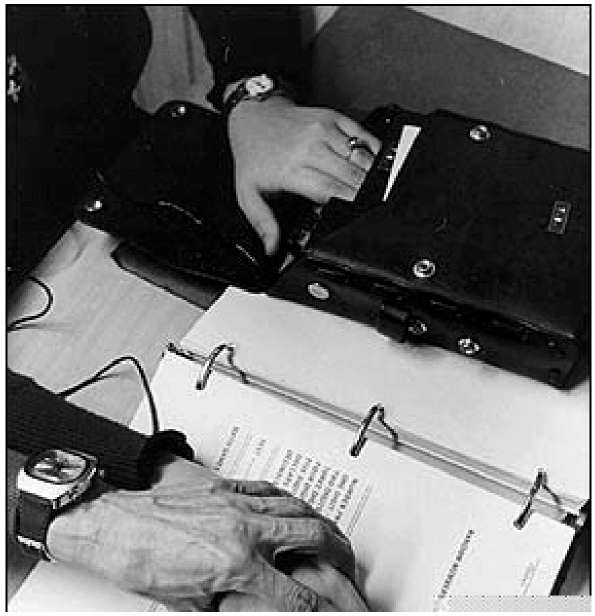
70’s

driven by rehabilitation research

Optacon:

Braille reading device,

first tactile display



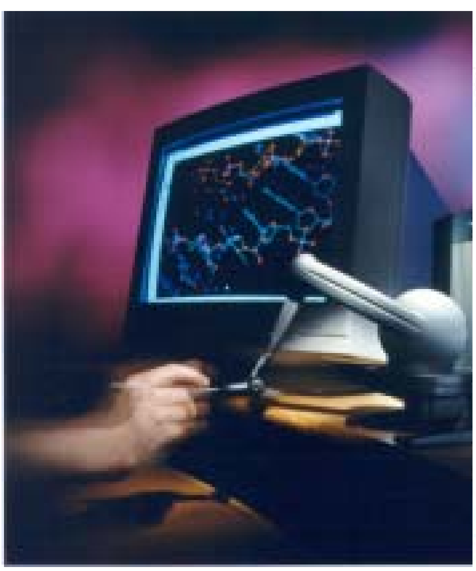
80’s: “force feedback”

improved teleoperation performance

Sarcos Arm

early 90's

- 1992: first "conference" on haptic feedback
  (session at a large mechanical engineering conference – mainly about device design)
- 1994: Minsky's "virtual sandpaper"
  - example of texture rendering caused a "sensation"
- 1994: PHANToM invented - for sale in **1995**



late 90's:

- sensory and cognitive psychophysics studies undertaken explicitly to improve haptic displays
- 1997: first haptic game joystick for sale
- 1999: Immersion.com went public
- today, proliferation of research displays

physical interaction design

touchable interfaces:

what's so special about touch?

what kind of interaction will it be good for?

special qualities of touch

bidirectionality: encompasses intention, manipulation, gesture and perception

social loading: intentional, socially invasive and committing

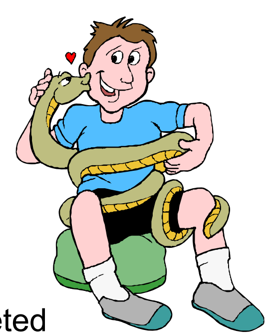
gesture and expression: convey functional and emotional signals through touching

multi-parametered: force, pressure, moisture, temperature, texture…

resolution and associability: precise control & discrimination, poor absolute resolution

motivations for touching

we touch intending to -



- do a task
- probe an object
- poke to elicit a reaction
- fidget to relieve tension
- communicate a message
- verify that an action is completed
- enjoy aesthetic pleasure or comfort
- connect physically or emotionally to living things.

inhibitions to touching

we avoid a touch through perception that it would be

and then, there are the "haptically challenged."

information available from touching

assessments of an object's dynamic and material properties.

verification of engagement and completion

continuous monitoring of ongoing activity and gradual doneness.

building mental models for invisible parts of a system.

judgments of other people.

when active touching helps:
potential benefits

reconfigurability:
- represent environment changes haptically
  (e.g. # of knob detents)

dealing with complexity:
- offer cues to user options
- differentiate buttons
- merge discrete steps into fluid continuous control gesture
- transport electronic tool use away from desktop

when active touching helps:
potential benefits

comfort and aesthetics:
- pleasant tactility
- satisfying motion & dynamics
- ergonomics
- bidirectional environment coupling
- muscle memory
- personalization

affect and communication:
- adds social context and presence to mediated user-user or user-machine connections.

haptic feedback in discrete and continuous control

buttons for discrete control and information:

- distinction / ID of objects
- impose edges on continuous input
- notify of failure / confirm operation success
- reflex-rate user reactions

handles for continuous control & monitoring:

- expressive input
- lo-res, lo-attention monitoring
- teaching, training & guiding

abstraction in user-target mediation

abstraction

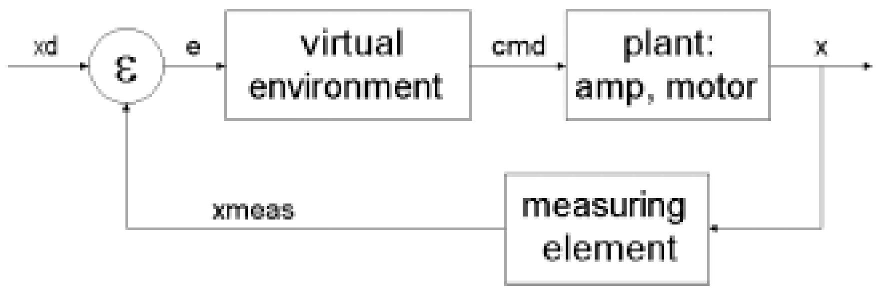
direct manipulation: environment signal or model is rendered literally

container manipulation: simple hierarchical layer of abstraction. raw signal / model is rendered in “bins”

annotation: haptic marks on signal or model indicate interesting content

mediating dynamic system: user manipulates virtual dynamic system to observe / change environment *(See Karon’s UIST talk this year)*

force feedback: how does it work?



force feedback displays

- grounded & ungrounded configurations
- actuation
- sensing

grounded interfaces:
solidly connected to the “world”

- similar to a robot
- compute kinematics to locate “user” relative to “world”
  1. determine endpoint position
  2. derive velocities
  3. calculate desired endpoint force and send to motors
- sometimes need to model & compute device dynamics to compensate for dynamics in device

ungrounded haptic interfaces

joint angles are measured and forces applied relative to mount point on the body

Virtual Technologies’ (Immersion now) Cybergrasp

things that can be “actuated”:

computer computes value & displays it to user

force / torque

vibration or impulse

motion arrest - *brake*

temperature

pressure - *inflate/deflate/vibrate*

touch – *make/break physical contact*

common actuator technologies for haptic displays

- electric motors – DC brush most common
- brakes - stable!
- pneumatic – no messy fluids + fast;
  springy + require compressed air source
- hydraulic – strong, fast, valves nonlinear.
  large systems: safety issues + nasty liquids
- SMA – shape memory alloy. tiny, fragile, tricky cooling requirements but can be densely packed.
- piezo – small displacement, strong / fast

sensing:
what is there to sense?

pick your body part:

contact

position, velocity, acceleration

applied force

pressure (squeeze, press)

type of grasp

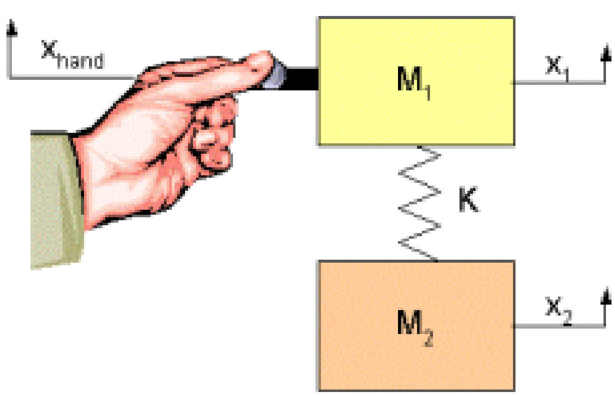
temperature

rendering force feedback

basic procedure for haptic rendering

1. read device position
2. decide which mode we're in …
   changes triggered by, e.g.
   - penetrating a virtual object
   - user- or application-triggered events
3. calculate display force based on mode & position
4. send corresponding force command to motors

rigid or multi-body dynamics:



rendering textures

make these feel different:

- plastic
- steel
- glass
- rubber
- foam
- fur ???

using virtual models of:

- hardness
- height maps
- spatial and/or temporal functions
- dynamic methods: e.g. damping
- friction: many models

areas of basic research:

- hardware & device design
- rendering
- uni- and multimodal cognition & psychophysics
- **interaction**

hardware

device design: engineers make neat robots; but rarely approach from application / user perspective

constraints on **component technology:**

actuators need more help than sensors:

- cost
- size
- weight for performance
- robustness
- bandwidth

→ need to develop novel methods for force and pressure display and sensing.

rendering
how to make it feel like something

unimodal haptic rendering:

- techniques for fast, smooth, stable display of models
  - 2- and 3-D
  - dynamic / static
  - literal / abstract
  - many researchers

multimodal rendering research examples:

- physically based haptic/auditory acoustic modeling
  Pai, UBC
- "fast" perception: display to automatic, reflexive sensory system.
  Rensink & MacLean, UBC

interaction

under-studied – need to focus more HCI attention onto the problems!

some examples:

- communication
- adaptive multimodal interfaces
- metaphors for physical control *(UIST talk)*

communication
what can feels **mean**?

- lowest level: design and learn people's ability to distinguish & associate complex "hapticons"
- highest level: people and machines communicate with a two-way haptic language
- in between: a lot of work!

adaptive interfaces

- e.g. multimodal application feedback that adjusts itself to the user's context:
  - emotional state (upset, excited, tired?)
  - attention
  - learning level
- input: biometric sensing

the future ?

- improved environment modeling
  both physically based & empirical
- novel force actuation & sensing
- immersive virtual reality systems
- integrated multimodal feedback
- commonly understood haptic language
- *ubiquitous haptics*

getting going

- who does it?
- where is the haptics community?
- what's for sale?

who can do it?

haptic feedback design is pretty multidisciplinary:

application interface design (conceptualizing it)	• application immersion • interface creation & integration • concept prototyping
human side (perceiving and interpreting it)	• perceptual psychology • cognition • user experimentation & analysis • biomechanics & kinesiology
machine side (making it happen)	• multisensory display design & control • realtime software architecture design • rendering algorithms • physical system modeling

different approaches to multidisciplinary, application-driven design

going it alone: you have a choice of

- depth: psychophysics, mechanism design, rendering
- breadth: integration

or, collaborative research
among academics & within companies

I want to learn more: where is the haptics community?

conferences & publications

- Haptics Symposium ('92-present)
  http://www.VR2002.org/
- haptics-e: The Electronic Journal of Haptics Research
  http://www.haptics-e.org/
- a course on physical interfaces, inc. selected readings
  http://www.cs.ubc.ca/~cs532/

community websites

- the Haptics Community Webpage
  http://haptic.mech.nwu.edu/
- the Eurohaptics Community
  http://www.eurohaptics.org/

what's for sale?

I have a great idea for a haptic feedback application, but I don't want to build my own haptic display.

what can I buy? here's a start:

- Sensable Technologies: http://www.sensable.com/
  6-degree of freedom desktop displays ($13.5-80K USD)
- Immersion Inc.: http://www.immersion.com/
  entertainment & medical devices; embedded automotive apps
- Reachin Technologies http://www.reachin.se/
  integrated haptics/graphics VR systems (based on Sensable)
- ACT Labs: http://www.act-labs.com/
  high-end force feedback steering wheel ($170 USD)

slides available:

http://www.cs.ubc.ca/~maclean/publics/