Multimodal Environments with Haptic Feedback for e-Learning

- Tutorial -

Felix G. Hamza-Lup, Ph.D*.*

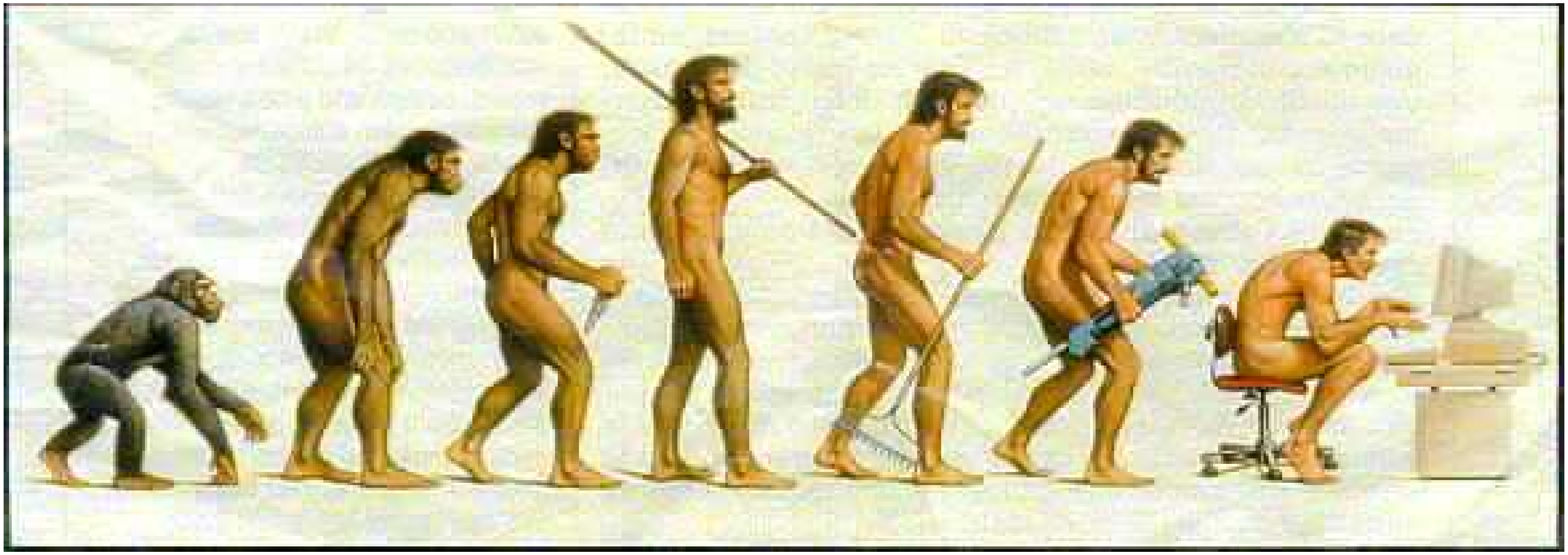
Computer Science and Info Technology
Armstrong Atlantic State University
Director HapticMed
www.felixlup.info

EL&ML 2011, February 23-28, 2011 - Gosier, Guadeloupe, France

Outline

- **The Human - human perception**
  - ***Visual***
  - ***Auditory***
  - ***Touch (Haptic)***
- The Machine - input/output
- Multimodal environments – the VR myth
- Haptics - brief history
- Haptic hardware and software
- Application domains
- E-learning with haptics
- Assessment
- Conclusions

Human Perception



The Human

- Information I/O …
  - visual, auditory, haptic, movement
- Information stored in memory
  - sensory, short-term, long-term
- Information processed and applied
  - reasoning, problem solving, skill, error
- Emotion influences human capabilities
- Each person is different

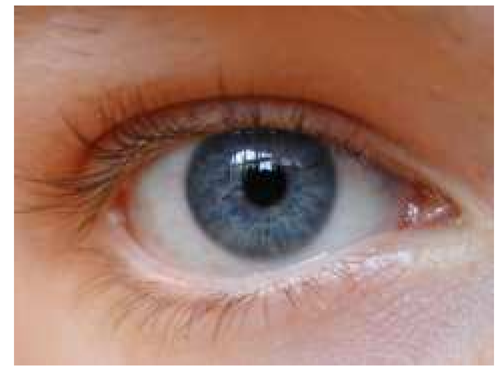
Vision

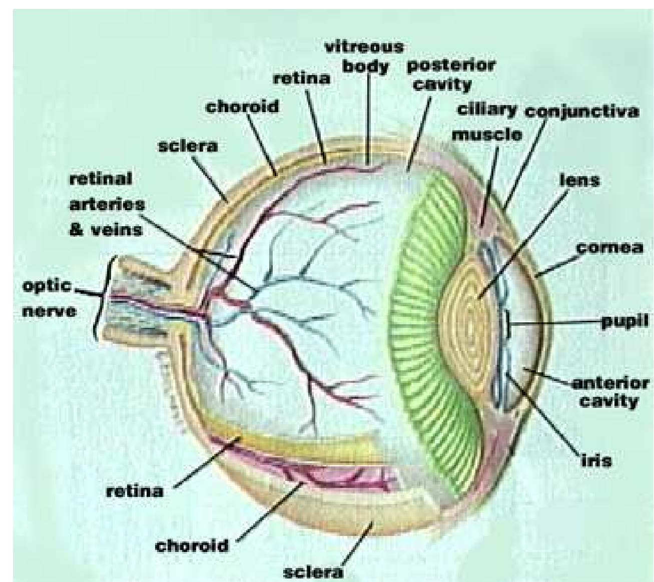
Two stages in vision

- physical reception of stimulus
- processing and interpretation of stimulus

The Eye - physical reception

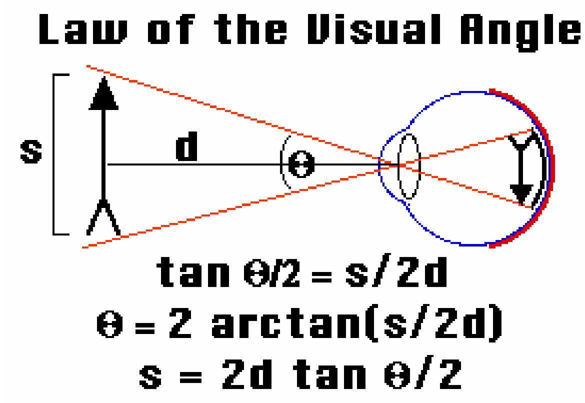
- Mechanism for receiving light and transforming it into electrical energy
- Light reflects from objects
- Images are focused upside-down on retina
- Retina contains rods for low light vision and cones for colour vision
- Ganglion cells (brain!) detect pattern and movement

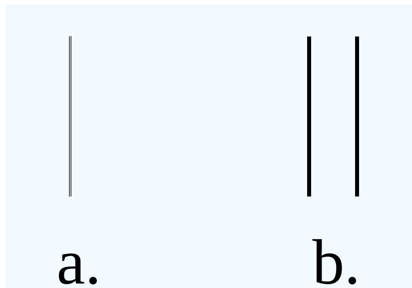




Interpreting the signal

- Size and depth
  - visual angle indicates how much of view object occupies
    (relates to size and distance from eye)
  - visual acuity is the ability to perceive detail (limited)
  - familiar objects perceived as constant size (in spite of changes in visual angle when far away)
  - cues like overlapping help perception of size and depth





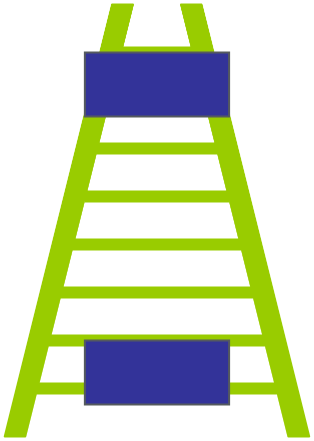
Interpreting the signal (cont)

- Brightness
  - **subjective** reaction to levels of light
  - affected by luminance of object
  - measured by just noticeable difference
  - visual acuity increases with luminance as does flicker
- Colour
  - made up of hue, intensity, saturation
  - cones sensitive to colour wavelengths
  - blue acuity is lowest
  - 8% males and 1% females colour blind

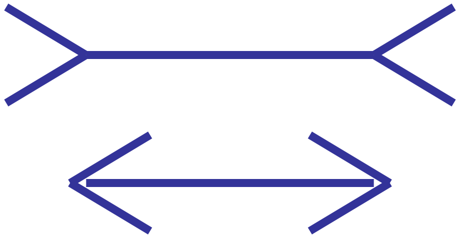
Interpreting the signal (cont)

- The visual system compensates for:
  - movement
  - changes in luminance.
- Context is used to resolve ambiguity
- Optical illusions sometimes occur due to over compensation

Optical Illusions



the Ponzo illusion



the Muller Lyer illusion

Reading

- Several stages:
  - visual pattern perceived
  - decoded using internal representation of language
  - interpreted using knowledge of syntax, semantics, pragmatics

- Reading involves saccades and fixations
- Perception occurs during fixations
- Word shape is important to recognition
- Negative contrast improves reading from computer screen

Reading (cont.)

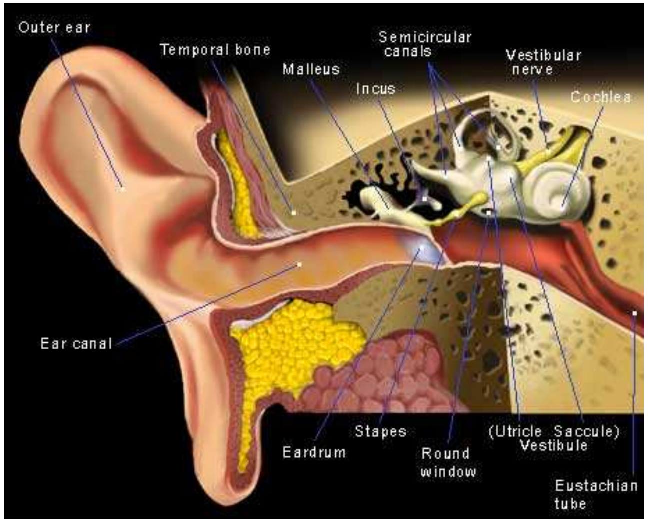
Aoccdrnig to a rseearch sduty at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be in the rghit pclae. The rset can be a toatl mses and you can sitll raed it wouthit porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe.

Hearing

- Provides information about environment:
  distances, directions, objects etc.

- Physical apparatus:
  – outer ear – protects inner and amplifies sound
  – middle ear – transmits sound waves as vibrations to inner ear
  – inner ear – chemical transmitters are released and cause impulses in auditory nerve

- Sound
  – pitch – sound frequency
  – loudness – amplitude
  – timbre – type or quality



Hearing (cont)

- Humans can hear frequencies from 20Hz to 15kHz
  - less accurate distinguishing high frequencies than low.

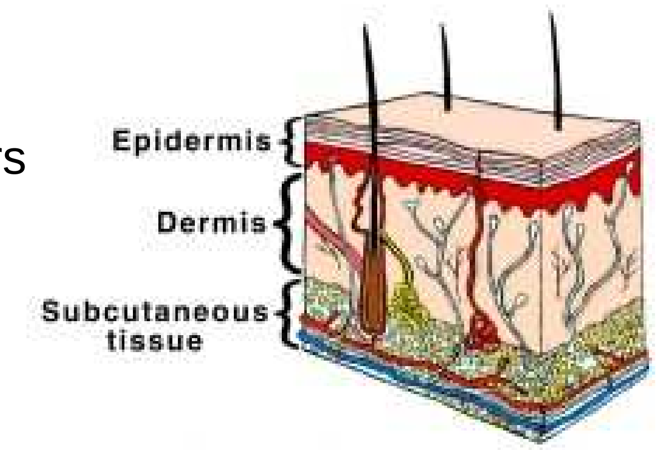
- Auditory system filters sounds (*Broadbent's filter theory* [1])
  - can attend to sounds over background noise.
  - for example, the *cocktail party phenomenon*.
    - ability to focus one's listening attention on a single talker among a mixture of conversations and background noises

Haptics (Touch)

- Provides important feedback about environment.
- Is key sense for someone who is visually impaired.
- Somatosensory System - the ability to sense touch
- Stimulus received via receptors in the skin (2500/cm^2):
  - Thermoreceptors – heat and cold
  - Nociceptors – pain
  - Mechanoreceptors – pressure
  - Proprioceptors – sense the position of different parts of the body

  (some instant, some continuous)

- Some areas more sensitive than others e.g. fingers
- Kinethesis - awareness of body position
  - affects comfort and performance.



Haptics (cont.)

- P channel, as measured in threshold experiments typically operates over the vibratory frequency range of 40-800 Hz - *Bolanowski [2]*

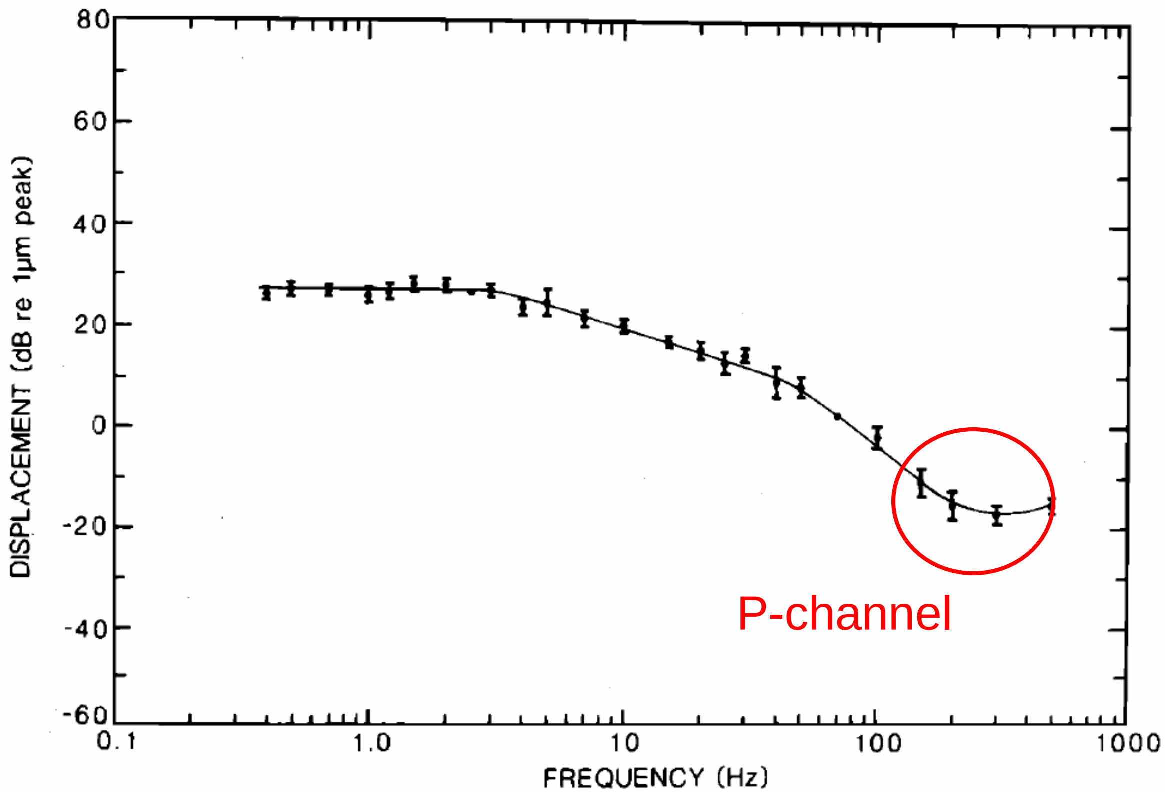


FIG. 1. Threshold-frequency characteristic relating stimulus intensity to stimulus frequency. The results are the averages of five observers. The error bars in this and the figures to follow signify the standard error of the means, their absence indicating that the error was too small to be depicted. Skin-surface temperature was maintained at 30 °C. Stimulus contactor size was 2.9 cm^2.

(!) 1000 Hz

Response to stimuli

- Time taken to respond to stimulus:

  reaction time + **movement time**

- Movement time dependent on age, fitness etc.
- Reaction time - dependent on stimulus type:
  - visual ~ 200ms
  - auditory ~ 150 ms
  - pain ~ 700ms
- Increasing reaction time decreases *accuracy* in the unskilled operator but not in the skilled operator.

Response to stimuli (cont)

- Fitts' Law describes the time taken to hit a screen target:

$$Mt = a + b \log_2(D/S + 1)$$

where: a and b are empirically determined constants
Mt is movement time
D is Distance
S is Size of target

$\Rightarrow$ targets as large as possible
distances as small as possible

Memory

There are three types of memory function:

Sensory memories

Attention

Short-term memory or working memory

Rehearsal

Long-term memory

Selection of stimuli governed by level of arousal.

Sensory memory

- Buffers for stimuli received through senses
  - iconic memory: visual stimuli
  - echoic memory: aural stimuli
  - haptic memory: tactile stimuli
- Examples
  - “sparkler” trail
  - stereo sound
- Continuously overwritten

Short-term memory (STM)

- Scratch-pad for temporary recall
  - rapid access ~ 70ms
  - rapid decay ~ 200ms
  - limited capacity - 7± 2 chunks

Examples

212348278493202

0121 414 2626

HEC ATR ANU PTH ETR EET

Long-term memory (LTM)

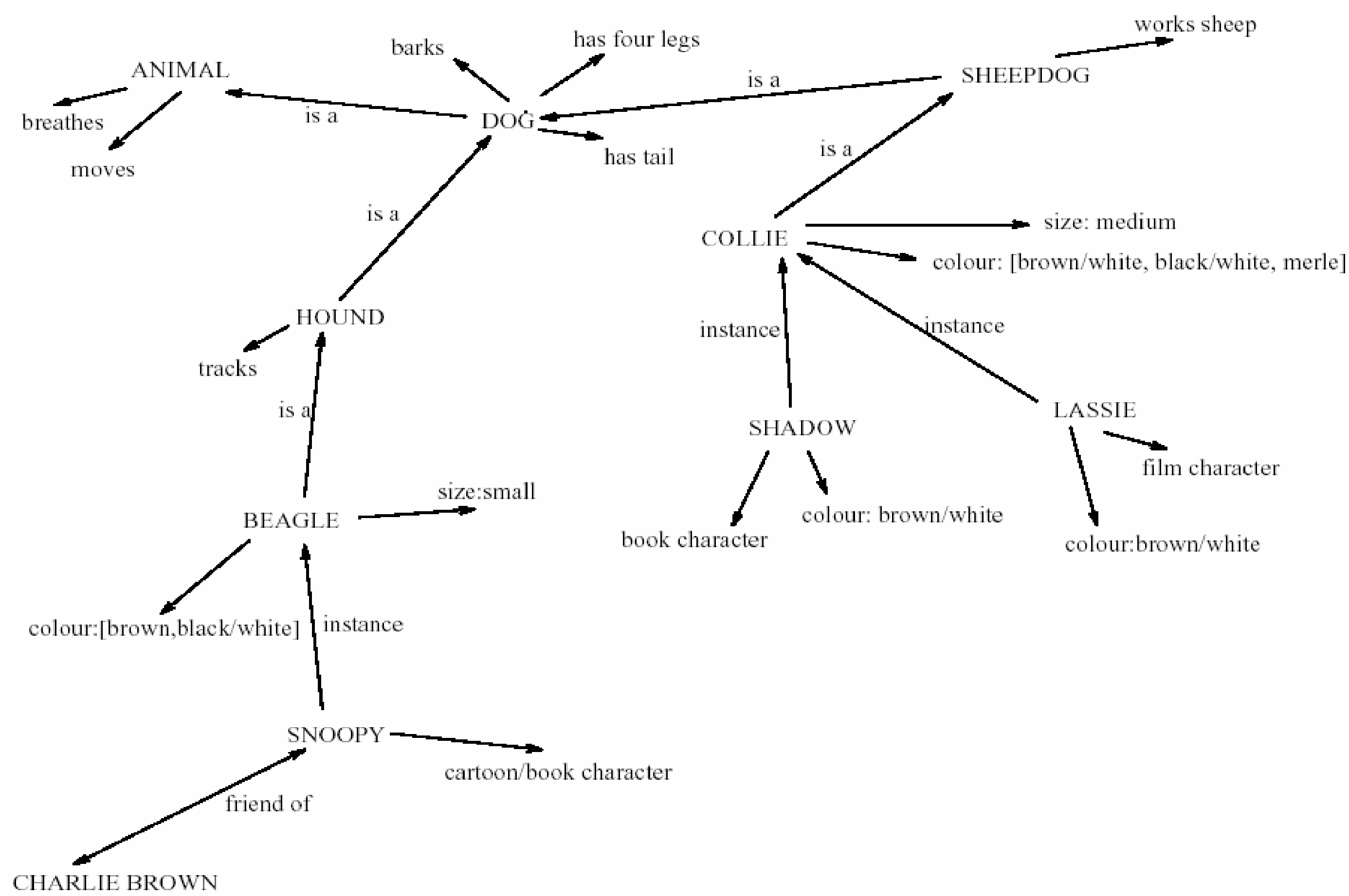
- Repository for all our knowledge
  - slow access ~ 1/10 second
  - slow decay, if any
  - huge or unlimited capacity
- Two types
  - episodic – serial memory of events
  - semantic– structured memory of facts,concepts, skills

semantic LTM derived from episodic LTM

Long-term memory (cont.)

- Semantic memory structure
  - provides access to information
  - represents relationships between bits of information
  - supports inference
- Model: semantic network
  - inheritance – child nodes inherit properties of parent nodes
  - relationships between bits of information explicit
  - supports inference through inheritance

LTM - semantic network



Models of LTM - Frames

- Information organized in data structures
- Slots in structure instantiated with values for instance of data
- Type–subtype relationships

DOG

Fixed
- legs: 4

Default
- diet: carniverous
- sound: bark

Variable
- size:
- colour

COLLIE

Fixed
- breed of: DOG
- type: sheepdog

Default
- size: 65 cm

Variable
- colour

Models of LTM - Scripts

Model of stereotypical information required to interpret situation

Script has elements that can be instantiated with values for context

Script for a visit to the vet

Entry conditions: *dog ill*
vet open
owner has money

Result: *dog better*
owner poorer
vet richer

Props: *examination table*
medicine
instruments

Roles: *vet examines*
diagnoses
treats
owner brings dog in
pays
takes dog out

Scenes: *arriving at reception*
waiting in room
examination
paying

Tracks: *dog needs medicine*
dog needs operation

Models of LTM - Production rules

Representation of procedural knowledge.

Condition/action rules

if condition is matched

then use rule to determine action.

IF dog is wagging tail
THEN pat dog

IF dog is growling
THEN run away

LTM - Storage of information

- Rehearsal
  - information moves from STM to LTM
- Total time hypothesis
  - amount retained proportional to rehearsal time
- Distribution of practice effect
  - optimized by spreading learning over time
- Structure, meaning and familiarity
  - information easier to remember

LTM - Forgetting

Decay

- information is lost gradually but very slowly

Interference

- new information replaces old: retroactive interference
- old may interfere with new: proactive inhibition

so may not forget at all memory is selective …

… affected by emotion – can subconsciously `choose' to forget

LTM - Retrieval

Recall

- information reproduced from memory can be assisted by cues, e.g. categories, imagery

Recognition

- information gives knowledge that it has been seen before
- less complex than recall - information is cue

Reasoning

1. deduction
2. induction
3. abduction

Problem solving

Deductive reasoning

- Deduction:
  - derive logically necessary conclusion from given premises.

    e.g. If it is Friday then she will go to work
    It is Friday
    Therefore she will go to work.

- Logical conclusion not necessarily true:

    e.g. If it is raining then the ground is dry
    It is raining
    Therefore the ground is dry

Deduction (cont.)

- When truth and logical validity clash …

  e.g. Some people are babies

  Some babies cry

  Inference - Some people cry

  Correct?

- People bring world knowledge in by mistake

Inductive reasoning

- Induction:
  - generalize from cases seen to cases unseen

    e.g. all elephants we have seen have trunks
    therefore all elephants have trunks.

- Unreliable:
  - can only prove false not true

  … but useful!

- Humans not good at using negative evidence

  e.g. Wason's cards.

Wason's cards

7 **E** **4** **K**

If a card has a vowel on one side it has an even number on the other

Is this true?

How many cards do you need to turn over to find out?

…. and which cards?

Abductive reasoning

- reasoning from event to cause

  e.g. Sam drives fast when drunk.

  If I see Sam driving fast, assume drunk.

- Unreliable:
  - can lead to false explanations

Problem solving

- Process of finding solution to unfamiliar task using knowledge.
- Several theories.
- Gestalt
  – problem solving both productive and reproductive
  – productive draws on insight and restructuring of problem
  – attractive but not enough evidence to explain `insight' etc.
  – move away from behaviourism and led towards information processing theories

Problem solving (cont.)

Problem space theory

– problem space comprises problem states
– problem solving involves generating states using legal operators
– heuristics may be employed to select operators e.g. means-ends analysis
– operates within human information processing system e.g. STM limits etc.
– largely applied to problem solving in well-defined areas e.g. puzzles rather than knowledge intensive areas

Problem solving (cont.)

- Analogy
  - analogical mapping:
    - novel problems in new domain?
    - use knowledge of similar problem from similar domain
  - analogical mapping difficult if domains are semantically different
- Skill acquisition
  - skilled activity characterized by chunking
    - lot of information is chunked to optimize STM
  - conceptual rather than superficial grouping of problems
  - information is structured more effectively

Errors and mental models

Types of error

- slips
  - right intention, but failed to do it right
  - causes: poor physical skill,inattention etc.
  - change to aspect of skilled behaviour can cause slip
- mistakes
  - wrong intention
  - cause: incorrect understanding

    humans create mental models to explain behaviour.

    if wrong (different from actual system) errors can occur

Emotion

- Various theories of how emotion works
  - James-Lange: emotion is our interpretation of a physiological response to a stimuli
  - Cannon: emotion is a psychological response to a stimuli
  - Schacter-Singer: emotion is the result of our evaluation of our physiological responses, in the light of the whole situation we are in
- Emotion clearly involves both cognitive and physical responses to stimuli

Emotion (cont.)

- The biological response to physical stimuli is called *affect*
- Affect influences how we respond to situations
  - positive $\rightarrow$ creative problem solving
  - negative $\rightarrow$ narrow thinking

"Negative affect can make it harder to do even easy tasks; positive affect can make it easier to do difficult tasks"

(Donald Norman)

Emotion (cont.)

- Implications for interface design
  - stress will increase the difficulty of problem solving
  - relaxed users will be more forgiving of shortcomings in design
  - aesthetically pleasing and rewarding interfaces will increase positive affect

Individual differences

- long term
  - sex, physical and intellectual abilities
- short term
  - effect of stress or fatigue
- changing
  - age

Ask yourself:

Will design decision exclude section of user population?

Psychology and the Design of Interactive Systems

- Some direct applications
  - e.g. blue acuity is poor
    $\Rightarrow$ blue should not be used for important detail

- However, correct application generally requires understanding of context in psychology, and an understanding of particular experimental conditions

- A lot of knowledge has been distilled in
  - guidelines
  - cognitive models
  - experimental and analytic evaluation techniques

Outline

- The Human - human perception
- **The Machine**
  - ***Input***
  - ***Output***
- Multimodal environments – the VR myth
- Haptics - brief history
- Haptic hardware and software
- Application domains
- E-learning with haptics
- Assessment
- Conclusions

The Computer

I have a 3 **GHz** laptop …with 10 **Hz** fingers

The Computer

A computer system is made up of various elements

Each of these elements affects the **interaction**

- input devices – text entry and pointing
- output devices – screen (small&large), digital paper
- virtual reality – special interaction and display devices
- physical interaction – e.g. sound, haptic, bio-sensing
- paper – as output (print) and input (scan)
- memory – RAM & permanent media, capacity & access
- processing – speed of processing, networks

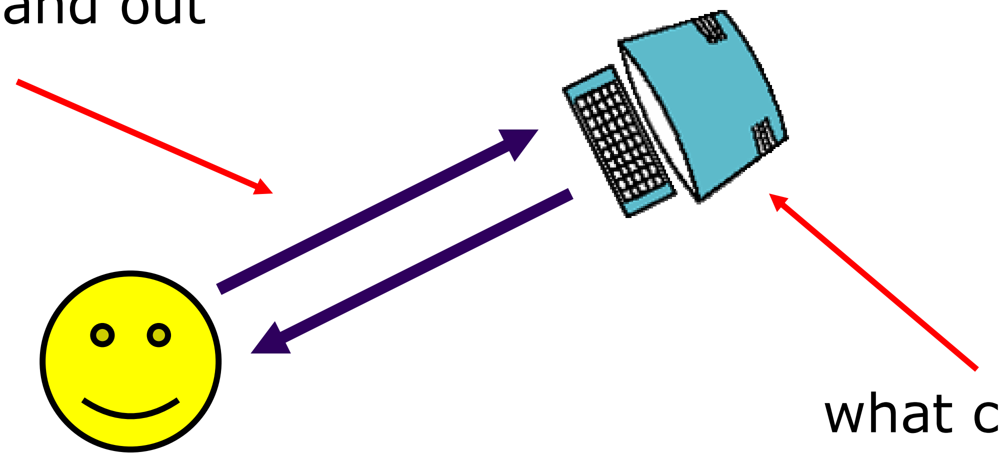
Interacting with computers

to understand human–*computer* interaction

… need to understand computers!

what goes in and out

devices, paper,
sensors, etc.



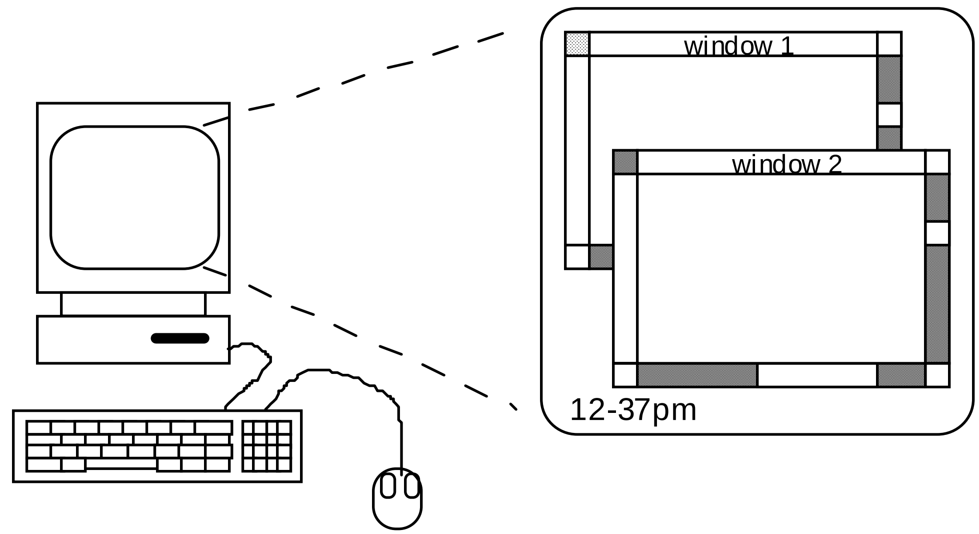
what can it do?

memory, processing,
networks

A ‘typical’ computer system

- screen, or monitor, on which there are **Windows**
- keyboard
- mouse/trackpad

- variations
  - desktop
  - laptop
  - PDA



the devices dictate the styles of interaction that the system supports

If we use different devices, then the interface will support a different style of interaction

How many “computers” …

in your house?

- PC
- TV, VCR, DVD, HiFi, cable/satellite TV
- microwave, cooker, washing machine
- central heating
- security system

in your pockets?

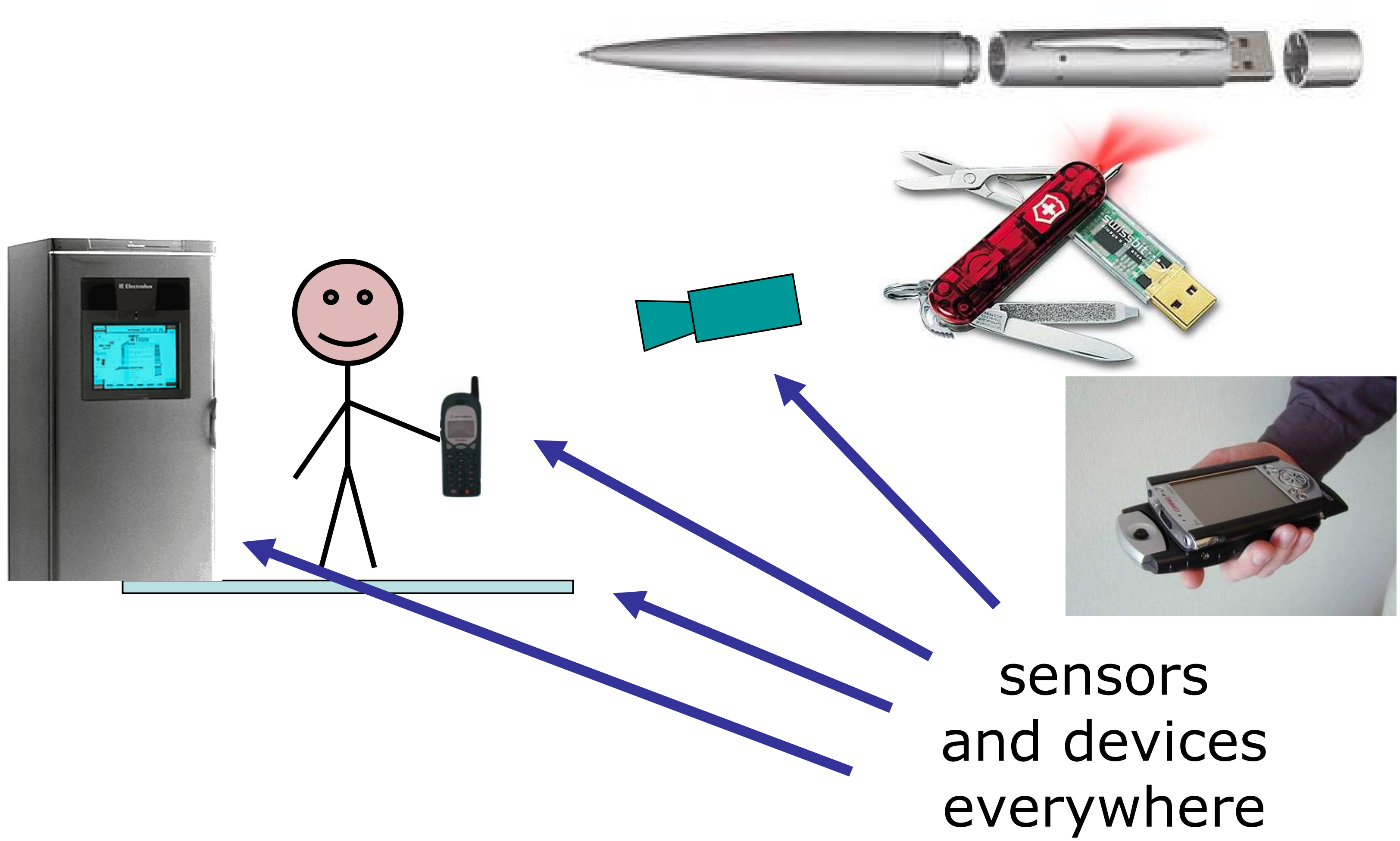
- PDA
- Phone
- mp3 player
- camera
- smart card
- electronic car key

XDA

Interactivity? (Levels of Interaction)

- Batch processing
  - punched card stacks or large data files prepared
  - long wait ….
  - line printer output
  - … and if it is not right …
- Now most computing is interactive
  - rapid feedback
  - the user in control (most of the time)
  - doing rather than thinking …
- Is faster always better?

Richer interaction – every …where/time



INPUT

Text Entry Devices

keyboards (QWERTY et al.)

chord keyboards, phone pads, handwriting, speech

Keyboards

- Most common text input device
- Allows rapid entry of text by experienced users
- Keypress closes connection, causing a character code to be sent
- Usually connected by cable, but can be wireless

Special Keyboards

- Designs to reduce fatigue for RSI
- For one handed use

  e.g. the Maltron left-handed keyboard

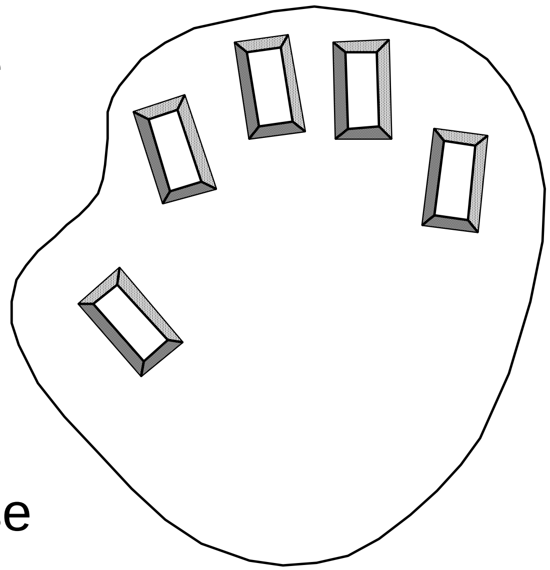
- 10-15% improvement in speed and reduction in fatigue

- **BUT** - large social base of QWERTY typists produce **market pressures** not to change

Chord keyboards

only a few keys - four or 5
letters typed as combination of keypresses
compact size

- ideal for portable applications
- short learning time - keypresses reflect letter shape
- fast - once you have trained



BUT - social resistance, plus fatigue after extended use
NEW – niche market for some wearables

Phone pad and T9 entry

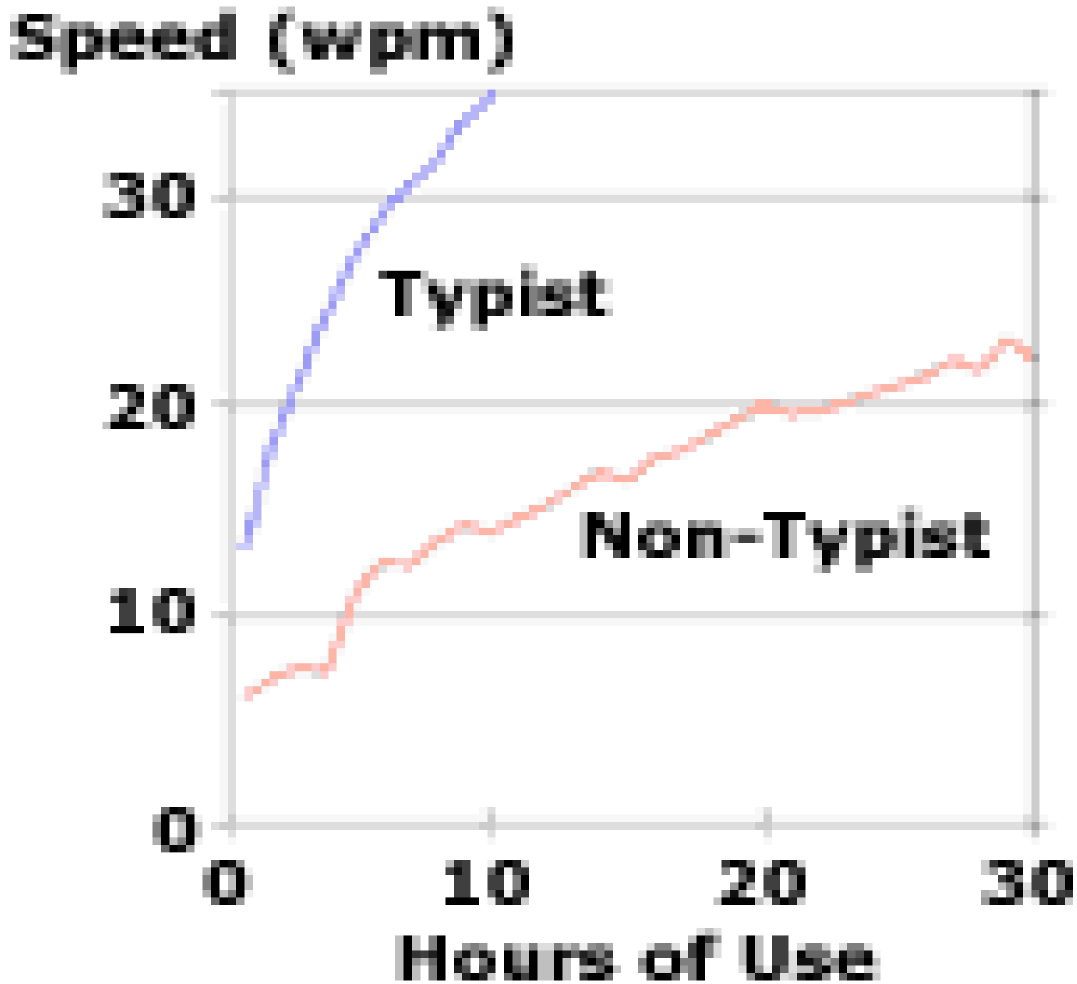
- Use numeric keys with multiple presses

  2 – a b c   6 - m n o
  3 - d e f   7 - p q r s
  4 - g h i   8 - t u v
  5 - j k l   9 - w x y z

  hello = 4433555[pause]555666

  surprisingly fast!

- T9 predictive entry
  - type as if single key for each letter
  - use dictionary to 'guess' the right word
  - hello = 43556 …
  - but 26 -> menu 'am' or 'an'



http://www.matias.ca/halfkeyboard/

Projected light keyboard

http://www.virtual-laser-keyboard.com/

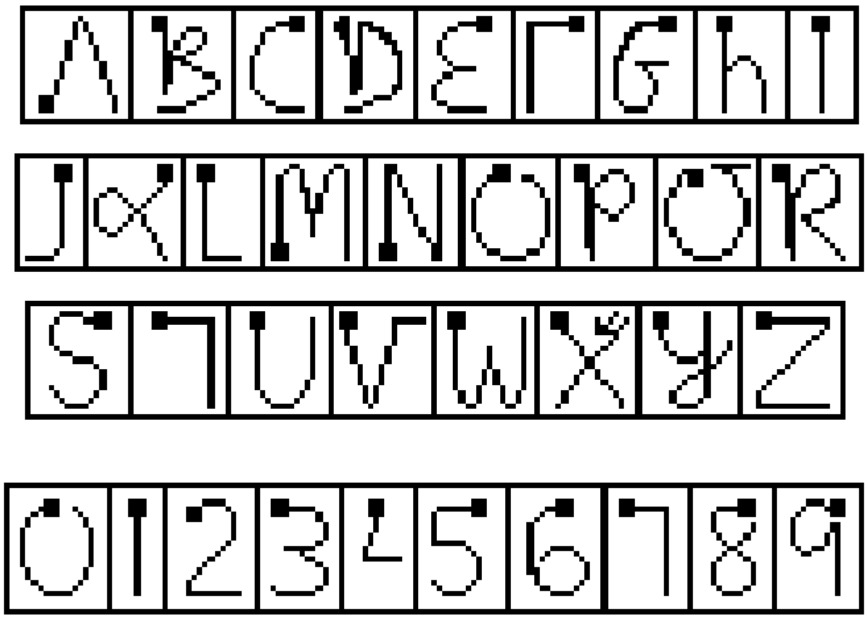
Handwriting recognition

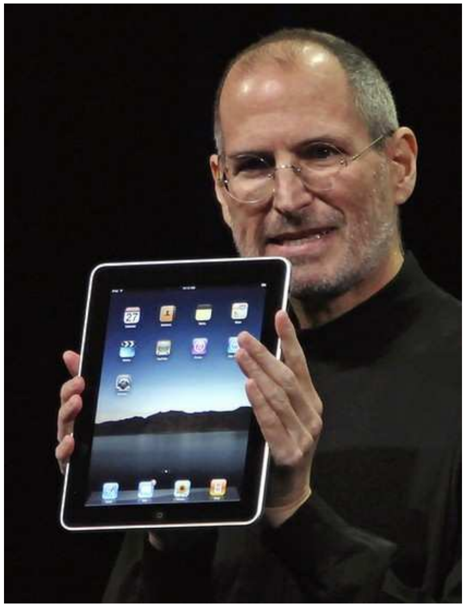
- Text can be input into the computer, using a pen, touch screen
  - natural interaction
- Technical problems:
  - capturing all useful information - stroke path, pressure, etc. in a natural manner
  - segmenting joined up writing into individual letters
  - interpreting individual letters
  - coping with different styles of handwriting
- Used in PDAs (now **XDA**s), and tablet computers … … leave the keyboard on the desk!

Stylus / Pen

On-screen Keyboard

PDA - Graffiti Application





XDAs


Headset jack
Sleep/Wake button
Receiver
SIM card tray
Ring/Silent switch
Camera (on back)
Volume buttons
Status bar
Application buttons
Touchscreen
Home button
Dock connector
Speaker
Microphone

Speech recognition

- Improving rapidly
- Most successful when:
  - single user – initial training and learns peculiarities
  - limited vocabulary systems
- Problems with
  - external noise interfering
  - imprecision of pronunciation
  - large vocabularies
  - different speakers

Speech recognition (cont.)

- “Speech recognition can reduce costs by 30 to 40%, and early users will have a very high competitive advantage.” - *Nick van Terheyden, MD, CMO, Philips Speech Recognition Systems* [3]

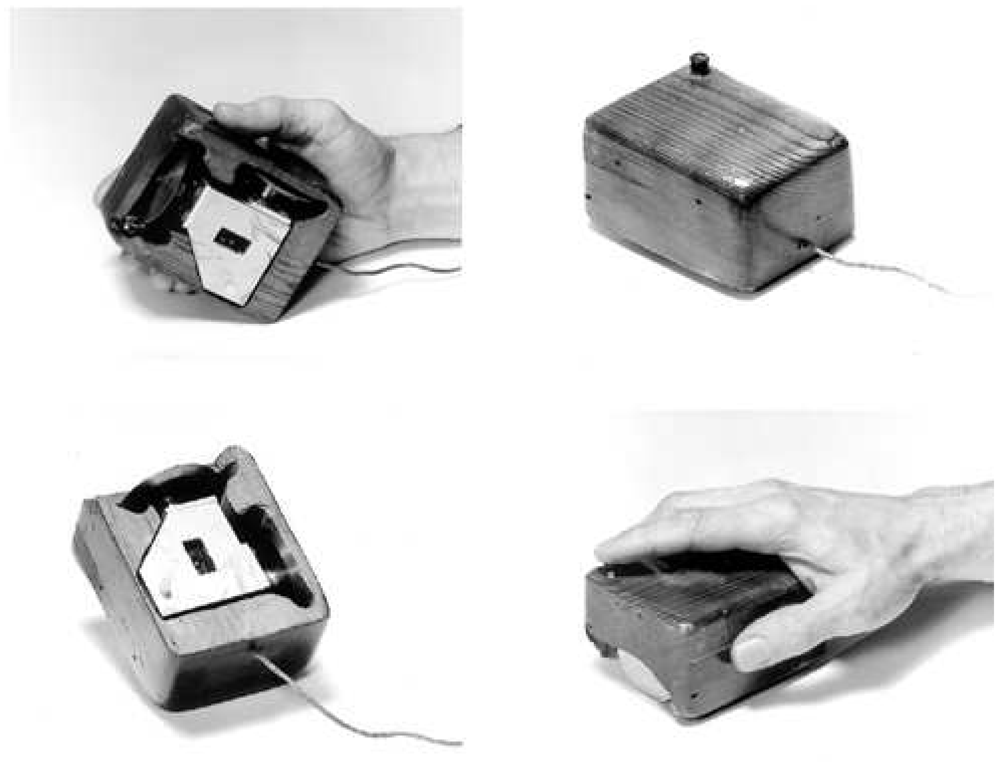
- Lexical information extracted from combined prosodic and acoustic features that correspond to intonation pattern of “salient words” will yield robust recognition of emotion from speech [4,5]

Positioning, Pointing and Drawing

mouse, touchpad
trackballs, joysticks etc.
touch screens, tablets
eyegaze, cursors

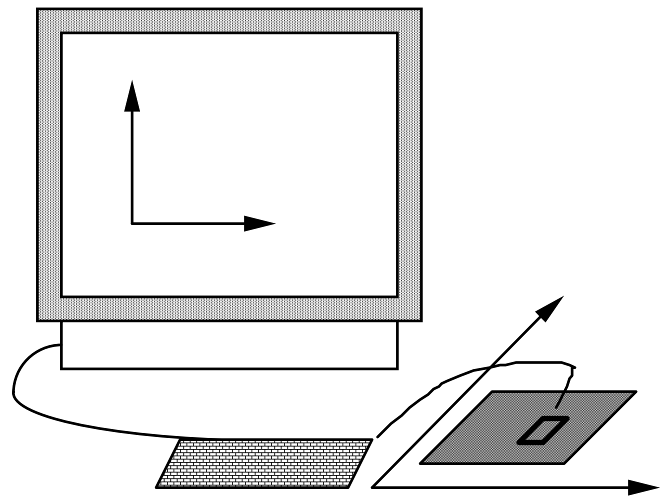
The Mouse

- Handheld pointing device
  - very common
  - easy to use
- Two characteristics
  - planar movement
  - buttons



The Mouse (cont.)

Mouse located on desktop
- requires physical space
- no arm fatigue



Relative movement only is detectable.
Movement of mouse moves screen cursor
Screen cursor oriented in (x, y) plane,
mouse movement in (x, z) plane …

… an *indirect* manipulation device.
- device itself doesn't obscure screen, is accurate and fast.
- hand-eye coordination problems for novice users

How does it work?

Two methods for detecting motion

- Mechanical
  - ball rotates orthogonal potentiometers
  - can be used on almost any flat surface
- Optical
  - LED underside of the mouse
  - less susceptible to dust and dirt
  - detects fluctuating alterations in reflected light intensity to calculate relative motion in (x, z) plane

3D

Even by foot …

- some experiments with the *footmouse*
  - controlling mouse movement with feet …
  - not very common :-)

- but foot controls are common elsewhere:
  - car pedals
  - sewing machine speed control
  - organ and piano pedals

Touchpad

- small *touch* sensitive tablets
- 'stroke' to move mouse pointer
- used mainly in laptop computers
- good 'acceleration' settings important
  - fast stroke
    - lots of pixels per inch moved
    - initial movement to the target
  - slow stroke
    - less pixels per inch
    - for accurate positioning

Trackball and thumbwheels

Trackball

- ball is rotated inside static housing
  - like an upside down mouse!
- relative motion moves cursor
- indirect device, fairly accurate
- separate buttons for picking
- very fast for gaming
- used in some portable and notebook computers.

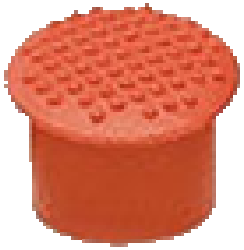
Thumbwheels …

- for accurate CAD – two dials for X-Y cursor position
- for fast scrolling – single dial on mouse

Joystick and keyboard nipple

Joystick

- indirect
  pressure of stick = velocity of movement
- buttons for selection
  on top or on front like a trigger
- often used for computer games
  aircraft controls and 3D navigation



Keyboard nipple

- for laptop computers
- miniature joystick in the middle of the keyboard

Touch-sensitive screen

- Detect the presence of finger or stylus on the screen.
  - works by interrupting matrix of light beams, capacitance changes or ultrasonic reflections
  - direct pointing device
- Advantages:
  - fast, and requires no specialised pointer
  - good for menu selection
  - suitable for use in hostile environment: clean and safe from damage.
- Disadvantages:
  - finger can mark screen
  - imprecise (finger is a fairly blunt instrument!)
  - lifting arm can be tiring

Future of Input - Eye gaze/gesture&voice recognition

- Control interface by eye gaze direction
  - e.g. look at a menu item to select it
- Uses laser beam reflected off retina
  - … a very low power laser!

- Potential for hands-free control
- High accuracy requires headset

OUTPUT

Display devices

Auto-stereoscopic 3-D Display(courtesy of Dimension Technologies Co.)

bitmap screens (CRT & LCD)

large & situated displays

digital paper

Resolution and colour depth

- Resolution:
  - number of pixels on screen (width x height)
    - e.g. SVGA 1024 x 768 , XDA (I-Phone, 640x960
  - density of pixels (pixels/dots per inch – d/ppi)
    - typically between 96 and 300 dpi, (I-Phone, 326 ppi)

- Aspect ratio:
  - ration between width and height
  - 4:3 for most screens, 16:9 for wide-screen TV
- Colour depth:
  - black/white or greys only
  - 256 from a palette
  - 8 bits each for RGB => 16 million colors

Large displays

- Used for meetings, lectures, etc.
- Technology
  - –plasma – usually wide screen
  - –video walls – lots of small screens
  - –projected– RGB lights or LCD projector
    - – hand/body obscures screen
    - – may be solved by 2 projectors + clever software
  - –back-projected
    - – frosted glass + projector behind

Situated displays

- Displays in 'public' places
  - large or small
  - very public or for small group
- Display only
  - for information relevant to location
- Interactive
  - use stylus, touch sensitive screen
- in all cases … the location matters
  - meaning of information or interaction is related to the location

Hermes[6] a situated display

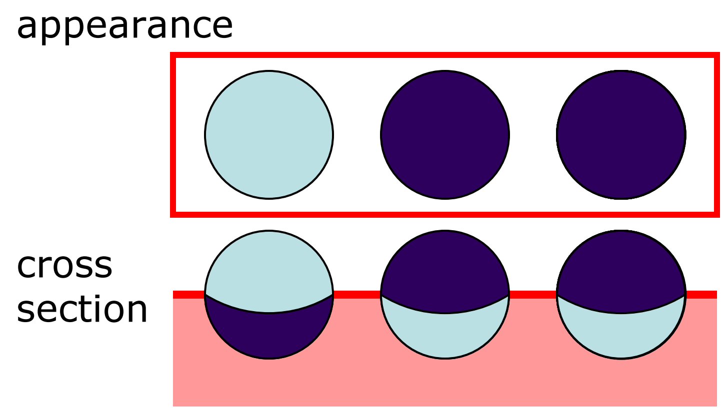
small displays
beside
office doors

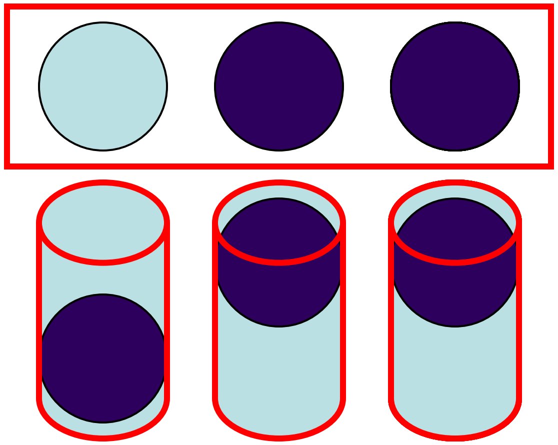
handwritten
notes left
using stylus

office owner
reads notes
using web interface

Digital paper

- what?
  - thin flexible sheets
  - updated electronically
  - but retain display
- how?
  - small spheres turned
  - or channels with coloured liquid and contrasting spheres
  - rapidly developing area

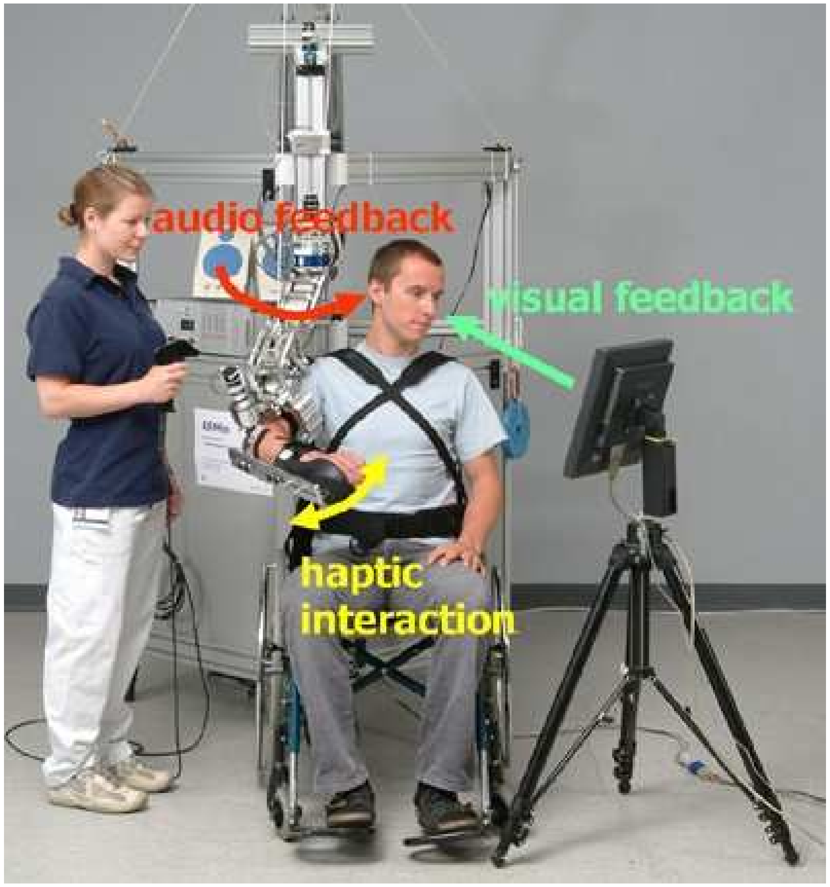




Outline

- The Human - human perception
- The Machine - input/output
- **Multimodal environments – the VR myth, AR**
- Haptics - brief history
- Haptic hardware and software
- Application domains
- E-learning with haptics
- Assessment
- Conclusions

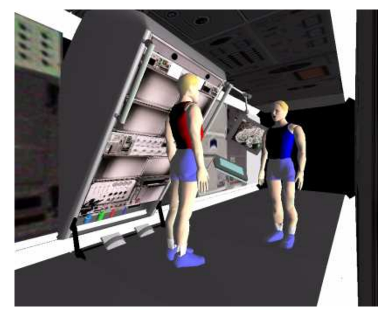
MultiModal Environments



Milgram's Reality-Virtuality Continuum

Mixed Reality

Complete Real	Augmented Reality (AR)	Augmented Virtuality (AV)	Complete Virtual (VR)



Reality - Virtuality (RV) Continuum

Adapted from Milgram, Takemura, Utsumi, Kishino. [7]

VR vs. AR

- Virtual Reality: Replaces Reality
  - Immersive Displays
- Augmented Reality: Enhances Reality
  - See-through Displays
- Augmented Reality Characteristics
  - Combines Real and Virtual Images
  - Interactive, real-time computation… 30fps or more
  - Virtual Objects are registered in 2D/3D

Virtual Reality and 3D Interaction

Output: seeing 3D (helmets and caves)

Input: positioning in 3D space, grasping

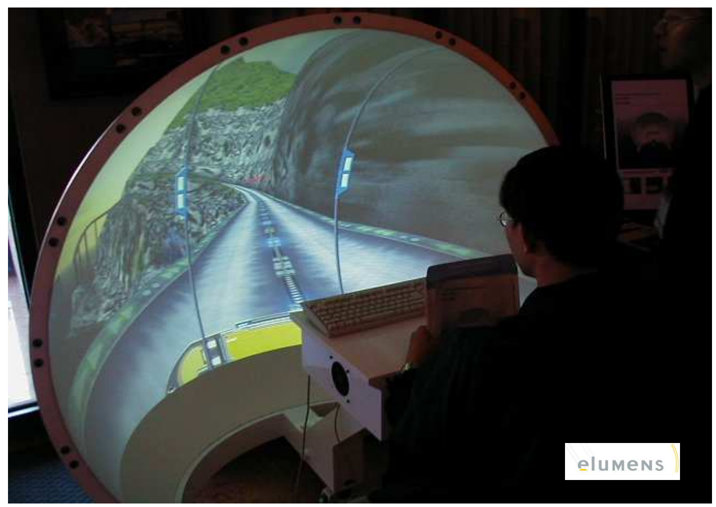
NEWS Network Enabled WorkSpaces
Armstrong Atlantic State University
Department of Computer Science

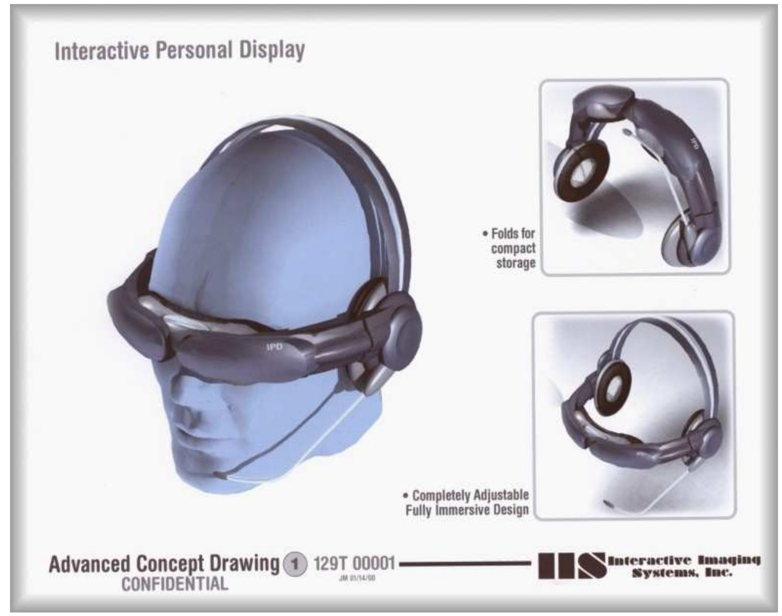
HAPTIC MED

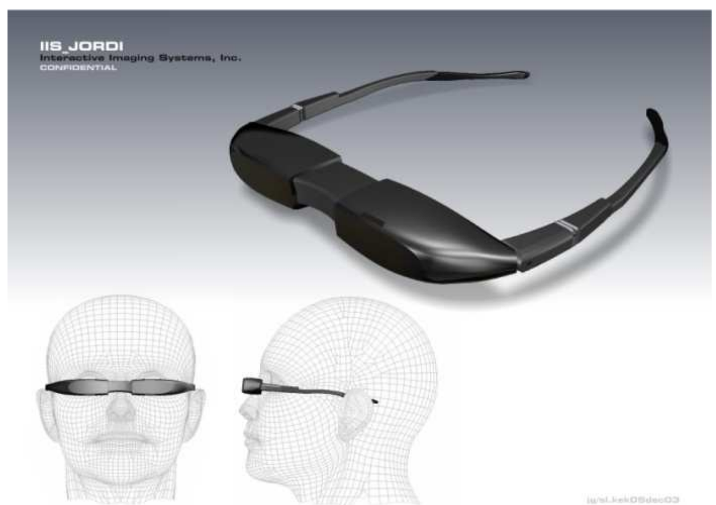
Mini-Workbench

The ImmersaDesk

CAVE 3-D large volume display (Fakespace Co.)




Interactive Personal Display
• Folds for compact storage
• Completely Adjustable Fully Immersive Design
Advanced Concept Drawing 1 129T 00001
CONFIDENTIAL
Interactive Imaging Systems, Inc.


IIS_JORDI
Interactive Imaging Systems, Inc.
CONFIDENTIAL

Positioning in 3D space

- The 3D mouse
  - six-degrees of movement: x, y, z + roll, pitch, yaw
- Data glove
  - fibre optics used to detect finger position
- VR helmets
  - detect head motion and possibly eye gaze
- Whole body motion tracking
  - accelerometers strapped to limbs or reflective dots and video processing

Sounds

- Beeps, bongs, clonks, whistles and whirrs
- Used for error indications
- Confirmation of actions e.g. key-click

Touch, taste, smell

- **Touch** important
  - in games … vibration, force feedback
  - in simulation … feel of surgical instruments
  - called *haptic* devices
  - recent technology *(4 years ago mass-produced)*
- Taste, smell
  - current technology very limited

Key elements of VR

- Immersion
- Interactivity

VR Classroom
1.Assessment of Attention deficit hyperactivity disorder (ADHD)
2.Teaching scenario evaluation
3.Assessment of Interactivity during class

Why is VR still a “myth” ?

- Motion Sickness
  - time delay
    - move head … lag … display moves
    - *conflict:* head movement vs. eyes
  - depth perception
    - headset gives different stereo distance
    - but all focused in same plane
    - *conflict:* eye angle vs. focus
  - conflicting cues => sickness
    - helps motivate improvements in technology

Outline

- The Human - human perception
- The Machine - input/output
- Multimodal environments – the VR myth, AR
- **Haptics - succinct history**
- Haptic hardware and software
- Application domains
- E-learning with haptics
- Assessment
- Conclusions

NEWS Network Enabled WorkSpaces
Armstrong Atlantic State University
Department of Computer Science

HAPTIC MED

Haptics

What is “Haptics” ?

- Derived from the Greek *ἁπτικός* (*haptikos*), means pertaining to the sense of touch
- 5 senses: sight, smell, taste, touch, and hearing
- Haptic interfaces

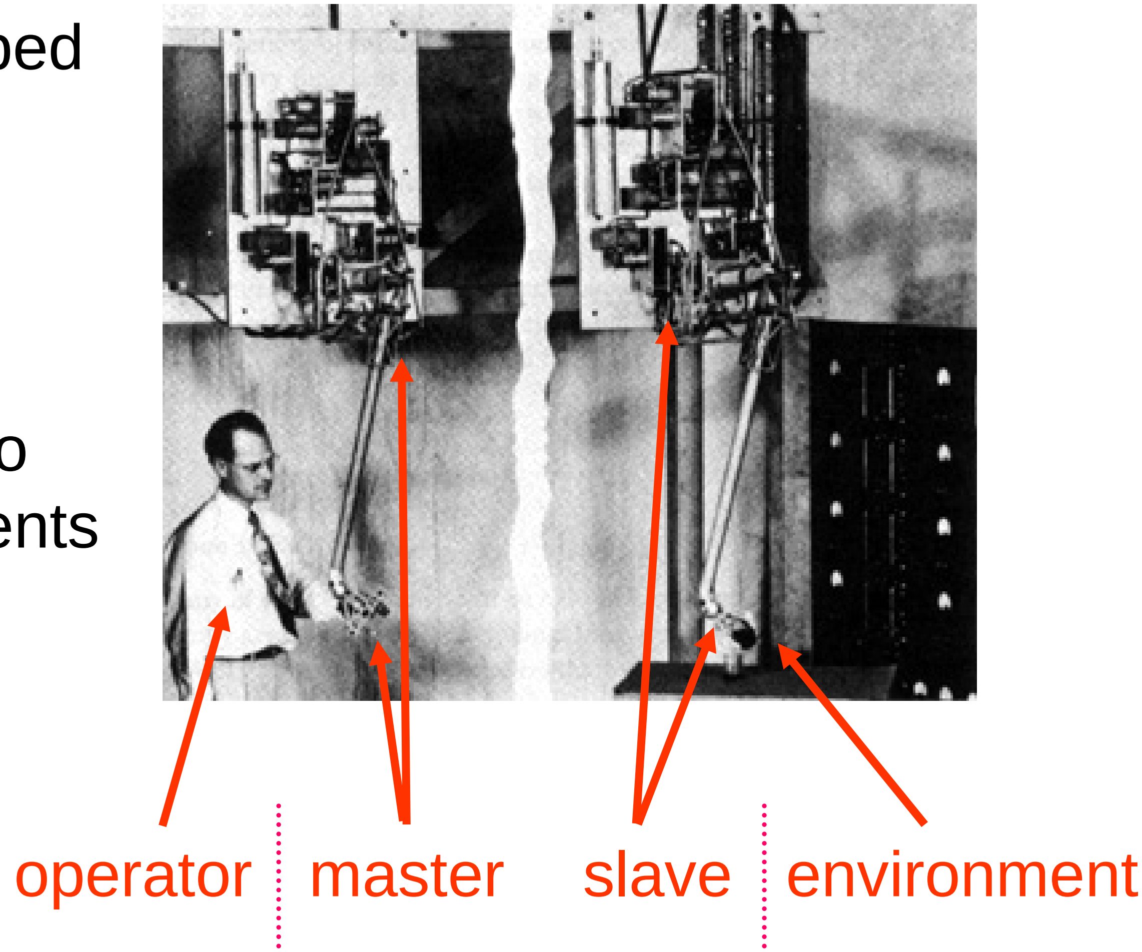
Haptics

Haptics – early R&D (1800)

- Ernst Heinrich Weber (1795-1878)
  - the results of many of his experiments in De Tactu ("The Touch") in 1834.
  - response to weight, temperature, and pressure
  - determined that there was a threshold of sensation that must be passed before an increase in the intensity of any stimulus could be perceived
  - "Two objects touching the skin simultaneously seem to us to be separated by a shorter distance, the lower the tactile acuity of the touched parts."

Haptics – early R&D (1950)

- First systems developed ~ 1950's
  - handling radioactive materials
- Can provide access to dangerous environments
- Benefit from natural human abilities



[The E1 developed by Goertz at Argonne National Lab]

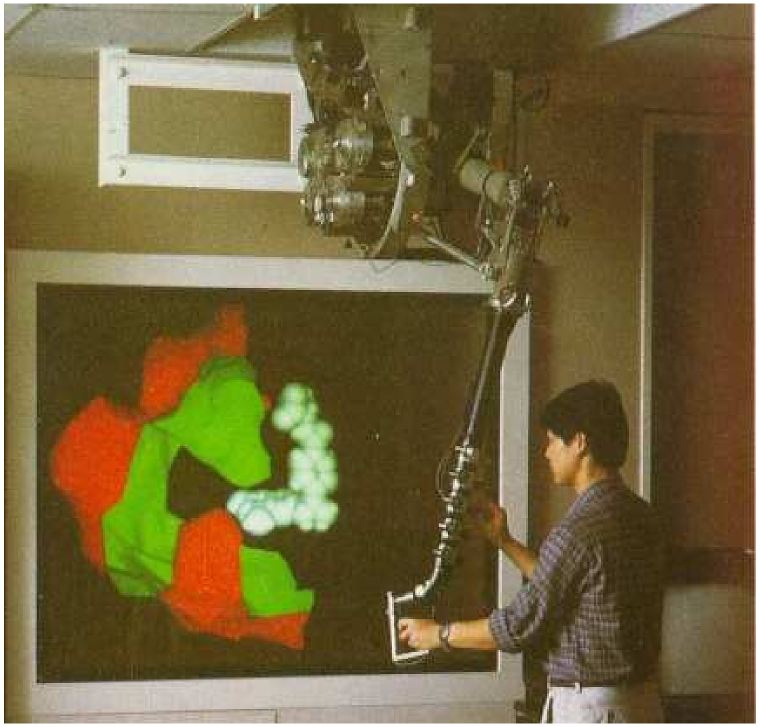
Haptics – early R&D (1960)

- Military flight simulators
  – skills honing

- GE's Dubbed Hardiman [9]
  – exoskeleton
  – weighed 1,500 lbs and included 28 joints
  – lift up to 1,500 lbs

Haptics – early R&D (1970)

- GROPE Project (1967-'90) [8]
  - a haptic+visual for 6-D force fields of interacting protein molecules
  - "*haptic-augmented interactive systems seem to give about a [two-fold](#) performance improvement over purely graphical interactive systems*"



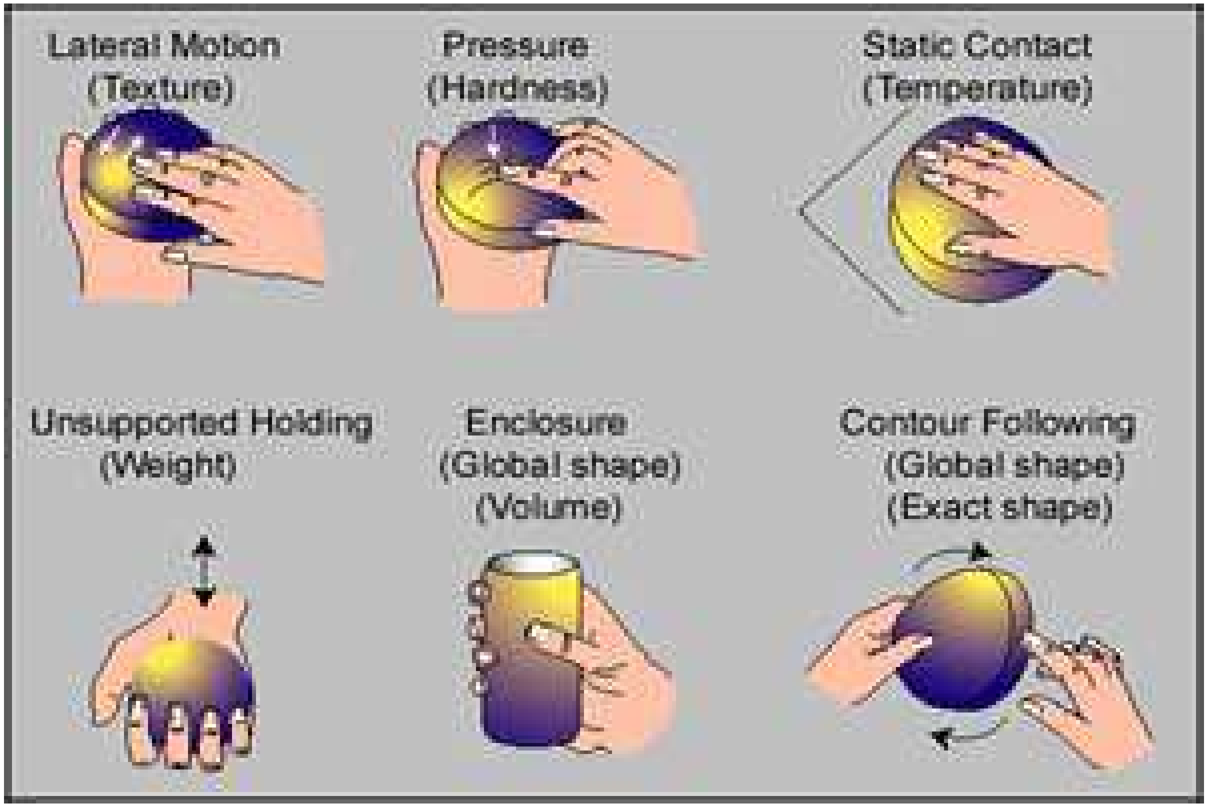
"The Docker" – molecule manipulation

Haptics – early R&D (1980)

- Computing:
  - Improved algorithms
  - Improved computing power
  - Rich color graphics and high-quality audio

- 1987 Lederman and Klatzky (1987) [10] summarized 4 basic procedures for haptic exploration
  - **lateral motion** (stroking) provides information about the surface texture of the object
  - **pressure** gives information about how firm the material is
  - **contour following** elicits information on the form of the object
  - **enclosure** reflects the volume of the object.

Haptic – R&D



Lateral Motion
(Texture)
Pressure
(Hardness)
Static Contact
(Temperature)
Unsupported Holding
(Weight)
Enclosure
(Global shape)
(Volume)
Contour Following
(Global shape)
(Exact shape)

Haptics – early R&D (1990)

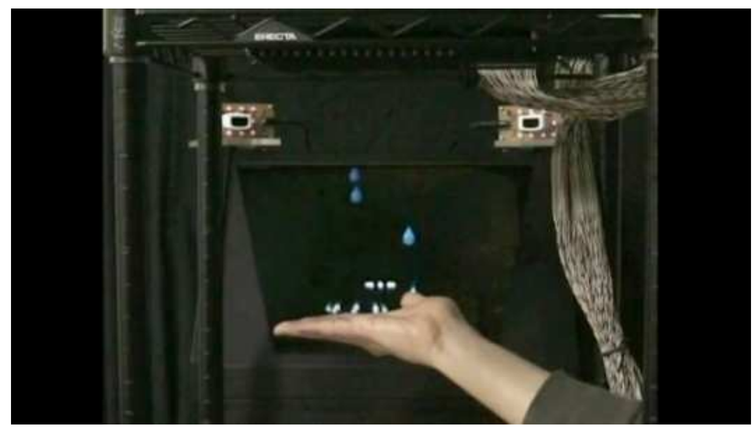
- Shortcoming in simulation products were identified.
- Graphics and animations looked incredibly realistic however they **could not convey** what it actually feels like to break through a venal wall with a needle, for example.
- Immersion was founded in 1993
  - Video games
  - Medical simulators

(!) still too expensive for public

Haptics – R&D (2000)

- Immersion TouchSense® technology is incorporated into gaming systems (Sony, Microsoft)

- 1,500 Immersion Medical simulators have been deployed at hospitals and medical schools
- (2007) Novint released the Falcon, the first consumer 3D touch device
- (2009) University of Tokyo
  - 3D holograms that can be "touched" through haptic feedback using "acoustic radiation" to create a pressure sensation on hands [11]



Outline

- The Human - human perception
- The Machine - input/output
- Multimodal environments – the VR myth, AR
- Haptics - succinct history
- **Haptic hardware and software**
- Application domains
- E-learning with haptics
- Assessment
- Conclusions

Hardware

- Falcon – Novint [12]

Phantom Omni

6 DOF I

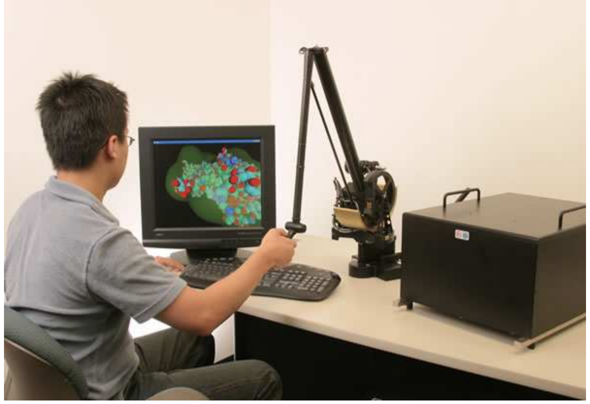
450 dpi ~ 0.055 mm.

Phantom Desktop

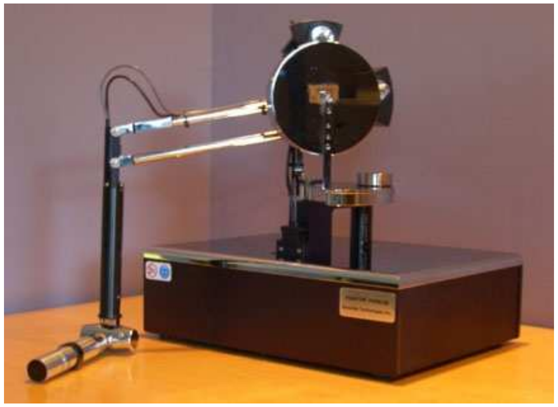
Resolution: 1100 dpi ~ 0.023 mm.

SensAble [13]

Hardware



Premium 3.0/6DOF Haptic Device



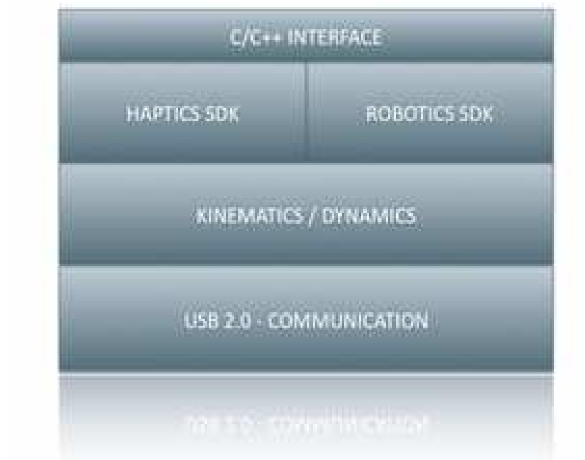
PHANTOM Premium 1.5/6DOF

The PHANTOM Desktop haptic device with the Auto Suture® 5mm Endo Clinch® II device attached.

Hardware

Omega 3

Omega 7



(!) CHAI3D Libraries

3 active translations
3 passive rotations
1 active grasping

Force Dimension [14]

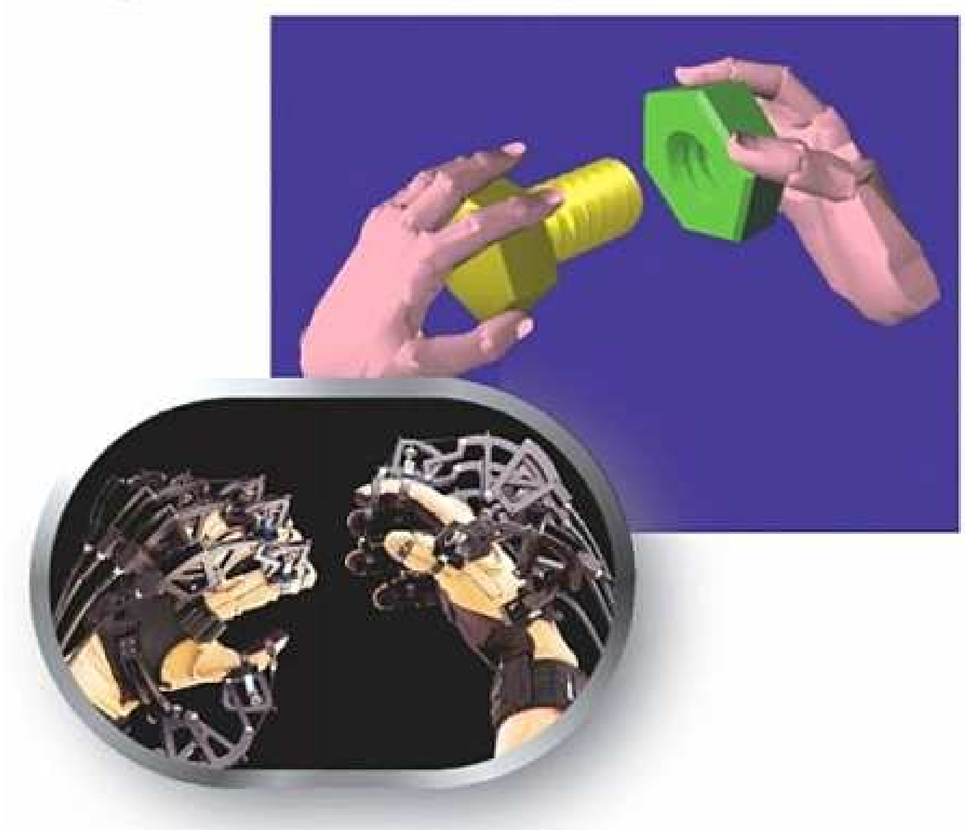
NEWS Network Enabled WorkSpaces
Armstrong Atlantic State University
Department of Computer Science

HAPTIC MED

Hardware

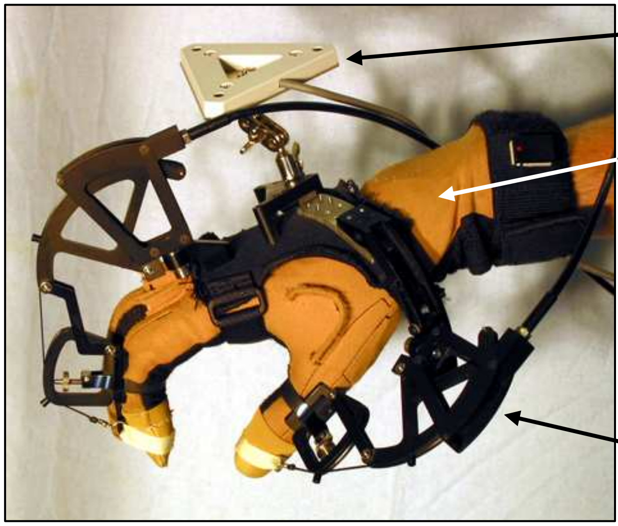
Cyber Grasp

Cyber Force



Hardware

- CyberGlove™ instrumented glove
  - 22 bend sensors
  - calibrated for dexterous manipulation
- CyberGrasp™ fingertip force feedback
  - lightweight exo-skeleton
  - uni-directional force feedback
- Logitech hand tracker
  - ultrasonic transducers and sensors
  - 6 DOF position and orientation



[CyberGlove and CyberGrasp are products of Immersion Corporation]

NEWS Network Enabled WorkSpaces
Armstrong Atlantic State University
Department of Computer Science

Hardware

Butterfly Haptic – magnetic levitation

Maglev 200™
Magnetic Levitation
Haptic Interface

Butterfly Haptics [15]

Hardware

Planar 3D

CRT – Shutter Glasses

SenseGraphics

LCD Based

Projector based

Hardware – Visual Volume

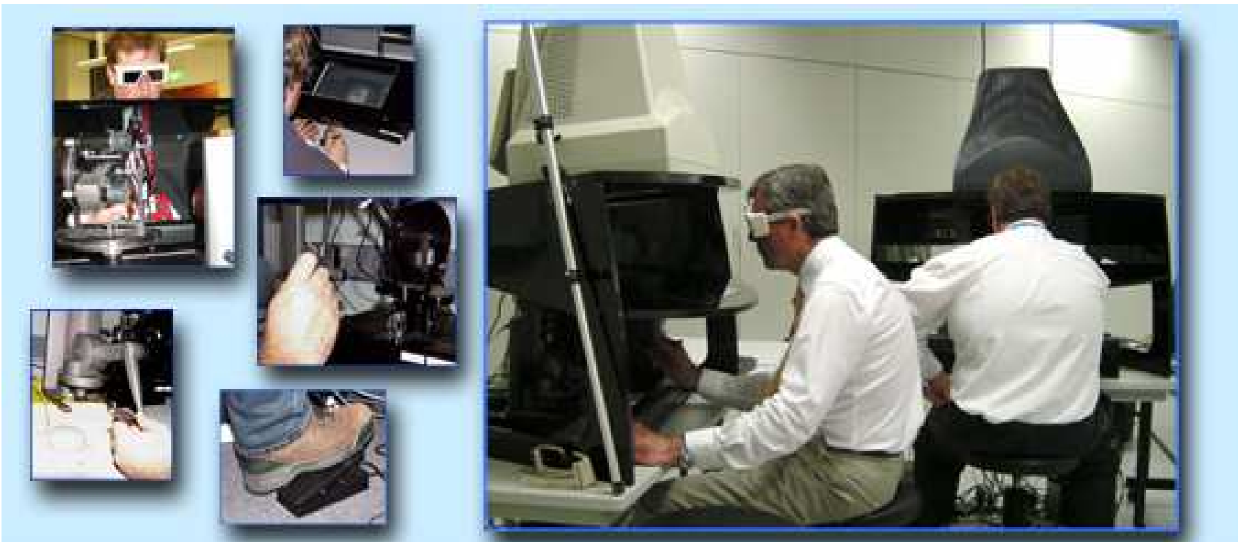
Hardware – Medical Sim

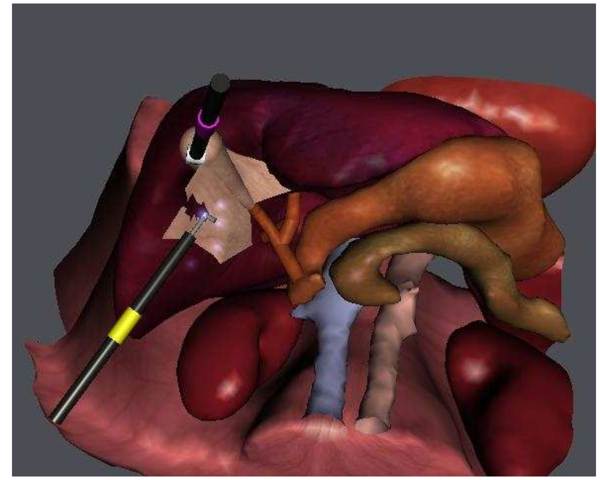
1. The LapVR Surgical Simulator

2. AccuTouch® endoscopy Surgical Sim.

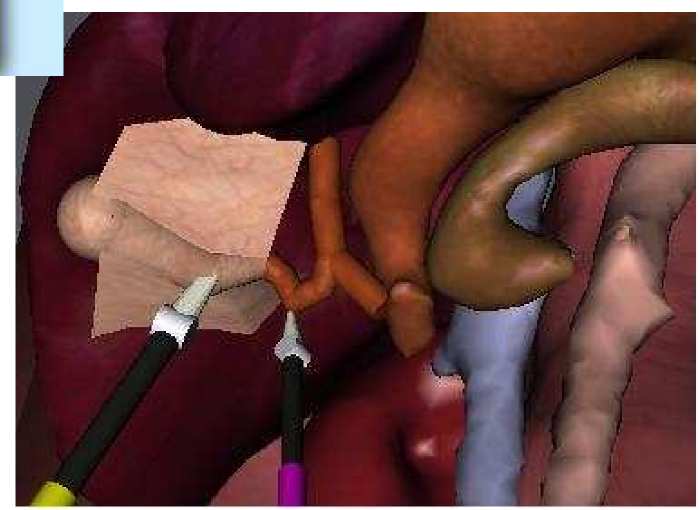
3. CathLabVR System

Hardware – Medical Sim





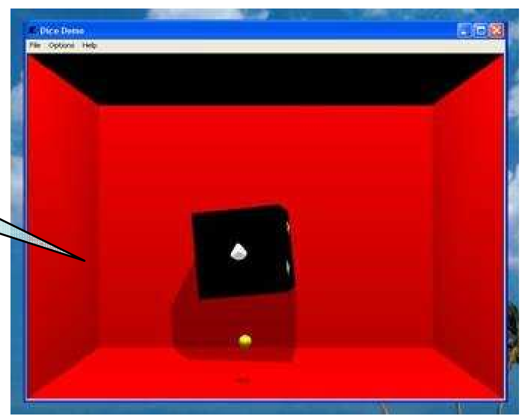
Gallbladder Surgery [16]
Telepresence



Working principle

physical reference point

virtual reference point



- Robotic arm that tracks position and orientation of user's hand.
- Updates position and orientation information every ms (1KHz)
- Visual representation of physical reference point within virtual application.

Software

- Modeling and 2D/3D environment development:
  - Advanced level: OpenGL, C, C++
  - Medium level: **X3D** [17] **, Pyton Scripting**

- Tactile interaction programming:
  - Advanced level: C++, C
  - Medium level: **H3D** [18], **Pyton Scripting** [19]

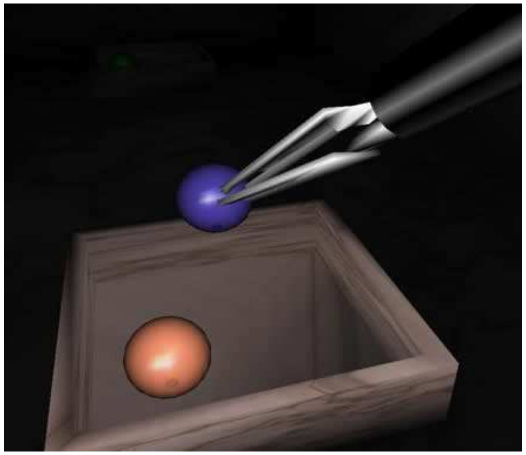
Software

1. Reachin [20] – is a provider of state of the art human computer interface technology and is the world-leading haptic software solution provider.

2. CHAI 3D [21] – an open source set of C++ libraries for computer haptics, visualization and interactive real-time simulation

Software

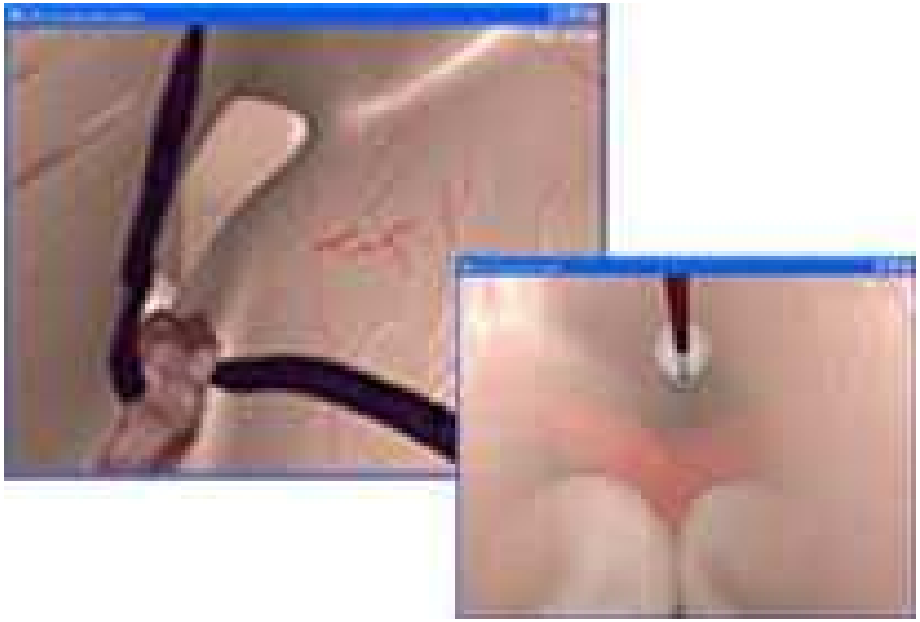
3. Spring [22] – a real-time soft-tissue simulation platform for building and running surgical simulators to be used in medical education of surgeons. (HAVNET)



4. SOFA [23] – Software for Observing Force-feedback Algorithms is an aid in debugging haptic algorithms and providing custom haptic device implementation.

Software

5. GIPSI – General Physical Simulation Interface [24]
    - an open source/open architecture framework for developing organ level surgical simulations.
    - facilitate shared development of reusable models
    - heterogeneous models of computation
    - framework for interfacing multiple heterogeneous models.

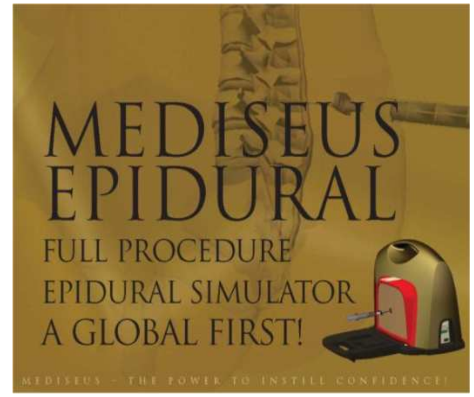


Outline

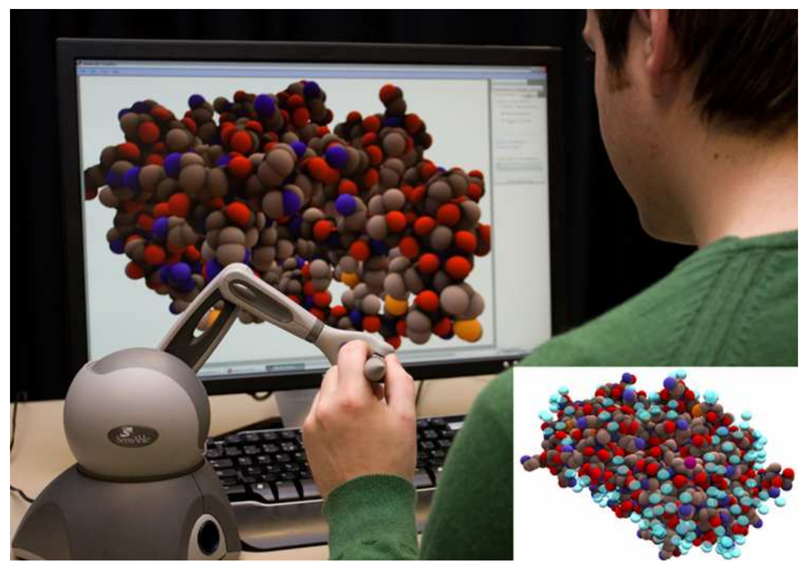
- The Human - human perception
- The Machine - input/output
- Multimodal environments – the VR myth, AR
- Haptics - succinct history
- Haptic hardware and software
- **Application domains**
- E-learning with haptics
- Assessment
- Conclusions

Applications Domains

- **Google in 2006:** **446,000 hits** for **"haptic".** (**0.19** seconds)
- **Google in 2007:** **1,030,000 hits** for **"haptic".** (**0.28** seconds)
- **Google in 2008:** **1,840,000 hits** for **"haptic".** (**0.27** seconds)



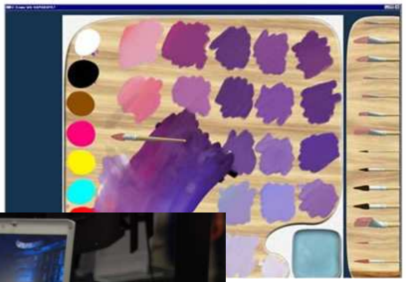
- Medical
  - **Remote Surgery** [25]
  - **Telementoring/Training**
  - **Patient Rehabilitation**



NEWS Network Enabled WorkSpaces
Armstrong Atlantic State University
Department of Computer Science

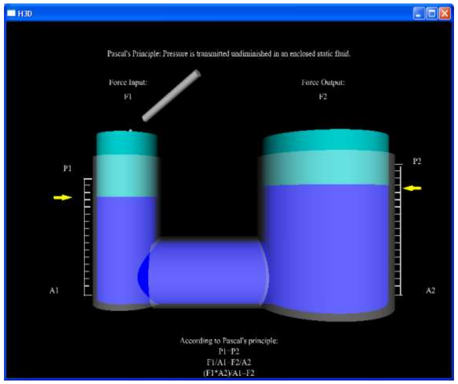
Application Domains

Sculpting [26]

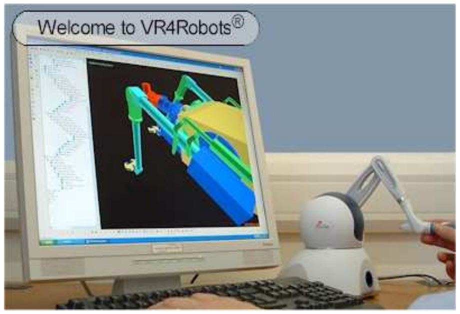


- Entertainment
  - **Haptic Games (*booming*)**

- Robotics
  - **Hazardous Environments**
  - **Remote Manipulation (Telerobotics)**



- Education
  - **Simulation of Abstract Concepts**



- Academic Research
  - **Multimodal Environments**

Outline

- The Human - human perception
- The Machine - input/output
- Multimodal environments – the VR myth, AR
- Haptics - succinct history
- Haptic hardware and software
- Application domains
- **E-learning with haptics**
  - **HaptEK16**
  - **FEEL**
- Assessment
- Conclusions

E-Learning

- Learning is about Knowledge transfer:
  - students must learn more today than 50, even 10 years ago (specially in technical fields)
  - still same main methods for teaching & learning:
    - concept understanding
    - some level of memorization
      - “*I hear and I forget. I see and I remember. I do and I understand*” – Confucius

- Knowledge transfer occurs through (social) interaction
  - Engagement
  - Immediate feedback (Interactive speed … seconds)
  - Real-world contexts (relate to real world contexts)

E-Learning

- 5 senses (or maybe more …)
  - I hear (hearing), I see (vision), I do (haptic), [taste, smell]
  - Input: all 5 (for most people)
  - Output: mainly haptic, (also I can make sounds)

- Current technology allows us to simulate:
  - Sounds - for some time now (radio, etc.)
  - Vision – (tele=remote, visor=vision) TV

    (!) Charley Chaplin – no sound, black/white, 2D

    later – with sound, even later – color

    (!) majority is still 2D

    oh! you think some computer applications are 3D

    you are wrong – most GUIs 2D – move the mouse in 2D

    (!) We believe next step will be **3D – widespread**
  - Haptic (touch) – just now booming (inexpensive hardware)
  - Taste – do we want to simulate this ?
  - Smell – this is possible, interesting to explore

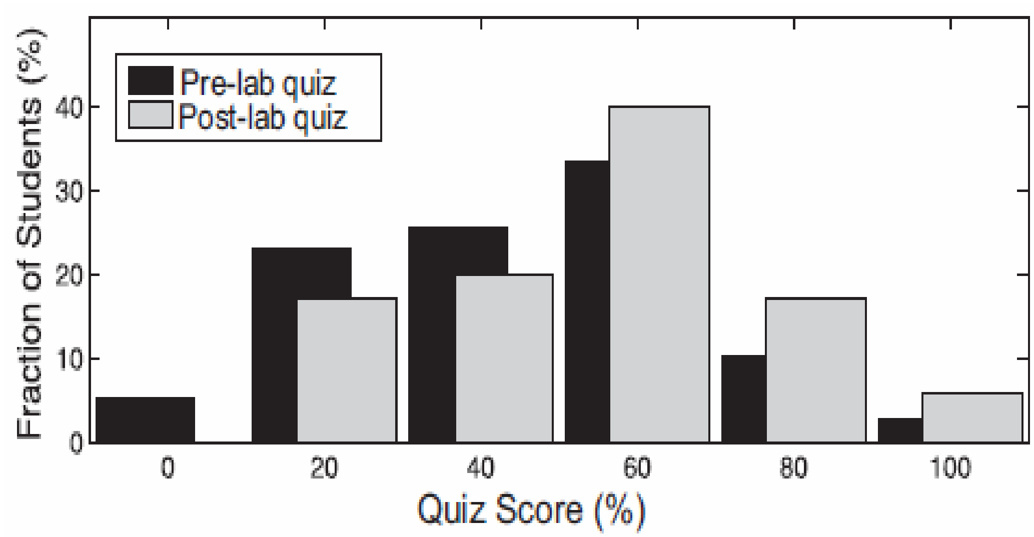
Haptics in Education

- Theory, abstract concepts:
  - Use of haptic simulations improves student comprehension of subject matter

- Integrating haptics into education:
  - Work done at Johns Hopkins University to incorporate haptics into graduate, undergraduate, and grade school curricula [27]
    - Use the low-cost haptic paddle, developed at Stanford University
  - Study done with undergraduate students over two year period
    - Combined haptics into junior-level dynamic systems (i.e. systems in un-accelerated motion) courses

Haptics in Education (cont.)

- Results:
  - Students scored at least 10% higher on quizzes after labs with the haptic paddle
  - Students became more excited about the material

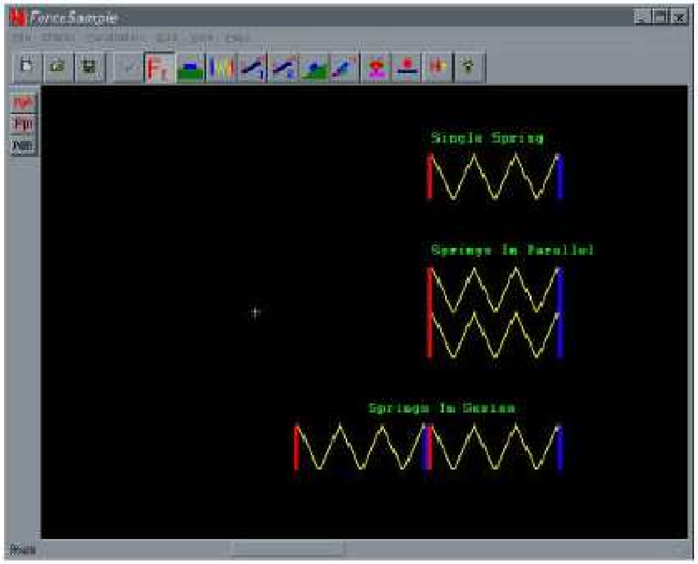


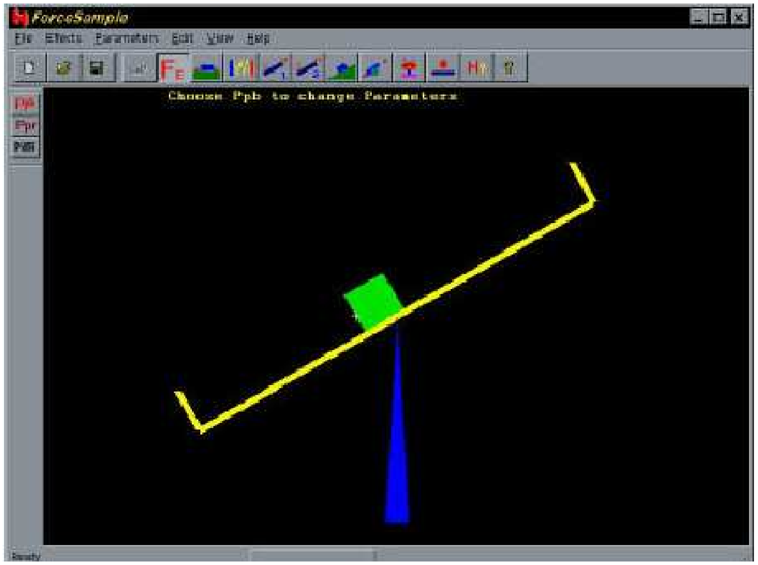
Haptics and Physics

- Haptics-Augmented Physics Simulators for High School Students [28]
  - Developed at Ohio University
  - Make use of a low-end haptic gaming joystick, the Microsoft Sidewinder
  - Program and tutorials available over the Internet
  - Several different activities for the students

Haptics and Physics

- Block on an inclined plane
  - Uses the joystick to move the block up the plane
  - User can change mass, coefficients of friction, and the slope of the plane
  - Bare, two-dimensional scene

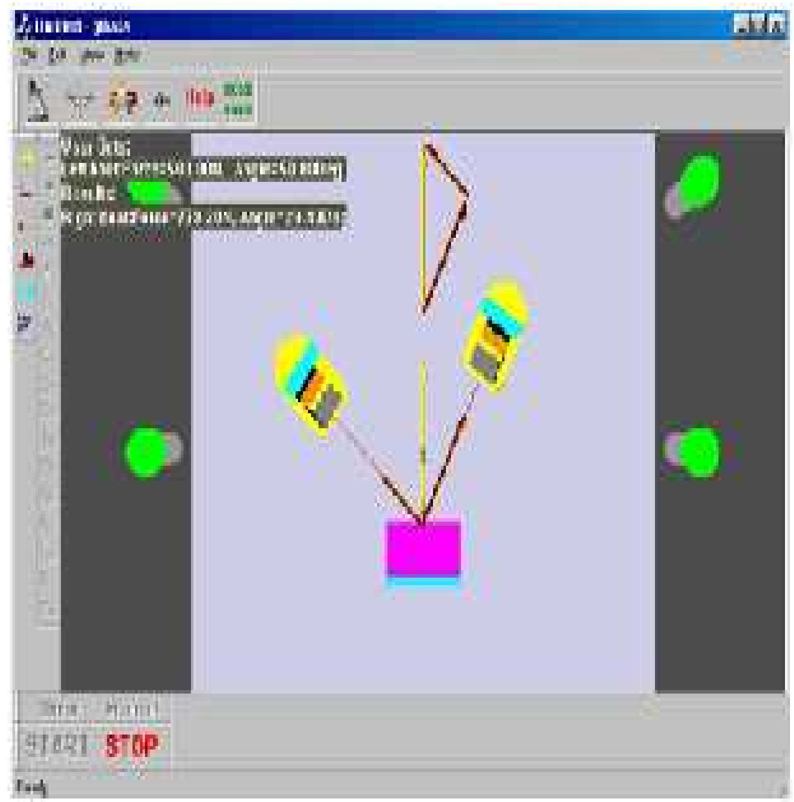




- Spring Forces
  - User pushes against a springs of a given arrangement(parallel, single, series)

Haptics in Physics

- Other developments [29]
  - Vector Addition: Boats Towing a Barge
    - Students set the magnitude and direction of one boat, the computer calculates the other
    - Student can feel (singularly) any of the vector forces



Haptics in Physics

- Newton's 2nd Law:
  - The net force on an object is equal to the mass of the object multiplied by its acceleration: (**F** = *m***a**)

- Two masses connected by a cable [29]
  - Student can change mass, coefficient of friction
  - Student can feel forces of friction, cable tension, weight, and inertial forces for either mass
  - Computer calculates acceleration, cable tension, and friction

NEWS Network Enabled WorkSpaces
Armstrong Atlantic State University
Department of Computer Science

HAPTIC MED

HaptEK16

Haptic Environments for K-16

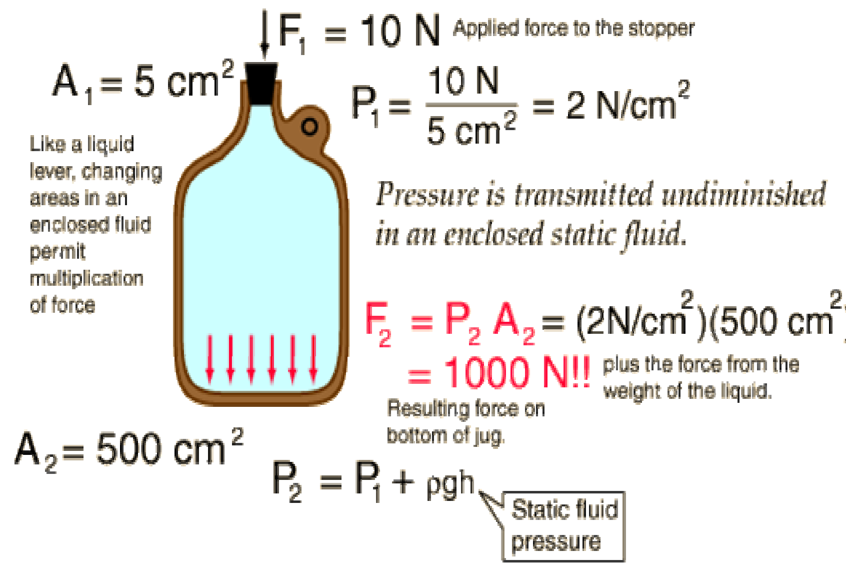
EL&ML 2011, February 23-28, 2011 - Gosier, Guadeloupe, France

HaptEK16 - Goals

- Multimodal environments for simulation
  - 3D+ Haptics+Sound
- Improve student attention
- Improve laboratory experience
- Alternative assessment

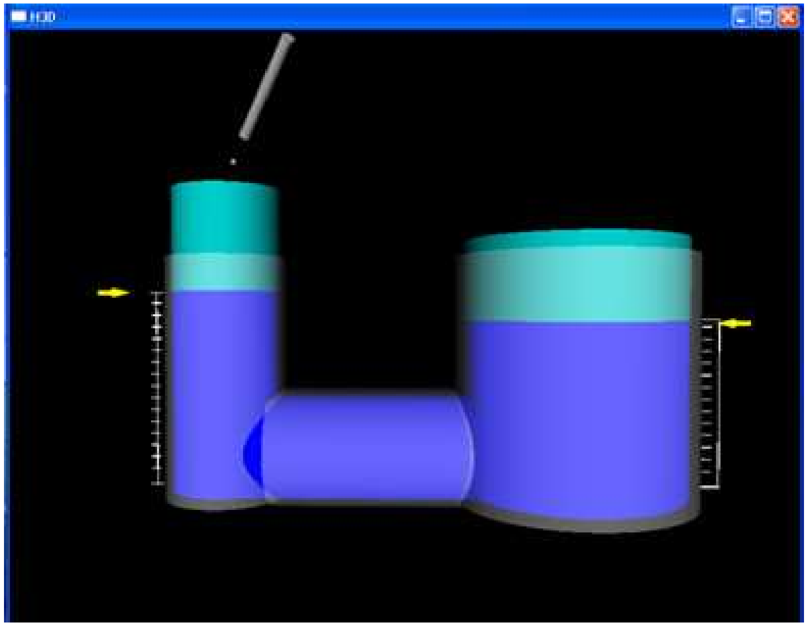
HaptEK16 - Hydraulics & Haptics

- Students often leave physics courses with faulty mental models
- HaptEK16 [30] - Teaches the difficult concepts underlying Pascal's principle and its application to hydraulics



HaptEK16

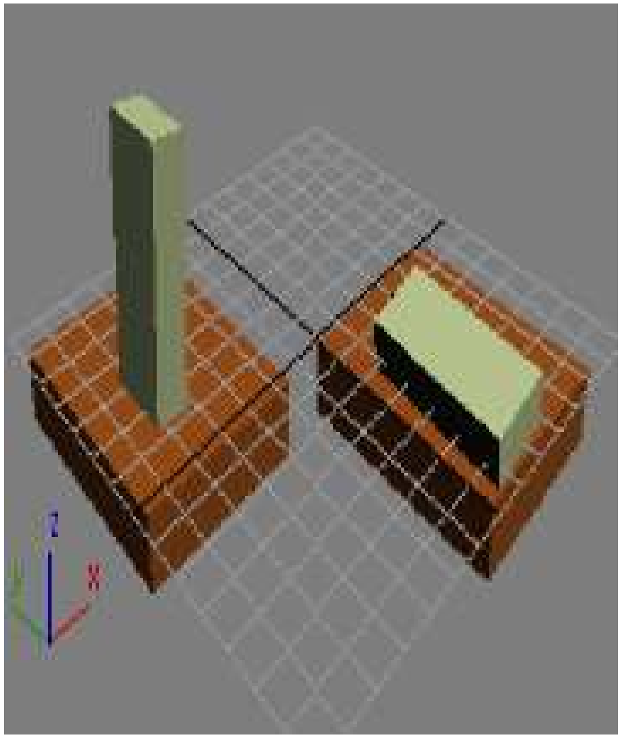
- Each HapteK16 activity is augmented in various ways by haptic feedback so the student can feel force magnitude.

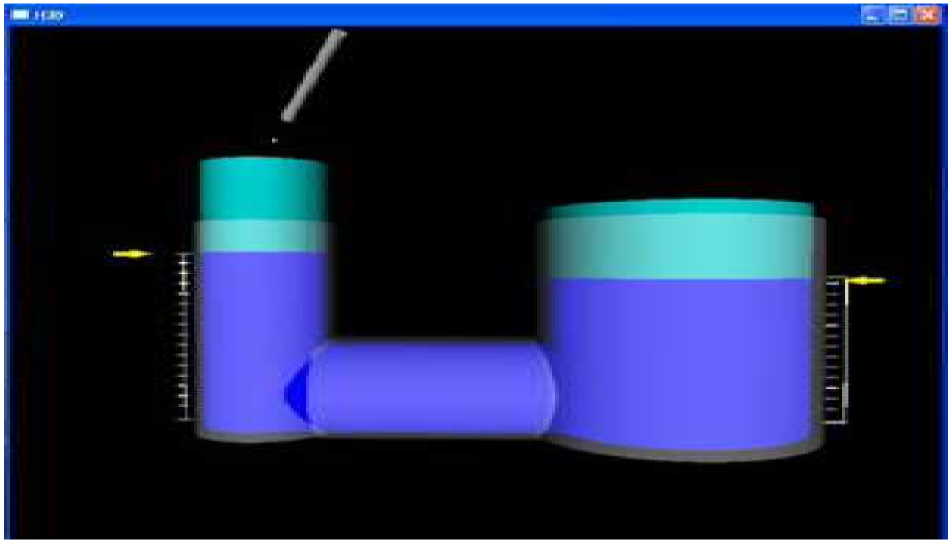


HaptEK16 - Activities

- Activities

1. Pressure=Force/Area
2. Hydraulic Lift





FEEL

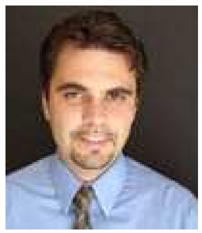
Framework for Electronic Enhancement of Laboratories

EL&ML 2011, February 23-28, 2011 - Gosier, Guadeloupe, France

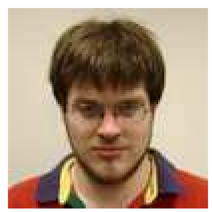
Haptic Simulation of Static & Kinetic Friction [31]

Applied Physics

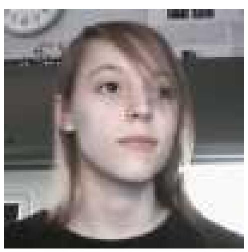
William Baird



Felix Hamza-Lup



James LaPlant

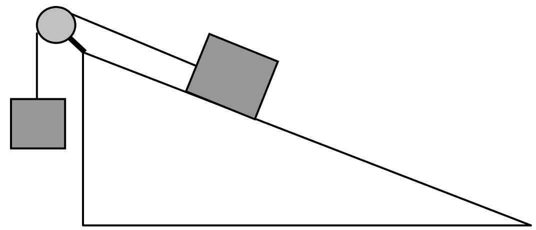


Elizabeth Murrell

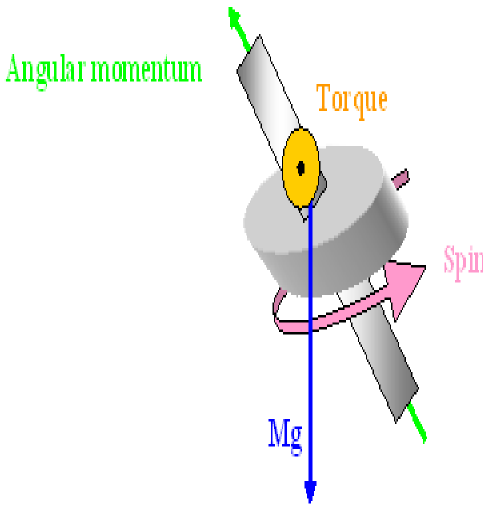
Nathan Hack

Potential for Haptic Simulation

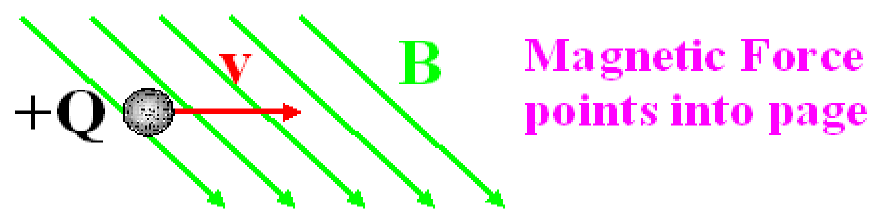
– Friction



– Angular Momentum
Gyroscope



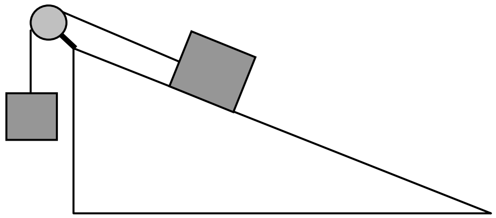
– Lorentz Force

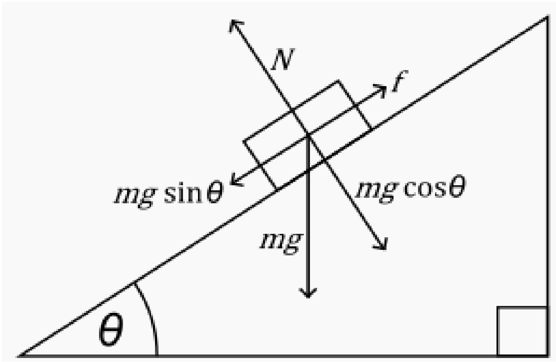


Haptics & Friction

- Problems
  - Difficult for students to comprehend
  - Static friction defined by an inequality
  - Angles

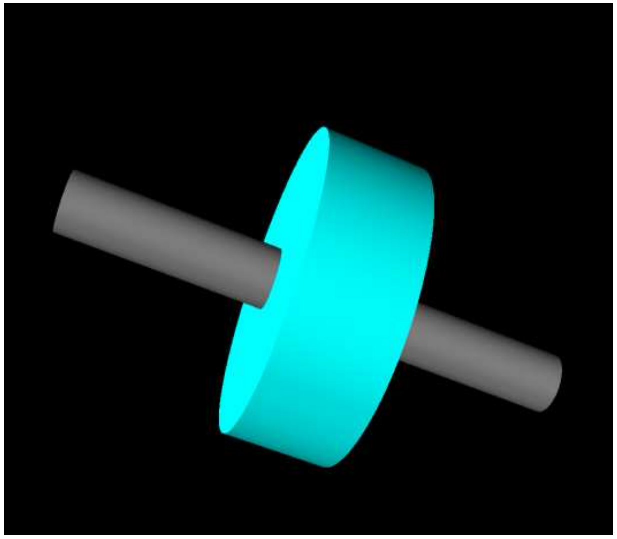
- Advantages of Haptic Simulation
  - Real-time experiment customization
  - Reproducibility of experiments with consistent results
  - Avoid confounding variables
  - **Interactive and 3D => engaging**



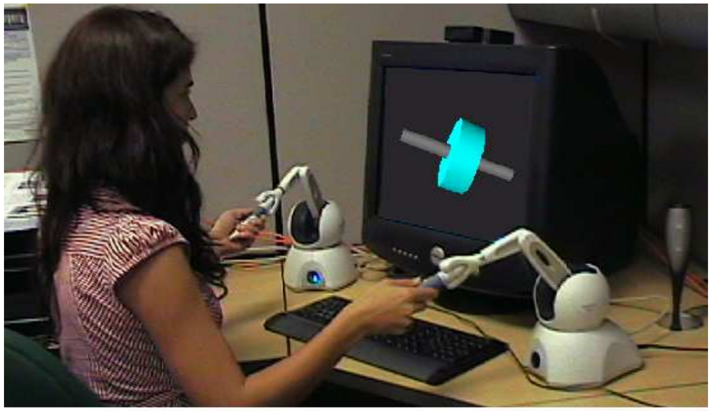


http://en.wikipedia.org/wiki/Inclined_plane

Haptics & Angular Momentum



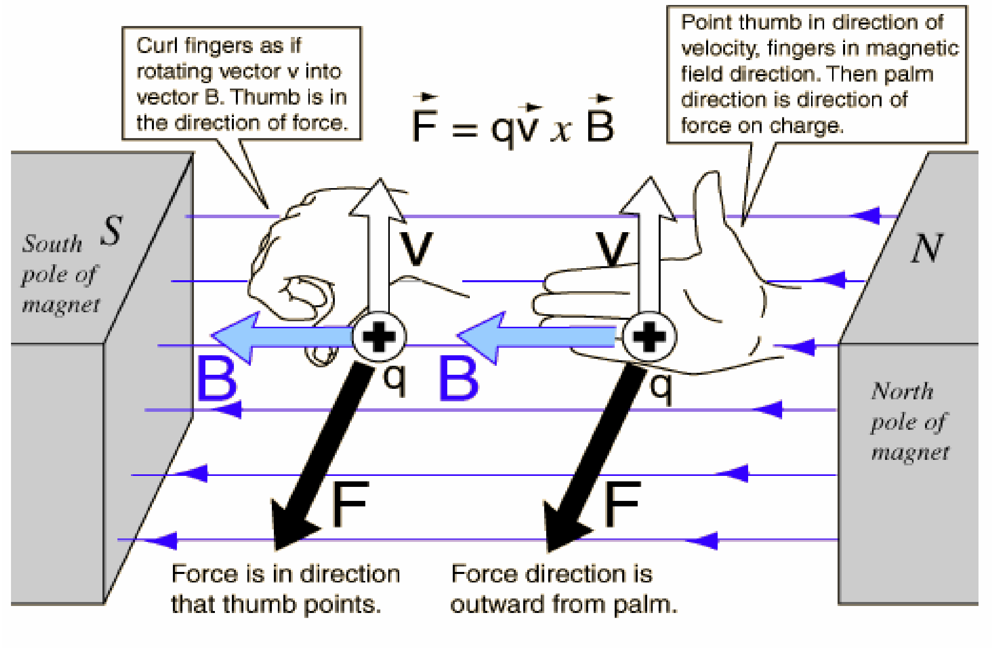
- Problems
  - The force is not intuitive
  - Constant changes in the experiment
- Haptics
  - Real-time configuration changes
  - Maintain a constant simulation
  - **Interactive => engaging**
- Use two haptic devices to hold the wheel's axle on the screen.



Haptics & Lorentz Force

Problems

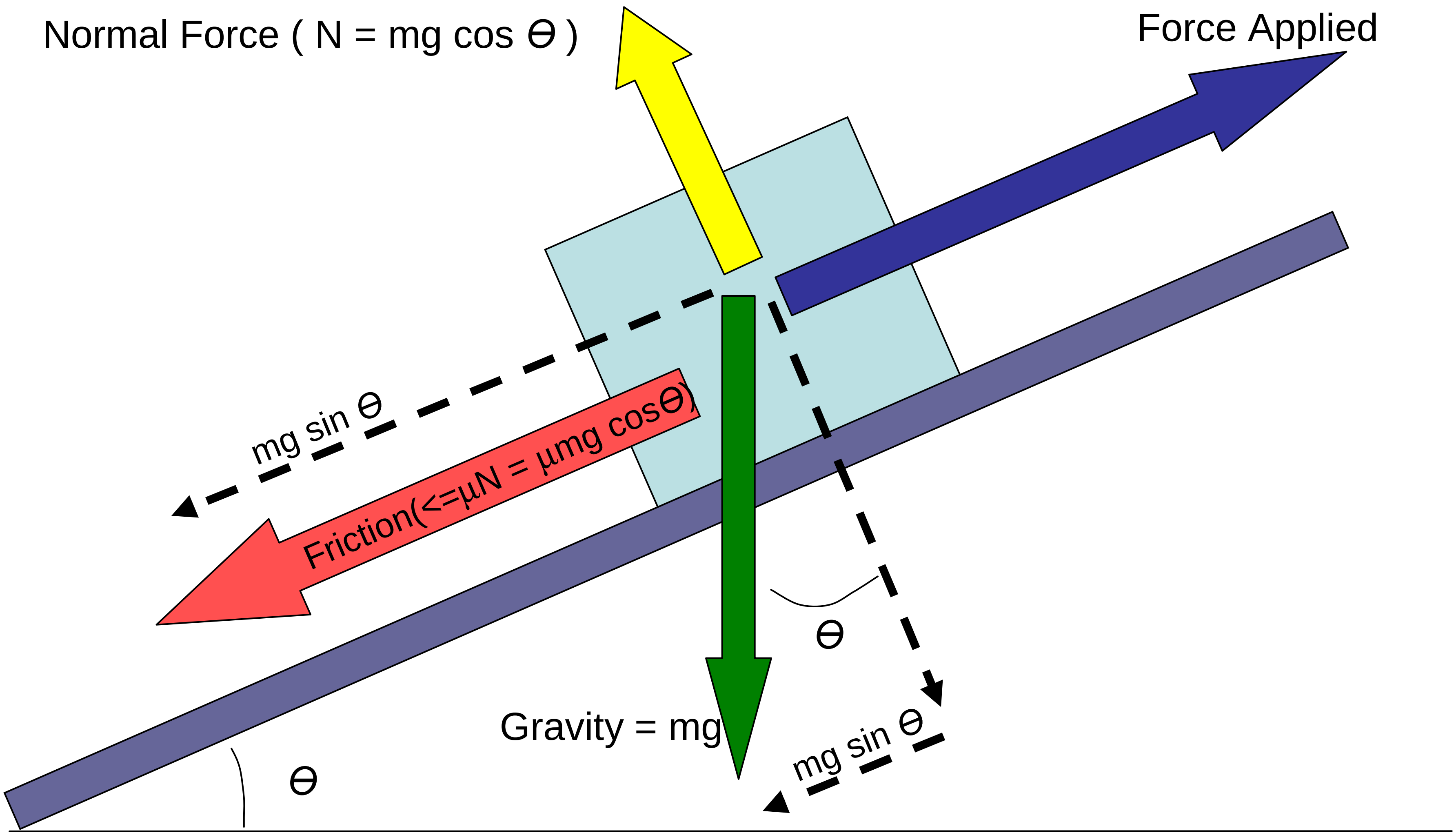
- Cross product
- 3D
- Hard to illustrate in 2D
- Impossible to feel the forces experimentally



http://hyperphysics.phy-astr.gsu.edu/HBASE/magnetic/imgmag/rthnd.gif

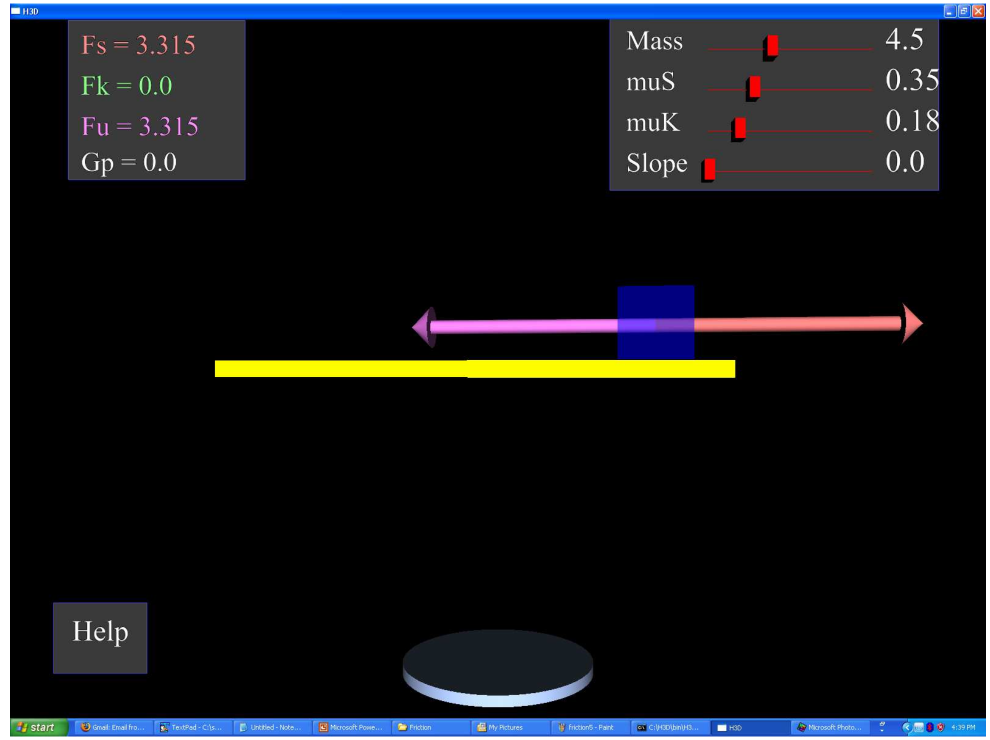
- Haptics
  - Reproducible simulations/experiments
  - 3D
  - **Interactive**

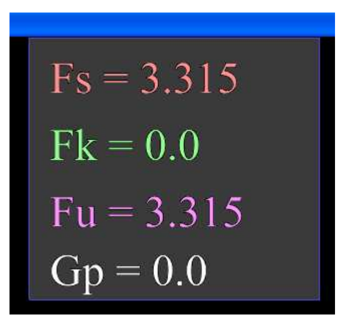
Remember Friction ?

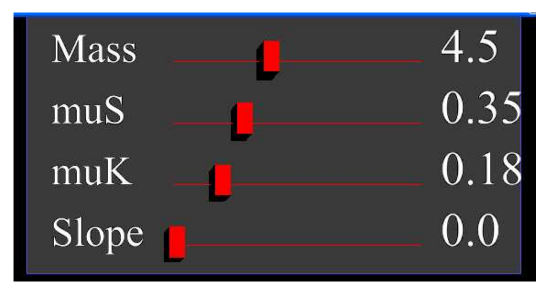


Multimodal Simulator
- Visual Component -

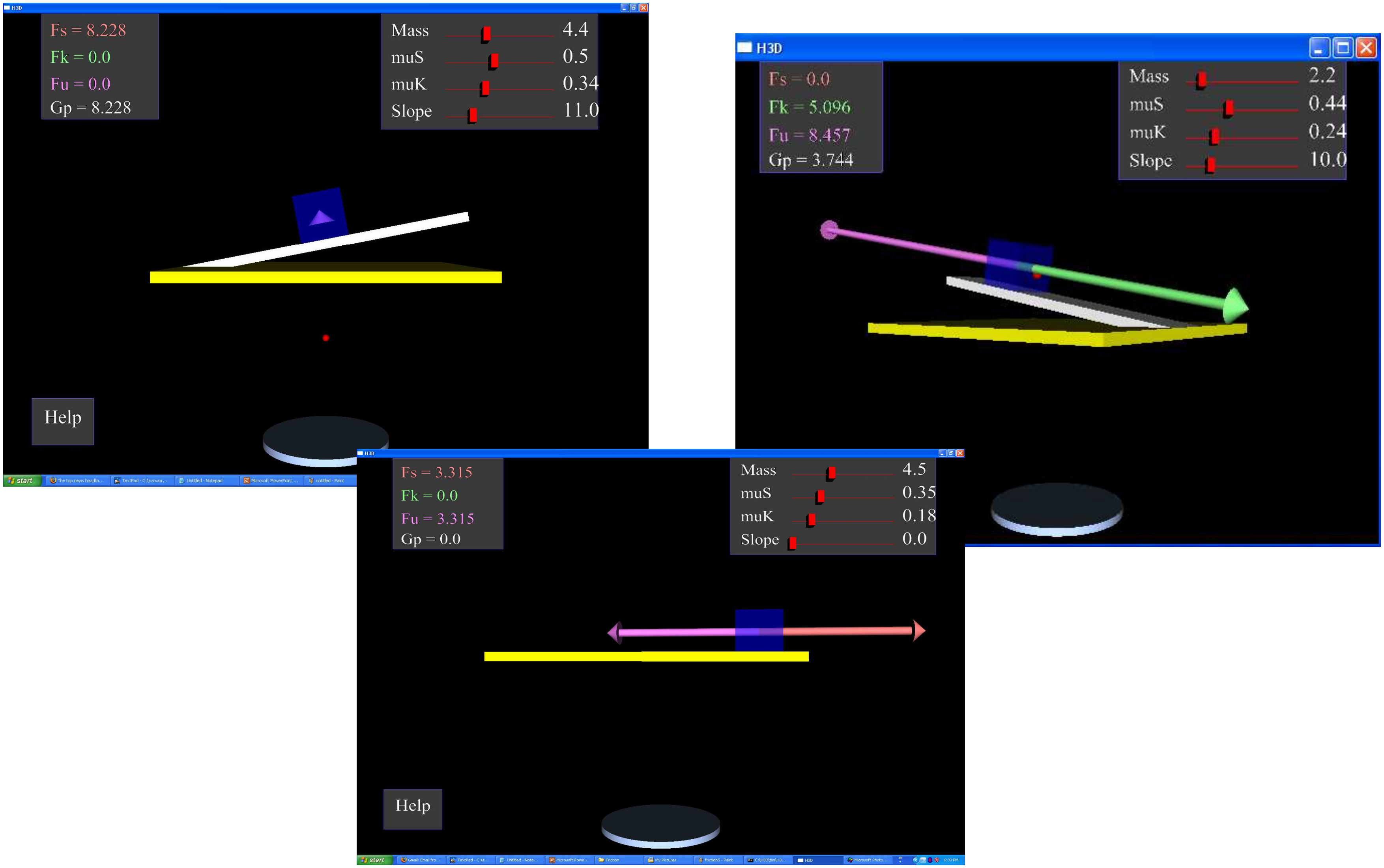
- Floating menus show forces and allow users to modify physical values
- Vectors show the forces acting on the cube
  - Give students a visual representation of the magnitude of the forces
- Scene Exploration
  - Scene rotation
- Help button to give instructions and explain the simulator components







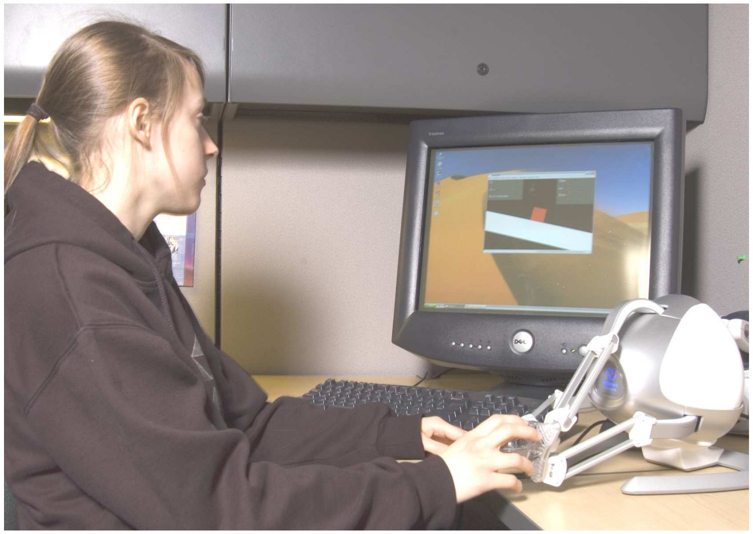
Scenarios


H3D
Fs = 8.228
Fk = 0.0
Fu = 0.0
Gp = 8.228
Mass 4.4
muS 0.5
muK 0.34
Slope 11.0
Help
H3D
Fs = 0.0
Fk = 5.096
Fu = 8.457
Gp = 3.744
Mass 2.2
muS 0.44
muK 0.24
Slope 10.0
Fs = 3.315
Fk = 0.0
Fu = 3.315
Gp = 0.0
Mass 4.5
muS 0.35
muK 0.18
Slope 0.0
Help

Student Interaction

- Students interact with the scene using the Novint Falcon haptic device

- Hypothesis:
  - Haptic interaction with the scene will make it more “real” and more instructive.
  - Will capture student attention => student is an active participant in the learning process



Implementation

- Application Programming Interface (API)
  - Haptics 3D (H3D) – an API for developing 3D scenes with force feedback
  - Extensible 3D (X3D) – open standard for 3D scene design and implementation
  - Python – object oriented scripting language – provides advanced behaviour for developing complex H3D scenes

Outline

- The Human - human perception
- The Machine - input/output
- Multimodal environments – the VR myth, AR
- Haptics - succinct history
- Haptic hardware and software
- Application domains
- E-learning with haptics
- **Assessment**
- Conclusions

Assessment

- NOT easy
- Mainly in a laboratory setup
  - Parallel executions of lab experiments in a real/visuo-haptic scenario
- Issues
  - with scheduling students
  - with haptic tool learning curve (warm-up trials)
  - collecting data

Assessment

- Quantitative vs Qualitative Data
- Subjective vs Objective Components

Assessment

- Spring 2009 Physics 2211 students (who have completed a traditional lecture/lab treatment of friction) are randomly placed in one of two groups

Group A	Group B
Conceptual test	
Haptic Simulation	Review Text
Repeat test	
Review Text	Haptic Simulation
Final Test	

Conclusions

- Integration of haptic in e-Learning
  - is possible both as cost and technology
  - design of haptic e-learning modules is difficult
- Kind of a “Digital Divide” on haptics currently… but gaming changes that rapidly …
- Network-based (distributed) haptics is possible but strict Quality of Service parameters must be maintained.

References (1)

[1] Broadbent, D.E. (1954-03). “The role of auditory localization in attention and memory span”. Journal of Experimental Psychology 47 (3): 191–196.

[2] Bolanowski, S.J; Gescheider, G.A.; Verrillo, R.T.; and Checkosky, C.M. ‘‘Four Channels Mediate the Mechanical Aspects of Touch.’’ Journal of the Acoustical Society of America 84 (1988): 1680–1694.

[3] http://speechrecognition.wordpress.com/category/trends-statistics

[4] C. Lee and S. Narayanan, “Toward detecting emotions in spoken dialogs” IEEE transaction on speech and audio processing, vol.13, 2005.

[5] M. E. Hoque, M. Yeasin, M. M. Louwerse. “Robust Recognition of Emotion from Speech”, 6th International Conference on Intelligent Virtual Agents, Marina Del Rey, CA, 2006

[6] Hermes http://www.caside.lancs.ac.uk/hermes.php

[7] P. Milgram and A. F. Kishino, Taxonomy of Mixed Reality Visual Displays IEICE Transactions on Information and Systems, E77-D(12), pp. 1321-1329, 1994.

[8] Frederick P. Brooks, Jr., Ming Ouh-Young, James J. Batter, and P. Jerome Kilpatrick. 1990. Project GROPEHaptic displays for scientific visualization. SIGGRAPH Comput. Graph. 24, 4 (September 1990), 177-185. (http://cismm.cs.unc.edu/tag/docking/)

References (2)

[9] GE Iron Man, http://www.reliableplant.com/Read/27561/GE-Iron-Man-suit

[10] Klatzky, R.L., Lederman, J. and Metzger, V.A, (1985) “Identifying objects by touch: An expert system”. Perception and Psychophysics, Vol. 37, pp. 299-302.

[11] Takayuki Iwamoto, Mari Tatezono, Takayuki Hoshi, Hiroyuki Shinoda, "Airborne Ultrasound Tactile Display," *SIGGRAPH 2008 New Tech Demos*, Aug., 2008.

[12] Novint’s Falcon device. http://novint.com/

[13] SensAble http://www.sensable.com

[14] Force Dimension http://www.forcedimension.com/

[15] Butterfly Haptics http://butterflyhaptics.com/

[16] CSIRO http://www.ict.csiro.au/page.php?did=164

[17] H3D http://www.h3dapi.org/

[18] X3D http://www.web3d.org/x3d

[19] Python http://www.python.org/

References (3)

[20] ReachIn, http://www.reachin.se/

[21] Chai3D, http://www.chai3d.org/

[22]Spring – HAVNET, http://havnet.stanford.edu/

[23] Sofa - Software for Observing Force-feedback Algorithms, http://www.sofa-framework.org/

[24] GiPSi - General Physical Simulation Interface, http://gipsi.case.edu/

[25] Chebbi, B., Lazaroff, D., Bogsany, F., Liu, P.X., Liya Ni, Rossi, M. “Design and implementation of a collaborative virtual haptic surgical training system.” Mechatronics and Automation (2005), 2005 IEEE International Conference, vol. 1(29), pp. 315-320

[26] Chris Gunn. “Collaborative virtual sculpting with haptic feedback”. Virtual Reality (2006) vol. 10, pp. 73-78

[27] David Grow, Lawton N. Verner, Allison M. Okamura, “Educational Haptics”, AAAI 2007 Spring Symposia - Robots and Robot Venues: Resources for AI Education, 2007

References (4)

[28] Robert L. Williams II, Meng-Yun Chen, Jeffery M. Seaton, “Haptics-Augmented High School Physics Tutorials”. International Journal of Virtual Reality 5(1), 2000.

[29] Robert L. Williams II, Xingxi He, Teresa Franklin, and Shuyan Wang, “Haptics-Augmented Engineering Mechanics Educational Tools” World Transactions on Engineering and Technology Education, 6(1): 27-30.

[30] F. G. Hamza-Lup and M. Adams (2008) “Feel the Pressure: e-Learning System with Haptic Feedback,” 16th Symposium on Haptic Interfaces for Virtual Environments and Teleoperator Systems, 13–14 March, Reno, Nevada

[31] F. G. Hamza-Lup, E. Murrell, J. LaPlant, W. Baird, and D. M. Popovici (2010) “Simulator Visuo-Haptic pentru Reprezentarea Conceptelor de Frecare Statica si Dinamica,” Romanian Computer Human Interaction (ROCHI), 2–3 September, Bucharest, Romania