Haptic User Interfaces

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Haptic, tactile and tangible defined

Webster:

hap-tic

1. relating to or based on the sense of touch
2. characterized by a predilection for the sense of touch <a haptic person>

tac-tile

1. perceptible by touch: TANGIBLE
2. of or relating to the sense of touch

tan-gi-ble

1. a : capable of being perceived especially by the sense of touch : PALPABLE

   b : substantially real : MATERIAL

What is haptics?

- Physical interaction via touch
- Uniquely bi-lateral sensory modality
- Touching and interacting with real, virtual and remote environments

Why is it interesting and important?

- primal, intuitive, pervasive, expressive, unexplored…

Terminology

- *haptic*: an adjective, ”a haptic interface”
- *haptic interaction*: the act of touching objects
- *haptics*: noun, the study of haptic interaction
- *human haptics*: human touch perception and manipulation
- *machine haptics*: concerned with robot arms and hands
- *computer haptics*: concerned with computer mediated haptics

Terminology

- *haptically*: making use of touch interaction
- *haptic interface*: a user interface / device permitting human to have touch interaction with real or virtual environments

Human sensory system

- *Tactile information*: ”Referring to the sense of contact with the object, mediated by the responses of low-threshold mechanoreceptors innervating the skin, within and around the contact region”.

- *Kinesthetic information*: ”Referring to the sense of position and motion of limbs along with the associated forces conveyed by the sensory receptors in the skin around the joints, joint capsules, tendons, and muscles together with neural signals derived from motor commands”.

Human sensory system

Quantities derived from cutaneous mechanoreceptors:

- temporal and/or spatial information
- normal indentation
- lateral skin stretch
- relative tangential motion
- vibration
- micro texture
- shape
- compliance

Human sensory performance

Absolute detection thresholds:

- surface texture: 0.1 micro-meters
- static skin displacement: 20 micro-meters
- transient temperative variations: 0.05 °C
- between-points resolution 1 mm at fingertips
- localization resolution 0.15 mm
- position reproduction 2 mm at fingertips
- pressure 0.03 Newton/cm^2

Human sensory performance

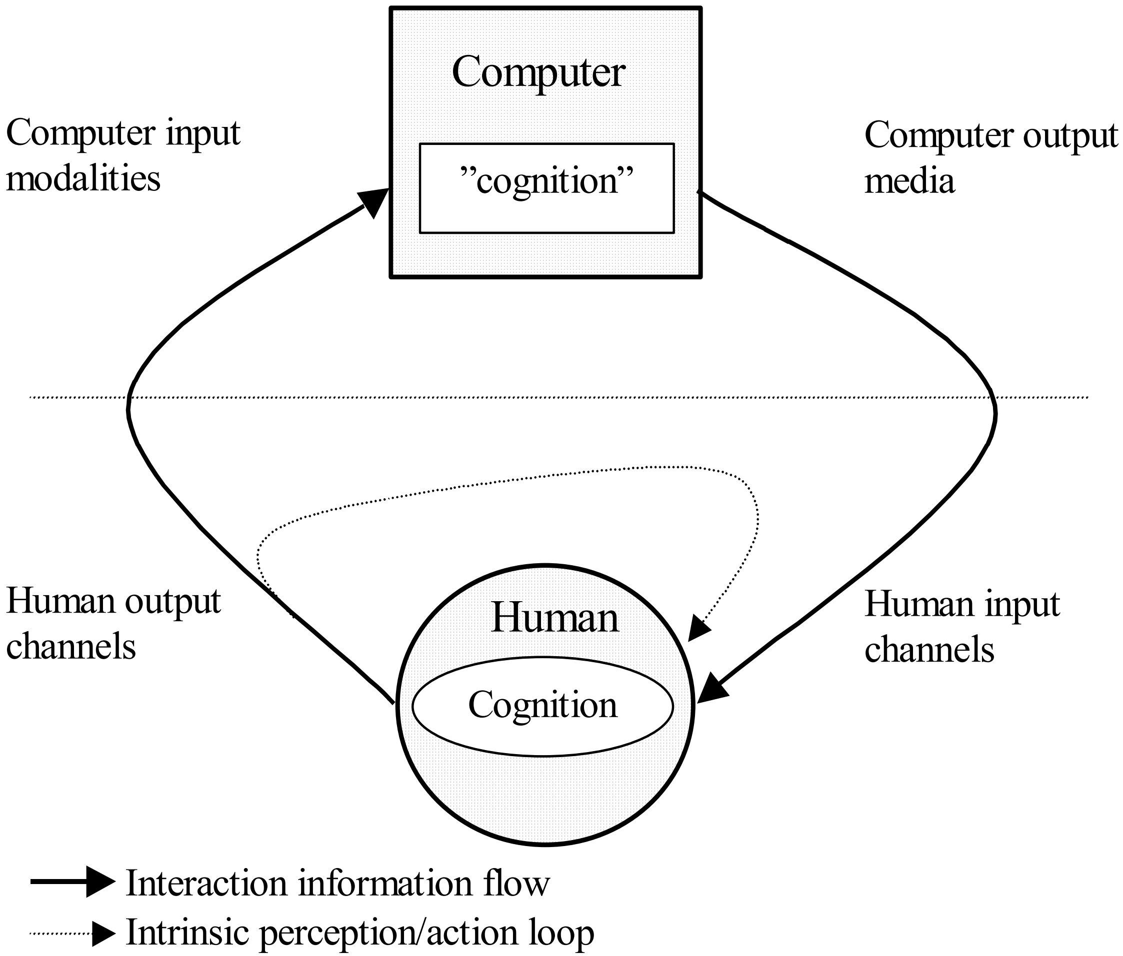
Just noticeable differences in active touch:

- length: 10%
- velocity: 10%
- acceleration: 20%
- force: 7%
- stiffness: 3% (soft surfaces) … 8% (hard surfaces)
- viscosity: 14%
- mass: 21%
- rigidity perceived at: 25 N/mm

Haptic stimulation modalities

- force and position
- tactile
- vibration
- thermal
- electrical

Multimodal human-computer interaction



Senses and modalities

Sensory perception	Sense organ	Modality
Sense of sight	Eyes	Visual
Sense of hearing	Ears	Auditive
Sense of touch	Skin	Tactile
Sense of smell	Nose	Olfactory
Sense of taste	Tongue	Gustatory
Sense of balance	Organ of equilibrium	Vestibular

[Silbernagel, 1979]

Why haptic feedback?

- Currently haptic feedback is an underused modality
  - However, touch is one of the most important senses in the real world – why not in user interfaces?
  - Touch is a parallel channel to seeing and hearing. It can be used to give additional information to the user.
  - Touching can easily be done while speaking or listening, since it has been important during the evolution of humans.

Multimodal issues

- visual information strongly influences haptic perception
- auditory information weakly influences haptic perception
- haptic sub-modalities of vibration, tactile array and temperature stimulation enhance sense of presence
- spatial and temporal registration of vision, haptics and audition are important

Touch input

- Touch input is already quite widely used in different areas, but tactile output is just emerging.
- Some uses for touch input: public information kiosks, automatic teller machines, palmtop computers, portable computers.



Touch input devices

- Devices that detect touch position: touchscreens, touchpads, tablets.
  - can have a display or just an input tablet
  - many devices also detect the amount of pressure used when touching
    - ➔ possibilities for pressure-sensitive interaction techniques
- Touch-sensing: sensing touch in mice and trackballs (Ken Hinckley, Microsoft)
  - The programs can react on touching the device

Haptic output devices

- Only recently the technology has advanced to the level that allows us to mimic real touch sensations when using computers.

Haptic output devices

Inexpensive devices:

- The most common tactile devices are still the different force feedback controllers used in computer games, for example force feedback joysticks and wheels.
- In 1999 Immersion Corporation's force feedback mouse was introduced as Logitech Wingman Force Feedback Mouse
- In 2000 Immersion Corporation's tactile feedback mouse was introduced as Logitech iFeel Tactile Feedback Mouse

Haptic output devices

More sophisticated devices:

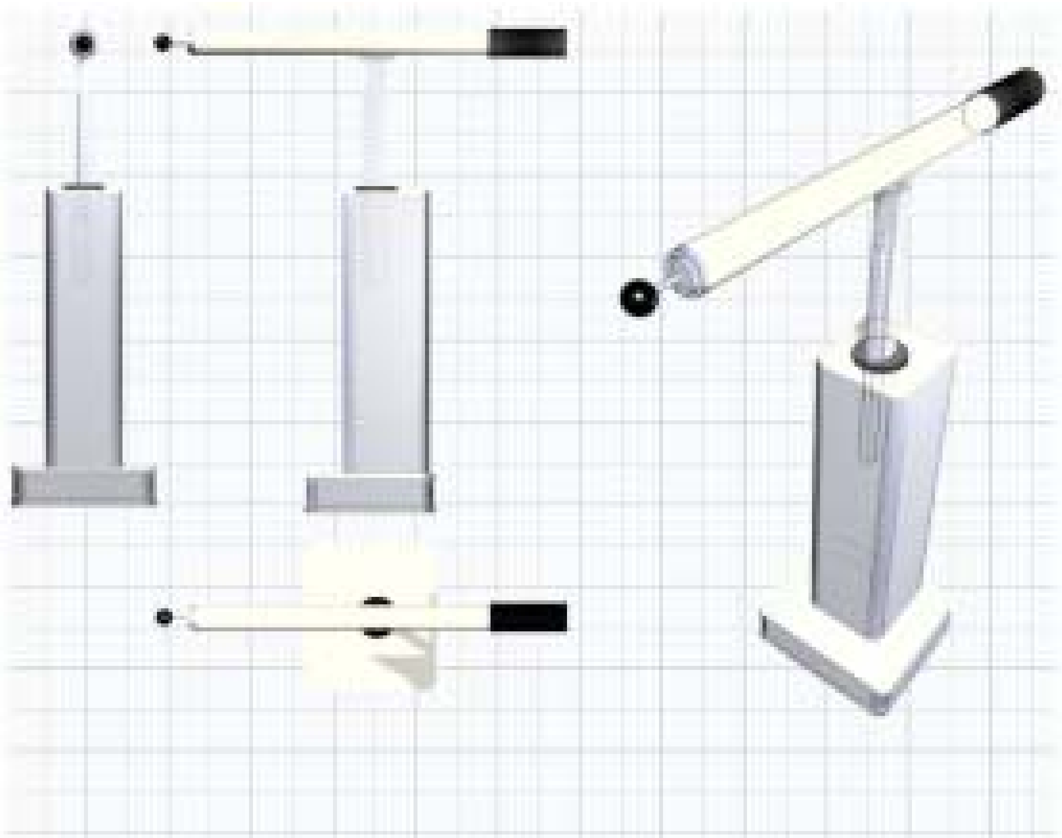
- SensAble Technologies: PHANTOM
- Immersion Corporation: Impulse Engine
- Often very expensive, and non-ergonomic.

CyberForce

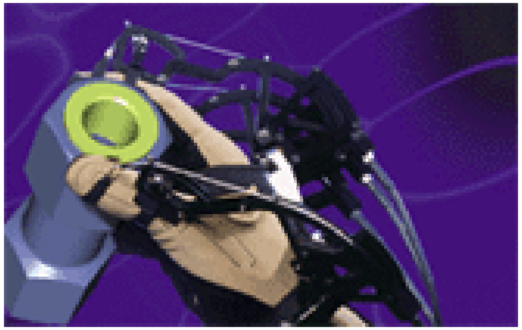
CyberTouch

Impulse Engine 2000

FCS Systems: HapticMASTER



CyberGrasp



CyberGrasp

Technical Specifications

Maximum Continious force:12 N per finger

Force Resolution: 12-bit

Weight: 350g

Working Radius: 1 meter

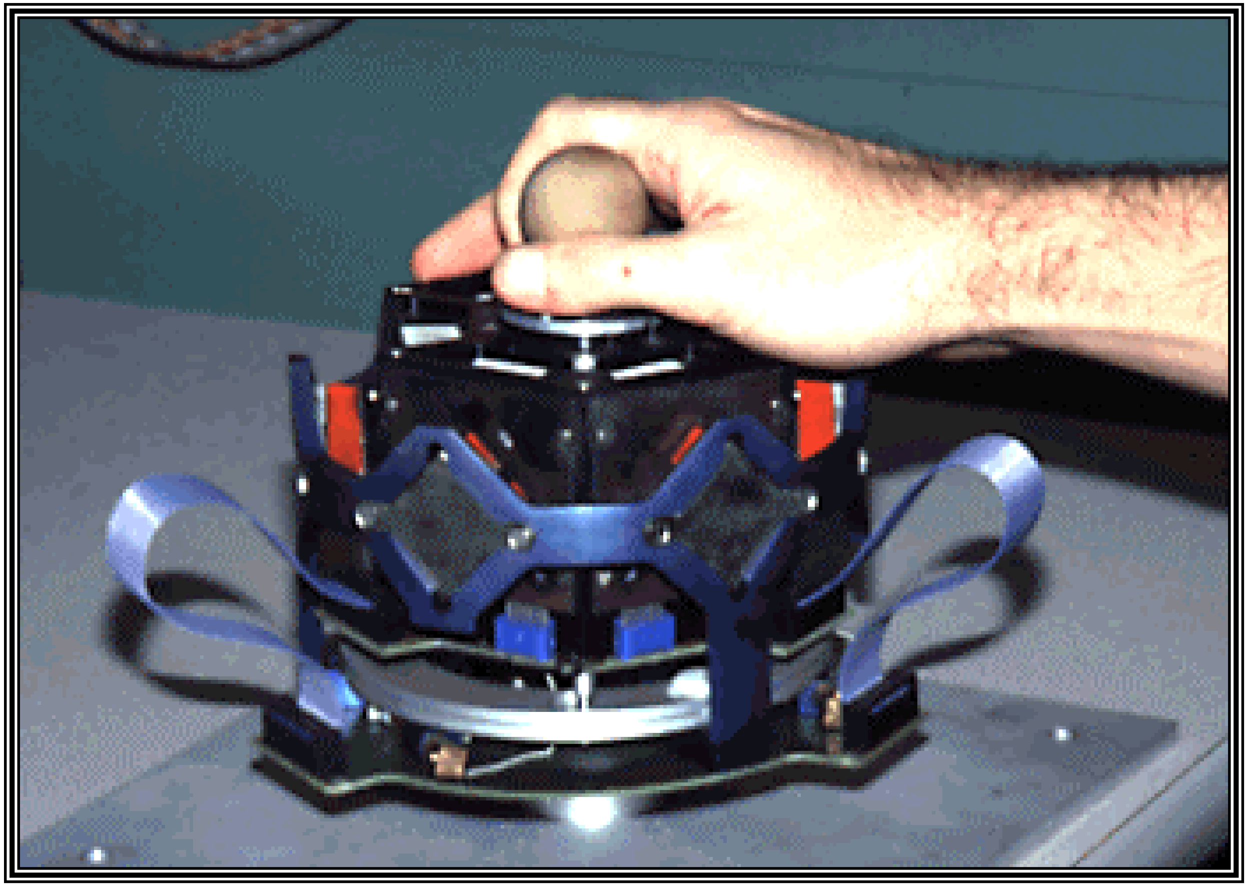
Force Transmitted by Cables

Example devices: Active, Ground based - 1

- • 1 Degree of freedom
  - Steering Wheels
  - Hard Driving (Atari)
  - Ultimate Per4mer (SC&T2)
- • 2 Degree-of-freedom
  - Pens and Mice
  - Pen-Based Force Display (Hannaford, U. Wash)
  - MouseCAT/PenCAT (Hayward, Haptic Tech., Canada)
  - Feel-It Mouse (Immersion)
  - Joysticks
  - Force FX (CH Products)
  - Sidewinder Force Feedback Pro (Microsoft)

Microsoft SideWinder Force Feedback Joystick

Magnetic Levitation Haptic Interface (CMU)



Example devices: Active, Ground based - 2

- • 3 Degree-of-freedom
  - PHANToM (SensAble Technologies)
  - Impulse engine (Immersion)
- • 6+ Degree-of-freedom
  - Teleoperator masters (MA-23, Argonne, CRL)
  - Freedom 6/7 (Hayward, MPB Technologies)
  - 6DOF (Cybernet)
  - PHANTOM Premium 6 DOF

Sensable: PHANTOM

http://www.sensable.com/

3 DoF Force Feedback Joystick

Medical Force Feedback System

What makes a good haptic interface? - Performance 1

- • Transparency and fidelity are the goals
- - How do we get them?
- • Good intrinsic mechanical behavior
  - low mass
  - balanced
  - high structural stiffness
  - high structural resonance frequency
- • Easy to back-drive
  - low mass
  - low friction

What makes a good haptic interface? - Performance 2

- • Efficient transmission
  - low friction
  - impedance matched
- • Good sensing of interface state
  - resolution
  - dynamic range
  - low hysteresis
- • Good actuation
  - bandwidth
  - resolution
  - dynamic range

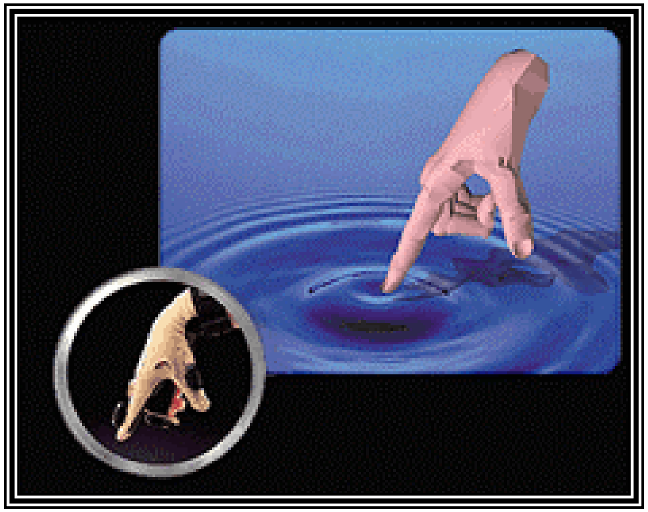
What makes a good haptic interface? - Performance 3

- • Some considerations and tradeoffs
- • Contrast and bandwidth are important
- • Consider point versus whole-hand interactions
- • Consider tool versus finger interactions
- • Complexity goes up by N!
- • More degrees of freedom result in *lower* performance for given cost/volume
- • High stiffness can lead to high friction
- • Bandwidth limited by lowest structural resonance so keep K/M large
- • Larger M requires more power flows for a
- given bandwidth

Other stimulation modalities

- • Vibration and tactile arrays (Howe, Harvard)
- • Thermal stimulation (Ottensmeyer, MIT)
- • Tactile and Thermal Glove (Scuola Superiore S.Anna. Italy)
- • Electrical (Bach-y-Rita)

CyberTouch



Cyber Touch Characteristics

Technical Specifications

- Vibro Tactile Stimulator : six (one for each fingers, one for the palm).
- Vibrating Frequency: 0-125 Hz.
- Vibration Amplitude: 1.2 N peak-peak @125 Hz (Max).

Applications for Haptic feedback

- Applications for the disabled people
  - for example, presenting information or models with a haptic display when the user does not see well
- Haptic feedback as a part of graphical user interface
  - for example, to be used to give feedback on specific events
- Games, virtual reality
  - the simulated world feels more real when the user can really touch it

Applications for Haptic feedback

Two- and Three-dimensional modeling

- the user does not just see the object but can also feel it: helps to better understand the shape of the object

Rehearsing medical operations

- related to haptic modeling and visualization; no need for paid voluteers or dead bodies when training the doctors.

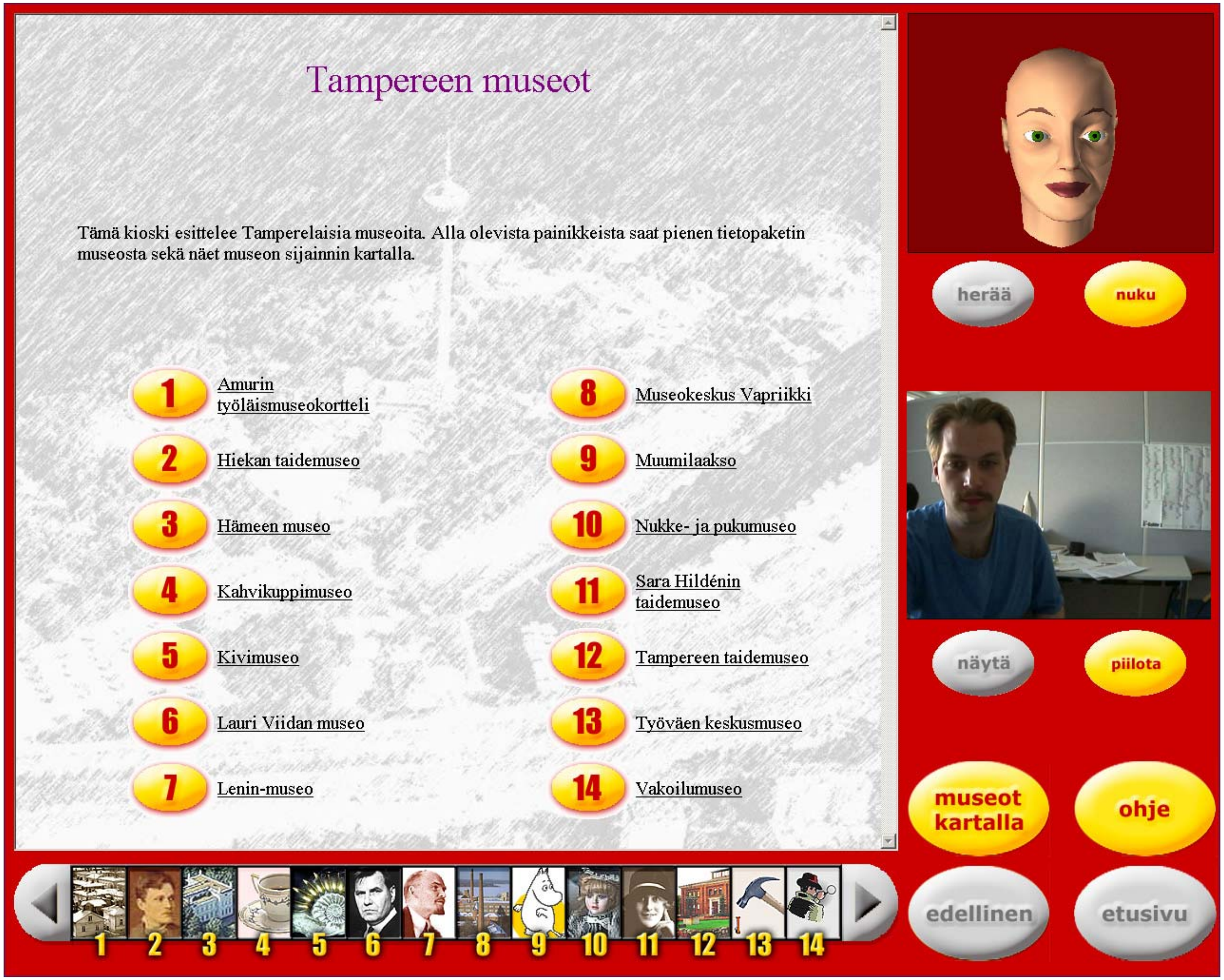
Haptic, auditory and visual environment for visually impaired children

People: Maarit Mannonen, Virpi Pasto, Jouni Salo, Arto Hippula, and Roope Raisamo

Financed by NUH, **N**ordiskt **U**tvecklingscenter för **H**andikapphjälpmedel

- Haptics will be used with visual and auditory modalities to make the user interface more informative and concrete.
  - Our focus in on tutoring systems for the visually impaired children
- Redundant information can compensate for disabilities.
- We cooperate with the research teams and organizations for the disabled people in the Nordic Countries.

Multimodal kiosk interfaces



Multimodal kiosk interfaces

- Currently possible applications with the kiosk
  - Interface agent can turn to user's direction
  - The agent can greet and farewell the users
  - Help can be provided to the user
  - Users can be invited to use the kiosk, when detected nearby

Multimodal kiosk interfaces[4,5]

People: Erno Mäkinen, Petri Tuominen,
Saija Patomäki, Matias Hasu, and Roope Raisamo

Financed by Tekes (& Helsinki University of Technology)

- The emphasis is on research and development of multimodal information kiosk interfaces.
  - Our present kiosk is a multimodal system in which a touchscreen acts as the main input and output device.
  - machine vision, user interface agents and alternative input methods are investigated and developed to augment the interface.

[4] Mäkinen *et al*. 2002, [5] Mäkinen and Raisamo 2002

Research on Haptic User Interfaces

Research on haptic user interfaces in the World

- Microsoft Research
- Glasgow Interactive Systems Group (GIST)
  - Stephen Brewster
  - Marilyn Rose McGee
  - Ian Oakley
- York University: Vision,Graphics and Robotics Lab
  - Scott MacKenzie
- University of Toronto: The Input Research Group
  - Bill Buxton

Research on Haptic User Interfaces

Research on haptic user interfaces in the World

- The Robotics Institute
  - Andrew Mor
- MIT Artificial Intelligence Lab: Haptics Group
  - Mark Ottensmayer
- Purdue University: Haptic Interface Research Laboratory
  - Hong Tan
- IBM Almaden
  - Shumin Zhai

Research on Haptic User Interfaces

Research on haptic user interfaces in the World

- University of Stanford: Music and Aquistics Research Activities
- BioRobotics Lab: Haptics Research
- Cooperative Research Center for Advanced Computational Systems
- CSIRO (Scientific and industrial research for Australia)
- Fractal Graphics - Research and Development
- The Haptics Community Web Page
- CERTEC, Sweden
- KTH, Sweden
- Uppsala University, Sweden
- …

Research on Haptic User Interfaces

Research on haptic user interfaces in Finland (outside Tampere):

- There has been only some research in VTT (Oulu) and in some research centers (e.g., Nokia).
- Tactile feedback has mostly been used in user interfaces for the disabled people, as user interfaces for the blind.

Research on Haptic User Interfaces

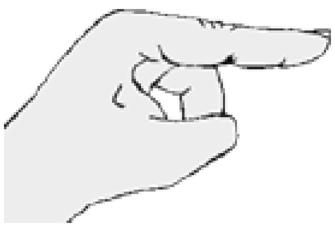
Research on Haptic User Interfaces in Tampere

- Basic research at the Department of Computer and Information Sciences in a three-year research project ”Tactile User Interfaces”.
- Some applied research projects on haptics for the visually disabled, and haptic in 3d data visualization.
- Some research in this area has also been done at VTT in Tampere

Video

- CHI 99 Video Proceedings
  Brygg Ullmer and Hiroshi Ishii:
  mediaBlocks: Tangible Interfaces for Online
  Media (4:56)

Haptic User Interfaces



http://www.cs.uta.fi/hci/mmig/

Slides 2-11 are based on a part of SIGGRAPH 98 tutorial on physical interaction by Kenneth Salisbury from the Artificial Intelligence Lab in Massachusetts Institute of Technology.

Slides 21-35 are based on a presentation by Dr. Pierre Boulanger

Department of Computing Science, University of Alberta