Haptic interfaces

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The touch modality

Somatosensory system

Tactile, temperature, pain

Kinesthetic

Haptic

Proprioception

1.3 square meter, 4-5kg skin

Protects the body from the surrounding world.

Provides information about the position of the body and touch.
Somatosensory system

Tactile perception is defined as perception mediated solely by variations in cutaneous stimulation (Loomis & Lederman, 1986).

Kinesthetic perception is defined as perception from joints and muscles, by limb movement alone, of hardness, viscosity and shape.

Proprioception is the sense of position of the body in relation to gravity as well as our movement through space. Receptors in the vestibular apparatus are involved.

Haptic perception

Haptic perception is defined as perception in which both the cutaneous sense and kinesthesis convey significant information about distal objects and events (Loomis & Lederman, 1986; Gibson, 1966).

Haptic system unifies input from many sources, e.g., position of fingers, pressure, into a unitary experience.
Intermodal relations

The sensory modalities are specialised for different tasks (Freides, 1974).

Therefore, specific characteristics of any particular perceptual task should be considered, in relation to the specific properties of the sensory modality (modalities), that provides information for performance of the task (Heller & Schiff, 1991).

This specialisation emerges more strongly as the complexity of the task increases (Freides, 1974).

Vision is generally dominant over both touch and audition for the perception of spatial location.

Vision is more effective than touch for perception of shape (Heller & Schiff, 1991). Focus on one point at a time + peripheral vision.

Audition is more effective than vision for the perception of temporally distributed events (Bruno & Penel, 2002). Parallel perception in 360°.

Touch is at least as accurate as vision in the perception of texture.

If vision is blurred people rely more on touch for perception of form (Heller & Schiff, 1991). Focus on several points at once.
Intermodal relations

The sense of touch is unique in that it is the only sense with which one can both perceive the information at the same time as one can modify it.

Haptic systems

Gives force feedback in different degrees of freedom.

Provides both tactile and kinesthetic perception.

Resistance is applied via motors in the joints of a robotic arm when the proxy is on the surface of a graphical object.
Haptic devices

Phantom Desktop

3 degrees of freedom for haptic feedback but 6 visually.

All surfaces and objects can be felt. Haptic qualities like softness/hardness, textures, friction, weight, magnetism and pulling forces.

Haptic device

Falcon

3 haptic & visual degrees of freedom.

All surfaces and objects can be felt.

Cheaper device, 239 USD.

Not as good haptic perception but good enough for e.g. games.
Haptic device

Haptic master system
6 haptic degrees of freedom
Can take forces up to 2.5 kg

Haptic devices

CyberGrasp™
Exoskeleton that provides haptic feedback to all fingers or that covers more or less of the body. http://www.youtube.com/watch?v=BkB8EDy3eA1o
Haptic devices

Game consoles

1 degree of freedom

Makes it possible to feel a bump, curb, pothole, and fender-bender or vibrations when off track with a force feedback wheel.

Tactile interface

Braille display

A row of special 'soft' cells.

A soft cell has 6 or 8 pins made of metal or nylon.

Pins are controlled electronically to move up and down to display characters.
Haptic applications

Taking a blood sample

Haptic applications

Experience the feeling of a gearbox
Medical applications

Radiology

Haptic feedback can significantly reduce the time taken (18 %) to track target areas/tumours/organs (Anderlind, Noz, Sallnäs, Lind, Maguire, 2007).

A haptic/visual mode (Phantom Omni haptic device ) and a visual only mode. Test images were CT-scans of a dummy vertebra.

Medical applications

Dental surgery

Oral surgery simulator to train dental students to extract wisdom teeth.

The teacher’s tacid knowledge is made concrete using the simulator as a mediating artifact. Students feel and hear when they drill in teath and jaw bone.

Observations of surgery and interviews with surgeons at the Dep. of Oral surgery to validate the design of the prototype. Implementation in dentistry education.

Forslund, J., Sallnäs, E-L. and Palmerius, K.J. 2009
Medical applications

Dental surgery

![Dental surgery image]

Extended physiological proprioception (EPP)

When a person actively manipulates an object with a tool like e.g. when doing laparoscopy, the surgeon after a lot of training, perceives that the tools are like an extension of the hands. The perceptual experience is transparently transferred to the end of the tool or a prosthetic limb (Simpson, 1972).
Simulations of surgical procedure

Simulator where one can experience how it feels and what it looks like when eye-surgery is performed.

Photorealistic pictures of an eye and force feedback that makes it possible to feel the eye tissue by using a surgical tool that is simulated.

Medical applications

Haptic organ rendering

Supporting multi-disciplinary medical pre-operative conference.

How haptic feedback can be used when people communicate about and collaboratively analyse patient data such as CT images.
Medical applications  Haptic organ rendering

Perceptualization

Haptic & audio feedback for joint analysis of scientific data

Haptic feedback, sonification and visual feedback in combination hypothetically increase the "cognitive bandwidth".
Perception of 2D objects

Active touch – when the person actively controls the input of touch stimuli by exploration. Haptic perception depends on active touch (Appelle, 1991).

Passive touch – when the person does not control the input of touch stimuli actively by exploration e.g. When the touch stimuli is pressed against the skin.

2D shapes is significantly easier to recognize with active touch than with passive touch.

People can recognize 95% of "cookie cutter" shapes when actively exploring them compared to 29% when shapes were pressed on skin (Gibson, 1979; Apelle, 1991).

Tactual Stereognosis

The ability to feel three dimensions by exploring objects with the hands. Humans can recognize 96% of 2000 objects without looking at the objects.

- Searching phase to localize the object. Rapid swooping movements, not very tactile.

- Positioning phase when holding the object with the hands and establishing its position in relation to the body centre.

- Exploration phase when different features are explored and relative distances are measured. Micro movements with pauses at critical points like corners or detailed parts of the object.
People use specific exploratory procedures to classify objects (Lederman and Klatzky, 1987).

- Lateral motion is meant only for perceiving texture
- Unsupported holding for perception of weight
- Pressure for perception of hardness of the material
- Static contact principally gives information on temperature

Enclosure gives global information on shape, size, texture, and hardness

Contour following provides precise knowledge about shape and size, and a vague idea about texture and hardness

Two phases of the object exploration procedures in humans
1. whole hand, vague haptic and tactile information about properties
2. specific exploratory procedures to feel particular object features

(Kahol et al., 2006)

Haptic force feedback makes joint manipulation of objects significantly faster & more precise.

People perceived their performance to be significantly better in a haptic environment.

People perceived themselves to be significantly more virtually present in a haptic environment. (Salmela, Rasmuss-Grohn, & Sjöström (2000))

But people did not always perceived themselves to be more socially present in the haptic environment. Significantly improved social presence when audio communication was not provided.
Results from the Fitts’ Law study

Fitts’ law proved to hold for a collaboratively performed hand off task in both the haptic and the nonhaptic condition Sallnäs, Zhai (2003).

\[
Y = 1.007 + 0.579 \times \log_2(D/W + 1)
\]

\[
R^2 = 0.992
\]

Effect of cube size:

\[
(F_{5,50} = 30.2, p < 0.0001)
\]

\[
T = 1.01 + 0.579 \log_2(D/W + 1)
\]

\[
(r^2 = 0.99)
\]

Assistive technology

Support group work in school between visually impaired and sighted pupils.

Haptic feedback provides a shared representation of the work space.

To grasp, move and hand off objects was unproblematic.

Haptic and verbal guiding was important for joint task performance.

Visually impaired are not fully aware of changes in a dynamic environment without auditory feedback. Interaction sound in a second version made joint task performance significantly faster.

Moll, J. & Sallnäs, E-L. 2009
Assistive technology

Interaction sound in a second version made joint task performance significantly faster.

- Grasp sound
- Touch down sound
- Touch down sound on another object
- Localisation sound

Increased awareness of own as well as other’s actions.

Moll, J. & Sallnäs, E-L. 2009

Verbal guiding

| S: | Ok, right... right, right... left... feel, ..you can feel the corner |
|    | [B moves to the upper right corner] |
| S: | ... and then go to the left a bit. stop!.. down.. left, left... down...go down till you feel the ground... and then go forward until you feel the wall |
|    | [B moves the block to the upper wall, sliding it on the floor] |
| S: | ... and right until you feel the boxes,... so, yeah... let go |

Haptic guiding

| S: | [S grabs the B’s avatar] |
|    | [He drags the B to the beginning of the L-shape] |
| S: | Now, here we have an L-shape... |
|    | [S drags the B to the top of the shape] |
| S: | ...this is the top. |
|    | [S now drags the B back and forth on the L-shape’s north-southern part a few times] |
| S: | Ok, and this is the bottom right... and then we have this cube that is taller than the others |
|    | [He drags B up and down on a tall block placed beside the L] |
| S: | We have another one just like it |
What is communication?

“the psychological signals whereby one individual can influence the behaviour (thoughts) of another”  

Cherry, 1957

Dialogue structure:
- turn-taking
- back-channel feedback

Gestures:
- symbolic (thumbs up)
- deictic (pointing)
- iconic (show object’s movement)
- beats
- pantomimics (show skill)

Facial:
- emblems (nodding)
- affect display
- conversational sign.

Gaze:
- attention
- deictic references
- mental activity
- emotions

Position:
- discussants location in relation to each other and the surroundings

Relative orientation:
- discussants relative position to each other

Communicative functions of haptic feedback?

- deictic references (pointing, referring to objects, directions etc)
- pantomimics (show skill)
- iconic (show object’s movement)
- attention/embodiment
- turn-taking (indicate that someone wants to speak)
- intention (complex set of haptic cues)
- affect display (anger or insecurity)
Collaborative functions of haptic feedback

- Hand off objects and feel that they are received by another person.
- Guide someone directly or through an object for easier navigation.
- Haptic feedback can to some extent substitute verbal communication.
- Manipulate and construct composed objects together, lift, pull, push.
- Teaching someone a skill, that might be tacit knowledge.
- Treating patients remotely e.g. ultra sound (France Telecom).
- Improved efficiency and precision during joint object manipulation.

Haptic communication

Feather, Scent and Shaker

A set of shakers, feathers and scent from a framed photo.

Two people had one shaker each and shaking one device caused the other to vibrate and vice-versa. Saw no graphical representation of the other person.

(Strong and Gaver, 1996)
Haptic communication

ComTouch

Vibrotactile feedback that complement mobile voice communication.

People developed a vibrotactile encoding system like Morse code.

Emphasized what they were saying by synchronizing the tactile pattern with speech.

Used vibrotactile signals to indicate that they intended to speak, turn-taking.

People mimicked each other’s signals in order to get other’s attention, or as symbolically patting the other on the arm. (Chang et al., 2002)

Haptic communication

HandJive

Small handheld and mobile device.

Users could move parts in the device in eight discrete positions.

People tended to compete if the haptic feedback was direct and continuous.

Indirect haptic feedback and preferably discrete positions induced more cooperative behavior.

People could learn complex patterns of “Tactilese” and started to improvise their own routines. (Fogg et al., 1998)
Haptic functions for collaboration

- Hand off objects and feel that they are received by another person.
- Guide someone, practice a movement or help to navigate.
- Haptic feedback can to some extent substitute verbal communication.
- Manipulate and construct composed objects together, lift, pull, push.
- Teaching someone a skill, that might be tacid knowledge.
- Treating patients remotely e.g. ultra sound.

Haptic collaborative environment

Carry a stretcher through a detailed 3D virtual model of a chemical processing plant together with another person. The virtual model had obstacles in the form of pipework, vessels, pumps, valves other machinery and handrails.

Two different haptic feedback systems were used, PHANToM and Argonne arm. Users could feel:

- pushing and pulling forces transmitted through the stretcher
- collisions between the stretcher and walls or other obstacles
- a feeling of sliding along a wall.

Haptic feedback made the joint manoeuvring of the stretcher easier. (Hubbold, 2002)
Haptic collaborative environment

A haptic cursor communication mechanisms in a 2D multiuser interface, PHANToM.

- The users' cursors could be felt and pushed.
- One user could force another user to go the path that the first user goes.
- A "locate" tool allowed a person to be guided to another user.
- A "grab" tool allowed one user to force another user to move to her/him.

People usually warned the other verbally before initiating haptic interaction.

More of the available space was used with haptic feedback for doing their task.

Haptic feedback significantly increased (virtual) presence & perceived usability.

(Oakley et al., 2001)
Thank you?

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