Mobile & ubiquitous haptics

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Haptic communication
Communication via touch (1/2)

- Touch can be used as an alternative information communication channel

- Examples of early work:
  - Braille (Louis Braille, 1824)
    - Tactile language used by visually impaired users
    - Different configurations of 6 or 8 dots are used for presenting alphabetical information
  - Tadoma (Sophie Alcorn, ~1910)
    - “Tactile lip reading” for deaf-blind people: a person places his/her thumb on the speaker's lips while the other fingers touch the speaker's face and neck
    - Possible to understand everyday speech at very high levels
Later work has used technology to stimulate the sense of touch for communication purposes.

Vibratese (Geldard, 1957)
- Like tactile Morse code
- 5 vibrators placed on the user’s trunk could present 45 basic elements (letters, numerals, short words)
- Elements coded by amplitude, duration and location
- Reading rates of approximately 38 words per minute have been reported
Tactile icons (1/2)

• **Tactons or tactile icons**
  - “Structured, abstract messages that can be used to communicate information non-visually” (Brewster and Brown, 2004)
  - Different actuators can be used to create tactons (e.g., vibration motors)
  - Coded by, e.g., amplitude, frequency, duration and rhythm
  - Should be practical, reliable, quick to identify and pleasant
Tactile icons (2/2)

- Tactons have been used for communicating different types of information
  - Alerts (Brown and Kaaresoja, 2006)
  - Directions (Yatani et al., 2009)
  - Letters (Rantala et al., 2009) video

- In general, interpreting the meaning of different icons gets more difficult when the number of icons increases
  - Use of tactons requires training
Interpersonal haptic communication

- The sense of touch plays an important part in traditional human-human interaction
  - Greetings
  - Affection
  - Playful touch
- This can be mimicked to some extend using haptic technology
- Interpersonal haptic communication attempts to mediate information between users who are physically apart
Example: inTouch

• One of the first prototypes for two-way haptic communication (Brave and Dahley, 1997)
  - Provides a physical link between users separated by distance
  - One user can move the rollers and simultaneously feel the movement created by another user

http://tangible.media.mit.edu/projects/intouch/
Example: ComTouch

- ComTouch (Chang et al., 2002) transferred finger touch input to vibrotactile stimulation

- The touch channel could be used during audio communication
  - Participant pairs used touch mainly for emphasis, mimicry and turn-taking
Example: Shake2Talk

- **Shake2Talk** allowed users to send and receive vibrotactile messages by combining auditory and tactile elements
  - Vibration presented using an eccentric rotating mass

(Brown and Williamson, 2007)
Example: CheekTouch

- With CheekTouch users could send different touch sensations by interacting with the touchscreen of a mobile phone (Park et al., 2009)
  - A 4x3 vibrotactile display for presenting mediated touch
Example: Touch gestures

- Mobile devices can detect different touch gesture types and convert them dynamically into vibrotactile stimulation (Rantala et al., 2011)
  - Squeeze and finger touch were preferred over shaking
  - This could be due to the fact that squeeze and finger touch better resembled real touch
Affective haptics
Affective haptics (1/4)

• Can haptics evoke emotions?
  - Touch is often private
  - Touch tends to increase trust and altruistic behavior
    • The Midas touch phenomenon -- a waitress received bigger tips when she would briefly touch her customers on the shoulder
  - For some interactions touch may be socially inappropriate

• Humans can express a range of emotions through real interpersonal touch (Hertenstein et al., 2006)
  - The effectiveness of mediated or “remote touch” depends on the users, design and technology used
  - Touch communication can be altered and used in ways that are not possible in the real world
Affective haptics (2/4)

• One way to study whether haptic interaction can evoke emotions is to measure participants’ subjective responses after use.

• With the dimensional theory of emotions, it is possible to use dimensions of valence and arousal for measurement.
  - In general, stimuli with high intensity or amplitude are often perceived as arousing and unpleasant.
  - More subtle stimuli are perceived as relaxing and pleasant.
Affective haptics (3/4)

- Another way is to use the differential theory of emotions which suggests that emotions can be seen as distinct categories (e.g., happiness, sadness and anger)

- One study showed that participant pairs were above chance in communicating distinct emotions remotely using a haptic knob (Smith and MacLean, 2007)
  - Researchers have also introduced several other prototypes but the effectiveness of evoking emotional responses is rarely studied empirically
In addition, it is also possible to measure psychophysiological responses such as:

- Heart rate (HR)
- Galvanic skin responses (GSR)
- Electromyographic responses (EMG)

These lower level responses can be used during haptic stimulation and they are generally more objective.
Example: The Haptic Creature

- Developed for studying display of affect in human-robot interaction (Yohanan et al., 2011)
  - Presents 9 emotional states when a user interacts with it via touch
  - 3 actuation types for presenting emotions: breathing (servomotor), ears (airflow to rubber bulbs), purring (ERM motor)
  - Could be used, e.g., for therapeutic interventions for children, the ill or the elderly
Example: Hug-over-distance

- An inflatable vest that can be remotely triggered to create a sensation resembling a hug (Mueller et al., 2005)
  - Air compartments in the vest are filled using a compressor
  - Creates some noise when actuated

- Couples in a user study did not consider the device useful in daily life

http://www.floydmueller.com/portfolio/hug_over_a_distance.htm
Example: TapTap

- A wearable scarf designed for emotional touch therapy (Bonanni et al., 2006)
  - Vibration motors and solenoids attached to the scarf were used for imitating touch gestures of tap, press, stroke and contact
  - Included also touch sensing for recording and playing back basic touch sequences
Haptic navigation
Haptic navigation

- Haptic and tactile stimulation can be used to provide directional navigation information.
- One of the advantages of using haptics is that visual and auditory senses are often already reserved for other purposes (e.g., observing traffic).
Example: Waypoint navigation

- Vibrotactile waist belt with eight tactors (van Erp et al., 2005)

- Spatial information translated into a direction on the torso, used in two experiments:
  - Experiment 1 with 12 pedestrians
    - After about 30 min, the participants demonstrated walking speeds near to normal
  - Experiment 2 in the context of a helicopter and a fast boat
    - Only directional information was provided
    - Vibrations were well recognized in both cases
Example: Sports applications

- Guidance of where to, how and when to move (van Erp et al., 2006)
  - Presenting tactical information (in soccer)
    - Belt indicates the direction where to move
    - Four other vibration signals:
      - High up the back “keep your head up”
      - Left shoulder “look left”
      - Right shoulder “look right”
      - Middle of the chest “stop”
  - Posture information (skating, cycling, rowing)
    - Corrective instructions (e.g., shoulders & back position)
    - Motion co-ordination pattern (posture plus timing)
Example: Lead-me

- Generates a pulling sensation by oscillating a small mass back and forth
  - Small acceleration forward, large backward
  - Provides a sensation of force

- Can be used for indicating direction and helping in navigation

video
Example: Skin stretch for direction

- Communicates directions with a small rubber cylinder pressed against a user’s fingertip (Gleeson et al., 2009)
  - Moves 0.05 to 1 mm at constant speed to create lateral skin stretch
  - Can be moved to four directions
  - In a study, directions could be perceived already with the smallest stretch distance (0.05 mm)
  - Could be applied to hand-held devices
Example: CabBoots

[Image]

Example: Haptic radar

video  http://www.k2.t.u-tokyo.ac.jp/perception/HapticRadar/index-e.html
Haptics in cars
Haptics in cars (1/2)

- Haptics can be useful in a car environment where user’s cognitive load is often high
  - Using alternative modalities for communicating information to the driver may reduce the load

- Also, modern cars have less physical controls (e.g., knobs, sliders) that could provide passive haptic feedback and enable eyes-free use
  - Active stimulation could potentially bring some of this haptic information back
  - Haptic stimulation in a car must be carefully designed so that it is not confused with environmental vibration
Haptics in cars (2/2)

• Influence of steering wheel torque feedback in a dynamic driving simulator (Toffin et al., 2003)
  - Drivers on the simulator control their vehicles in curves with quite different torque feedback strategies
  - Zero torque or inverted torque feedback makes driving almost impossible

• Using spatial vibrotactile cues to direct visual attention in driving scenes (Ho et al., 2005)
  - Vibrotactile stimuli presented on either front or back to inform of the rapid approach of a car
  - Participants responded significantly faster when vibrotactile cues were given
Example: Pneumatic steering wheel

- A pneumatic tactile alerting system for the driving environment (Enriquez & MacLean, 2001)
  - A steering wheel with pneumatic pockets to produce pulsations at around 5 Hz
  - Lowered reaction time significantly
  - Using three frequency levels provided extra information that helped to identify a problem
Example: Touchscreen haptics in a car

- Studying the effect of touchscreen haptics on driving performance in a simulator (Pitts et al., 2010)
  - Driving performance unaffected by vibration feedback
  - However, participants spent less time looking at the screen when vibration was used
  - Vibration also improved user experience and increased confidence
Example: Lane departure warning

- Car manufacturers use haptic warnings of lane departure
  - Cameras or other sensors detect if the vehicle drifts out of the lane
  - In case of a lane departure, haptic feedback is given to the seat (Citroën), safety belt (Citroën) or steering wheel (BMW) to get the driver’s attention

http://www.citroen.co.uk/about-us/technology/safety/lane-departure-warning-system/
Rehabilitation
Rehabilitation

- Providing haptic stimulation to a user’s body can be used, for example, for guiding limb movement.

- The advantage of using haptics is that instructions can be directed to and felt in a particular body site:
  - This can be more intuitive than using visual or auditory information for guidance.

- Both force feedback and tactile feedback have been studied in this context.
Example: Telerehabilitation through a mobile device

- Kinesthetic therapy for patients with arm motion coordination disorder (Gutierrez et al., 2004)
  - Grounded haptic device attached to the patients arms
  - Therapist uses a handheld device to monitor and control the tasks
Example: HapticWalker

- Full foot guidance for rehabilitation
  - Gait restoration is often necessary after neurological injuries
  - Freely programmable walking trajectories

- Virtual reality applications
  - Head mounted display (HMD) for visual immersion
  - Virtual ground (e.g., floor, staircase up/down, inclined plane)
  - Different ground conditions (e.g., concrete, wood = hard contact, carpet = soft contact)
Example: Balance aids

- **Passive: vibrating insoles** (Priplata *et al.*, 2003)
  - Improved the balance of elderly people when they stood on a pair of randomly vibrating insoles (figure on the left)

- **Active: tilt sensors & vibrotactile actuators designed for balance-impaired persons** (Wall *et al.*, 2001)
  - Gives feedback to the user when to move one’s leg (figure on the right)
Example: Movement retraining

- Track the normal gait of a user and provide tactile feedback in real time for learning a new gait that strains the knees less (Shull et al., 2011)
  - Vibrotactile actuators presented feedback to the knees and toes
  - Skin stretch feedback for the trunk

- Six week gait retraining program reduced symptoms for individuals with knee osteoarthritis and knee pain