Chapter 14:
Touch and Movement

The Resonant Interface
HCI Foundations for Interaction Design
First Edition

by Steven Heim

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Chapter 14 Touch and Movement

- The Human Perceptual System
- Using Haptics in Interaction Design
- Technical Issues Concerning Haptics

Chapter 14 Touch and Movement

- The Human Perceptual System
  - The haptic system is well suited for the acquisition of knowledge about the physical and spatial aspects of our environment
    - Redundant with our visual system
    - Depends on contact with the environment

Chapter 14 Touch and Movement

- The Human Perceptual System
  - Physical Aspects of Perception
  - Psychological Aspects of Perception

The Human Perceptual System

- Physical Aspects of Perception
  - Touch (tactile/cutaneous)
    - Located in the skin, enables us to feel
      - Texture
      - Heat
      - Pain
  - Movement (kinesthetic/proprioceptive)
    - The location of your body and its appendages
    - The direction and speed of your movements

Physical Aspects of Perception

- Touch (tactile/cutaneous)
  - Mechanoreceptor Types and Characteristics
    - **Pacinian corpuscles** respond to vibration, which is interpreted as:
      - Acceleration
      - Roughness (for example, the vibration of an electric shaver)
    - **Ruffini endings** respond to skin stretch, which is interpreted as:
      - Lateral force
      - Motion detection
      - Static force

Physical Aspects of Perception

- Touch (tactile/cutaneous)
  - Mechanoreceptor Types and Characteristics
    - **Meissner corpuscles** respond to velocity or flutter, which is interpreted as:
      - Slip
      - Grip control
      - Movement at the skin surface (for example, a glass slipping through the fingers)
    - **Merkel disks** respond to skin curvature, which is interpreted as:
      - Spatial shape
      - Texture (for example, Braille letters)

Physical Aspects of Perception

- Factors involved in pressure sensation
  - **Sensorial Adaptation**: The rate at which a receptor adapts to a stimulus
  - **Pressure Detection**: The smallest perceivable pressure (absolute threshold) and the smallest detectable difference in pressure (just-noticeable difference [JND])
  - **Subjective Magnitude**: Perception of stimulus intensity is subjective and is affected by size of contact area, stimulus frequency, and temporal factors

Physical Aspects of Perception

- Factors involved in pressure sensation
  - **Apparent Location**: When two stimuli are applied at the same time we have a tendency to feel the stimulation at a point somewhere between them
  - **Masking**: The presence of one stimulus interferes with the detection of another
  - **Spatial Resolution**: Our ability to know how many stimuli are being applied to the skin is affected by the location of contact

Physical Aspects of Perception

- Factors involved in pressure sensation
  - **Temporal Resolution**: Two stimuli presented within a short interval might be interpreted as one stimulus
  - **Active and Passive Exploration**
    - In passive exploration, the stimulus is presented to the skin while the finger or hand remains still
    - Active touch involves movement on the part of the person who is haptically exploring

Physical Aspects of Perception

- Factors involved in pressure sensation
  - **Adaptation**: If stimuli of the same frequency continue for a certain period of time, our perception of their magnitude decreases and the absolute threshold increases

Physical Aspects of Perception

- Significance for Haptic Devices
  - Rapid adaptation receptors must be continually stimulated to maintain a sense of touch.
  - Absolute thresholds are variable and must be determined according to specific situational factors.
  - The smallest perceivable difference in pressure is affected by the amount of pressure being applied.

Physical Aspects of Perception

- Significance for Haptic Devices
  - Our ability to determine the number of pressure stimuli is related to their distance from each other; this distance changes depending on the location of stimulation
  - The amount of time between stimuli can affect our perception of the number of stimuli.
  - Some haptic stimuli can mask other stimuli, depending on spatial and temporal factors.

Physical Aspects of Perception

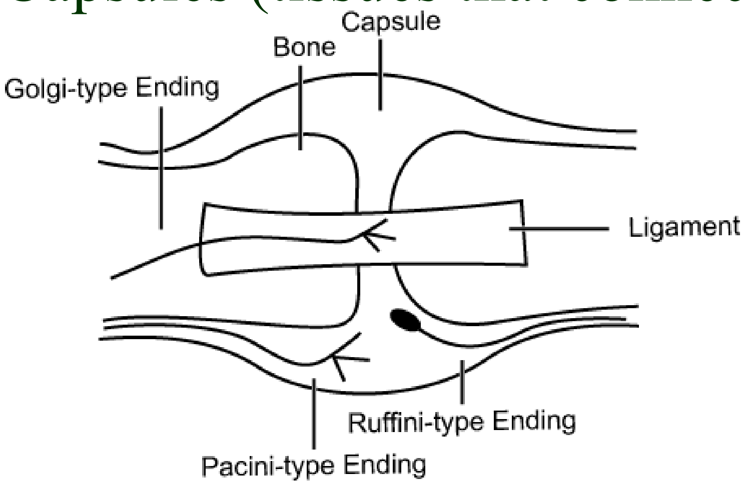
- Significance for Haptic Devices
  - We can gather more haptic information if we are allowed actively to explore a stimulus

Physical Aspects of Perception

- Movement (kinesthetic/proprioceptive)
  – We use the angles of our joints to determine the position of our limbs
  – We determine movement by the rate of change in the position of those joints

Physical Aspects of Perception

- Proprioceptic/Kinesthetic Receptors
  - Proprioceptors are found in the:
    - Muscles
    - Tendons (tissues that connect muscles to bones)
    - Ligaments and Capsules (tissues that connect bones to each other)



Physical Aspects of Perception

- Bidirectionality

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The haptic system senses external forces coming from the environment as well as exerts force on the environment

- We also use the movements of our joints to calculate the forces that are exerted by the objects in our environment

Physical Aspects of Perception

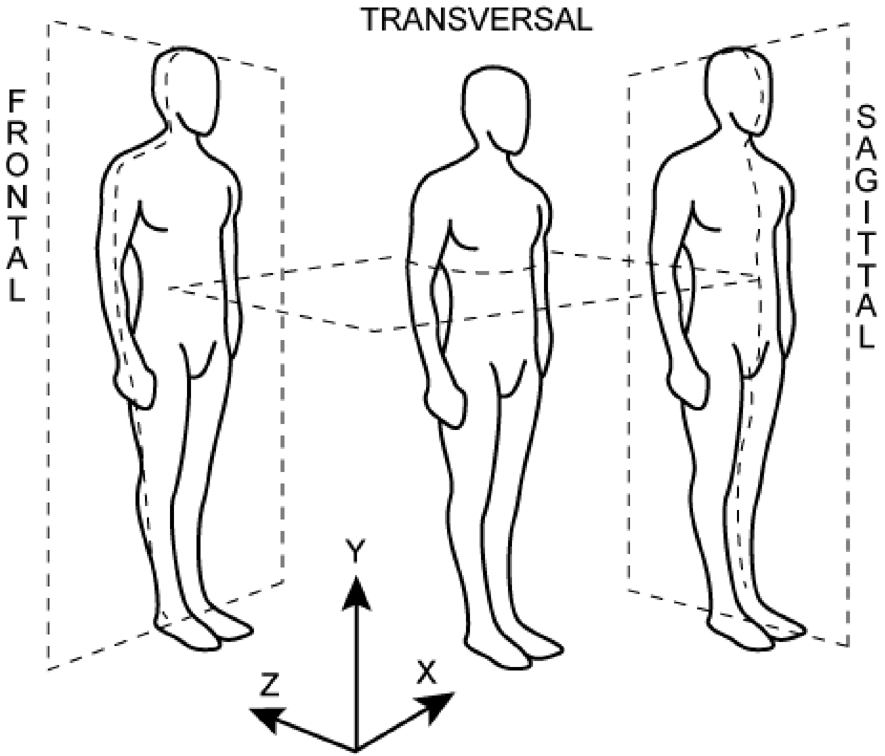
- Joint Movement
  - Anatomical reference point
    - Erect standing position
    - Feet flat, separated slightly
    - Arms relaxed and at the sides
    - Palms facing forward

Physical Aspects of Perception

- Joint Movement
  - Distal—farther from torso
  - Proximal—closer to torso
  - Medial—closer to midline
  - Lateral—away from midline
  - Anterior—toward front (ventral)
  - Posterior—toward back (dorsal)
  - Caudal—away from head (inferior)
  - Cranial—approaching head (superior)

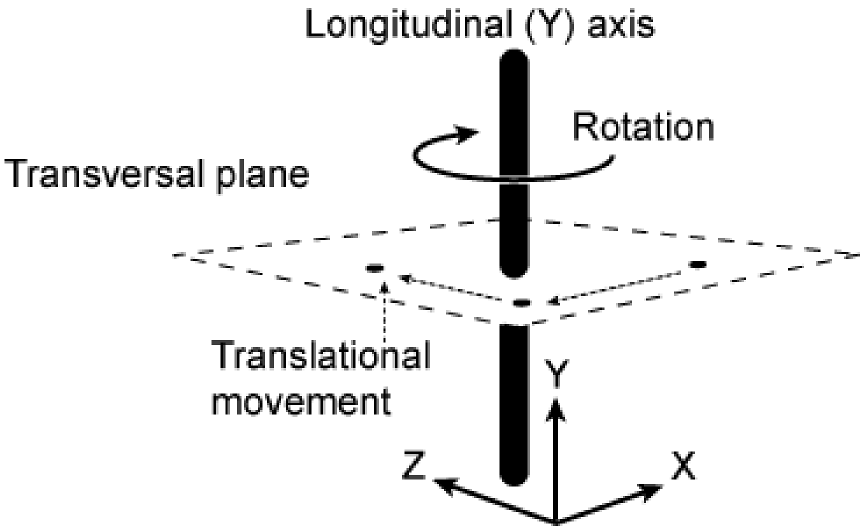
Physical Aspects of Perception

- Planes and Axes



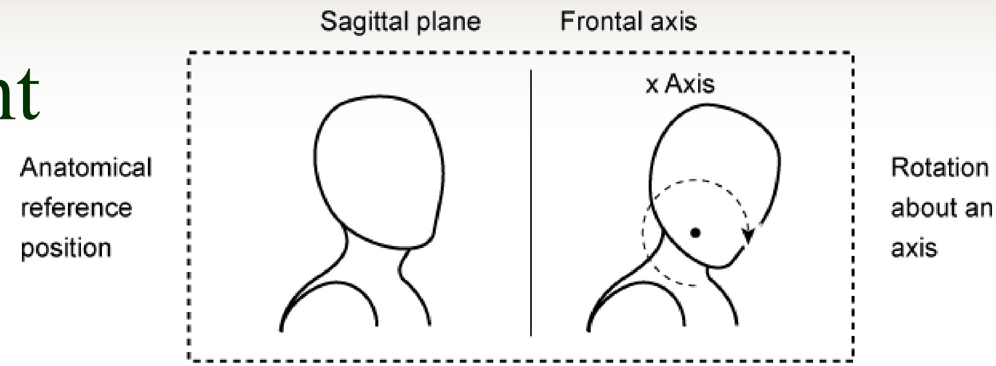
Physical Aspects of Perception

- Degrees of Freedom
  - Movement on a plane is called translation
    - X, Y, Z coordinate system
  - Movement around an axis is called rotation
    - pitch, roll, and yaw

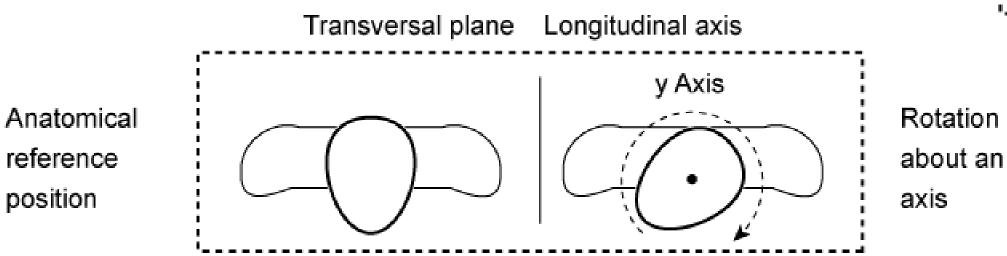


Physical Aspects of Perception

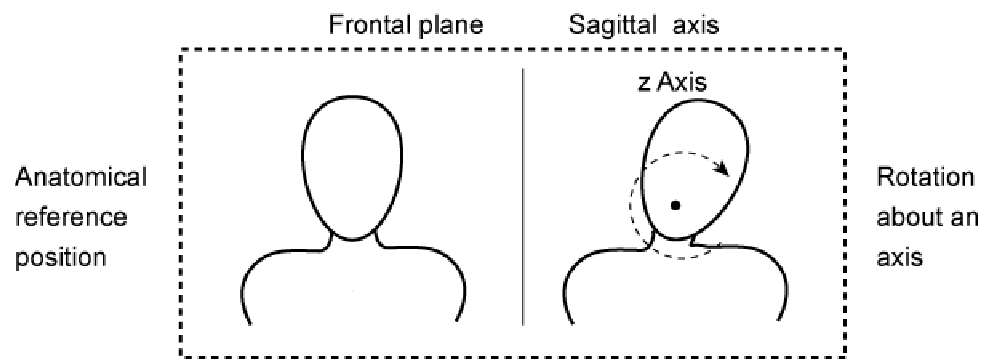
- Rotational Movement



Pitch



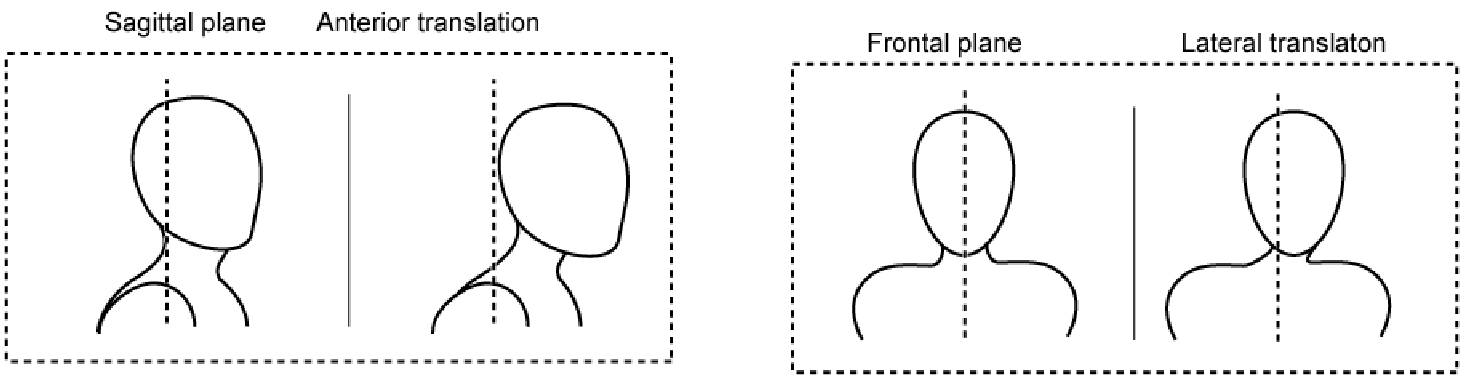
Yaw



Roll

Physical Aspects of Perception

- Translational Movement



Possible translational movements of the head.

Physical Aspects of Perception

- Tactile/Kinesthetic Integration
  - A unified system of perception
  - Our extensive system of limb joints allows us to position our hands to achieve the most tactile information possible from an object of interest
  - Subjects who have been given local anesthesia on their fingertips exhibit deterioration in grasping control

Physical Aspects of Perception

- Discuss the ways we integrate tactile and kinesthetic stimuli to experience the world

The Human Perceptual System

- Psychological Aspects of Perception
  - Kinetic Space Perception
  - Rotational Dynamics
  - Parallelity
  - Non-Euclidean Space
  - Tactile Perception
  - Object Recognition

Psychological Aspects of Perception

- Kinetic Space Perception

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The haptic system involves action–perception coupling

- Active or dynamic touch
  - We move our bodies and appendages to gain information about our physical space

Psychological Aspects of Perception

- Rotational Dynamics
  - Carello and Turvey (2000) suggest that rotational dynamics is fundamental to haptic perception
  - Involves the angular acceleration, the force applied (torque), and the center of mass (CM) of the limb that is being rotated
  - If a haptic device alters the CM of a user's appendage, then the user's sense of peripersonal space will be altered

Psychological Aspects of Perception

- Parallelity

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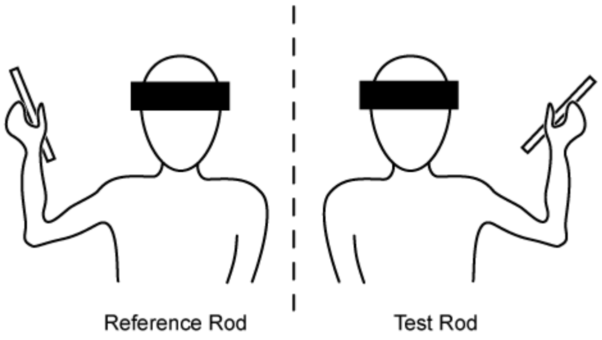
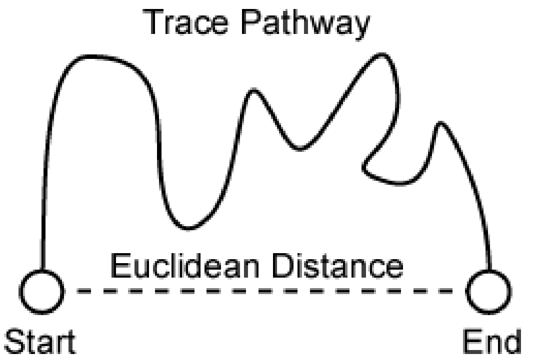
Haptic space perception does not correlate accurately with physical space

- Our haptic perception of the parallelity of objects in our environment is not exact



Psychological Aspects of Perception

- Euclidean space
  - Our haptic perception does not provide an accurate account of what is real



  - People consistently overestimated the real distance, and they made greater errors as the length of the trace pathway increased *(Faineteau, Gentaz and Vivani, 2003)*

Psychological Aspects of Perception

- Research Results
  - Haptic stimuli must be used as a secondary feedback mechanism that supports other kinds of feedback
  - Haptic feedback is closely aligned with visual feedback in our normal interactions with our environment

Psychological Aspects of Perception

- Tactile Perception
  - Real-life
    - Distinguishing a piece of sandpaper from a sheet of note paper
    - Perceiving small skin deformations from the slightly raised dots of Braille displays
  - Interaction design
    - Coding data on a graph or chart
    - Feeling material on a retail website

Psychological Aspects of Perception

- Object Recognition
  - We can identify objects from haptic stimuli
  - Haptic edge detection is slow and inaccurate

MAXIM

Cutaneous information can aid in object identification

- Object recognition is generally more accurate if a familiar view of an object is used
- Recognition is also enhanced when multiple points of contact with an object are possible

Psychological Aspects of Perception

- Coding Tactile Information
  - Location
  - Temporal Pattern
  - Frequency
  - Intensity

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To code haptic information, we must use multiple parameters and significant differences

Psychological Aspects of Perception

- Considerations for Haptic Interfaces
  - The weight of a wearable haptic device can affect our perception of our bodies.
  - Perception of haptic space is not accurate.
  - Tactile and kinetic perceptions are connected and should not be separated in haptic interfaces.

Psychological Aspects of Perception

- Considerations for Haptic Interfaces
  - We can recognize objects by their tactile aspects.
  - Object recognition depends on familiarity with the view and the number of contact points.
  - Information can be coded by using various tactile parameters such as location, temporal patterns, frequency, and intensity or by using combinations of these parameters

Chapter 14 Touch and Movement

- Using Haptics in Interaction Design
  - Teleoperation
  - Medical Uses
  - Users with Disabilities
  - Aerospace
  - Scientific Visualizations
  - Modeling
  - Art
  - Collaboration
  - Data Representations—Graphs
  - Gaming

Using Haptics in Interaction Design

- Teleoperation
  - The addition of haptic feedback to teleoperation can provide additional, and at times crucial, information and afford greater control of remote devices
  - High refresh rates and data throughput are required
  - System latency can have a detrimental effect on the user's perception of the remote environment

Using Haptics in Interaction Design

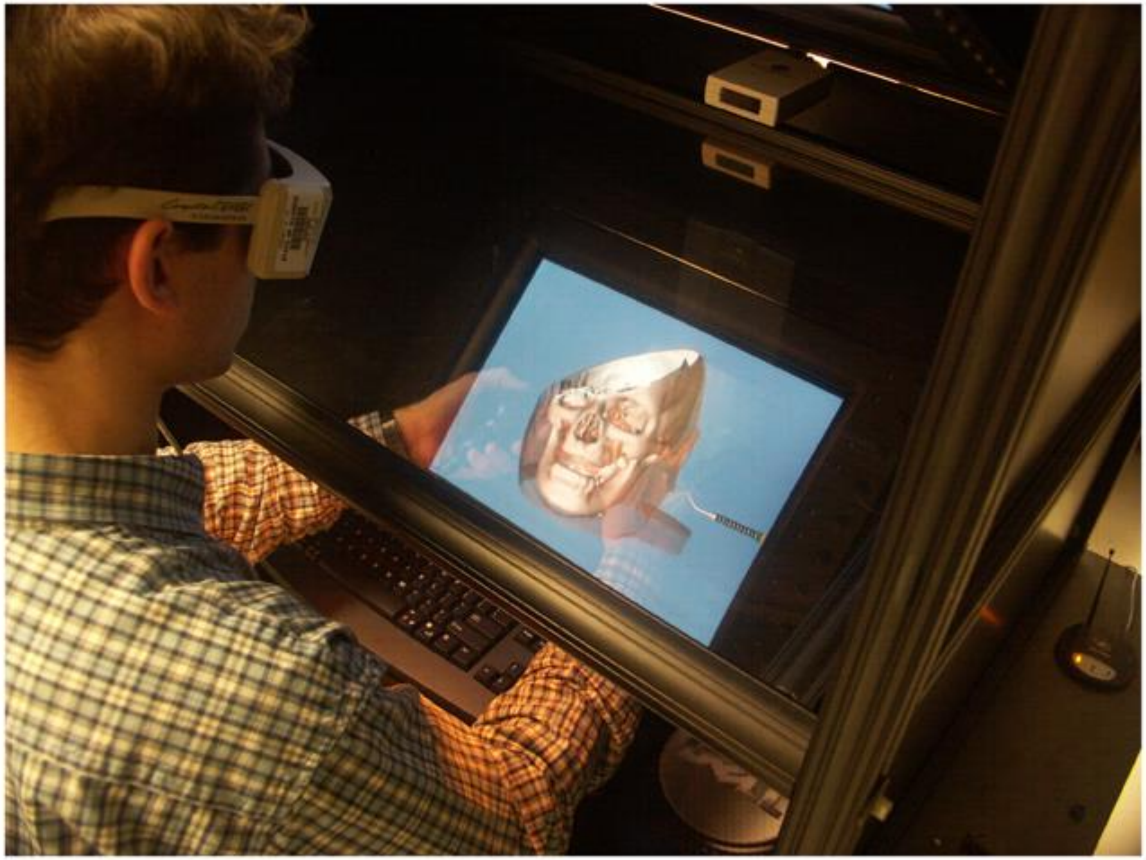
- Medical Uses
  - Can afford realistic and cost effective simulation environments for medical training and assessment
  - Haptic simulations has also been explored for dental training
  - Palpation and Instrument/Tissue Interaction

Using Haptics in Interaction Design

- Medical Uses
  - ImmersiveTouch™, a haptically augmented virtual reality (VR) system
    - Force feedback
    - Head and hand tracking
    - High-resolution, high-pixel-density stereoscopic display provides stereo visualizations of 3D data in real time
    - 3D audio provides an immersive VR environment

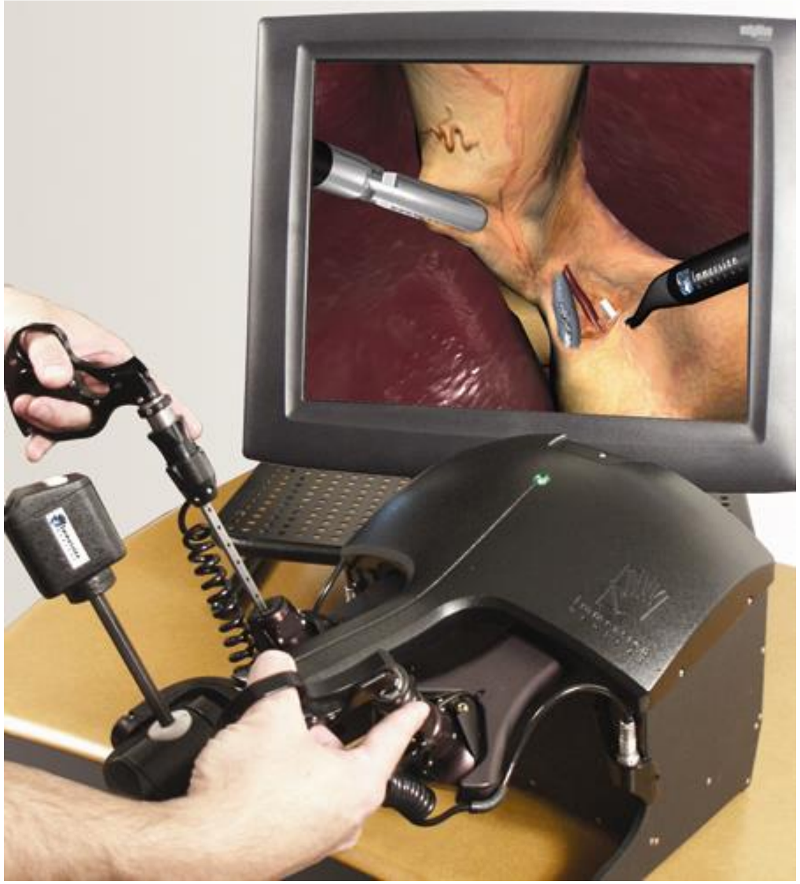
Using Haptics in Interaction Design

- ImmersiveTouch™



Using Haptics in Interaction Design

- Medical Uses
  - Minimally Invasive Surgery



The Laparoscopic Impulse Engine
a five-DOF device designed by Immersion Corporation

Using Haptics in Interaction Design

- Users with Disabilities
  - Electronic Travel Aids/Human Navigation Systems

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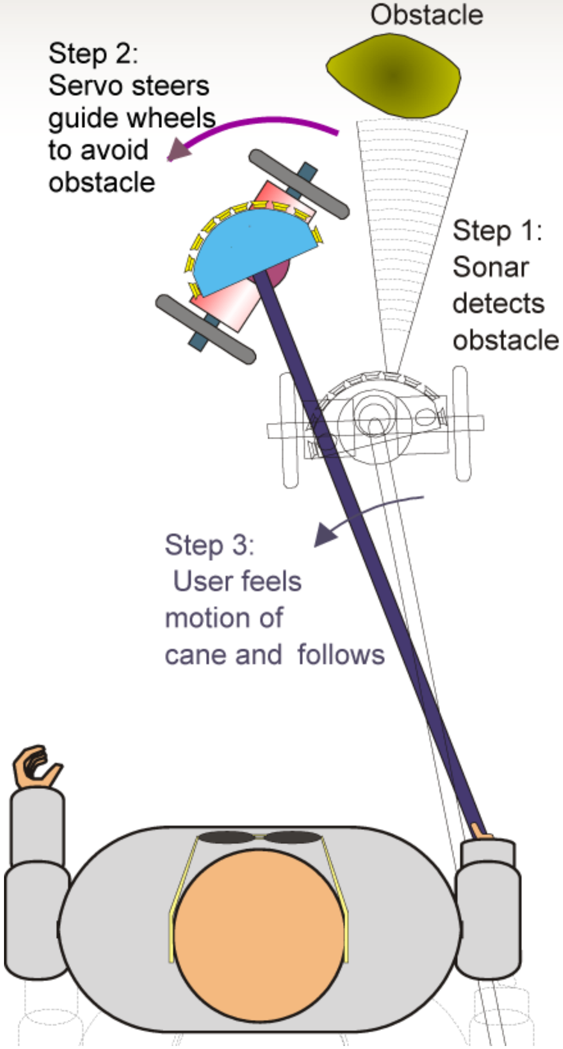
Haptic stimulation can aid with navigation in real-world as well as virtual environments

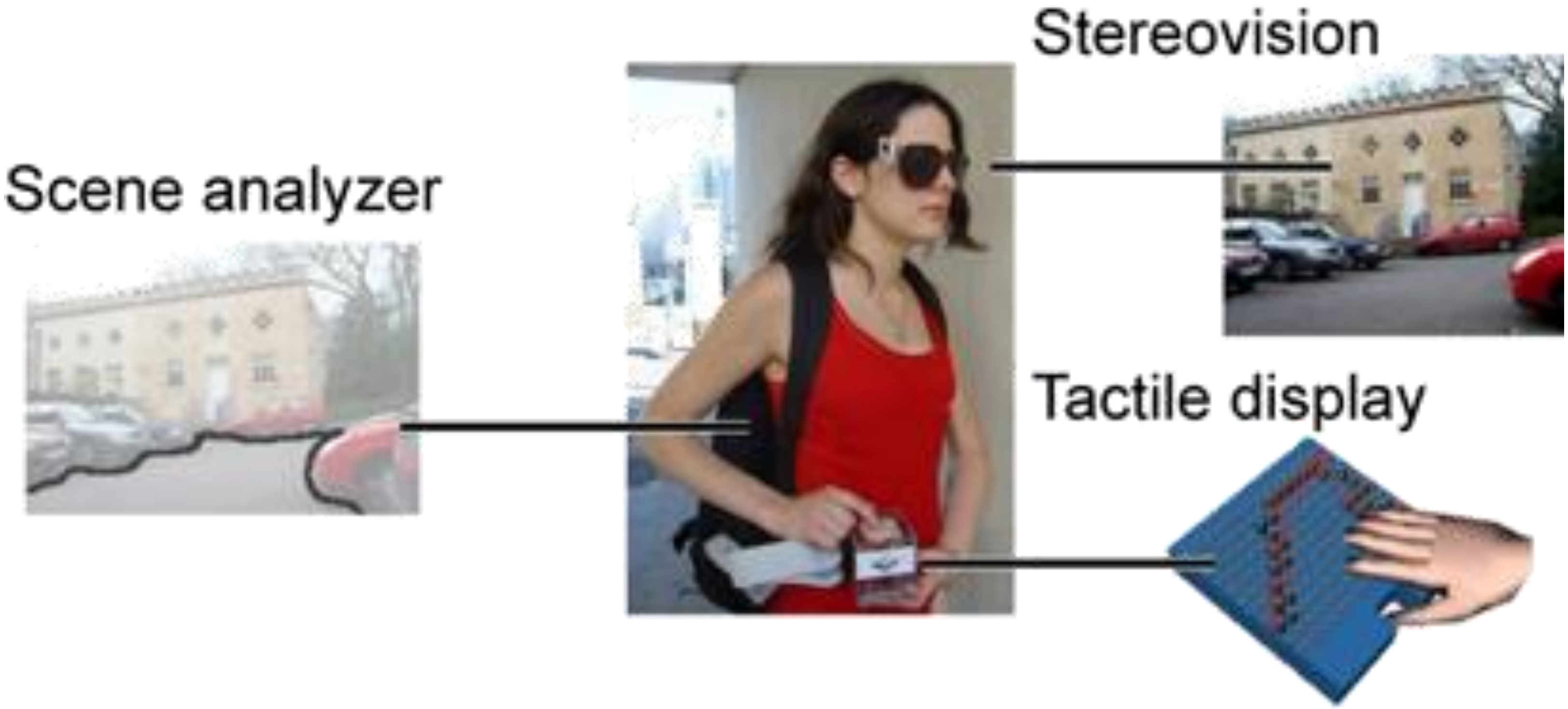
Using Haptics in Interaction Design

- The GuideCane
  (Ulrich and Borenstein, 2001)



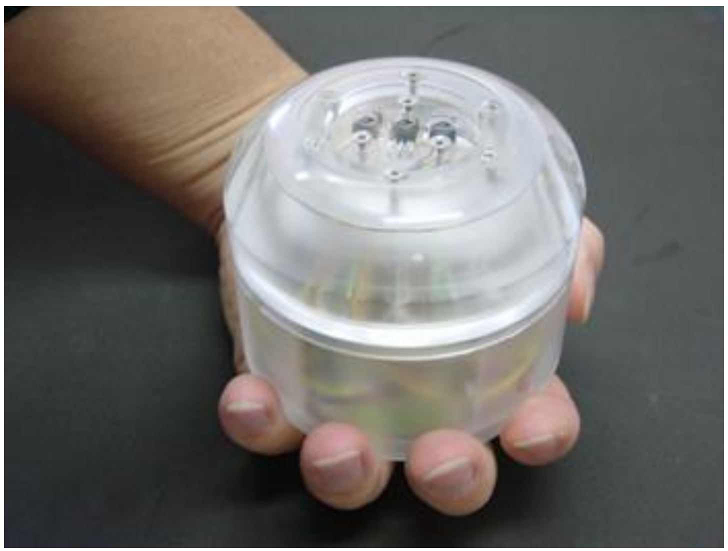
Using Haptics in Interaction Design

- Intelligent Glasses *(Velázquez, Maingreaud, and Pissaloux, 2003)*

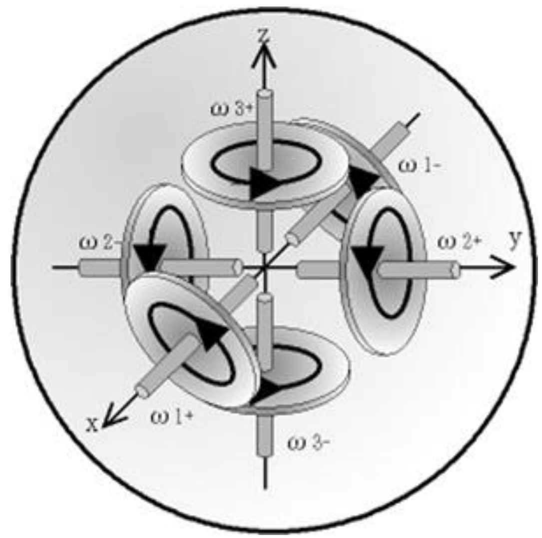


Using Haptics in Interaction Design

- The GyroCubeWireless *(Nakamura & Fukui, 2003)*



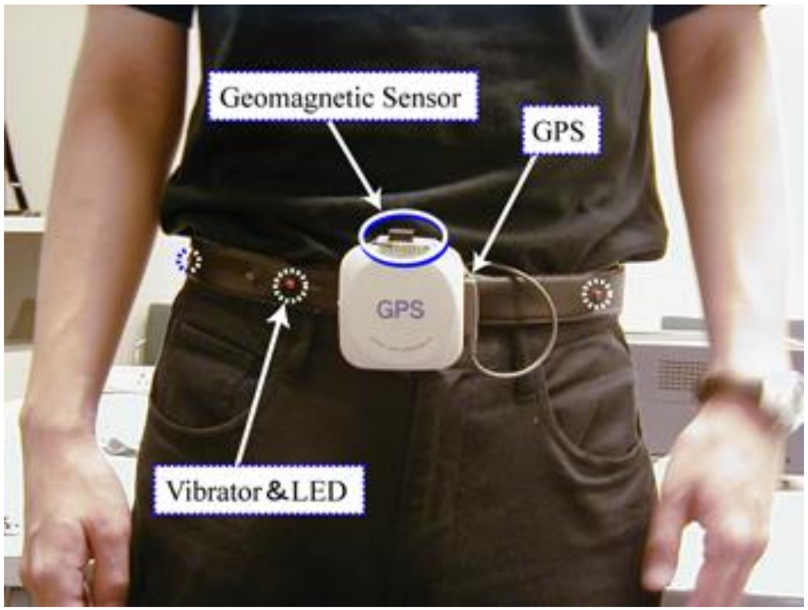
Outside

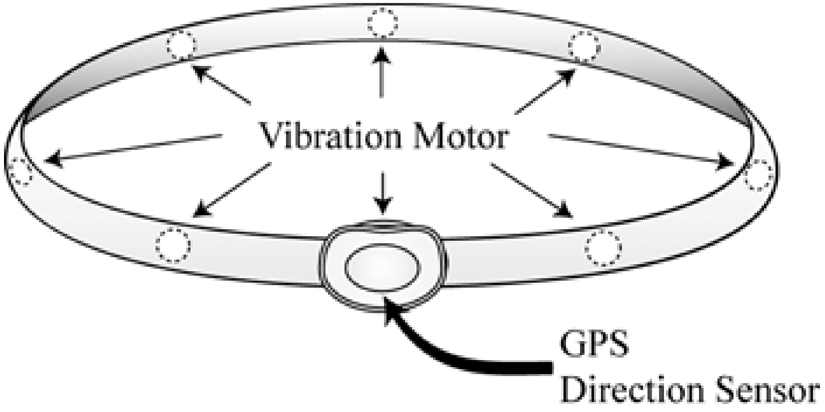


Gyroscopes

Using Haptics in Interaction Design

- The ActiveBelt *(Tsukada and Yasumrua, 2004)*





Device architecture of ActiveBelt
GPS, global positioning system; LED, light-emitting diode.

Using Haptics in Interaction Design

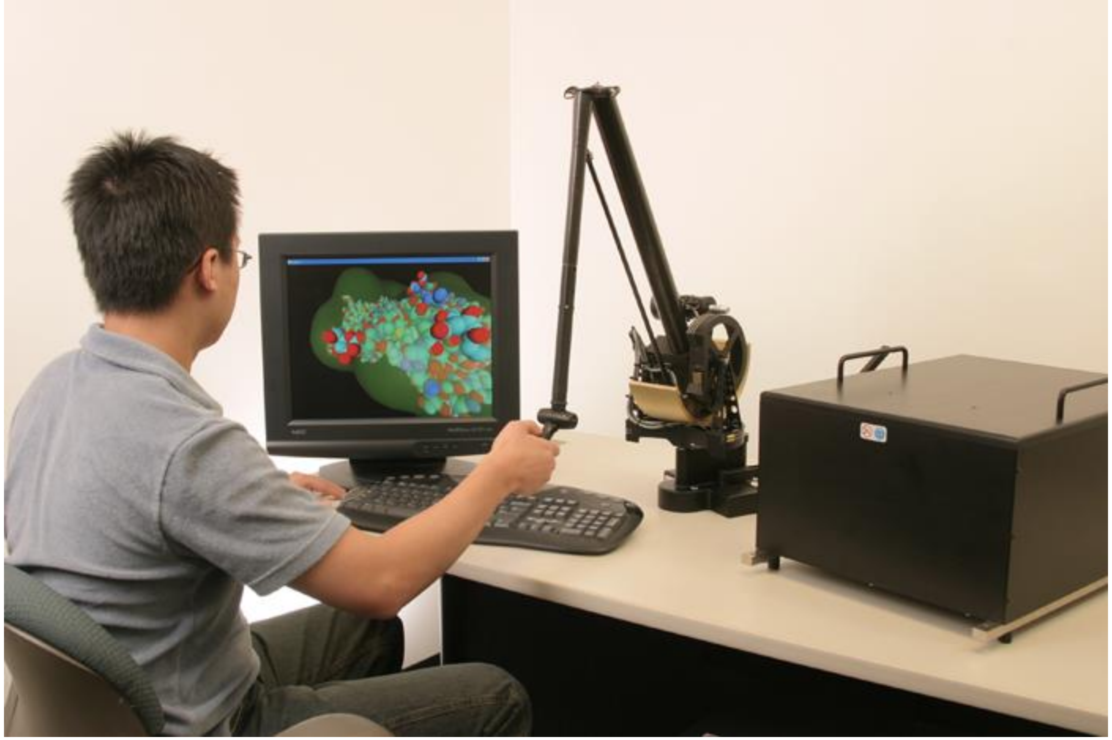
- Motor Disabilities
  - HAL-5 (Hybrid Assistive Limb), CYBERDYNE Inc. www.cyberdyne.jp

Using Haptics in Interaction Design

- Aerospace
  - Vibrotactile stimulation was incorporated into a tactile torso display by van Erp and van Veen to help NASA astronauts with orientation awareness in zero-gravity situations *(van Erp & van Veen, 2003)*
    - “Tap on the shoulder” principle

Using Haptics in Interaction Design

- Scientific Visualizations
  - PHANTOM Premium 3.0/6DOF haptic device
  - The SenSitus molecular docking software package



Using Haptics in Interaction Design

- Modeling

MAXIM

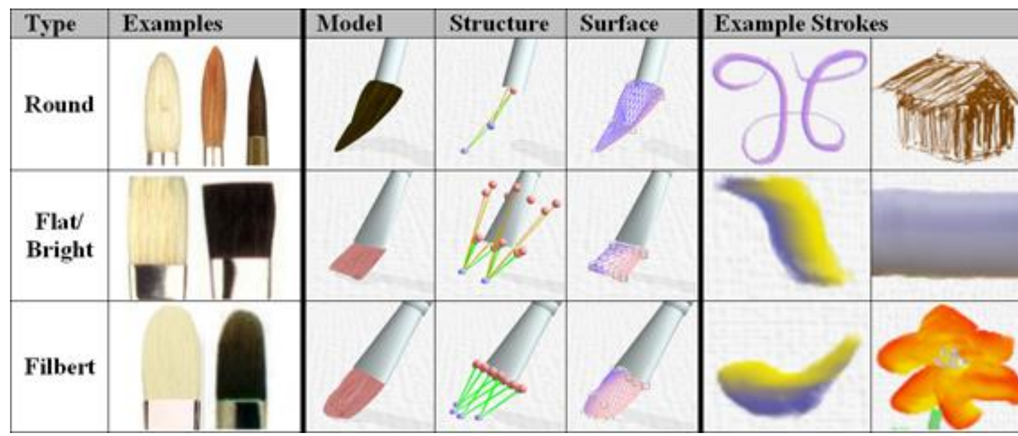
Haptic stimulation can enhance the sense of realism in virtual environments

- "Virtual prototyping" can be extended to a wide range of design activities, including
  - Product visualization
  - Fit analysis
  - Dynamic simulation
  - Maintenance analysis

Using Haptics in Interaction Design

- Art
  - Haptic technologies can enrich the experience and process of digital artistic creation

DAB Haptic Painting System



Paint brushes, virtual equivalents (skeletal structure and surface mesh) and example strokes

Using Haptics in Interaction Design

- Collaboration

MAXIM

Haptic stimulation can increase a sense of presence

- Collaborative environments have incorporated haptic feedback not only to offer users a greater sense of presence, but also to help them more easily locate others in the environment

Using Haptics in Interaction Design

- Data Representations—Graphs

MAXIM

Haptic stimuli can be used to represent data

- Line graphs present significant obstacles for the visually impaired
- Positive results have been obtained from multimodal graphic presentation

Using Haptics in Interaction Design

- Discuss how haptic feed back can be used to help visually disabled people to interact with line graphs

Using Haptics in Interaction Design

- Gaming
  - Contemporary digital gamming systems use haptic feedback to create a more realistic and engaging experience for the players
  - Haptic feedback has been incorporated into controller devices such as joysticks, gamepads, and wheel-based controllers
  - Game developers use Immersion Studio® to design haptic effects of gaming environments

Using Haptics in Interaction Design

- Haptic effects that can be created using the Immersion Studio for Gaming
  - **Position-Based Effects**
    - **Wall Effects**—these effects create the sensation of a wall that is horizontal, vertical, or placed at an angle
    - **Enclosure Effects**—these effects create the sensation that the cursor is constrained either inside or outside of an enclosure
    - **Inertia Effect**—this effect gives the sensation of pushing something that has wheels

Using Haptics in Interaction Design

- **Position-Based Effects cont.**
  - **Slope Effect**—this gives the effect of rolling a ball up or down a hill
  - **Texture Effect**—this creates the impressions of a series of bumps
- **Resistance Effects**
  - These effects create the sensation of viscosity; they can simulate friction (damper, friction, inertia)
- **Time-Based Effects**
  - These effects change over time and can create sensations of vibration, sway, pulsing, ramp, or vector force

Chapter 14 Touch and Movement

- Technical Issues Concerning Haptics
  - Haptic Displays
  - Tactile Displays
  - Force Feedback Displays
  - Desktop Devices
  - Haptic System Concerns

Technical Issues Concerning Haptics

- Haptic Displays
  - A haptic display provides force feedback and/or tactile output and is responsive to the position of and forces exerted by a user through the use of a haptic-enabled device
  - The available devices are varied and, for the most part, address highly specialized applications

Technical Issues Concerning Haptics

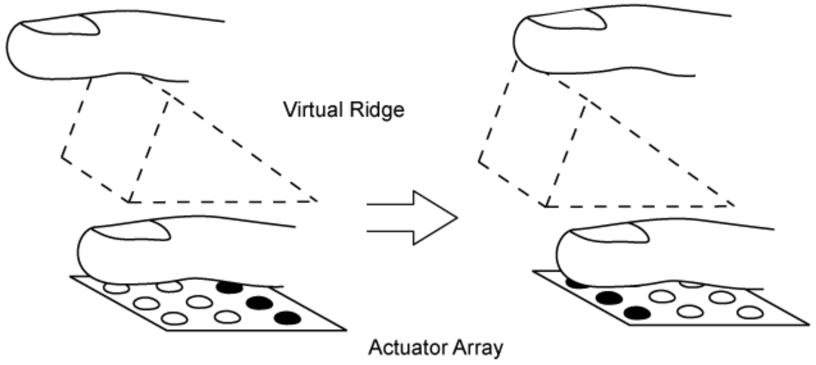
- Tactile Displays
  - A tactile display should be able to:
    - Sense the pressure applied by the user (sensors)
    - Communicate the tactile properties of a virtual object to the user (actuators)

Technical Issues Concerning Haptics

- Tactile Sensors
  - Force-Sensitive Resistors
  - Ultrasonic Force Sensors
  - Piezoelectric Stress Rate Sensors

Technical Issues Concerning Haptics

- Tactile Actuators
  - Vibrotactile Systems
    - Voice Coils
    - Loudspeakers
    - Micro-Pin Arrays



Technical Issues Concerning Haptics

- Tactile Actuators
  - Electrotactile Systems
  - Thermotactile Systems
  - Lateral Skin Stretch

STReSS tactile display

Technical Issues Concerning Haptics

- Force Feedback Displays
  - Exoskeletons
  - Manipulator Arms
  - Manipulator Gloves

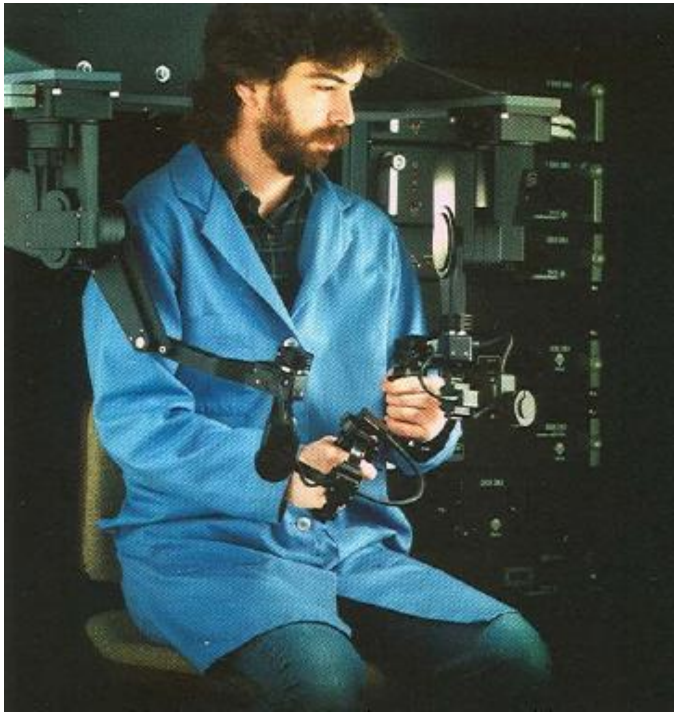
Technical Issues Concerning Haptics

- Force Feedback Displays
  - Exoskeletons

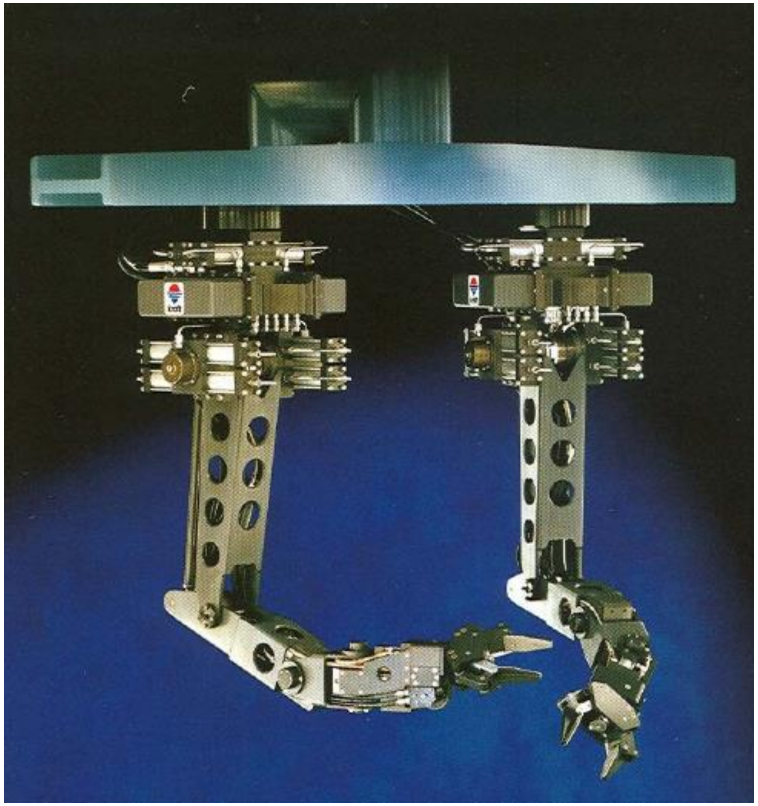
HAL-5 (Hybrid Assistive Limb)
CYBERDYNE Inc.
www.cyberdyne.jp

Technical Issues Concerning Haptics

- Force Feedback Displays
  - Manipulator Arms



The Grips operator controls

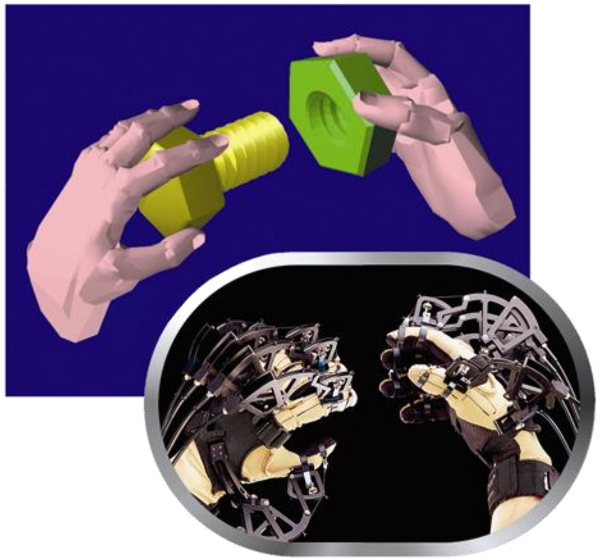


The Grips remote manipulator arm

Technical Issues Concerning Haptics

- Force Feedback Displays
  - Manipulator Gloves

CyberGlove II

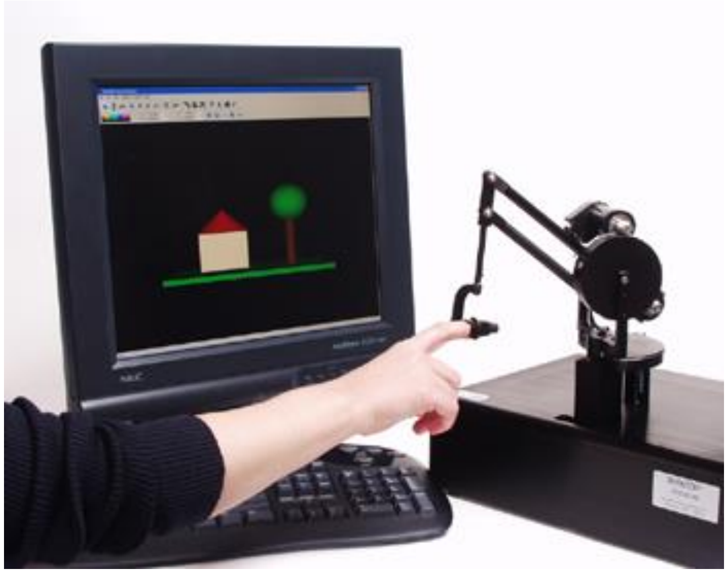


CyberGrasp

CyberForce

Technical Issues Concerning Haptics

- Desktop Devices
  - SensAble PHANTOM haptic devices

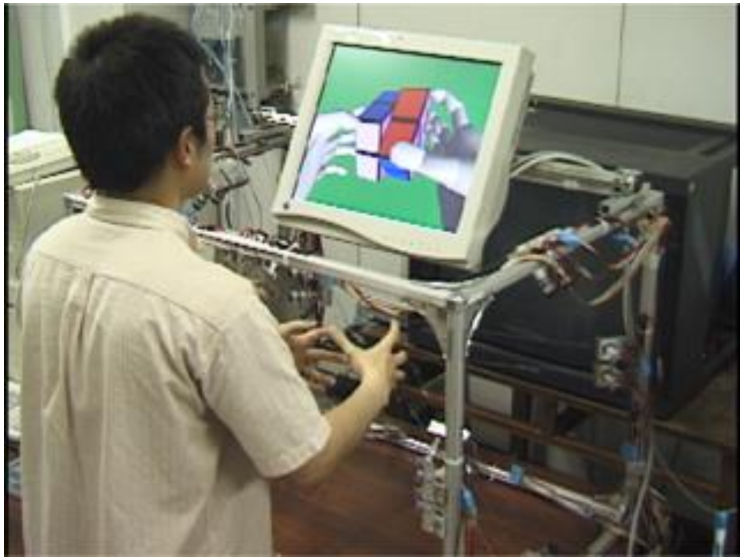


PHANTOM Premium 1.0 haptic device

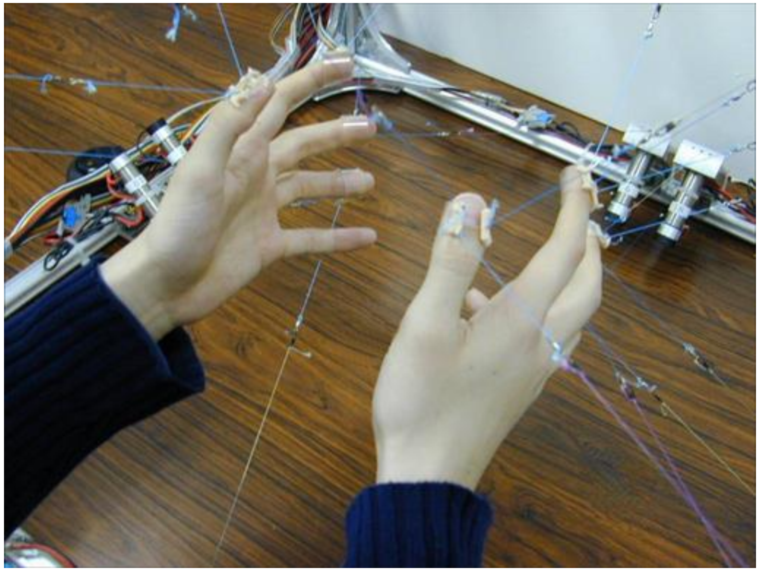
PHANTOM Premium 1.5 & 1.5 high-force haptic device

Technical Issues Concerning Haptics

- Desktop Devices
  - Space Interface Device for Artificial Reality (SPIDAR) *(Sato, 2002)*



SPIDAR-8. Rubik's Cube



SPIDAR-8. Finger attachments.

Technical Issues Concerning Haptics

- Haptic System Concerns
  - System Use
    - Perceptual Thresholds
    - Size/Weight
    - User Fatigue
    - Pain
    - Annoyance
    - Cost
    - Portability
    - Computing Environment

Technical Issues Concerning Haptics

- Haptic System Concerns
  - System integrity
    - Backdriveability
    - Latency
    - Stability