Universidade de Aveiro
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Output Devices - II

Realidade Virtual e Aumentada 2019

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The human senses need specialized interfaces

- Visual displays for visual feedback
- 3-D audio hardware for localized sound
- Haptic interfaces for force and touch feedback
- …

- In addition to the visual displays, sound:
  - enhances the presence
  - enhances the display of spatial information
  - can convey simulated properties of elements of the environment (e.g. mass, force of impact...)
  - can be useful in designing systems where users monitor several communication channels (selective attention)

Aural Displays

- Auditory displays are another approach to presenting information to the user

- Sound displays are computer interfaces that provide synthetic sound feedback to the user interacting with the virtual world

The sound can be :

- monoaural (both ears hear the same sound)

  or

- binaural (each ear hears a different sound)

Aural Displays: a taxonomy (Sherman and Craig, 2003)

- Stationary displays
- Head-based displays

- High-fidelity audio devices are less expensive than visual displays

- The addition of high-quality sound can help in creating a compelling experience, even when the quality of the visual presentation is lacking

Auditory perception

Auditory perception is quite complex and is affected by:

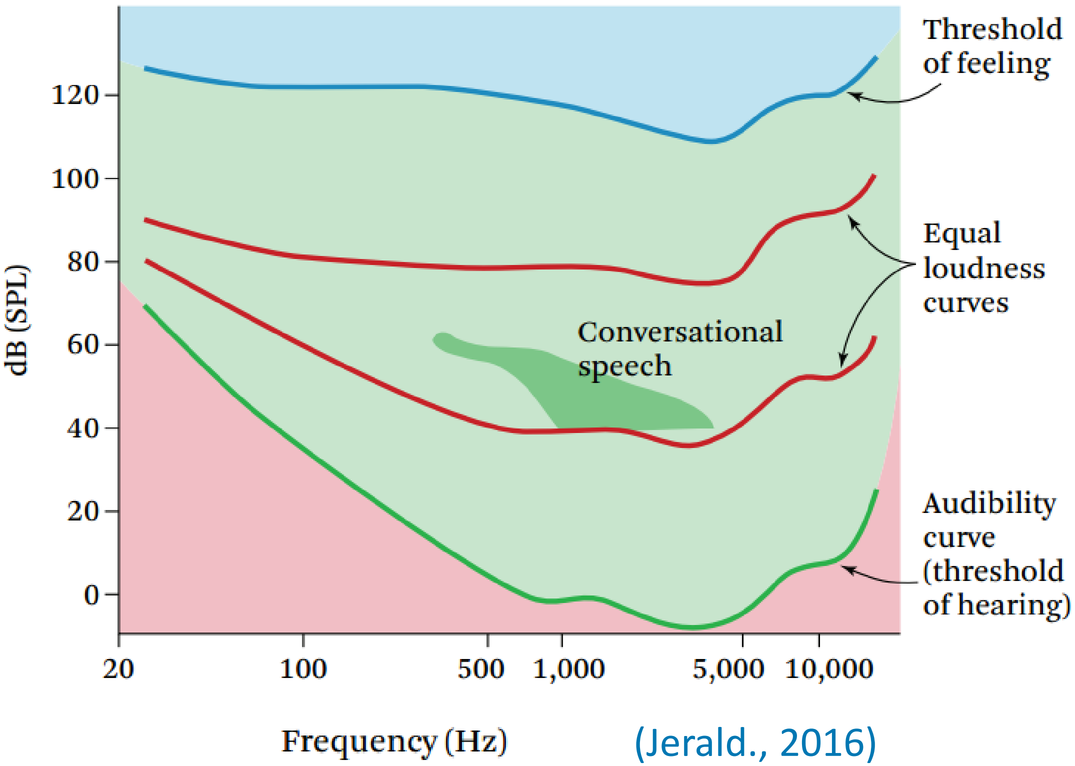
- head pose,
- physiology,
- expectation,
- and its relationship to other sensory modality cues

We can deduce qualities of the environment from sound (e.g. dimensions)

The audibility curve and auditory response area

- The area above the audibility curve represents volume and frequencies that we can hear

- The area above the threshold of feeling can result in pain



(Jerald., 2016)

- Binaural cues (also known as stereophonic cues) are two different audio cues
- One for each ear, that help to determine the position of sounds
- Each ear hears a slightly different sound (in time and in level)
- Interaural time differences provide an effective cue for localizing low-frequency sounds
- Spatial acuity of the auditory system is not nearly as good as vision

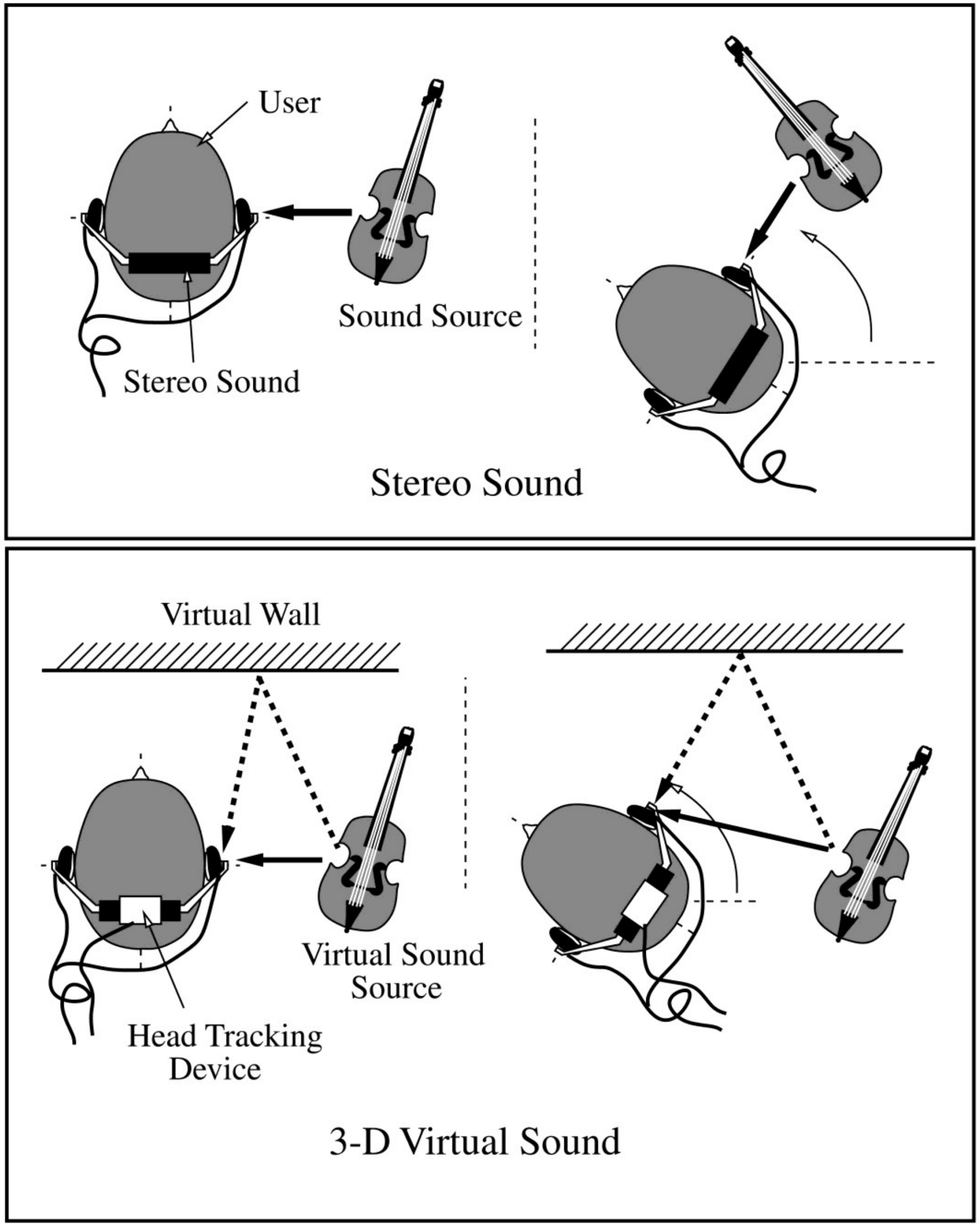
3-D Aural Displays

- Spatialized 3D sound enables users to take advantage of their auditory localization capabilities

- Localization cues allow to determine the direction and distance of a sound source:
    - binaural cues,
    - spectral cues,
    - Head Related Transfer Functions (HRTFs),
    - sound intensity,
    - reverberation, …

- 3-D sound should not be confused with stereo sound

- 3D sound can ideally position sounds anywhere around a listener

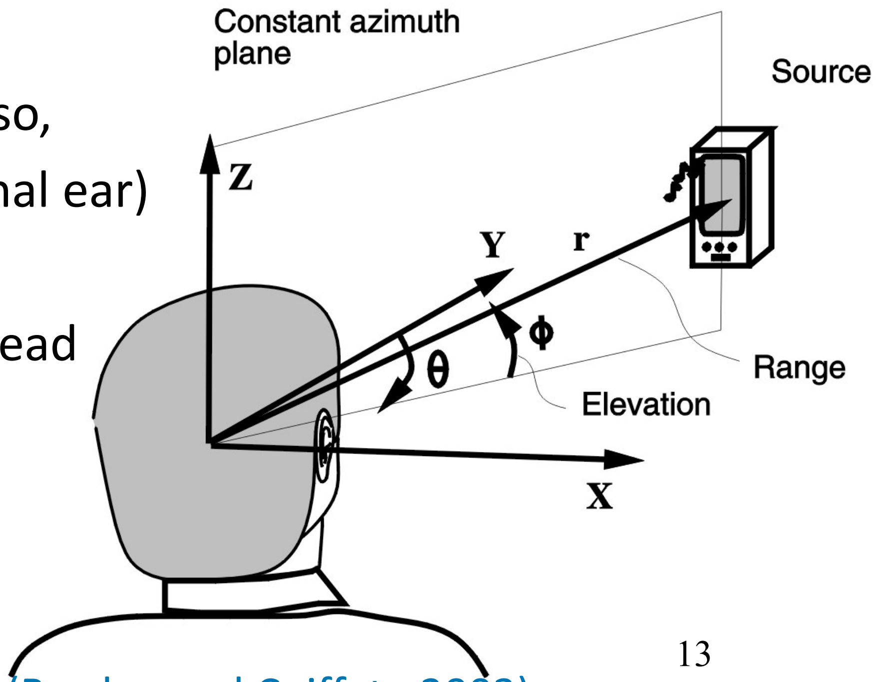


(Burdea and Coiffet., 2003)

Human Hearing

- From the two signals that reach our ears we extract information about the location of sound sources
- A sound to the right of the listener produces a wave reaching the right ear before the left ear

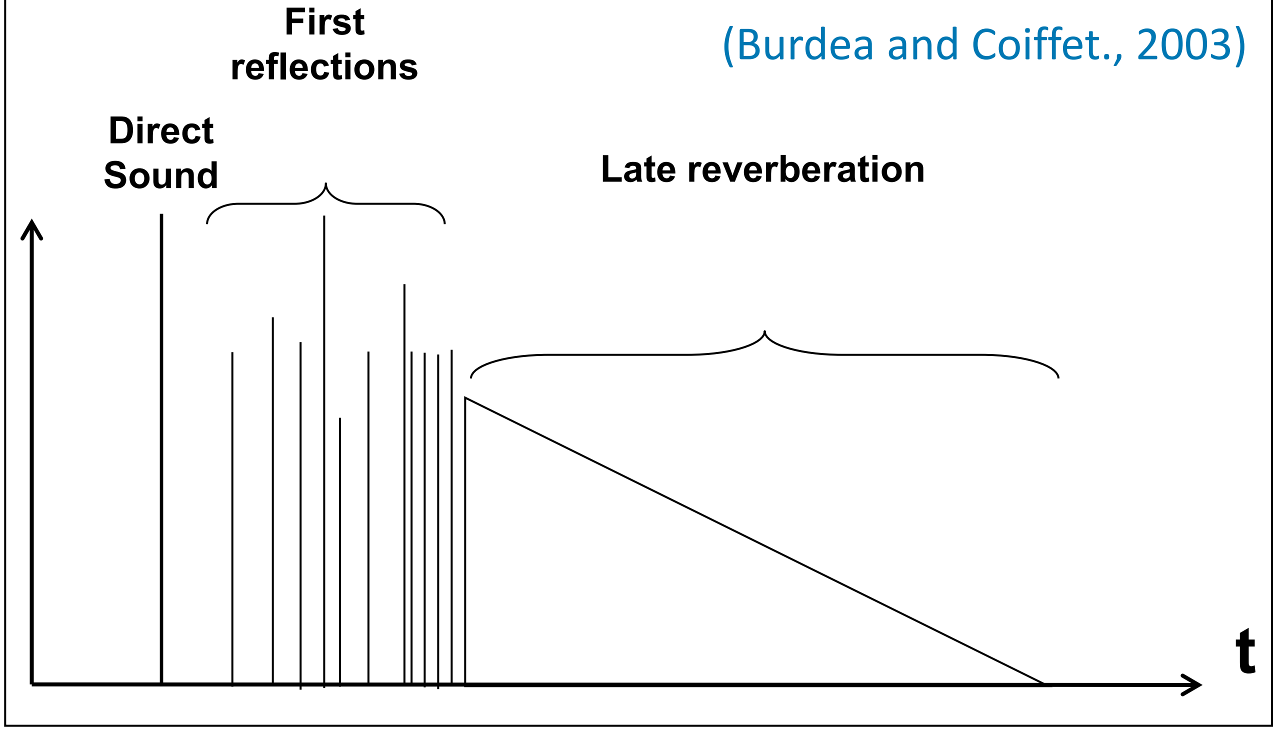
  (the right ear signal delayed with respect to the left ear signal)
- Both ear signals are "filtered" by the torso, head, and in particular, the pinna (external ear)
- The left ear signal is attenuated by the head
- This can be captured by the HRTFs (Head Related Transfer Functions)



(Burdea and Coiffet., 2003)

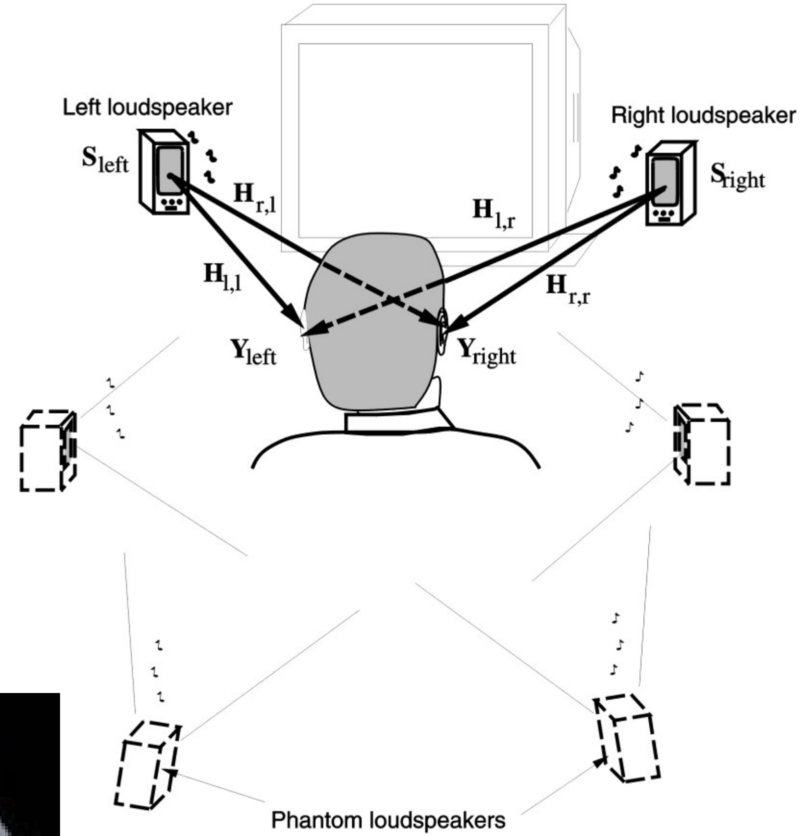
Auralization

- Auralization: recreation of the acoustic environment.
- Produces a 3D sound space by digital means based on binaural human hearing principles (psycho-acoustic)



(Burdea and Coiffet., 2003)

3-D Audio Displays



- We gain a significant amount of information via sound
- Sound often tells our eyes where to look
- We use our hearing to keep us constantly aware of the world
- Given the importance of sound and relatively low cost to implement in VR:

VR application designers should consider how sound might be used to positive effect in the applications they build

Haptic Interfaces

- Greek *Hapthai* means the sense of touch (physical contact)
- Haptics perception groups **taction** and **kinesthesia** sensations

  touch feedback and **force feedback**

- the haptic sense is powerful to believe something is "real"
- Is very hard to fool; creating a satisfactory display device is difficult
- Haptic interfaces are **generally both input and output**

- **Kinesthesia** is the perception of movement or strain from within the muscles, tendons, and joints of the body.

- Proprioception, also refers to an individual's ability to sense their own body posture, even when no forces are acting upon it

- **Taction** is the sense of touch that comes from sensors at the surface of the skin

- **Tactile display** includes stimuli for temperature and pressure on the skin:

  Thermoreception

  Mechanoreception (immediate and long-term changes in pressure)

Touch Feedback

- Relies on sensors in and close to the skin
- Conveys information on contact surface
- Geometry, roughness, slippage, temperature
- Easier to implement than force feedback
- Most devices focus specifically on the fingertips

Passive Touch vs. Active Touch

- **Passive touch** occurs when stimuli are applied to the skin

It can be quite compelling in VR when combined with visuals.

- **Active touch** occurs when a person actively explores an object, usually with the fingers and hands

- Passive/ active touch should not be confused with passive / active haptics

- Humans use three distinct systems together when using active touch:
  - Sensory
  - Motor
  - Cognitive

Force Feedback

- Relies on sensors on muscle tendons and bones/joints proprioception
- Conveys information on contact surface compliance, object weight, inertia
- Actively resist user contact motion
- More difficult to implement than touch feedback
- Most displays focus on the limbs (e.g. manipulation arm)

- Haptic displays are significantly more difficult to create than are visual or aural displays, because our **haptic system is bidirectional**

- It not only senses the world, **it also affects the world**

- Touch is the only bidirectional sensory channel and, apart from taste, it is the only sense that **cannot be stimulated from a distance**

Herein lies part of the difficulty:
the display requires direct contact with the human body

Main methods of haptic interface in virtual reality

- Tactile displays
(touching, grasping, feeling surface textures, or sensing temperature)

- End-effector displays
(provide resistance and pressure)

- 3D Hardcopy
(provides haptic and visual representation objects; works only as output)

Touch Feedback Interfaces...

https://www.ifeelpixel.com/description/

- Can be desktop or wearable;

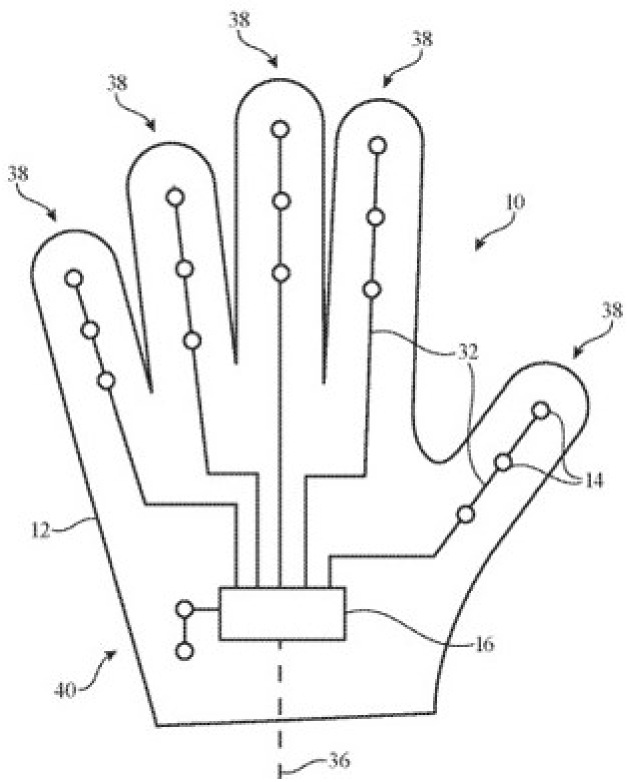
  - touch feedback mice;

  - gloves;

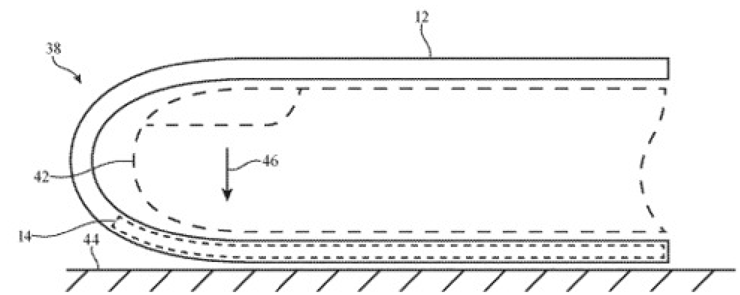
  - temperature feedback actuators; …

http://www.cyberglovesystems.com/cybertouch

Apple patent for force-sensing gloves, 2019



Potential force-sensing component position in a glove



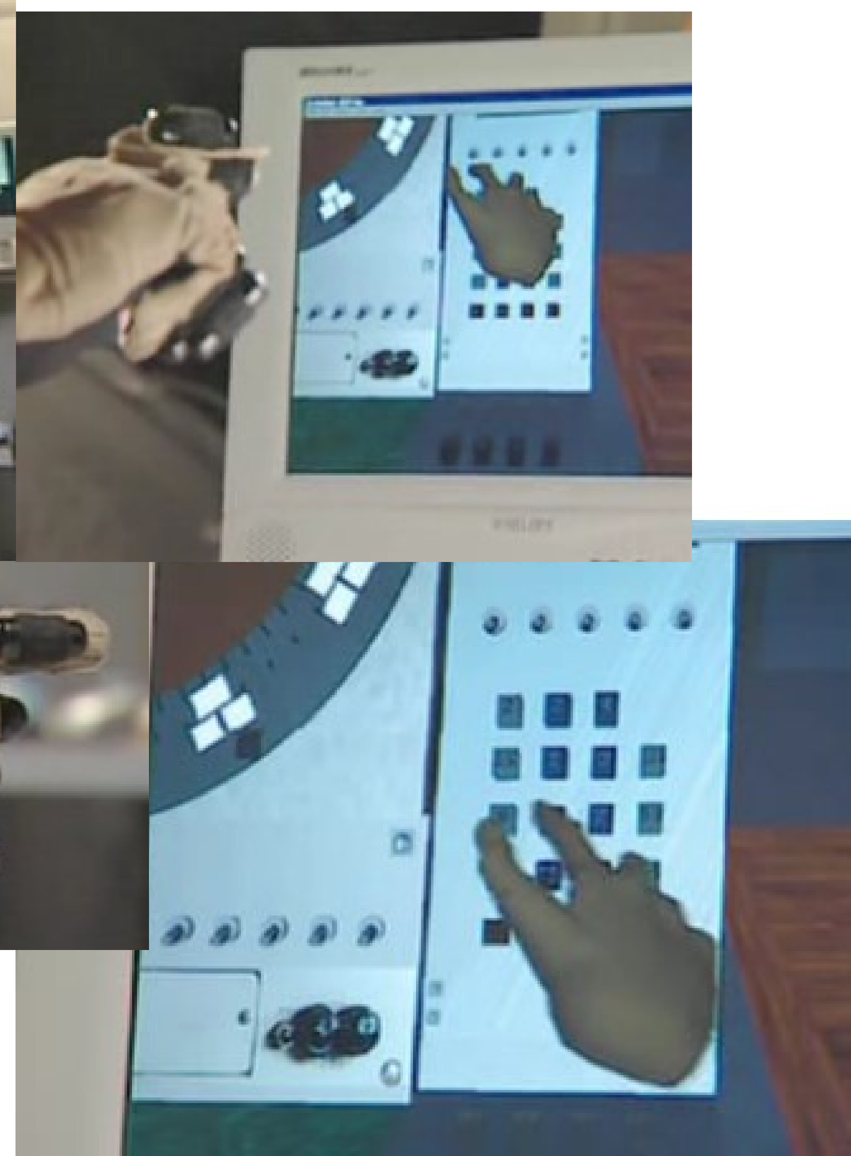
Area of a glove's finger that could be made sensitive to force

https://appleinsider.com/articles/19/01/15/apple-working-on-force-sensing-gloves-for-gesture-controls

Temperature feedback

- Added simulation realism by simulating surface thermal “feel”
- No moving parts
- Uses thermoelectric pumps made of solid-state materials sandwiched between “heat source” and “heat sink”
- Single pump can produce 65°C differentials

Input + output
CyberTouch Glove



http://www.cyberglovesystems.com/cybertouch/#photos

Medical Training
Bimanual Haptic Simulator for Medical Training

https://dl.acm.org/citation.cfm?id=2386090
https://www.youtube.com/watch?v=QmtHecrOVXo

Virtual Reality Cerebral Aneurysm Clipping Simulation With Real-Time Haptic Feedback

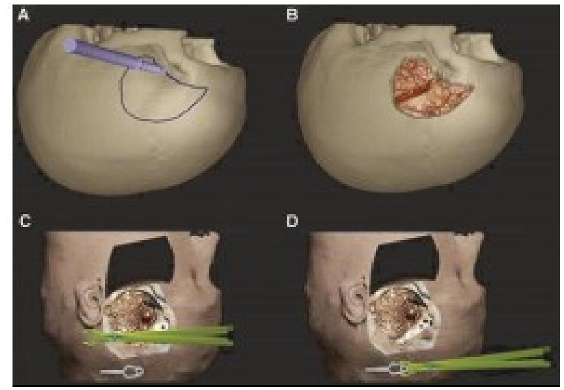
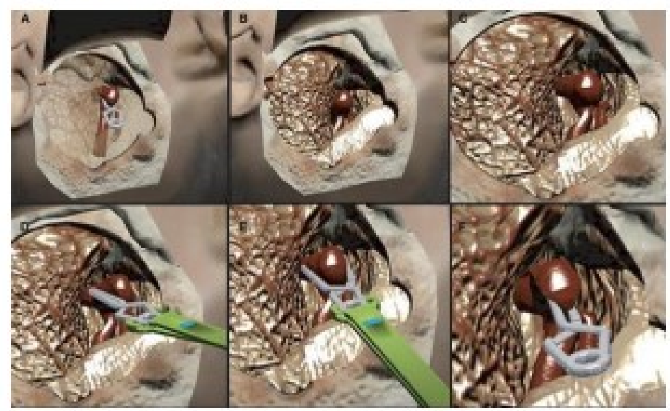


Image tools:

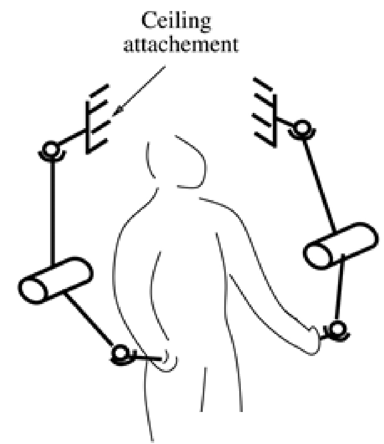


https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4340784/
https://operativeneurosurgery.com/doku.php?id=virtual_reality_simulator_for_aneurysmal_clipping_surgery

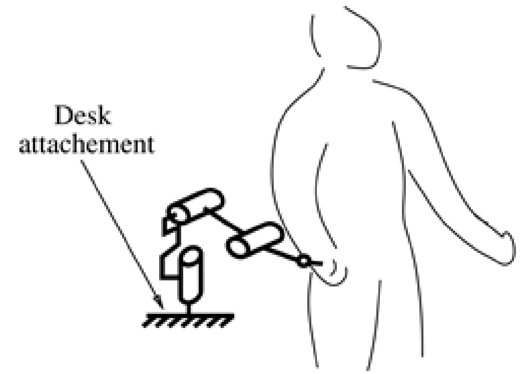
Training in veterinary
Haptic Cow and Haptic Horse

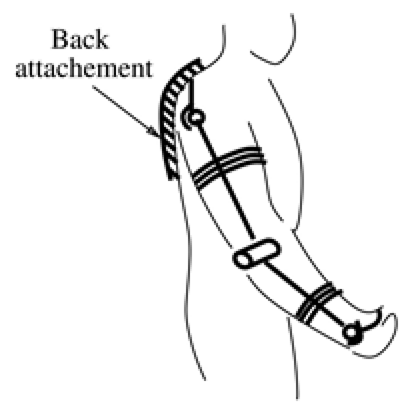
https://norecopa.no/norina/the-haptic-cow-simulator

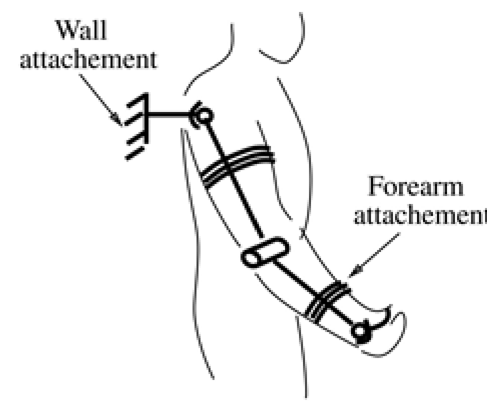
Force Feedback Interfaces



- Need mechanical grounding to resist user motion
- Can be grounded on desk, wall, or on user body
- More difficult to construct and more expensive
- Than tactile feedback interfaces







(Burdea and Coiffet., 2003)

- Disadvantages of force feedback devices:

  – high cost

  – may take workspace of desktop

  – large weight

  – safety concerns

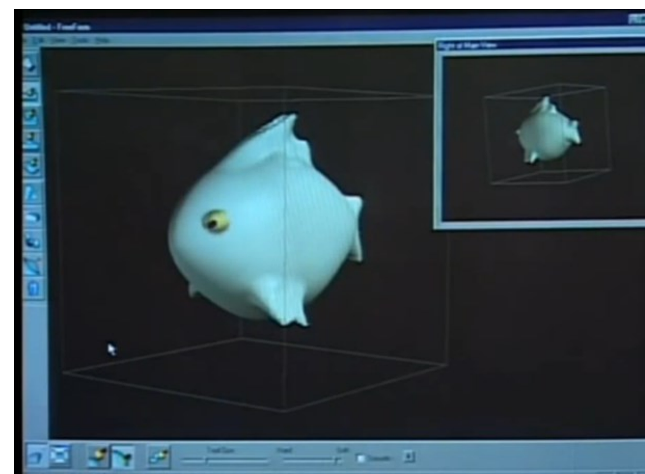
  – high bandwidth requirements

Force Feedback Interfaces: Geomagic Touch (former PHANToM Omni)

- Main application:

- Medical simulations and training exercises
stylus emulates physical sensations (puncturing, cutting, probing or drilling) of using a syringe, scalpel, …

- Other commercial, and scientific applications:
  - Robotic Control
  - Virtual Reality
  - Teleoperation
  - Training and Skills Assessment
  - 3D Modeling
  - Applications for the Visually Impaired
  - Entertainment
  - Molecular Modeling
  - Rehabilitation
  - Nano Manipulation, ...



http://www.youtube.com/watch?v=0_NB38m86aw

- Haptic devices vary according to workspace size, force, DOFs, inertia and fidelity

CyberGrasp Glove

https://www.youtube.com/watch?v=UrhSno47B4o
https://www.youtube.com/watch?v=4aMCJDOEi0k

CyberGlove Systems Haptic Workstation Overview

- Allow to evaluate ergonomics, assemblability and maintainability of prototypes before they exists

- Eliminates the number of physical prototypes

- In several industries:
- Automotive
- Aerospace
- Medical …

https://www.youtube.com/watch?v=4aMCJDOEi0k

Olfatory Interfaces

The harbinger of smell interfaces: Sensorama, 1962

Contains different odorants and
a system to deliver them through air
and a control algorithm to determine

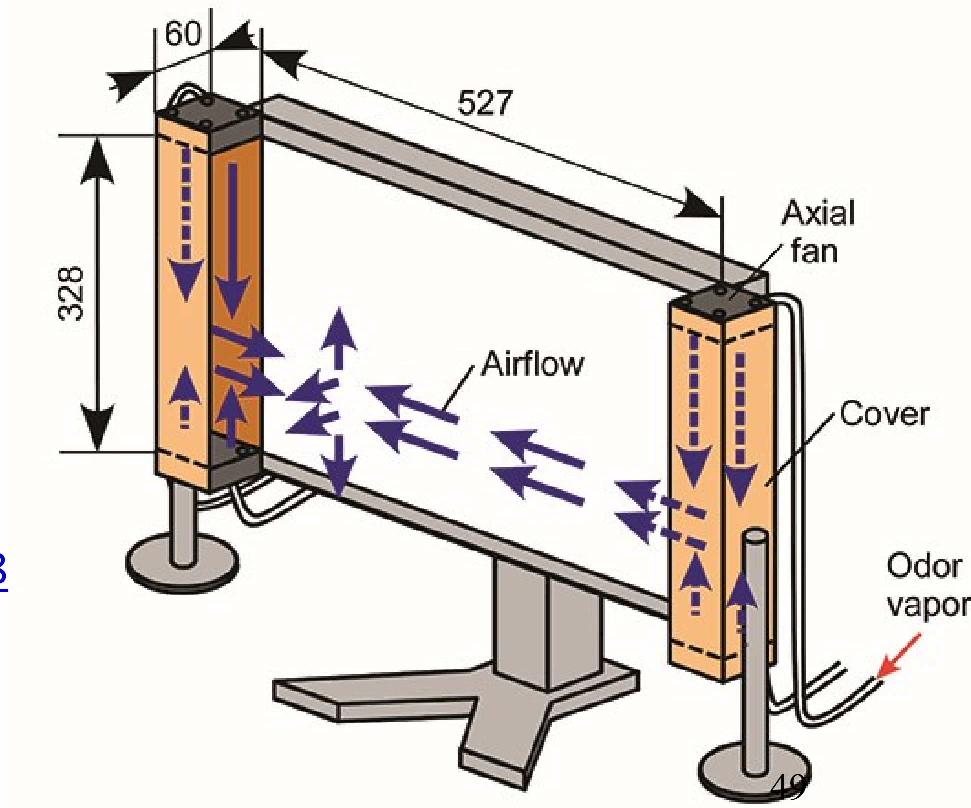
- the mix of odorants
- its concentration and
- the time of the stimulus

- Smelling Screen

(Matsukura, Yoneda, & Ishida, 2013)
delivers odorants through a four fans system
in arbitrary positions of the screen.

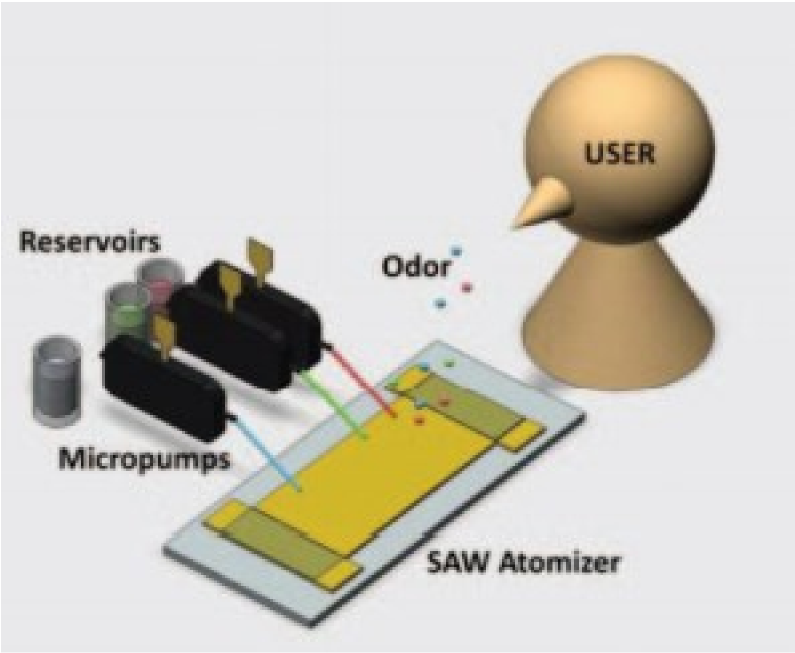
Smelling Screen

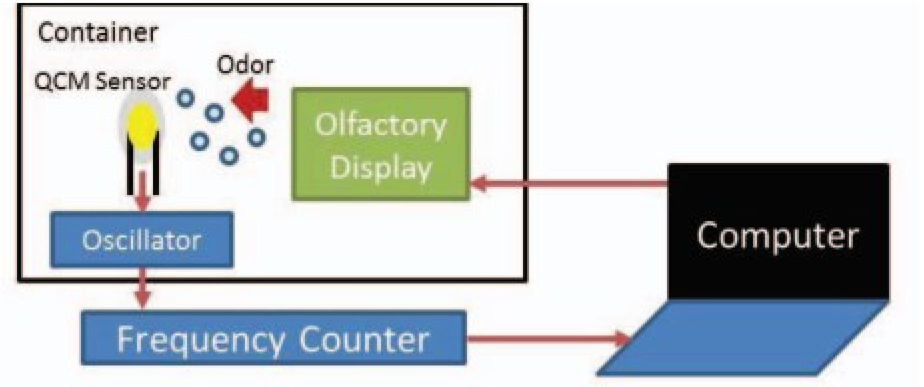
- Releases scents into the air with directional accuracy
- It is regular television with four fans mounted along its edges that pump odors in the right direction
- It generates scent from hydrogel "aroma chips," heated to produce vapor



http://www.theverge.com/2013/3/31/4166884/japanese-smelling-screen-might-be-the-next-big-thing-in-advertising

Olfactory Display Using Surface Acoustic Wave Device and Micropumps for Wearable Applications





Measurement using QCM sensor.

Hashimoto, K., & Nakamoto, T. (2016). Olfactory Display Using Surface Acoustic Wave Device and Micropumps for Wearable Applications. In *IEEE Virtual Reality 2016* (pp. 179–180). http://doi.org/10.1109/JSEN.2016.2550486

Vestibular Interfaces

- The vestibular perceptual sense provides the leading contribution about the sense of **balance** and **spatial orientation**

- The human organ that provides this perception is located in the inner ear, but it does not respond to aural stimuli

- Helps humans sense **equilibrium**, **acceleration**, and **orientation** with respect to gravity

- Allows to coordinate movement with balance

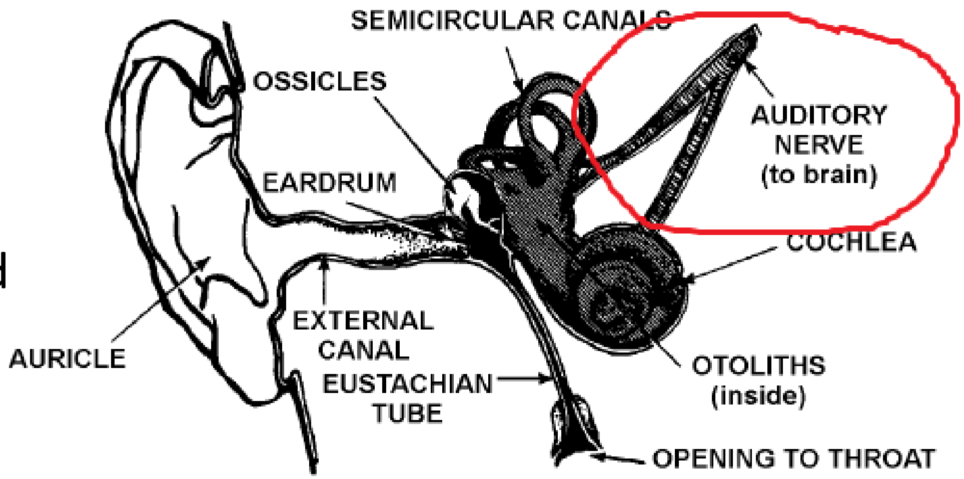
- **Inconsistency between visual cues** such as the horizon line and **balance** can lead to nausea and other symptoms of **simulator sickness**

Vestibular sense

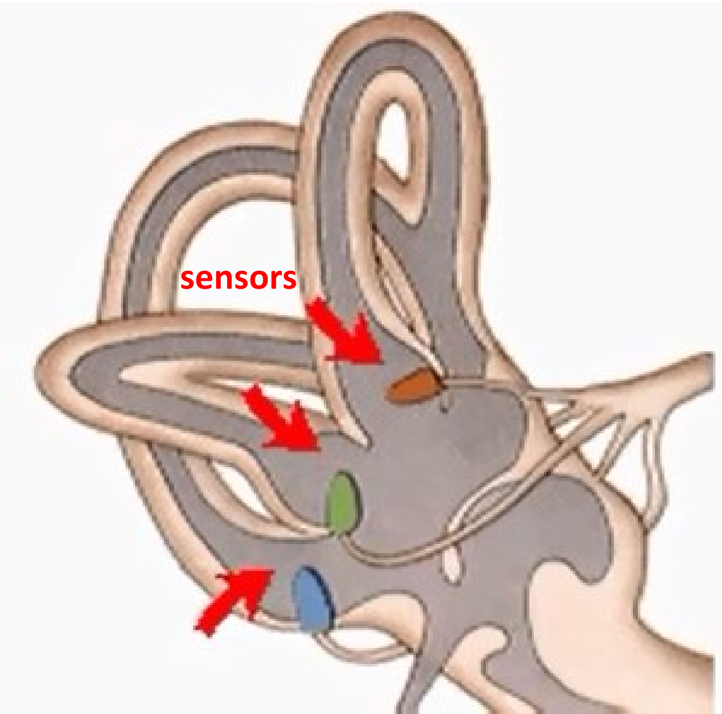
The brain uses information from:

- vestibular system in the head and
- proprioception throughout the body

to understand the body's dynamics and kinematics (including its position and acceleration)



Semicircular canals-> rotational movements
Otoliths -> linear accelerations



https://psychlopedia.wikispaces.com/Vestibular+Sense

Vestibular displays

- Are accomplished by physically moving the user

- Motion platforms, can move the floor or seat occupied by the user or group

- Are common in:
  - large flight simulator systems
  - entertainment venues

https://en.wikipedia.org/wiki/Flight_simulator

http://en.futuroscope.com/

Main bibliography

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- D. Bowman, E. Kruijff, J. LaViola Jr., I. Poupyrev, *3D User Interfaces: Theory and Practice*, Addison Wesley, 2004

What next ??!

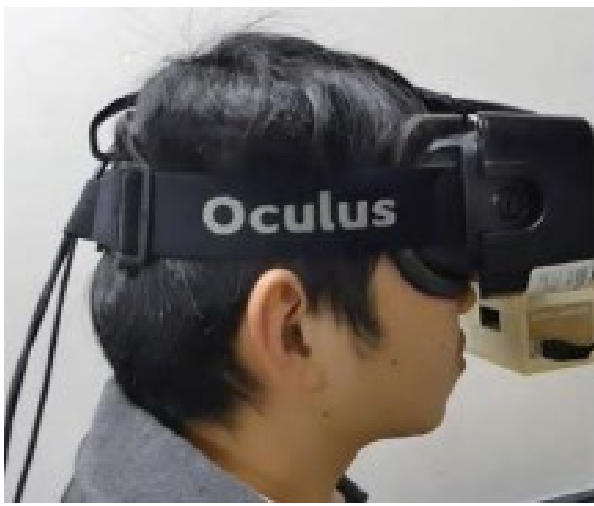
"A multi-sensory feedback suit to experience the next level of gaming. Finally you get to feel what you've only been able to see."

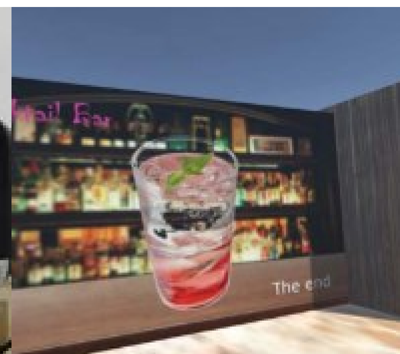
Not yet ready …

http://www.kickstarter.com/projects/141790329/araig-as-real-as-it-gets

https://en.wikipedia.org/wiki/Haptic_suit

Displays to other senses: smell and taste





Recent work on smell and taste in Virtual and Augmented Reality

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- Lin, Y. (2018). TransFork : Using Olfactory Device for Augmented Tasting Experience with Video See-through Head-mounted Display. In *Virtual Reality Software Technolog VRST’18*.

- Spence, C., Obrist, M., Velasco, C., & Ranasinghe, N. (2017). Digitizing the chemical senses : Possibilities & pitfalls. *International Journal of Human - Computer Studies*, *107*(April), 62–74.