Wearable Computing

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Output Devices

- Wearable Displays
- Audio Output
- Tactile Output

History and Science

- History: Young field with old roots
- Science: International Research, mainly conferences

Output Device Classes

1. Optical
   - Body-mounted, Head-mounted, projection, ambient
2. Audible
3. Tactile

Wearable Displays

Image from TZI, T. Nicolai

Human Vision

- Spectral response: 400 to 700 nm, changes with age
- Adaptive resolution, 120 Megapixel (rods for greyscale)
- High resolution visual center (fovea), color receptors (6-7 million cones)
- 180 Degree low resolution with motion detection, greyscale
- High sensitivity about 15-20 degrees off the optical axis, single photon detection
- Integrated signal preprocessing for motion, edges, noise filtering

The Eye

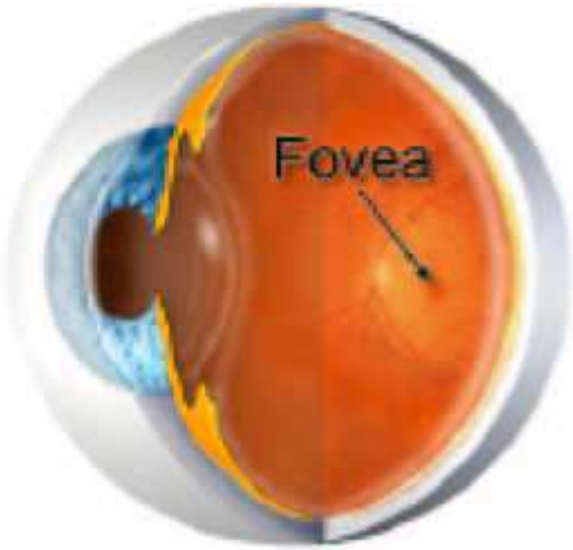

Image from Vorlesung Mensch-Maschine-Interaktion, LMU, Andreas Butz und Albrecht Schmidt

Human Vision: Accomodation and Sensitivity

- Adjustable lens system
- Focal range: 20 cm - ∞
- Dynamic range: $1 : 10^6$ for dark environments, at least 1:10000
- Chemical (rhodopsin) and mechanical (iris) adaption of sensitivity

Human Vision: Resolution

- Angular resolution: Visual Acuity
- Measured with optometrician charts
- 20/20 (100%) visual acuity: Person can recognize a letter that spans less than a 5 minutes of arc visual angle
- Effective Resolution: about 1 arc minute

Effective resolution on a sheet of paper

- Viewing distance: 30 cm
- Paper Size: about 30x20 cm
- Viewing angle $2 \arctan \frac{1}{2} \approx 53°$
- 53*60=3360 pixel
- 30cm =11.8 inch. $\frac{3360}{11.8} \approx 284 DPI$
- Why do people buy 1200 DPI printers?

Display Technology

- reflective, transflective, back-illumination, front-illumination
- B/W, greyscale, color
- CRT, LCD, TFT, OLED, DLP,...

Body-worn displays

- Wearable Computer displays
- re-used PDAs
- body-worn projection devices

Wrist-Displays

- Symbol
- Xybernaut
- IBM linux watch
- Fossil Wristwatch Palm

Symbol

Image from Symbol Technology Inc.

Xybernaut

Image from TZI H. Kenn

IBM

Image from IBM

Fossil

Image from fossil website

HMDs

- HMD = Head-Mounted Display
- Monocular vs. Binocular
- See-Through vs. See-Around
- Various resolutions, color and B/W

How do HMDs work?

- Eye minimum focal distance = 20 cm

Image from TZI H. Kenn

Focal Distance for HMDs

- Simulate aparent focal distance
- Additional optics
- calculation of resolution uses aparent focal distance

Lumus HMD

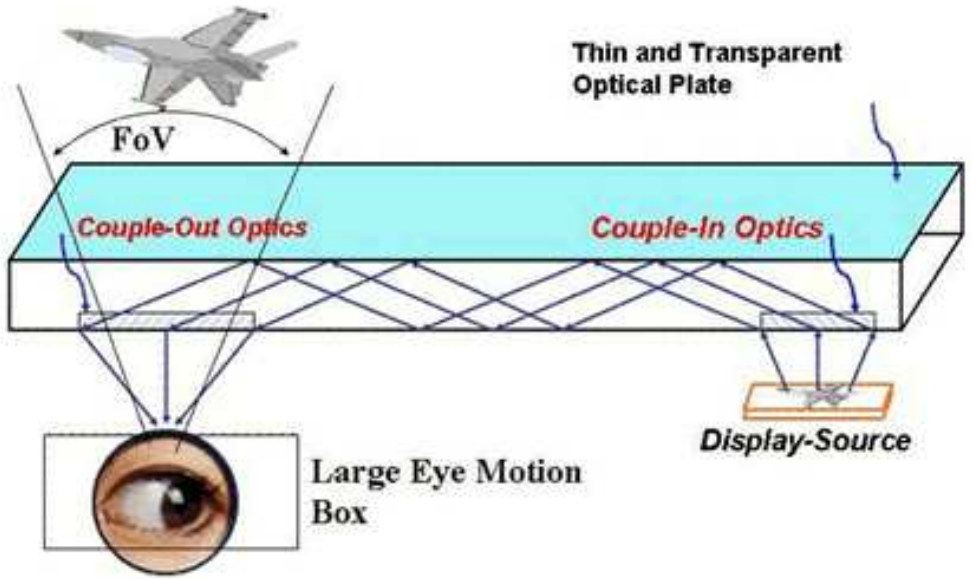

Image from lumusvision.com website

Xybernaut

Image from TZI H. Kenn

Microoptical

Image from TZI H. Kenn

Hearing

- Audible frequencies: 20-20kHz (for really young people)
- Dynamic range: 3dB-130dB (logarithmic scale! +3 dB = Energy $\times 2$)
- Equal loudness is frequency-dependent
- Hearing threshold is age-dependent

FletcherMunson Equal Loudness Contours

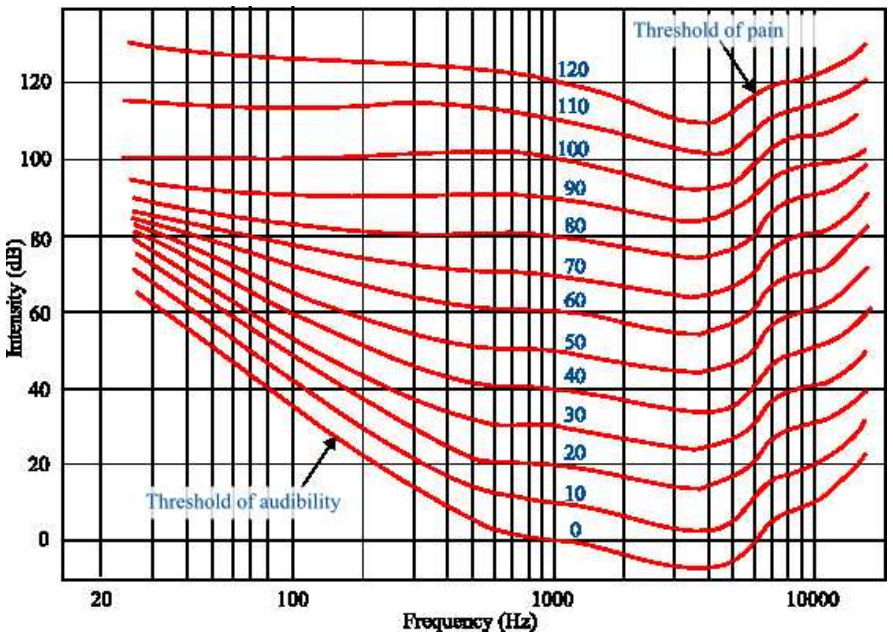

Image from wikipedia.org

Noise

- undesired disturbance affecting a signal. Here: acoustic noise
- Measured like sound
- Signal-to-noise ratio: ratio of signal levels of wanted (signal) and unwanted (noise) sound

Headphones

- Open vs closed
- Closed: high attenuation of noise, bulky, separation from environment
- open: low attenuation of noise, interaction with the environment possible

In Ear

- “earplug” style, found in many mobile devices
- exist in combination with body microphone technology

Active noise compensation

- Problem: environment noise
- But: interaction with the environment necessary
- Idea: record external noise through microphones, invert, play back through headphones
- possible: frequency-dependent noise compensation (only low frequencies)
- Implementations: Bose, Sennheiser
- Effect: -15dB noise reduction (Sennheiser PXC 250)

Sennheiser NoiseGard Headphone

Image from Sennheiser website

Sennheiser NoiseGard Controller

Image from Sennheiser website

Excenter-Vibration

- Needed if “output” needs to be unobtrusive (see roulette wheel prediction)
- Simple technologies: Motors, Solenoids
- Motor with excenter disk: Mobile phone “silent” alarm
- Solenoid: electromagnetic, delivers small “punch”, can be used for morse code

Force Feedback

- Part of input devices
- Simulates feedback force from a mechanical device
- simple implementations: Joystick, Racing Game Steering Wheel (simulate spring behaviour)
- Professional application: steering wheel feedback through “lane assistant”
- Professional application: telemedicine operation system, chirurgic training

Braille Displays

- Output of standard Braille letters
- Screen emulation
- Drivers for many operating systems
- Preinstalled in some linux distributions (Knoppix)

Braillex 40 char display

Image from papenmeier.de website

Braille PDA

- Linux PDA with keyboard and Braille display
- Normal PDA functions incl. e-mail and web access
- build-in ethernet and WLAN

Braillex Elba

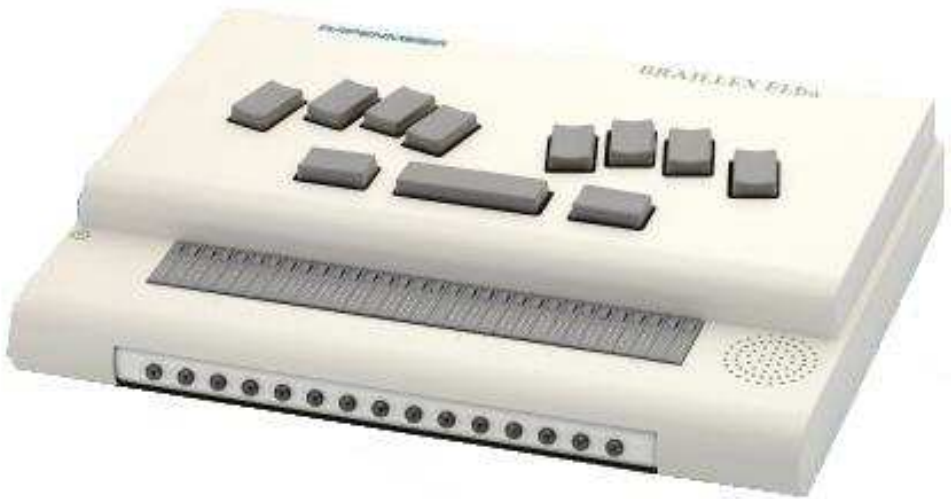

Image from papenmeier.de website

Summary

- Viusual
- Audible
- Tactile