Chapter 1

Wearable Output Devices

Recap

Slide History and Science:

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

1.1 Output Devices

Slide Output Device Classes:

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

1.1.1 Wearable Displays

Slide Wearable Displays:

Image from TZI, T. Nicolai

Slide 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

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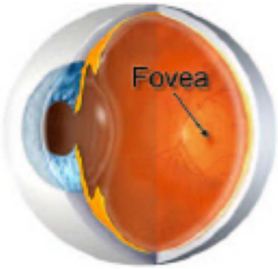
Slide The Eye:



Slide 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

Slide 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

Slide Effective resolution on a sheet of paper:

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

diaphragm = Blende

Visual Acuity: http://www.tedmontgomery.com/the_eye/acuity.html

Dynamic Range http://clarkvision.com/imagedetail/eye-resolution.html

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Slide Display Technology:

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

Slide Body-worn displays:

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

Slide Wrist-Displays:

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

Slide Symbol:

Image from Symbol Technology Inc.

Slide Xybernaut:

Image from TZI H. Kenn

Slide IBM:

Image from IBM

Slide Fossil:

Image from fossil website

Slide HMDs:

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

Slide How do HMDs work?:

- Eye minimum focal distance = 20 cm

Image from TZI H. Kenn

Slide Focal Distance for HMDs:

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

Slide Lumus HMD:

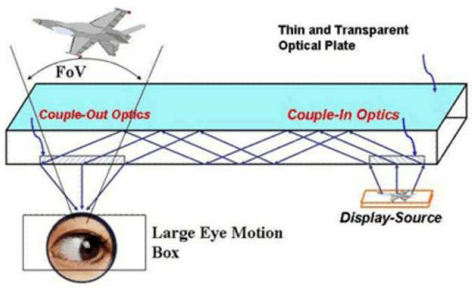

Image from lumusvision.com website

Slide Xybernaut:

Image from TZI H. Kenn

Slide Microoptical:

Image from TZI H. Kenn

1.1.2 Audio Output

Slide 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

Slide FletcherMunson Equal Loudness Contours:

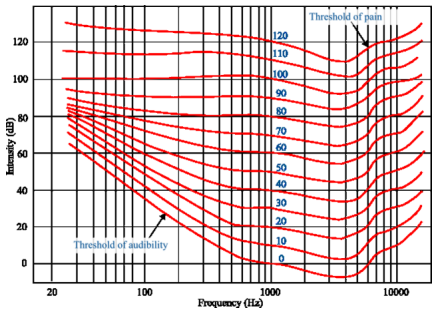

Image from wikipedia.org

Slide 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

Slide Headphones:

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

Slide In Ear:

- “earplug” style, found in many mobile devices

- exist in combination with body microphone technology

Slide 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)

Slide Sennheiser NoiseGard Headphone:

Image from Sennheiser website

Slide Sennheiser NoiseGard Controller:

Image from Sennheiser website

http://www.sennheiser.com/sennheiser/icm_eng.nsf/root/04924#

1.1.3 Tactile Output

Slide 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

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Slide 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

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Slide Braille Displays:

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

Slide Braillex 40 char display:

Image from papenmeier.de website

Slide Braille PDA:

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

Slide Braillex Elba:

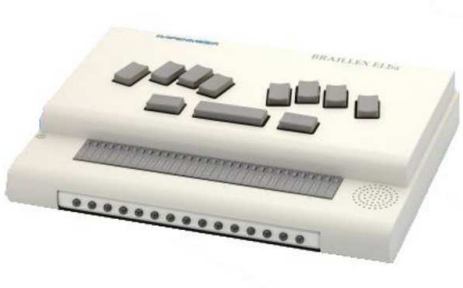

Image from papenmeier.de website

Summary

Slide Summary:

- Viusual
- Audible
- Tactile
