MMI 2: Mobile Human-Computer Interaction

Mobile Input and Output

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Review

- Was sagt „Fitts‘ Law“ aus?
- Was ist der „index of difficulty“?
- Welche Ansätze zur mobilen Texteingabe existieren?
- Welche Ideen zur Beschleunigung / Verbesserung / Reduzierung des Eingabeaufwands existieren?
- Was sind Vor- und Nachteile von (Touchscreen-)Gesten-Eingabe?
- Wie funktionieren Template-basierte Erkenner?

Preview

- Display technologies
- Haptics and audio

Lectures

#	Date	Topic
1	19.10.2011	Introduction to Mobile Interaction, Mobile Device Platforms
2	26.10.2011	History of Mobile Interaction, Mobile Device Platforms
3	2.11.2011	Mobile Input and Output Technologies
4	9.11.2011	Mobile Input and Output Technologies, Mobile Device Platforms
5	16.11.2011	Mobile Communication
6	23.11.2011	Location and Context
7	30.11.2011	Mobile Interaction Design Process and Prototyping
8	7.12.2011	Evaluation of Mobile Applications
9	14.12.2011	Visualization and Interaction Techniques for Small Displays
10	21.12.2011	Mobile Devices and Interactive Surfaces
11	11.1.2012	Camera-Based Mobile Interaction 1
12	18.1.2012	Camera-Based Mobile Interaction 2
13	25.1.2012	Sensor-Based Mobile Interaction 1
14	1.2.2012	Sensor-Based Mobile Interaction 2
15	8.2.2012	Exam

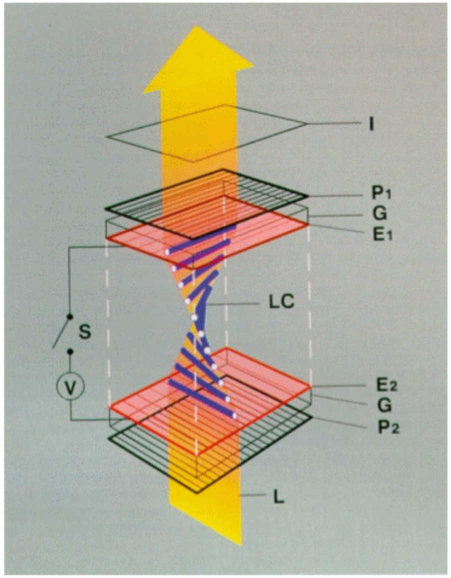
Übung: Gesten, Animation

- Gesten-Eingabe
  - Android package android.gesture
- Animation
  - Android property-animation
- Scenario: 2 wizards, on opposite mountaintops, are fighting in a magical duel
  - wizards cast offensive or defensive spells
  - must cast an offensive spell to attack
  - offensive spells travel for a fixed amount of time from casting wizard to attacked wizard
  - incoming offensive spells must be defended against by casting a defensive spell of the same element type

DISPLAY AND TOUCH SCREEN TECHNOLOGIES

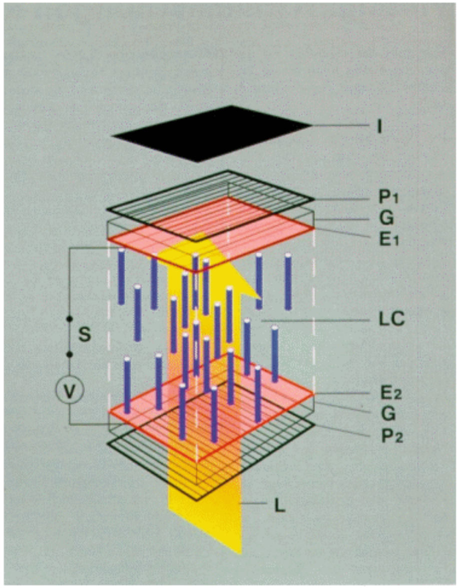
Liquid Crystal Display (LCD)

- An LCD cell is a voltage-controlled “light valve”
- Twisted nematic effect
  - Orientation of molecules controls orientation of polarized light
  - Off: Liquid crystal molecules form helix structure, 90° rotation
  - On: Electric field aligns molecules, second polarizer blocks light

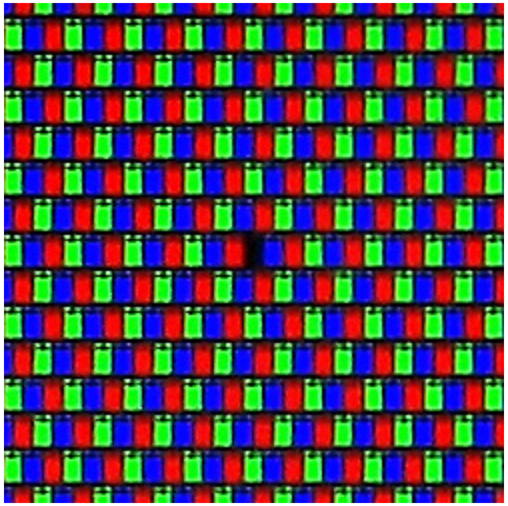


Off state

Source: Wikipedia

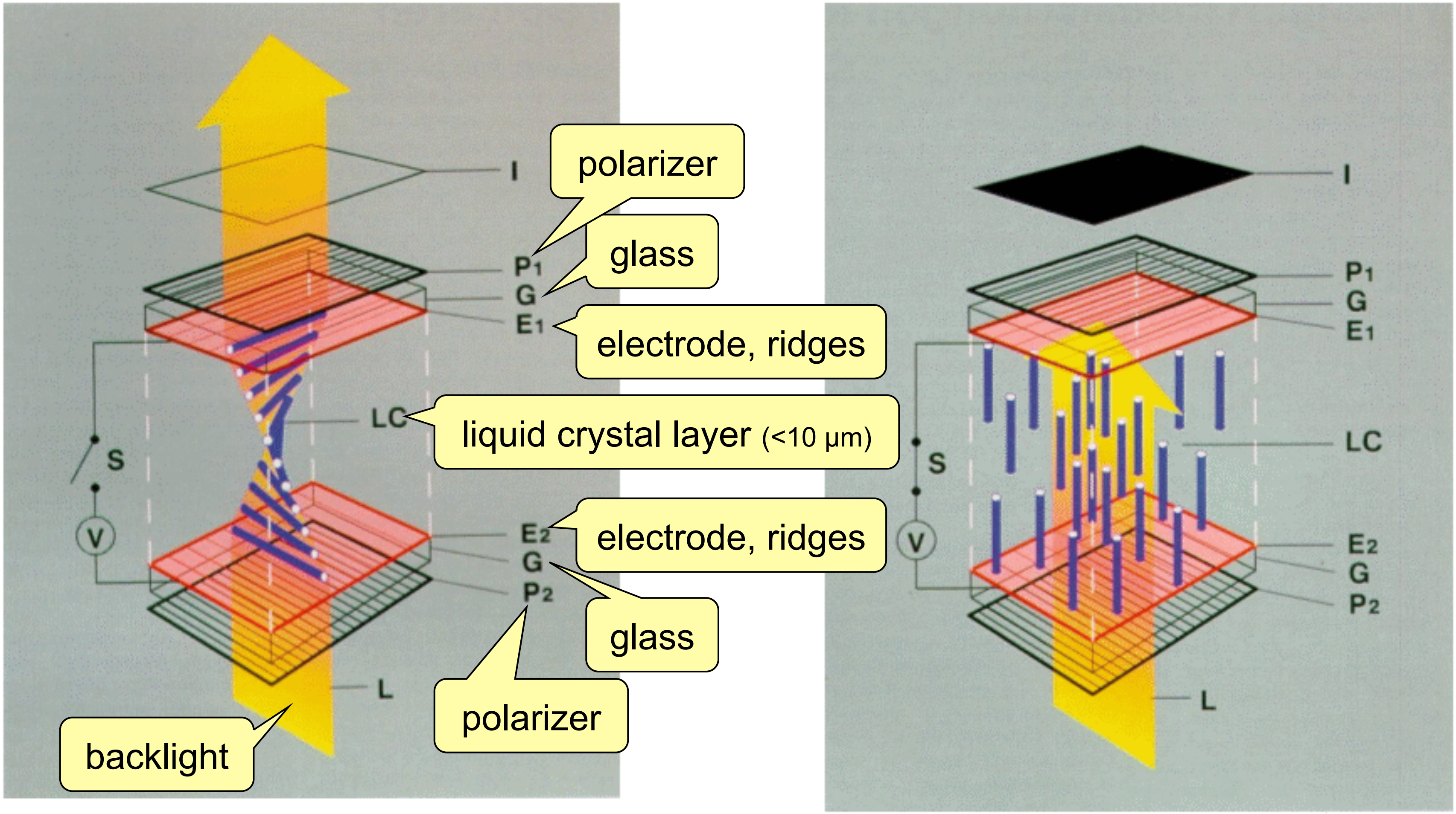


On state



LCD pattern

Liquid Crystal Display (LCD)



Off state

Source: Wikipedia

On state

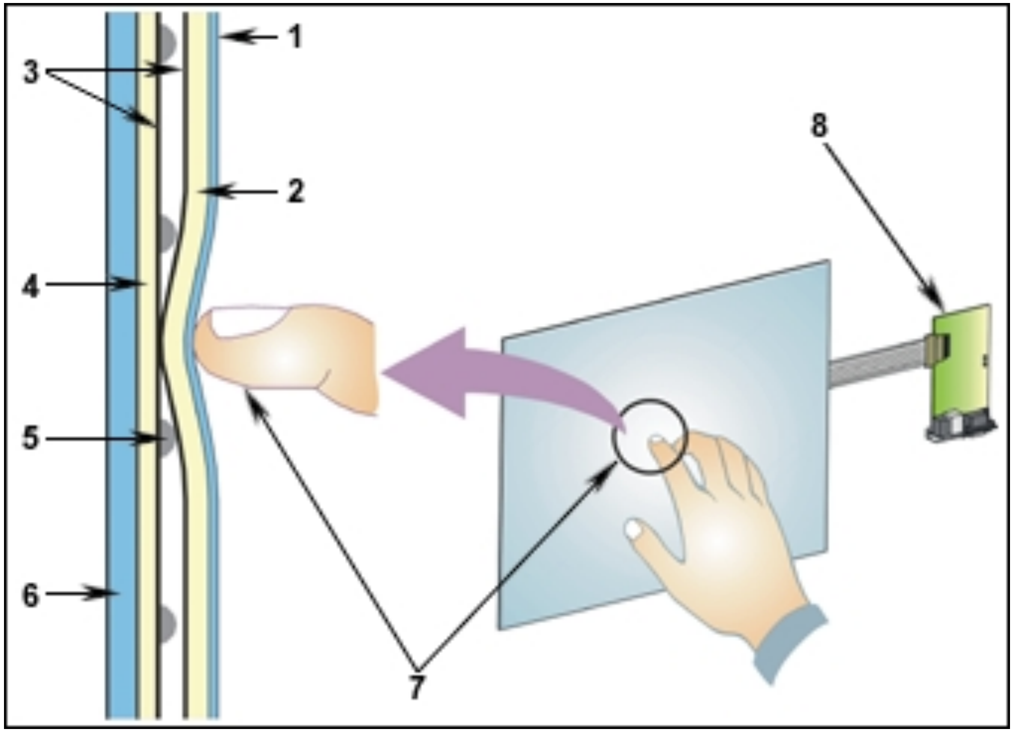
Liquid Crystal Display (LCD)

- Advantages
  - Low power consumption for controlling the twisted nematic effect
    - Low operating voltages (batteries)
    - Now current flow required
  - Cheap
  - Compact: light, small, low depth
  - Flicker free, sharp, undistorted image
- Disadvantages
  - Backlight illumination consumes significant amounts of power
  - Difficult manufacturing process (dead pixels, defective panels)
  - Fixed pixel resolution
  - Limited contrast and viewing angles (early LCDs)

Touch Screens

- Resistive
  - Suitable for stylus input
- Capacitive
  - Direct finger input

Resistive Touch Screens

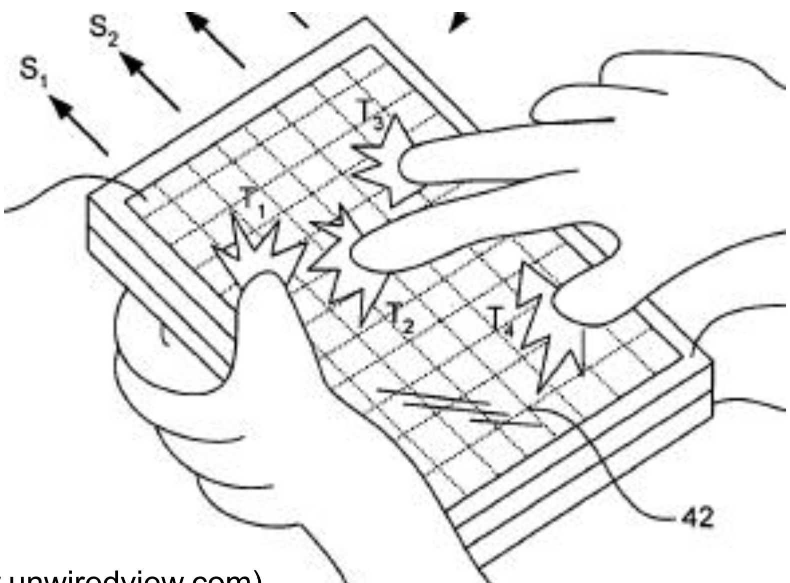


(www.fastpoint.com)

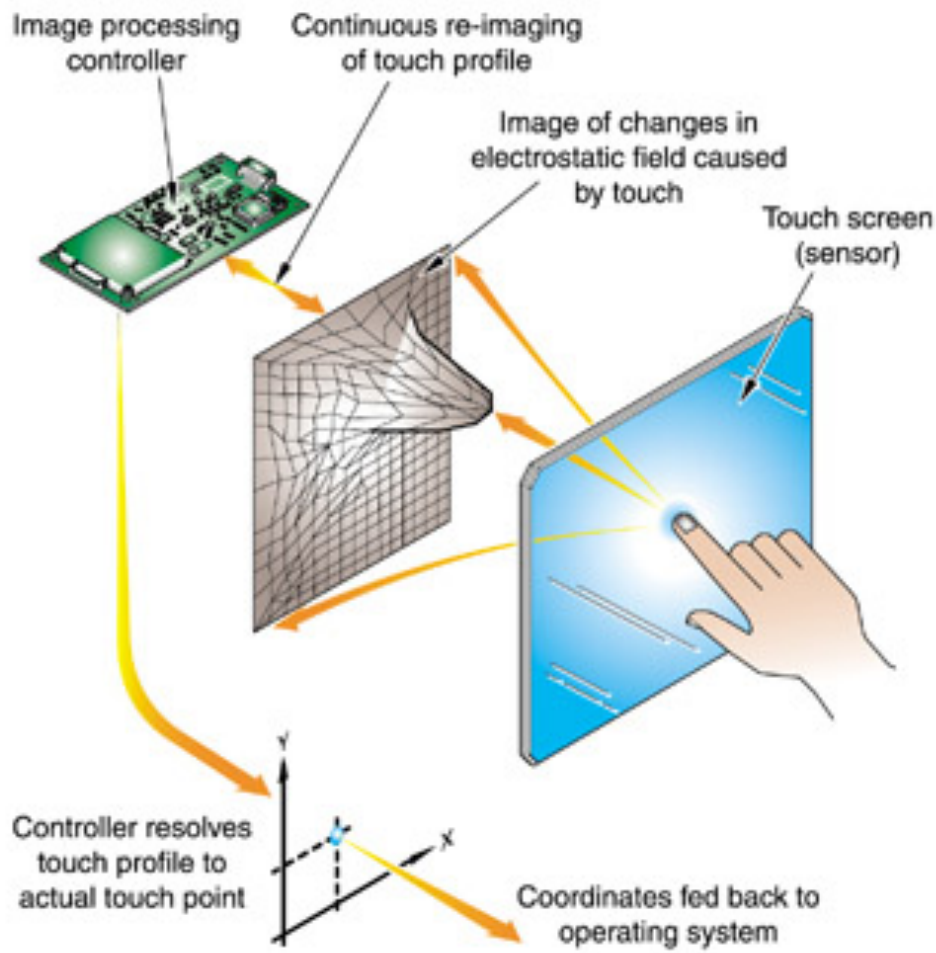
1. Polyester film
2. Upper resistive circuit layer
3. Conductive metal coating
4. Lower resistive circuit layer
5. Insulating dots
6. Glass/acrylic substrate
7. Touching the overlay surface causes (2) to touch (4), producing a circuit switch from the activated area
8. Touchscreen controller measures voltages through resistive layers and converts them into the digital X and Y coordinates

Capacitive Touch Screens

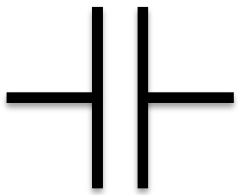
- Senses capacitive changes
  - Only works with finger, not with stylus
- iPhone
  - Uses additional grid for multitouch disambiguation



(www.unwiredview.com)



Self-Capacitance Touch Screen



parallel plate capacitor

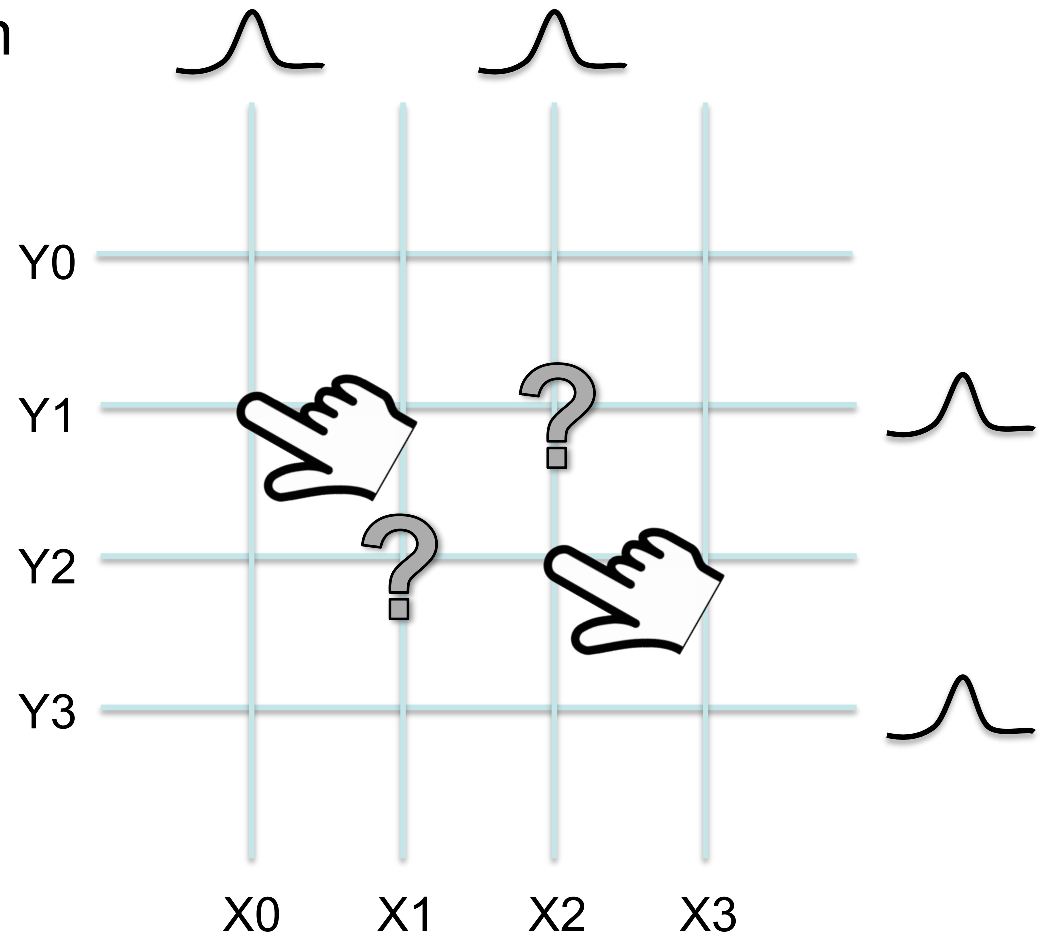
- Detects only a single touch point
- Measures capacitance of electrode to ground
  - Capacitance = "ability to store electrons"
- Finger near electrode: human body capacitance changes self-capacitance of electrode

- Materials: copper, indium tin oxide (ITO), printed ink
  - ITO: (almost) transparent capacitive electrodes
- Rows isolated from columns in grid arrangement
- Size and spacing between electrodes determines precision

Gary Barrett and Ryomei Omote: Projected-Capacitive Touch Technology. Information Display 3/10, pp. 16-21

Self-Capacitance Touch Screen

- Scans each electrode individually
- Capacitance between electrode and ground
- Multiple touches: "ghosting"



Mutual Capacitance Screen

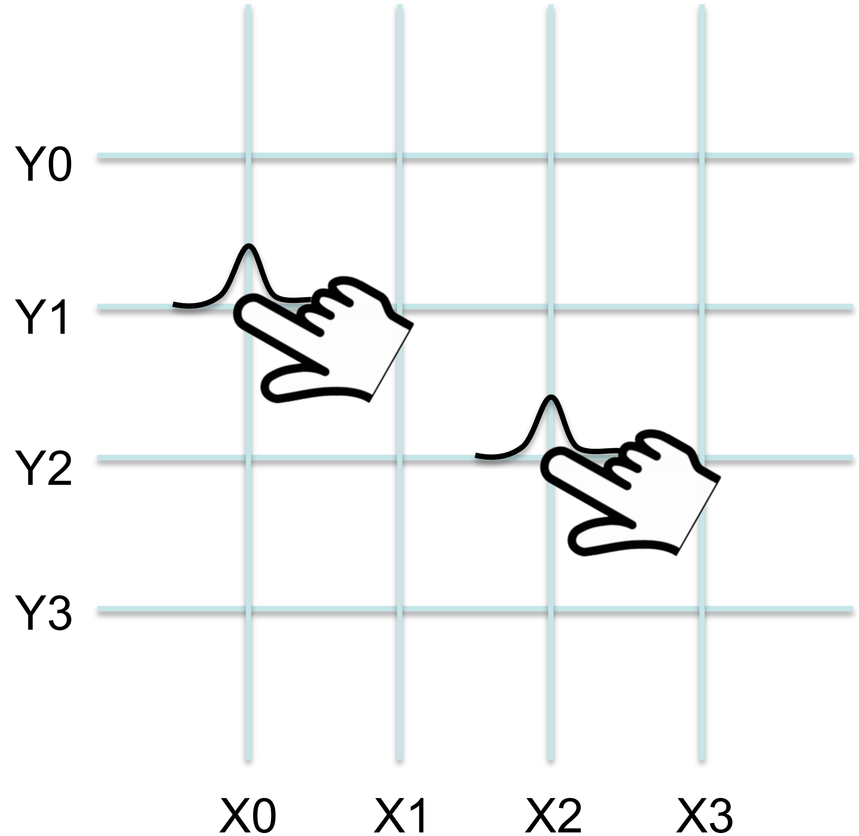
- Unlimited number of touch points
- Measures capacitance of intersections of electrodes
- Human-body capacitance changes capacitance of intersections (“steals” charge)

- High resolution
- Less sensitive to EMI than self-capacitance

- Typically 9 columns, 16 rows = 144 electrode intersections
- Interpolation achieves 1024x1024 (10 bit) resolution

Mutual Capacitance Screen

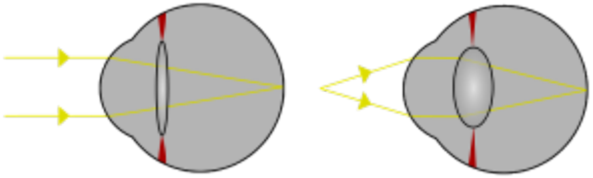
- Senses each pair (X_i, Y_j) of electrodes individually
- Capacitance between electrodes



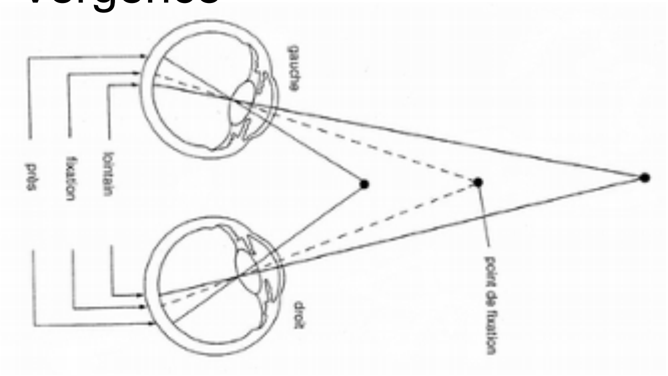
Depth Cues 3D Vision

- Eyes get slightly different images
  - 5cm horizontal shift
- Accomodation
  - Each eye's lens changes when focusing object
- Convergence
  - The two eyes converge when focusing on object
- Motion parallax
  - Objects at different distances
  - Head is moved movement

Accommodation



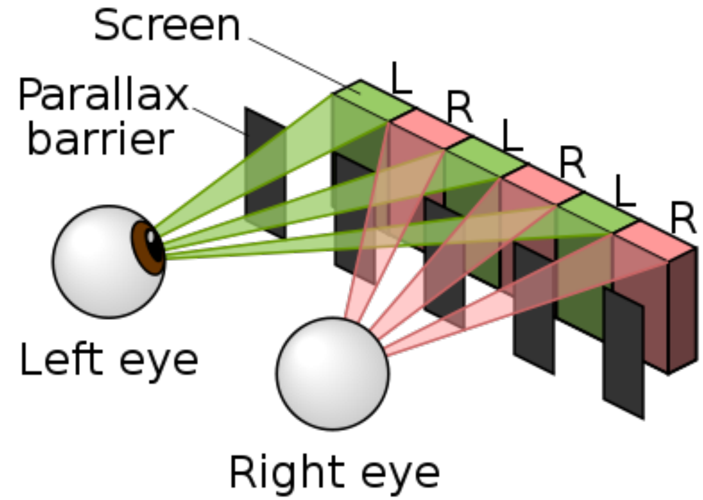
Vergence

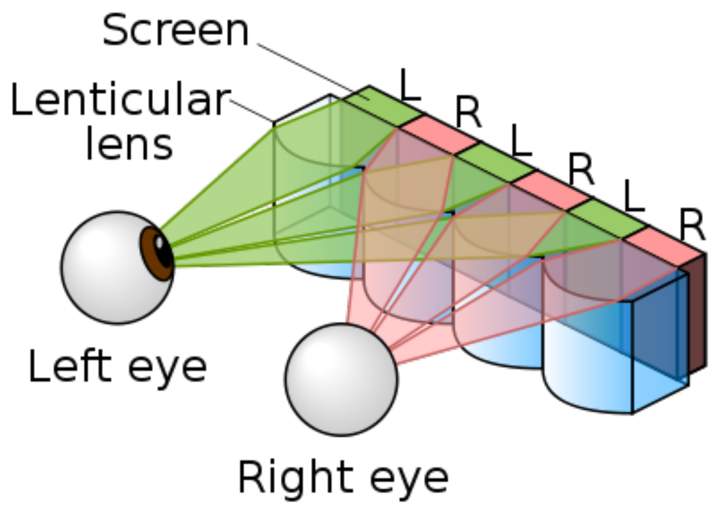


- Current technologies do not provide all depth cues

Auto-Stereoscopic Displays

- Displays providing two images for binocular perception of 3D depth without glasses
- Principles used in mobile devices
  - Parallax-barrier
  - Lenticular lens
- Single viewer, no movement parallax
  - Eye-/head-tracking for generating multiple views in real-time

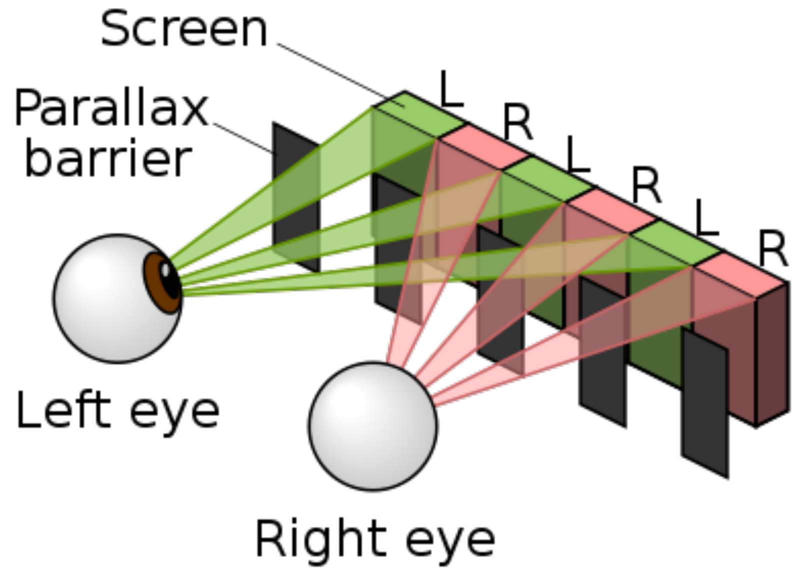


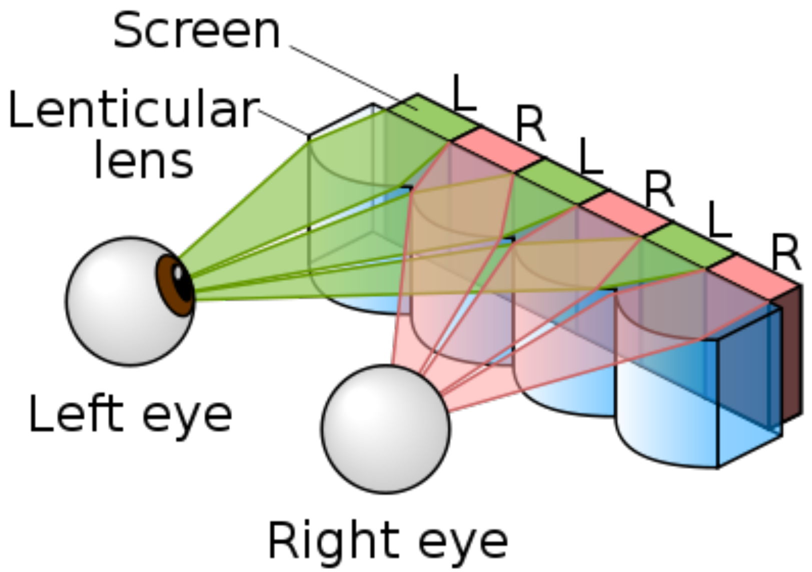


Auto-Stereoscopic Displays

- Parallax barrier
  - Small “sweet spot”
  - Reduced backlight
  - Reduced horizontal resolution
  - Variant: Barrier in front of backlight (quality, brightness)
  - Cheap

- Lenticular columns
  - Larger “sweet spot”
  - Brighter
  - Reduced horizontal resolution

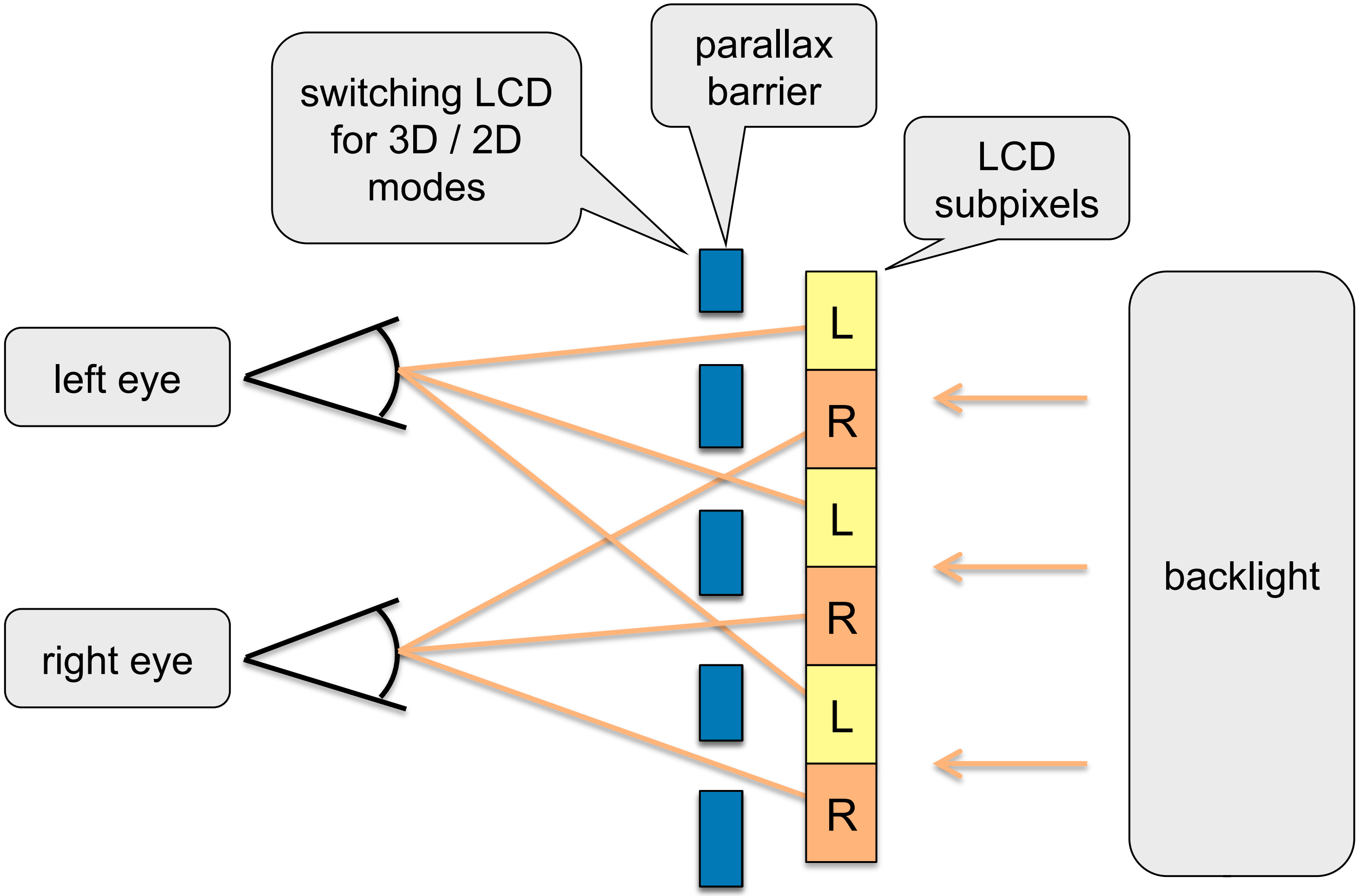




Auto-Stereoscopic Displays

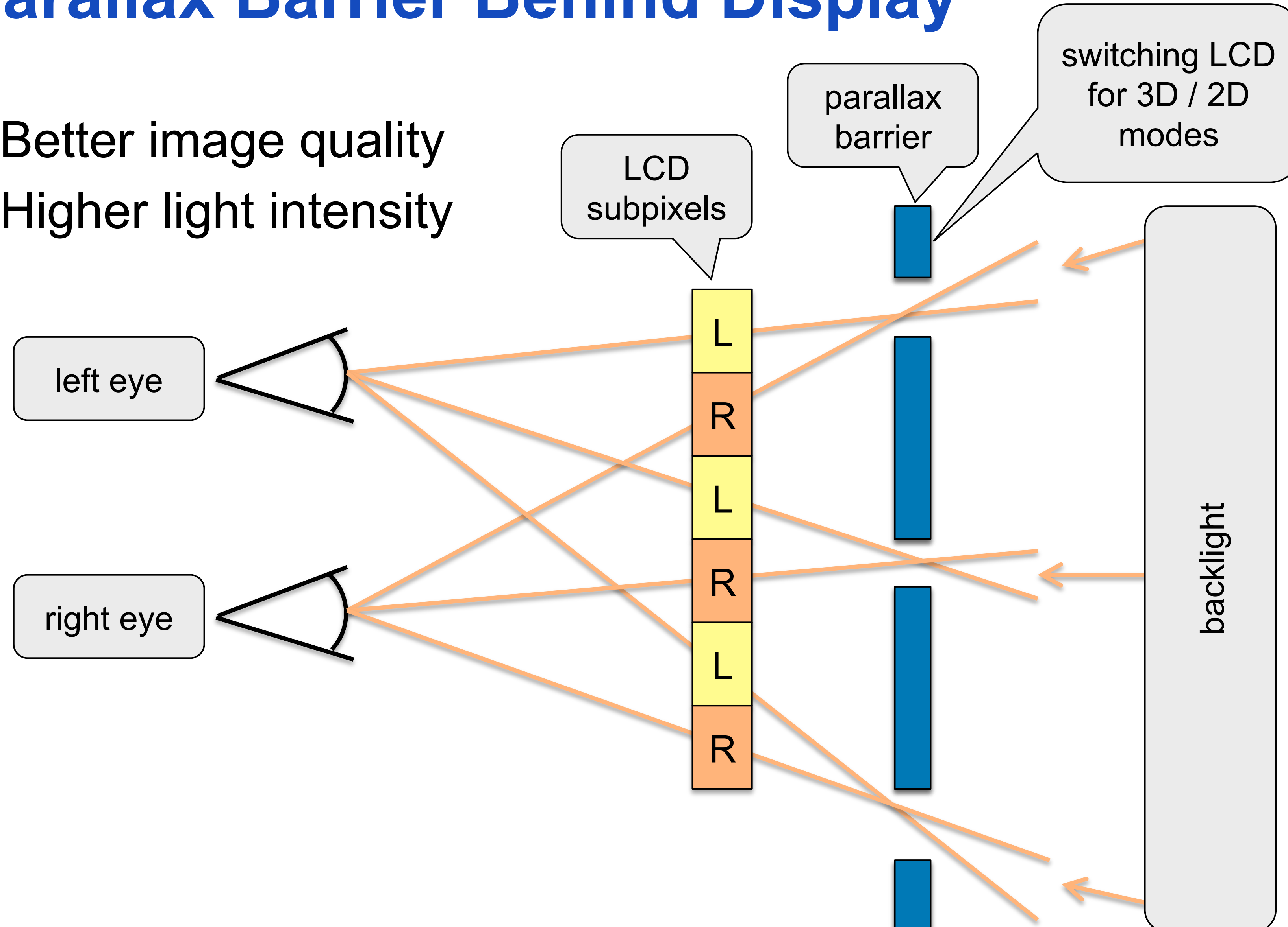
- Mobile devices with auto-stereoscopic displays
- Parallax-barrier auto-stereoscopic displays
  - Hitachi first 3D display mobile phone (2009)
  - Nintendo 3DS
  - Fujifilm FinePix camera
  - HTC EVO 3D
  - LG Optimus 3D
  - Barrier behind subpixels in front of backlight: higher quality
- Lenticular lense auto-stereoscopic displays
  - 3DeeSlide hardware overlay for iPhone

Parallax Barrier in Front of Display

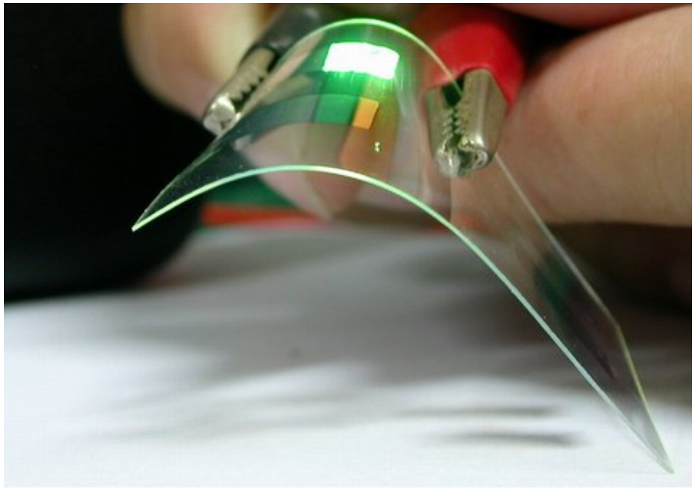


Parallax Barrier Behind Display

- Better image quality
- Higher light intensity



Organic Light-Emitting Diode (OLED)



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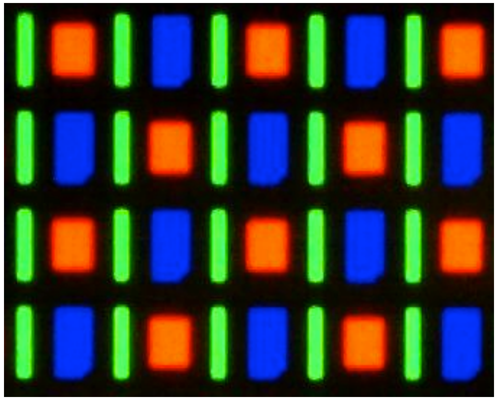
- OLEDs rely on semiconducting organic materials that emit light when electric current is applied
  - Do not need backlight
  - High contrast ratio
- Thinner than paper
- Flexible & rollable (in principle)
  - Plastic substrates, sealing organic material
- Power efficient (typically 60-80% of LCD)
  - Black OLED pixel does not consume power
  - Bright images can consume more power than LCD
- Active-Matrix OLED (AMOLED)
  - Thin-film transistor (TFT) backplane to switch pixels on/off

Organic Light-Emitting Diode (OLED)

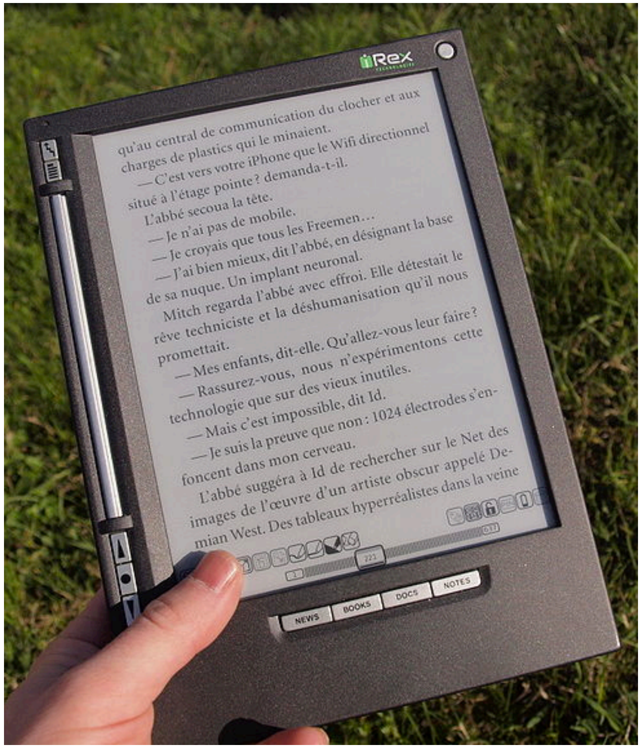
- Transparent OLEDs
  - Head-up displays, smart windows, AR
  - Stacked OLED layers for 3D displays?
- Color issues of OLEDs
  - Blue subpixels age more quickly than red or green subpixels
  - Reduced brightness changes color balance
  - Solution: Reduce electric current density through blue subpixels by making them larger
- Lower lifespan than LCDs
  - Less of an issue for mobile devices
- Used by several phone manufacturers
  - Examples: Google / HTC Nexus One with AMOLED display



Google's Nexus One AMOLED, 200x magnification

Electronic Paper (E-Paper, E-Ink)

- Appearance like ink on paper
  - High contrast
  - Wide viewing angle
  - Reflects ambient light
  - Can be read in direct sunlight
- Very power efficient
  - Keeps display contents without power
  - Needs power to change contents
  - Very slow refresh rate
- Used in mobile devices
  - E-books
  - Mobile phones
  - Wristwatches



Outdoor usage of an e-book reader

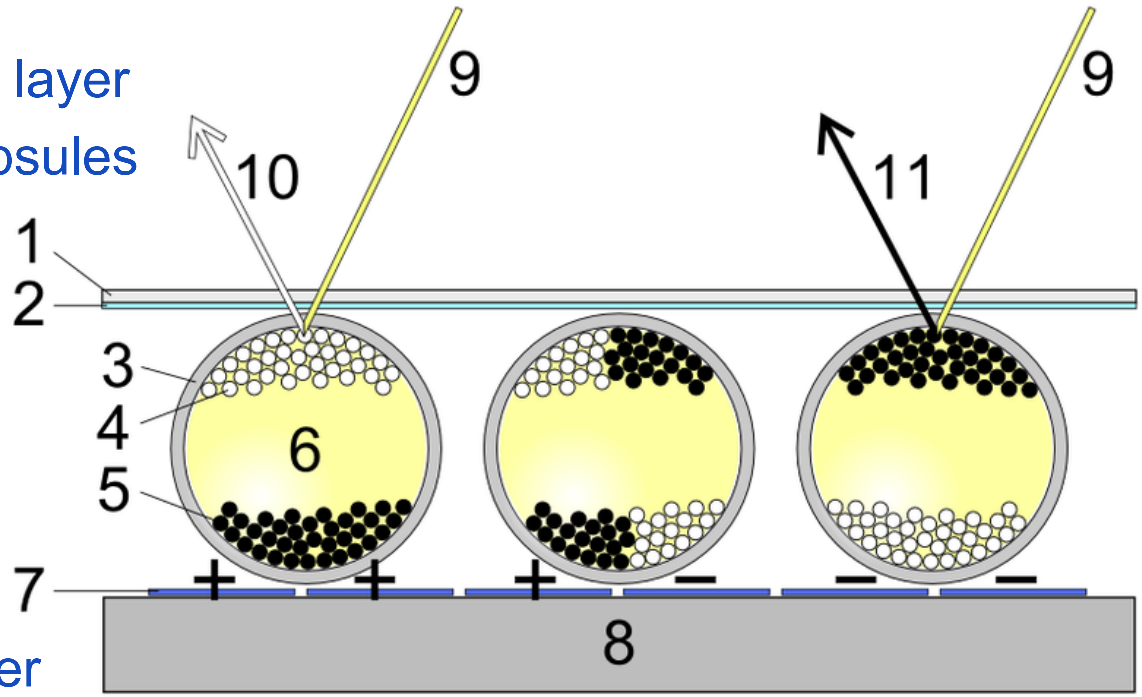
Electrophoretic Display, E-Ink

- Arrange charged pigment particles in an electric field
- Electrophoresis
  - Motion of electrically charged particles in a fluid under the influence of an electric field
- Electrophoretic display
  - White titanium dioxide particles (1μm) in black oil
  - Between (transparent) conductive plates (10-100μm distance)
  - Polarization of conductive plates determines location of particles
  - Bright if particles are at front plate, dark if at back plate
- Negatively and positively charged particles for contrast
- Microcapsules allows for flexible displays
- Used in Amazon Kindle, iRex iLiad (prev. slide)

Electrophoretic Display, E-Ink

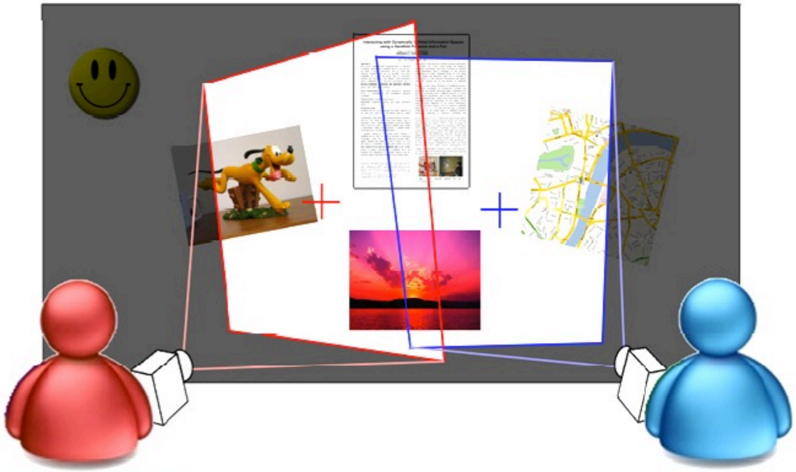
Arrange charged pigment particles in an electric field

1. Upper layer
2. Transparent electrode layer
3. Transparent micro-capsules
4. Positive charged white pigments
5. Negative charged black pigments
6. Transparent oil
7. Electrode pixel layer
8. Bottom supporting layer
9. Light
10. White
11. Black



Pico Projectors

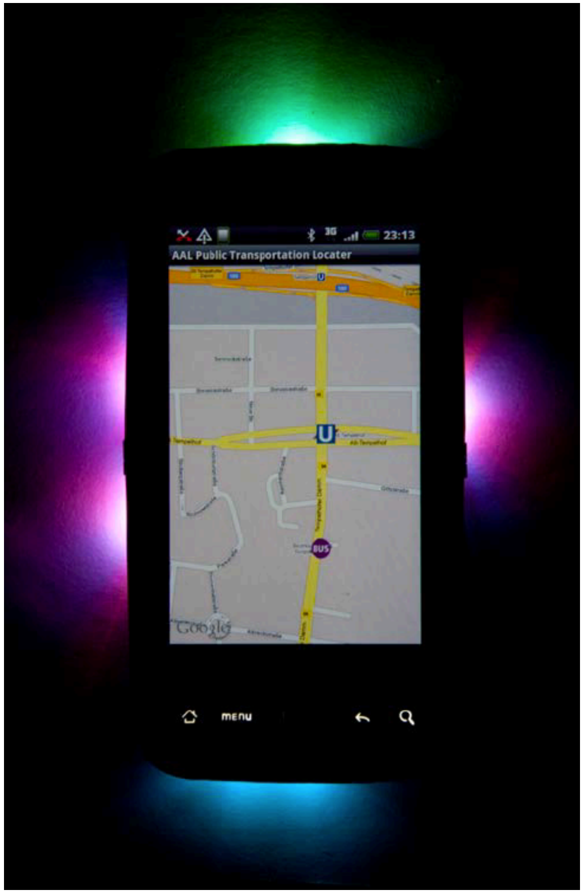
- Standalone or integrated in mobile phones
- Laser projectors avoid focus problem
  - Sharp image at any distance
- Interesting for collaborative applications
  - Example: sharing media
- Problems of handheld
  - Jitter
  - Fatigue
- Problems (current technology)
  - Availability of projection space
  - Ambient light
  - Power consumption

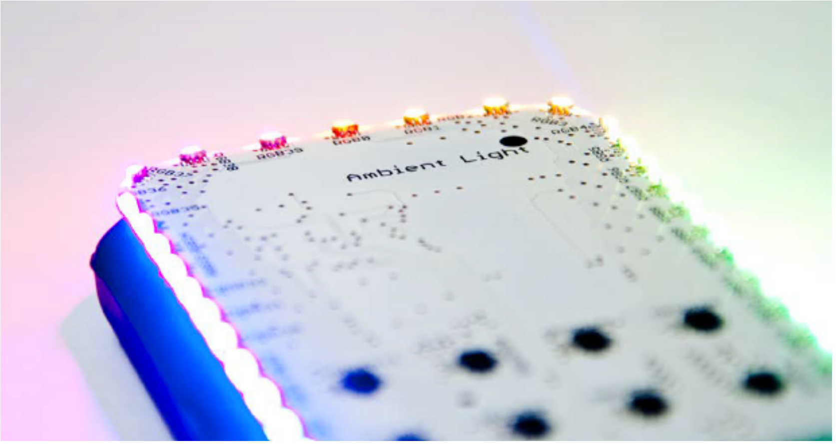


Xiang Cao et al.: Multi-User Interaction using Handheld Projectors, UIST 2007

Around-Device Projection on Tabletops

- Ambient light metaphor
  - Extending display area
  - Visualizing off-screen objects
  - Visualizing spatial operations
  - Visualizing device-to-device interactions
- Directly interact with the projection





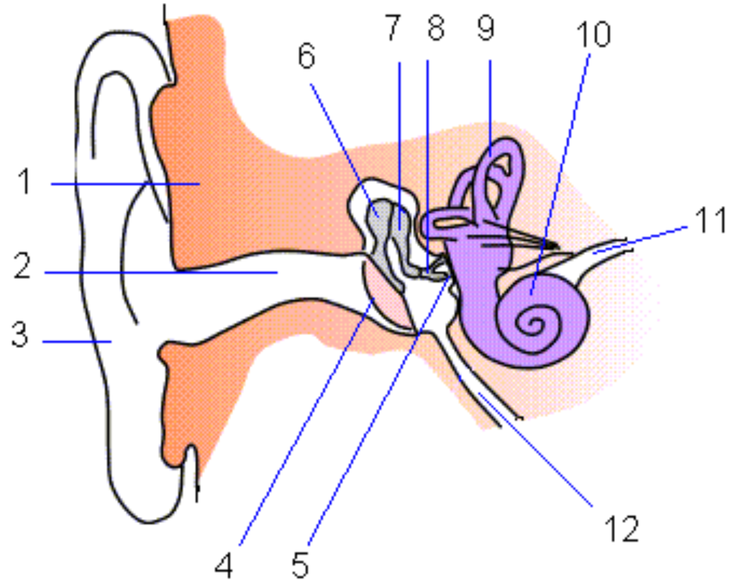
Qin, Rohs, Kratz: Dynamic Ambient Lighting for Mobile Devices. UIST 2011, demo.

Around-Device Projection on Tabletops

http://www.youtube.com/watch?v=ct1GBNk2-rE Video by Qian Qin

AUDIO AND HAPTICS

Auditory System



- Ear drum (4) senses sound
- Cochlea (10): Translates sound into nerve impulses

- Temporal resolution: 100 [50,200] ms
- Audible frequency: 20 Hz – 15 kHz
  - Most sensitive: 400 – 8000 Hz
  - Distinguishability bis 1.5 Hz
- Spatial hearing → Cocktail party effect

Perceptual Dimensions

- Pitch
  - Higher frequencies perceived as higher pitch
  - Humans hear sounds in 20 Hz to 20,000 Hz range
- Loudness
  - Higher amplitude results in louder sounds
  - Measured in decibels (db), 0 db represents hearing threshold
- Timbre
  - Characteristic overall sound quality (spectral content?)
- Time

Decibels of Everyday Sounds

Sound	Decibels
Rustling leaves	10
Whisper	30
Ambient office noise	45
Conversation	60
Auto traffic	80
Concert	120
Jet motor	*140*
Spacecraft launch	*180*

Spatial Hearing

Aspects forming spatial percept

- Arrival time (inter-oral time difference)
- Damping between ears (inter-oral amplitude difference)

Paradox of up-down-hearing

- Ear shape and HRTF

Additional features

- Cocktail party and spatial discriminants
- Dichotic pitches and spatial processing articafts
- Visual and auditory cue merging

Using Sound

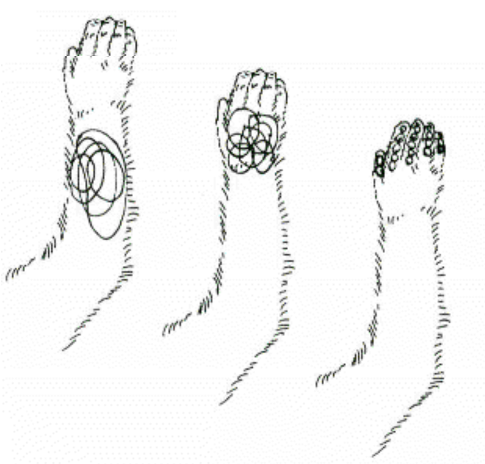
- Natural sounds can give subtle feedback cues
  - "Click" sound of locking / unlocking a door
  - "Zzz" sound of a zipper
  - Roaring sound when car muffler gets a hole
- Natural sounds reflect complex interactions of objects
  - Materials (hollow or solid, rough or smooth, etc.)
  - Interactions (hitting, sliding, breaking, bouncing, etc.)
  - Spatial position (distance, direction)
- Computer-generated sounds in user interfaces
  - Simple signals: beeps, bells, buzzers, ringing
    - Draw attention, can be annoying
  - Auditory icons: naturalistic sounds
  - Earcons: abstract sounds

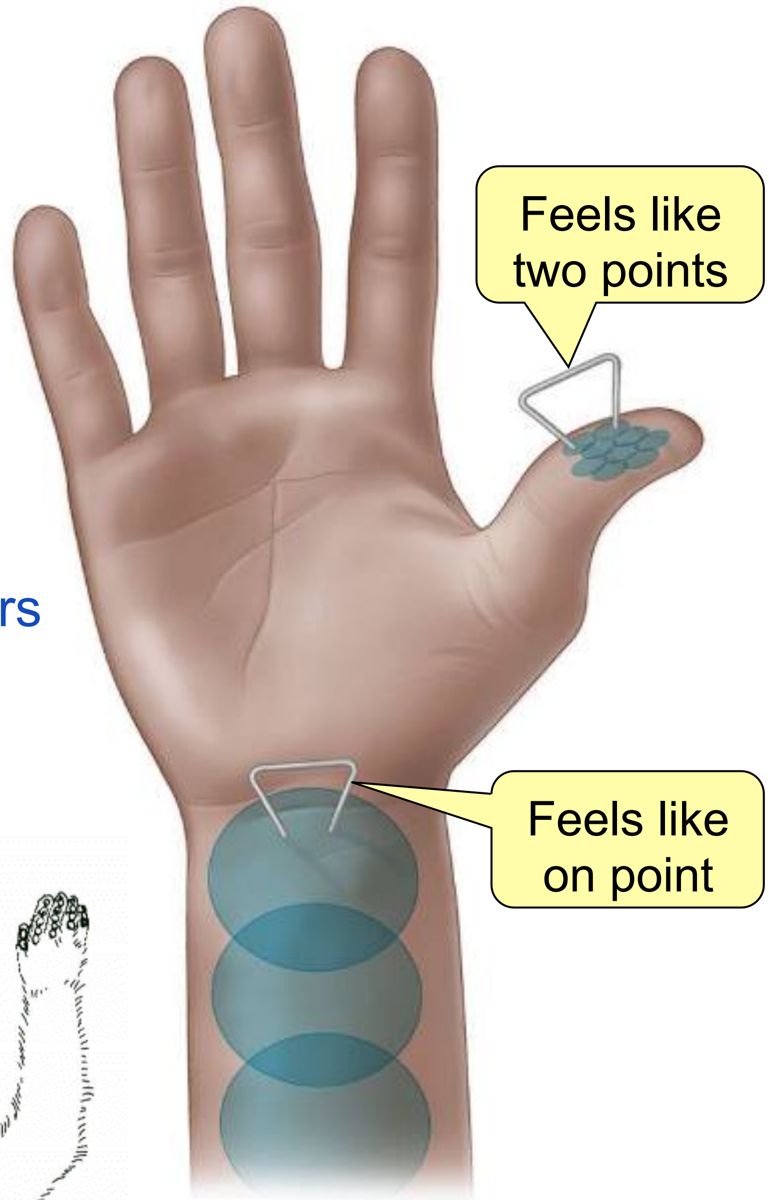
Haptic System

- Haptic perception of mechanical stimuli
  - Tactile perception (skin reception)
    - Recognize pressure, touch and vibration on the skin
  - Kinaesthetic perception/proprioception
    - Perception of body, limbs, muscles and joints
  - Temperature and pain perception
- Tactile perception
  - Resolution is dependent on position on body (e.g. finger > arm)
  - Vibrations: maximum sensitivity at 250 Hz
- Vital for everyday interaction
  - Cannot grab a raw egg without haptic perception
  - Surface texture
  - Weight of objects

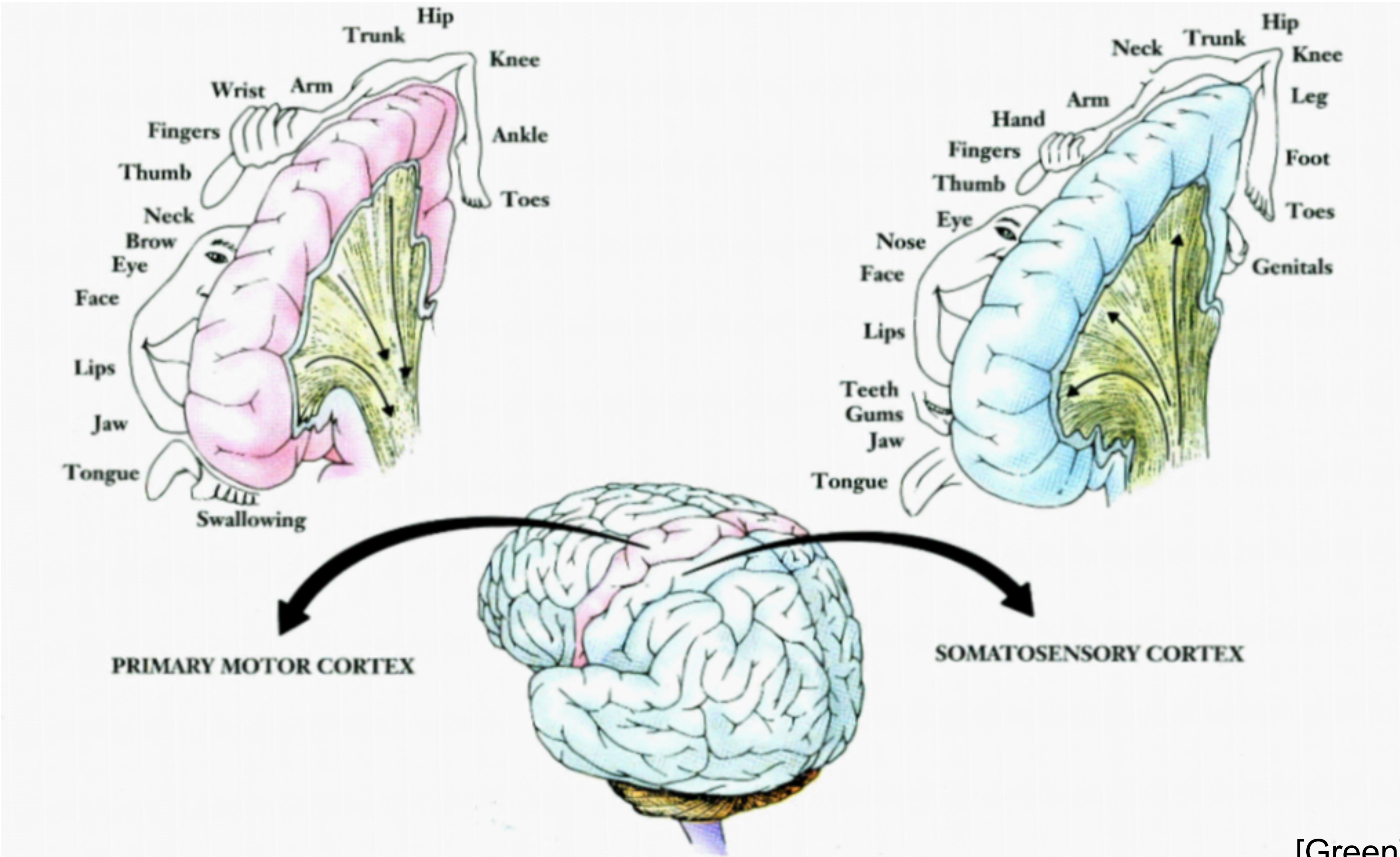
Tactile Acuity

- Mechanoreceptors detect skin deformations
- Tactile acuity
  - More acuity to fingers, mouth, nose, and tongue
  - Distance between mechanoreceptors
  - Size of cortical representations
- Two-point threshold
  - Distance at which two touch points feel distinct





Cortical Pathways of Touch



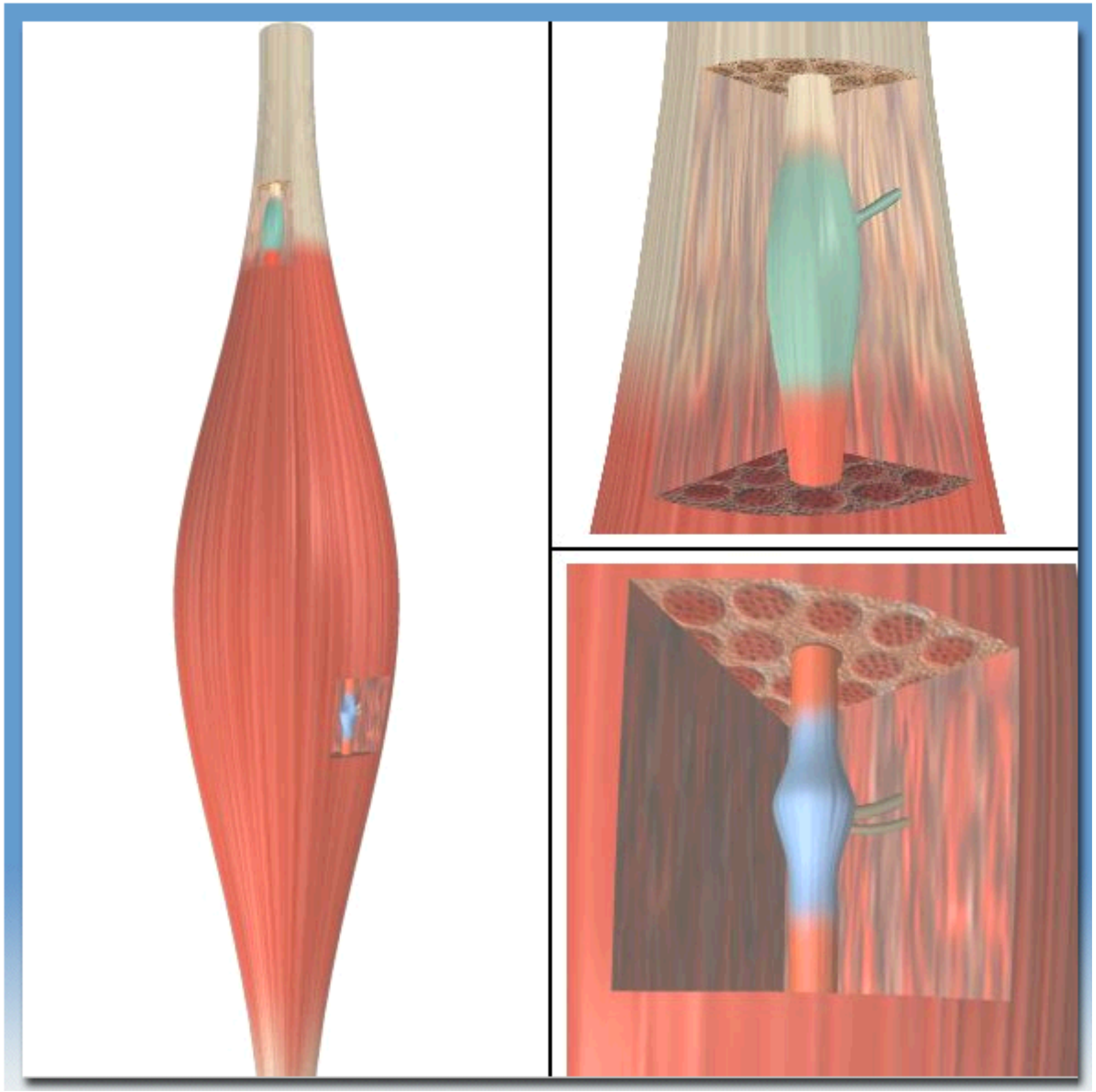
[Green]

Remapping Body Size to Sensitivy

J. Forsyth in (Cook 99)

Proprioception

- All muscles have nerve fibers which detect the amount the muscle is stretched
- All joints have fibers which detect the relative position of each bone
- Together these allow you to determine the position of every part of your body



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Multimodality

- Involve different senses through different modalities
  - Audio, tactile
  - Suit different users, tasks, and contexts
- Problems of visual modality
  - Screen space small
  - Eyes heavily used when mobile
- Reasons for multimodality
  - Sole use of one modality not effective
  - Particular modality may not always be available all of the time
  - User involved in other tasks → Attention may be occupied

Multimodal Interaction

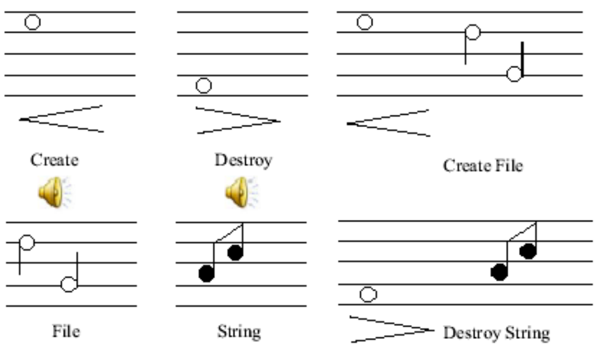
- Allow people to do everyday tasks while using mobile technology
  - “Eyes-free” or “hands-free”
- Interaction techniques that suit real environments
  - Non-speech sounds + tactile feedback
  - Sensors for gestural input
  - Speech input

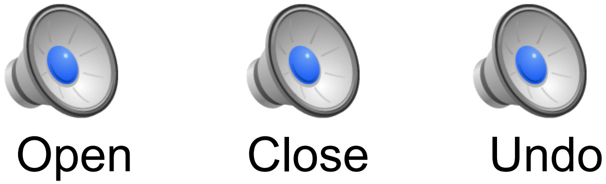
Non-Speech Audio

- Earcons (Blattner)
  - Musically structured sounds (abstract)
- Auditory Icons (Gaver)
  - Natural, everyday sounds (representational)
- Sonification
  - Visualization using sound
  - Mapping data parameters to audio parameters (abstract)

Earcons

- Structured audio messages based on abstract sounds
  - Created by manipulation of sound properties: timbre, rhythm, pitch, tempo, spatial location (stereo, 3D sound), etc.
- Composed of motives
- Can be compound
  - Sub-units combined to make messages
- Or hierarchical
  - Sounds manipulated to make complex structures





Examples from: http://www.dcs.gla.ac.uk/~stephen/earconexperiment1/earcon_expts_1.shtml

Auditory Icons

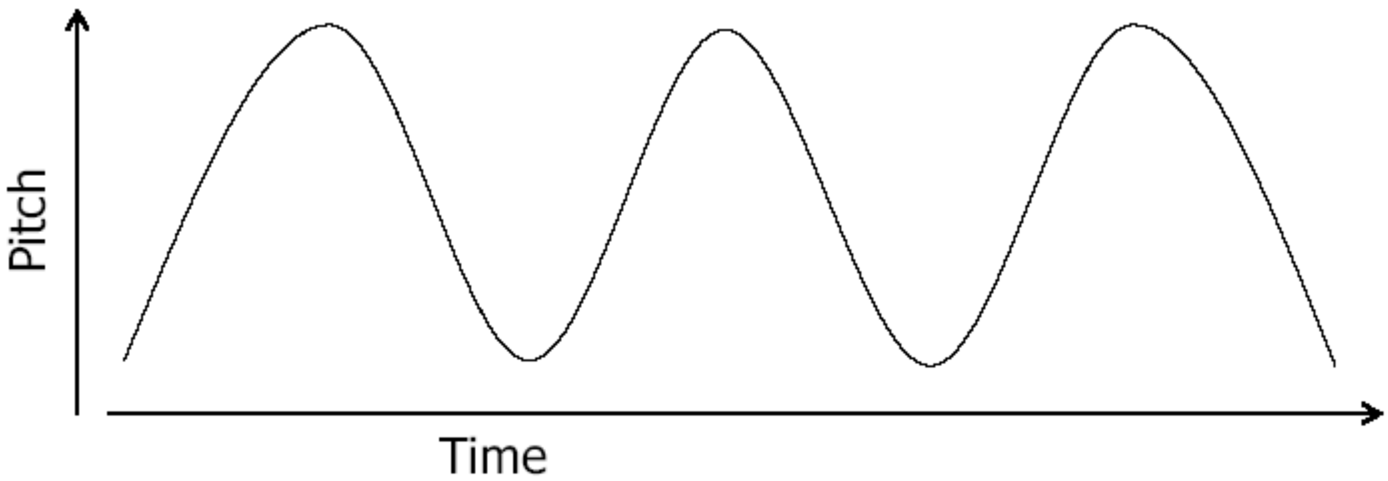
- Sounds mapped to interface events by analogy to everyday sound-producing events
  - E.g., selecting — tapping; copying — filling
  - Iconic v. symbolic mapping
- Auditory icons can be parameterized
  - E.g. material for type, loudness for size
  - Multiple layers of information in single sounds
  - Reduces repetition and annoyance
- The SonicFinder
  - Selecting, copying, dragging



Gaver, W. W., (1986). Auditory icons: Using sound in computer interfaces. Human-Computer Interaction, 2, 167-177.

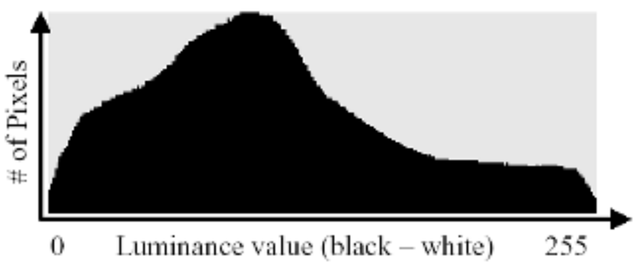
Sonification

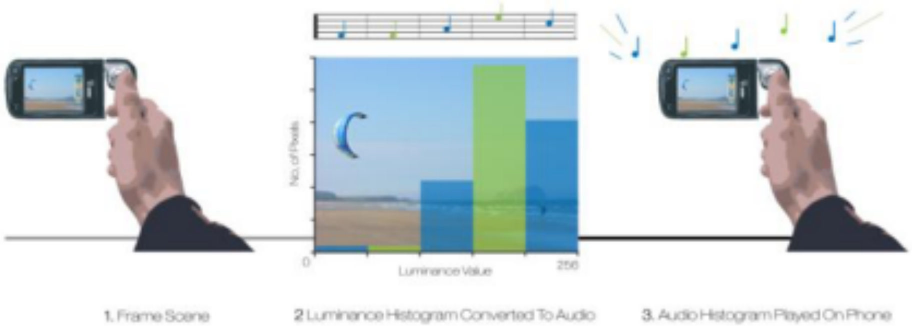
- Mapping of data values to auditory parameters
- Most commonly x-axis to time, y-axis to pitch



Sonification of Luminance Histograms in Digital Cameras

- Difficult to focus visual attention on subject and technical parameters
  – Exposure, aperture, battery life, image mode, etc.
- Idea: Sonified luminance histogram





- Sonification of remaining memory space

Brewster and Johnston: Multimodal Interfaces for Camera Phones. MobileHCI 2008.

Spatial Audio Interaction

- Increase the audio display space
- Spatial audio
  - "Cocktail party effect"
  - Provides larger display area
  - Monitor more sound sources
- "Audio Windows" (Cohen)
  - Each application gets its own part of the audio space
- Pie Menus (Brewster, CHI'03, Marentakis, CHI'06)
  - Audio items placed around the head

Cohen. Integrating graphics and audio windows. Presence: Teleoper. Virtual Environ. 1, 4 (Oct. 1992), 468-481.

Brewster, Lumsden, Bell, Hall, Tasker. Multimodal 'eyes-free' interaction techniques for wearable devices. CHI '03.

Marentakis, Brewster. Effects of feedback, mobility and index of difficulty on deictic spatial audio target acquisition in the horizontal plane. CHI '06.

Why Haptic Interaction?

- Has benefits over visual display
  - Eyes-free
- Has benefits over audio display
  - Personal not public
  - Only the receiver knows there has been a message

- People have a tactile display with them all the time
  - Mobile phone

Tactile Technologies

- Vibration motor with asymmetric weight
  - Eccentricity induces vibrations
  - Speed controls vibration frequency
  - Precision limited (several ms startup time)

PMD 310 vibration motor

Tactaid VBW32 actuator

Phone vibration motor

C2 Tactor actuator

3 cell pin array

Actuators now in other kinds of devices

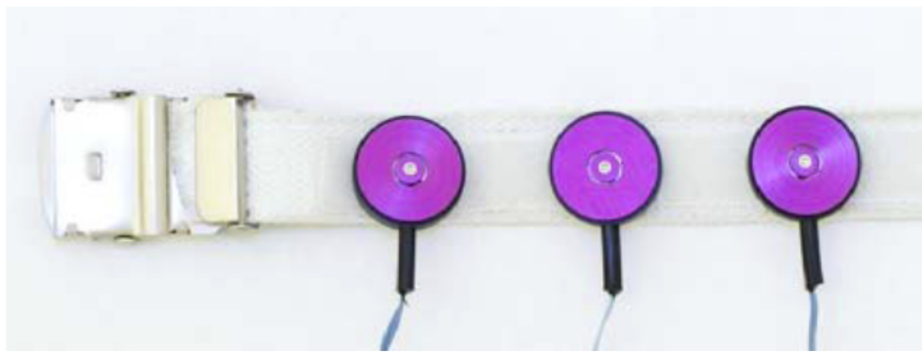
Design of Tactons

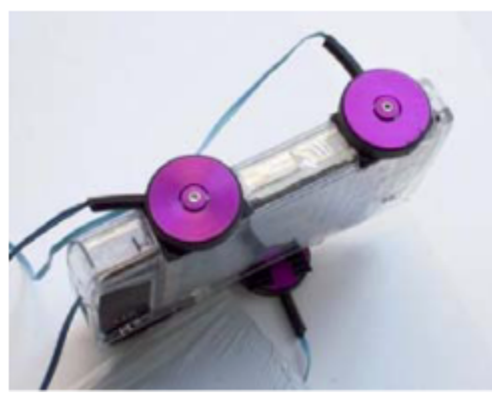
- Tactons = tactile icons
  - Structured, abstract messages that can be used to communicate non-visually (Brown, 2005)
  - Tactile equivalent to Earcons

- Encode information using parameters of cutaneous perception
  - Body location
  - Rhythm
  - Duration
  - Waveform
  - Intensity

Tacton Parameters

- Spatial location (on forearm, waist, hand) very effective
  - Good performance with up to 4 locations
  - Wrist and ankle less effective, especially mobile



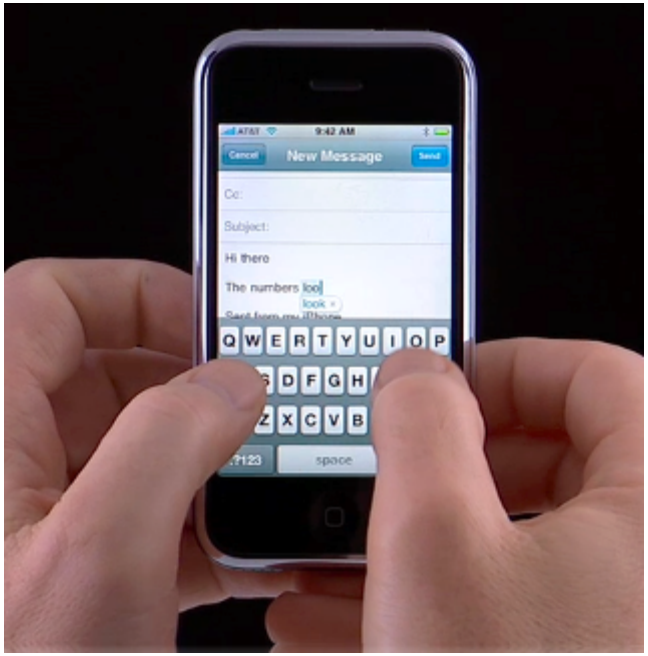


Tacton Parameters

- Rhythm very effective
  - Easily identified with three levels
- Waveform
  - Carefully designed sine, square, and sawtooth wave forms very effective (tuned to capabilities of actuator)
- Intensity
  - Two levels
  - Hard to use and may need to be controlled by user

Example: Tactile Button Feedback

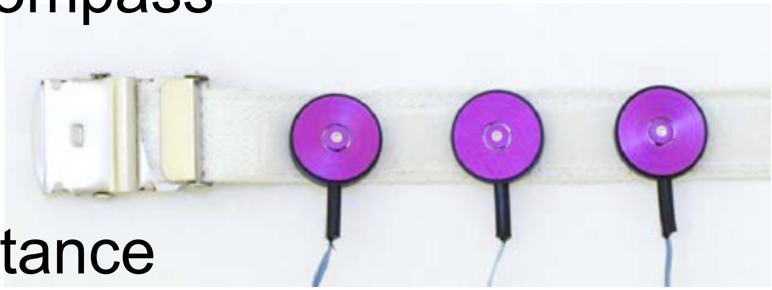
- Touchscreen phones have no tactile feedback for buttons
  - More errors typing text and numbers
- Performance comparison of physical buttons, touchscreen, and touchscreen+tactile
  - In lab and on subway
- Touchscreen+tactile as good as physical buttons
  - Touchscreen alone was poor



Brewster, Chohan, Brown: Tactile feedback for mobile interactions. CHI '07.

Example: Tactile Navigation

- Non-visual interface for GPS + compass
- Belt of 4 actuators
  - Placed north, south, east, west
- Vibrations gave direction and distance



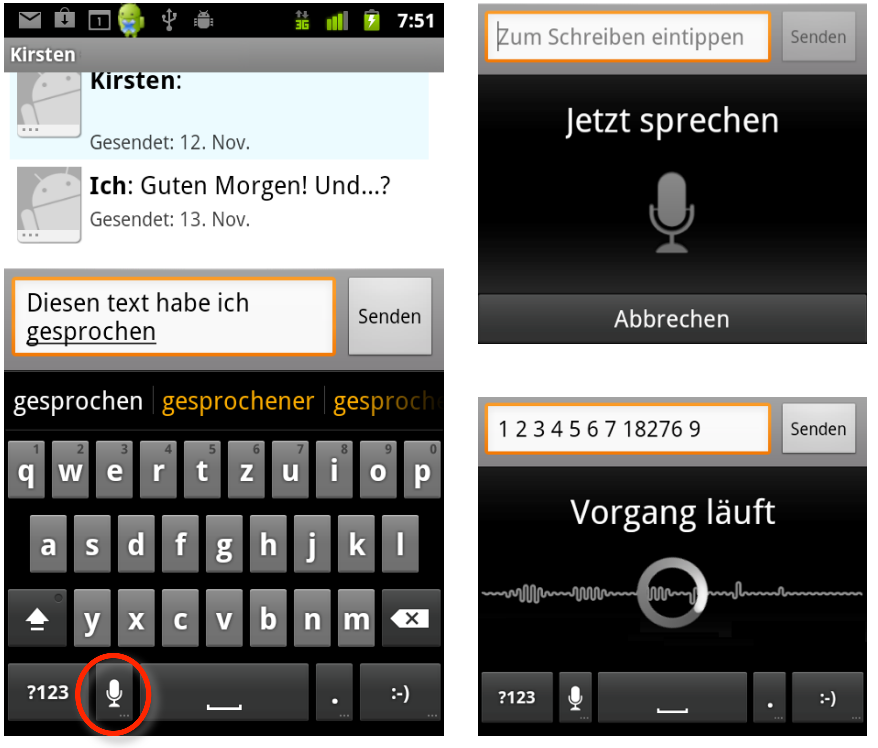
- Users could follow paths accurately without a screen

Speech Output: Text-To-Speech (TTS)

- Based on concatenation of pieces of recorded speech
  - phones: smallest unit of distinct perceptual properties (≠ phonemes)
  - diphones: transitions between adjacent phones (2500 in German)
  - syllables
  - words, phrases (for specific domains)
- Alternative: model vocal tract, completely synthetic speech
  - not as common
- Prosody: intonation / pitch variation, rhythm, stress
  - depends on semantics (e.g., exclamation, question)
  - important for naturalness of TTS output
- Android TTS engine
  - package android.speech.tts
  - http://android-developers.blogspot.com/search/label/Text-to-Speech

Speech Input: Speech Recognition

- Google Voice Search
  - Speak search terms
- Voice-enabled keyboard
  - Speaking text messages
- Android Speech Input API
  - developer.android.com/resources/articles/speech-input.html



- Apple Siri for iOS
  - Voice recognition and personal assistant
  - Integration with apps: reminders, messaging, calendar, maps, etc.

Speech Input 1

http://www.youtube.com/watch?v=RiU8GPIsZqE

Speech Input 2

http://www.youtube.com/watch?v=Avp9aUkM5g0

The End