

Mobile Information Systems

Lecture 04: I/O on mobile devices (1/2)

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I/O on mobile devices

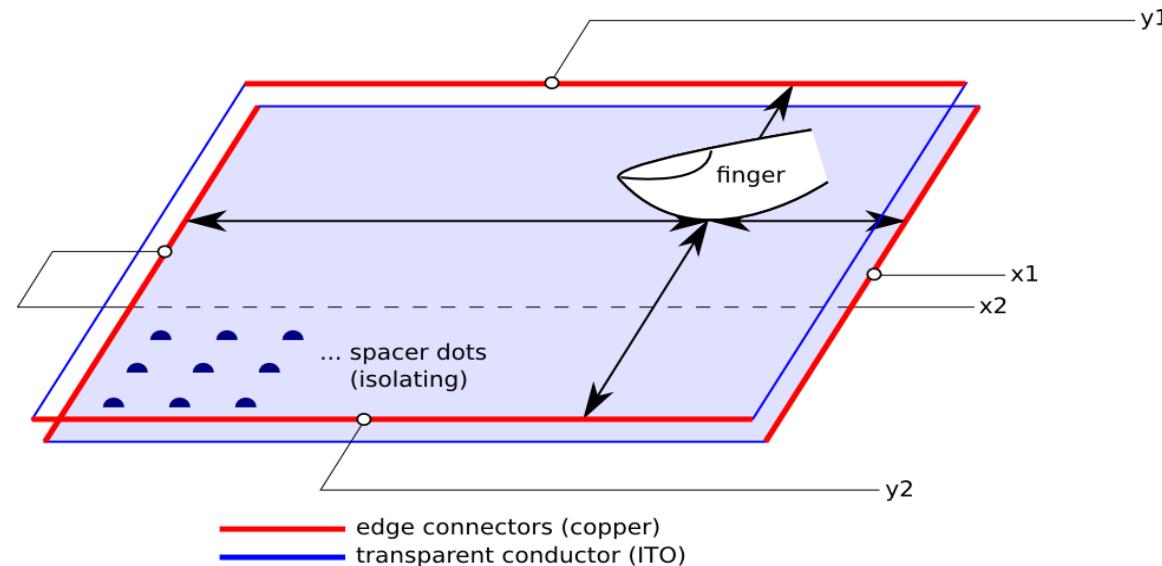
- Issues, revisited
 - Today: Touch, gestures, motion
 - Next week: Vision & other I/O channels
- Solutions
 - Common (commercial) approaches
 - Research projects

I/O issues: touch (recap)

- Preface: touchscreen technology
- Issues:
 - No haptic feedback (unlike keyboards)
 - Occlusion – hand/fingers covers part of display
 - Precision – user hits multiple pixels, covers target
 - No “hover” state – “Midas touch problem”
 - Reachability

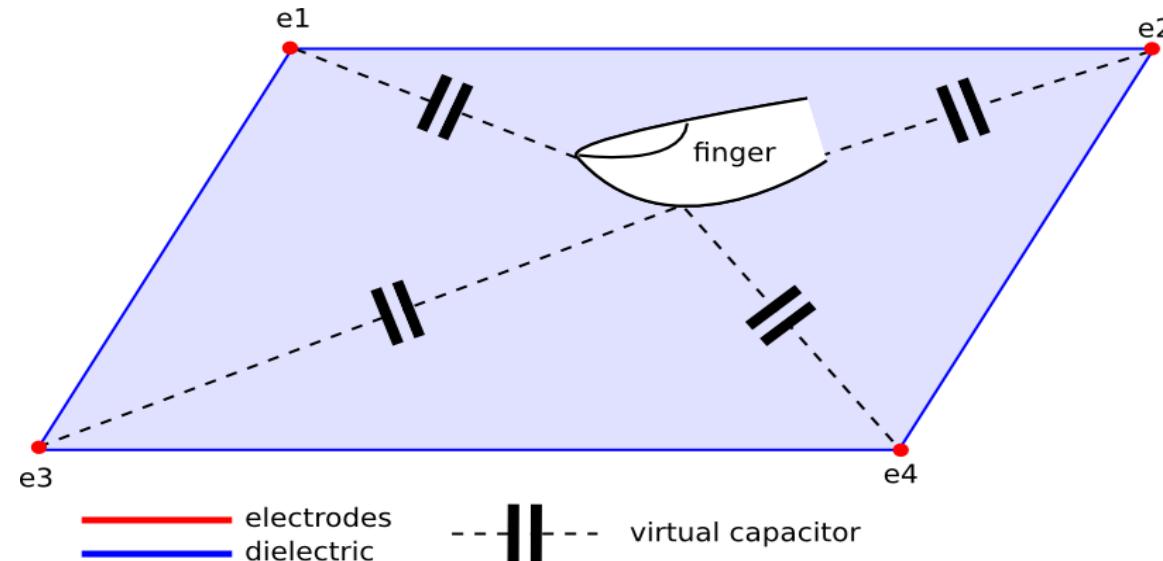
Touch – technology: resistive

- Cheap, low-end technology (no multitouch)
 - Two conductive layers separated by spacers
 - Can be used with gloves, pens, ...



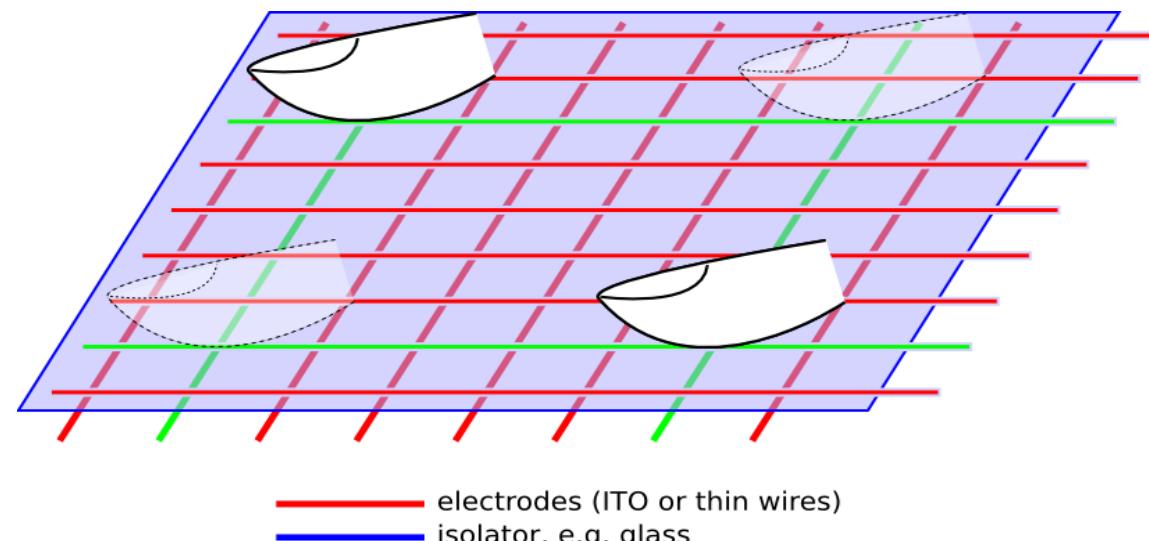
Touch – technology: capacitive (1)

- Common in POS terminals etc. (no multitouch)
- Robust, simple (but not usable with gloves)



Touch – technology: capacitive (2)

- “Projected capacitive” - two variants:
 - Mutual capacitance: each row/column measured
 - Self capacitance: each crossing measured indiv.



Touch – haptic feedback (1)

Image source (FU): <http://tactustechnology.com/wp-content/uploads/2014/08/White-Paper-New-Tagged-PDF.pdf>

- “Phorm” overlay by Tactus
 - Multiple layers of transparent foil
 - Thin channels allow fluid to flow into “bubbles”
 - All bubbles raise/lower simultaneously
 - Prototype with fixed bubble arrangement → only usable with one single keyboard layout

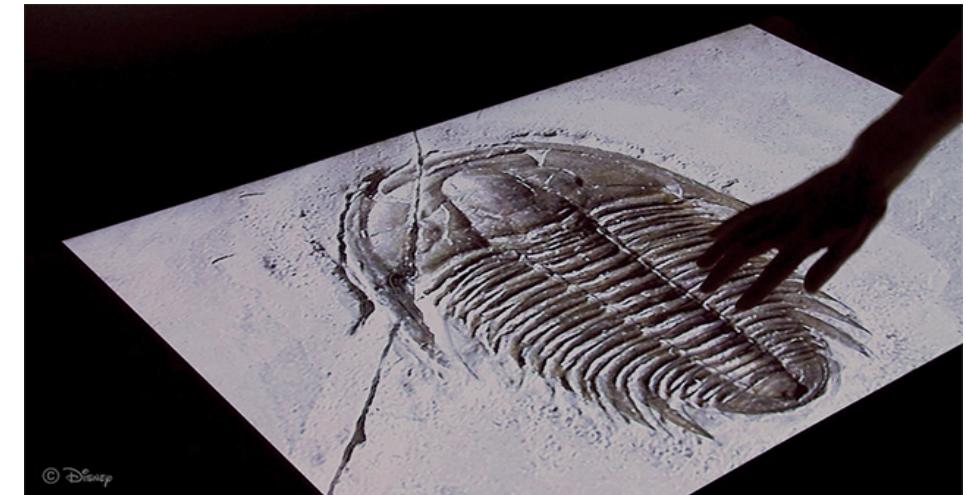


Touch – haptic feedback (2)

Image source (FU): <https://dl.acm.org/citation.cfm?id=2502020>

- “Tactile Touch Screen” using electrovibration
 - Static electric charge on whole screen, modulated relative to finger position
 - Modifies friction screen ↔ finger
 - Creates feeling of ridges & valleys
 - Only single-touch

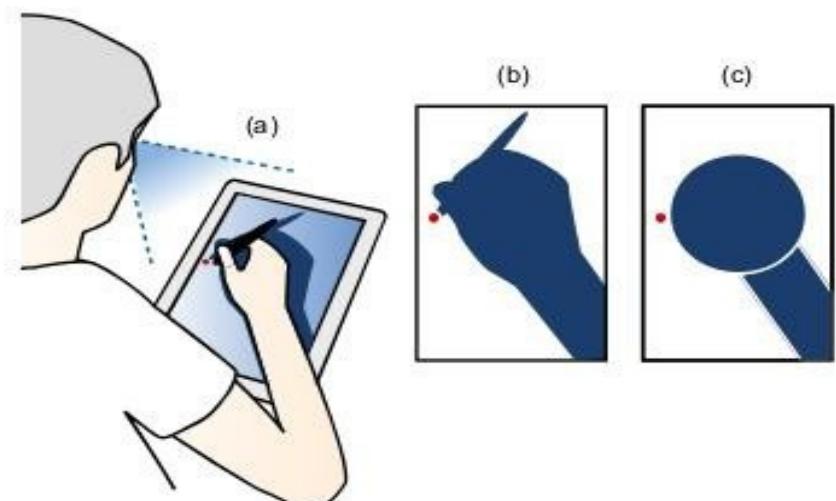
“Tactile Rendering of 3D Features on Touch Surfaces”,
Kim et al., UIST 2013



Touch – occlusion (1)

Image source (FU): <http://dl.acm.org/citation.cfm?id=1518787>

- Create geometric model of user's hand/arm
- Use model to rearrange pop-ups etc.
- Rule of thumb: objects below/right of touch point → higher chance of being overlooked

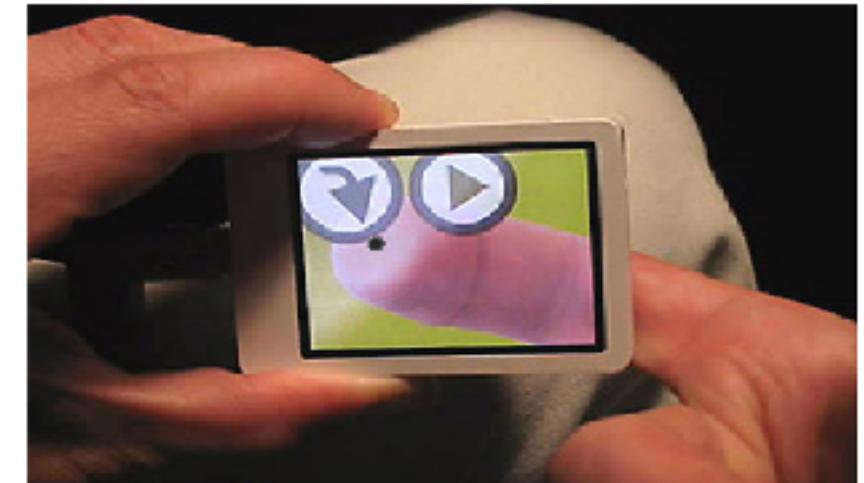


"Hand Occlusion with Tablet-sized Direct Pen Input",
Vogel et al., CHI 2009

Touch – occlusion (2)

Image source (FU): <http://dl.acm.org/citation.cfm?id=1518995>

- NanoTouch: back-of-device interaction
 - Second touch-/clickpad on device backside
 - “Virtual” finger shown on screen
→ illusion of “transparent” device
 - Enables very small screens

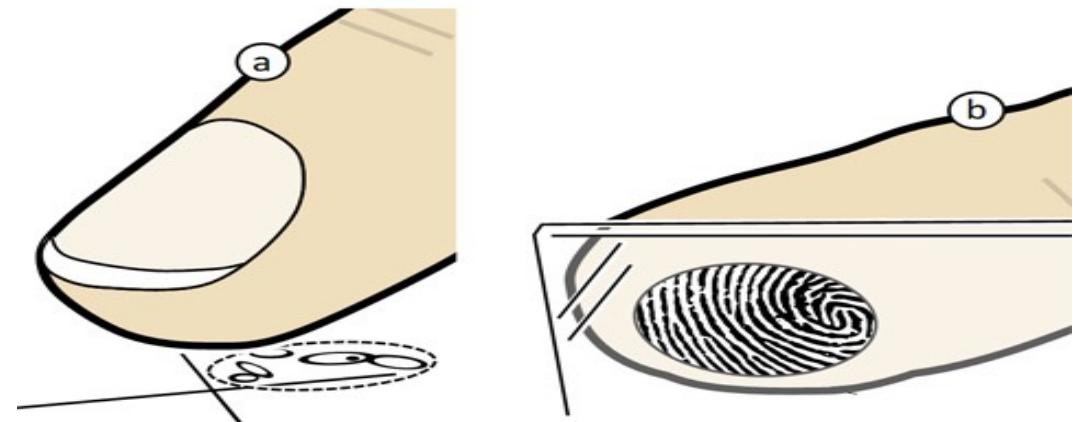


“Back-of-device Interaction allows creating very small touch devices”,
Baudisch et al., CHI 2009

Touch – precision (1)

Image source (FU): <http://dl.acm.org/citation.cfm?id=1753413>

- “Perceived Input Point Model”
 - Different perception of touched point for different users and for different angles (a)
 - Possible solution: use high-resolution sensor (b) to extract fingerprints → detect touch angle → improve accuracy



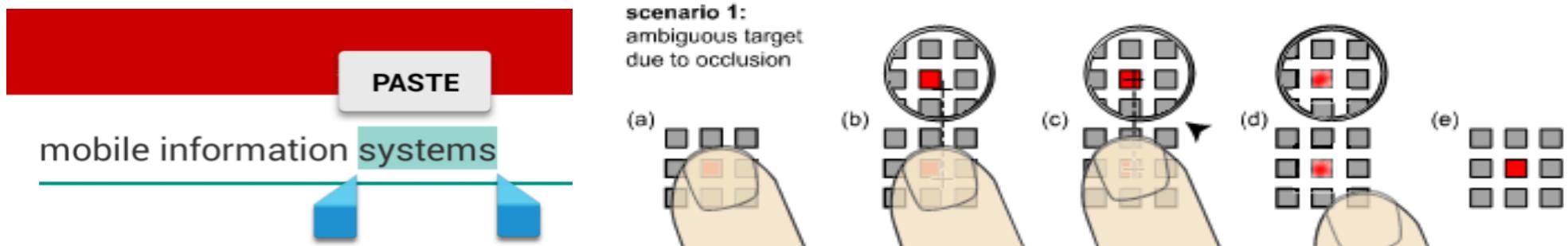
“The Generalized Perceived Input Point Model and How to Double Touch Accuracy by Extracting Fingerprints”,
Holz et al., CHI 2010

Touch – precision (2)

Right image source (FU): <http://dl.acm.org/citation.cfm?id=1240727>

- “Offset Cursor”: introduces fixed distance between touch point and actual target (e.g. Android selection handles, left)
- “Shift” - creates dynamic lens view over small targets (e.g. iOS text selection, right)

“Shift: A Technique for Operating Pen-Based Interfaces Using Touch”, Vogel et al., CHI 2007

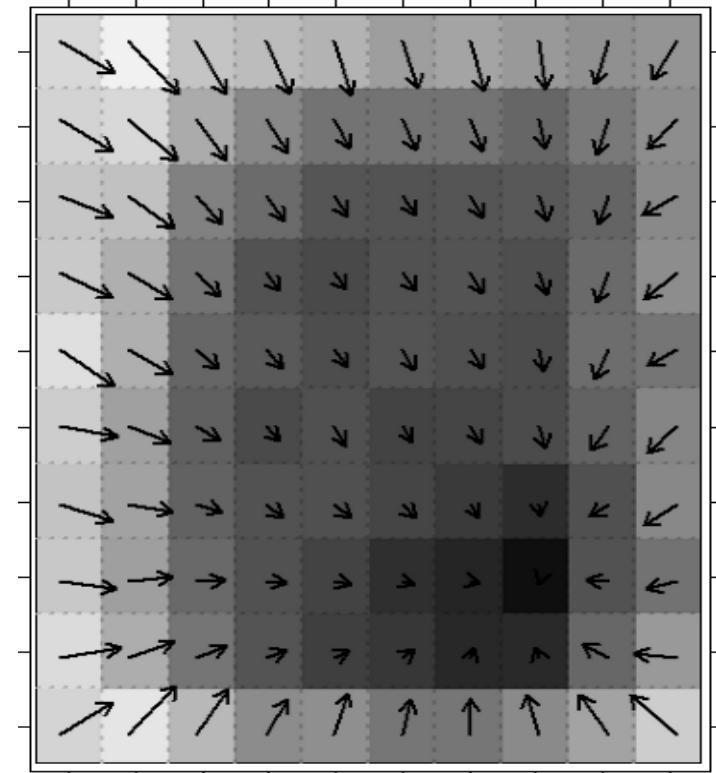


Touch – precision (3)

Image source (FU): <https://dl.acm.org/citation.cfm?id=2037395>

- “100 000 000 Taps”
 - Use mobile game to analyze high number of tap events
 - Create average offset maps for individual phone models
 - May still be context-specific

“100,000,000 taps: analysis and improvement of touch performance in the large”, Henze et al., MobileHCI 2011



Touch – reachability?

Image source (FU): <https://www.androidauthority.com/note-3-one-handed-operation-how-to-280458/>

- Problem for one-handed use
- Affects precision and reach
- Built-in “one-handed mode” (Android) or “reachability mode” (iOS)
- Precision still worse (why?)



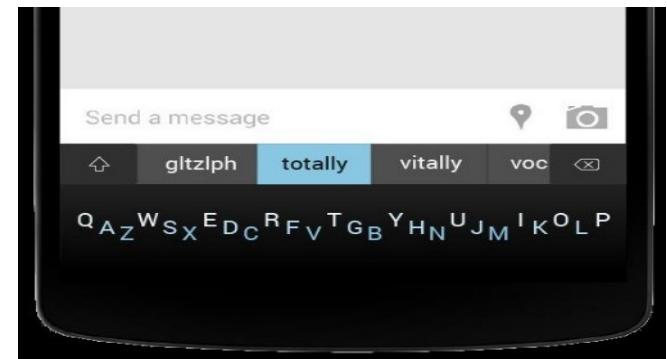
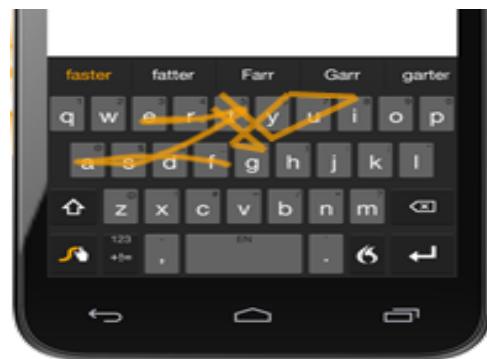
Android

iOS

Touch – precision: keyboards

Image sources (FU): <http://www.swype.com/>, <http://minuum.com/>

- Less precise than physical keyboards
 - word prediction (WP) helps:
 - “classic” QWERTY + WP
 - Swiping across letters + WP (Swype/Swiftkey, left)
 - Single line of letters + WP (Minuum, right)



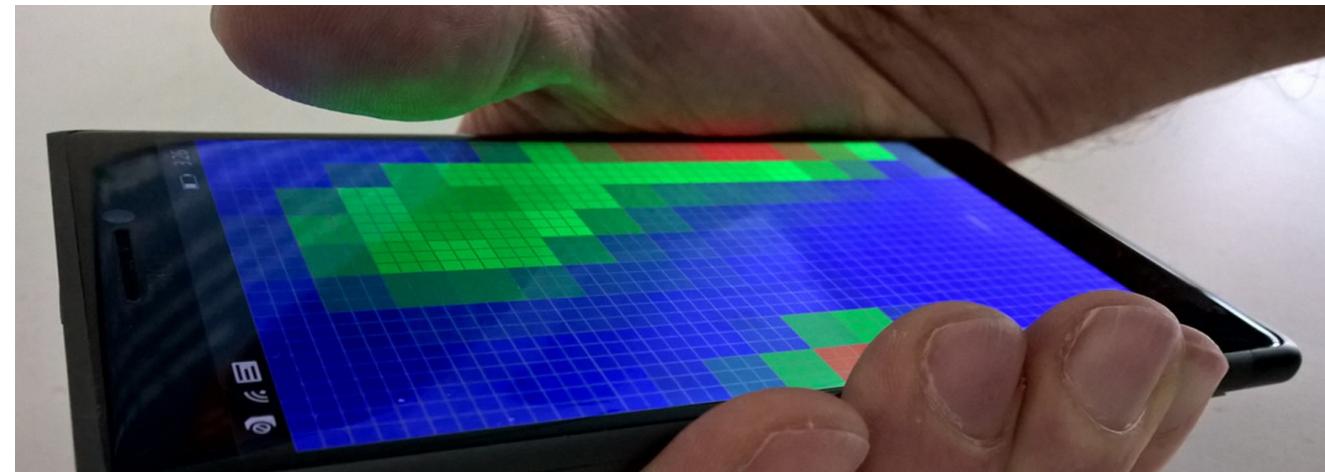
Touch – hover state (1)

- No hover state → “Midas Touch Problem”
- Also appears with some styli, eye tracking, ...
- Solved by “lift-off strategy”
 - Touch down → screen starts giving feedback
 - Touch moves → continuous feedback
 - Touch up → action is triggered
- Developed in 1988, used everywhere now
<https://www.cs.umd.edu/hcil/touchscreens/>

Touch – hover state (2)

Image source (FU): <https://dl.acm.org/citation.cfm?doid=2858036.2858095>

- “Pre-Touch Sensing”
 - Many capacitive screens *can* sense hover
 - Usually filtered out by touchscreen controller
 - Allows detection of hover, grip, touch force, ...



“Pre-Touch Sensing for Mobile Interaction”, Hinckley et al., CHI 2016

Touch: summary

- Drawbacks ↔ Mouse:
 - Less precision
 - More occlusion
 - No hover state (mostly)
 - No haptic feedback
- 1:1 transfer of desktop UIs will almost certainly fail
- Needs new strategies

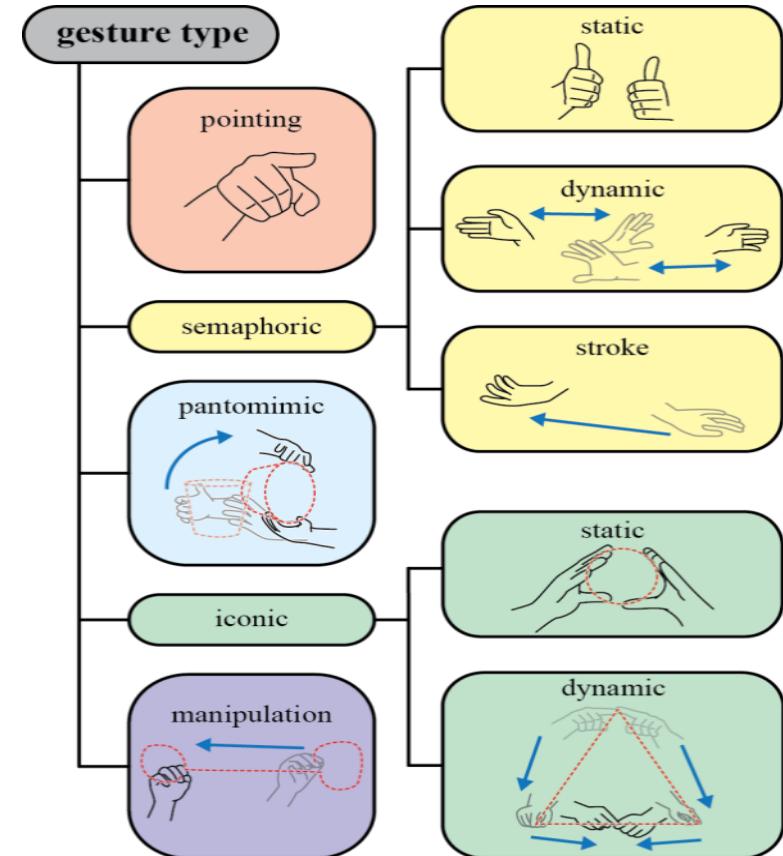
I/O issues: gestures (recap)

- Discoverability
 - How do I know which gestures are available?
 - Even more difficult for complex gestures
- “Natural” interaction
 - What's a natural gesture?
 - Strong personal & cultural preferences
- No standards
 - E.g. swipe; long-press: very different meanings for each app/OS
 - Exception: pinch-zoom

Gestures: what is a gesture?

Source (FU): <http://research.microsoft.com/pubs/175454/GesturesTR-20121107-RoA.pdf>

- Taxonomy
 - Pointing/"deictic"
 - Semaphoric
 - Gesticulation, sign language?
 - Pantomimic
 - Describes actions
 - Iconic
 - Conveys shapes
 - Manipulation
 - Implies physical link

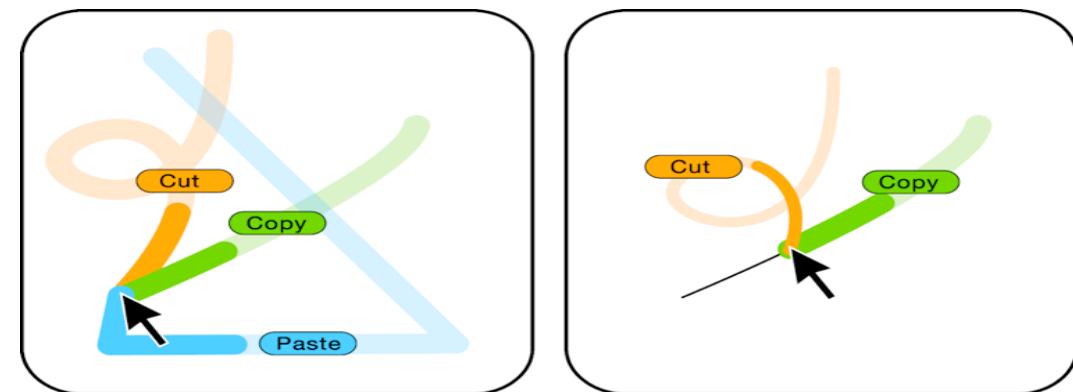


Gestures – discoverability (1)

Image source (FU): <http://dl.acm.org/citation.cfm?id=1449724>

- Feedback
 - Provides information after correct execution
 - Helps with reinforcement learning
- Feedforward
 - Provides information before/during execution
 - OctoPocus →

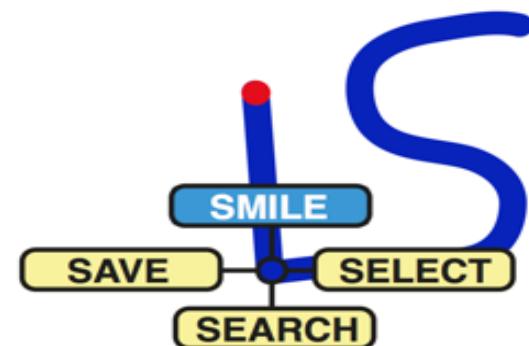
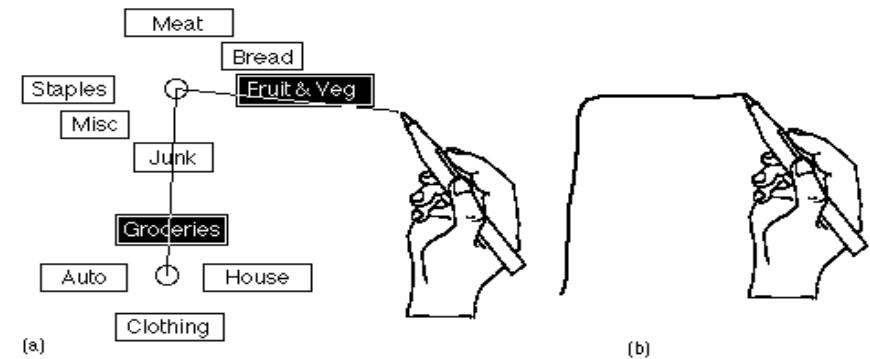
"OctoPocus: A Dynamic Guide for Learning Gesture-Based Command Sets", Bau et al., UIST 2008



Gestures – discoverability (2)

Image sources (FU): <http://dl.acm.org/citation.cfm?id=169426>, <http://dl.acm.org/citation.cfm?id=2481321>

- **Marking Menus (Buxton)**
 - Display radial menu after short dwell time
 - Multiple hierarchy levels
 - Easy transition from novice to expert (without dwell time)
- **Augmented Letters (Roy)**
 - Start with first letter of command
 - “Tail” selects subcommand



Gestures: what is “natural”?

Image sources (FU): <http://dl.acm.org/citation.cfm?id=2480317>

- Elicitation studies
 - Show intended effect/describe action *first*
 - Users execute gesture which they consider most appropriate/best suited, gesture is recorded
 - Often very little agreement, except simple actions
 - Test: what gesture would you use to delete a line in a touchscreen-based code editor?

RefactorPad: editing source code on touchscreens, Raab et al., EICS 2013

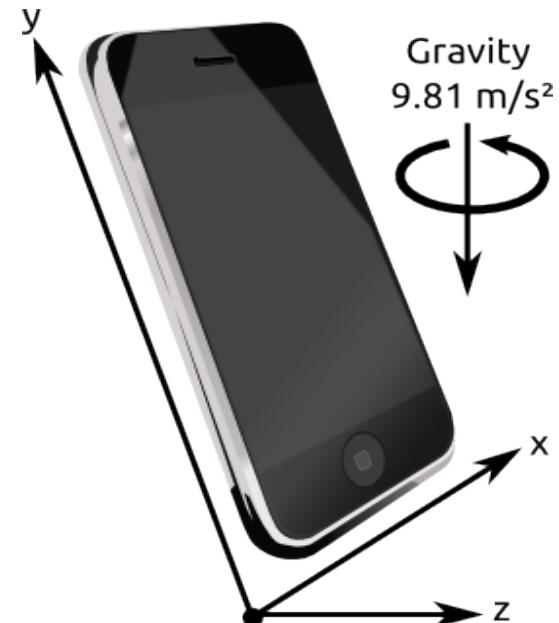


I/O issues: motion (recap)

- Motion as input
 - Motion of device: inertial measurement unit (IMU)
 - Motion of user: EMG, camera-based approaches
- Motion as output
 - Mostly vibration alerts (binary channel)
 - Extension: multiple vibration motors
 - Moving/shape-changing phones
 - Moving the user itself?

Motion input – device sensors (1)

- IMU (Inertial Measurement Unit) contains:
 - Accelerometer (3 axes/DOF*)
 - Measures acceleration, including gravity ("down")
 - Cannot sense rotation around "gravity axis"



(*) DOF = Degrees Of Freedom

Motion input – device sensors (2)

- IMU (Inertial Measurement Unit) contains:
 - Magnetometer/compass (3 axes/DOF)
 - Measures earth's magnetic field ("north")
 - Distorted by large metal objects, power lines etc.
 - Gyroscope (3 axes/DOF)
 - Measures rate-of-turn
 - Compensates sudden magnetometer errors

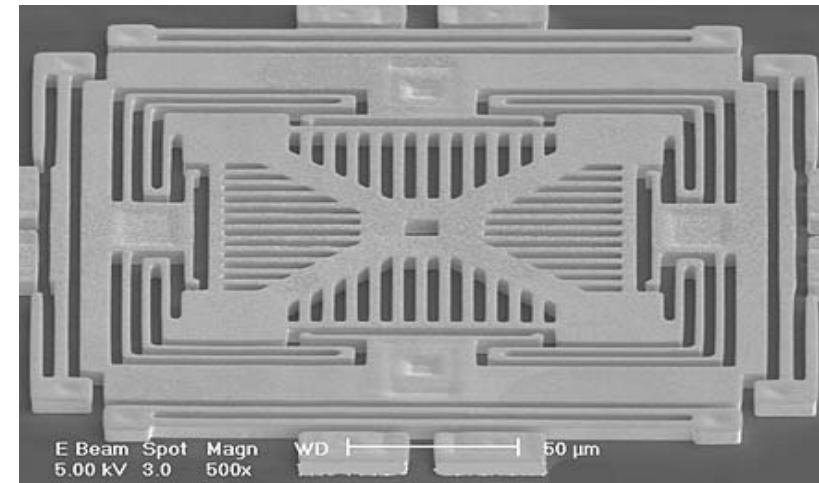
Motion input – device sensors (3)

- 9 total measurements → sensor fusion algorithm
→ 3 DOF absolute orientation
- Combine with position (GPS) → 6 DOF “pose”
- IMU data can also be used to estimate position
relative to some starting point
- High power consumption for all 3 sensors
→ only accelerometer enabled by default,
at low update rate (~ 1 measurement/sec.)

Motion input – MEMS (1)

Image source (FU): <http://archives.sensorsmag.com/articles/1203/20/fig1.jpg>

- *MEMS* = Micro ElectroMechanical Systems
 - Microscopic springs, weights, actuators etc. etched on silicon wafer
 - Same manufacturing process as for regular ICs
→ directly integrated with read-out electronics



MEMS Accelerometer
(electron microscopy)

Motion input – MEMS (2)

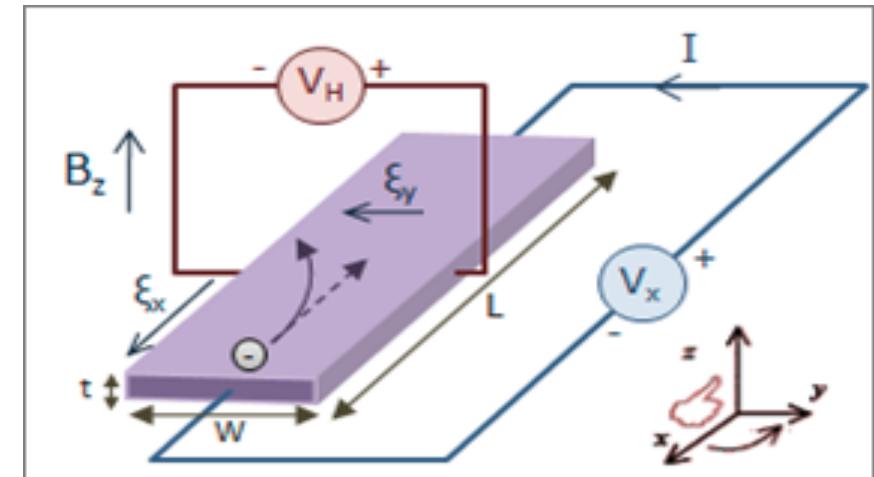
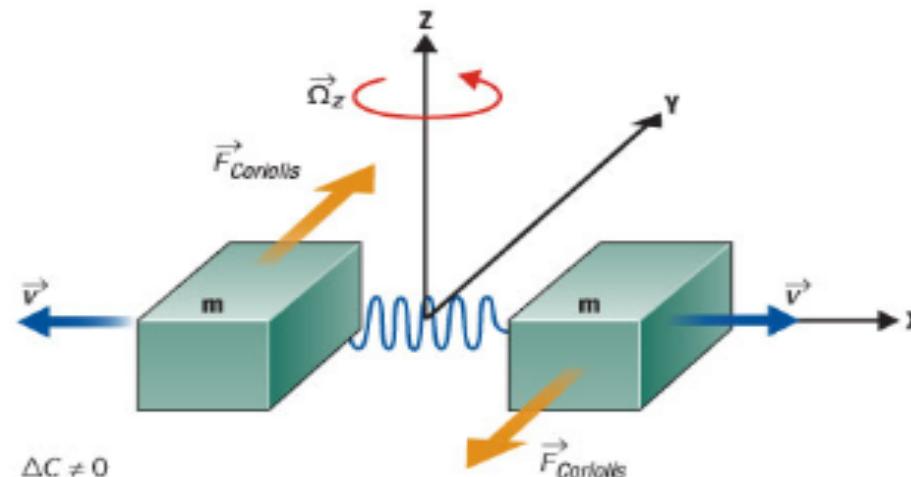
- Example measurements:
 - Force on spring-loaded weight → acceleration
 - Spring “stiffness” limits senseable range
 - Lateral force on vibrating weight → rotation
 - No rotating elements, despite “gyroscope” name
 - Hall effect current → magnetic field
 - Highly sensitive to stray magnetic fields, even from on-device power supply

Motion input – MEMS (3)

Image source (FU): <http://electroiq.com/blog/2010/11/introduction-to-mems-gyroscopes/>

Image source (PD): https://en.wikipedia.org/wiki/Hall_effect

- Vibrating Structure Gyroscope: measure lateral force F_{Coriolis} (= asymmetric displacement) on vibrating weights
- Hall effect sensor: measure V_H induced by magnetic field B_z



Motion input – MEMS calibration

See also: <https://electronics.stackexchange.com/questions/22144/magnetometer-%E2%88%9E-shaped-calibration>

- Magnetic field strength of earth constant
→ independent of measurement angle
- In reality: angle-dependent offset
(aka “hard iron”/“soft iron” effects)
- 8-shaped movement used for calibration
→ cover as many different angles as possible
→ calculate offsets and compensate errors

Motion input – add-on controllers

Image sources: (CC) own picture, (FU) <https://www.litho.cc/>

- Many flavours, usually with buttons, touchpad, IMU, BTLE
- e.g. Daydream controller (l), Litho (r), many clones



Motion input – muscle sensing

Image source (FU): <https://www.thalmic.com/en/myo/>

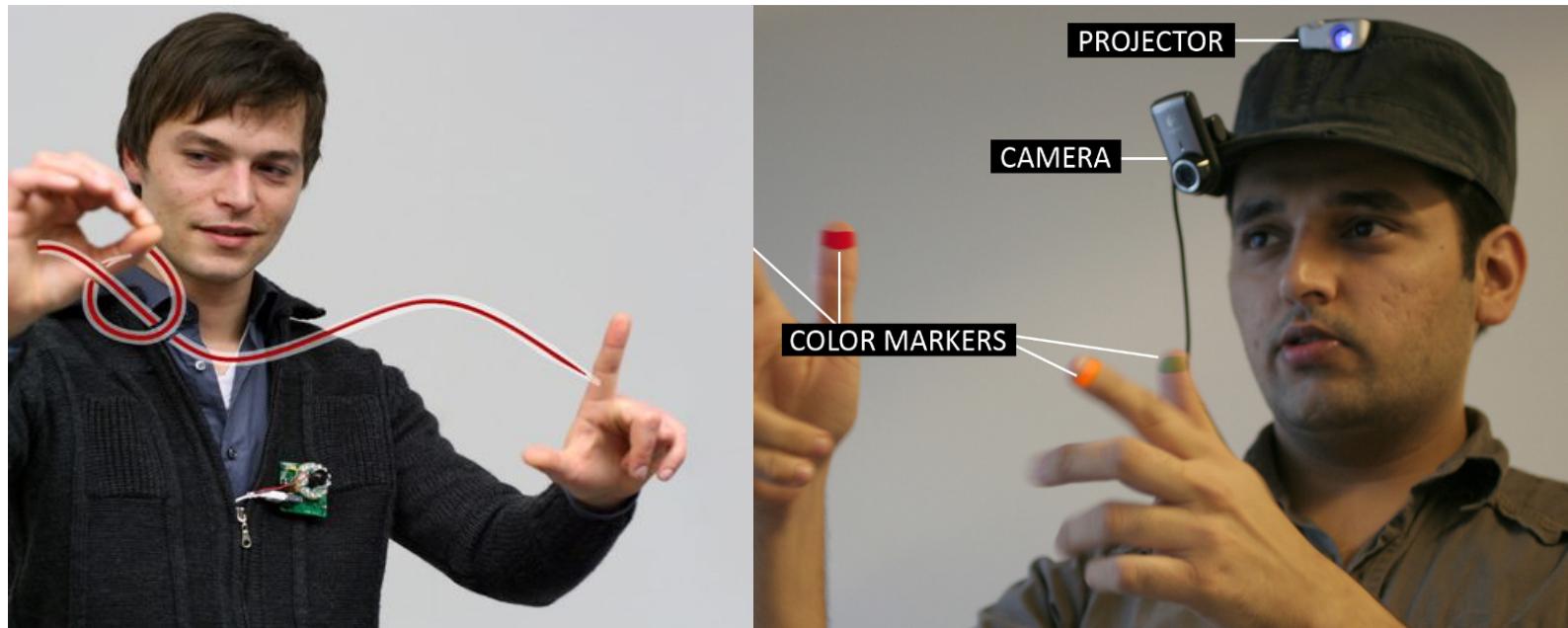
- Myo: EMG (electromyography) device
- Measures tiny electric currents created by muscle movement and tension
- Data can be used to infer hand/arm gestures
- Scenario: hands-free phone control



Motion input – free-air gestures

Image source (FU): <http://dl.acm.org/citation.cfm?id=1866033>, <http://dl.acm.org/citation.cfm?id=1667160>

- Imaginary Interfaces (l) & SixthSense (r)
- Both based on body-worn cameras



Motion input – deformation

Image source (FU): <https://dl.acm.org/citation.cfm?id=1979136>

- PaperPhone: Bend Gestures in Mobile Devices
- Borrows metaphors from physical paper
 - Earmarking
 - Flipping pages
 - ...

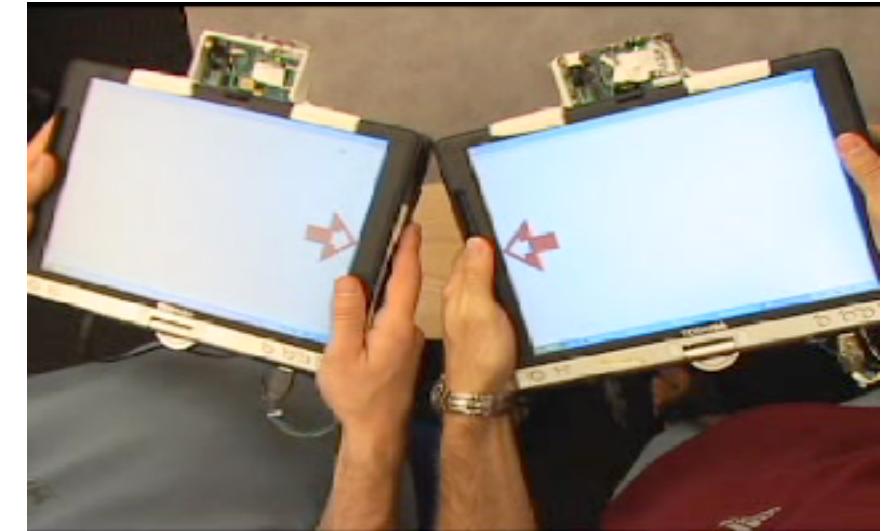


“PaperPhone: understanding the use of bend gestures in mobile devices with flexible electronic paper displays”,
Lahey et al., CHI 2011

Motion input – bumping

Image source (FU): <http://research.microsoft.com/en-us/um/people/kenh/papers/ubicomp03abstract.pdf>

- Bumping devices together creates connections/exchanges data
- Also (was) available as a contacts app
- How would you implement this?



“Bumping Objects Together as a Semantically Rich Way of Forming Connections between Ubiquitous Devices”, Hinckley et al., Ubicomp 2003

Motion output – “Shoe me the way”

Image source (FU): “Shoe me the Way”, M. Schirmer et al., MobileHCI 2015

- Vibration output: only binary?
- Can still encode numerical information
- E.g. directions (left/right) → use multiple vibration sources as spatial cues
 - In shoes
 - On belt
 - On vest
 - ...



Motion output – user itself? (1)

Image source (FU): http://www.antalruhl.com/media_tech/gvs.htm

- Galvanic Vestibular Stimulation (GVS)
 - Low current stimulates inner ear
 - Affects sense of balance
 - Can (theoretically) be used for navigation and to compensate motion sickness in VR



Motion output – user itself? (2)

Image source (FU): <https://dl.acm.org/citation.cfm?id=2481355>

- Muscle-propelled Force Feedback
 - Electrodes cause involuntary muscle movement
 - Feels like force exerted by device on its own
- Issues:
 - Electrode attachment
 - Safety considerations



"Muscle-propelled force feedback: bringing force feedback to mobile devices", Lopes et al., CHI 2013

Motion output – “breathing phone”

Image source (CC): <http://www.fabianhemmert.com/projects/shape-changing-mobiles>

- Change various parameters of mobile device
 - Shape, thickness, center of gravity, ...
- Use them to convey “ambient information”
 - E.g. slow, regular breathing
→ no missed calls,
no new texts



Motion: summary

- Motion input:
 - Device motion sensed by 3-9 MEMS sensors
 - User motion sensed via device or camera
- Motion output:
 - Mostly vibration in commercial devices
 - Some weird/interesting research concepts

The End

