Mobile Information Systems

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

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I/O on mobile devices

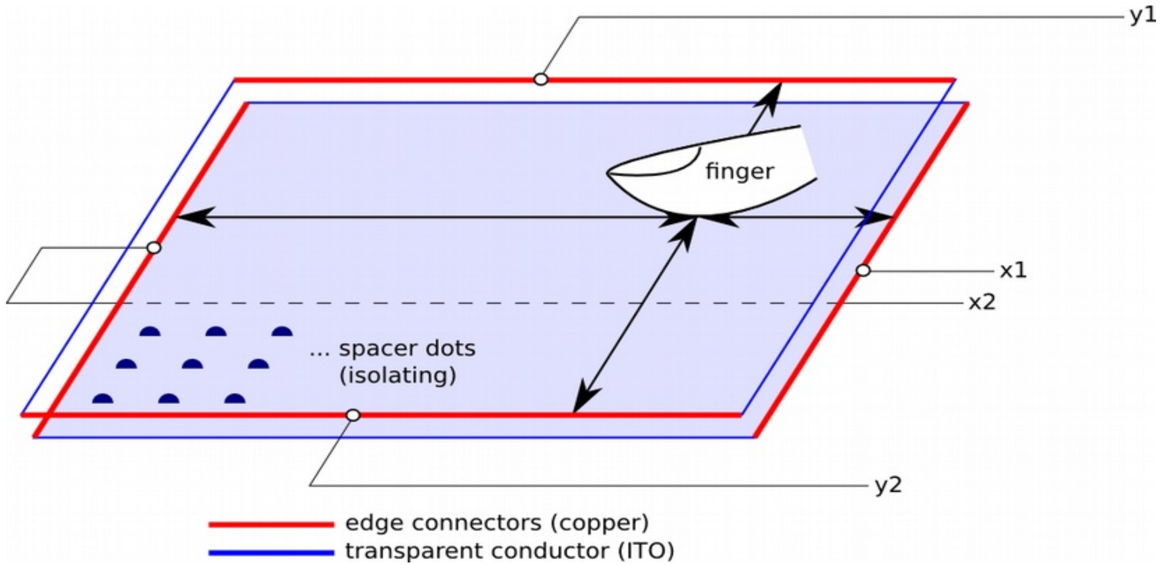
- Issues, revisited
  - Today: Touch, gestures, motion
  - Next week: Vision & other I/O channels
- Solutions
  - Common (commercial) approaches
  - Research projects

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

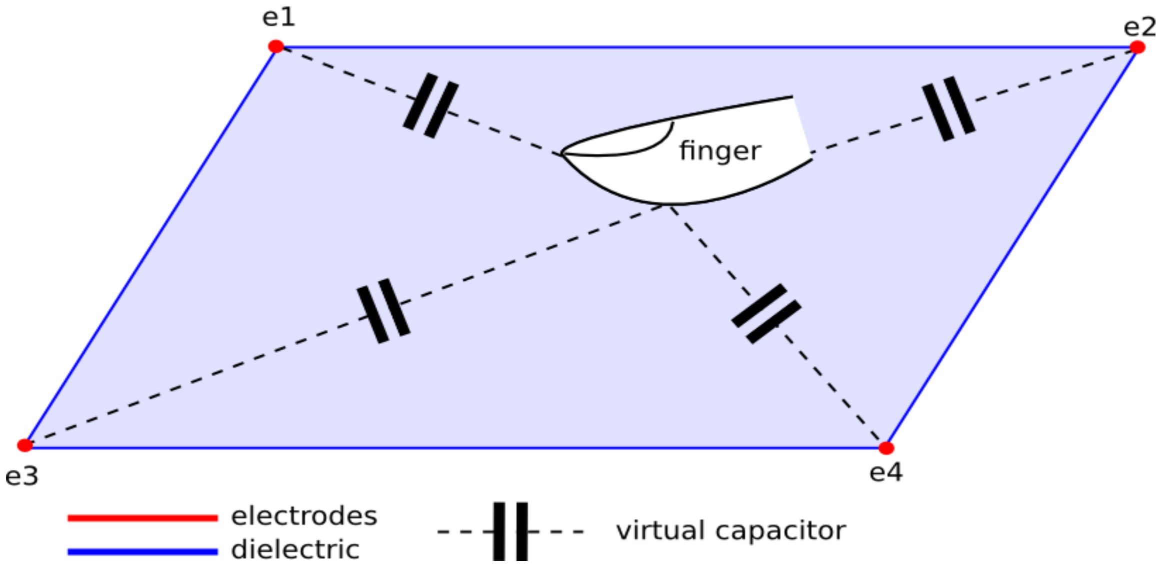
Touch – technology: resistive

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



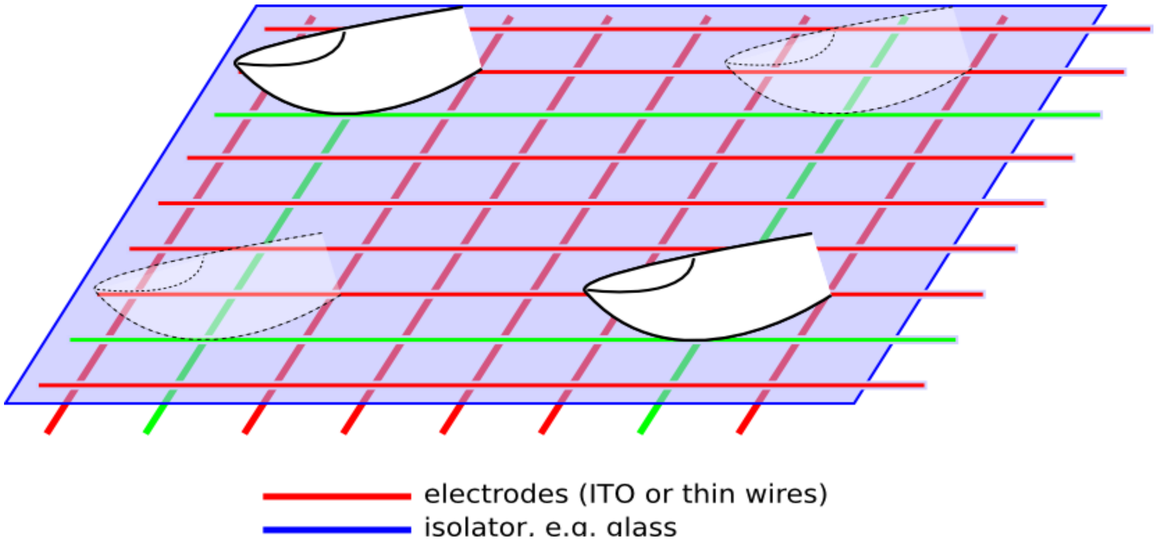
Touch – technology: capacitive (1)

- 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

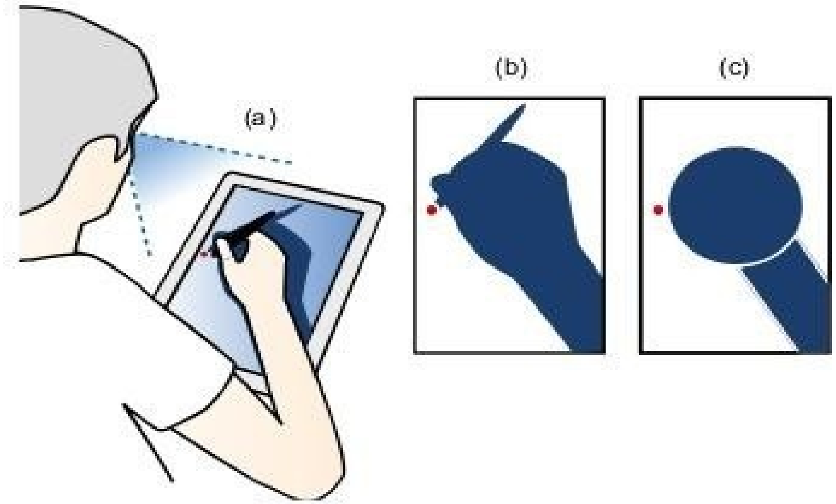
- "Tactile Touch Screen" using electrovibration
  - Static electric charge on whole screen, modulated relative to finger position
  - Modifies friction screen ↔ finger
  - Creates feeling of ridges & valleys
  - Only single-touch

"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

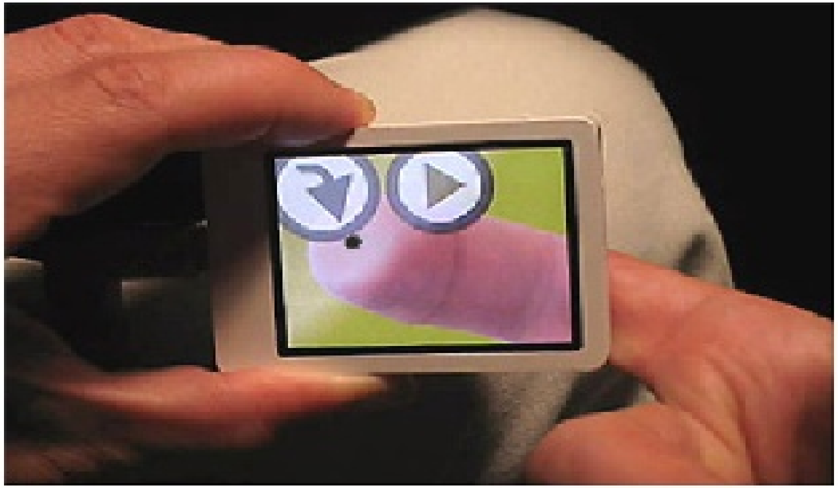


"Hand Occlusion with Tablet-sized Direct Pen Input", Vogel et al., CHI 2009

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



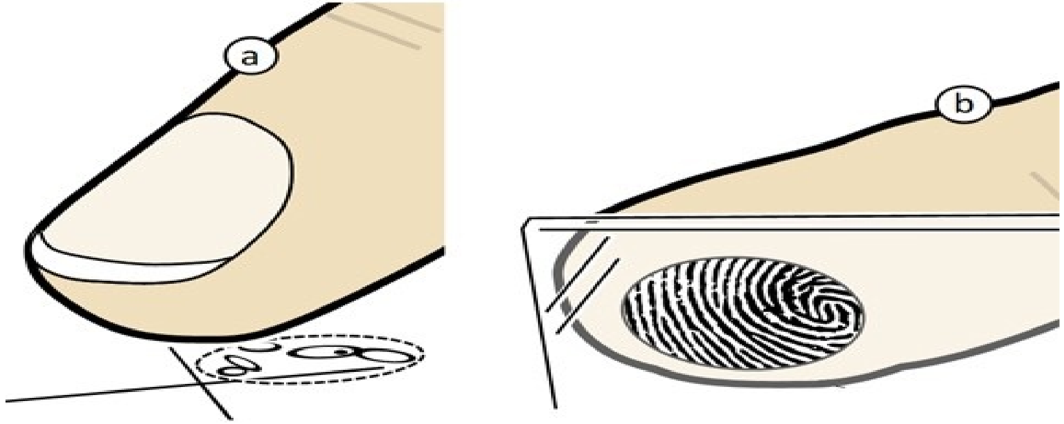
"Back-of-device Interaction allows creating very small touch devices", Baudisch et al., CHI 2009

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

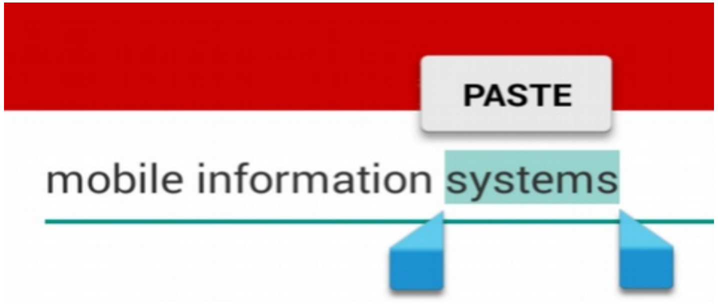


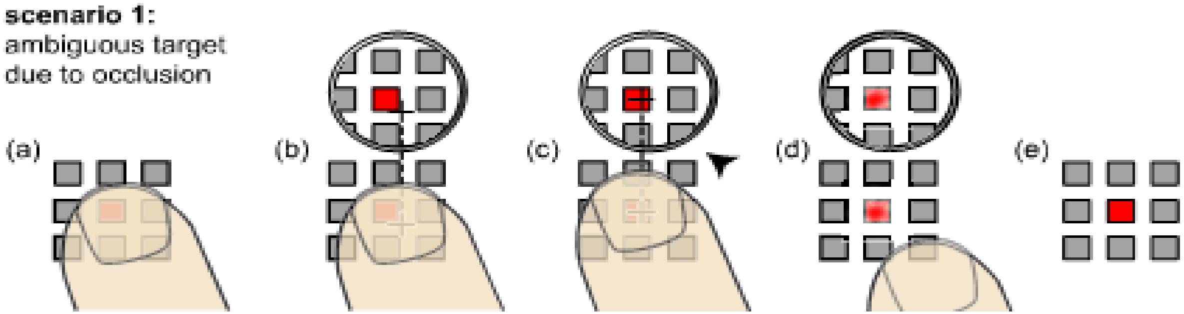
Touch – precision (2)

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

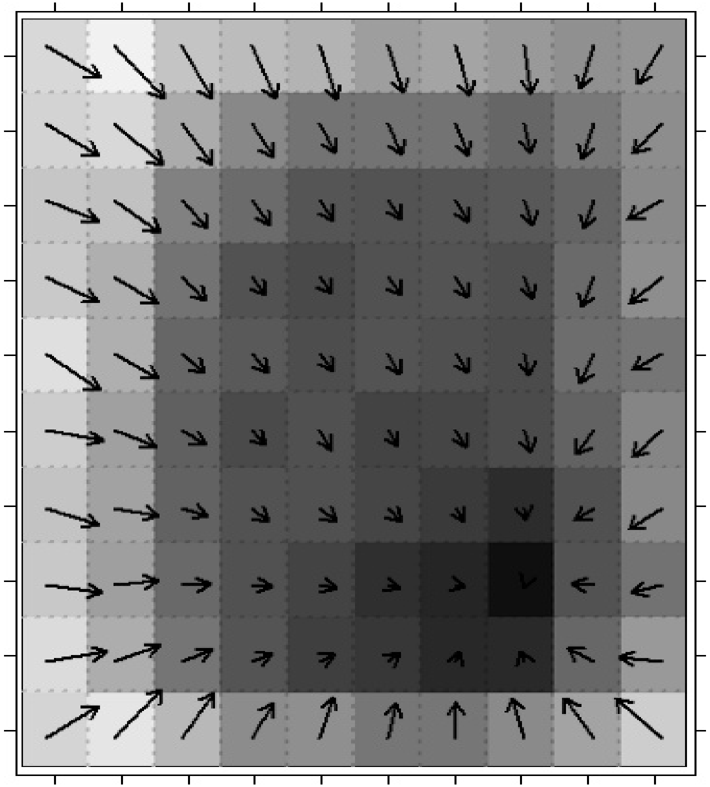




Touch – precision (3)

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



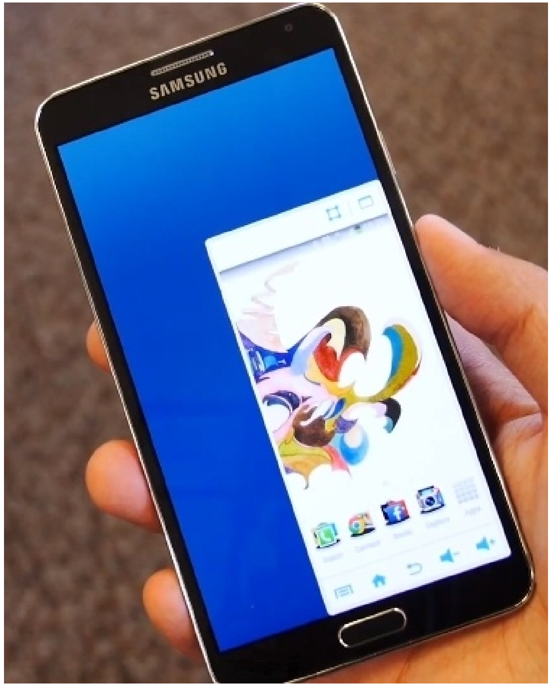
Offset vectors for Samsung Galaxy S

"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

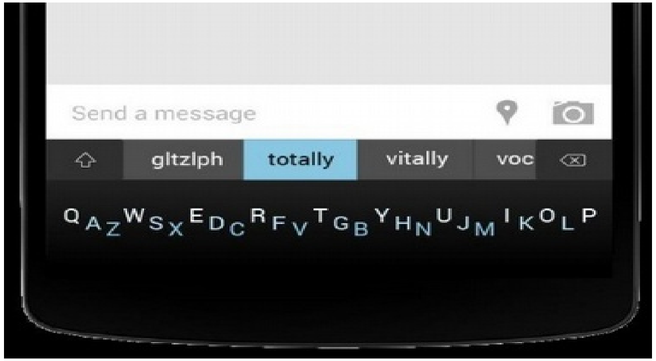
iOS

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)



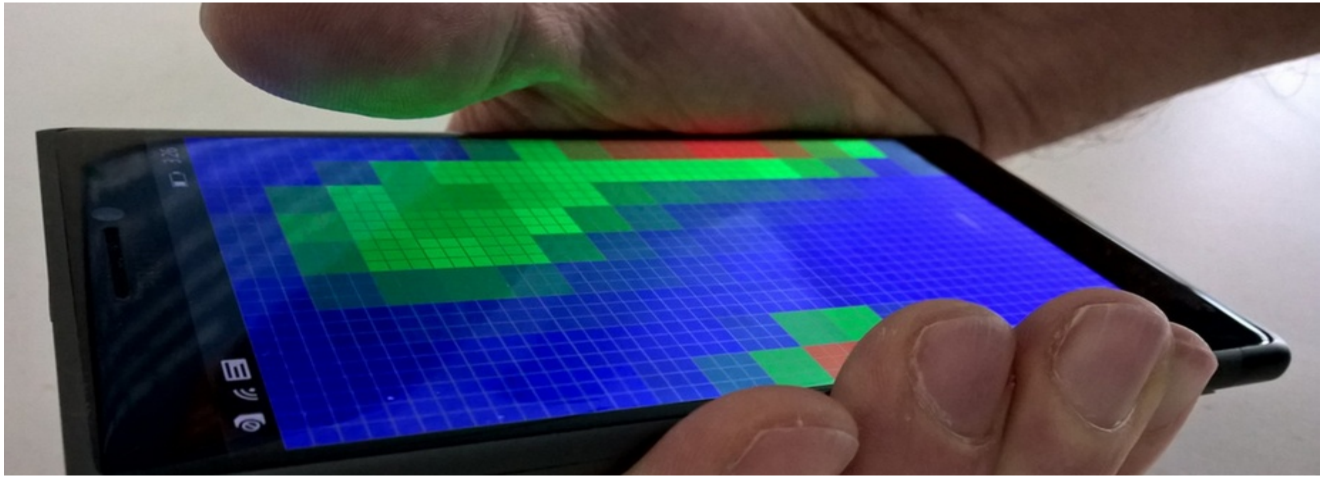
Touch – hover state (1)

- 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, ...



Touch: summary

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

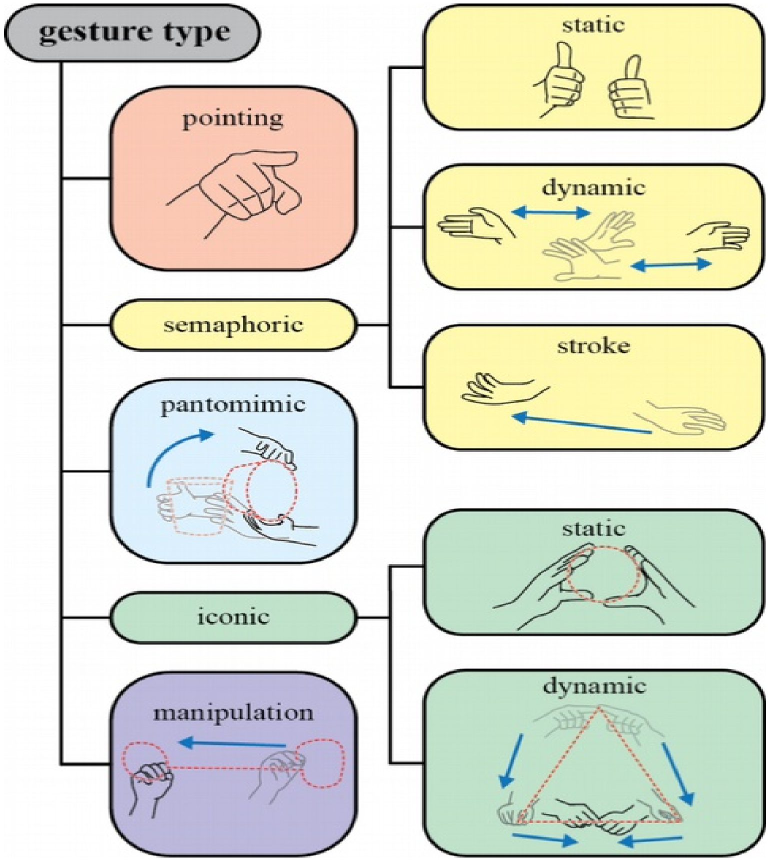
I/O issues: gestures (recap)

- 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

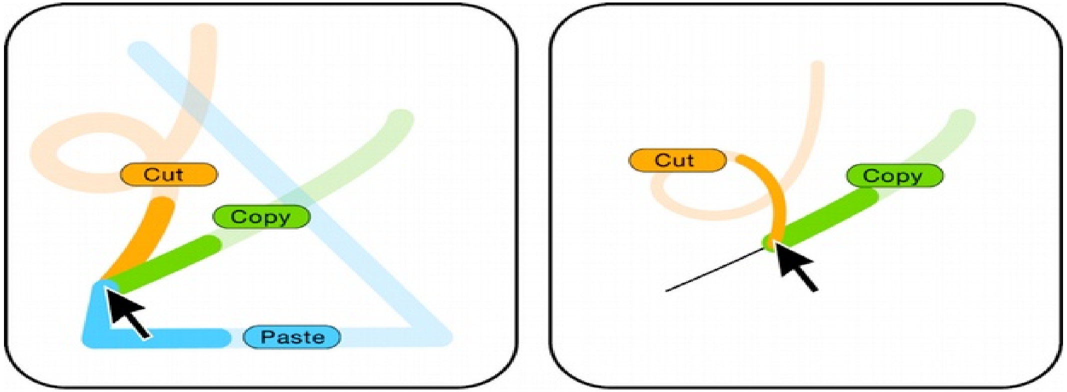
- Taxonomy
  - Pointing/"deictic"
  - Semaphoric
    - Gesticulation, sign language?
  - Pantomimic
    - Describes actions
  - Iconic
    - Conveys shapes
  - Manipulation
    - Implies physical link



Gestures – discoverability (1)

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

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

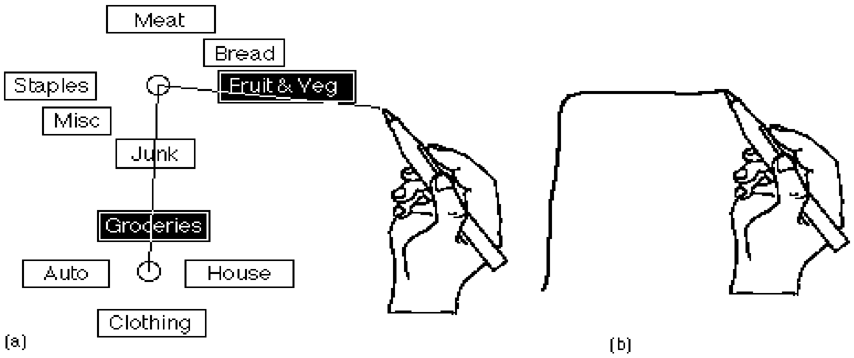


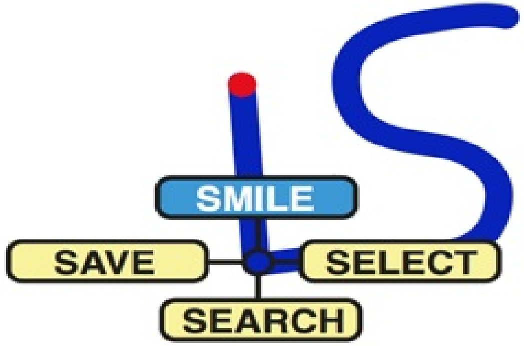
"OctoPocus: A Dynamic Guide for Learning Gesture-Based Command Sets", Bau et al., UIST 2008

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



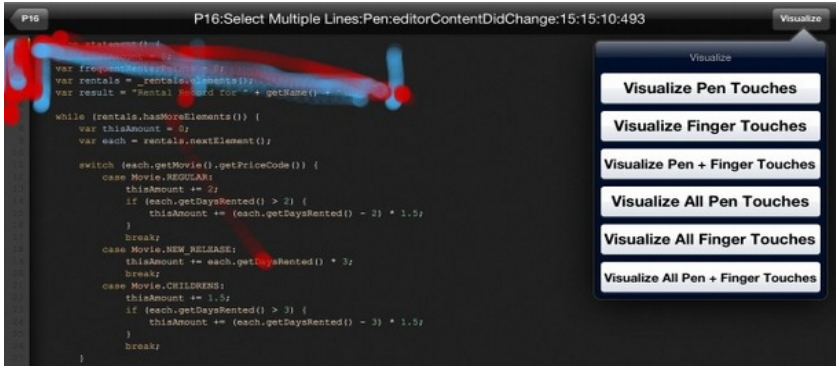


Gestures: what is “natural”?

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?

Visualization of gestures for “Select Multiple Lines”



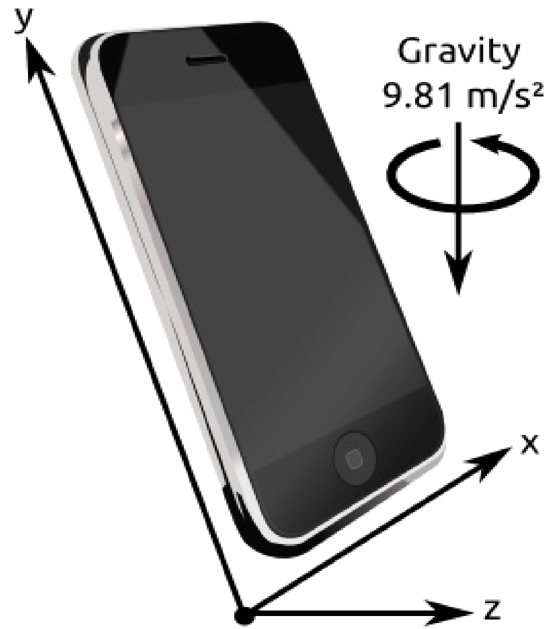
RefactorPad: editing source code on touchscreens, Raab et al., EICS 2013

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

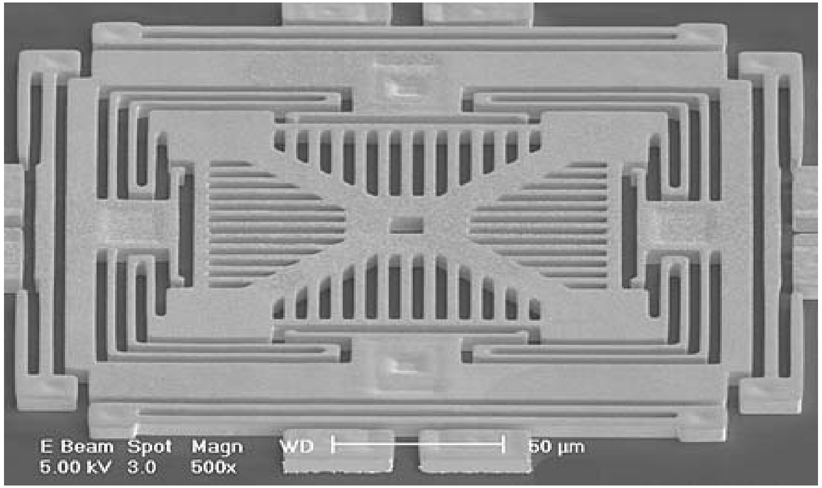
Motion input – device sensors (3)

- 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)

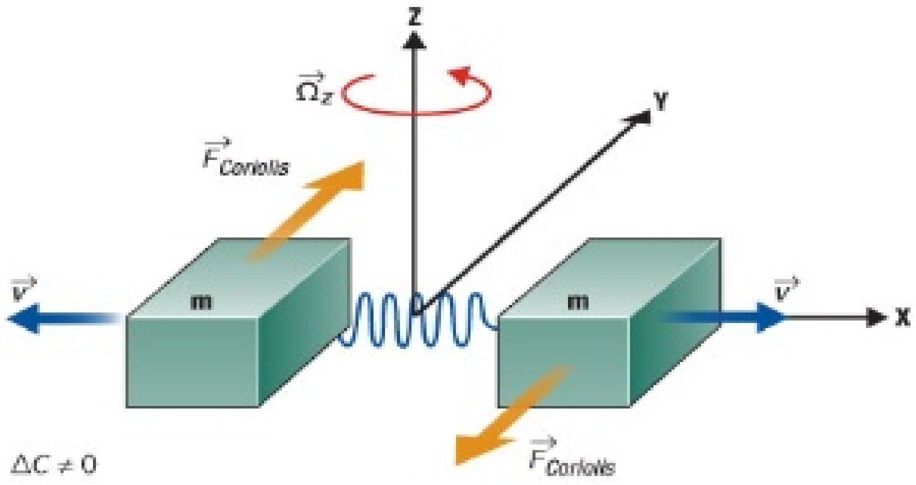
Motion input – MEMS (2)

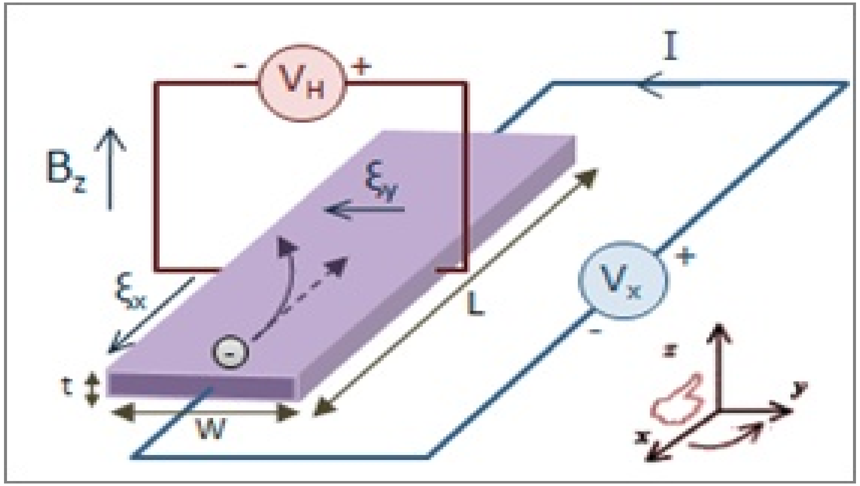
- Example measurements:
  - Force on spring-loaded weight → acceleration
    - Spring “stiffness” limits senseable range
  - Lateral force on vibrating weight → rotation
    - No rotating elements, despite “gyroscope” name
  - Hall effect current → magnetic field
    - Highly sensitive to stray magnetic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

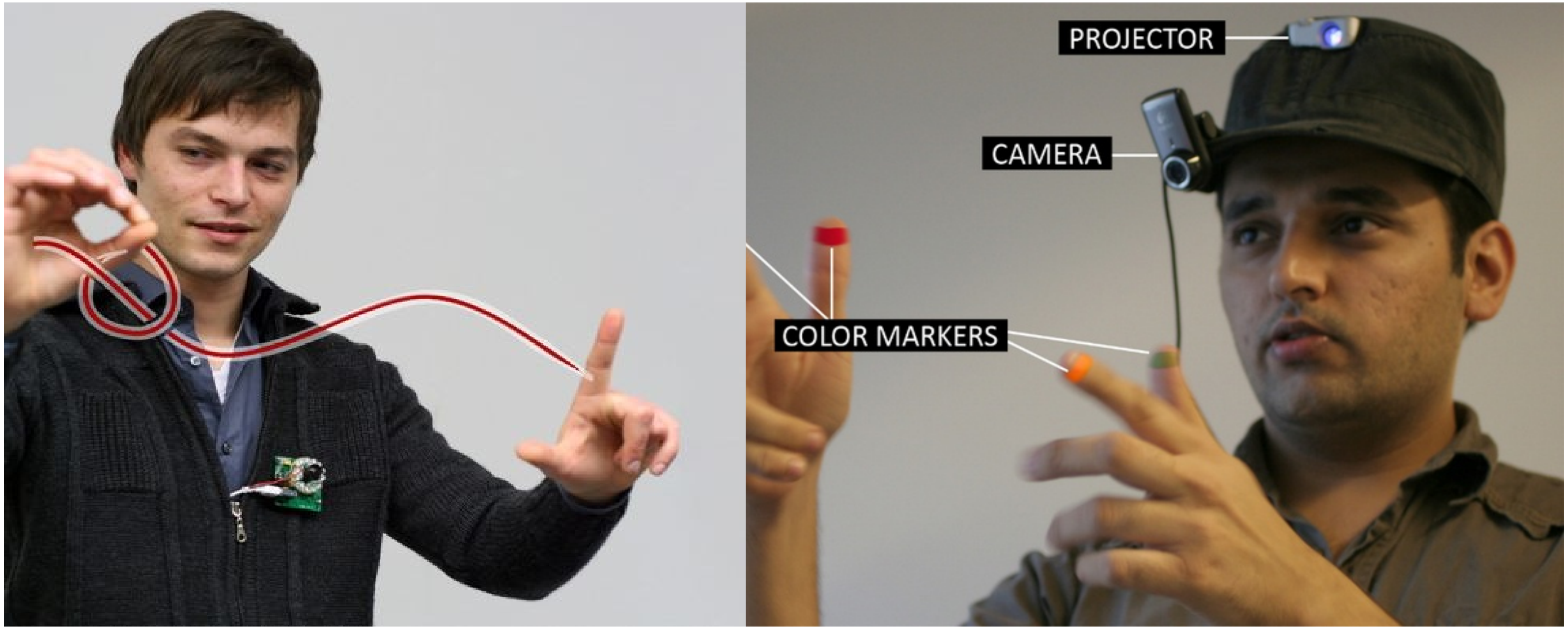
Image source (FU): https://www.thalmic.com/en/myo/

- 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

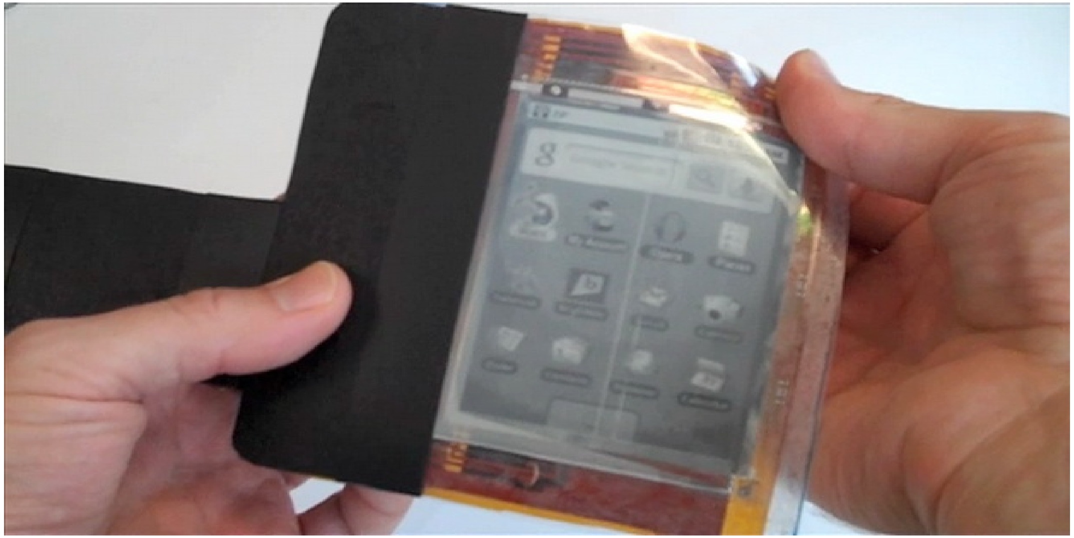
- Imaginary Interfaces (l) & SixthSense (r)
- Both based on body-worn cameras



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
  - ...

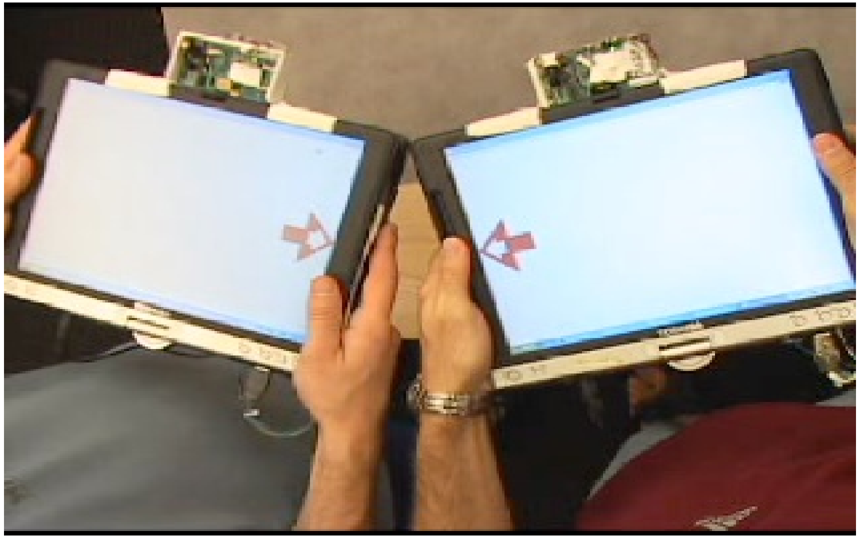


"PaperPhone: understanding the use of bend gestures in mobile devices with flexible electronic paper displays", Lahey et al., CHI 2011

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”

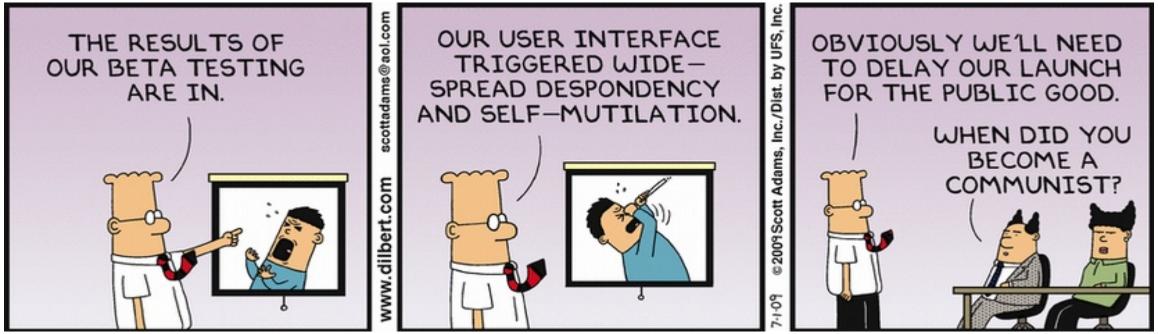
Image source (CC): http://www.fabianhemmert.com/projects/shape-changing-mobiles

- 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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