Interaction Techniques for Mobile Devices

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Research Topics

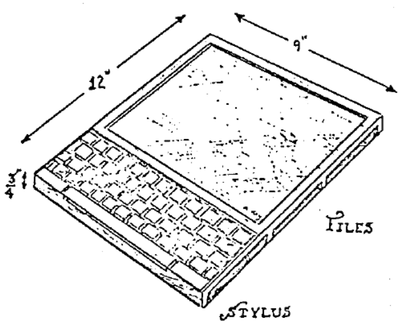
- Mobile human-computer interaction
  - Interaction techniques and devices
  - Evaluation methods and models for mobile HCI
  - Sensor-based interaction
  - Applying computer vision in HCI
- Physical-virtual integration
  - Context: Objects, places, people
  - Device as mediator for environment
  - Device ensembles
- Mobile devices as a new medium
  - Persuasive technology
  - Mobile educational games
  - Mobile social networking

Early Mobile Devices

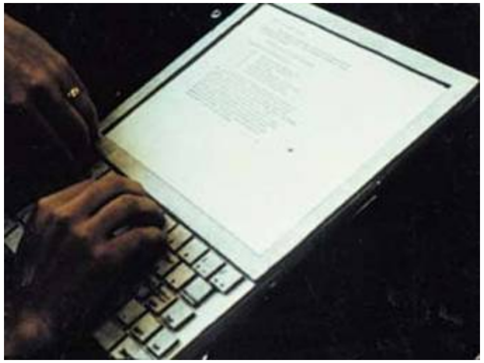
- 1946 AT&T first commercial mobile phone service for private customers
  - Mounted in vehicles
  - Weighted 80 lbs
- 1972 Motorola prototype for Portable Radio Telephone
  - First mobile phone call April 3, 1973
  - DynaTAC 8000x first mobile telephone
    - could connect to the telephone network
    - could be carried by the user
  - www.cbc.ca/news/background/tech/cellphones/firstcellphone.html

Martin Cooper (considered the inventor of the mobile phone)

Alan Kay’s Dynabook (1968)



- Vision of a mobile computer with focus on UI
- A portable interactive personal computer, as accessible as a book

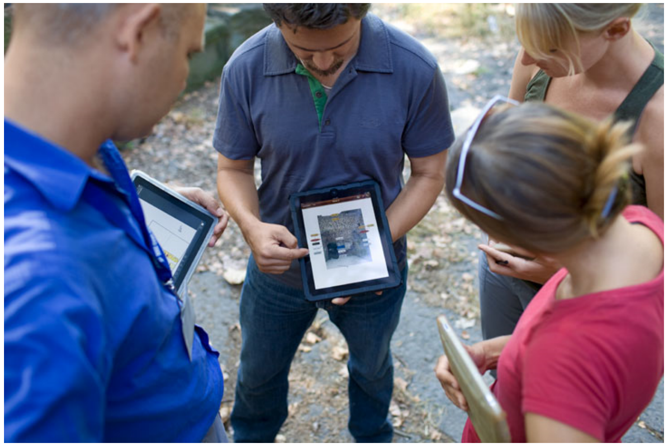


- Envisioned as a learning aid for children
- Problem: software that facilitates dynamic interactions between the computer and its user
- “The Dynabook will have considerable local storage and will do most computing locally, it will spend a large percentage of its time hooked to various large, global information utilities which will permit communication with others of ideas, data, working models, as well as the daily chit-chat that organizations need in order to function. The communications link will be by private and public wires and by packet radio.”

http://www.artmuseum.net/w2vr/archives/Kay/01_Dynabook.html

Special Application Areas for Mobiles

- Field work supported by tablet PCs
- Example: Work in archaeological sites
  - Capture notes and images
  - Exchange data
  - Match items to databases



- Source: www.apple.com/ipad/pompeii

Mobile Interaction is Usage in Context

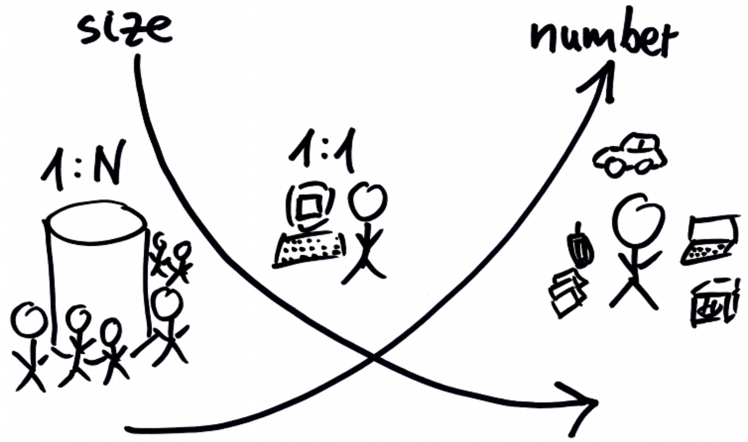
- Primary real-world task

Adapted from a slide by Albrecht Schmidt

Watch for cars when wearing headphones

Adapted from a slide by Albrecht Schmidt

Ubiquitous Computing



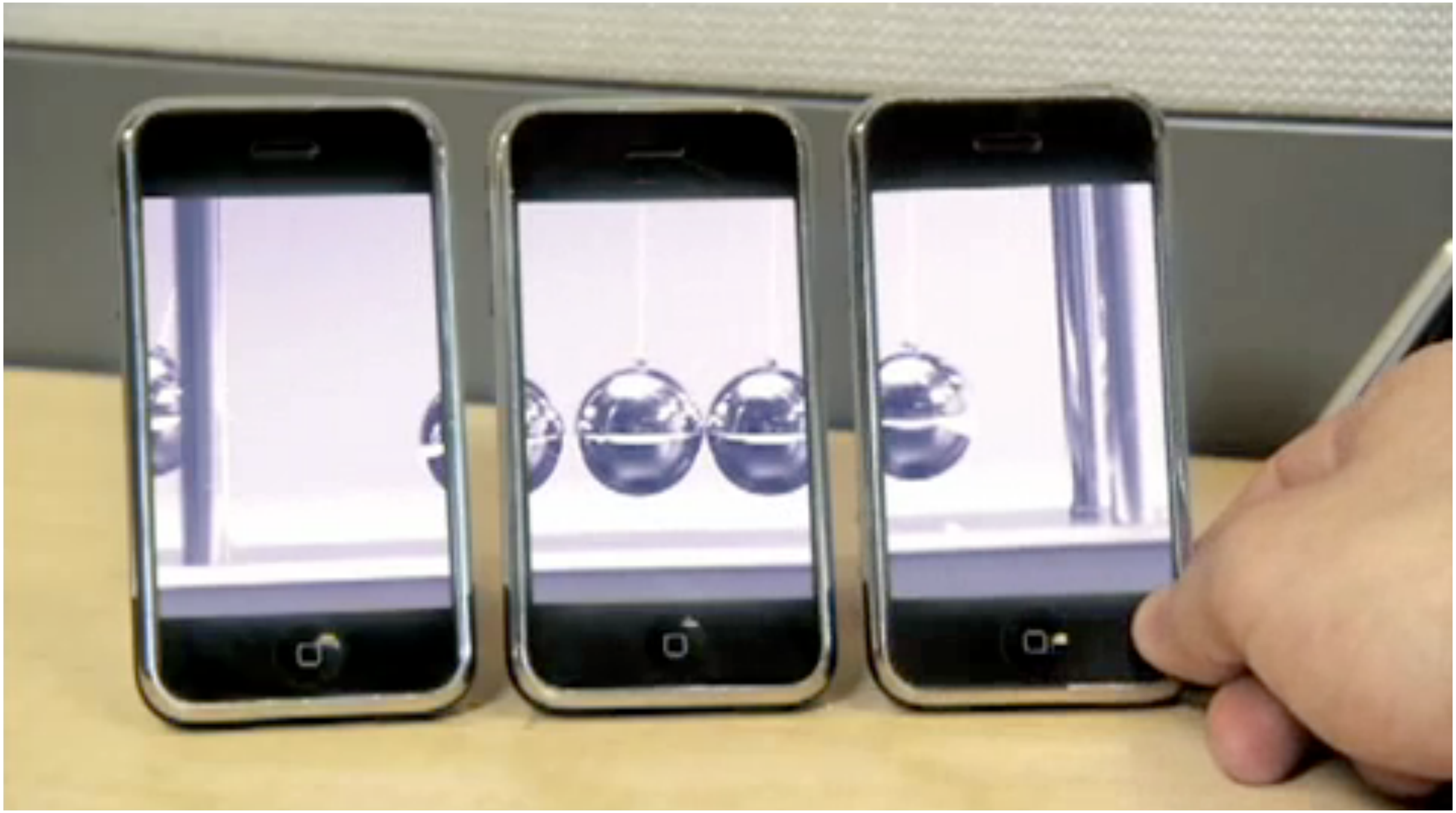
"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."

Mark Weiser

- Computers embedded in everyday things
- Technology moves into the background
- Computers in the world, instead of world in the computer

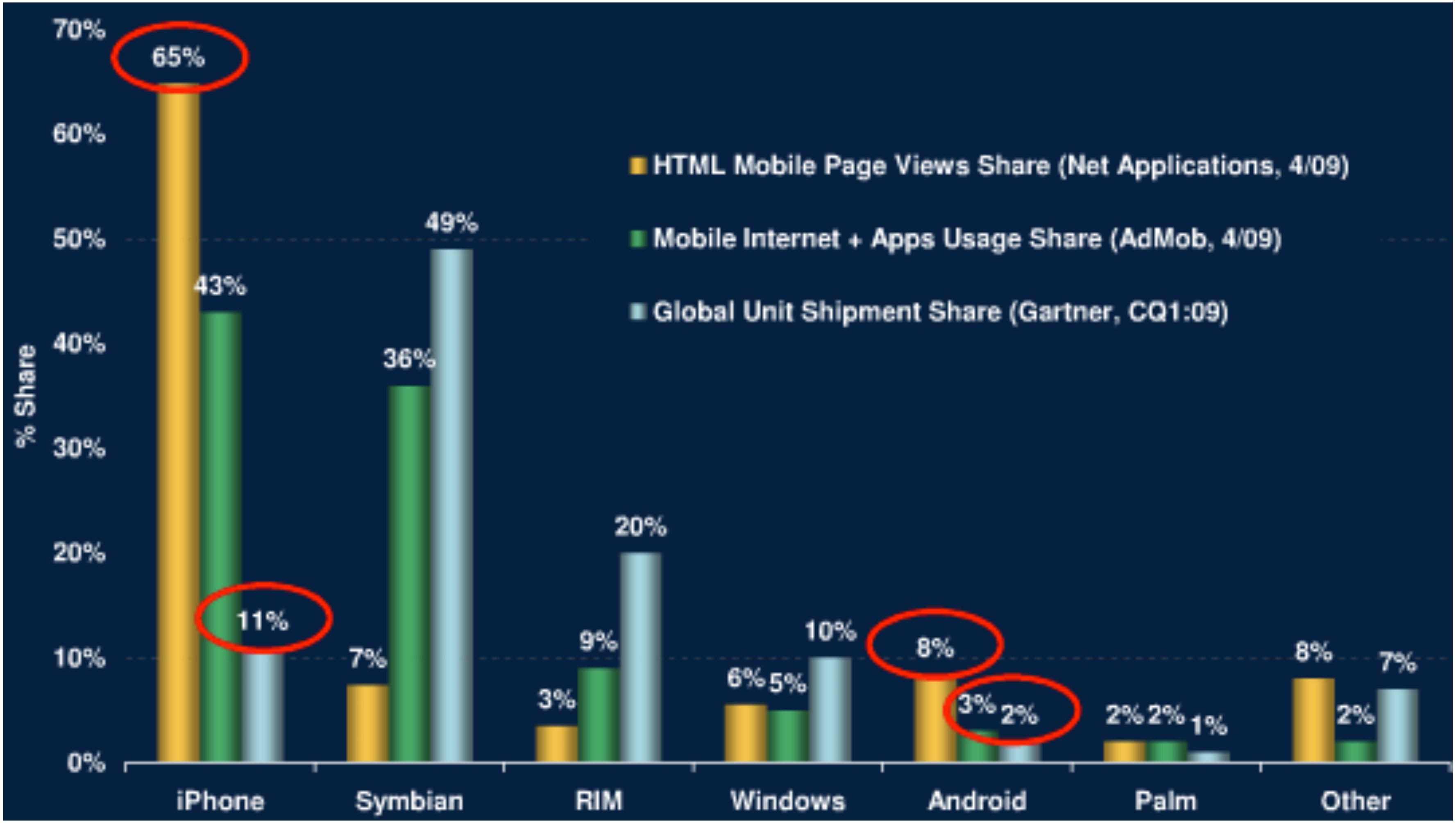
- Mobile devices as always available mediators
- Entry point into the digital world

What can you do with your phone?



http://www.youtube.com/watch?v=Pgsw-NgDoFE

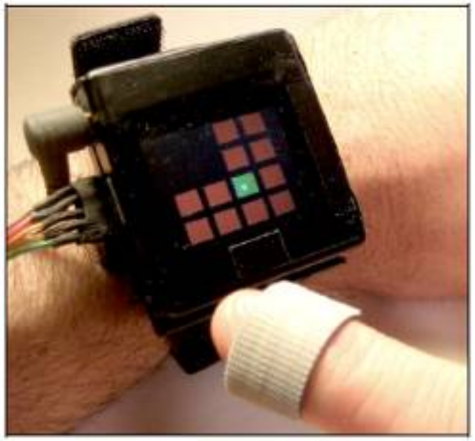
iPhone / Android: Mobile Web Share > Shipment Share

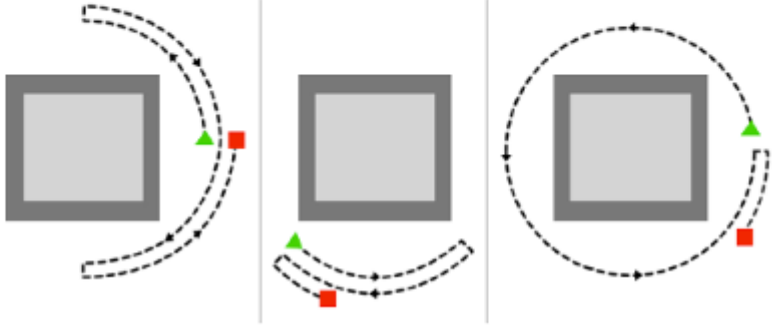


Source: Morgan Stanley, 2009

Magnets as Input Devices

- "Abracadabra" (Harrison, Hudson)
  - Wireless, unpowered, high fidelity finger input for mobile devices
- Extending the input area beyond the device
- User study: 92% selection accuracy for 16º radial targets

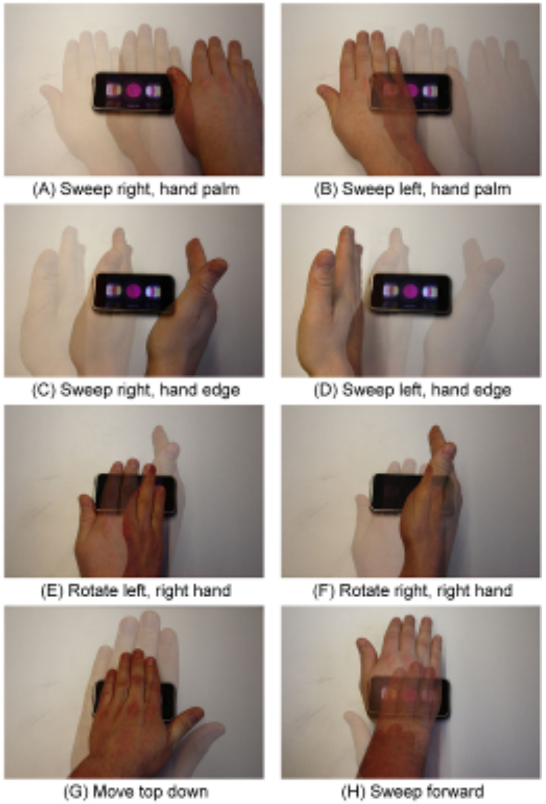




Harrison, Hudson: Abracadabra: Wireless, High-Precision, and Unpowered Finger Input for Very Small Mobile Devices. UIST 2009.

Around-Device Interaction with IR Distance Sensors

- Interaction beyond the physical device
  - Scales down to very small devices
- Include the space around the device
  - Coarse movement-based gestures
  - Static position-based gestures
- Prototype: IR distance sensors

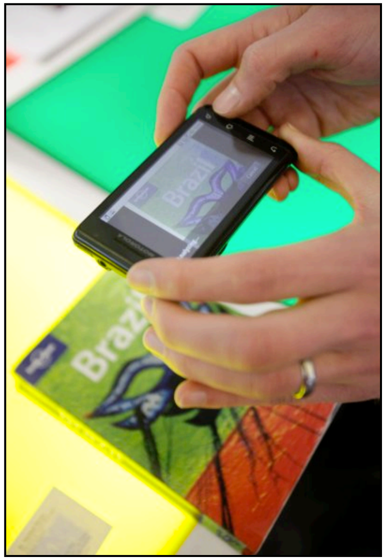


(A) Sweep right, hand palm
(B) Sweep left, hand palm
(C) Sweep right, hand edge
(D) Sweep left, hand edge
(E) Rotate left, right hand
(F) Rotate right, right hand
(G) Move top down
(H) Sweep forward

Kratz, Rohs: HoverFlow: Expanding the Design Space of Around-Device Interaction. MobileHCI 2009.

Visual Search: Camera Phones Recognize the World Around Us

- Example: Google Goggles for Android
  - Visual search queries for the Web
  - Recognizes a wide range of artifacts
  - Landmarks, barcodes, book covers, etc.
  - Text translation
- Future?
  - Plants, cars, faces?



Visual Code Widgets (2004)

- Printable user interface elements
  - Embedded in user's environment
  - Camera phone as "see-through tool"

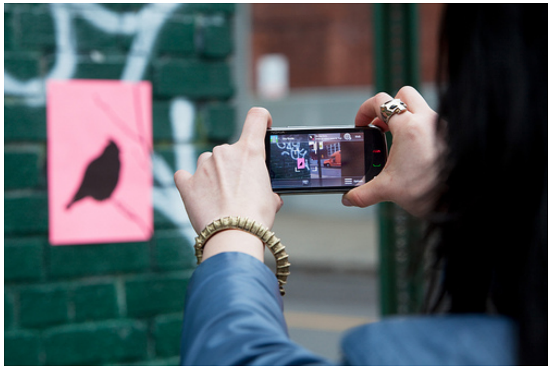
Handheld Augmented Reality Games on Cereal Boxes: “Penalty Kick” (2005)

Mobile Augmented Reality Applications

Layar

Wikitude

WikEye



Nokia Point & Find

Google Goggles

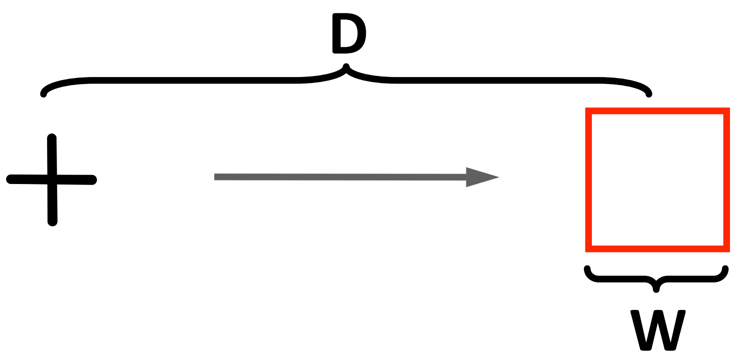
Image courtesy of VentureBeat

Pointing Tasks with Camera Phones

- Target acquisition in 3D space
  - Device movement in 3D space around the user (pointing “in the air”)
  - Targets with variable characteristics
- Augmentation through narrow viewport: “magic lens”
  - Noticeable system delay
  - Limited display update rate
  - Gaze deployment between display and background
- See-through interface → visual feedback loop

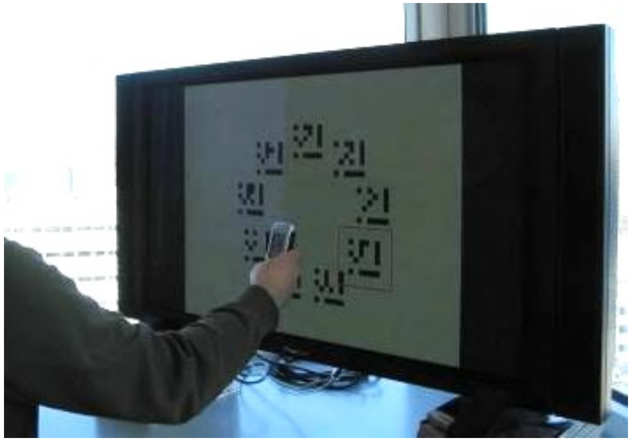
Modeling Mobile AR Pointing with Fitts' Law?

- Goal-directed movement onto target



- $MT = a + b \log_2 (D / W + 1)$

- Lab study (Rohs, Oulasvirta, 2008):
  Fitts' law does not accurately predict movement time for see-through AR pointing

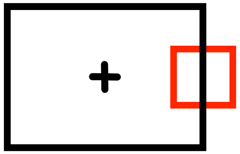


Analysis of Mobile AR Pointing Task

- Task: Move cursor onto target

- Phase 1: Target directly visible
  Task 1: Move lens over target

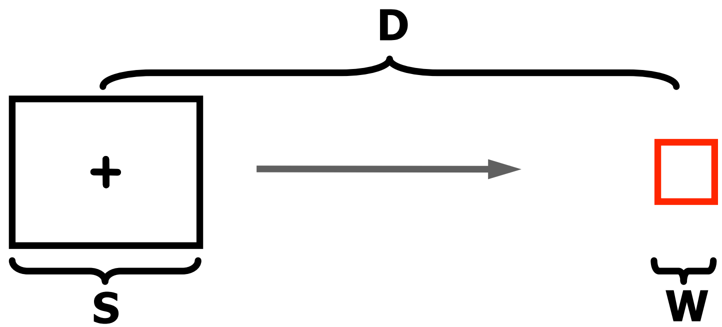
- Phase 2: Target behind display
  Task 2: Move crosshair over target



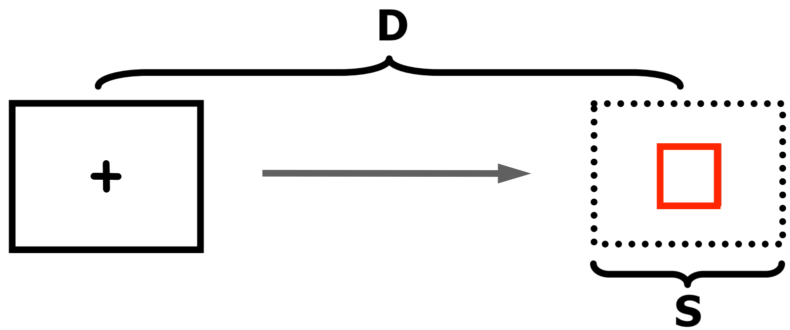
(Rohs, Oulasvirta, Target Acquisition with Camera Phones when used as Magic Lenses. CHI 2008)

Analysis of Mobile AR Pointing Task

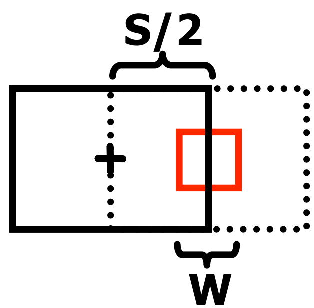
- Task: Move cursor onto target



- Phase 1: Target directly visible
  $MT_p = a_p + b_p \log_2(D / S + 1)$



- Phase 2: Target behind display
  $MT_v = a_v + b_v \log_2(S/2 / W + 1)$

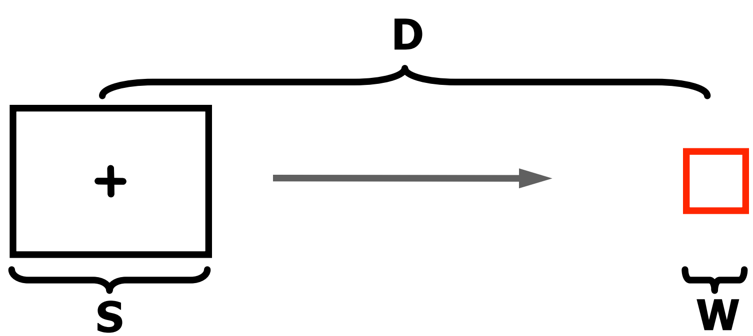


(Rohs, Oulasvirta, Target Acquisition with Camera Phones when used as Magic Lenses. CHI 2008)

Model for Mobile AR Pointing

- Two-component Fitts' law model

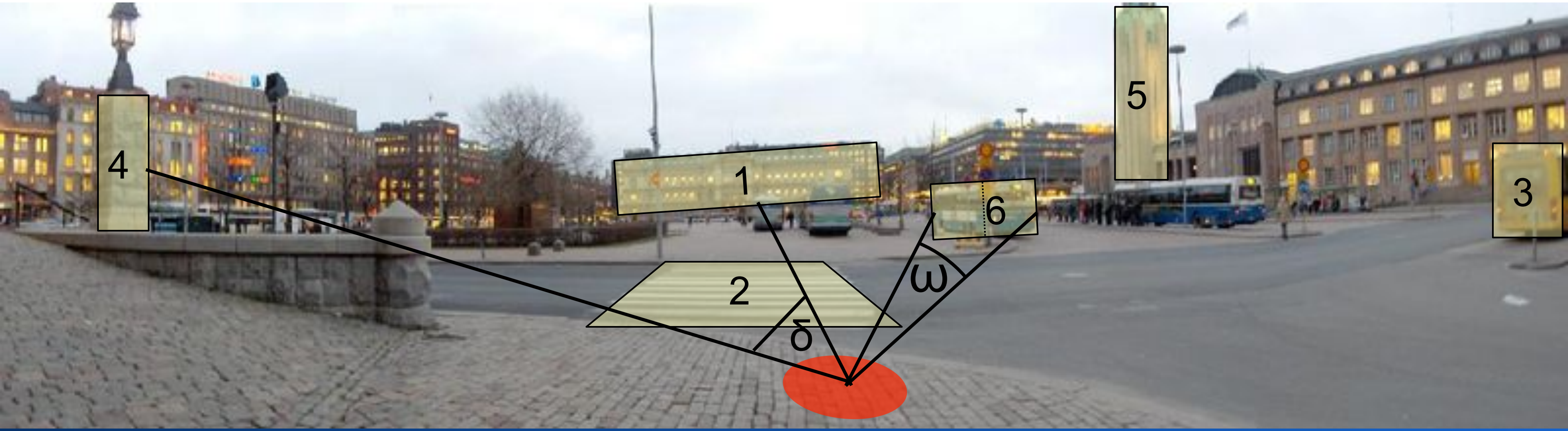
- $MT = a + b \log_2(D / S + 1) + c \log_2(S/2 / W + 1)$



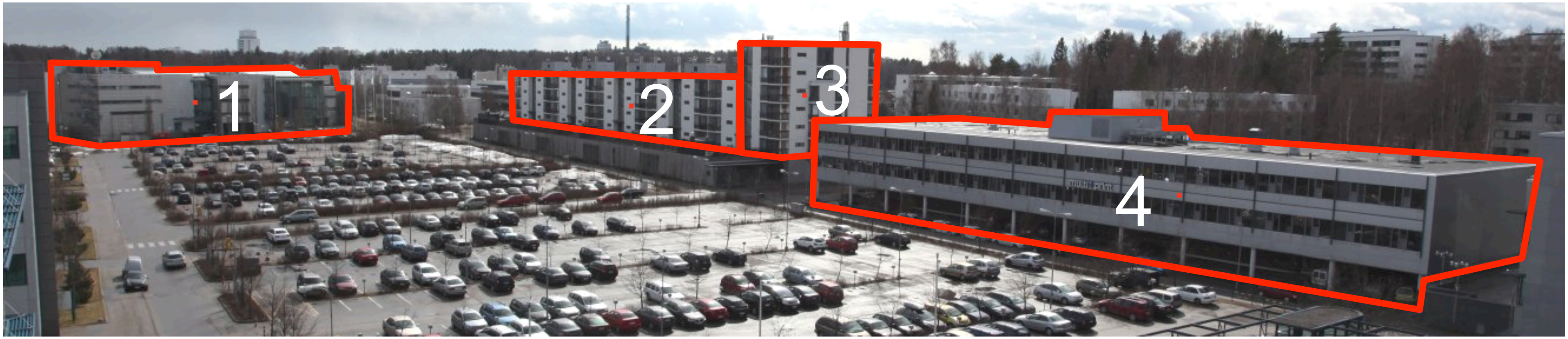
(Rohs, Oulasvirta, Target Acquisition with Camera Phones when used as Magic Lenses. CHI 2008)

Mobile AR Pointing in the Real World

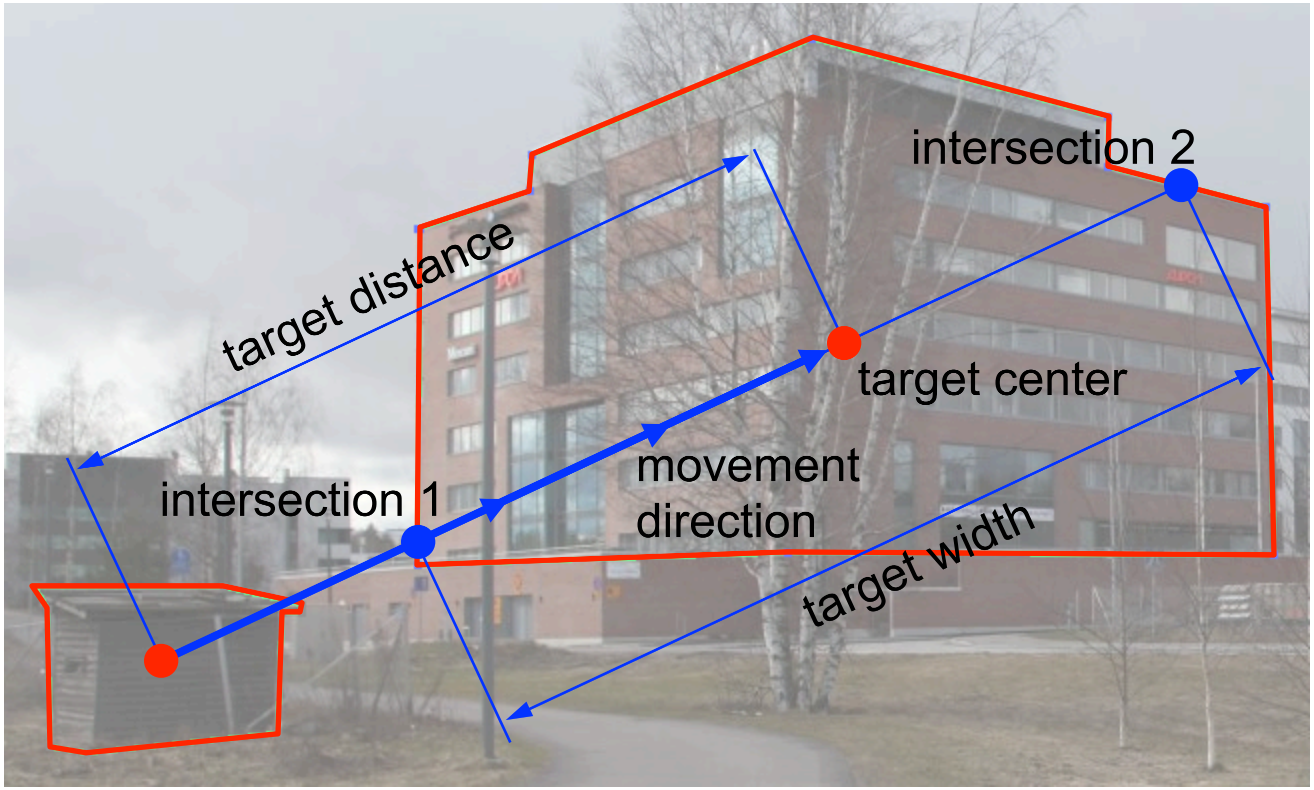
- Real world study
  - 3D targets, varying shape, size, z-distance, visual context
  - Angular measure of target distance δ and size ω



Example Sites from Users' Perspective

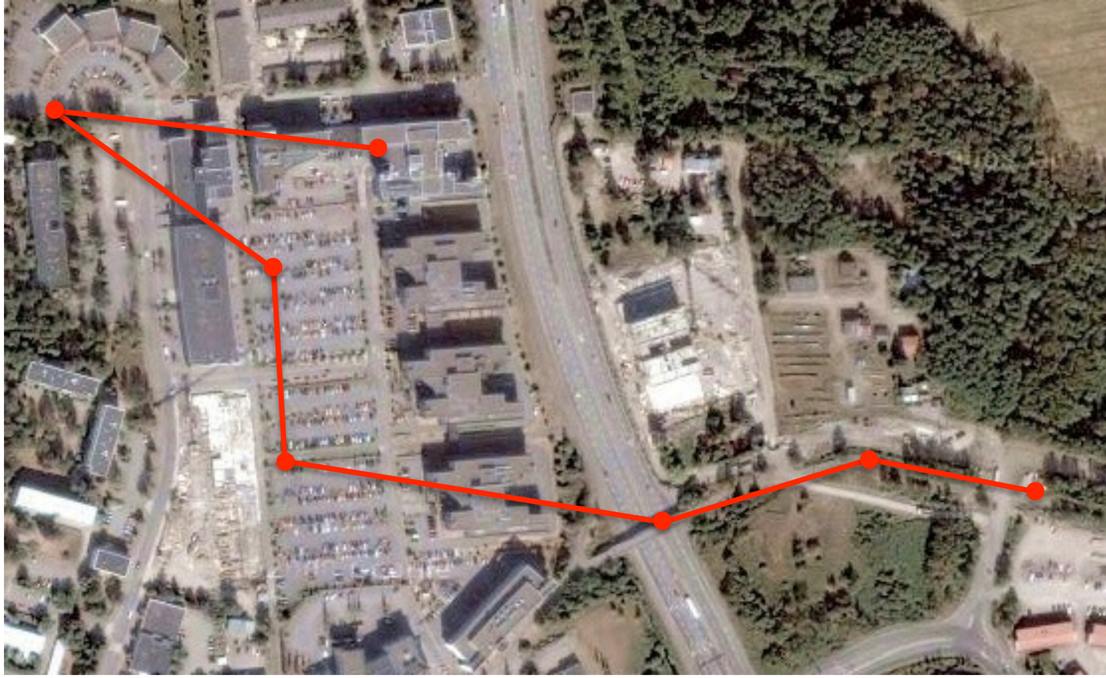


Non-Uniformly Shaped Targets



- Target center is centroid of target area
- Target width measured along movement direction

Experiment



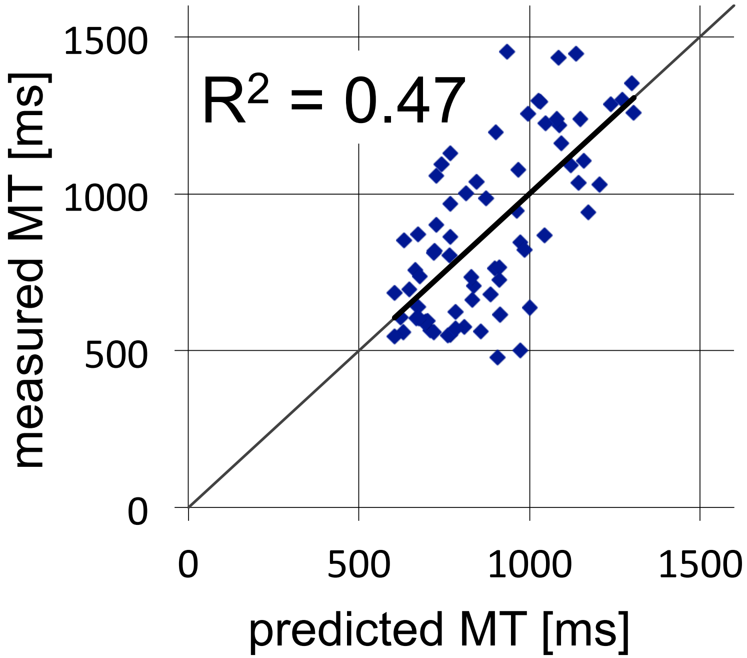
- 12 participants x 7 sites x 6 target pairs x 24 selections
- Reciprocal pointing task
- ID = 0.72..3.91, D = 6.8°..74.8°, W = 2.3°..35.3°, S = 42.5°
- Saving viewfinder image & timestamp on selection
- Manual post-hoc analysis of selection points

Results

MT_{avg} = 885 ms, errors = 2%

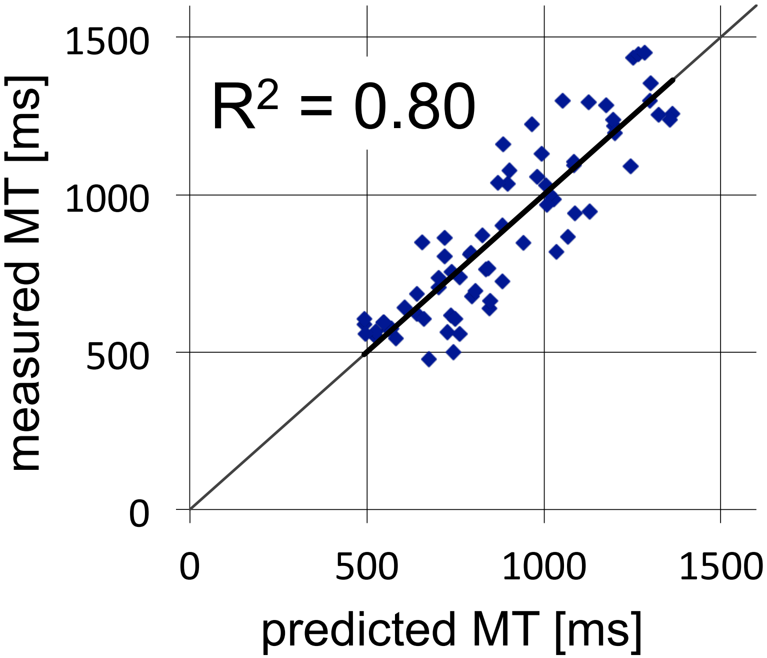
Standard Fitts' law:

$t = 447 + 220 \log_2(D/W+1)$ [ms]



Two-component model:

$t = 185 + 727 \log_2(D/S+1) + 62 \log_2(S/2/W+1)$ [ms]



Control Loops in Physical Pointing

Iterative corrections model [Crossman & Goodeve]

- Movements >200 ms controlled by visual feedback
- Ballistic sub-movements of constant time (135-290 ms)
- Each sub-movement has distance error ε (4-7%)
- Derive Fitts' law from iterations through feedback loop

physical pointing

observe target distance

$\downarrow \tau_P = 100$ ms

plan hand movement

$\downarrow \tau_C = 70$ ms

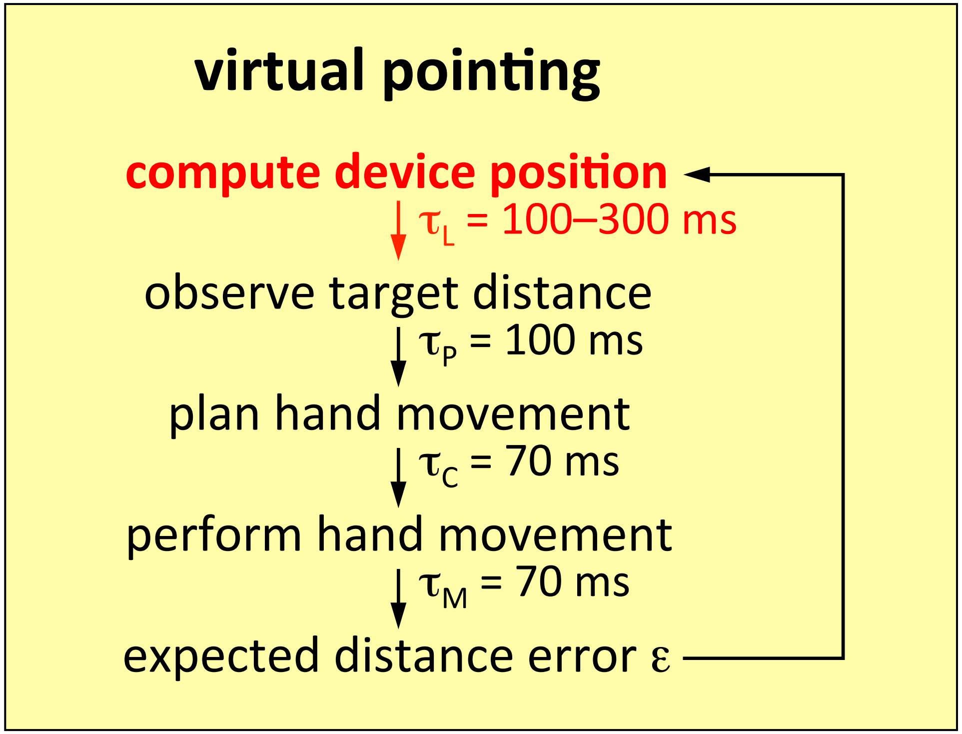
perform hand movement

$\downarrow \tau_M = 70$ ms

expected distance error ε

Control Loops in Virtual Pointing

Machine lag and frame rate introduce delay in feedback loop




INFORMATION

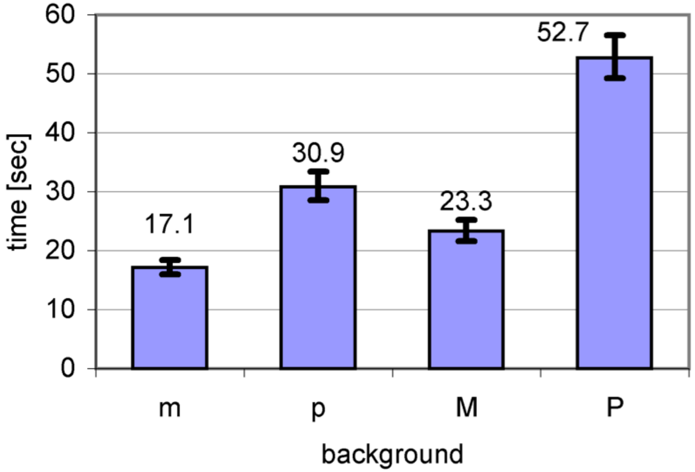
Eye-Tracking Study

- Binocular head mounted Eyelink 2 system (SR Research)
  - 250 Hz sample rate
  - Recorded eye movements and video of subject's view
- Typical sequence for visual context
  - Checking price on display
  - Eyes move ahead to scan for next item
  - Hand movement follows

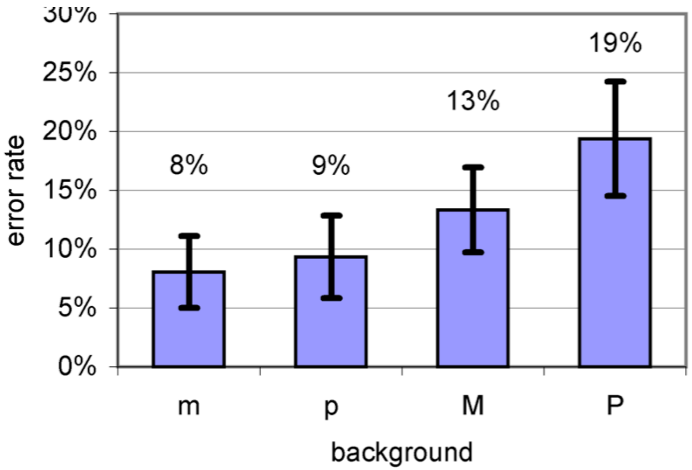

St. Mauritz

Results by Availability of Visual Context

Time by background:



Error rate by background:



m = small map

M = large map

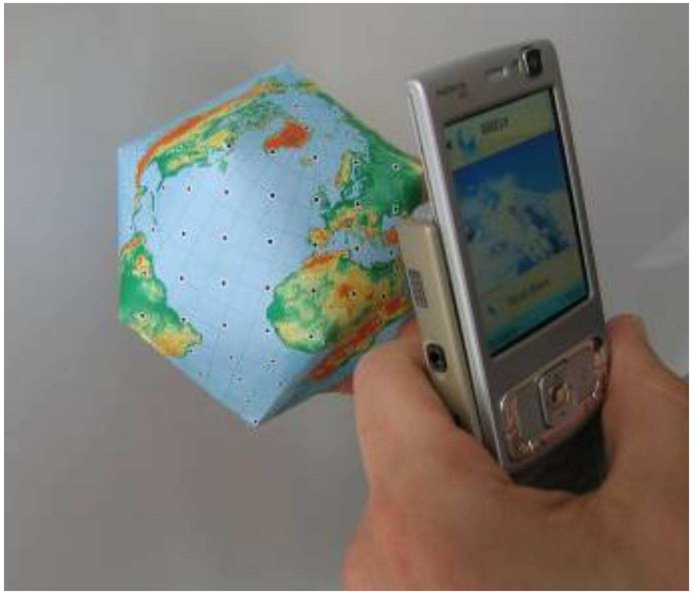
p = small pattern

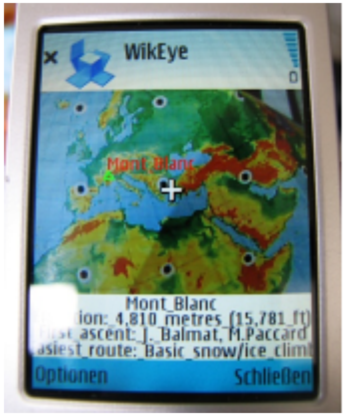
P = large pattern

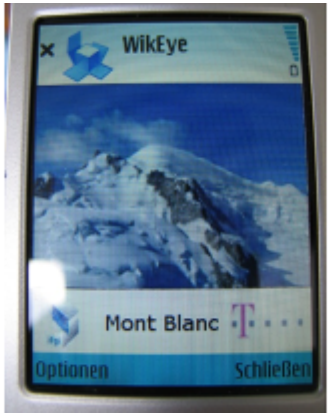
- Visual context reduces search time by 44.4% (small) and 55.8% (large)
- Effectiveness of visual context depends on item density

Tangible Interaction with a Paper Globe

- Tangible interaction with physical 3D models
  - The world is not flat
  - Avoid geographic misconceptions resulting from 2D projection
- Camera phone augments the globe with “global” information
  - Countries, natural resources, flows of trade, news events, etc.
- Educational scenarios

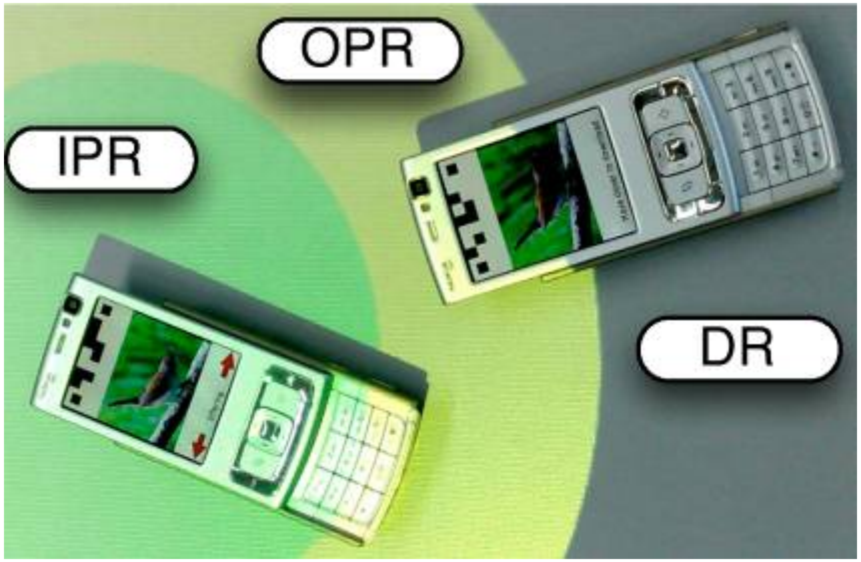




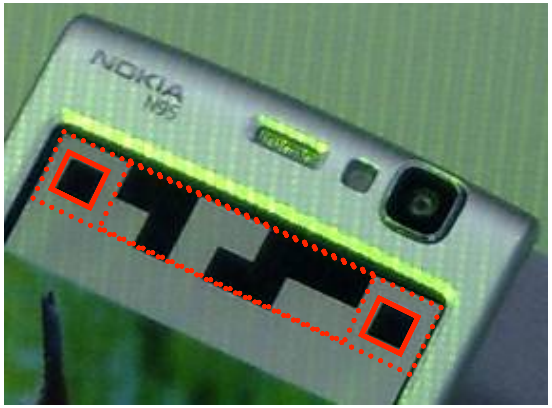


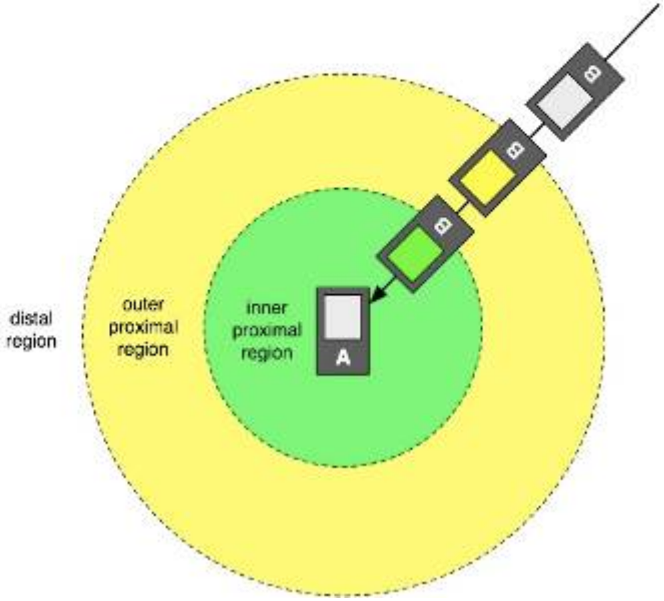
Johannes Schöning, Michael Rohs, Antonio Krüger: Mobile Interaction with the “Real World.” MIRW 2008.

Mobile Devices and Interactive Tabletops



- Camera-projector system
  - Works with regular tables
  - Pubs, cafés, meeting rooms
- Map spatial configurations to application-specific semantics
  - Proximity regions around devices
- Dynamic marker



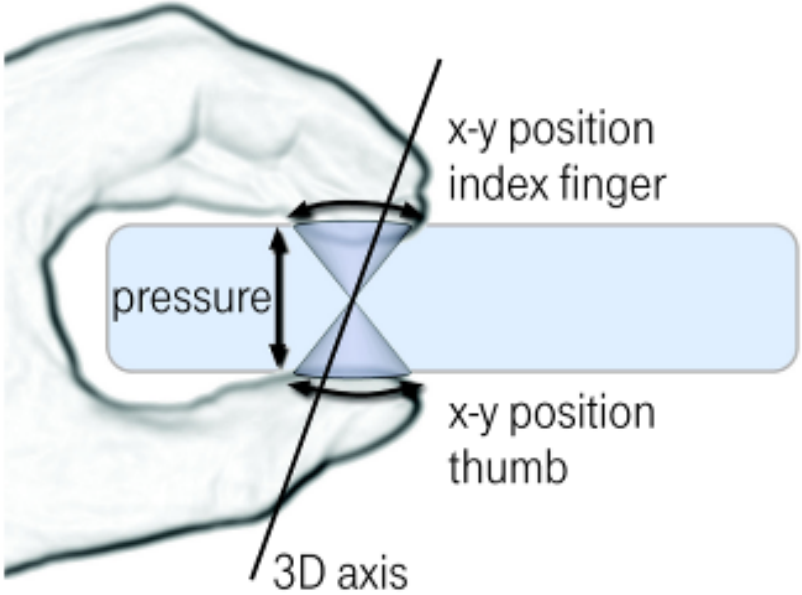


Kray, Rohs, Hook, Kratz: Bridging the Gap between the Kodak and the Flickr Generations: A Novel Interaction Technique for Collocated Photo Sharing. IJHCS 2009.

Linking Mobile Devices with Interactive Tabletops

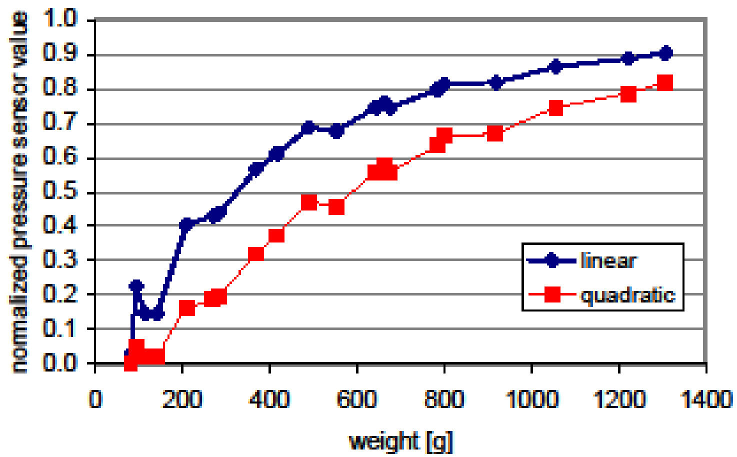
Pressure-Sensitive Two-Sided Multitouch Interaction

- Metaphor
  - Holding an object between thumb and index finger
- Common in everyday interactions
  - Grabbing, sliding, twisting, turning
- Local input with high expressivity
  - Precise pressure
  - Thumb - index finger positions

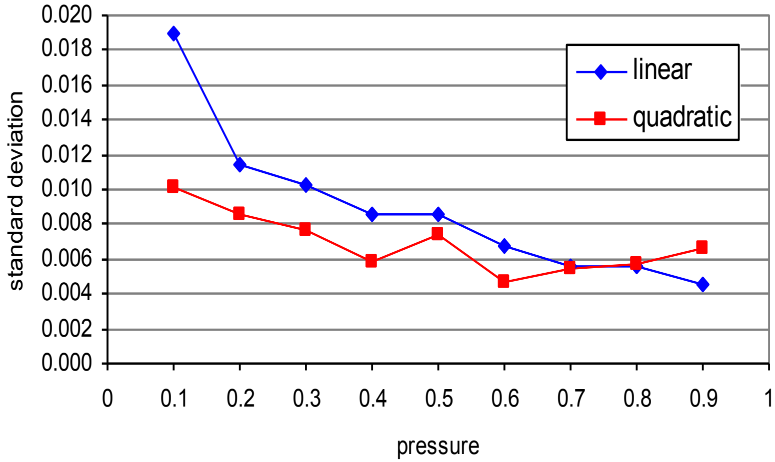


Sensor Linearity and Pressure Stability

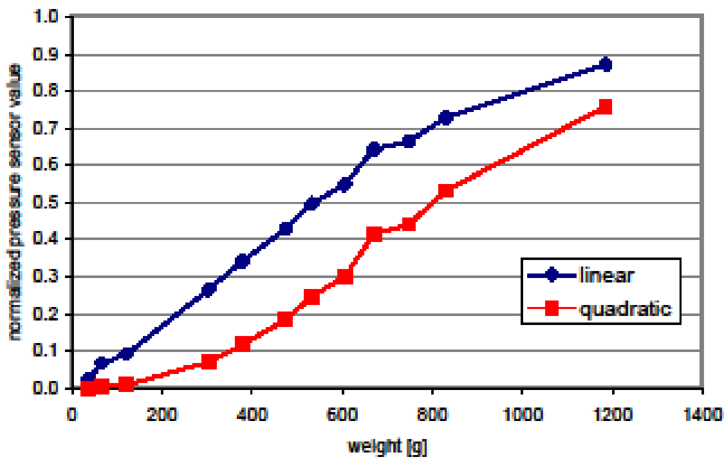
Voltage divider



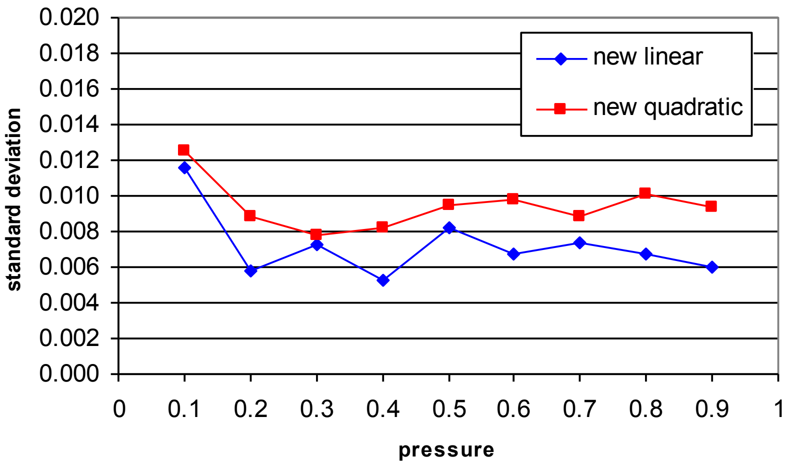
Pressure stability (volt. div.)



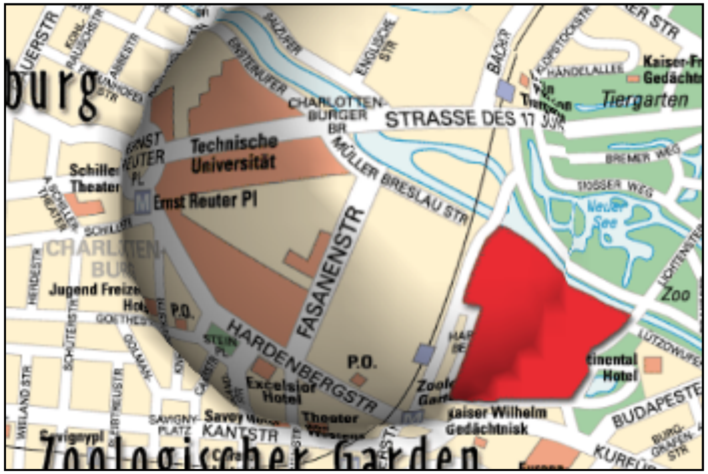
Opamp-based circuit

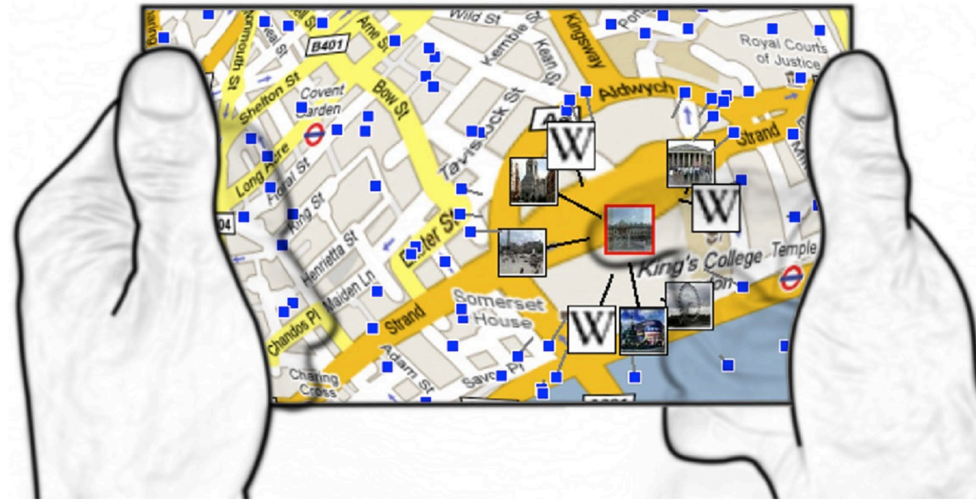


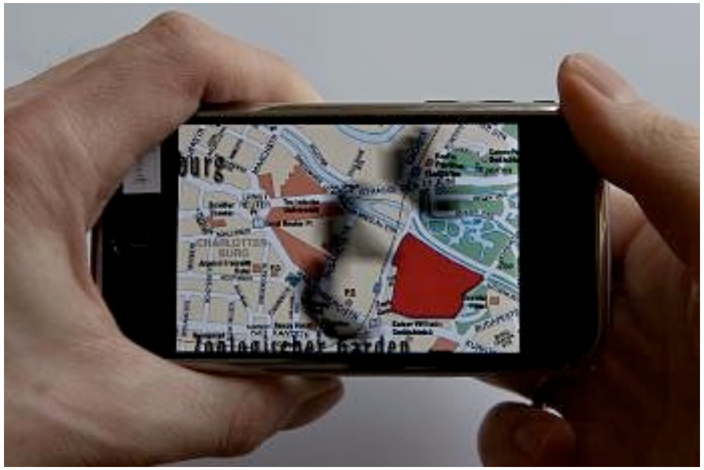
Pressure stability (opamp)



Pressure-Sensitive Map Zooming





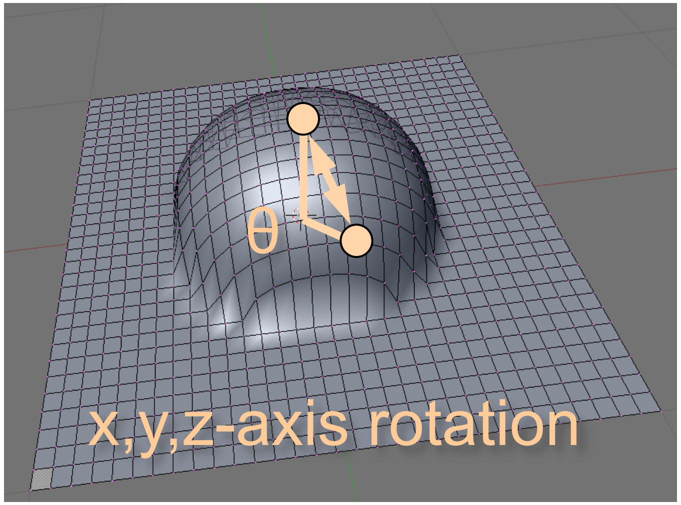


Essl, Rohs, Kratz: Squeezing the Sandwich: A Mobile Pressure-Sensitive Two-Sided Multi-Touch Prototype. Demo at UIST 2009.

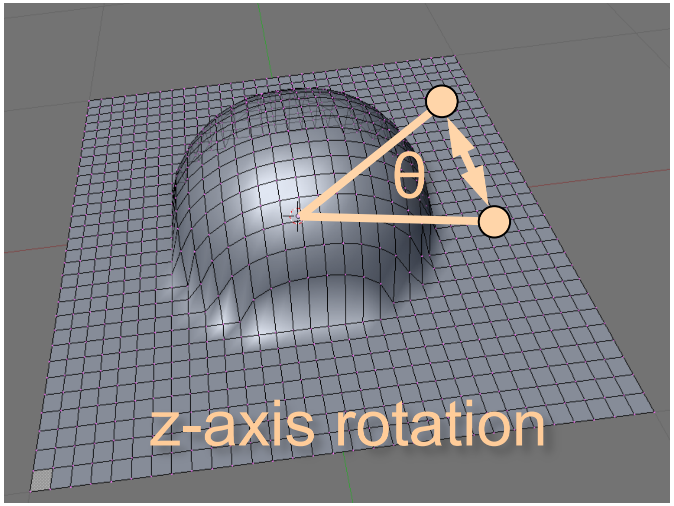

Front
6474
Tiergarten
BRESLAU STR
FASANENSTR
HARDENBERGSTR
P.O.
Zoo

Virtual Trackballs for 3D Object Rotation

- x,y,z-axis rotation

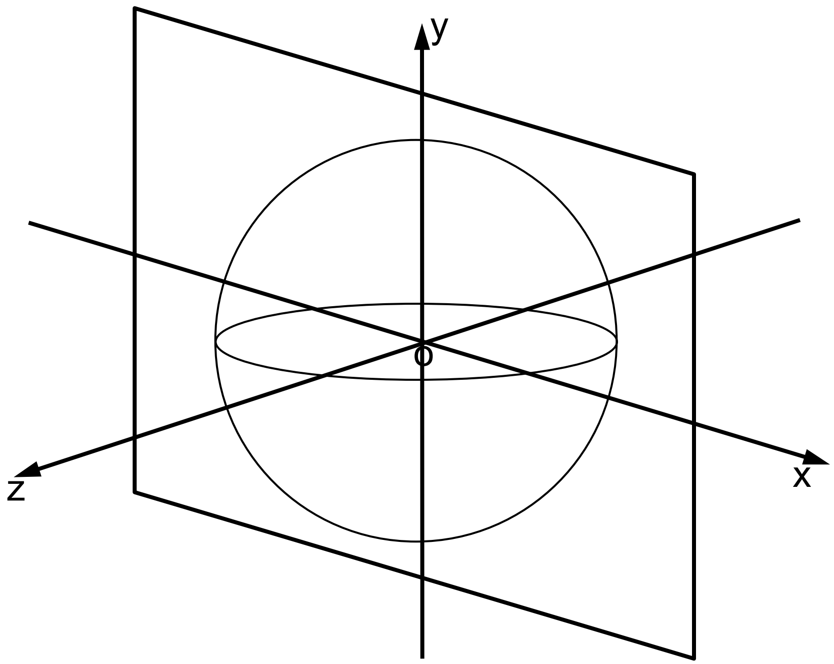


z-axis rotation

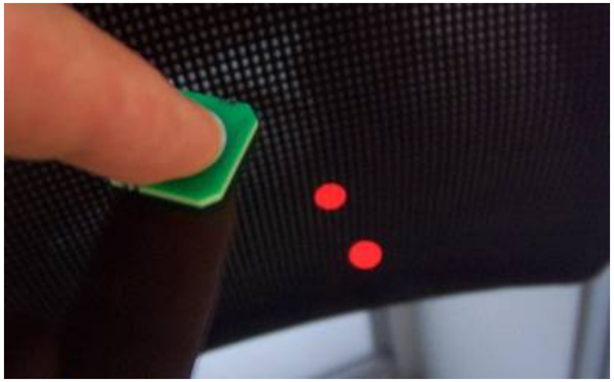


Extension of Virtual Trackball to Back of Device

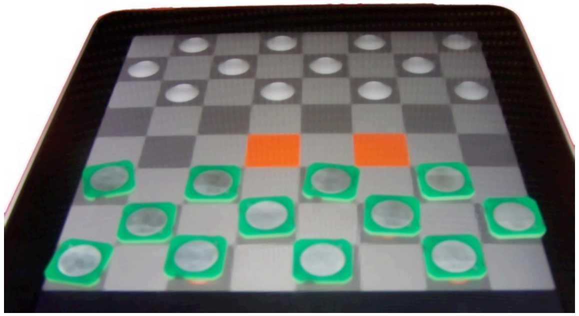
- Full sphere operated from both sides instead of hemisphere operated from front

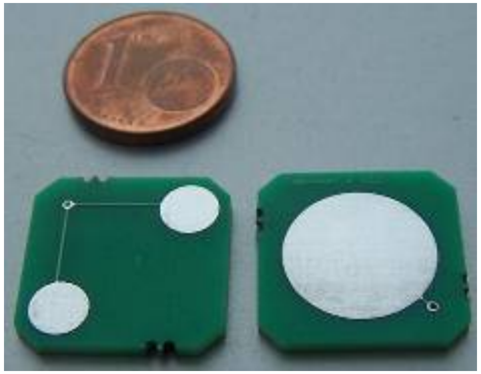


CapWidgets: Capacitive Markers for Multitouch Screens



- Make physical widgets usable on devices on a capacitive touch screen
  - iPad, Android tablets
- Enables
  - Board games using physical pieces
  - Physical dials and switches
- Research topics
  - Material & design of capacitive markers
  - Construction of active markers
  - Applications for capacitive widgets on mobile devices



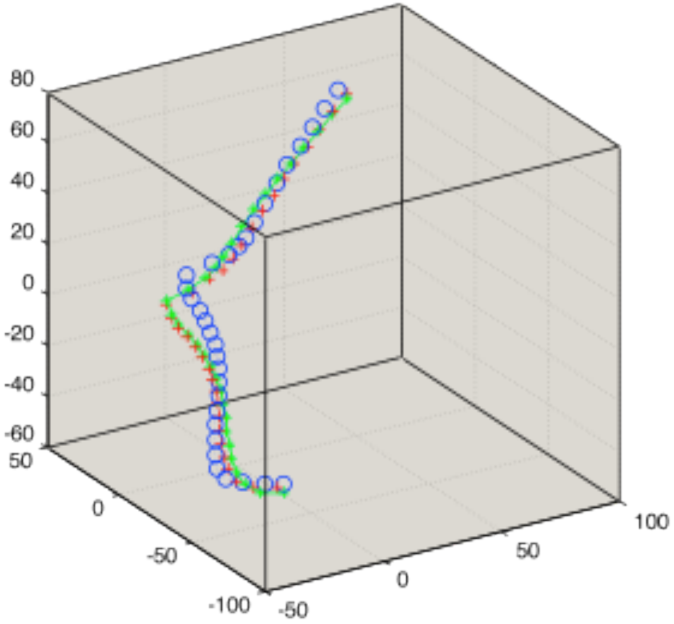


Kratz, Westermann, Rohs, Essl: CapWidgets: Tangible Widgets versus Multi-Touch Controls on Mobile Devices. Work in Progress, CHI 2011.

CapWidgets: Capacitive Markers for Multitouch Screens

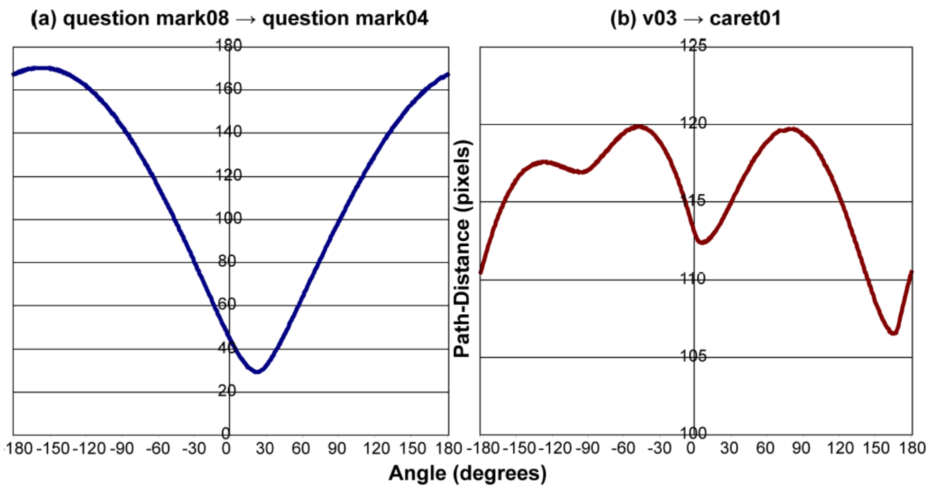
Prototyping Movement Gestures on Mobile Devices

- Accelerometers and gyroscopes
- Machine learning techniques
  - Hidden Markov Models (HMM)
  - Artificial Neural Networks (NN)
- Protractor 3D
  - Extension of Li's Protractor 2D
  - Template-based recognizer
  - Closed-form solution to input rotation matching
  - Highly efficient data-driven motion gesture recognizer



Finding the Optimal Angular Distance

- Wobbrock et al., UIST'07
  - Given query and template, try different orientations and take best one
- Li, "Protractor", CHI'10
  - Closed form solution for 2D
  - Better speed and performance



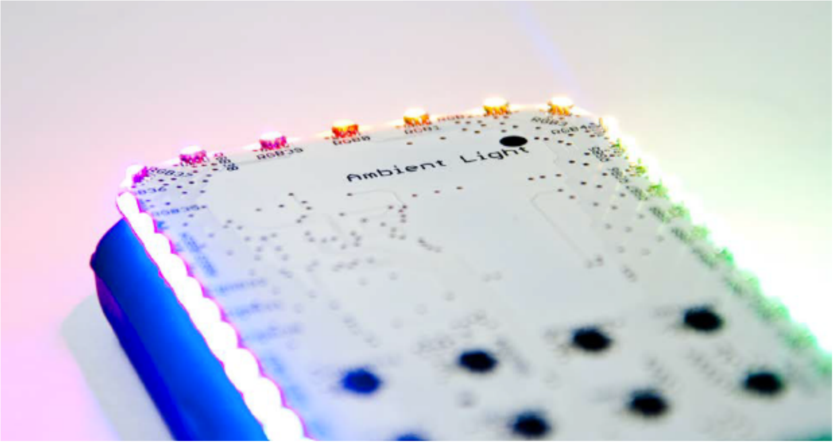
Wobbrock et al., UIST'07

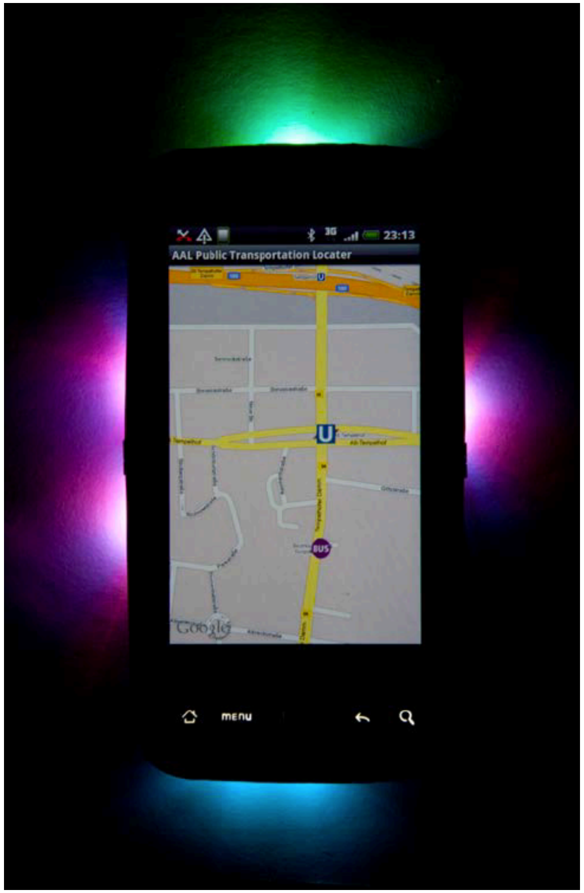
- Kratz, Rohs, IUI'11: Closed form solution for 3D
  - Exhaustive search in 3D space is prohibitive
  - Rotation represented using quaternion $\mathring{q}$, maximize

$$\sum_{i=1}^{n} (\mathring{q} \mathbf{g_i} \mathring{q}^*)^T \cdot \mathbf{t_i} \qquad \mathring{q} = w + iq_x + jq_y + kq_z$$

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.

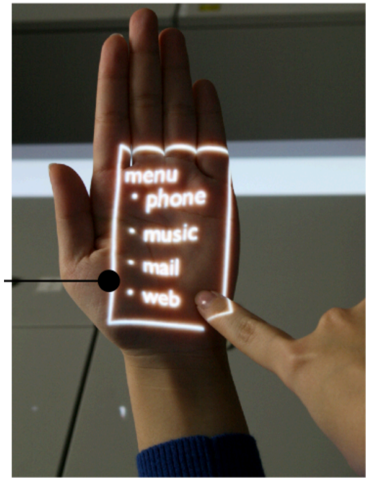
Around-Device Projection on Tabletops

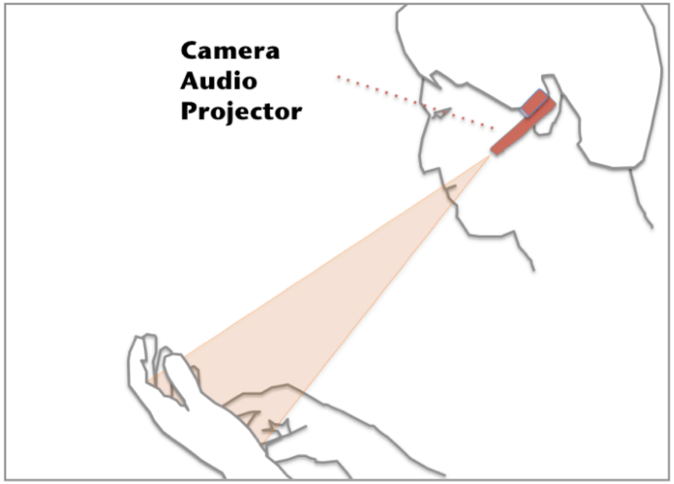
http://www.youtube.com/watch?v=ct1GBNk2-rE

Wearable Pico Projectors

- Advantages
  - Frees hands
  - Less jitter
- Examples
  - Sixth sense (Mistry)
  - Earphone (Rekimoto)
  - Helmet mounted
  - Glasses
- Adaptive projection
- Gesture recognition

Mistry, Maes, Chang. WUW – Wear Ur World: A wearable gestural interface. CHI EA 2009.

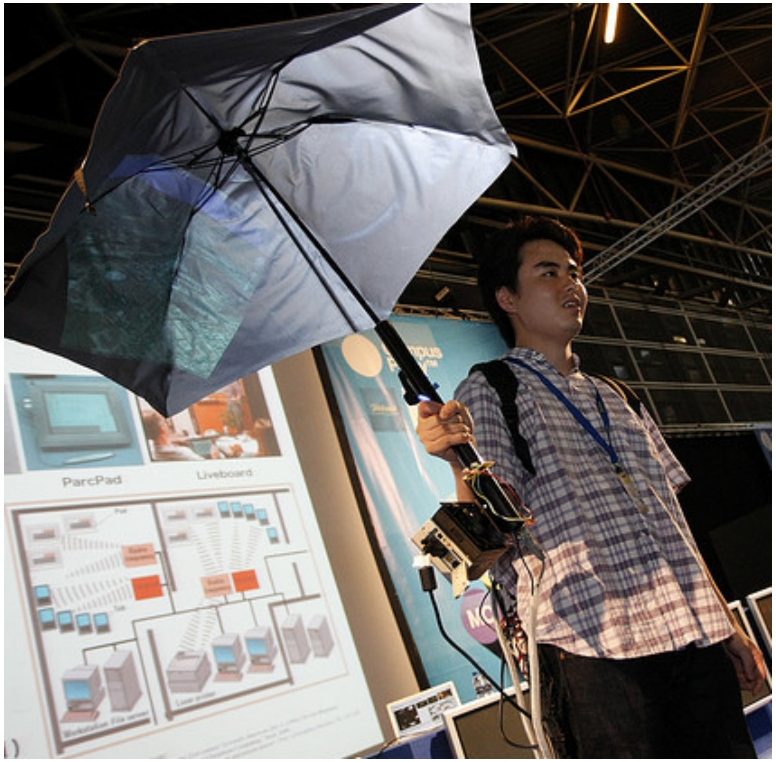




Tamaki, Miyaki, Rekimoto. BrainyHand: an ear-worn hand gesture interaction device. CHI EA 2009.

Handheld Pico Projectors

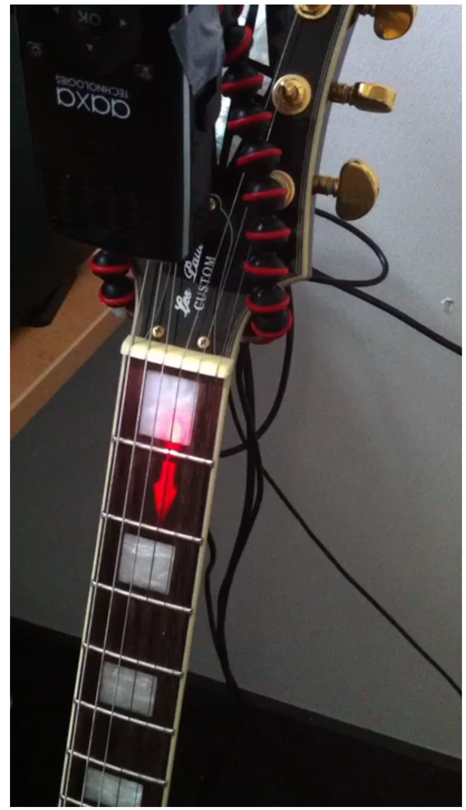
- Pileus – The Internet Umbrella
  - www.pileus.net
- Integrated projection space
- Object provides context



Hashimoto, et al.: Pileus: The Umbrella Photo Browser to Relay Experiences in Rainy Days. UbiComp 2006 Demo.

Pico Projectors Attached to Objects

- Ad-hoc attachable to physical objects
  - Musical instrument
  - Mechanical tool
  - Bicycle
  - etc.



Löchtefeld, et al.: GuitAR – Supporting Guitar Learning through Mobile Projection. CHI EA 2011.

Questions and Comments

Thank you!

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Interaction Techniques for Mobile Devices

Mobile devices have become ubiquitous, but current interaction techniques are still rather traditional. In this talk I present our work on interaction techniques for mobile devices involving sensors, actuators, and tangible objects. I discuss interaction techniques for camera phones involving non-electronic media, such as large-scale paper maps. These techniques transform passive paper maps into entry points to the mobile Internet and augment them with dynamic content. In an eye-tracking study we investigated the effectiveness of visual context beyond the mobile device display, by comparing a dynamic peephole interface (without visual context beyond the device display) to a magic lens interface (with video see-through augmentation of external visual context). I am also going to discuss pressure input for mobile devices as well as corresponding interaction concepts and application ideas. Pressure-sensitive multi-touch input enables a number of application possibilities for handheld pressure input, such as pressure-based fisheye views and 3D object manipulation. We conducted a study on the effectiveness of different device poses and pressure mapping functions. In terms of future topics I am going to present initial ideas on actuated projection interfaces and interaction with mobile robots.