tutorial notes

MOBILEHCI 2008

2 September, Amsterdam, The Netherlands

Program

9:00-11:00

Scott MacKenzie - Text input for mobile devices

Patrick Baudisch - Mobile GUIs and Mobile Visualization

11:30-12:30

Mirjana Spasojevic - Understanding Mobile User Experience

14:00-16:00

Albrecht Schmidt - Context-Aware Communication and Interaction

Stephen Brewster - Haptics, audio output and sensor input in mobile HCI

16:30-17:30

Michael Rohs - Camera-based interaction and interaction with public displays

tutorial notes

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Scott Mackenzie

Text input for mobile devices

Tutorial Day at MobileHCI 2008, Amsterdam

Text input for mobile devices by Scott MacKenzie

Scott will give an overview of different input means (e.g. key-based, stylus, predictive, virtual keyboard), parameters relevant for designing and assessing mobile text input (e.g., writing speed, cognitive load) and issues related to the context of use (e.g., walking/standing).

Mobile GUIs and Mobile Visualization by Patrick Baudisch

Patrick will introduce different approaches for creating mobile graphical user interfaces. He will talk about the design process, prototyping and assessment of user interfaces, trade-offs related to the design of mobile GUIs and different possible interaction styles. As one specific topic in mobile GUIs he will address concept for mobile interactive visualization (e.g. maps).

Understanding Mobile User Experience by Mirjana Spasojevic

Mirjana will discuss different means for studying mobile user needs and evaluating the user experience. This includes explorative studies and formal evaluations (in the lab vs. in the field), including longitudinal pilot deployments. The lecture will discuss traditional HCI methods of user research and how they need to be adapted for different mobile contexts and products.

Context-Aware Communication and Interaction by Albrecht Schmidt

Albrecht will give an overview of work in context-awareness and activity recognition that is related to mobile HCI. He will discuss how sharing of context in communication applications can improve the user experience. The lecture will explain how perception and sensing can be used to acquire context and activity information and show examples how such information can be exploited.

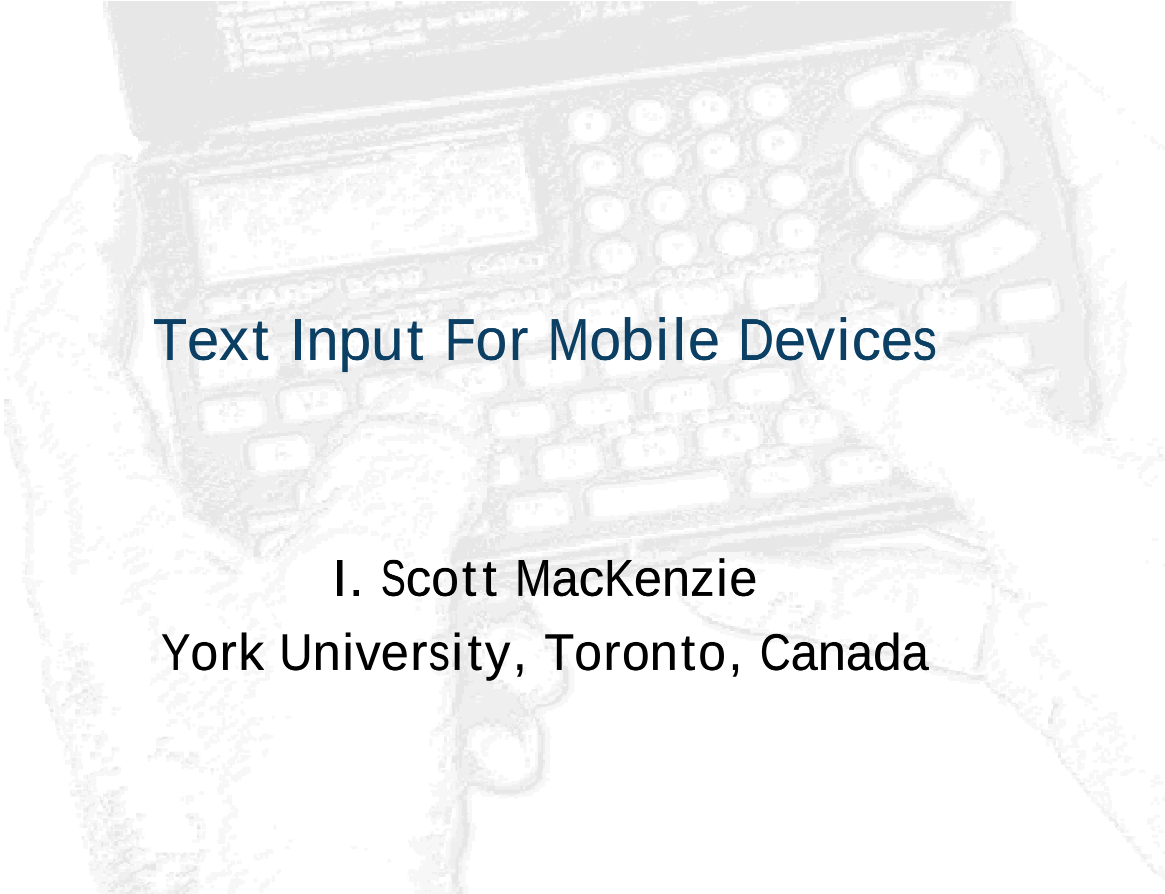
Haptics, audio output and sensor input in mobile HCI by Stephen Brewster

Stephen will discuss the design space for haptics, audio output as well as sensor and gesture input in mobile HCI. Furthermore he will assess resulting interaction methods and implications for the interactive experience.

Camera-based interaction and interaction with public displays by Michael Rohs

Michael will introduce you camera based interaction with mobile devices; this includes a assessment of optical markers, 2D-barcodes and optical flow as well as techniques related to augmented reality. In this context he will address interaction with public displays, too.

Spetember 2nd 2008

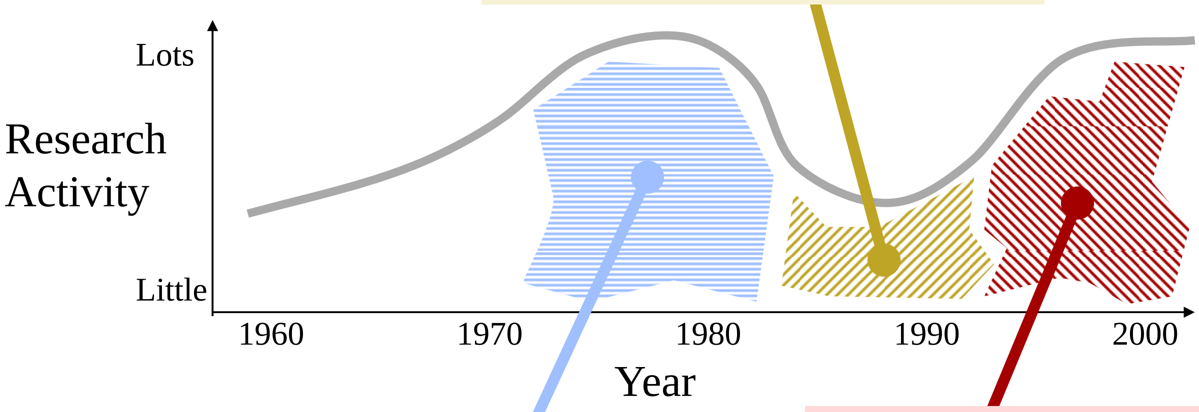


Text Input For Mobile Devices

I. Scott MacKenzie
York University, Toronto, Canada

Text Entry Research - Timeline

- **HUMAN-COMPUTER INTERACTION**
- GUIs
- Mouse input
- Direct manipulation



- **HUMAN FACTORS**
- Office automation
- Word processing
- Document management

- **MOBILE COMPUTING**
- Pen-based input
- Handwriting recognition
- Email, SMS messaging
- Two-way pagers, mobile phones

Mobile Text Entry

- >1 billion SMS messages sent each day
- Companies are ambitiously searching for improvements to mobile text entry techniques
- Many methods currently exist

Three broad categories

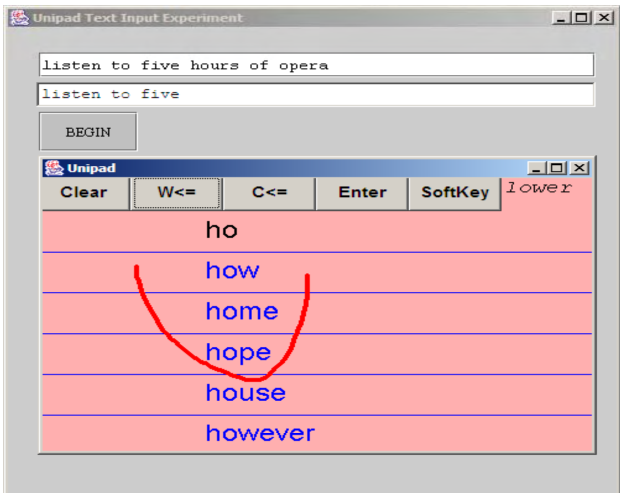
- Key-based
- Finger-based
- Stylus-based

Stylus Based Methods

- Handwriting with automatic recognition
- Tapping on soft or virtual keyboards.

Handwriting Example: Unipad

- Single-stroke handwriting recognition
- Language-based acceleration



KSPC ≈ 0.5
Entry speed > 40 wpm

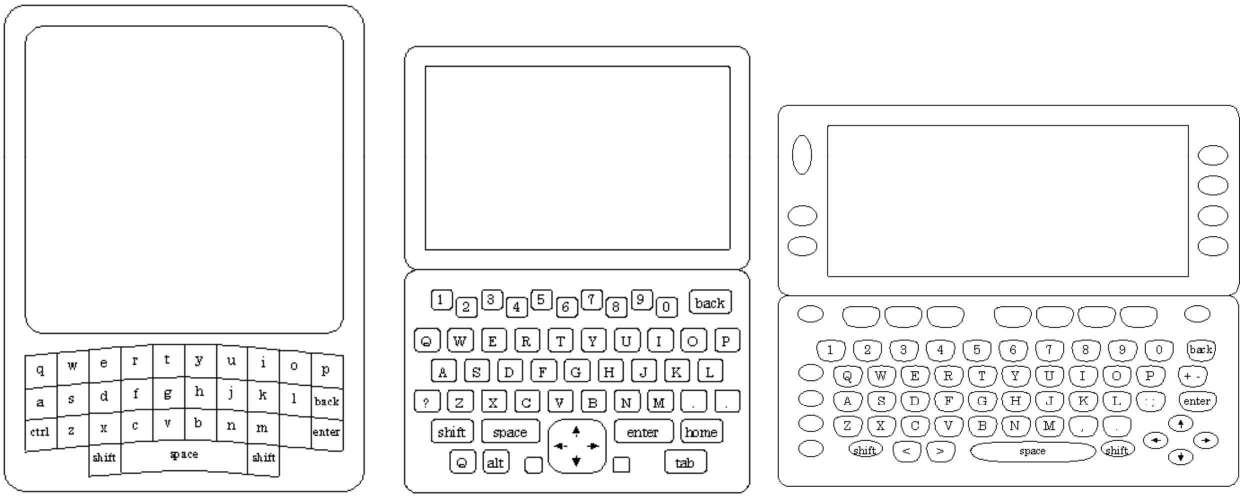
Virtual vs Physical Keyboards

- Virtual keyboards
  - Aka "soft keyboards" or "on-screen keyboards"
  - Similar to clicking buttons in a GUI
  - Typically used with a stylus (but also with a finger, eye tracking, and other input mechanisms)
- Physical keyboards
  - Desktop qwerty, miniature qwerty, mobile phone keypad, 5-button pager, 3-key date stamp, 1-key input, etc.
- Design Issues
  - Key layout, key size, key shape, number of keys, activation force, feedback, disambiguation, language modeling, word prediction, etc.

Keyboard Layouts – A Brief Tour

Qwerty

Design issues
- Designed to be slow!
- Prevents typing machines from jamming



Qwerty variations

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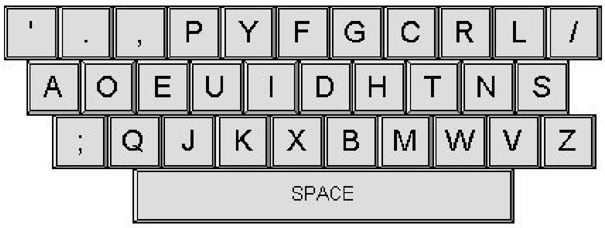
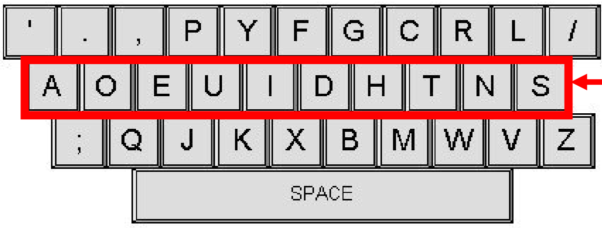


Dvorak

Design issues

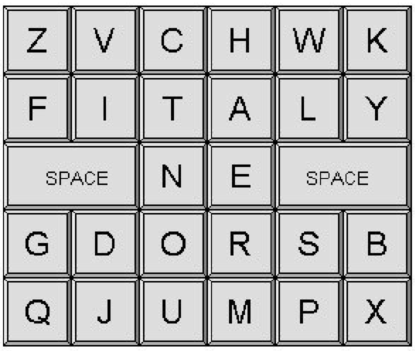
- Speed typing by maximizing home row and alternate hand typing



Dvorak

Home row contains 10 of 13 most frequent letters

Letter	Frequency
_	67962112
e	**37907119**
t	**28691274**
a	**24373121**
o	**23215532**
i	**21820970**
n	**21402466**
s	**19059775**
h	**18058207**
r	17897352
l	11730498
d	**10805580**
c	8982417
u	**8022379**
f	7486889
m	7391366
w	6505294
y	5910495
p	5719422
g	5143059
b	4762938
v	2835696
k	1720909
x	562732
j	474021
q	297237
z	93172



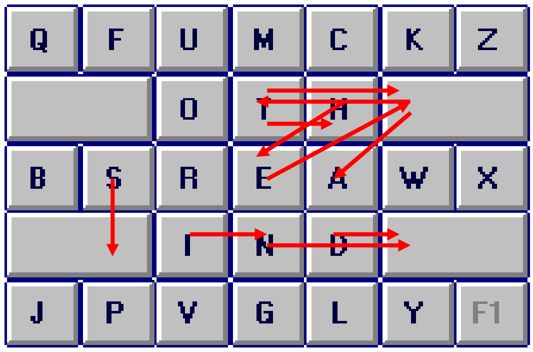
Fitaly

Opti

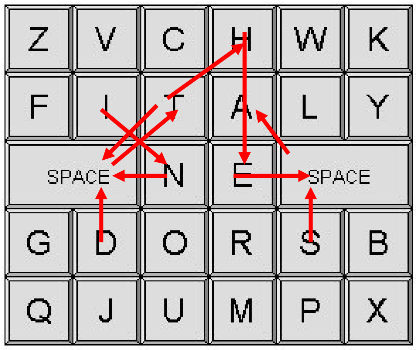
Design issues
- Stylus input on “soft keyboard”
- Speed entry by minimizing stylus movement for English text

Digram	Frequency
e_	**14788053**
_t	**11565380**
th	**10301807**
he	**9436372**
_a	**8454634**
s_	**8359914**
n_	**6419069**
t_	**6336756**
d_	**6235838**
in	**5534329**
...	...
uz	626
zl	626
mh	613
lh	584
cn	567
oq	547
aa	546
xq	543
wm	540
ij	536

Top 10



Opti



Fitaly

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Digram	Frequency
e_	14788053
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...	...
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mh	**613**
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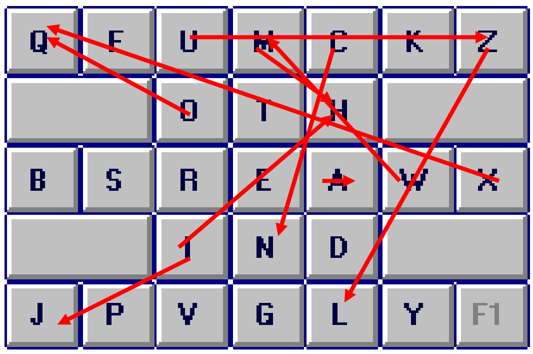
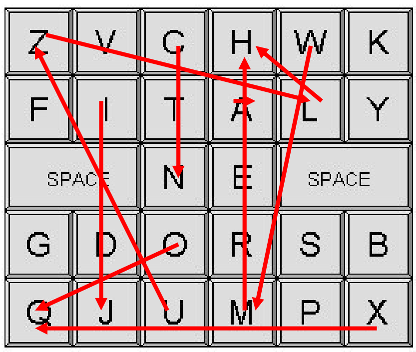
cn	**567**
oq	**547**
aa	**546**
xq	**543**
wm	**540**
ij	**536**

Bottom 10



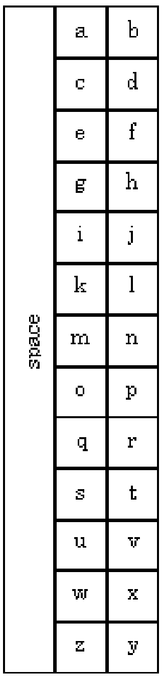
Opti

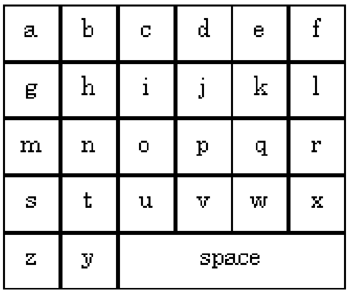


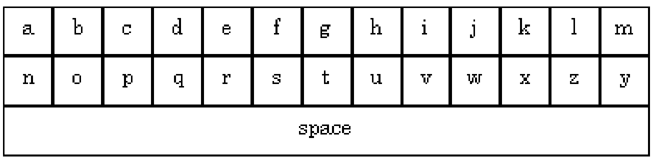
Fitaly

Performance Issues

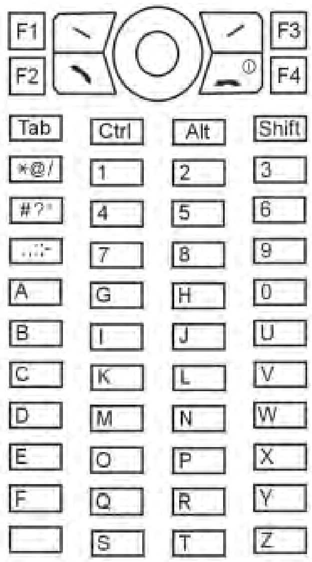
- *Fitaly* and *Opti* were designed to improve performance by minimizing movement distances (for English text entry)
- Is this a reasonable design goal?
  - Stylus input – YES
    - Movement is slow (Fitts' law)
    - Selection is fast (tap key)
    - Movement time >> selection time
  - Eye gaze input – NO
    - Movement is fast (saccades)
    - Selection is slow (dwell on key)
    - Movement time << selection time



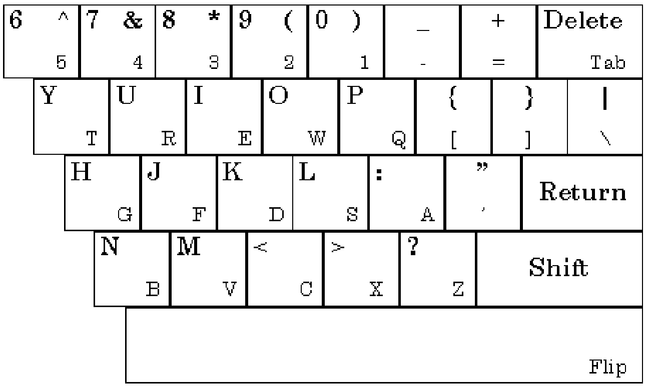




ABC



Design issues
- Non-qwerty shape
- Familiar letter arrangement

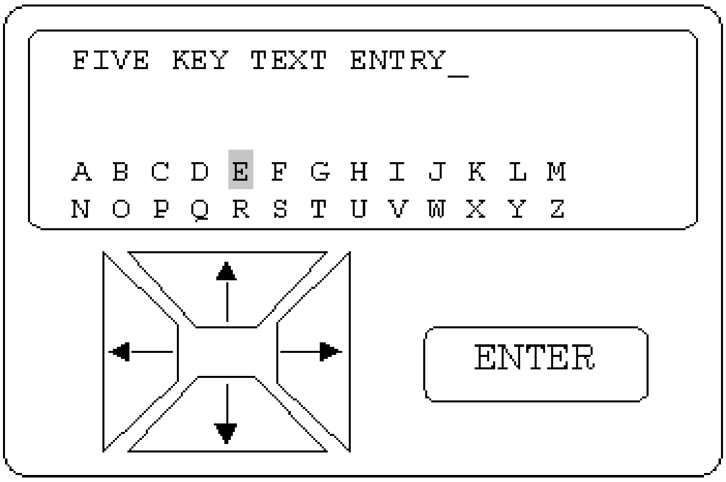


Half Qwerty

Design issues
- One-handed input

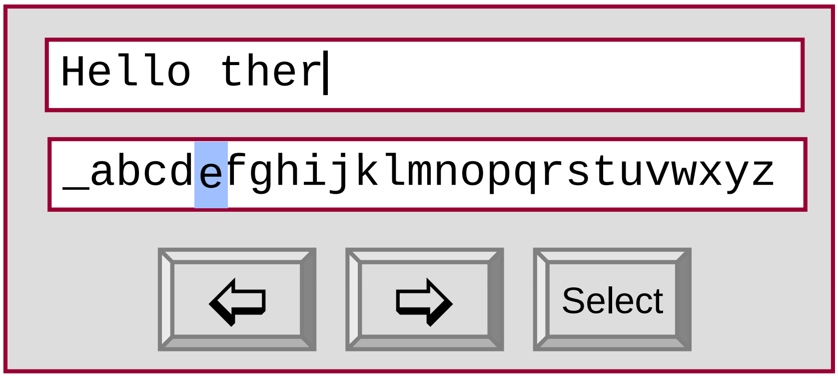
Phone

Design issues
- Legacy technology
- Includes letters for telephone exchange names



Five-key pager

Design issues
- Very small device with just 5 buttons

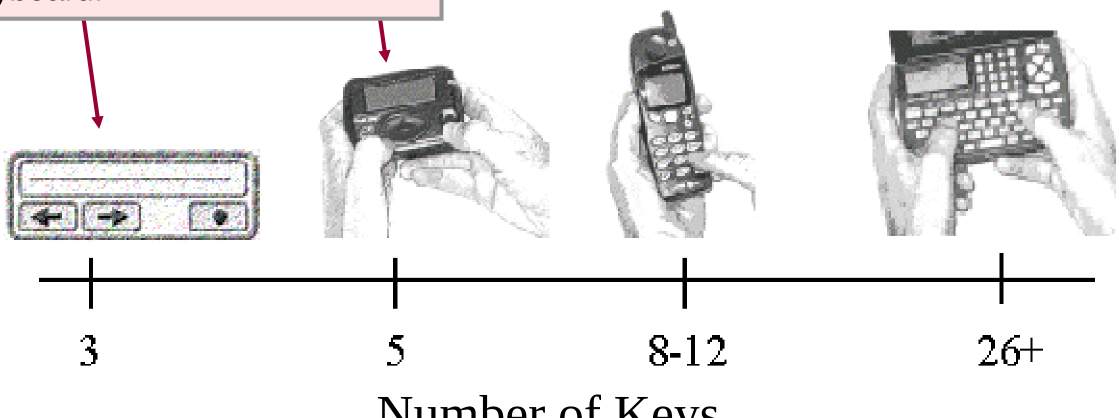


Three-key date stamp

Design issues
- Very small device with just 3 buttons
- Predictive techniques to increase entry speed

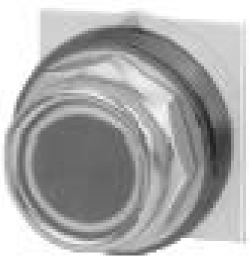
Number-of-keys Continuum

But…
The “keyboard” is on the display. The “keys” navigate the keyboard!



More **Ambiguity Continuum** Less

One-key Input



Is this possible?

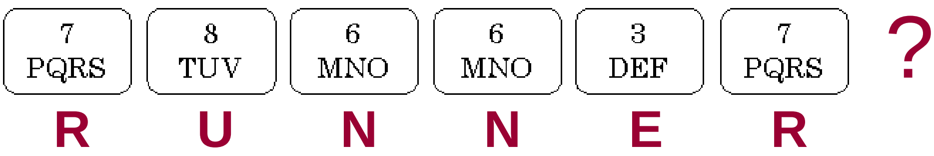
...sure

One-key Text Input

Design Issues
- What moves (a hot spot vs the underlying letters)
- Hot spot speed (places upper limit on entry speed, but faster = more errors)
- Hot spot path (cyclic vs reset on select)
- Letter arrangement (ABC vs. optimized)
- Error correction
- Combine with language acceleration techniques

Ambiguity

- Ambiguity occurs if there are fewer keys than symbols in the language
- Disambiguation is needed to select the intended letter from the possibilities
- Phone keypad is a typical example



Or, is it **SUMMER**, is it **STONES** **?**

Disambiguation Solution #1

- Multi-tap

7	8	6	6	3	7
PQRS	TUV	MNO	MNO	DEF	PQRS

```
RUNNER = 7778866n6633777
           R U N  N E  R

SUMMER = 7777886n633777
            S UM M E  R

STONES = 77778666N66337777
            ST  O  N E   S
```


Disambiguation Solution #2

- Dictionary-based (T9)

7	8	6	6	3	7
PQRS	TUV	MNO	MNO	DEF	PQRS

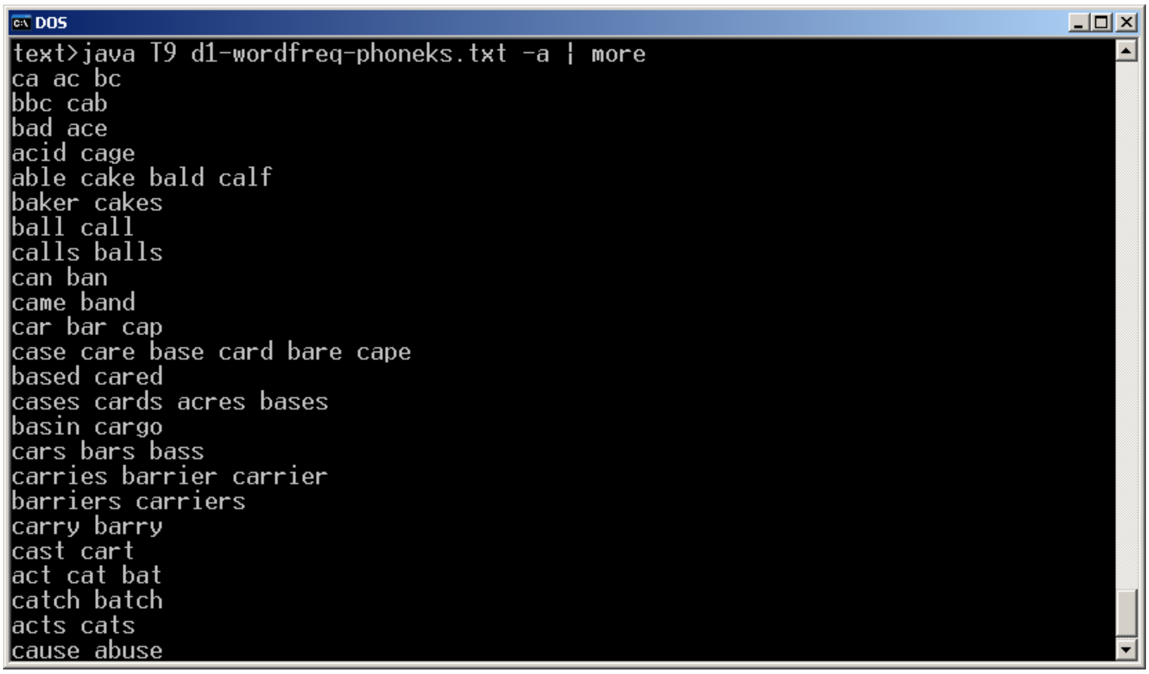
```
RUNNER = 786637nn
         RUNNE  R

SUMMER = 786637
         SUMMER

STONES = 786637n
         STONE S
```

Demo

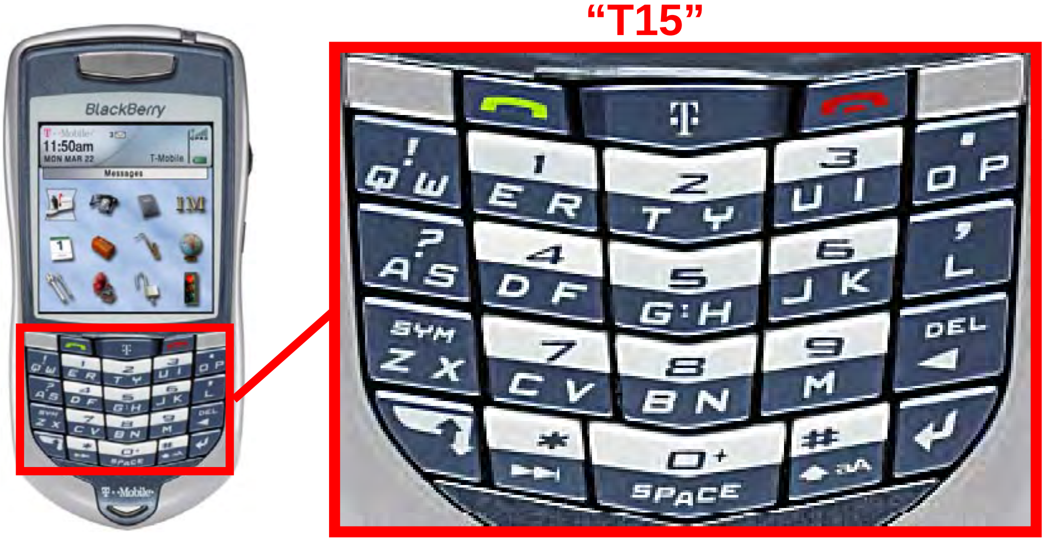
```
java T9 d1-wordfreq-phoneks.txt -a
```



T9-Qwerty Hybrid

- 7100t Blackberry by RIM (Research In Motion)

“T15”



Word Completion

- Basic problem…
  - Given preceding text, predict subsequent text
- Design issues
  - Dynamic vs. static language model
  - Word-level or phrase-level prediction
  - Size of candidate word list
  - Candidate word selection
  - Perceptual cost of attending to predictions
  - Improving performance (audio feedback?)

Demo: `java WordPredict d1-wordfreq.txt 10`

Word Completion Example

- Consider the word “vegetable”
  - How many and what keystrokes are required?

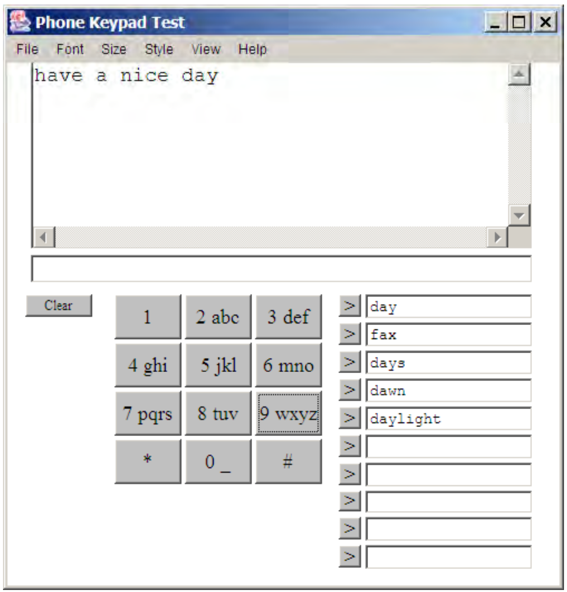
Word Stem	Candidate List
v	very voice view value various
ve	very version vehicle vehicles versions
veg	vegetables vegetation vegetable vegetarian vegetarians

4 keystrokes, KSPC = 0.4

```
vegetable 979 vegS      (stylus input, n = 5)
vegetable 979 vegNNS    (keypad input, n = 5)
```

6 keystrokes, KSPC = 0.6

Disambiguation + Word Completion



Demo: `java PhoneKeypad d1-wordfreq-phoneks.txt`

KSPC[a] Characteristics

Method	KSPC
Date Stamp #1	10.7112
Date Stamp #2	10.5507
Date Stamp #3	9.2143
Date Stamp #4	6.4150
Date Stamp #5	4.9230
Date Stamp #6	4.1032
5-key pager	3.1248
Multitap	2.0242
MessageEase	1.8157
LetterWise	1.1467
T9	1.0064
Qwerty	1.0000
wp-keypad-10	0.7939
wp-keypad-5	0.7293
wp-stylus-1	0.7176
wp-keypad-1	0.7176
wp-keypad-2	0.6867
wp-stylus-2	0.6272
wp-stylus-5	0.5366
wp-stylus-10	0.4896

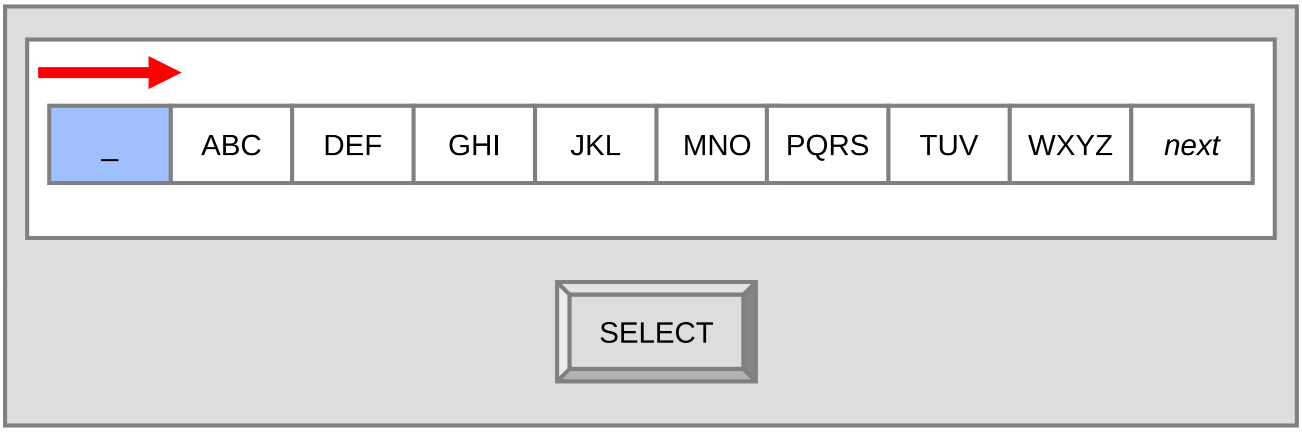
KSPC > 1 (Date Stamp #1 – T9)

KSPC < 1 (wp-keypad-10 – wp-stylus-10)

[a] Keystrokes entered per character of text generated

T9 With One Key

- A one-key implementation is possible
  - Advantage: fewer steps to reach desired letter
  - Disadvantage: disambiguation necessary



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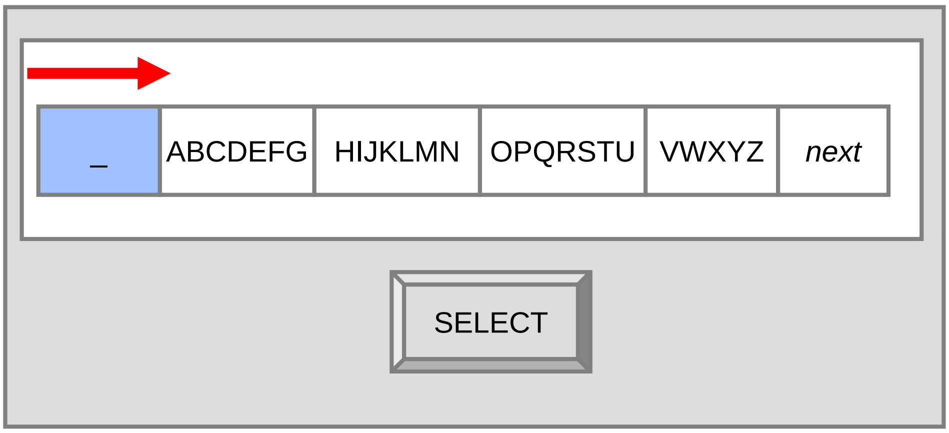
Fewer Steps



T9 With Eye Gaze

- T9 works remarkably well (KSPC ≈ 1)
- An eye gaze implementation is possible
  - Advantage: large keys
  - Disadvantage: disambiguation necessary

KSPC = 1.0064

	ABC	DEF
GHI	JKL	MNO
PQRS	TUV	WXYZ

KSPC = 1.0670

ABCDEFG	HIJKLMN
OPQRSTU	VWXYZ

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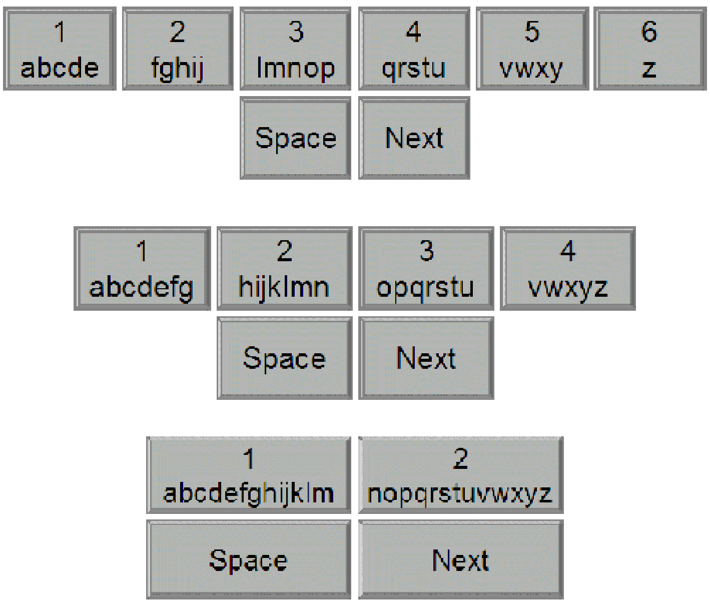
KSPC/Ambiguity Demo



Demo: `java T9 d1-wordfreq-k6ks.txt -k`
Demo: `java KSPCWords d1-wordfreq-t6ks.txt`

What's Ahead

- Performance issues
  - Measurement of entry speed
    - Characters per second vs words per minute
  - Measurement of accuracy
    - Measurement of character-level error rates
    - Type of errors
  - Other performance issues (particularly as per eye gaze)
  - Modeling movement, attention, cognition
- Evaluation
  - Research questions and how to answer them
  - Experiment design issues
  - Conducting user studies
  - Gathering and analyzing data
  - Reporting results in research papers

Evaluation Slides | Skip

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Evaluation

- Research questions
  - Typically, something like…
    - Is method A as fast/accurate as method B?
    - How much practice to reach, say, 15 wpm?
- Research questions come together in experiments as…
  - Independent variables, and
  - Dependent variables

Independent Variables

- These are the factors and levels in an experiment
- Examples

Factors	Levels
Input technique	Multitap, T9
Keyboard layout	Qwerty, Opti, Fitaly
Key size	small, medium, large
Type of feedback	visual, aural, both, neither
Session	1, 2, 3 ... 10
Word prediction	off, on
Gender	male, female

Dependent Variables

- These are the behaviours measured
- Examples

Variable	Units
Speed	Words per minute (wpm)
Accuracy	Percent errors (%)
Key activity	Keystrokes per character (kspc)
Backspace key events	Count or ratio
"Other" events	Count or ratio

Speed as a Dependent Variable

- Relatively straight forward to measure
- Example…

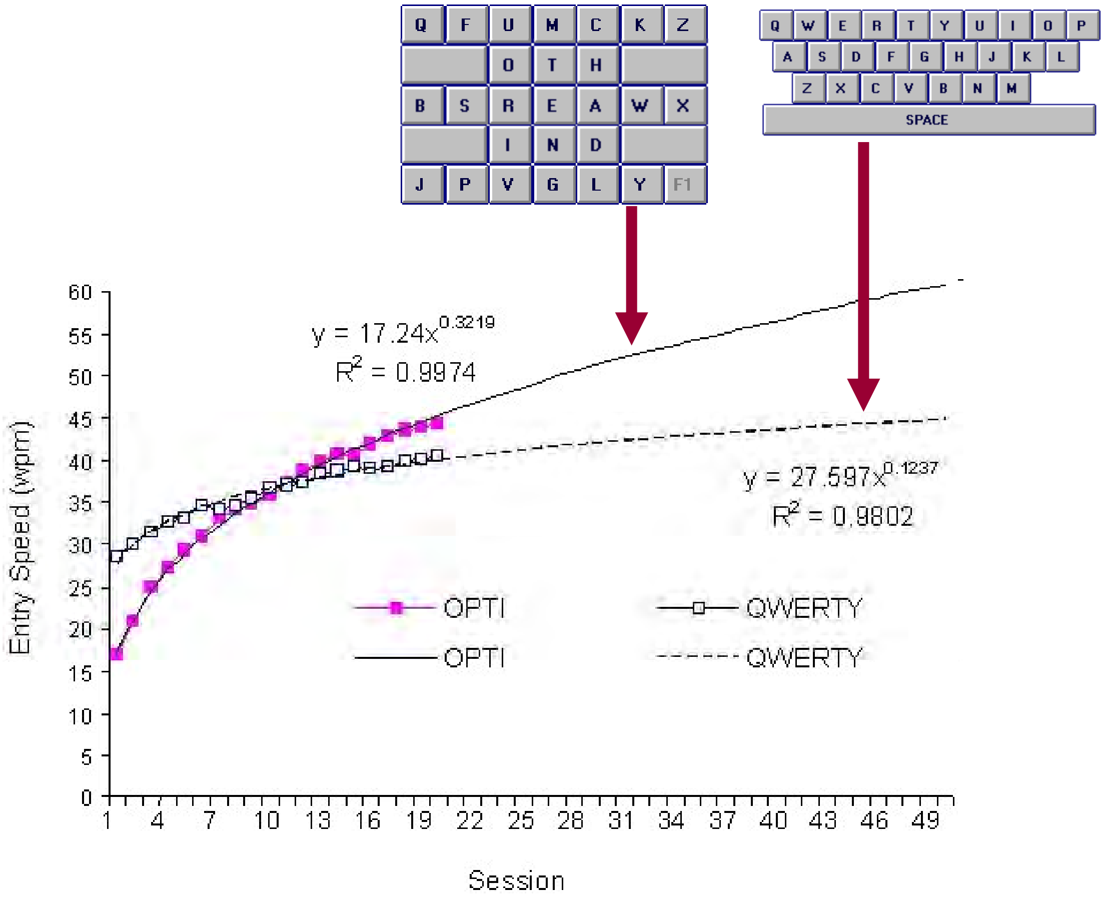
```
         1         2         3         4
1234567890123456789012345678901234567890123
the quick brown fox jumps over the lazy dog
```

t = 60 seconds = 1 minute
Number of characters = 43
Number of words = 43 / 5 = 8.6
Speed = 8.6 / 1 = 8.6 wpm

Note: Definition of a word: “five characters, including spaces, punctuation, etc”

Opti vs. Qwerty Example

- Two Independent variables
  - Keyboard layout with 2 levels: Opti, Qwerty
  - Session with 20 levels: 1, 2, 3, ... 20
- Referred to as a 2 x 20 factorial design
- The 40 test conditions were given to all participants, thus we have a 2 x 20 within-subject design (i.e., each subject received all 40 test conditions)
- Note: within-subject design = repeated measures design (cf. between-subjects design)



Accuracy as a Dependent Variable

- A bit trickier
- Example…

Presented text

the quick brown fox
the quixck brwn fox

Transcribed text

1. How many errors?

   2 (gee, that was easy)

2. What are the errors?

   - An "x" was inserted
   - An "o" was omitted

3. What is the error rate (%)?

   ER = 2 / 19 = 0.105 = 10.5%

Minimum String Distance (MSD)

- In the example, there were two errors
- Relative easy for us to spot
- Hard to automate (i.e., use software)
- Can be done using an algorithm from DNA analysis to compute the minimum distance between two strings
- Consider…

computer
coxzter

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		-1	0	1	2	3	4	5	6
			c	o	x	z	t	e	r
-1		0	1	2	3	4	5	6	7
0	c	1	0	1	2	3	4	5	6
1	o	2	1	0	1	2	3	4	5
2	m	3	2	1	1	2	3	4	5
3	p	4	3	2	2	2	3	4	5
4	u	5	4	3	3	3	3	4	5
5	t	6	5	4	4	4	3	4	5
6	e	7	6	5	5	5	4	3	4
7	r	8	7	6	6	6	5	4	3

Pseudo Code Algorithm[1]

```
function msd(A, B) {
  for i = 0 to |A|    // |A| = the length of A
     D[i, 0] = i
  for j = 0 to |B|
     D[0, j] = j
  for i = 1 to |A|
     for j = 1 to |B|
                       ⎛D[i-1, j] +1
        D[i, j] = min  ⎜D[i, j-1] +1
                       ⎝D[i-1, j-1] + r(A[i], B[j])⎠
  return D[|A|, |B|]
}
function r(a, b) {
  if a = b return 0
  otherwise return 1
}
```

[1]Soukoreff, R. W., & MacKenzie, I. S. (2001). Measuring errors in text entry tasks: An application of the Levenshtein string distance statistic. *Extended Abstracts of the ACM Conference on Human Factors in Computing Systems -- CHI 2001*, 319-320. New York: ACM.

MSD Properties

- Well-defined zero

  `msd(A, B) = 0, iff A = B`

- Bounded

  `0 ≤ msd(A, B) ≤ max(|A|, |B|) where`
  `|N| = length of string N`

- Commutative

  `msd(A, B) = msd(B, A)`

Text Entry Error Rate

$$\text{Error Rate} = \frac{\text{msd}(A, B)}{\max(|A|, |B|)} \times 100\%$$

But, there is a problem… Let's see

Accuracy - Revisted

Presented text

quickly
qucehkly

Transcribed text

1. How many errors?

   3 (that was a bit tricky)

2. What are the errors?

   Hmm, let's see

3. What is the error rate?

   ER = 3 / 8.25 = 0.364 = 36.4%

```
quic--kly
qu-cehkly

quic-kly
qucehkly

qui-ckly
qucehkly

qu-ickly
qucehkly
```

Optimal Alignments

```
quic--kly
qu-cehkly

quic-kly
qucehkly

qui-ckly
qucehkly

qu-ickly
qucehkly
```

- The answer to the question "What are the errors?" shows the set of "optimal alignments" (the set of string pairings with the computed MSD)
- Properties
  1. The set size is often > 1
  2. The alignments are often of different lengths (in the example, 9, 8, 8, 8)
- Because of #2, the error formula needs to be tweaked…

Text Entry Error Rate (new)

$$\text{Error Rate} = \frac{\text{msd}(A, B)}{\overline{S_A}} \times 100\%$$

Where $\overline{S_A}$ is the mean size of the alignments (in the example, 8.25)

Demo

```
Command Prompt - java MSD -m -a -er
text>java MSD -m -a -er
===========================
Minimum String Distance Demo
===========================
Enter pairs of strings (^z to exit)
hello
helo
MSD = 1
Error rate (old) = 20.0000%
Error rate (new) = 20.0000%
      h  e  l  o
   0  1  2  3  4
h  1  0  1  2  3
e  2  1  0  1  2
l  3  2  1  0  1
l  4  3  2  1  1
o  5  4  3  2  1
Alignments: 2, mean size: 5.0
hello
hel-o

hello
he-lo
-------------
```

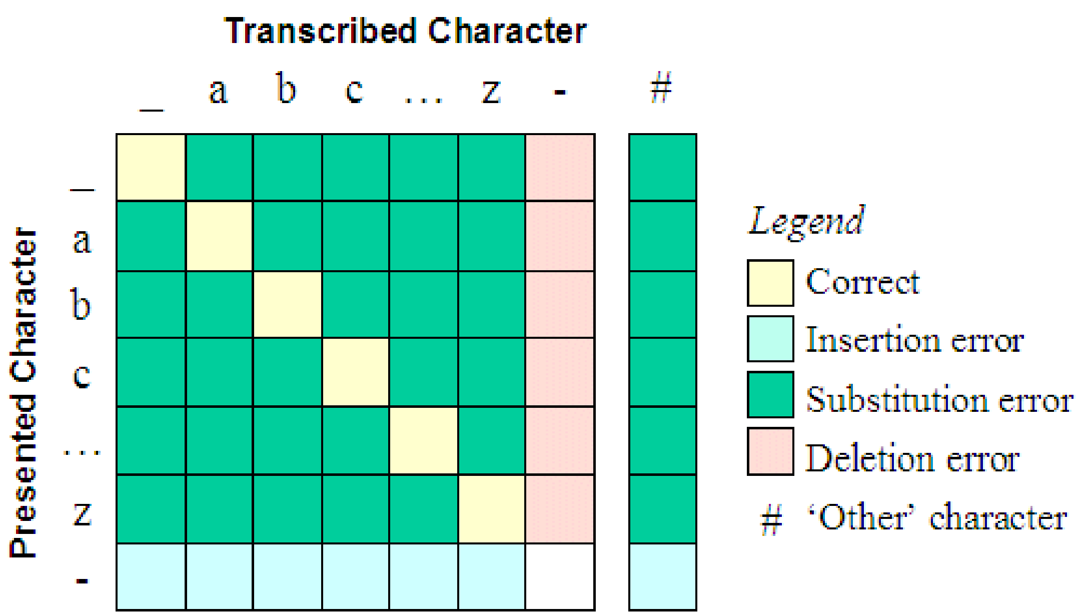

Optimal Alignments - revisited

- Properties (again)
  1. The set size is often > 1
  2. The alignments are often of different lengths (in the example, 9, 8, 8, 8)
- We just dealt with #2
- Implications of #1
  - We don't know what the "user" did
  - This is a problem if we wish to do character-level error analyses

Character-Level Error Analyses

- Reasonable compromise
  - Assume each error possibility occurs with equal probability
  - Instead of adding "1" for each error, add "1 / N", where N is the number of alignments, and repeat N times
  - Table view
    - For each character in the alphabet, tally the weighted occurrences of
      - Deletion errors
      - Substitution errors
      - Insertion errors
  - Matrix view (aka *confusion* matrix)
    - When a substitution error occurs, it is often important to know what was substituted (e.g., handwriting recognition)
    - Next slide...

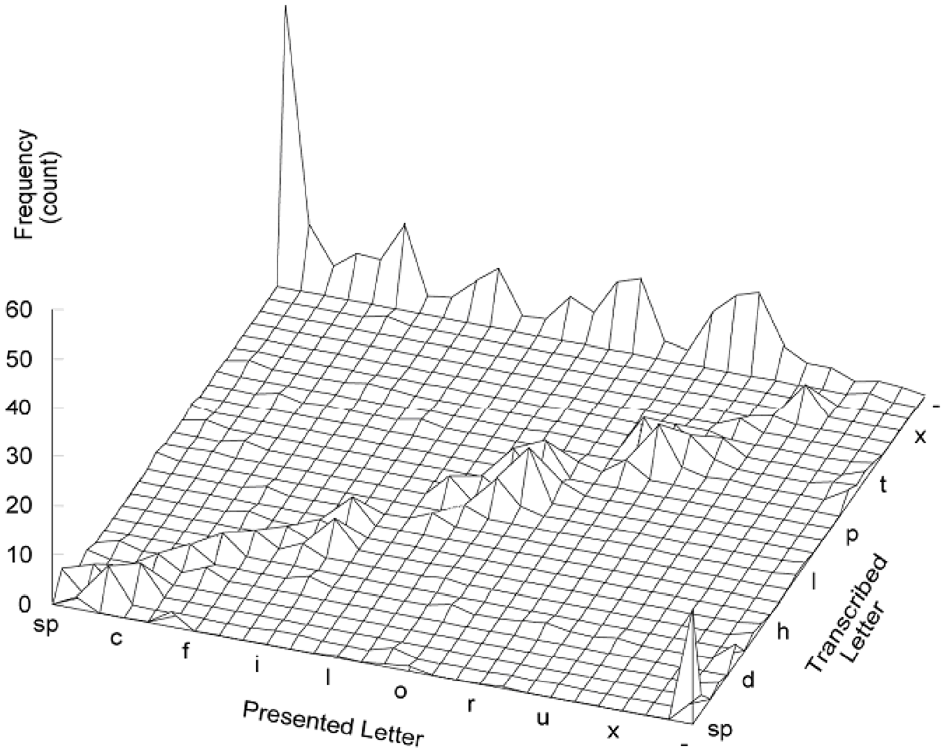
Confusion Matrix



Demo

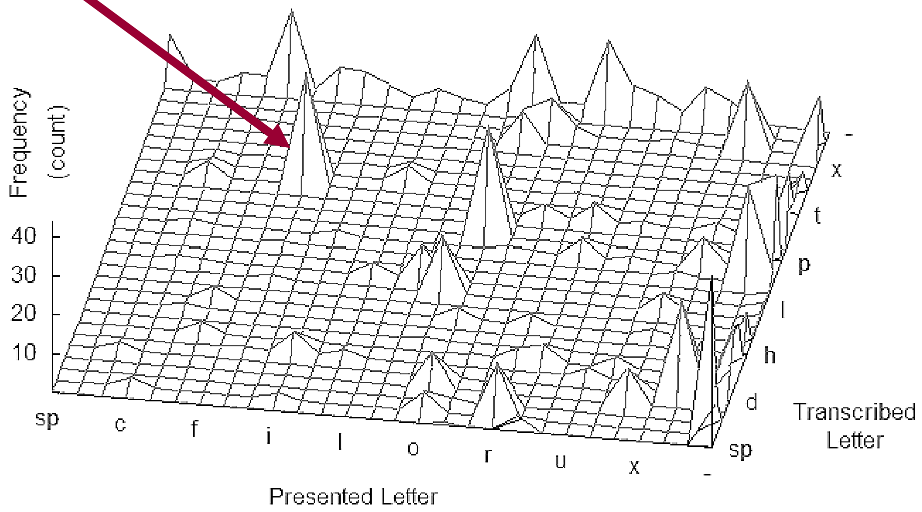
```
Command Prompt
text>java ErrorMatrix ds2-phrases.txt
usage: java ErrorMatrix file [-et] [-em] [-a] [-nd] [-pr] [-co]

where file = a file containing presented/transcribed strings
      -et  = output error table
      -em  = output error matrix
      -a   = output alignments (use for debugging/demo)
      -nd  = null diagonal cell entries in error matrix
      -pr  = use probabilities instead of counts in error matrix
      -co  = console output (looks better on display)
      (Note: default is no output)

text>
```


Three-Key Text Input Example



Handwriting Recognition Example

'g' often recognized as 'q'



Future Challenges

- We have compared "presented" with "transcribed" text
- What about the user's actions that produced the transcribed text?
- The correspondence is inherently one-for-one with a Qwerty keyboard, but this is typically not the case for mobile text entry
- Examples (next slide)

"lazy dog" – Multitap vs T9

Multitap:

lazy dog ← Presented text

55529999↓999036664 ← Keystrokes

l az y do g ← Transcribed text

T9:

lazy dog ← Presented text

5299*0364 ← Keystrokes

laz y dog ← Transcribed text

Bottom line:

Error analyses must consider the user's input stream, not just the final result.

Thank You

Referernces

1. Majaranta, P., MacKenzie, I. S., Aula, A., & Räihä, K.-J. Auditory and visual feedback during eye typing. *Extended Abstracts of CHI 2003*, New York: ACM, 2003, 766-767.
2. MacKenzie, I. S. KSPC (keystrokes per character) as a characteristic of text entry techniques, *Proceedings of the Fourth International Symposium on Human Computer Interaction with Mobile Devices*. Heidelberg: Springer Verlag, 2002, 195-210.
2. MacKenzie, I. S. Mobile text entry using three keys, *Proceedings of NordiCHI 2002*. New York: ACM, 2002, 27-34.
3. MacKenzie, I. S., Kober, H., Smith, D., Jones, T., and Skepner, E. LetterWise: Prefix-based disambiguation for mobile text input, *Proceedings of UIST 2001*. New York: ACM, 2001, 111-120.
4. MacKenzie, I. S., and Soukoreff, R. W. Character-level error analyses for evaluating text entry methods, *Proceedings of NordiCHI 2002*, New York: ACM, 2002, 241-244.
5. MacKenzie, I. S., and Soukoreff, R. W. Text entry for mobile computing: Models and methods, theory and practice, *Human-Computer Interaction* (2002), 17, 147-198.
6. MacKenzie, I. S., and Zhang, S. X. The design and evaluation of a high-performance soft keyboard, *Proceedings of CHI '99*. New York: ACM, 1999, 25-31.
7. MacKenzie, I. S., and Zhang, S. X. An empirical investigation of the novice experience with soft keyboards, *Behaviour & Information Technology 20* (2001), 411-418.
8. MacKenzie, I. S., Zhang, S. X., and Soukoreff, R. W. Text entry using soft keyboards, *Behaviour & Information Technology 18* (1999), 235-244.

tutorial notes

MOBILEHCI 2008

Patrick Baudisch

Mobile GUIs and Mobile Visualization

Tutorial Day at MobileHCI 2008, Amsterdam

Text input for mobile devices by Scott MacKenzie

Scott will give an overview of different input means (e.g. key-based, stylus, predictive, virtual keyboard), parameters relevant for designing and assessing mobile text input (e.g., writing speed, cognitive load) and issues related to the context of use (e.g., walking/standing).

Mobile GUIs and Mobile Visualization by Patrick Baudisch

Patrick will introduce different approaches for creating mobile graphical user interfaces. He will talk about the design process, prototyping and assessment of user interfaces, trade-offs related to the design of mobile GUIs and different possible interaction styles. As one specific topic in mobile GUIs he will address concept for mobile interactive visualization (e.g. maps).

Understanding Mobile User Experience by Mirjana Spasojevic

Mirjana will discuss different means for studying mobile user needs and evaluating the user experience. This includes explorative studies and formal evaluations (in the lab vs. in the field), including longitudinal pilot deployments. The lecture will discuss traditional HCI methods of user research and how they need to be adapted for different mobile contexts and products.

Context-Aware Communication and Interaction by Albrecht Schmidt

Albrecht will give an overview of work in context-awareness and activity recognition that is related to mobile HCI. He will discuss how sharing of context in communication applications can improve the user experience. The lecture will explain how perception and sensing can be used to acquire context and activity information and show examples how such information can be exploited.

Haptics, audio output and sensor input in mobile HCI by Stephen Brewster

Stephen will discuss the design space for haptics, audio output as well as sensor and gesture input in mobile HCI. Furthermore he will assess resulting interaction methods and implications for the interactive experience.

Camera-based interaction and interaction with public displays by Michael Rohs

Michael will introduce you camera based interaction with mobile devices; this includes a assessment of optical markers, 2D-barcodes and optical flow as well as techniques related to augmented reality. In this context he will address interaction with public displays, too.

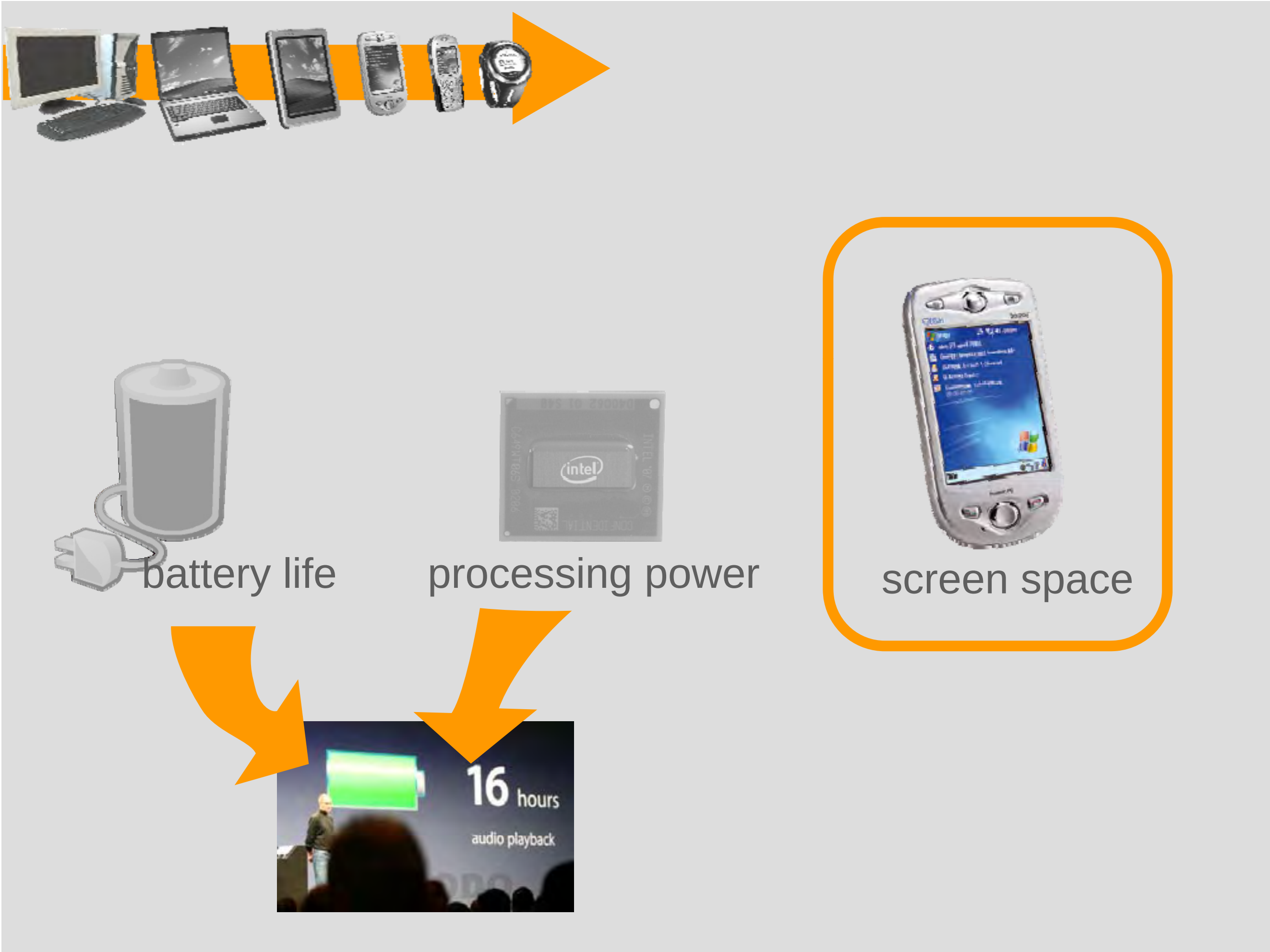
Spetember 2nd 2008

designing for
small screens

patrick
baudisch

microsoft research
adaptive systems—interaction focus

what changes?


intel
battery life
processing power
screen space
16 hours
audio playback


portability

mantra

always use the **most available** device

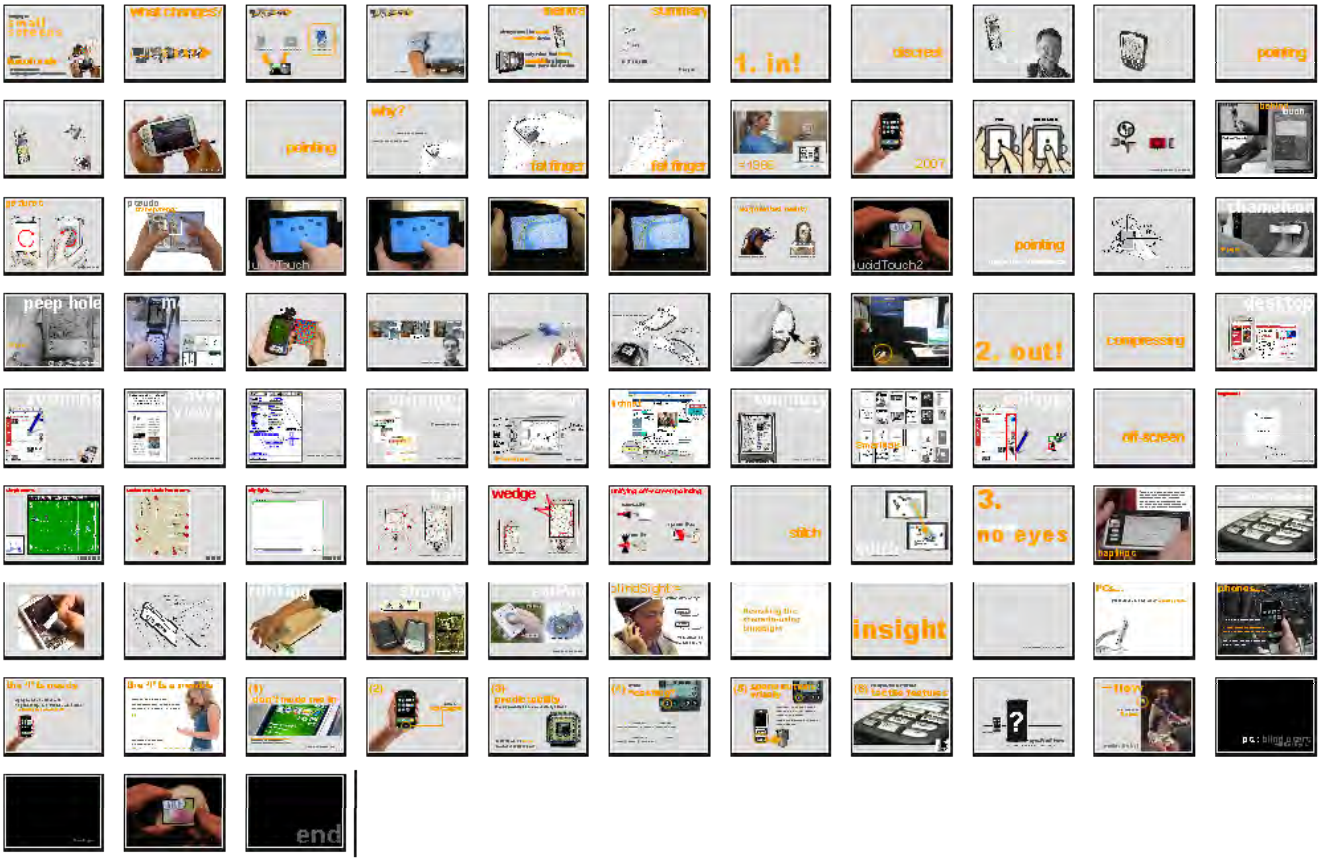
only when that **fails, escalate** to a larger, more powerful device

summary

in (discreet, touch, backside, device)

out (compress, off-screen, extend, audio, tactile)

so what should I use?


what changes?
summary
1. in!
pointing
fat finger
2007
pseudo
peep hole
2. out!
desktop
off-screen
wedge
stitch
3.
no eyes
insight
end

1. in!

in!

1. discreet

thumb wheel

keypad

d-pad/
joystick

→Scott

for **discreet** tasks use **discreet** controls
(such as buttons for typing or launching app)

and for **pointing** tasks?

in!

2. pointing/touch

1. quite ergonomic compared to desktop

2. discreet controls
and rate-control
very limited

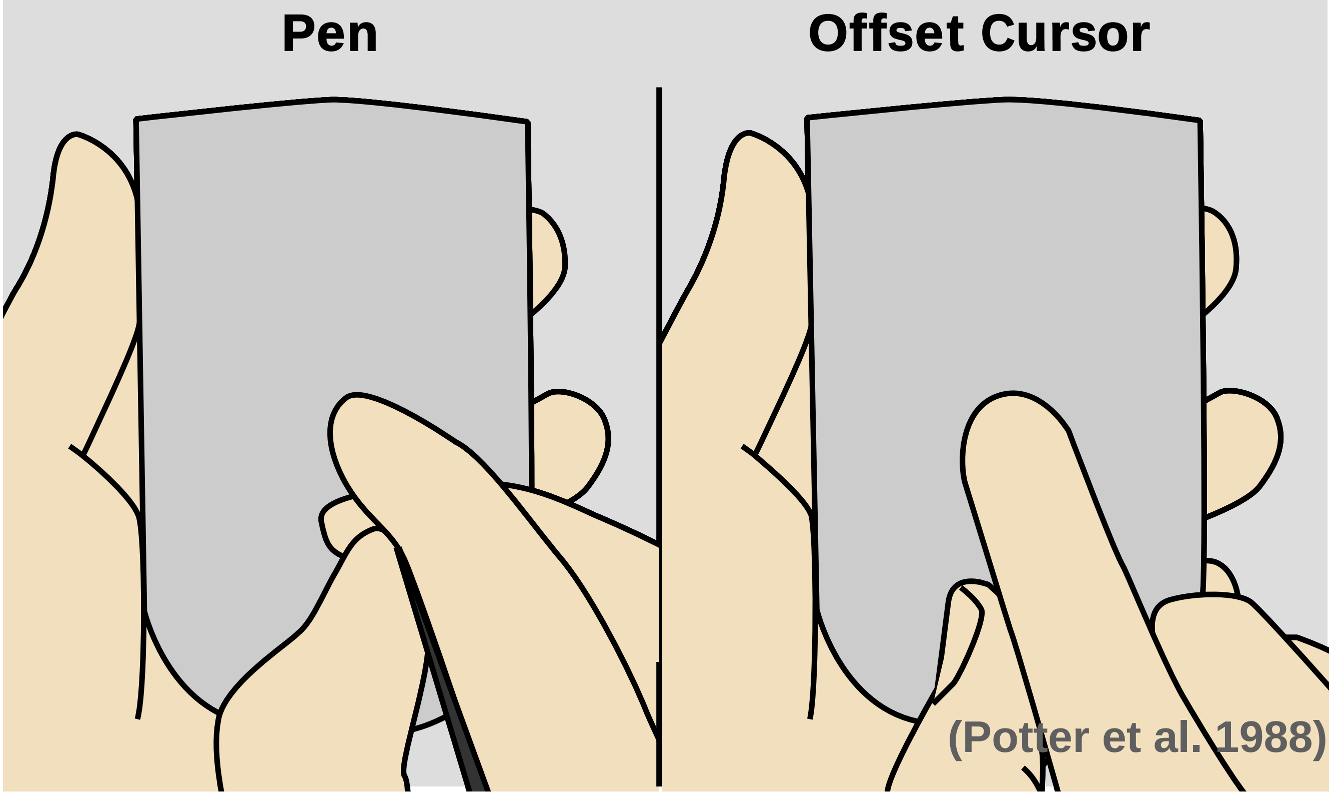
fat finger

<1988

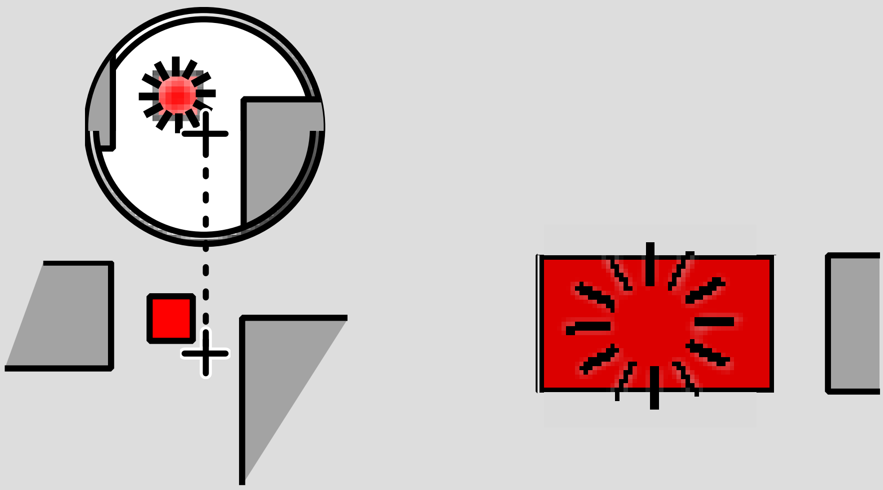
(→2007)

precision?

offset cursor

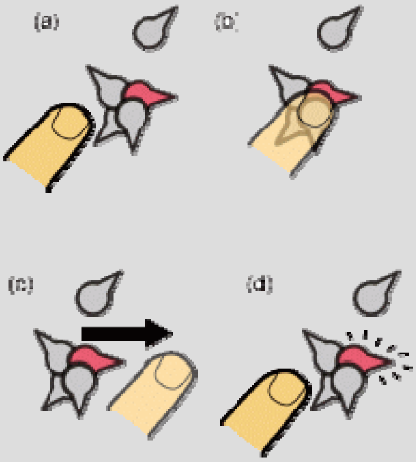


shift



[vogel & baudisch, CHI 2007]

escape

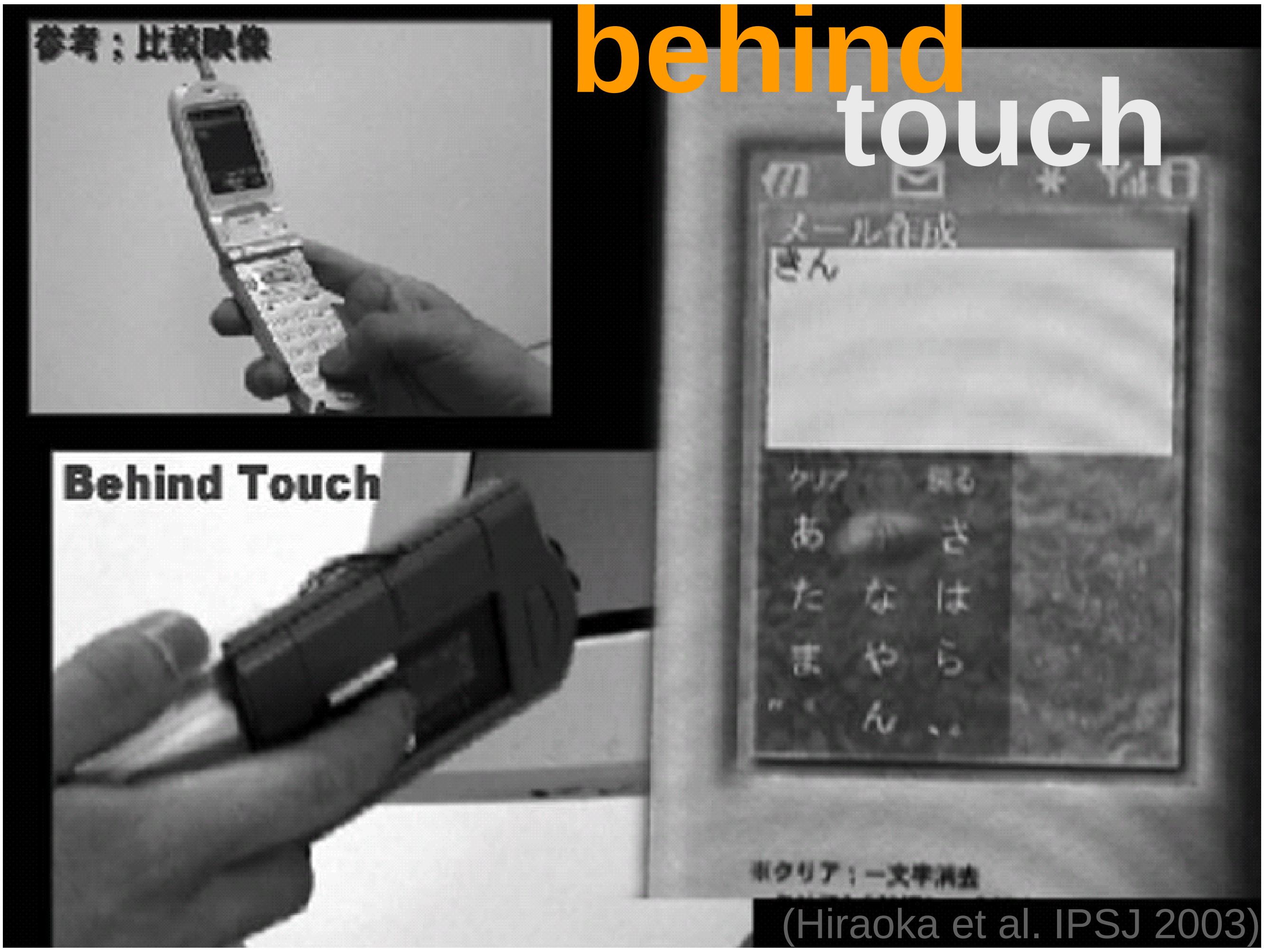


[yatani et al, CHI 2008]

in!

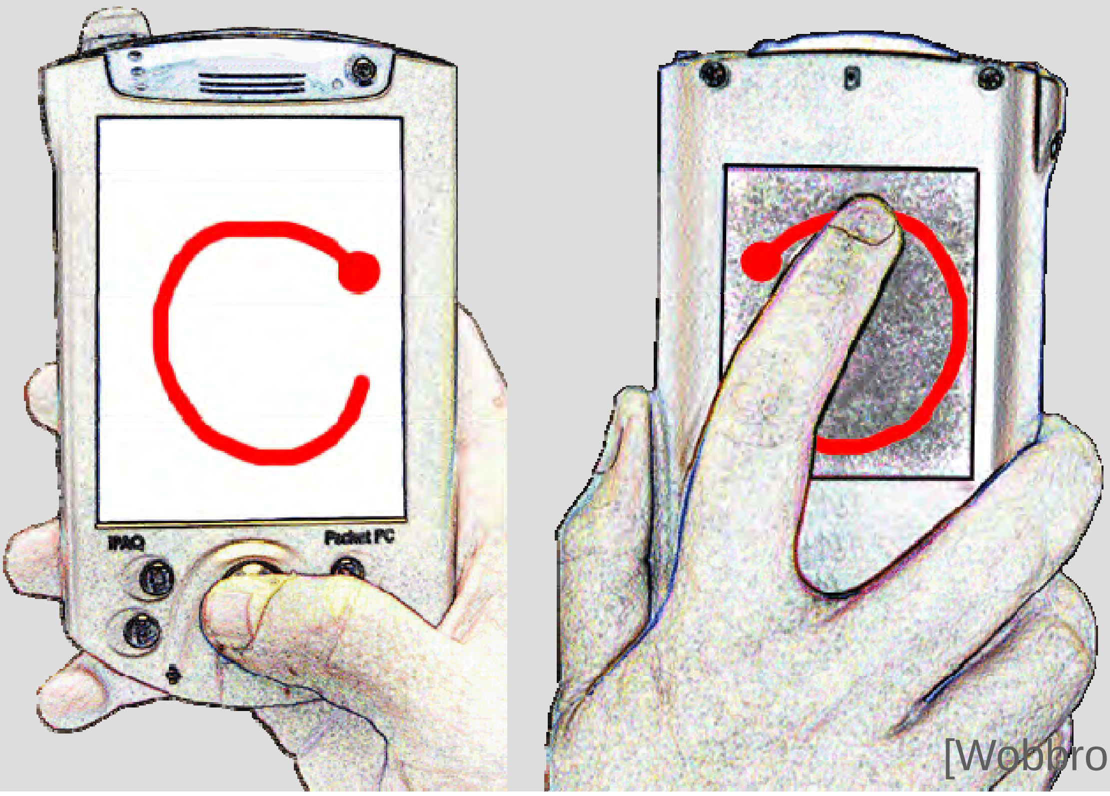
3. backside

behind touch



(Hiraoka et al. IPSJ 2003)

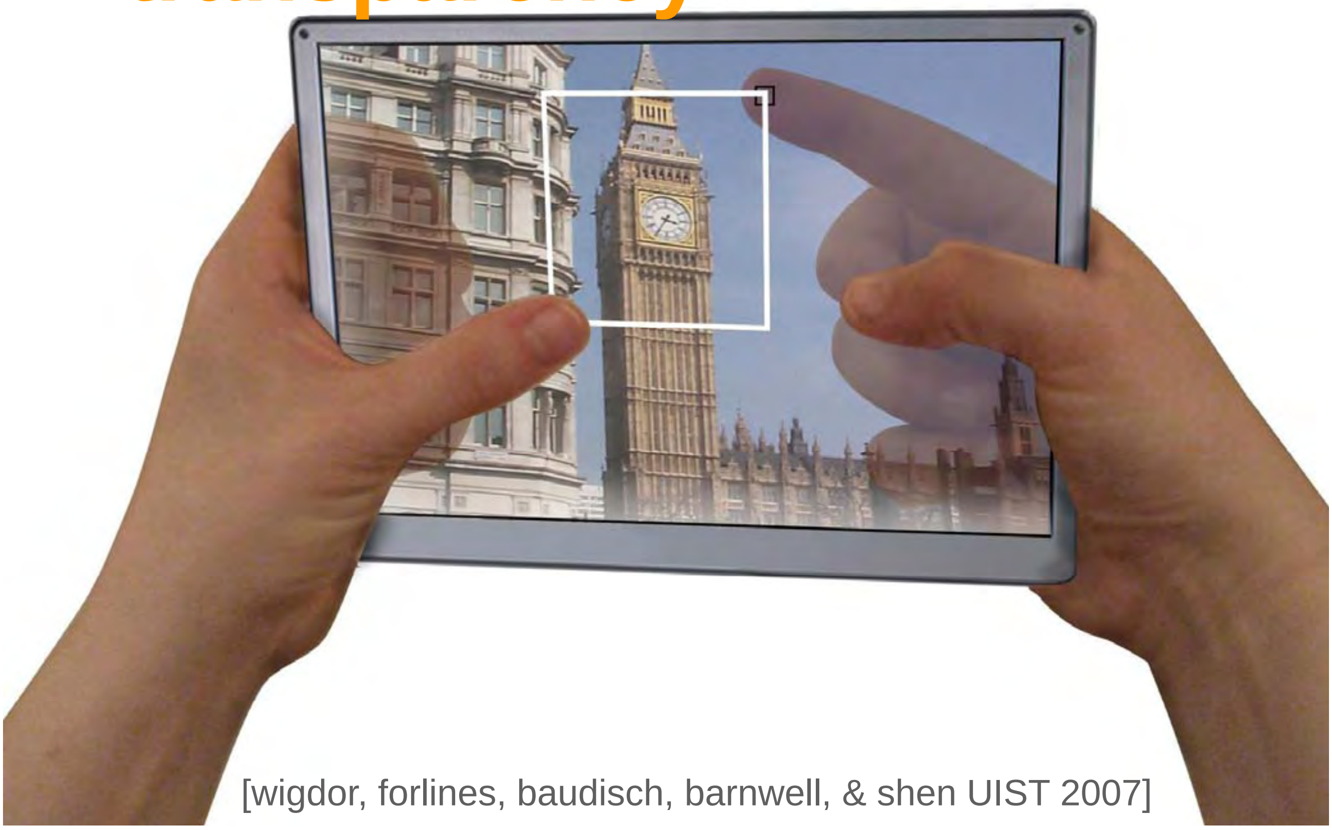
gestures



[Wobbrock at al]

half of that size?

pseudo transparency

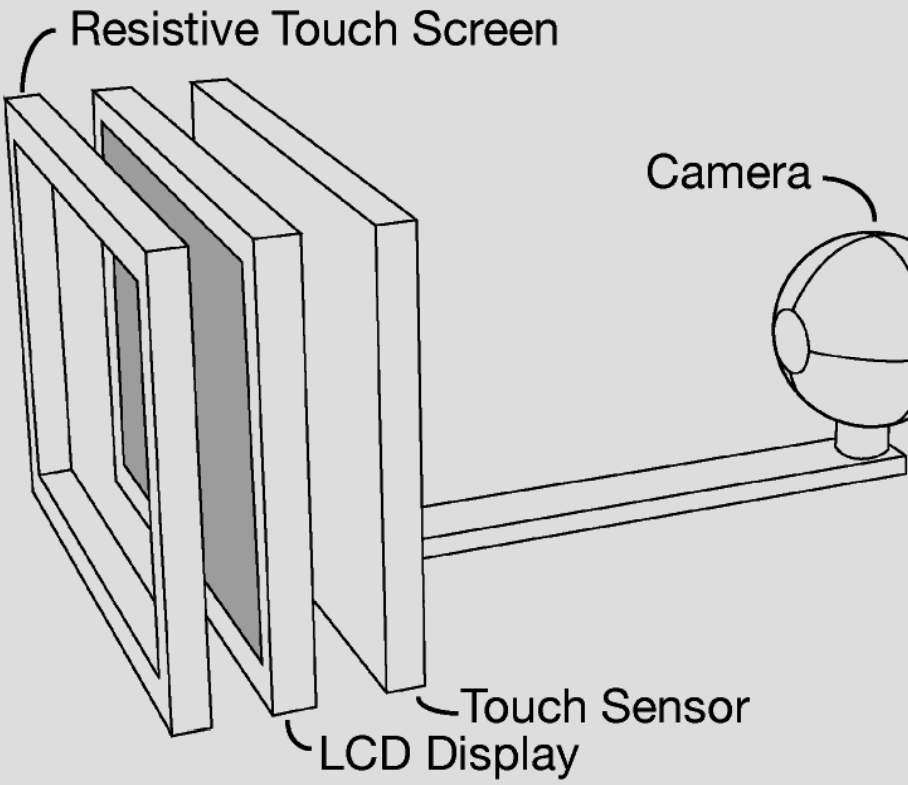


[wigdor, forlines, baudisch, barnwell, & shen UIST 2007]

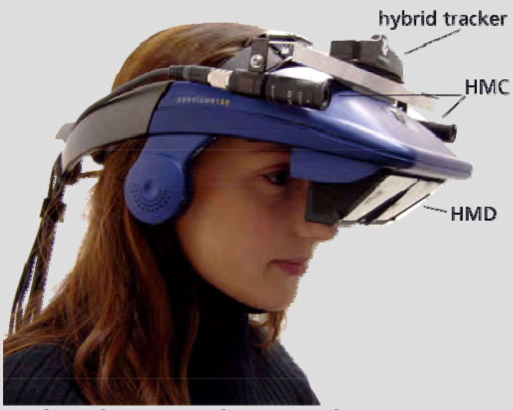

lucidTouch


XENARC


XENARC



borrowed from
augmented reality



physical see-through

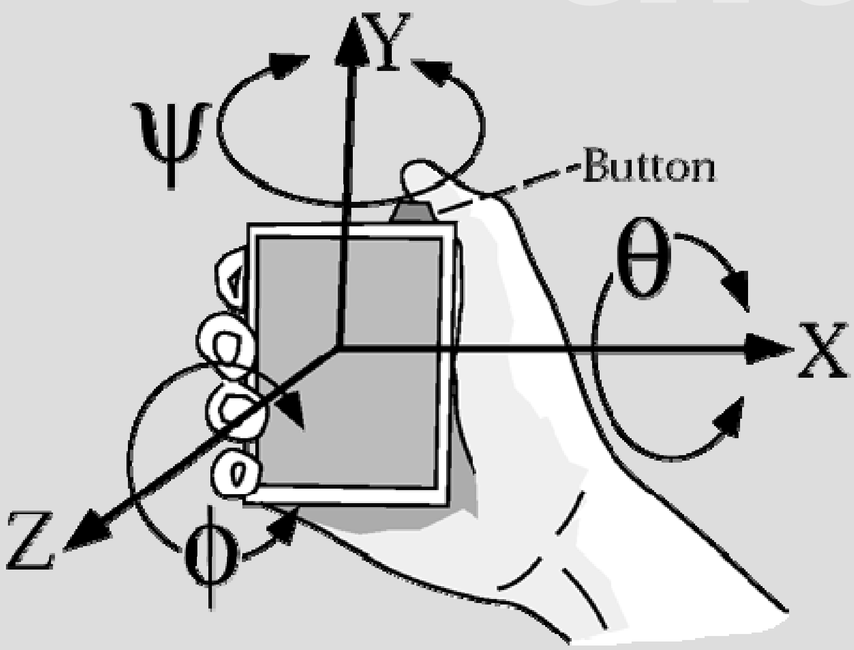
camera see-through


lucidTouch2

in!

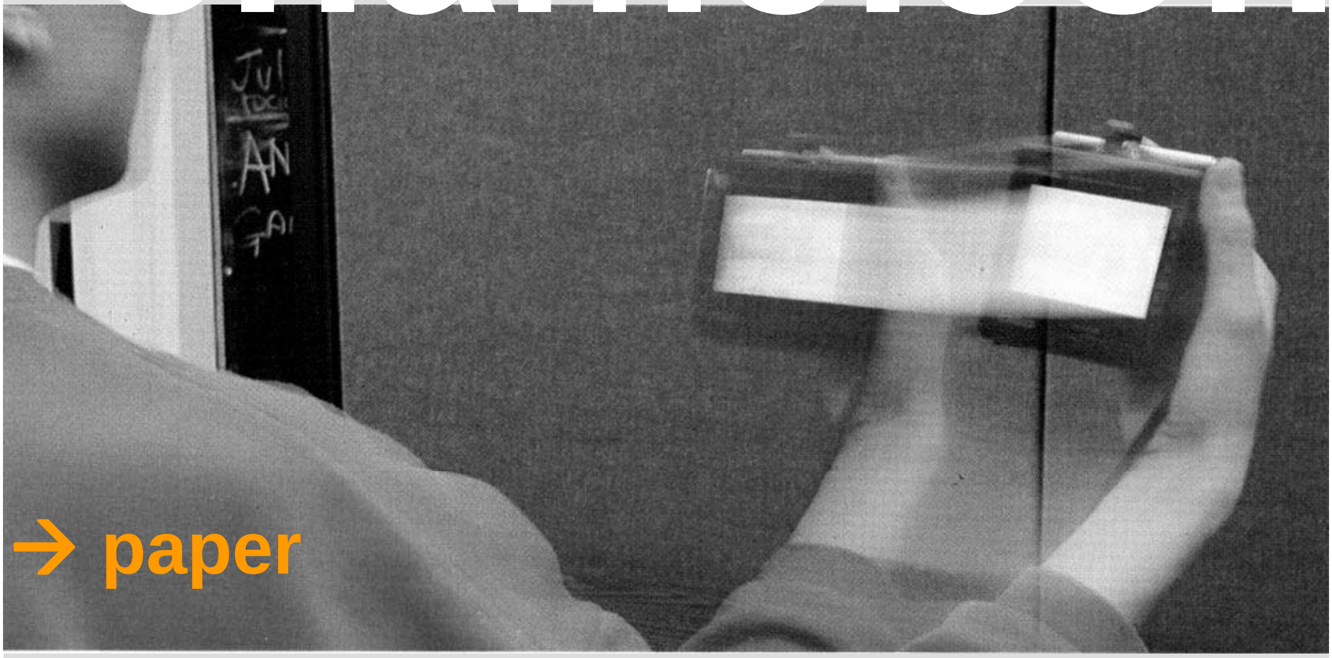
4. move device

tilting



[rekimoto uist 96]

chameleon



→ paper

[Fitzmaurice '93]

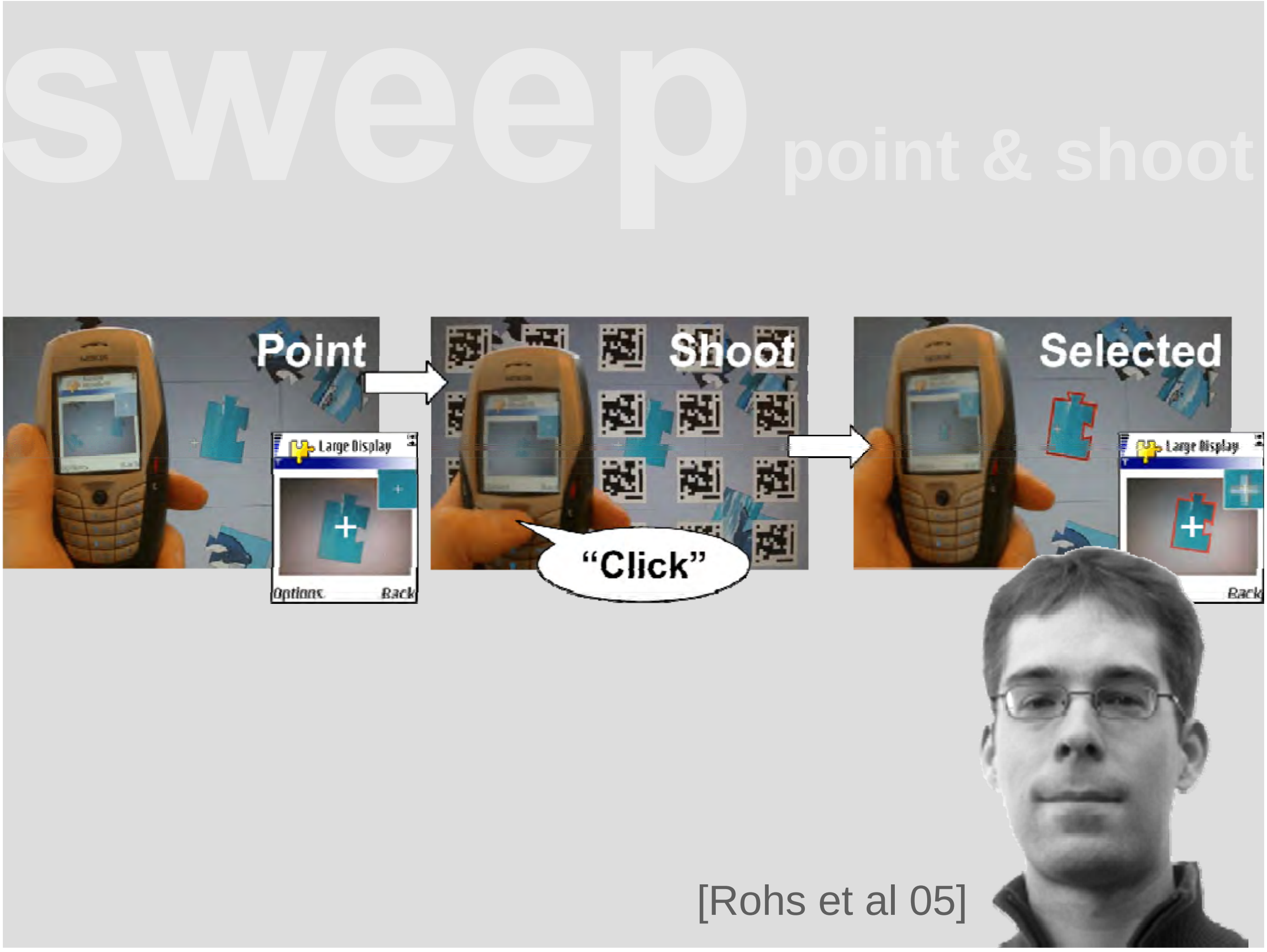
peep hole

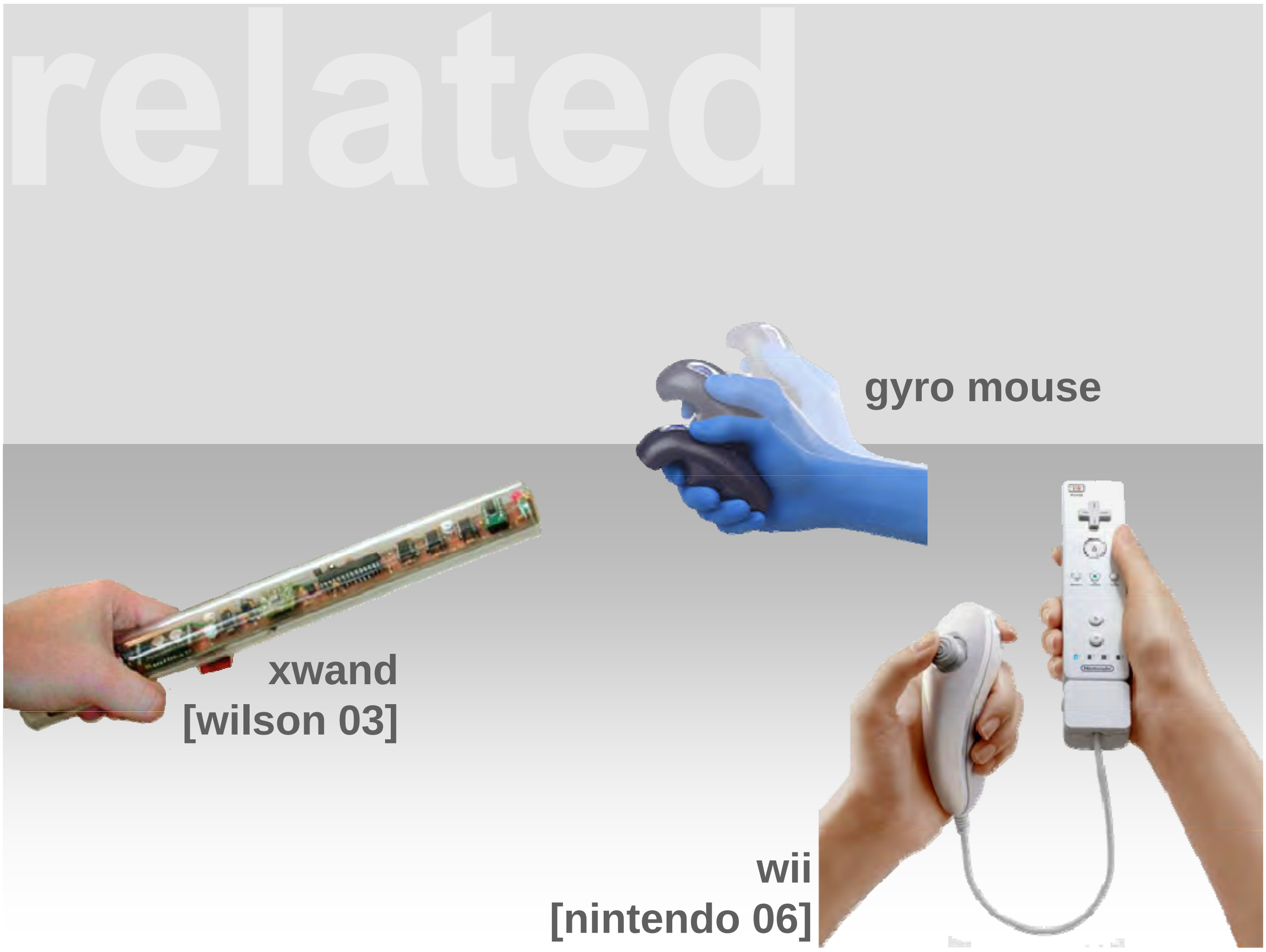
→ paper

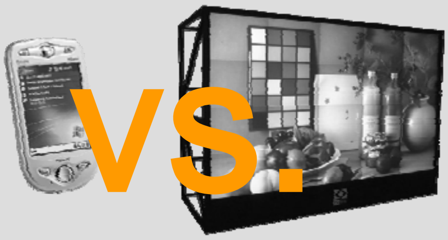
Ka-Ping Yee [CHI'03]


motion
[Wang, Zhai, Canny UIST 06]
MOTOROLA
Next
Score
0
Camera Tetris
verizon
Contact List
Donald Knuth
Bjarne Stroustrup
Don Norman
John Canny
James Landay
Jen Mankoff
Next
Score
0
Camera Tetris


tangimap
Pocket PC
TOSHIBA
[hachet GI 05]


sweep
point & shoot
Point
Shoot
Selected
Large Display
Options
Back
“Click”
Large Display
Back
[Rohs et al 05]


related
gyro mouse
xwand
[wilson 03]
wii
[nintendo 06]



limited screen size

user's perceptually limited

lack of keyboard & pointing device

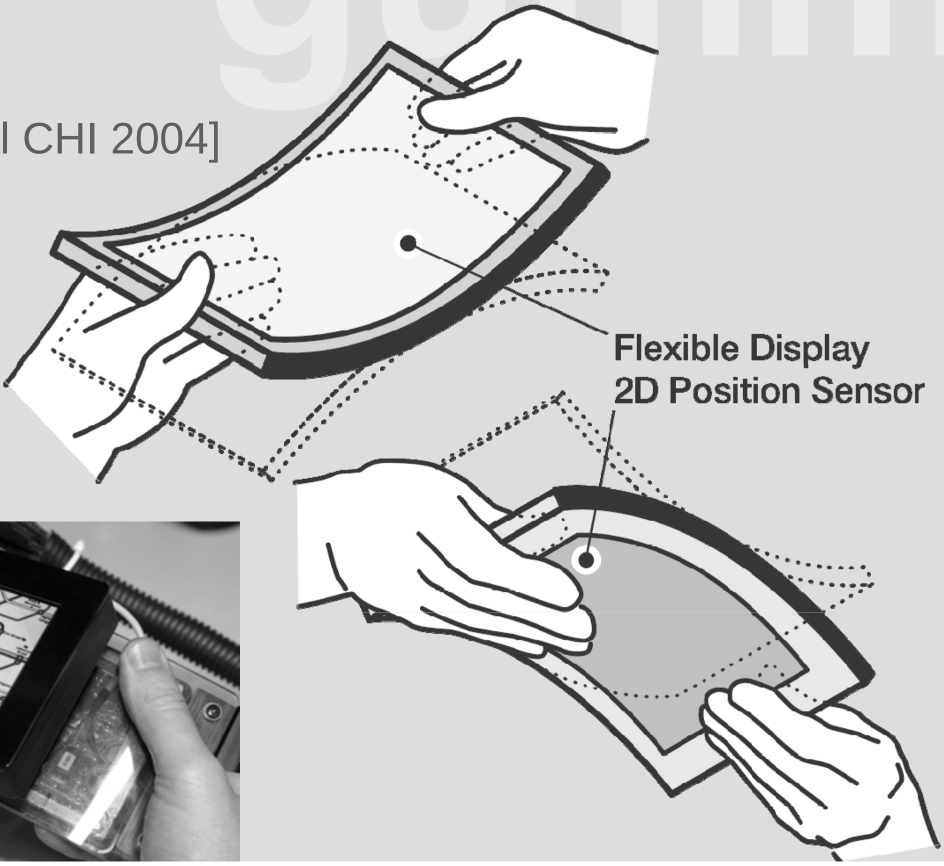
no space to set down keyboard and mouse

large display users **are** mobile users

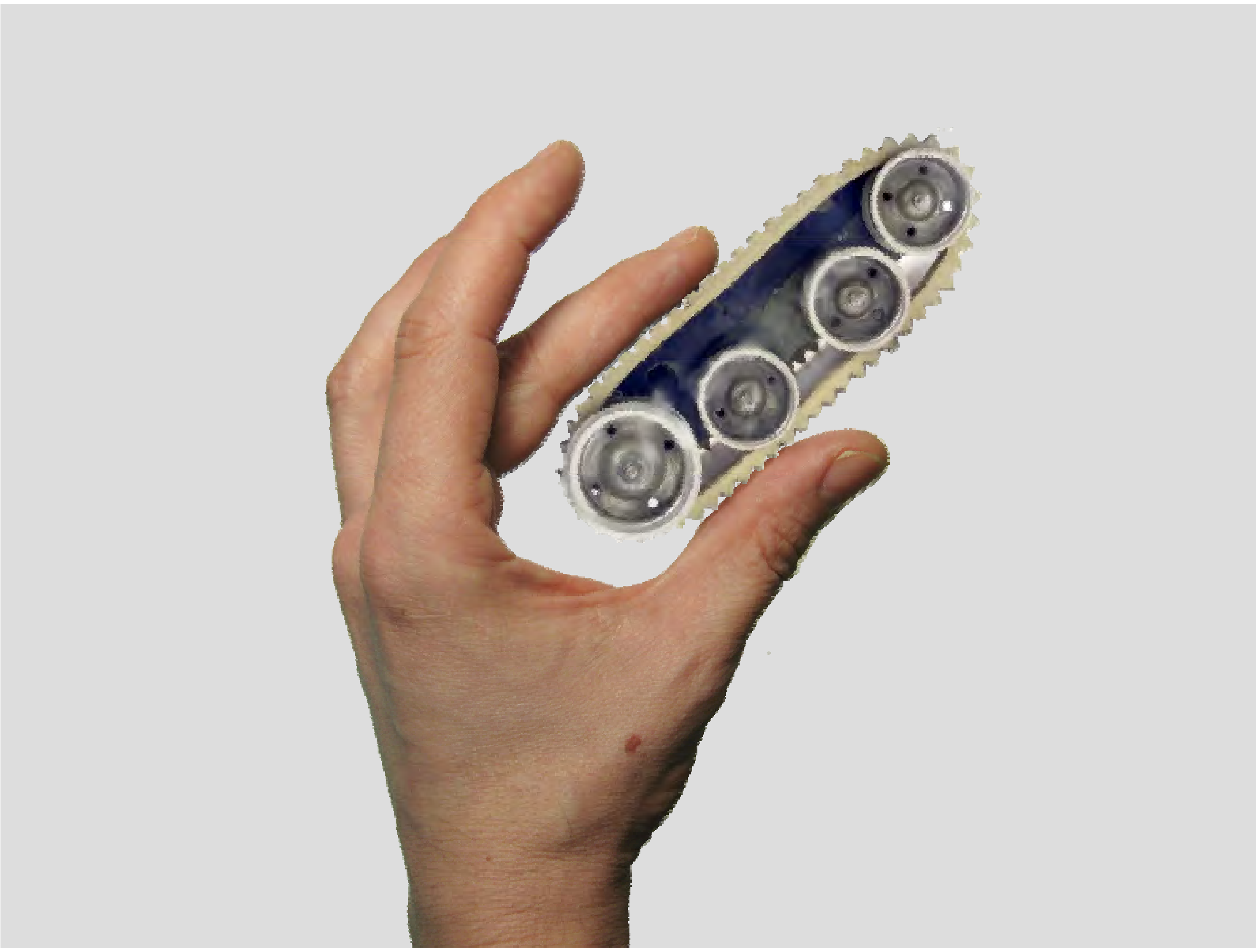
…

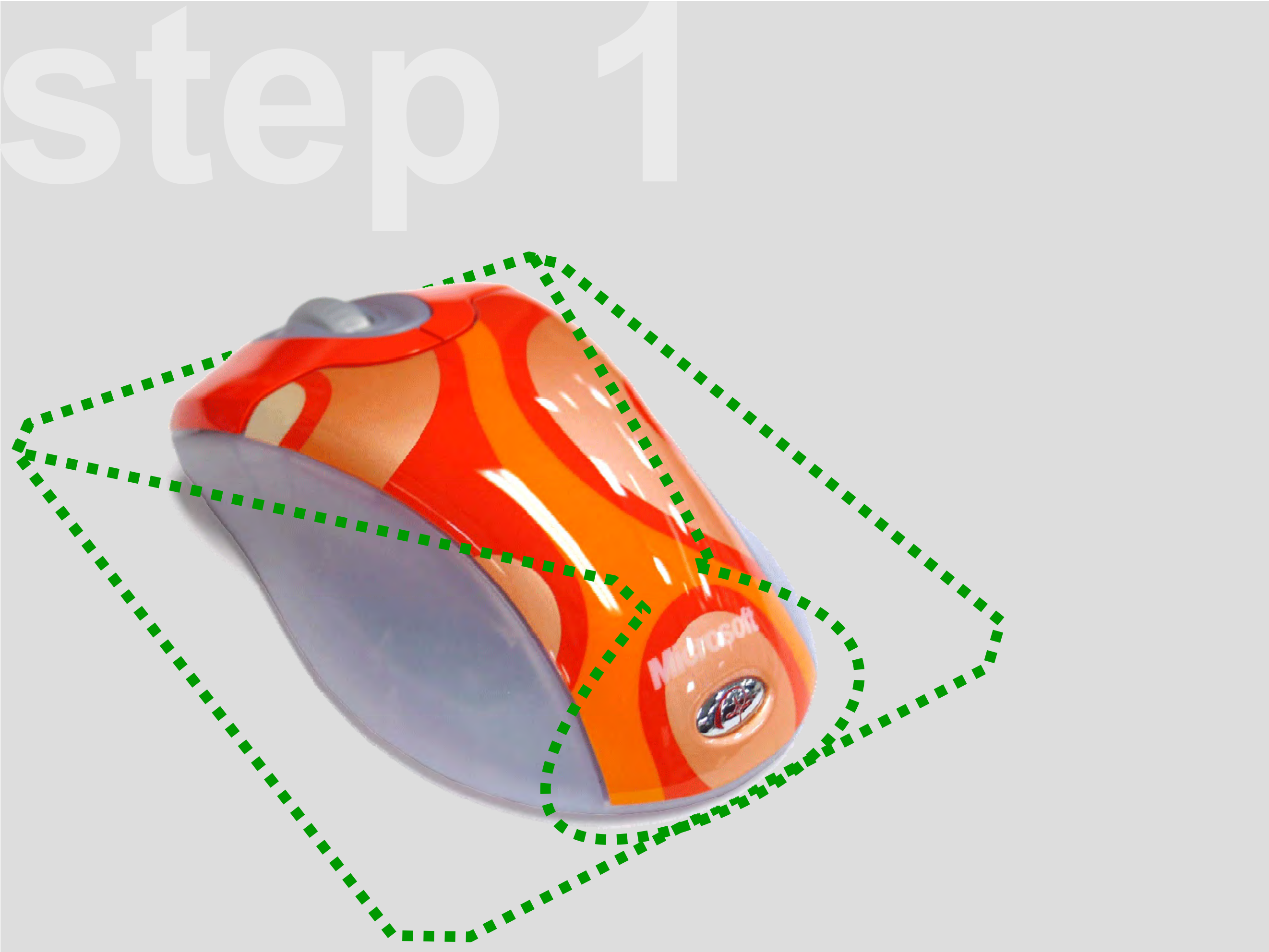
gummi

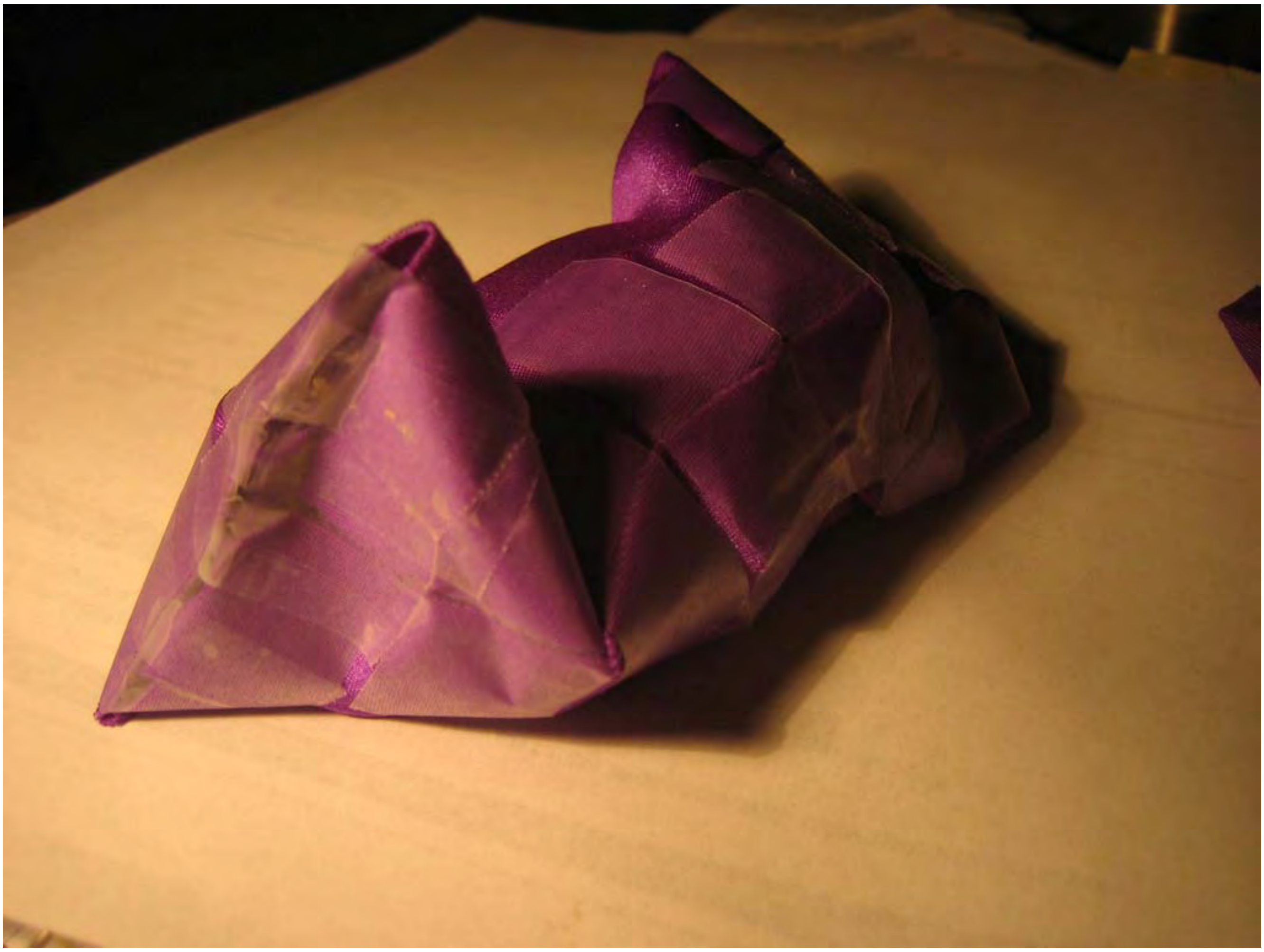
[schwesig et al CHI 2004]

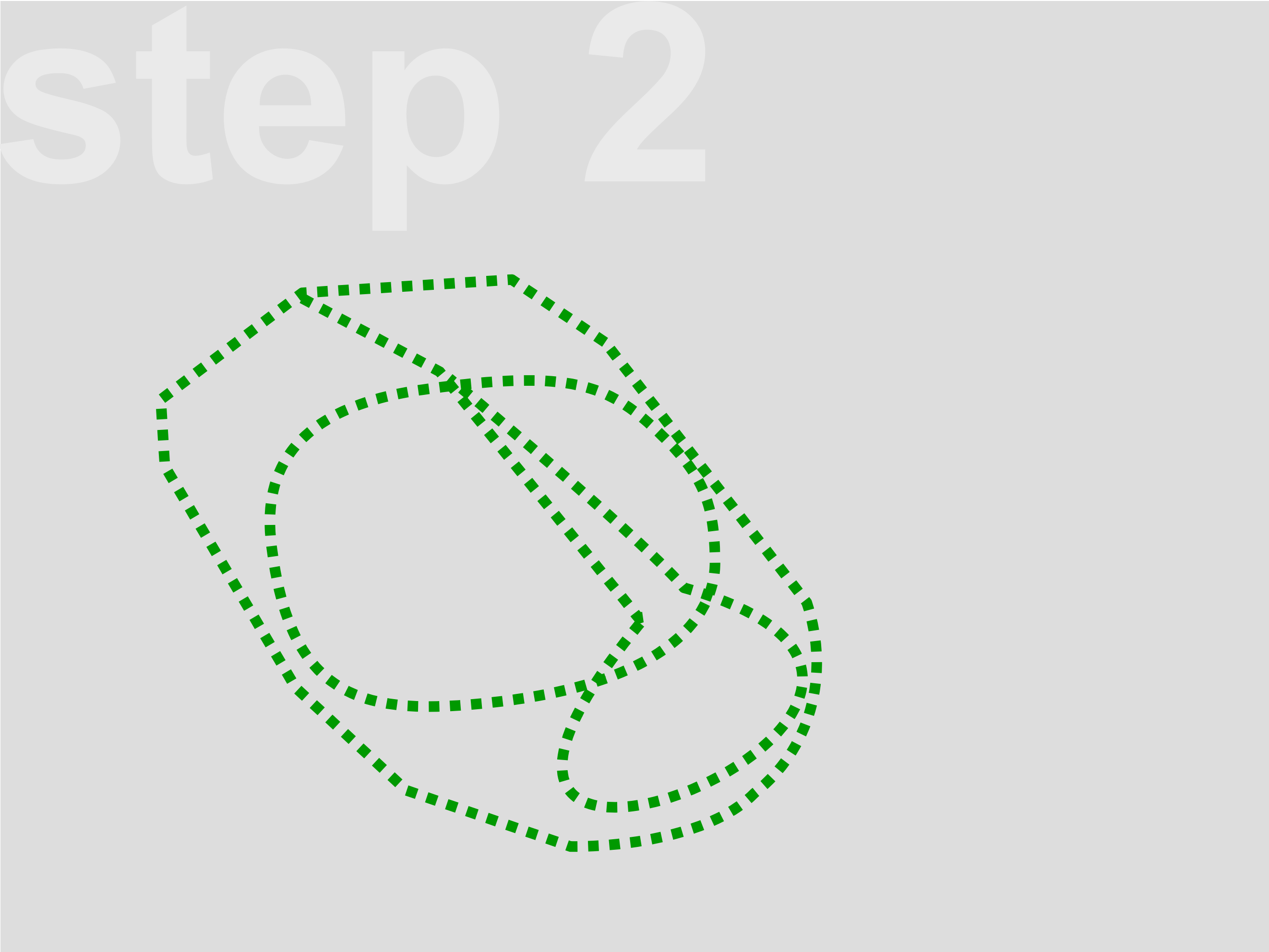


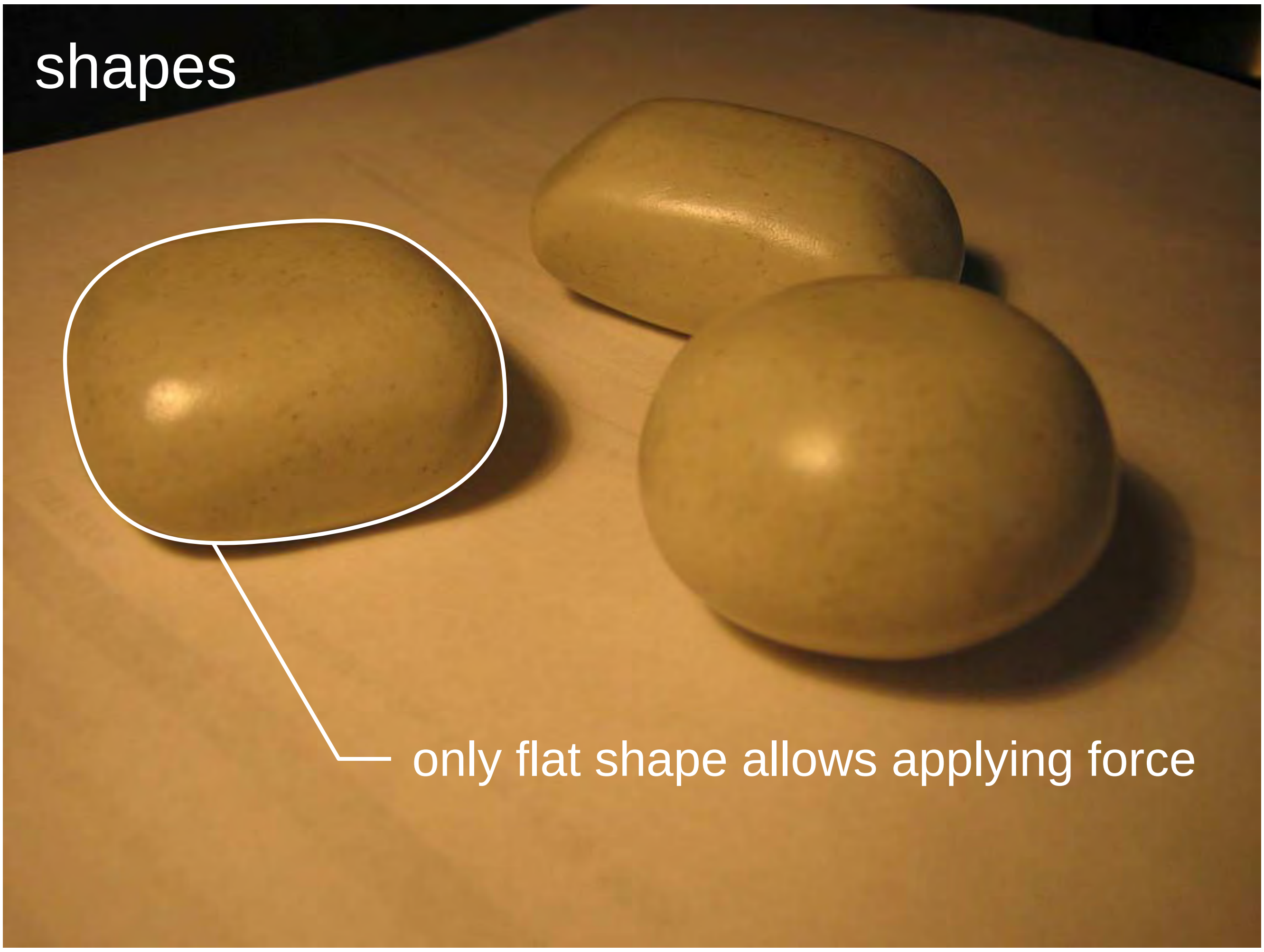

soap
hull
optical
sensor
core
[baudisch et al, UIST 2006]

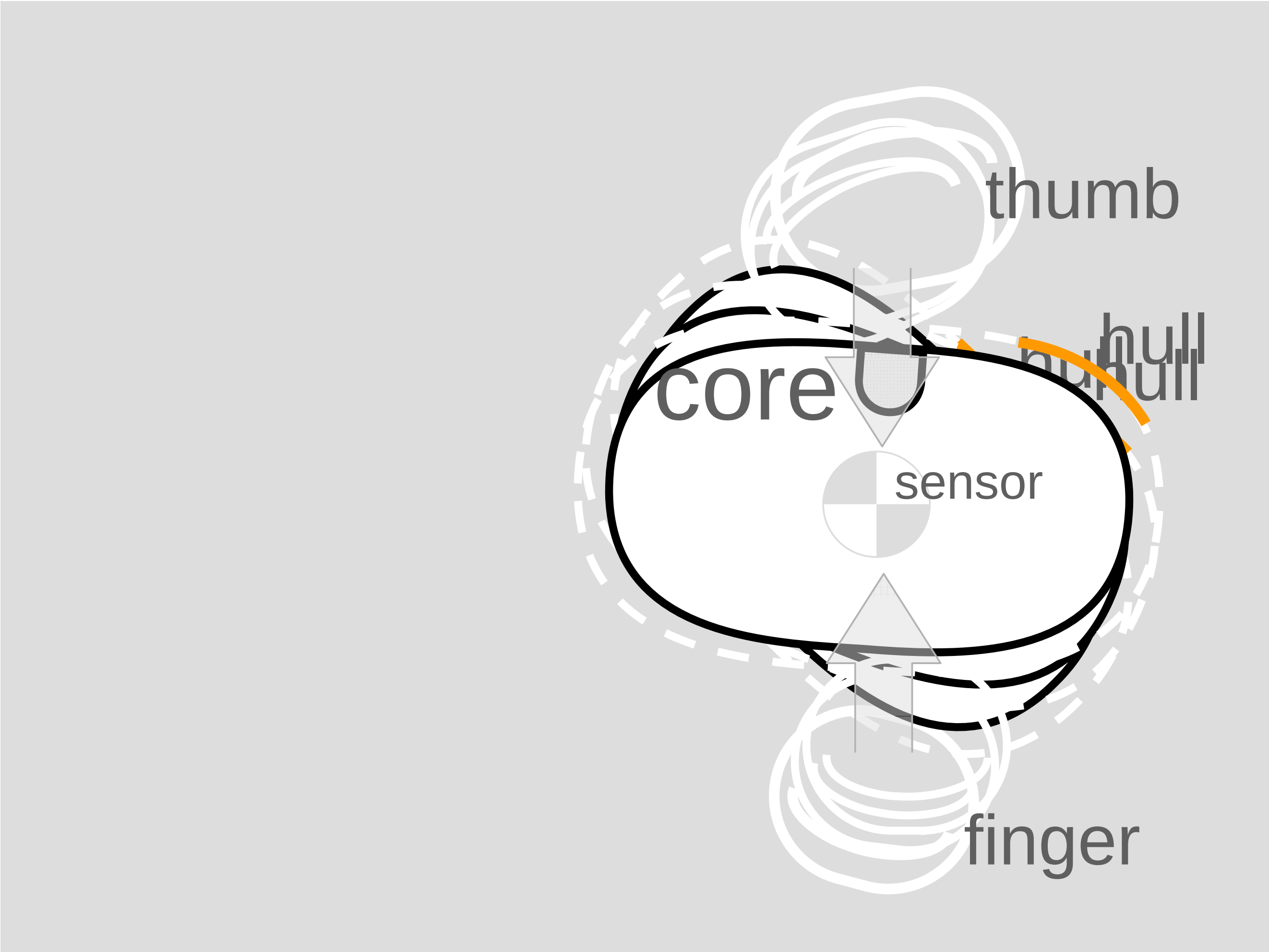


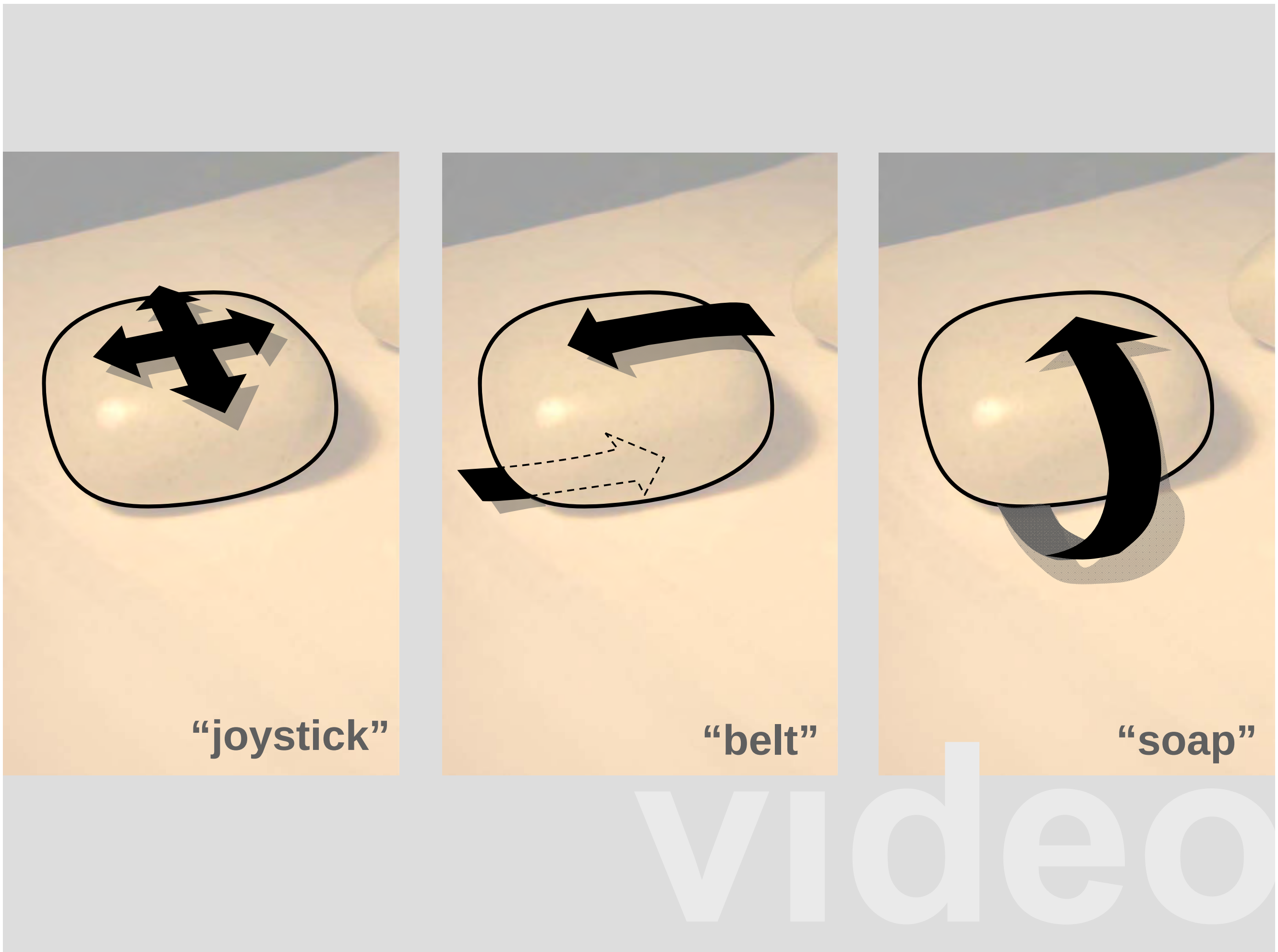

step 1
Microsoft

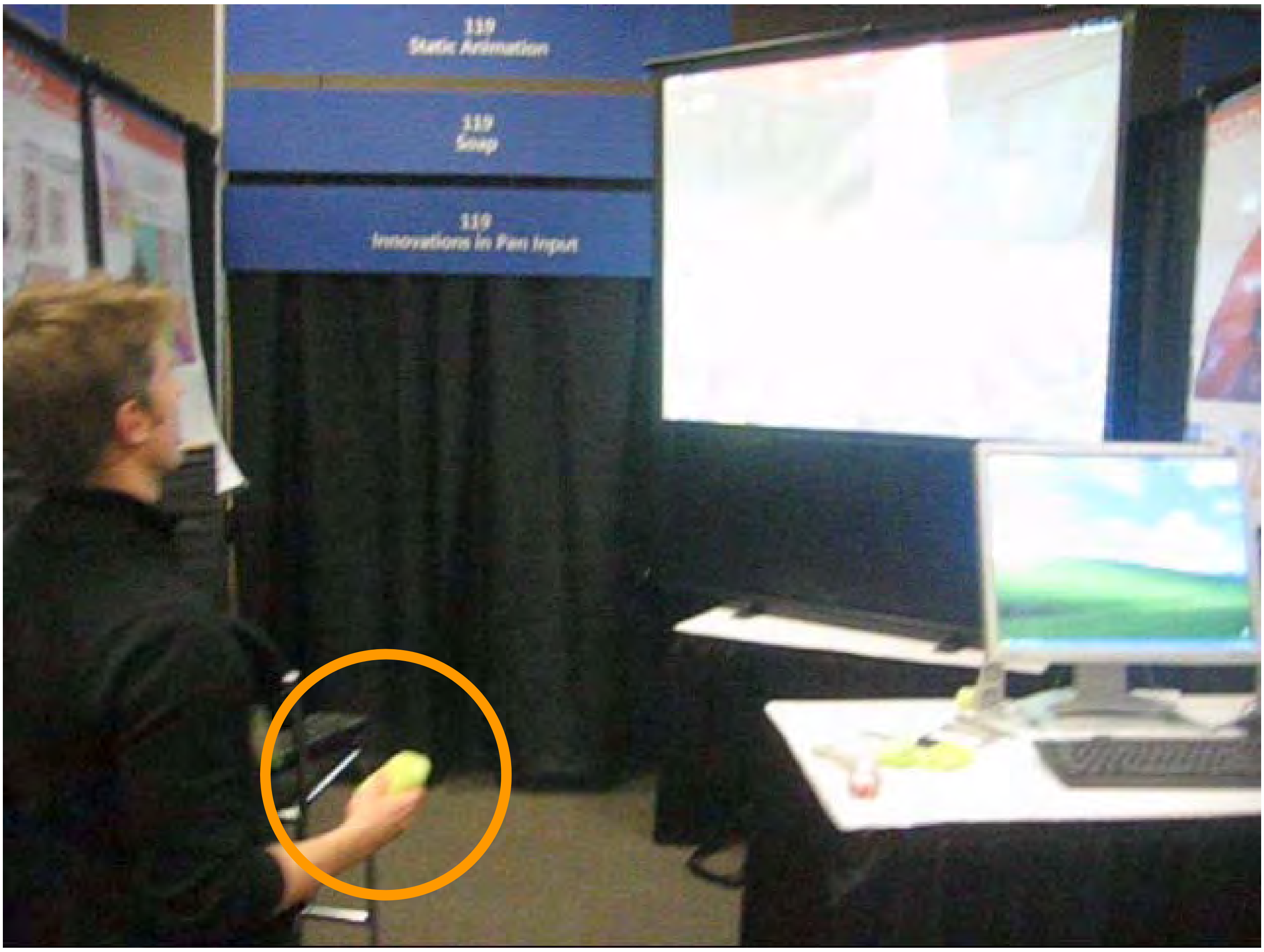



step 2


shapes
only flat shape allows applying force


thumb
hull
core
sensor
finger


"joystick"
"belt"
"soap"
video


119
Static Animation
119
Soap
119
Innovations in Pen Input


119
Static Animation
119
Soap
119
Innovations in Pen Input

2. out!

desktop contents

out!

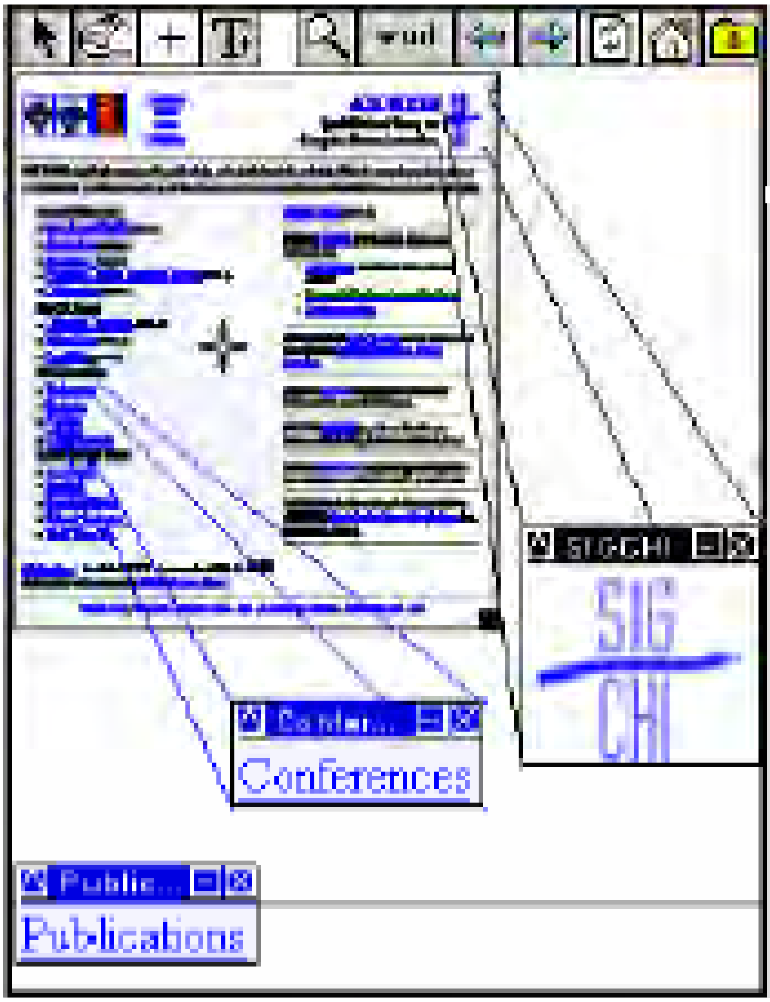
1. compressing

zooming

[Xie etc. al, www'04]

over views

[O'Hara et. at CHI 99]



web thumb

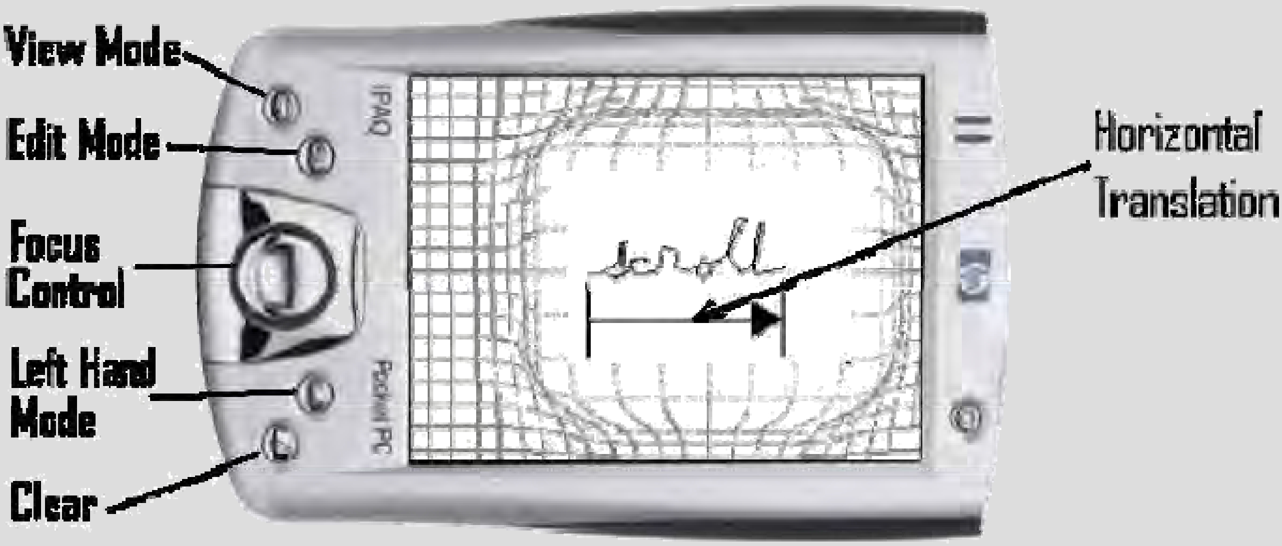
[Wobbrock et. al UIST'02]

enhanced thumbnails

→ semantic zooming

[suh, et al., chi'02]

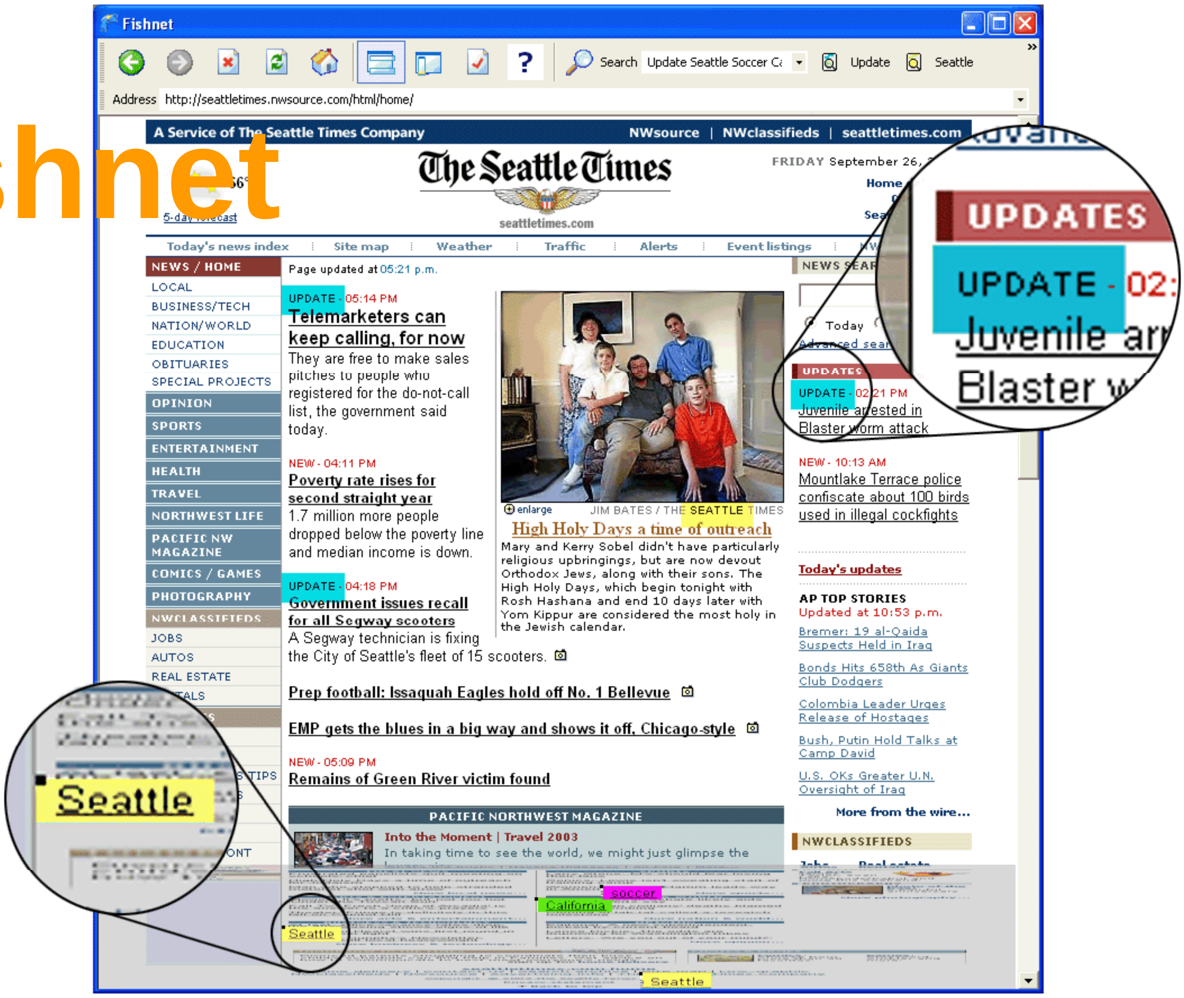
fisheye



→ furnas paper

[lank, chi'04]

fishnet



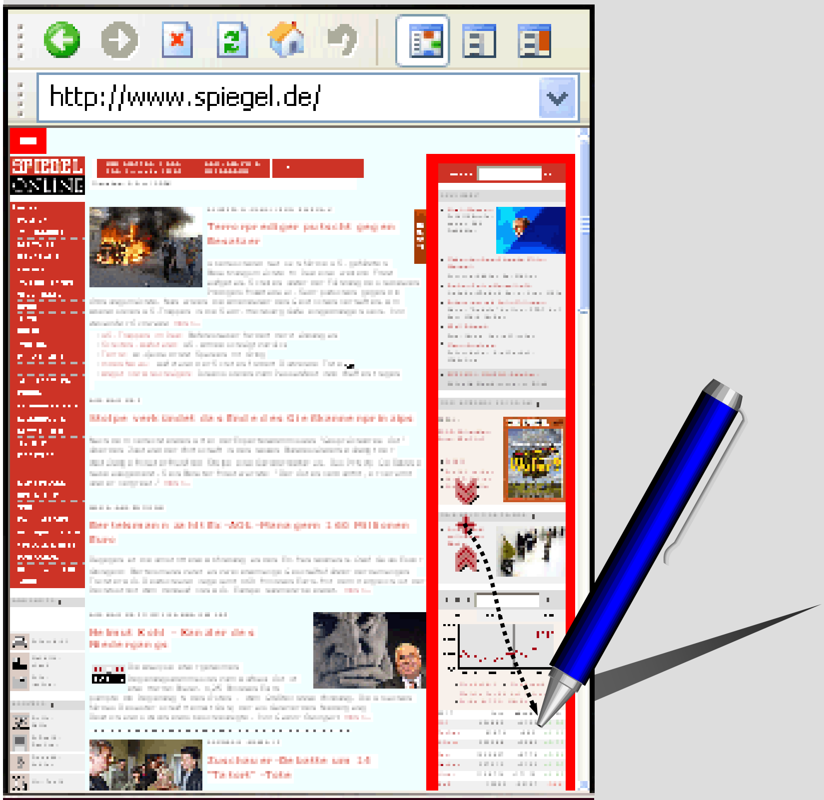
summary thumbnails

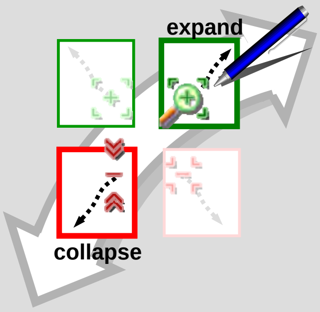
[lam & baudisch, CHI 05]

SmartNails

[Berkner et al 2004]

collapse to zoom



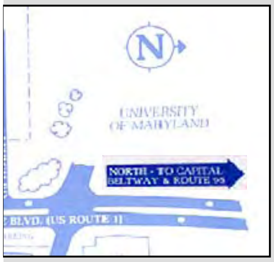


[baudisch, et al UIST 04]

out!

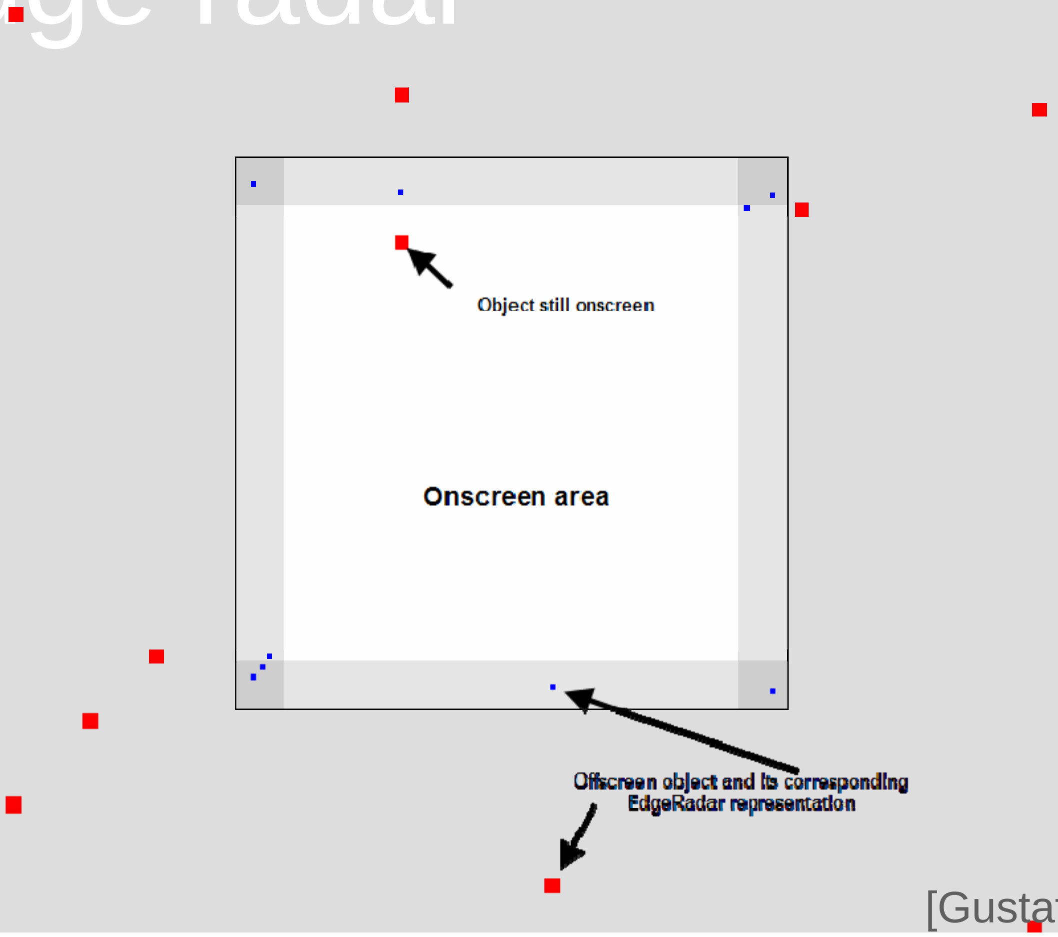
2. off-screen

simple arrows



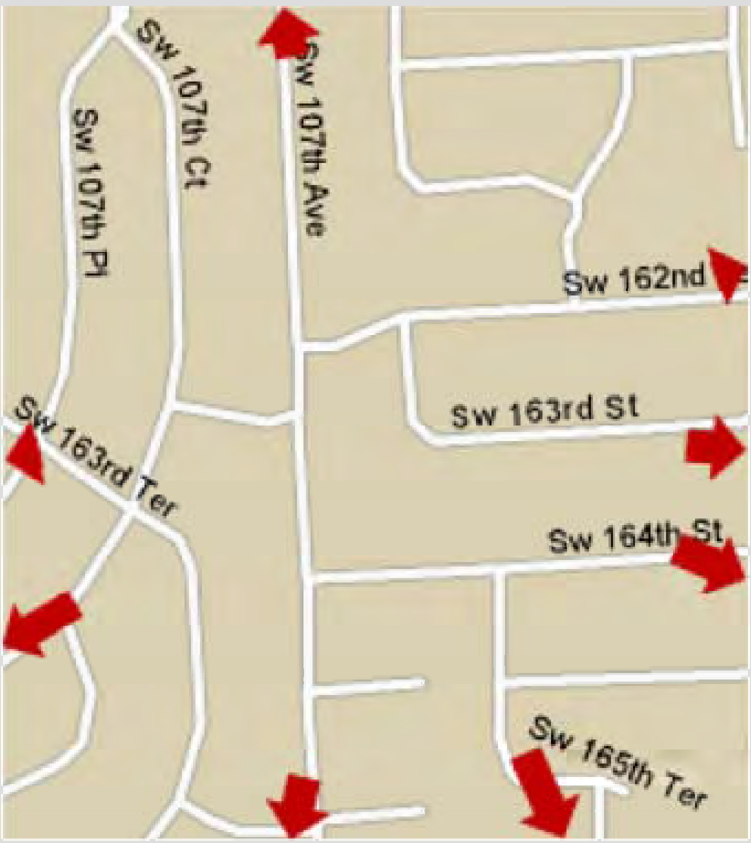
[Tecmo Bowl 87]

edge radar



[Gustafson 07]

scaled&stretched arrows



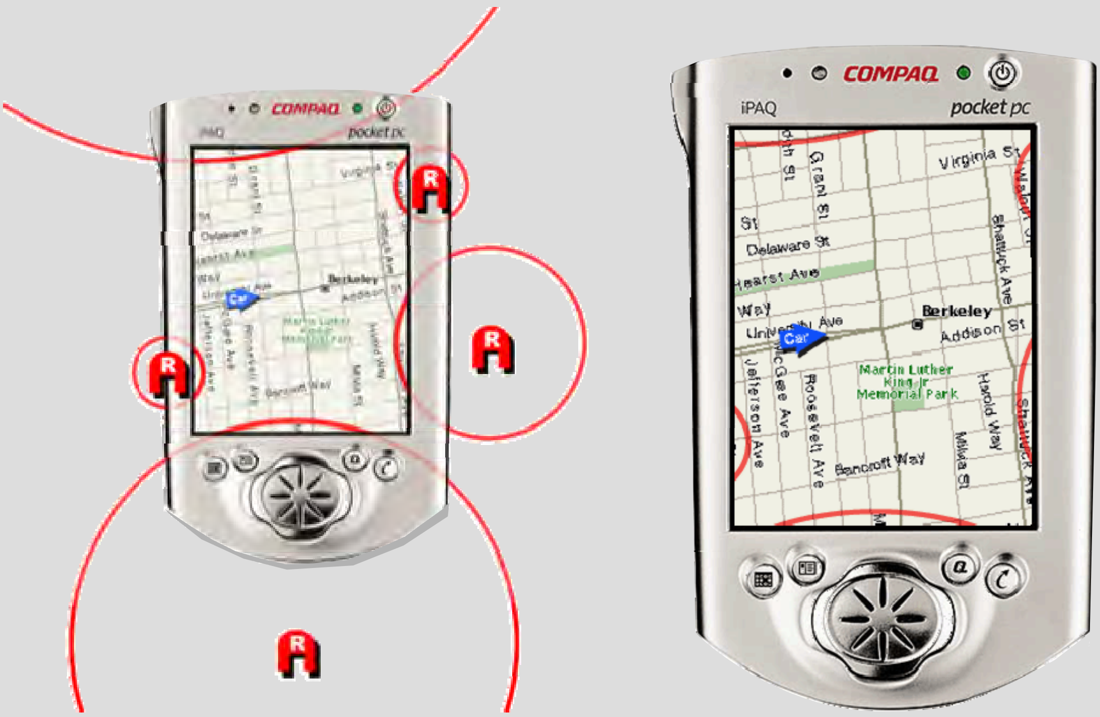
[Burigat 06]

city lights

“space-efficient fisheye technique”

[Mackinlay 03]

halo



[baudisch & rosenholtz, CHI 03]

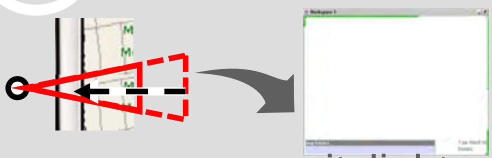
wedge

halo: clutter problem

wedge: avoids overlap

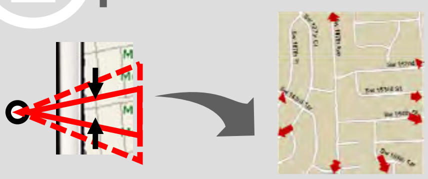
unifying off-screen pointing

1 intrusion → 0



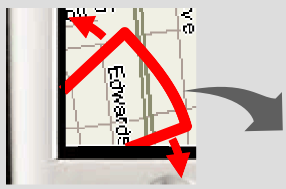
citylights

2 aperture → 0



arrows

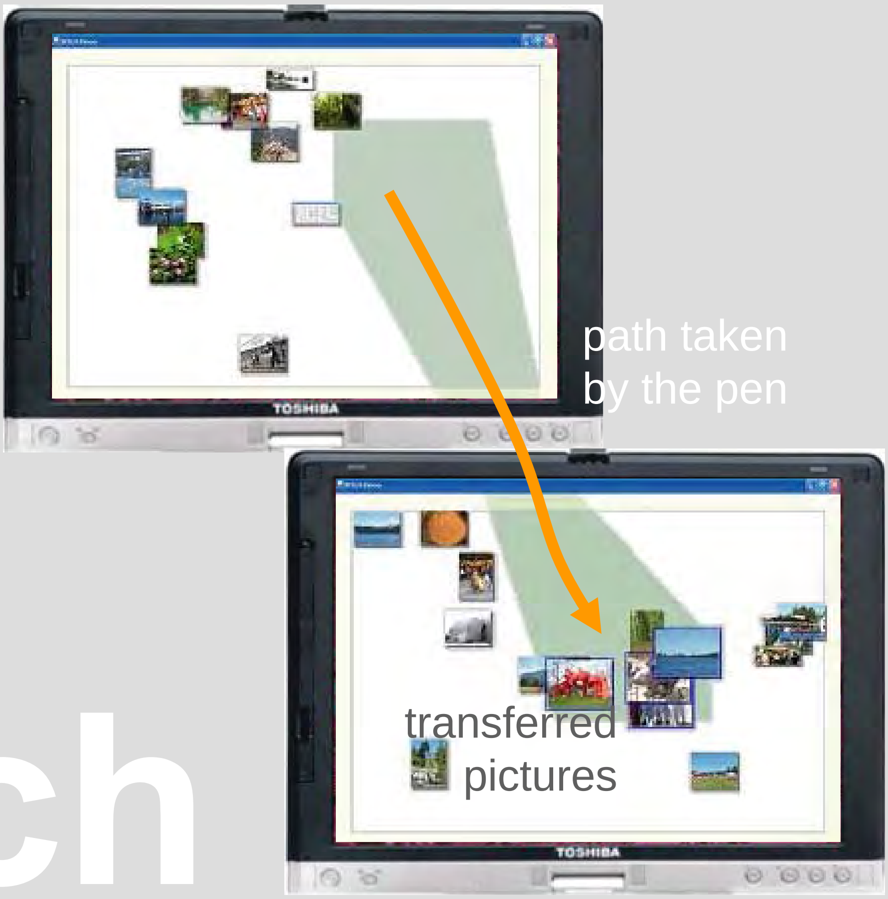
3 aperture → 360



halo

out!

3. extend



stitch

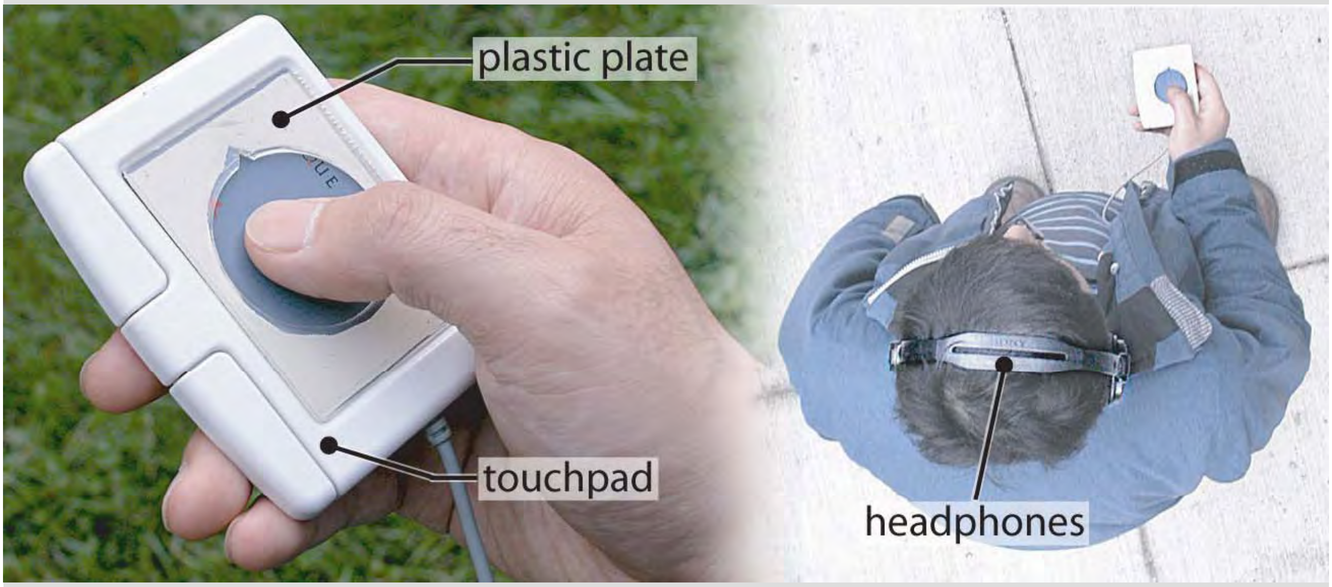
[hinckley et al 2004]

near-eye

out!

4. eyes-free/audio

earPod



[zhao et al, CHI 2007]

novice


experienced


expert

blindSight:=

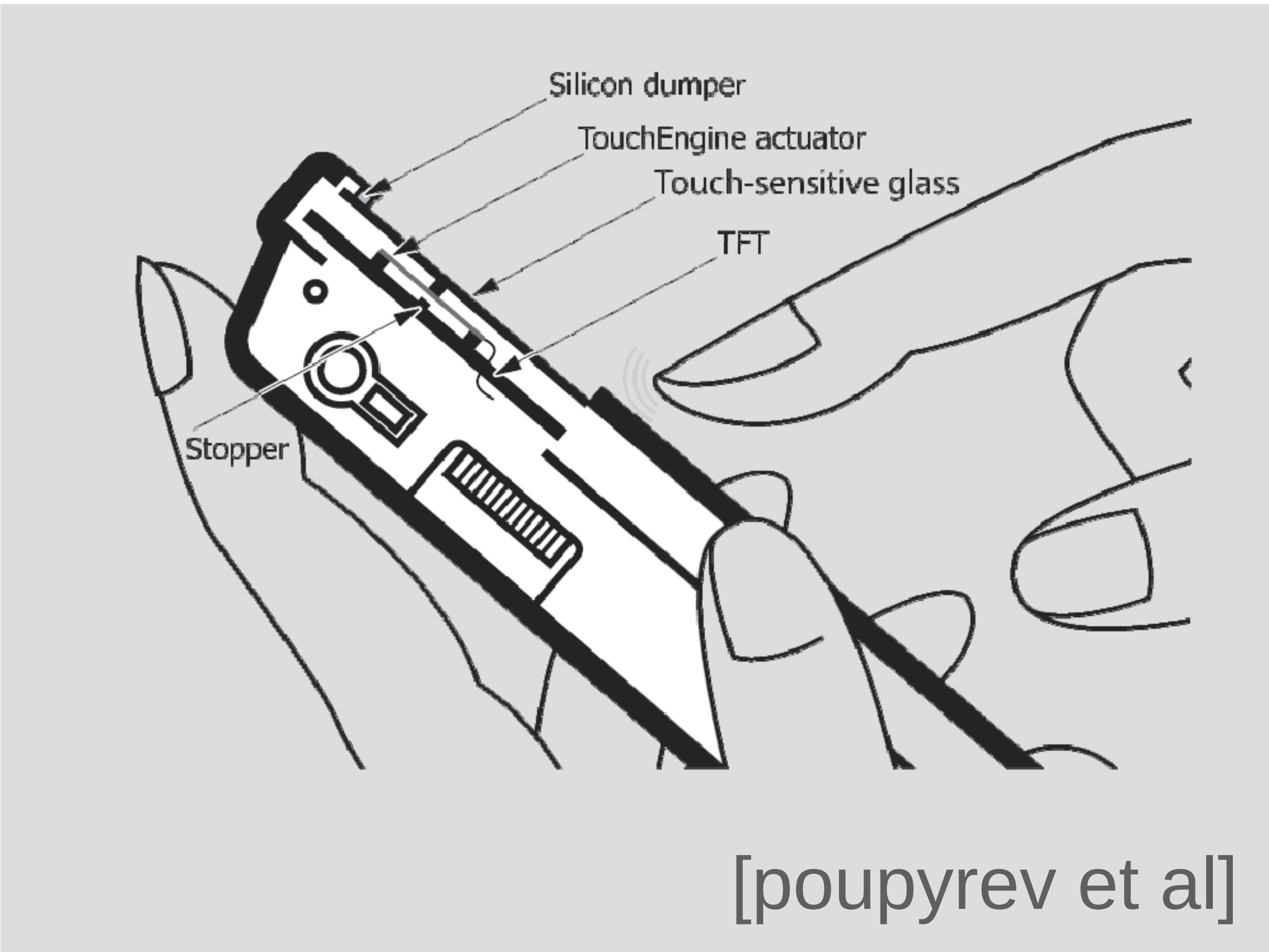

"How about Monday morning?"
calendar
"Monday 9am"
preview
"tic, tic, ssssh"
"Yeah, looks like I'm free after 10"

Revisiting the scenario-using blindSight

out!

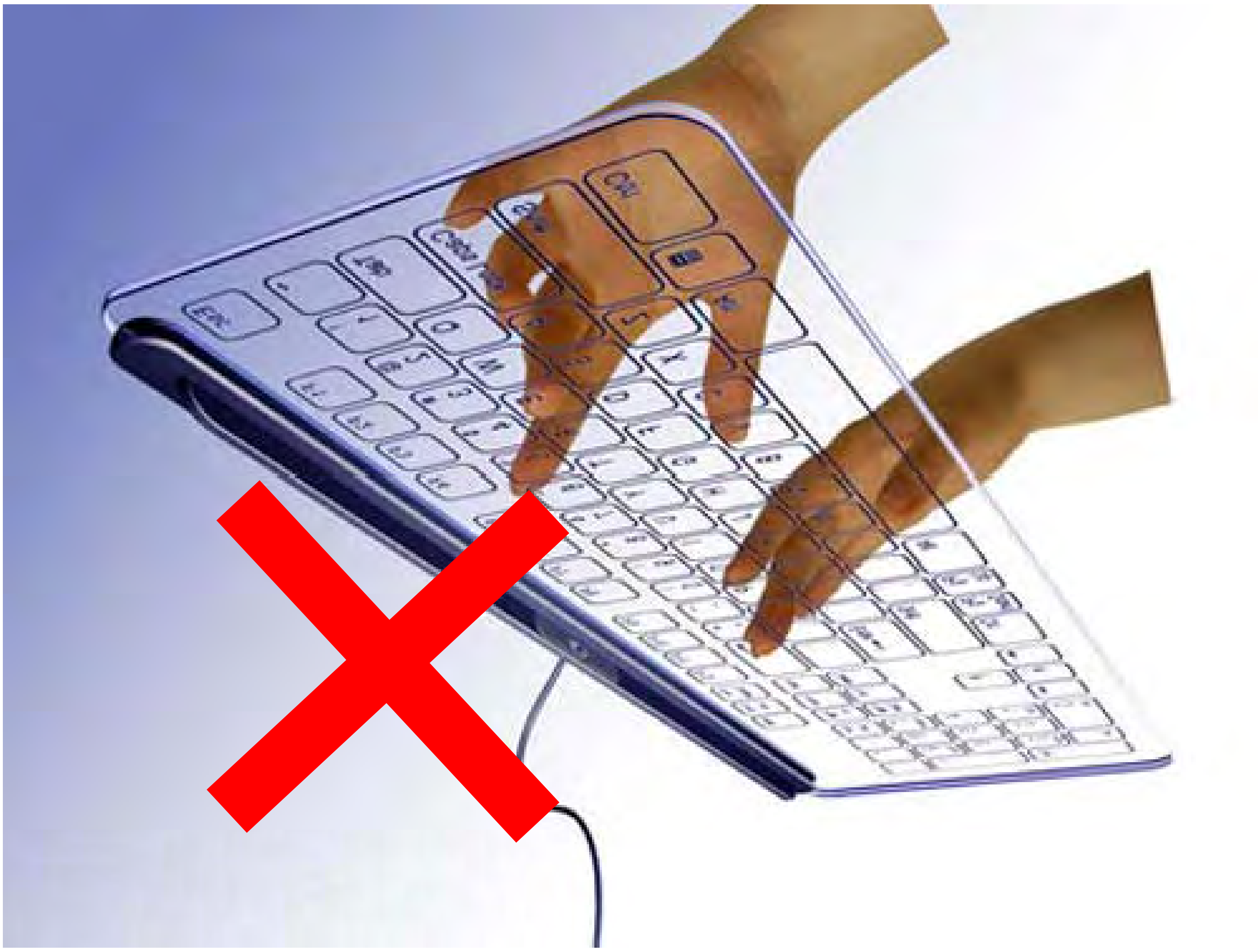
5. eyes-free/tactile


SONY
[poupyrev et al]


Silicon dumper
TouchEngine actuator
Touch-sensitive glass
TFT
Stopper
[poupyrev et al]

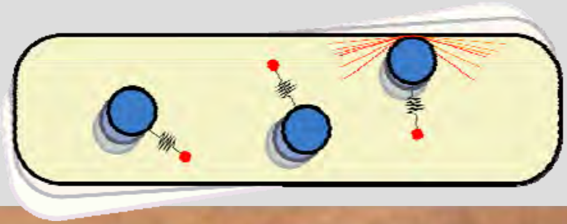

"Each press of a key returned a **clunky click and tactile snap** on the touch screen, which made typing feel incredibly responsive and very usable on the smooth screen surface."
NOKIA
haptikos


4
5
6
2
3



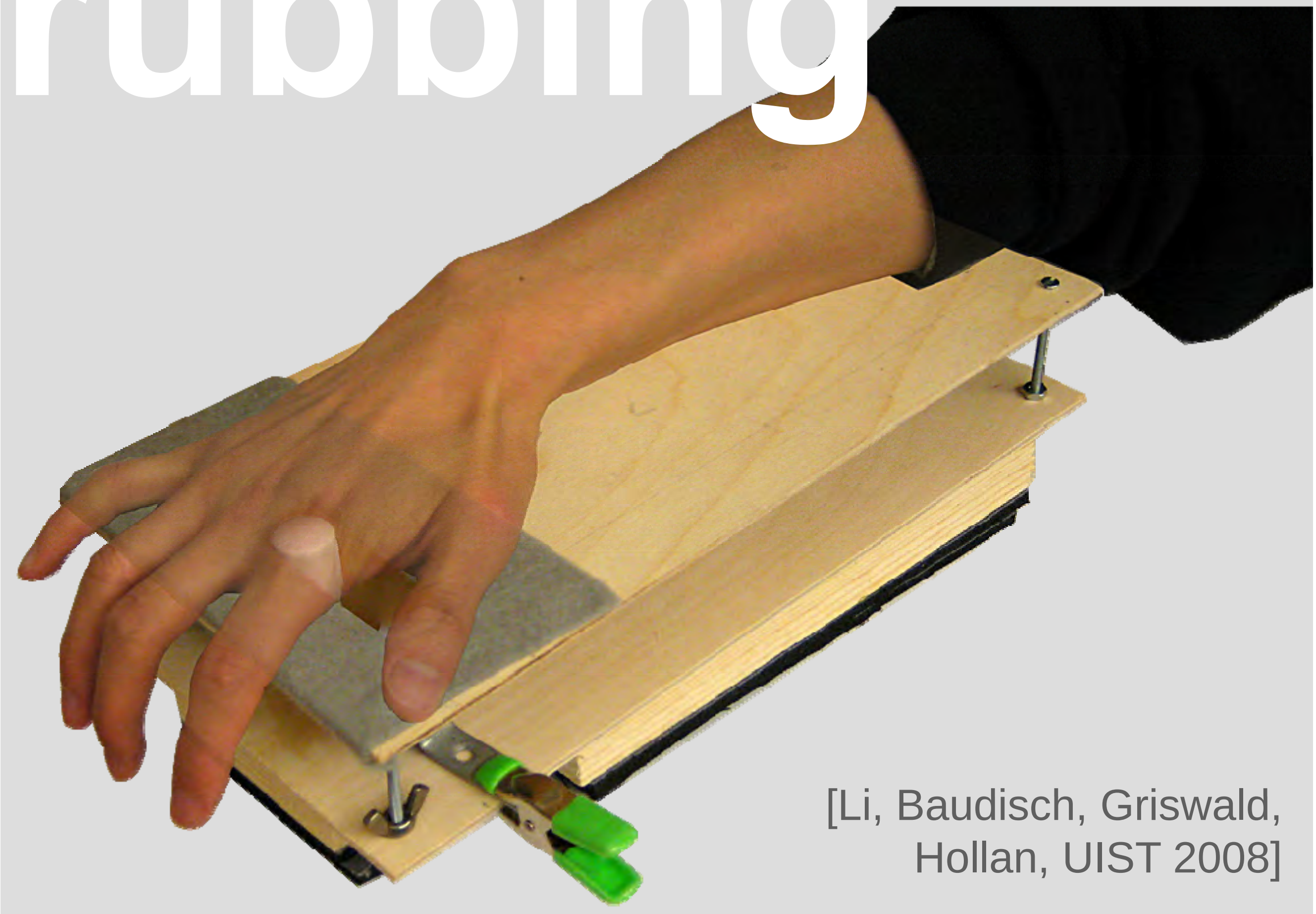
tactile features

shoogle



[williamson, CHI '07]

rubbing



[Li, Baudisch, Griswald, Hollan, UIST 2008]

summary

 in (discreet, touch, backside, device)

 out (compress, off-screen, extend, audio, tactile)

 so what should I use?

my 2t…

PCs...

PC screens have the users’ undivided attention

phones...

…are in in a mobile situation

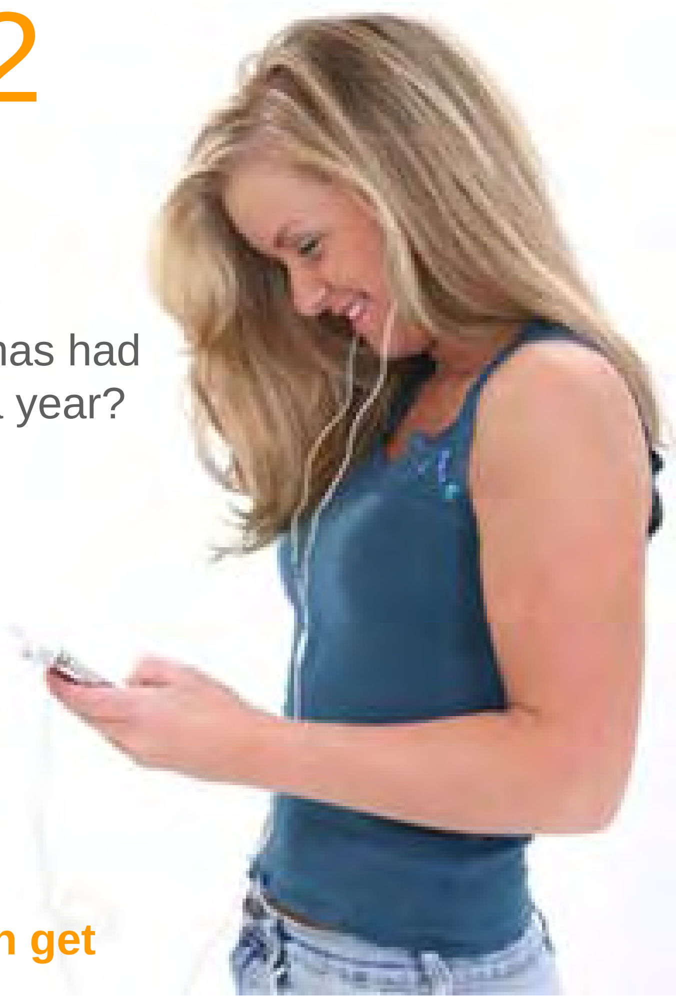
If they requires visual attention,
users will fail at their current activity

interference with social activities
drive off the road…

relying on the visual channel
- is good design on a PC (max bandwidth)
- but limiting on a mobile device

reason #1

reason #2



watch an iPod/iPhone user

can you tell whether he/she has had the device for a week or for a year?

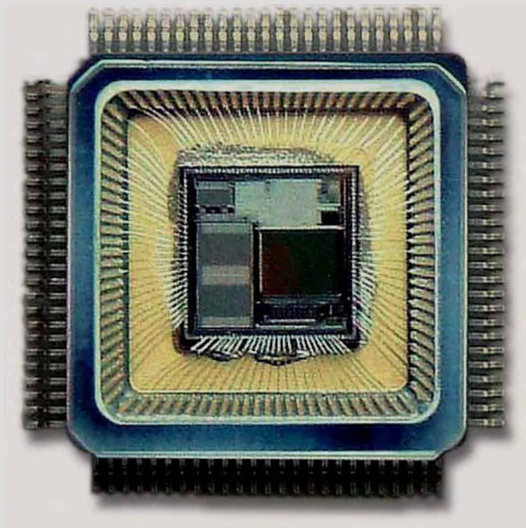
no

this might indicate that
(1) easy to learn
(2) use of visual channel limits how skilled users can get

so how to design for
eyes-free use?

(1) predictability

is more important than number of key strokes



"I use multi tap
because it always works"

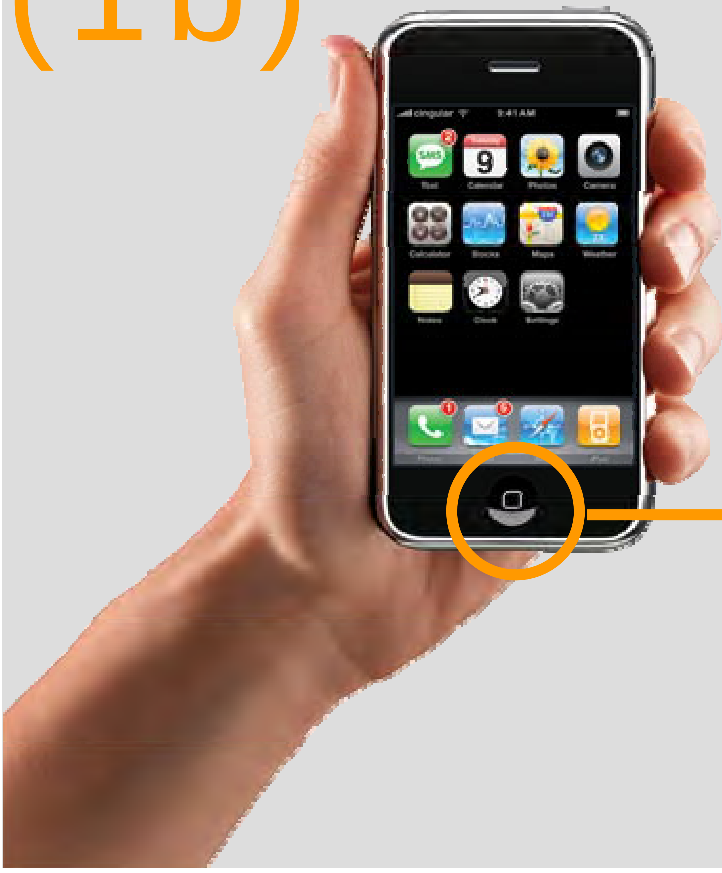
(Fitts' law is the **least** important of all UI laws)

(1a) don't mode me in

most-recently used list are 99% evil
they make new users 5% faster
but make experienced users 10x slower

also after install or flash

(1b)



offer an
escape

(2) avoid "casting"

for **discreet** tasks use **discreet** controls
(such as buttons for typing or launching app)

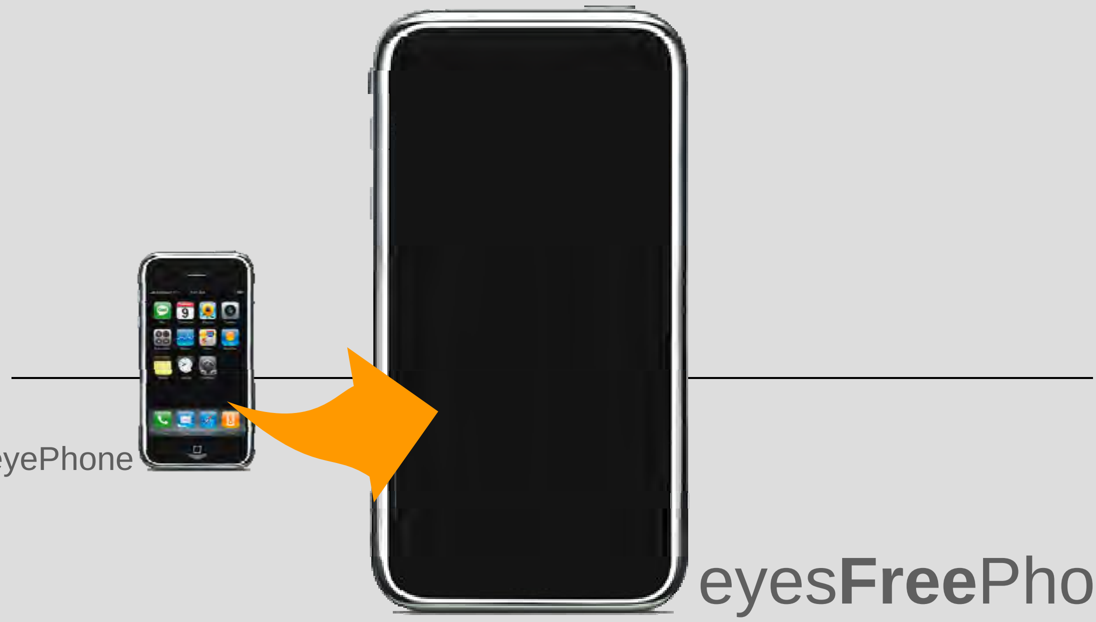
pointing controls for **pointing** tasks
(such as touch for panning)

(3) no eyes-free without tactile features

(3a) spend buttons wisely

does entering phone numbers deserve 80% or our buttons in home screen mode?

should each button in app start smart search?



eyePhone

eyes**Free**Phone

require as little visual attention as possible

ps.: blind users
will thank you

thank you!

end

tutorial notes

MOBILEHCI 2008

Mirjana Spasojevic

Understanding Mobile User Experience

Tutorial Day at MobileHCI 2008, Amsterdam

Text input for mobile devices by Scott MacKenzie

Scott will give an overview of different input means (e.g. key-based, stylus, predictive, virtual keyboard), parameters relevant for designing and assessing mobile text input (e.g., writing speed, cognitive load) and issues related to the context of use (e.g., walking/standing).

Mobile GUIs and Mobile Visualization by Patrick Baudisch

Patrick will introduce different approaches for creating mobile graphical user interfaces. He will talk about the design process, prototyping and assessment of user interfaces, trade-offs related to the design of mobile GUIs and different possible interaction styles. As one specific topic in mobile GUIs he will address concept for mobile interactive visualization (e.g. maps).

Understanding Mobile User Experience by Mirjana Spasojevic

Mirjana will discuss different means for studying mobile user needs and evaluating the user experience. This includes explorative studies and formal evaluations (in the lab vs. in the field), including longitudinal pilot deployments. The lecture will discuss traditional HCI methods of user research and how they need to be adapted for different mobile contexts and products.

Context-Aware Communication and Interaction by Albrecht Schmidt

Albrecht will give an overview of work in context-awareness and activity recognition that is related to mobile HCI. He will discuss how sharing of context in communication applications can improve the user experience. The lecture will explain how perception and sensing can be used to acquire context and activity information and show examples how such information can be exploited.

Haptics, audio output and sensor input in mobile HCI by Stephen Brewster

Stephen will discuss the design space for haptics, audio output as well as sensor and gesture input in mobile HCI. Furthermore he will assess resulting interaction methods and implications for the interactive experience.

Camera-based interaction and interaction with public displays by Michael Rohs

Michael will introduce you camera based interaction with mobile devices; this includes a assessment of optical markers, 2D-barcodes and optical flow as well as techniques related to augmented reality. In this context he will address interaction with public displays, too.

Spetember 2nd 2008

Understanding Mobile User Experience

Mobile HCI 2008 Conference Tutorial

September 2, 2008

Mirjana Spasojevic
Senior Principal Scientist, Nokia Research

Nokia Research Center

NOKIA

Content

- Goals of the tutorial
- Background: user-centered design (UCD) and user experience (UX)
- UX research methods
  - Qualitative vs. Quantitative
  - Contextual inquiry, diary studies
  - Storyboards and concept evaluations
  - Participatory design
  - Pilot deployments and Wizard of Oz
  - Longitudinal studies
- Discussion: UX method tradeoffs

Mirjana Spasojevic

- Senior Principal Scientist and Team Lead, Nokia Research Palo Alto
  - At Nokia since 2006
  - Leading IDEA (Innovate, Design, Experience, Animate) team
    http://research.nokia.com/research/labs/teams/innovate_design_experience_animate
  - Multidisciplinary research focused on UI/UX for mobile devices
- Prior positions:
  - Senior design researcher, Yahoo! Mobile BU
    - Led user research on Yahoo!'s WAP products and Yahoo! Go
  - Senior Scientist and Project Manager, HP Labs
    - Cooltown Program
    - Camera Phone research

Goals of the tutorial

What we will address in this tutorial:

- New developments and thinking regarding UCD and UX
- How is mobile experience pushing the limit of existing methods
- Details of applying specific methods to mobile UX research questions with case studies
- Discuss tradeoffs in selecting methods for the mobile domain

What this tutorial assumes:

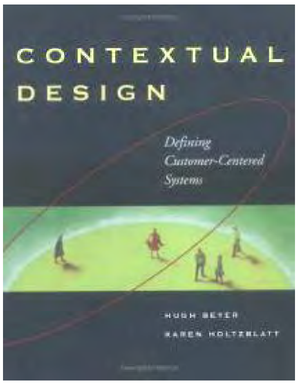
- General background on UCD and UX
- General UX research methodology (e.g. contextual inquiry, usability testing, …)

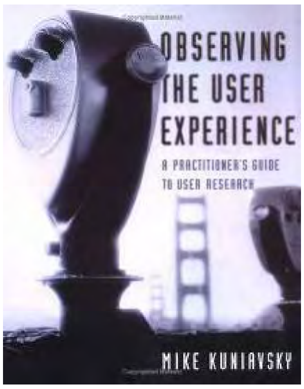
Background: UCD and UX

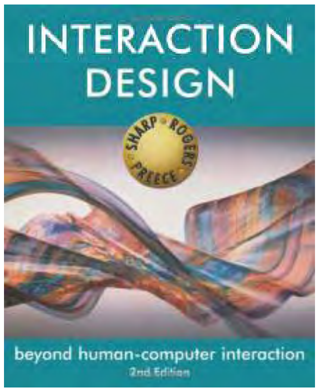
Why apply user-centered design process?

Why do user research?

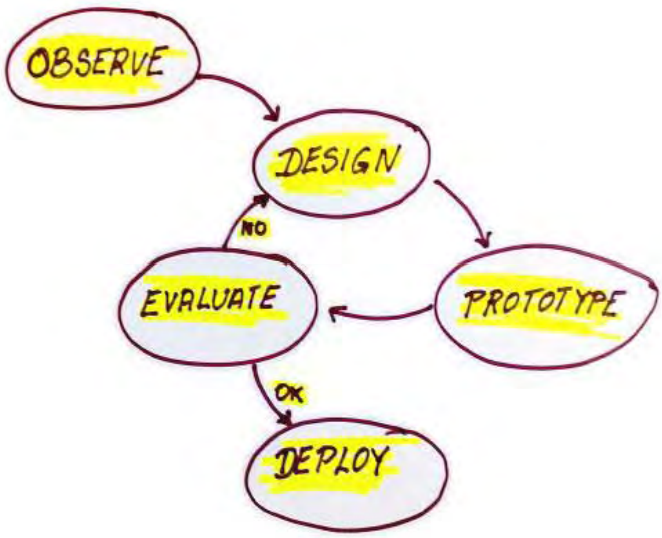
- We are not our users
- Users don't always share our assumptions, values, or interests
- Technologists are early adopters and visionaries
- Main stream users are pragmatic and conservative





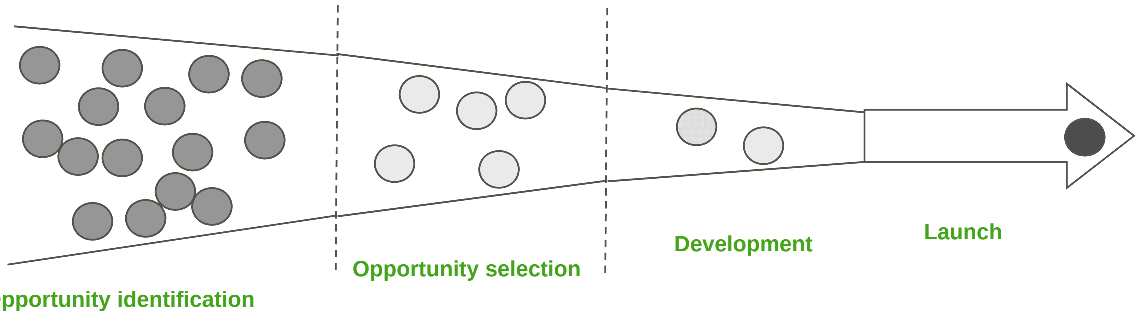


User-Centered Design Process



UX Research: Inform decisions throughout the research, design and development cycle

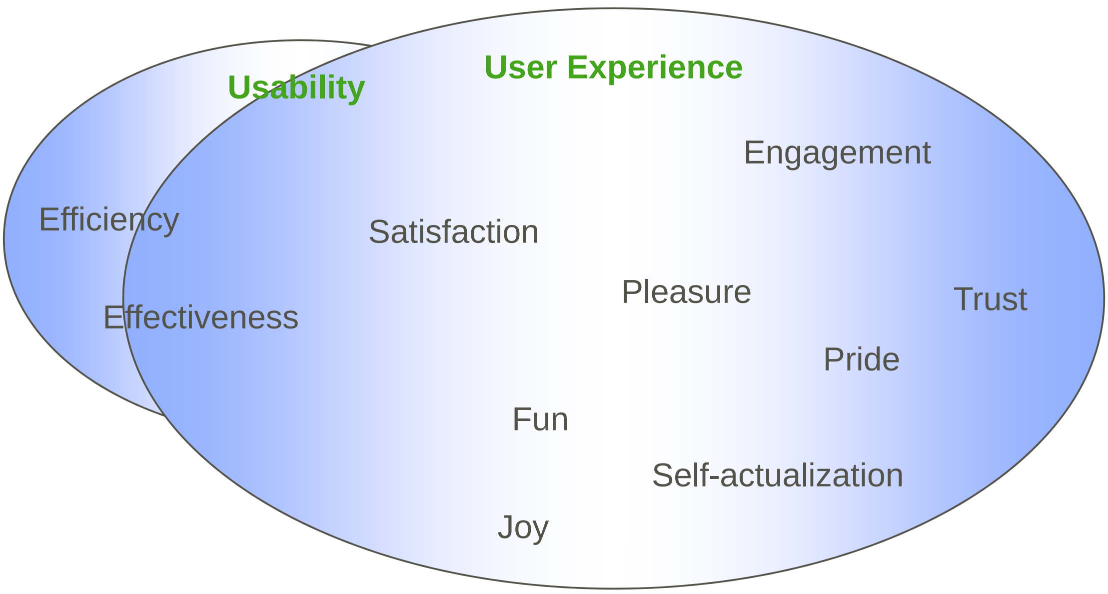
What do we build?	How do we build it?	Did we meet our goals?
Developing new ideas for products & features	**Create specifications, iterate on design prototypes, build**	**Evaluate product success and compare against competitors**
• Ethnographic (field) studies, diary studies • Develop personas • Develop concepts	• Rapid, iterative design & testing • Alpha/Beta stage usability studies • Pilot deployments	• Usability benchmarking / user experience assessments • Customer satisfaction surveys • Competitive evaluations



User Experience → Values

What matters?

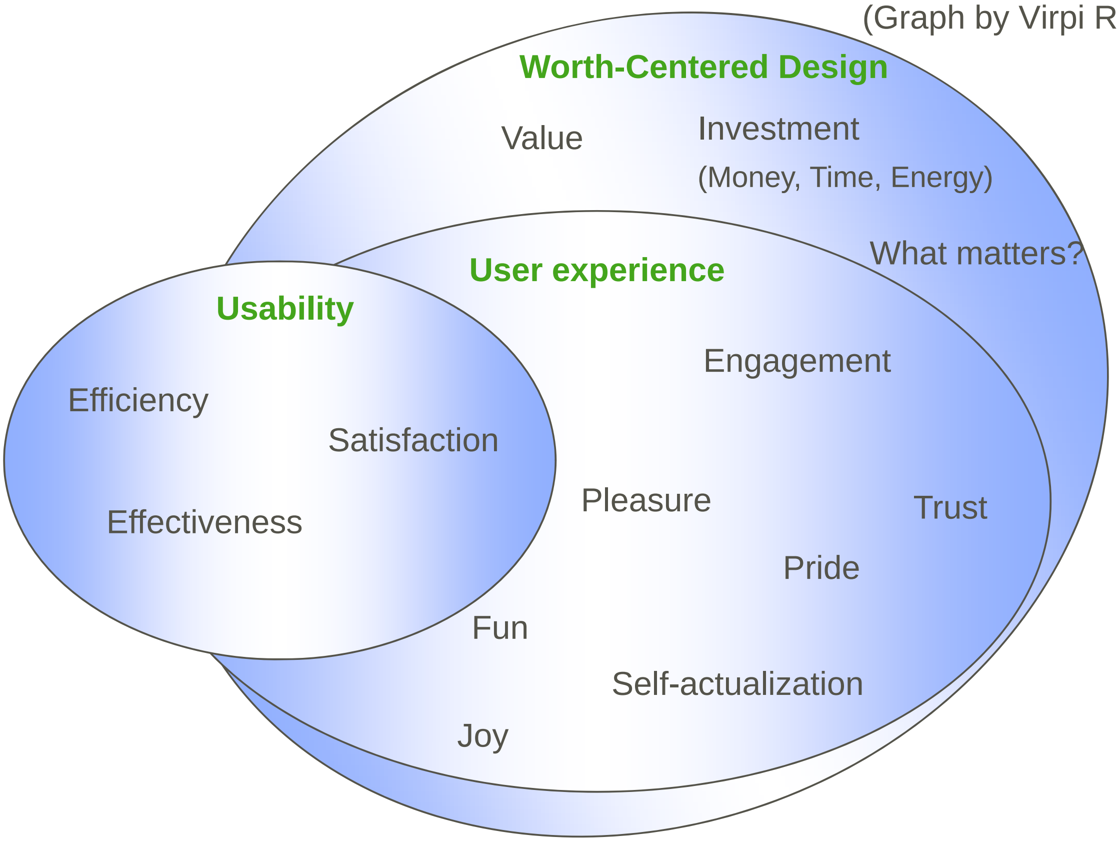
What users will value sufficiently to engage and invest in a technology?



(Courtesy: Virpi Roto)

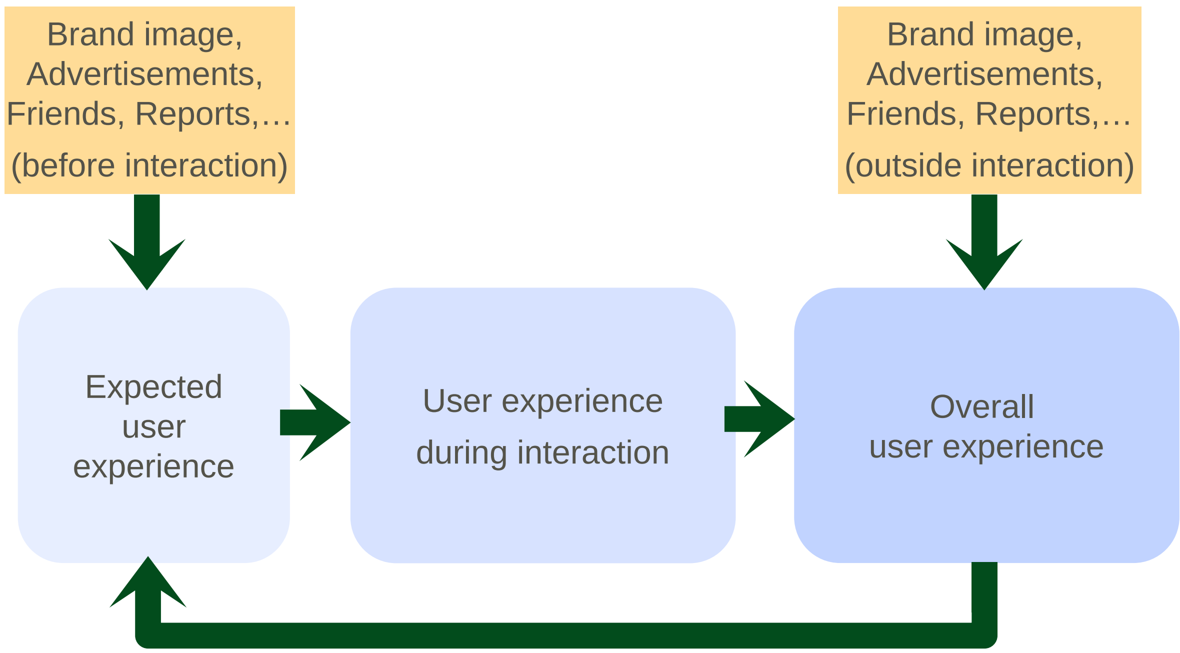
Worth-Centred Design vs. traditional UX

Gilbert Cockton
2006
(Graph by Virpi Roto)



Beyond Interaction

User experience forms not only during but also outside the interaction phase



(Courtesy: Virpi Roto)

Beyond traditional user study methods

Focus shifting away from lab tests

Radically new user study methods needed!

UX Research Methodology

- Qualitative vs. Quantitative
- Contextual inquiry, diary studies
- Storyboards and concept evaluations
- Participatory design
- Pilot deployments and Wizard of Oz
- Longitudinal studies

Qualitative vs. Quantitative data gathering

Organizational boundaries	Qualitative data	Quantitative data
UX Research (a.k.a. Design Research)	-Context of UX -Motivations, end goals -User requirements -How to design	-Validation of qualitative research -Usage patterns -Formal experiments
Data Mining		-Benchmarking -Fall-off analysis -Loyalty and customer lifecycle
Market Research	-Motivations, what people want and need -Opportunities for new products	-Customer satisfaction -High level requirements -Brand tracking

UX Research Methodology

- Qualitative vs. Quantitative
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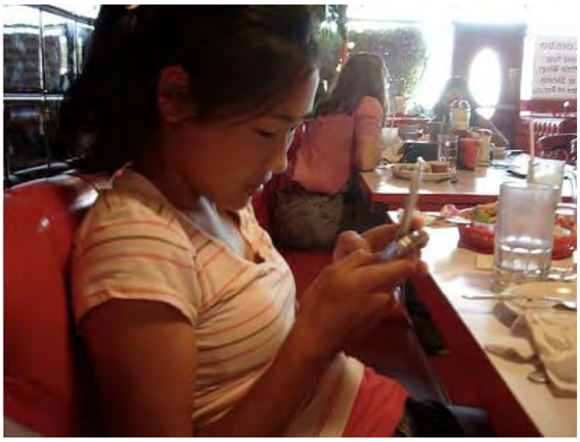
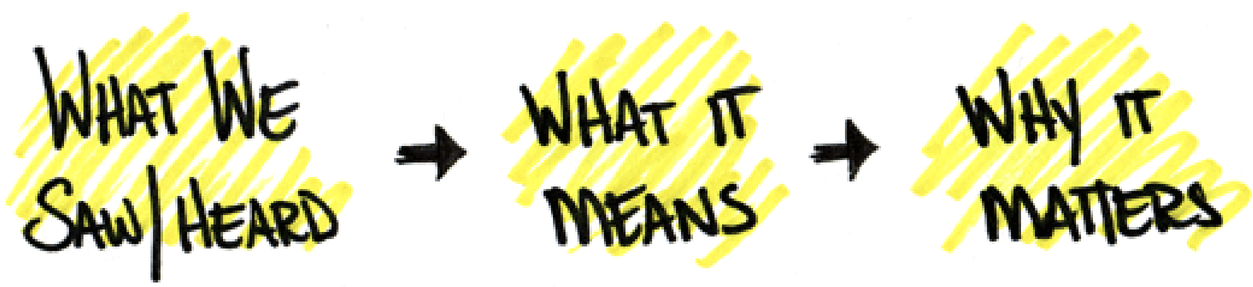
Contextual Inquiry (a.k.a. Ethnographic Research, Field Studies, Diaries and Shadowing)

- Collect information about usage
  - Directly observe actual use
  - Diaries completed by representative users
- In-depth "discussion" (unstructured or semi-structured interviews)
- Result: deep and rich stories of users' experiences
- Foundation for creating design principles and personas



Data Collection and Analysis



(Courtesy: R. Hinman)

Case Studies: Mobile Web Field Research

Target users

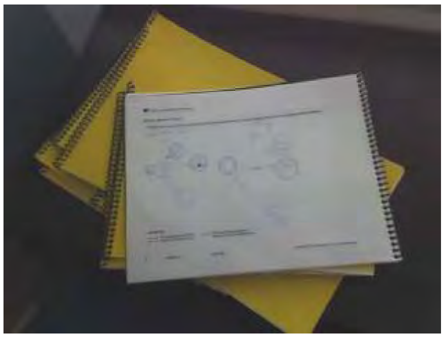
- Mobile web users
- Heavy users of internet services (mail, messenger, …)
- Ages: 18-34, gender balance

Qualitative study

- Diary study of mobile and computer use
- In-depth interviews to understand relevance, current use patterns and unmet needs

Broad research questions:

- What are users doing on mobile web, what they value and where are the pain points?
- What are additional unmet needs?
- What are users doing on the internet (PC) that could be augmented or replaced by services on the mobile?

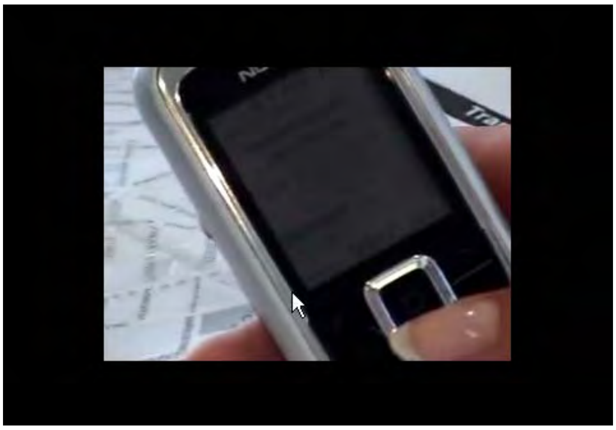


Design Principle

Think uniquely mobile, not mini PC

Emerging Insight

Research confirmed the obvious - browsing content on a mobile phone is difficult.



video

Users cited several obstacles to internet usage via their mobile phones:

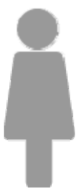
- phone's interface makes it difficult to enter URL
- text input through keys
- network speed/latency
- network reception
- small screen size
- perception of cost (perceived value)
- lack of cost transparency
- sites are not optimized for mobile phones
- scrolling is a pain

Despite the challenges, people ARE accessing the internet via their mobile phones

Here are a few things they are doing…

Emerging Insight

What are people doing on the mobile web?



Jeanine

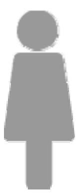
What she does:
Accesses Yellowpages.com from the Sprint carrier deck to find phone numbers and addresses of businesses.

Why she does it:
It is cheaper than 411 ($1.49)

Fred

What he does:
Checks and trades stocks while at work on his Treo.

Why she does it:
His work computer is monitored and he doesn't want people to know what he is doing.



Christina

What she does:
Orders pizza while on her way home from work.

Why she does it:
So that she doesn't have to talk on the phone and waste her minutes

Emerging Insight

Current behavior is the tip of the iceberg…

"If I would have asked people what they wanted, the would have said a faster horse." *- Henry Ford*

Current mobile internet use cases indicate what people are doing given the current mobile landscape. It is the tip of the iceberg; an indication of the basic needs this technology can fill.

"eBay on my phone… that would be deadly."

A working hypothesis is that what is relevant to people on their PC will be relevant to them on a mobile device. And users indicated that access to their favorite PC sites on their phones was desirable.

Emerging Insight

… but availability is not enough in a PC-centric world.

People are tethered to their PCs

Whether at work or home, all participants had access to more than one PC. Proximity to a PC is a key factor in whether or not users are willing to endure the challenges of internet access via their phone. If what they need can wait, then they do and prefer to access most info via a PC.

Information related to highly popular topics and events is ubiquitous

Big sporting events and breaking world news are ubiquitously represented by all media. Mobile Web competes against established channels of information with superior user experience.

Emerging Insight

People are apathetic about current mobile internet services.

"I'm lost!"

"I need to be prepared." **"I'm a fan!"**

"I need to save my minutes!"

"I need to check my MySpace account."

"Where's the train!?!"

"I'm bored!

"I need to find an address."

"I need a drink recipe."

"I wonder what my day will bring?"

"I need proof!"

"I want to rock!"

"I need to coordinate with friends."

I'll eat what I'm fed, but I won't love it

Participants browse news and weather on their carrier decks, but did not communicate that these were essential rituals in their life. There was little affinity or emotional investment in what is currently being offered.

A square peg in a round hole

Several users expressed that using internet on their phone would be the choice when all other options failed. The "internet" is too broad and open when you are driving to an interview and need directions.

Design Principle

Think uniquely mobile, not mini PC

Content is the main source for the mobile web building blocks.

Content is what people want, not PC applications and web sites originally designed for desktop access. Creatively combining content through mash-ups or organizing content by common tasks will be more useful to people than a list of links to web sites.

Mobile form factor an advantage, not a liability

With a "browsing" model, the entire form factor of the phone becomes a liability. The screen is too small, it's difficult to scroll, the input is cumbersome. Leverage the inherent properties of the phone instead of fight them.

New models, new metaphors

Miniaturizing what is available on the PC is not the answer. In order to create products that people love, we should move towards models that are quick, easy and packageable.

QR Codes

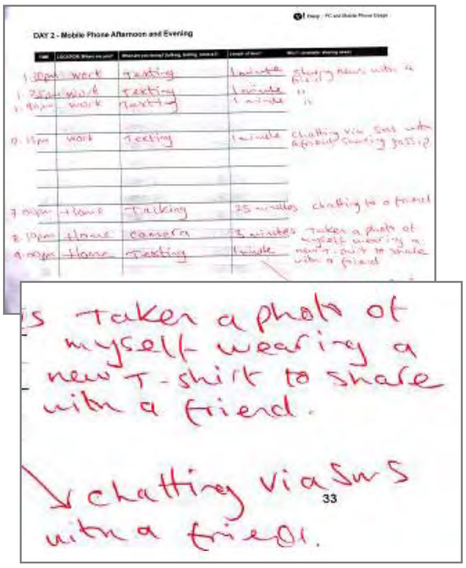
The inclusion of QR Code reading software on camera phones in Japan has led to a wide variety of new, consumer-oriented applications, aimed at relieving the user of the tedious task of entering data into their mobile phone. QR Codes storing addresses and URLS are becoming increasingly common in magazines and advertisements in Japan. The addition of QR Codes on business cards is also becoming common, greatly simplifying the task of entering the personal details of a new acquaintance into the address book of one's mobile phone.

Design Principle

Think building and reinforcing common ground and identity

Emerging Insight

People use mobile phones to make solo activities social.



"Should I buy this shirt?" - *Jonathan*

Several of our participants described using their camera phone to get friends' advice on purchases. They would take a photo of themselves in a piece of clothing and send it to a friend for an opinion.

Texting as a remedy for loneliness

Participants describe texting as a quick and easy way to bring people into an experience or to feel less alone.

"I usually text my friends on the tube coming home from work. It's mostly gossip, really. It makes the ride go quicker… it's the next best thing to having them there." *- Josephine*

Emerging Insight

The phone acts as a signifier to ourselves, reinforcing who we think we are and who we aspire to be…

Phone as a signifier

Whether adorning their phones with jewels or using meaningful photos as screensavers, participants use their phone as signifiers and reminders to reinforce their own sense of their identity.

Phone as a digital scrapbook

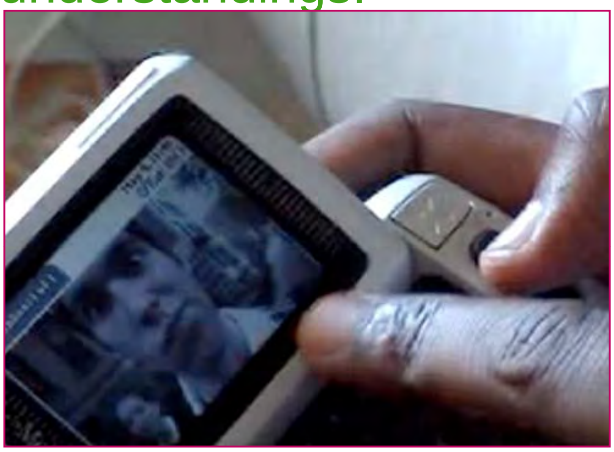
Participants also use their phones as digital photo albums, keeping pictures on their phone to remind them of the people or things they care about.

"… this was a picture taken of me and my friends at Valley Fair. My friend, Nitty, took it with a disposable camera so I scanned the photo at work and emailed it to my Sidekick."

Photos act as visual reminders of who we are:
Friend, parent, sibling, lover, spouse, child.

Emerging Insight

... and as a way to share a story. People are reinforcing existing relationships and shared understandings.



video

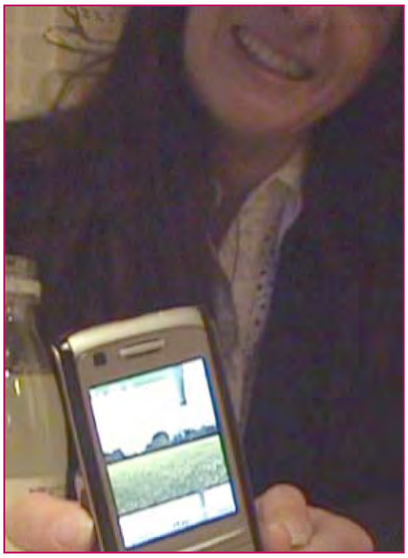
"We're having a smashing time!" - *Vanessa*
Participants use text and photos for storytelling. But these are not complex stories with a beginning, middle and end. They serve to reinforce a shared understanding of an event, as running commentary on the happenings of one's life.

They reinforce *common ground*.

Not a task
Unlike filling out a form on a web site, these types of activities are not tasks with a discrete beginning, middle and end. Like relationships, this behavior is continuous and ritualistic. There is a compelling emotional link that motivates people.

Emerging Insight

Mobile phones are unique in that they allow you to capture a moment in time.



Capture a slice in time

Phones are always with you, so they provide a level of immediacy. You can capture a slice in time in voice, text, image or video.

Identity management

Phones are being used as a tool for identity management.

Uniquely mobile

Other devices provide these features, but few put them together in such a unique way - and none are as portable and provide the immediacy.

Design Principle

Think building and reinforcing common ground and identity

Think continuous; not task

These conversations among people are continuous and they rely upon "common ground": what each person knows about the other person and the state of their relationship. The mobile device helps storytelling – there is an opportunity to better interweave images, voice, text for easier storytelling and easier interpretation of the story in the common context.

Think present and represent.

Sending images, choosing an avatar or a login name – these are all acts of presentation and self-representation. Consider how a mobile device helps reinforce one's sense of identity - to both themselves and to the world.

MyAdhan

MyAdhan has launched its prayer and fasting times SMS text message alert service to Muslims in the UK. After signing up to the website and configuring your account, you then start receiving daily text message prayer and fasting time specific to your location.

"Muslims in the UK can also get prayer times by request, without subscription. **MyAdhan** TEXT back service can be used to receive accurate postcode-specific fasting and prayer times, sent directly to your mobile, when you need it."

http://www.myadhan.com/index.php?cid=Adverts-Textback&pid=1&tid=0

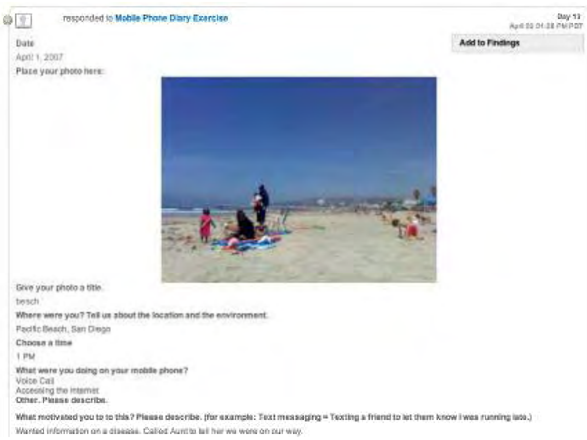
Summary

Design Principles

1. Think uniquely mobile, not mini PC
2. Think always with you, not just on the go
3. Think building and reinforcing common ground and identity
4. Think access to what's essential, not browsing

Deprivation study: Capturing context of use and unmet needs

- If current usage is low how to get people to give you relevant information about needs and opportunities?
- Solution: deprive them of the alternatives!
- Study design:
    - 8 users (4 men, 4 women)
    - Equipped with Nokia N93 and N80 phones
    - 3 days of reporting internet use
    - 4 day deprived of internet on a PC (only mobile!)
    - "Cheating vouchers" to allow for needed PC use



Sample entry from an on-line diary tool

video

Shopping Study: Collecting contextual information and needs

Diary study of existing shopping needs and behaviors

- 12 participants (9 female) aged 21-40
- **txt4l8r**: tool for capturing snippets in situ and then longer description later
- 116 entries (56 photos) over 1 month
- Pre- and post-study interviews to understand typical shopping behaviors and specific instances with full context

UX Research Methodology

•Qualitative vs. Quantitative

•Contextual inquiry, diary studies

•Storyboards and concept evaluations

•Participatory design

•Pilot deployments and Wizard of Oz

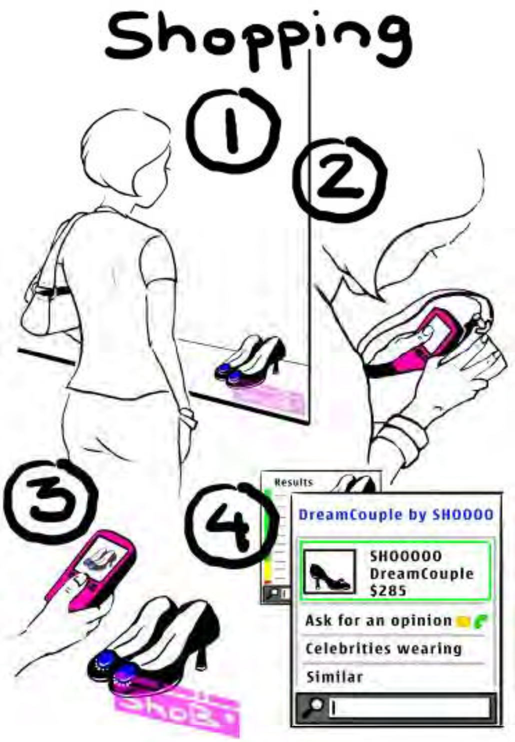
•Longitudinal studies

Storyboards and Concept Evaluation

Goal: get feedback on concepts from participants in 1-1 sessions or focus groups

Focus on realistic scenario and value, rather than UI

Participants able to modify concepts, suggest realistic scenarios based on their own experience



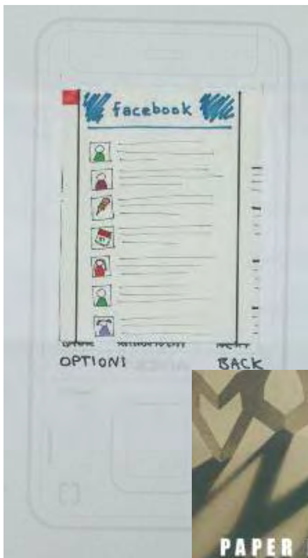
Sketch: Erika Reponen

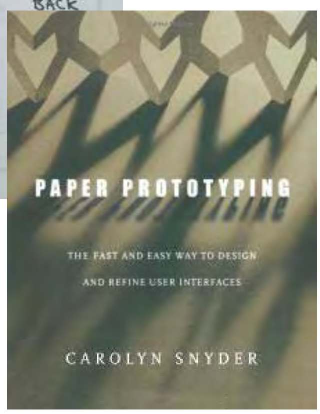
Participatory Design: Co-Designing with Users

•Rapid iteration between design and testing of ideas with low fidelity prototypes for quick feedback

•Move design forward and minimize risk of “bigger” usability problems later

•Established practice in web design but have not been used as much in the mobile domain – “muscle memory” issues





UX Research Methodology

- Qualitative vs. Quantitative
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Pilot deployments and Wizard of Oz

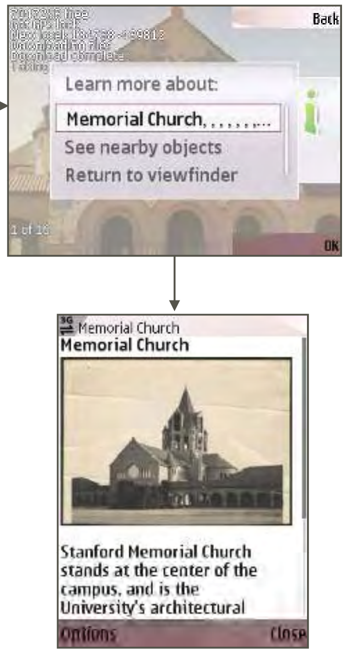
Tech centric vs. User-centric: new technical ideas and solutions are frequently embodies as initial prototypes, user population and context of use not certain.

Challenge: follow the user-centered design approach with a high fidelity prototype already present, fill-in-the-gaps.

Potential solutions:

- Pilot deployment of a prototype (when possible)
- Wizard of Oz: human in the loop to simulate the end-to-end solution

Case study: Mobile Augmented Reality



Post-capture matching

- User captures an image
- If successful, results are provided

UX Research Methodology

- Qualitative vs. Quantitative
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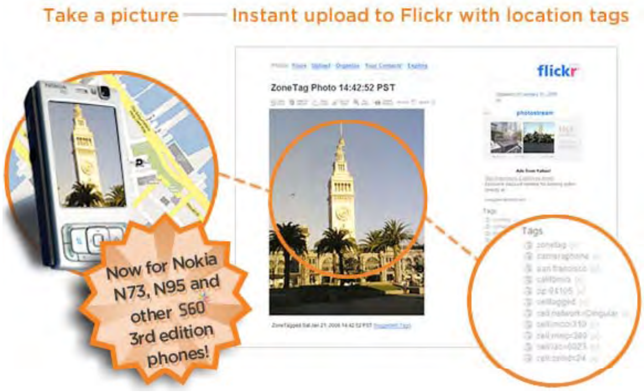
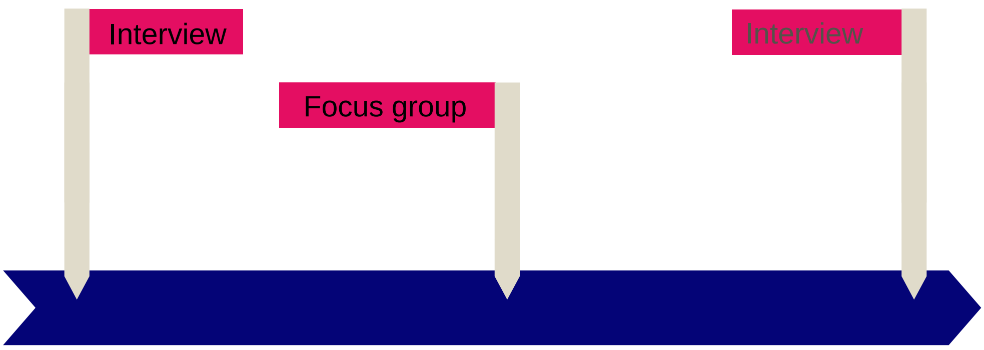
Case Study: Longitudinal deployment of ZoneTag and Zurfer

- 26 participants in 5 social groups for 3-6 months
- Nokia N80
  - Participant's SIM, covered data plan
- Flickr pro account for 6 months
- ZoneTag phone client
  - 2-click upload to Flickr
  - Geotagging
  - Suggests tags for each photo
- Zurfer phone client
  - View and comment on Flickr photos while mobile



Study method: Qualitative and Quantitative

One person's participation (3-6 months)



Quantitative data collection

- SmartPhone 360 logs (all activity on phone, including photo taking)
- ZoneTag server logs (tagging behavior, privacy settings)

Outcome: Requirements for Mobile Photoware

- Capture
- Editing
- Upload and storage
- Sharing and Privacy
- Annotation and organization
- Viewing
- Technological considerations

Discussion: UX research method tradeoffs

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Recap: Methodology choices and tradeoffs

Method	When appropriate	Pros	Cons
Diary/Interview	Pre-concept, persona generation	Rich data, realistic feedback on current tasks and needs	Self-reported, instructions to participants need to be crafted carefully
Shadowing/ Interview	Pre-concept/personas/ gather detailed data about tasks	Most reliable data about context of use	High overhead to conduct with many participants
Survey (web based)	All stages, validation of qualitative data	High number verification, confidence	Self reported, Self selected participants
Story boards	Concept development and testing	Detailed feedback, easy modifications	No feedback about in-context use, need some drawing skills
Wizard of Oz	Get feedback on use in context, focus on value	Feedback on value for in-context use	Some overhead, delays in the system
Pilot deployments	Get feedback on use in context, focus on value, feedback on UI issues	Detailed feedback on a system when used over a period of time	High overhead to set up, participants will focus on UI and specific use cases

Final thoughts…

- Research method is not a substitute for a **good research question**
- Mobility makes everything more difficult and more interesting
- You are at the forefront of a new research domain!

Thank you!

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tutorial notes

MOBILEHCI 2008

Albrecht Schmidt

Context-Aware Communication and Interaction

Tutorial Day at MobileHCI 2008, Amsterdam

Text input for mobile devices by Scott MacKenzie

Scott will give an overview of different input means (e.g. key-based, stylus, predictive, virtual keyboard), parameters relevant for designing and assessing mobile text input (e.g., writing speed, cognitive load) and issues related to the context of use (e.g., walking/standing).

Mobile GUIs and Mobile Visualization by Patrick Baudisch

Patrick will introduce different approaches for creating mobile graphical user interfaces. He will talk about the design process, prototyping and assessment of user interfaces, trade-offs related to the design of mobile GUIs and different possible interaction styles. As one specific topic in mobile GUIs he will address concept for mobile interactive visualization (e.g. maps).

Understanding Mobile User Experience by Mirjana Spasojevic

Mirjana will discuss different means for studying mobile user needs and evaluating the user experience. This includes explorative studies and formal evaluations (in the lab vs. in the field), including longitudinal pilot deployments. The lecture will discuss traditional HCI methods of user research and how they need to be adapted for different mobile contexts and products.

Context-Aware Communication and Interaction by Albrecht Schmidt

Albrecht will give an overview of work in context-awareness and activity recognition that is related to mobile HCI. He will discuss how sharing of context in communication applications can improve the user experience. The lecture will explain how perception and sensing can be used to acquire context and activity information and show examples how such information can be exploited.

Haptics, audio output and sensor input in mobile HCI by Stephen Brewster

Stephen will discuss the design space for haptics, audio output as well as sensor and gesture input in mobile HCI. Furthermore he will assess resulting interaction methods and implications for the interactive experience.

Camera-based interaction and interaction with public displays by Michael Rohs

Michael will introduce you camera based interaction with mobile devices; this includes a assessment of optical markers, 2D-barcodes and optical flow as well as techniques related to augmented reality. In this context he will address interaction with public displays, too.

Spetember 2nd 2008

Context-Aware Communication and Interaction

Albrecht Schmidt

University of Duisburg-Essen

http://www.pervasive.wiwi.uni-due.de/
albrecht.schmidt@acm.org

Overview

1. Introduction & Motivation
2. Example Systems/Applications
3. Defining Context
4. From Sensor to Context
5. Examples of off-the-shelf hardware and systems
6. Summary
7. Reference and Reading

1. Introduction & Motivation

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Perception and context enables smart behavior

- Perception in Nature
  - Adaptation to the environment
  - Foundation for intelligent behavior
  - Acting and reacting in an appropriate way
- Sense is more then sensor – the whole process
  - reception of the stimulus
  - translation from stimulus to signal
  - signal transport
  - the processing/matching on several levels

- Different senses
  - Vision, Hearing, Smell, Taste, Touch, Temperature
  - Gravity and acceleration , Position and constellation of (body) parts
  - Magnetic fields, Electric fields

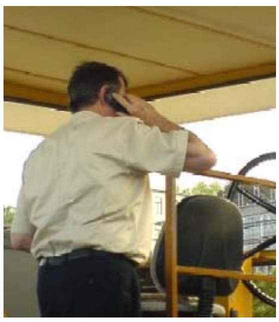
Sensing and perception

- Sensors already integrated in devices
  - Light sensor
  - GPS
  - Acceleration sensors
  - Touch and Temperature
  - Wireless (use for sensing)
- Sensors wirelessly linked
  - Step counter (e.g. Nike)
  - Physiological sensors (e.g. pulse)
- Processing power is available
  - Algorithms for context and activity recognition can be run on mobile devices
- Many sensors available

Devices are used everywhere – in Context

- Mobile and ubiquitous use

- Interaction with the mobile device is the secondary task



Context as key for efficient communication [Lenat98]

- Coding in context
  - Coding and representation chosen to fit the context
  - Obvious context information is not included in the coding (e.g. the question "*another drink?*" in the hotel bar at 2am implies: in this bar and now – not somewhere else or another day)
- Transport of the message
  - Media chosen appropriate for the current context (e.g. whispering with your neighbor during a lecture, shouting across the street to get the attention of a friend, drawing a sketch, etc.)
- Decoding of the message
  - Taking context information into account for decoding the message
  - Additionally to the explicitly transmitted message further context information is provided (e.g. surrounding situation, body language, form of the explicit representation)
  - Context is used to interpret the message

Mini-Exercise (60 seconds in pairs)

Phoning in the car

- Compare
  - hands-free phoning in the car
  - talking to a passenger on the front seat
  - talking with a child on the backseat
- What is safest?
- Why?

Context in Interactive Systems

- Use context for **adaptation** of
  - Application
  - Content
  - Presentation
  - Interaction modality
- Context as **content**
  - Tagging of media (e.g. location and time in photos)
  - Creating meta information
  - Context as the content (e.g. recording a walking track)
  - Real-time sharing of context (e.g. presence)
- **Rethink** user interface options
  - Output
  - Input
  - Communication

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Rethink Output

- Make use of context
- Adjusting media quality
- Adapt media usages
- Choose the modality
- Adapt content and visual representation
- Timing of output / notification
  - Interrupt at “apprpriate” times

Rethink Input

- Easing input by using context knowledge
- Automate input
  - current time
  - who is in a meeting
  - tracking documents used
  - places visited…
- Provide context-dependent defaults
- Optimize input space to fit to current context
  - recognizer for handwriting/speech,
  - context-sensitive menus

… this is not easy!!!

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Taking context of usage into account in the design of devices/applications

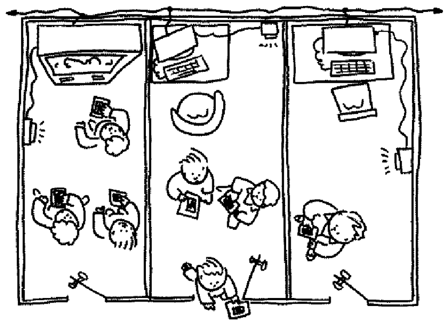
- At design time
  - Specifically designed for a certain context
- At run time
  - Recognizes the context
  - Acts depending on the context

http://www.tgdaily.com/content/view/28552/145/

2. Example Systems/Applications

ParcTab Context-Aware Computing System [Schilit94]

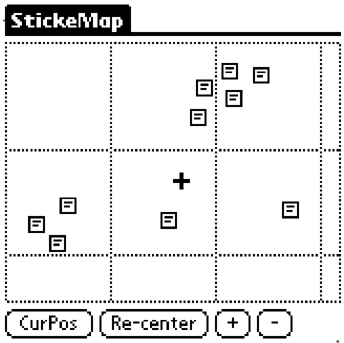
- Classification of applications using context-aware services
- Infrared location sensing
- Context as name-value pair
- Automatic behavior vs. manual interaction



Name	Room	Distance
caps	35-2200	200ft
claudia	35-2108	30ft
perfector	35-2301	20ft
snoball	35-2103	100ft

	manual	automatic
information	Proximate selection and contextual information	Contextual reconfiguration
command	Contextual commands	Context-triggered actions

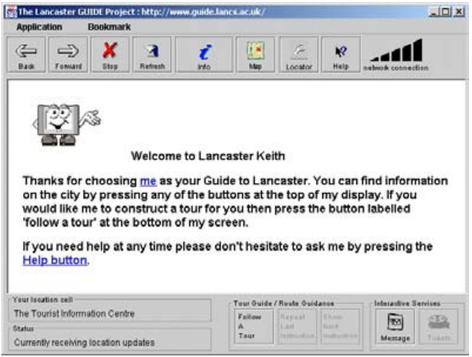
Human-Computer-Giraffe Interaction: HCI in the Field [Pascoe98]



- Actions triggered by location
- Notes that are linked to contexts
- Time and Location as contexts
- GPS receiver attached to a PDA

GUIDE – Towards Context in HCI

[Cheverst00]



- two classes of context were identified, namely personal and environmental context
- significant contexts
  - visitor's interests
  - current location
  - budget constraints,
  - Disabilities
- Cell Based Location (on WLAN)
- Support the user in creating a conceptual model

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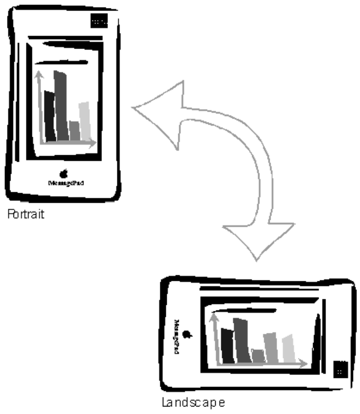
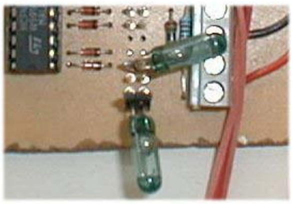
Physical context and device interaction [Schmidt99]





Extremely simple, but still it creates a new experience

- 2-Bit Input
- Not an input device
- Very specific function

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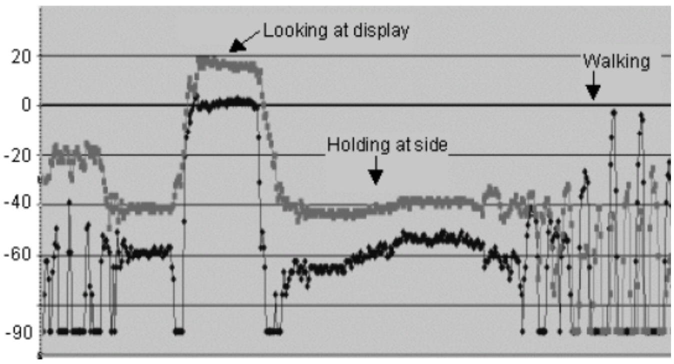
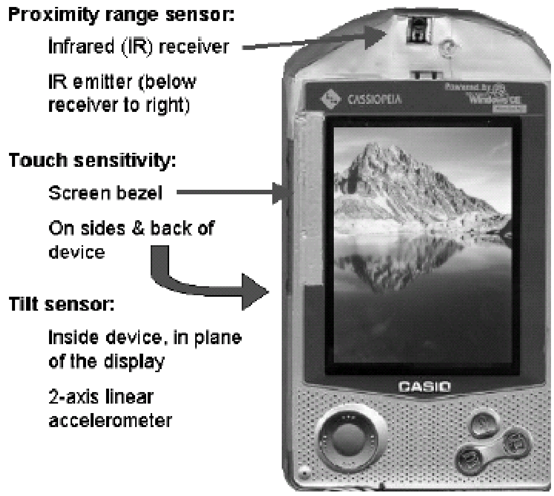
Mobile Phone that recognizes its interaction context [Schmidt99a]

Perception as key for smart devices

- Phone acts context dependent
- Sensors
  - Accelerometers
  - Microphone
  - Temperature
  - …
- Recognizes contexts
  - “in the user’s Hand”
  - “on a surface”
  - “in a bag”
  - …
- Algorithms with minimal processing

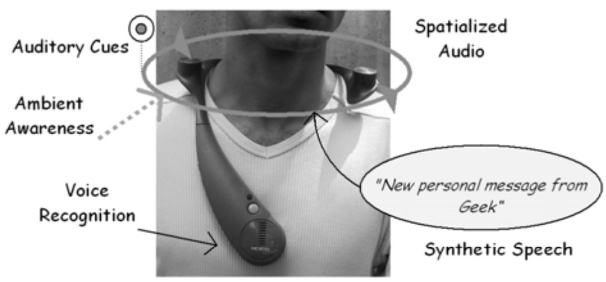
Sensing Techniques for Mobile Interaction [Hinckley00]

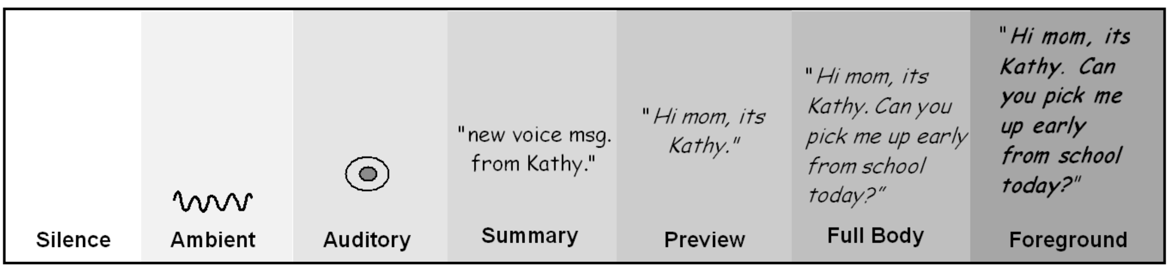




Nomadic Radio [Sawhney00]

- Scalable Auditory Presentation
- Contextual Notification, depending on
  - Message priority
  - Usage level
  - Likelihood of Conversation





Context Call [Schmidt00]

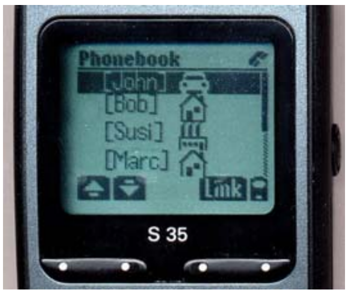
Sharing of context before the call is established

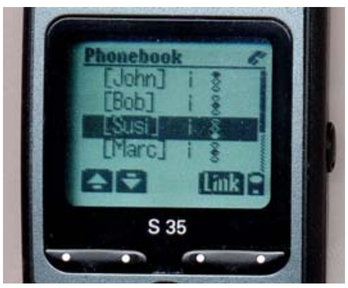
- **In real life we have social protocols for initiating conversation**
  - social skill – knowledge from both sites required!
  - trained from early childhood on

- **context matters - manly implicitly**
  - how important is it for me?
  - how convenient seams it for the other person?
  - relation between the communication partners?
  - what type of conversation will it be?
  - is it socially acceptable (topic/situation)?
- **To avoid situations like:**
  - "if I would have known that you are in a meeting I would not have called you."
  - "if I would have known that you are still at work I would not have called you."
  - …
  - "if I would have known that the phone is off and I can only leave a message I would not have called."

Context Phonebook

[Schmidt01]





- **User experience vs. technology**
- **phone users can selectively share context**
  - information about the situation
  - information about availability
  - …
- **caller can decided**
  - knows her own constraints
  - has some information about the other side
  - can judge if the call will be appropriate
  - context matters - manly implicitly

3. Defining Context and Interaction in Context

Defining Context - Schilit, 1994: "exploiting the changing environment"

"Such context-aware software adapts according to the location of use, the collection of nearby people, hosts, and accessible devices, as well as to changes to such things over time. A system with these capabilities can examine the computing environment and react to changes to the environment." [Schilit94].

Defining Context - Brown, 1997: "context-aware" – driven by context

"Indeed you could argue that every application which takes some account of the user is a context-aware application. In practice, the adjective "context-aware" is attached to applications that are mainly driven by the user's context. They tend to be mobile applications […]." [Brown97].

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Defining Context - Ryan, 1998: "context-awareness" – sense and act

"[…] 'context awareness', a term that describes the ability of the computer to sense and act upon information about its environment, such as location, time, temperature or user identity. This information can be used [...] to tag information [...] to enable selective responses [...] or retrieving information relevant [...]. [Ryan98].

Defining Context – Dey, 2000: Context - characterize the situation

"Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves." [Dey00]

"A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task." [Dey00].

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Resulting Interaction Paradigm: Implicit Interaction

- Utilizing context for human computer interaction

"Implicit human computer interaction is an action, performed by the user that is not primarily aimed to interact with a computerized system but which such a system understands as input." [Schmidt00a]

4. From Sensor to Context

What is a Sensor?

- A sensor is a technological device or biological organ that detects, or senses, a signal or physical condition or chemical compounds.
- A electronic, electrical, micro-mechanic or electro-mechanical device that responds to a stimulus, such as heat, light, or pressure, and generates a signal that can be measured or interpreted.
- A function of time that returns a value (binary, number, vector, array) dependent on a measured parameter.
- Examples: light, temperature, sound, radiation, power, flow, movement, acceleration, vibration, orientation, proximity, chemical, biological, physiological, …

see http://en.wikipedia.org/wiki/Sensor

Information “Sensors”

- Sensors that are related to the device or system Examples
  - battery voltage,
  - RSSI,
  - real-time,
  - current packet loss,
  - current power consumption
  - location sensors
  - devices in vicinity

- Access to information over a network (e.g. WWW)
  - weather in New York
  - share price of GOOGLE

Bio-Sensors

- Sensors to measure physiological parameters in humans and animals
- Towards sensing emotions…

- Example
  - Galvanic skin response
  - Heard rate
  - Blood pressure
  - Blood oxygen saturation
  - EEG, ECG
  - …

Image from http://affect.media.mit.edu/

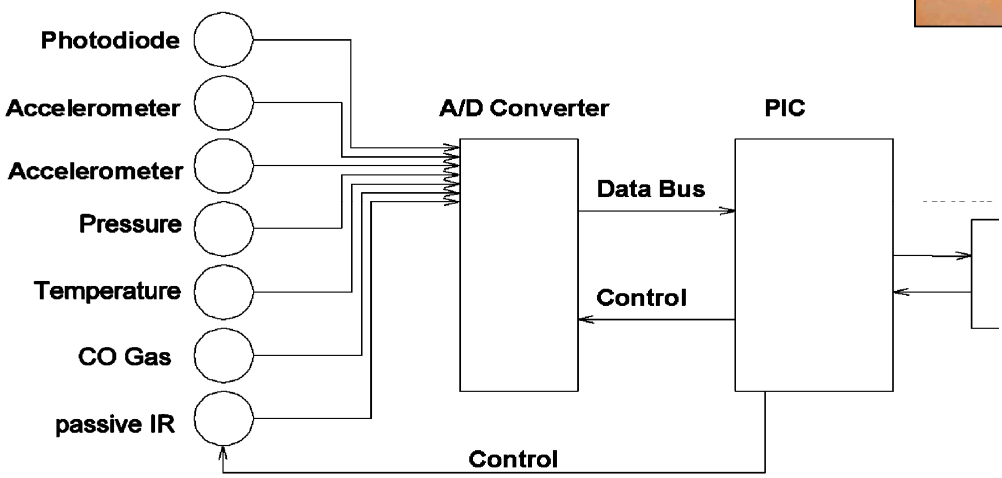
What can you measure? Some Examples

- Temperature Sensor
  - weather / temperature
  - human proximity and touch
  - device in operation
  - indoor / outdoor?
  - speed?
  - …
- Light Sensor
  - light level
  - light frequency (50Hz/60Hz)
  - indoor / outdoor?
  - movement?
  - usage of a environment
  - touch
  - …

- Accelerometer
  - tilt
  - vibration
  - acceleration
  - gestures
  - shock
  - position?
  - Interaction?
  - …

Dependent on the application a sensor can be used to measure different phenomena in the real world

Example of a technical setup



Sensors | AD - Conversion | Feature and context processing

Problems with Sensors

- Need for calibration
- Sensors are Inaccurate (within a given specification)
- Sensors are unreliable (within a given specification)
- Noise and false readings are common
- Timing between processor and sensor is often critical

- Mechanical Issues, casing
  "Sensor may need a hole to see the world"

Mini-Exercise (120 Seconds, in pairs)

- Assume a mobile device should be able to discriminate
  - Informal meeting
  - Presentation
  - Coffee break
  - Working alone
- Consider
  - What sensors can be used?
  - How do we describe the situations?
  - What trade-offs will we phase in the design?
  - What will obviously not work?

How to describe and match a Context/Situation?

- Descriptions differ depending on
  - Who (role) make a description
  - What the purpose of the description is
  - The individual creating the description
- Structure descriptions
  - Checklists
  - presence and absence of features
  - Sensor values
  - Perceived features
- Based on experience (learning)
  - Automated description depending on features

Modeling Context [Schmidt03]

- Modeling the domain
- Alternative approaches
  - Top-down
    Situation → Context → Features → Sensors
  - Bottom-up
    Sensors → Features → Context → Situation
- Do not try to model the world…
  …model your application's world!

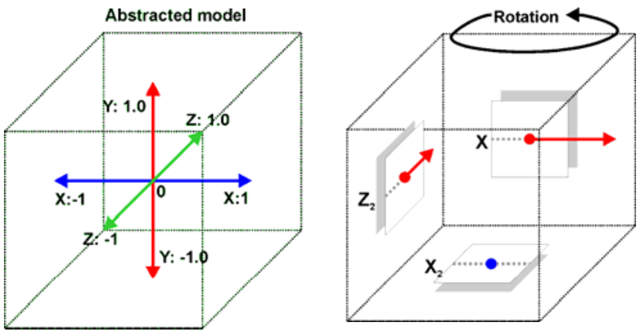
Parameters and requirements on Sensing for Context-Awareness [Schmidt,01]

- Design and Usability
- Energy Consumption
- Calibration
- Start-up Time
- Robustness and Reliability
- Portability, Size and Weight
- Unobtrusiveness, Social Acceptance and User Concern
- Price and Introduced Cost
- Precision and Openness

Arranging Sensors

- The position of sensors on a object or in the environment matters!
- Dependent on the position different phenomena will/can be measured
- The sensor in the “right” position can save processing and energy
- Embodiment – see robotics

- Example: placement of acceleration sensors in a interactive cube



Multiple Sensors

- Multiple sensors (of the same type) can ease recognition of certain phenomena
- Correlation of sensor readings
- Networked sensors and time stamped readings

- Example: detect the number of sound sources
  - very difficult with one microphone
  - much simpler with multiple distributed microphones

5. Examples of off-the-shelf hardware and systems

Mobile Phone: Nokia N95

- Mobile phone with
  - GPS
  - 3-axis Accelerometer
  - Network interfaces (Bluetooth, WLAN, GSM)
- Programmable
  - C
  - Python

- There are many more phones with different sensors and programming interfaces…

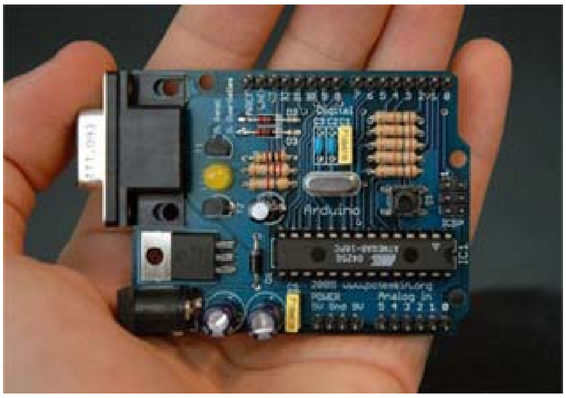
Physiological Sensing: NeXus-10

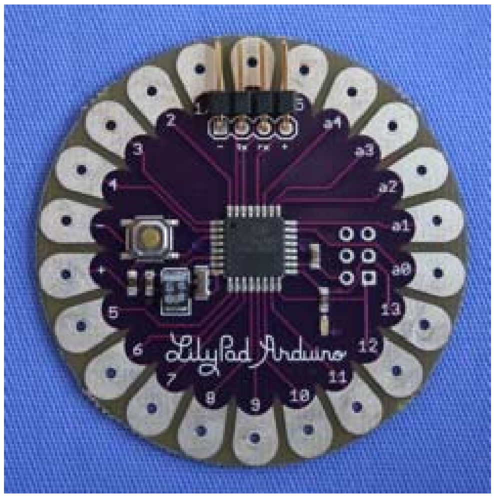
http://www.mindmedia.nl/german/nexus10.php

- 10 AD channels
- Variety of physiological sensors
- Mobile
- Bluetooth connectivity to PC/Laptop

Sensor Board: Arduino

http://www.arduino.cc/





- Variety of extensible and easy to use microcontroller boards
- Extensible with your own sensors

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MPTrain (Video) [Oliver06]

- Hardware:
  - physiological sensors wirelessly connected
  - music player
- Software
  - the user defined exercise pattern (desired heart-rate)
  - System constantly monitors heart-rate and speeds and plays music with specific features that encourages the user to speed up, slow down or keep the pace

6. Summary

Summary

- Perception as a key to smart behavior
- Context awareness to
  - Adjusting the output to the context
  - Easing input by using context knowledge
  - Share context information
- Many interesting examples exist
  - Location enters the the real world
  - Context still waits in the lab
- Definitions of context
- Sensing → context → actions
- Off-the-shelf hardware and systems are available

Directions

- Location is in the market place
- Context in user generated content
- Use of context in end-user configuration/programming
- Context sharing in communication
- Context prediction and learning of behavior
- Privacy issues
- Implanted sensors?

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Questions!

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More Information

- Our Website
  http://www.pervasive.wiwi.uni-due.de/
- My Blog
  http://albrecht-schmidt.blogspot.com/

tutorial notes

MOBILEHCI 2008

Stephen Brewster

Haptics, audio output and sensor input in mobile HCI

Tutorial Day at MobileHCI 2008, Amsterdam

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Speptember 2nd 2008

Haptics, audio output and sensor input in mobile HCI

Stephen Brewster

Glasgow Interactive Systems Group
Department of Computing Science
University of Glasgow

stephen@dcs.gla.ac.uk
www.dcs.gla.ac.uk/~stephen

September 2008

Research group

- Multimodal Interaction Group
- Key area of work is *Multimodality*
- More human way to work
  - Not everyone has all senses
  - May not always be available all of the time
- No one sense can do everything on its own
  - Need flexible forms of interaction to suit different users, tasks and contexts

Overview of tutorial

- Problems with interaction in a mobile world
- Non-speech audio
  - Why use audio?
  - Earcons, auditory icons and sonification, examples
- Haptics
  - Why use haptics?
  - Definitions, hardware, examples
- Sensor input
  - Why sensor input?
  - Definitions, hardware, gestures for input

Interaction problems

- Mobile interaction takes place in the real world
  - Users involved in other tasks
  - On the move
  - Contexts very varied
  - Users need effective ways to interact with sophisticated new applications and services
- Current interfaces can make interaction difficult

Screen is limited

- Screen space small
- Eyes heavily used when mobile
- Using up too much visual attention is dangerous
- Hard to design good graphical interfaces for use on the move

Input is limited

- Keyboards and pens hard to use when mobile
  - Buttons are small
  - Input difficult and error prone
  - Requires much visual attention
  - Two hands
- Touchscreen phones lose important tactile features
  - Requires more visual attention

Multimodal interaction

- Need interactions that allow people to get on with their lives whilst using the technology
  - 'Eyes-free' or 'Hands-free'
- Need to develop new interaction techniques that suit real environments of use
  - Non-speech sounds + tactile displays for output
  - Sensors for gestural input for input
  - Multimodal interaction

Non-speech audio interaction

- Music, structured sound, sound effects, natural sound
- Icons vs text, non-speech vs speech
- Why use audio?
  - Good for rapid non-visual feedback
  - Trends, highly structured information
  - Works well with speech and graphical displays
  - Omni-directional / attention grabbing
  - Reduced need for visual display, good for visually-impaired users

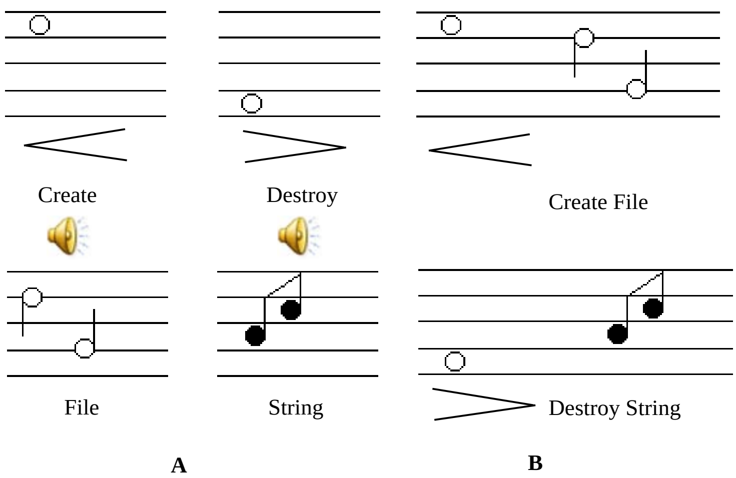
Main types of non-speech audio

- Simple beeps
- Earcons (Blattner): musically structured, abstract sounds *(abstract)*
- Auditory Icons (Gaver): natural, everyday sounds *(representational)*
- Sonification: visualisation using sound, mapping data parameters to audio parameters *(abstract)*

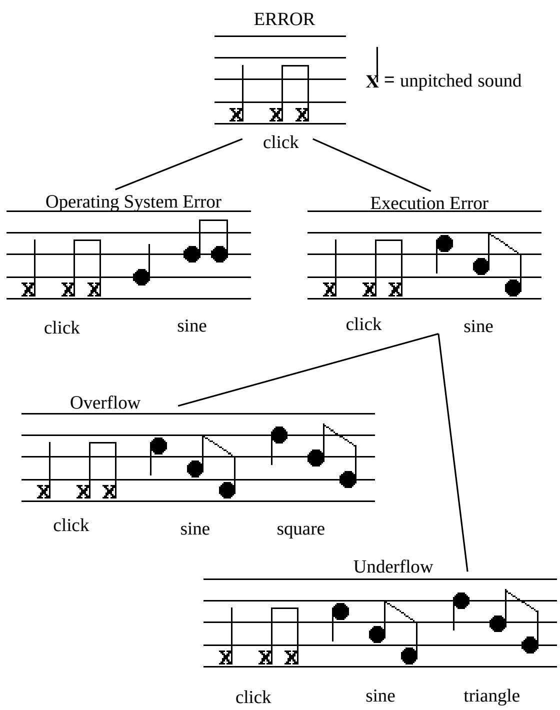
Earcons

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

Earcons



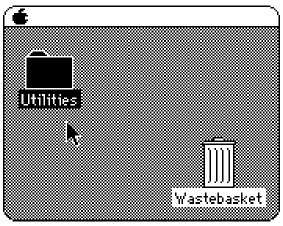
Hierarchical Earcons



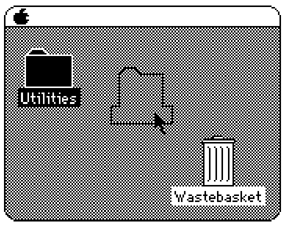
Auditory Icons

- Everyday, natural sounds represent objects and actions in the interface
- Sounds have an intuitive link to what they represent
- Sounds are multi-dimensional
- The SonicFinder
  - Selecting, copying, dragging

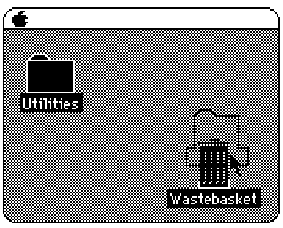
Auditory Icons



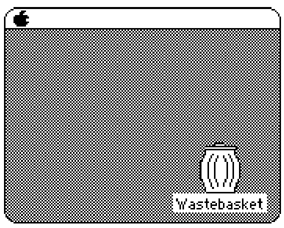
A) Papery tapping sound to show selection of folder.



B) Scraping sound to indicate dragging folder.



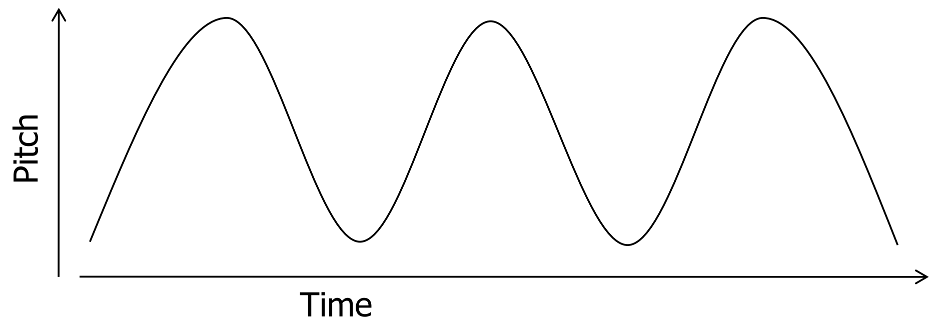
C) Clinking sound to show wastebasket selected



D) Smashing sound to indicate folder deleted.

Sonification

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



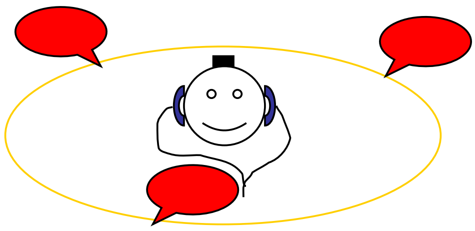
Sound in interaction

- Simple sounds for targeting can increase usability in stylus/button interface by 25% when mobile
  - Reduce size of on-screen targets
- Used for many other interaction improvements
  - Scrollbars, menus, progress bars, …

www.icad.org for many good audio examples

Example:3D audio interaction

- Need to increase the audio display space
  - Deliver more information
  - Quickly use up display space
- 3D audio
  - Provides larger display area
  - Monitor more sound sources
  - Planar sound (2.5D)
- 'Audio windows'
  - Each application gets its own part of the audio space (Cohen)



3D audio interaction techniques

- How do we use spatial audio?
  - Progress indicator (Walker, PUC)
  - Diary / NomadicRadio (Schmandt, TOCHI)
- Pie Menus (Brewster, CHI03, Marentakis, CHI06)
  - Audio menu items placed around the head
  - Cardinal points or front 180°
  - Users can select audio menu items with head gestures when on the move

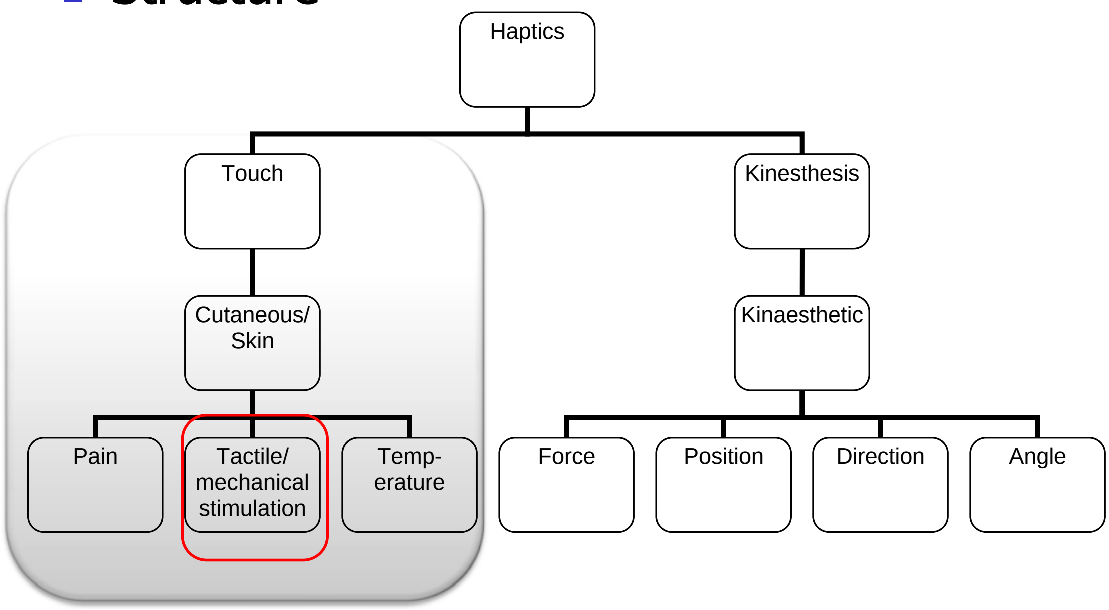
Haptics

- Definition
  - *Haptics*: Sense and/or motor activity based in the skin, muscles, joints and tendons
- Two parts:
  - *Kinaesthesis*: Sense and motor activity based in the muscles, joints and tendons
  - *Touch:* Sense based on receptors in the skin
    - *Tactile:* mechanical stimulation to the skin

From new ISO Tactile/Haptic standard 9241-910

Haptics

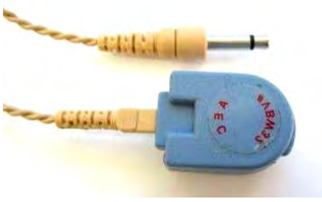
- Structure



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



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 of Earcons
- Vibrotactile feedback
- Encode information using parameters of cutaneous perception
  - Waveform
  - Duration/rhythm
  - Body location

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 waveforms very effective (*tuned* to capabilities of actuator)
- Intensity
  - Two levels
  - Hard to use and may need to be controlled by user

Brown, MobileHCI 05, 06

Crossmodal audio and tactile interactions

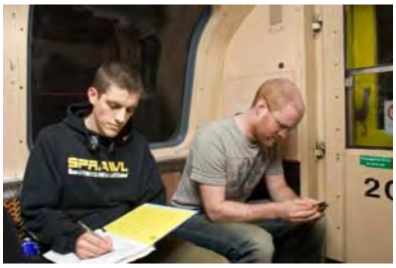
- Train people in one modality and use in another
  - Useful when one modality may be unusable
  - Trained with Earcons and tested with Tactons
  - Trained with Tactons and test with Earcons
  - Trained and tested in same modality
- Results very positive – training transferred well both ways
  - Equal to training within same modality

Hoggan, ACM ICMI, 2007

Example: tactile button feedback

- Touchscreen phones have no tactile feedback for buttons
  - More errors typing text and numbers

- Compared performance of real buttons to touchscreen and touchscreen+tactile
  - In lab and on subway
- Touchscreen+tactile as good as real buttons
  - Touchscreen alone was poor



Brewster, CHI 2008

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

Sensor input

- Definition: *Sensors convert a physical signal to an electrical one that can be manipulated symbolically within a computer*
- Why sensor input?
  - Input in new ways, new form factors
  - Discrete vs continuous, rich, natural movements
  - Very engaging for users
  - Interaction on the move
  - Context sensing
  - Input for users with disabilities

Chapter 10, HCI Handbook, 2nd Edition

Sensor types

- Common types include
  - Microphone
  - Camera (front and back), light sensor
  - Accelerometer (change in motion with respect to gravity)
  - GPS receiver for large scale movements
  - Touchscreen / multitouch
- Less common
  - Magnetometer
  - Gyroscope
  - Pressure
  - RFID tag reader
  - Physiological sensors (heart rate)
  - Contact microphone

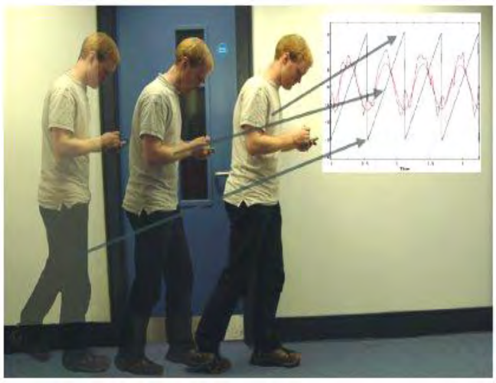
Example: SHAKE sensor pack

- SHAKE
  - Accelerometer, magnetometer, gyro, capacitive touch sensor, (RFID)
  - Bluetooth connection to host device

www.dcs.gla.ac.uk/research/shake/

Uses for sensor input

- Gesture interaction
- Context awareness
- Can sense gait and phase
  - Walking, running, standing, …
  - Results show that users tap more and are more accurate in some parts of gait phase



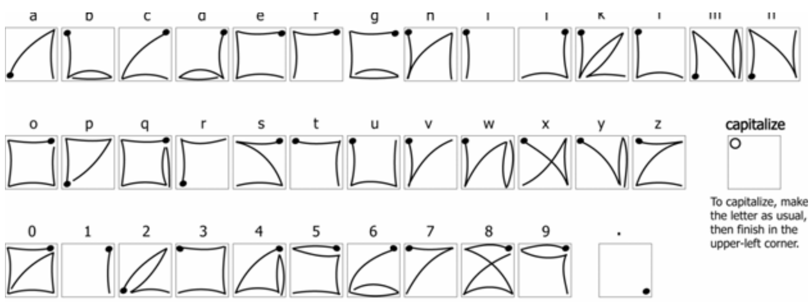
Crossan, 2007

Why gestures for input?

- Kinaesthetic perception means gestures can be 'eyes free'
- Can use many different parts of the body
  - Fingers, hands, head, or device
  - Can be one handed, no handed
  - Good if users are involved in something else, e.g. carrying bags, operating machinery
- Self-contained, no screen or surface needed
  - Can easily be used on the move
- Popular with users – Nintendo Wii

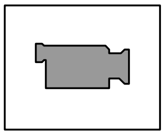
Touchscreen gestures

- iPhone rotate/zoom - Multitouch
- Metaphorical gestures (Pirhonen, CHI 2002)
  - Sweeps and taps to control music player
- Writing gestures
  - EdgeWrite (Wobbrock)



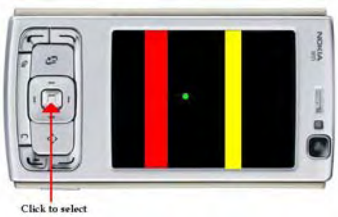
Gesturing with a device

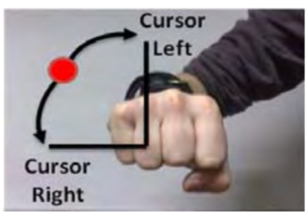
- Use the device itself to gesture or point
  - One-handed interaction
- "Tilt to Scroll"
  - (Oakley, 2005, Strachan, 2007)
  - Natural but problematic in bright light
- Can use other points on body to act as holders of information
  - BodySpace (Strachan, 2007)



Wrist gestures

- Can rotate wrist to control a cursor
  - Discreet form of input whilst holding a bag
- Investigated whether users could select targets using wrist
- Very effective
  - 90% accuracy for 9° targets
  - Mobile recognition techniques are challenging





Crossan, MobileHCI 2008 / www.gaime-project.org

Future

- Audio
  - Better quality 3D sound on mobiles
- Haptic
  - Higher quality tactile actuators (Luk, CHI06)
  - Pressure, temperature
  - Force-feedback displays??
- Sensors and gesture
  - Investigation of new body locations
  - Develop multitouch
  - Gesture recognition techniques robust to noise of real world movements

Conclusions

- Screens and keyboards are hard to use when mobile
  - Limit our mobile interactions
- Multimodal interaction
  - Sound and tactile feedback 'eyes free'
  - Gestures good as input can be 'hands-free'
  - Improve performance when mobile
- New multimodal interaction techniques provide new opportunities for applications and services

Haptics, audio output and sensor input in mobile HCI

GIST
GLASGOW INTERACTIVE SYSTEMS GROUP

stephen@dcs.gla.ac.uk

www.dcs.gla.ac.uk/~stephen

University of Glasgow

Resources - audio

- Audio
  - www.icad.org – audio conference series
  - Brewster, S.A. 2008. *Chapter 13: Nonspeech auditory output.* In The Human Computer Interaction Handbook 2nd Edition (Lawrence Erlbaum Associates, USA), pp 247-264. ISBN 978-0-8058-5870-9
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  - Sonification report: http://www.icad.org/node/400
  - Cohen, M. & Ludwig, L.F. (1991). Multidimensional audio window management. *International Journal of Man-Machine Studies*, 34, pp. 319-336
  - Walker, A. and Brewster, S.A.(2000). Spatial audio in small display screen devices. *Personal Technologies,* 4(2), pp 144-154.
  - Brewster, S.A., Lumsden, J., Bell, M., Hall, M. and Tasker, S. *Multimodal 'Eyes-Free' Interaction Techniques for Wearable Devices.* ACM CHI 2003. ACM Press, Addison-Wesley, pp 463-480
  - Marentakis, G.N. and Brewster, S.A. *Effects of Feedback, Mobility and Index of Difficulty on Deictic Spatial Audio Target Acquisition in the Horizontal Plane.* ACM CHI 2006, ACM Press Addison-Wesley, pp 359-368.

Resources - haptics

- Haptics
  - ISO Tactile/Haptic standard 9241-910 – coming out shortly
  - www.hapticsymposium.org
  - www.eurohaptics.vision.ee.ethz.ch
  - IEEE Transactions on Haptics – new journal
  - www.roblesdelatorre.com/gabriel/hapticsl/ - haptics email list
  - Jones, L., Sarter, N. (2008) Tactile Displays: Guidance for Their Design and Application. Human Factors, 50(1), pp 90-111
  - Klatzky, R. and Lederman, S. (2003) Chapter 6: Touch. In Handbook of Psychology, Vol. 4: Experimental Psychology. John Wiley and sons.
  - Brown, L.M., Brewster, S.A. and Purchase, H.C. *A First Investigation into the Effectiveness of Tactons.* In Proceedings of WorldHaptics 2005 (Pisa, Italy). IEEE Press, pp 167-176
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  - Leung, Maclean, Bertelsen, Saubhasik (2007). Evaluation of haptically augmented touchscreen gui elements under cognitive load. ACM International Conference on Multimodal Interfaces. ACM Press, pp 374-381
  - Luk, Pasquero, Little, Maclean, Levesque and Hayward (2006) A role for haptics in mobile interaction: initial design using a handheld tactile display prototype. ACM CHI 2006, pp 171-180
  - Hoggan, E, Brewster, S.A. and Johnston, J. *Investigating the Effectiveness of Tactile Feedback for Mobile Touchscreens*. In Proceedings of ACM CHI2008 (Florence, Italy). ACM Press Addison Wesley, pp 1573-1582

Resources - sensors and gestures

- Sensors and gestures
  - http://www.gw2009.de – workshop series on gesture
  - Wilson, A. 2008. *Chapter 10: Sensor- and recognition-based input for interaction.* In The Human Computer Interaction Handbook 2nd Edition (Lawrence Erlbaum Associates, USA), pp 177-199. ISBN 978-0-8058-5870-9
  - Hinckley, K. (2008). *Chapter 9: Input technologies and techniques.* In The Human Computer Interaction Handbook 2nd Edition (Lawrence Erlbaum Associates, USA), pp 161-176. ISBN 978-0-8058-5870-9
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  - Wobbrock, J., Myers, B. and Kembel, J. (2003) EdgeWrite: a stylus-based text entry method designed for high accuracy and stability of motion. ACM UIST 2003 (Vancouver, Canada), ACM Press, pp 61-70
  - Crossan, A., Williamson, J., Brewster, S.A. and Murray-Smith, R. *Wrist Rotation for Interaction in Mobile Contexts.* MobileHCI 2008 (Amsterdam, Holland).

tutorial notes

MOBILEHCI 2008

Michael Rohs

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Tutorial Day at MobileHCI 2008, Amsterdam

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Spetember 2nd 2008

Camera-Based Interaction and Interaction with Public Displays

Dr. Michael Rohs
michael.rohs@telekom.de
www.deutsche-telekom-laboratories.de/~rohs

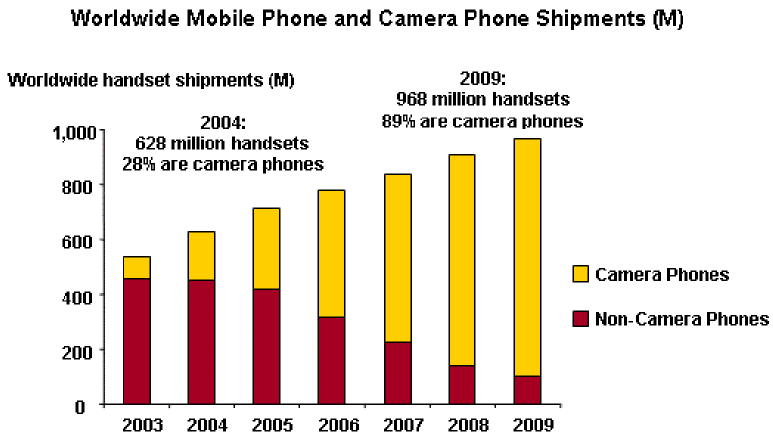
Deutsche Telekom Laboratories, TU Berlin

Mobile Camera Devices

- Motivations for integrating cameras in mobile devices
  - Taking snapshot of surroundings (camera phones)
  - Additional data input channel (2D barcodes)
  - Bridging different media types (paper and electronic media, mobile devices and electronic displays)
  - Linking mobile devices (authentication between devices via the visual channel)
  - Overlaying information onto the real world (augmented reality)
  - Creating input devices (optical movement detection)
  - Server-based image recognition (server analyzes uploaded image)

The Ubiquitous Camera Phone

- 2000: 1st camera phone (Sharp J-SH04)
  - 110k pixel CMOS sensor
- 2009: 89% of mobile phones shipped with camera



First camera phone (2000)
Sharp J-SH04
110k pixel CMOS sensor

Source: Jeff Hayes, InfoTrends CAP Ventures, http://www.capv.com/home/Multiclient/MobileImaging.html

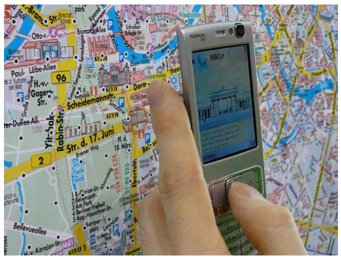
The Ubiquitous Camera Phone

- Even with low-quality cameras:
- Taking snapshots for documenting the real world
  - Usage model: take snapshot, upload to server
  - Example: architect on construction site
  - No image processing required

First camera phone (2000)
Sharp J-SH04
110k pixel CMOS sensor

Camera Phones for Physical Interaction

- Linking the physical to the virtual world
  - The environment as part of the interface
  - Integration with the user's activities
- Camera phones as "bridging" devices
  - Always available imaging device
  - Continuous wireless connectivity
  - Processing power enables on-device image processing
  - Display and audio capabilities
- Handheld camera vs. fixed camera
  - Traditionally predominantly fixed cameras



Categories of Mobile Imaging

Type of image data	Site of image processing	Type of image processing	Mobile processing requirements	Application
Single image	none	Image capturing	low	MMS, human-human, documentation
Single image	server	Advanced image recognition on server	low	"Tourist guide" applications
Single image	mobile device	Simple image analysis	low / medium	Marker recognition
Video stream	mobile device	Simple real-time image analysis	medium	Continuous marker recognition
Video stream	mobile device	Simple real-time optical flow analysis	medium	Optical movement recognition
Video stream	mobile device	Markerless tracking algorithms	high	Augmented reality

Issues of Camera-based Interfaces

- Digital cameras: Very rich sensor data
  - Interpretable by humans and machines
  - Can be processed in many ways
- General issues of perceptual interfaces (computer vision, gesture recognition, speech recognition)
  - Potential for recognition errors
  - Severity depends on application
- Problems of camera-based interfaces
  - Recognition errors
  - Delay for processing
  - Dependence on lighting conditions
  - Needs a lot of computational resources

Overview

- Visual markers / 2D Barcodes / 1D Barcodes
- Linking passive paper and electronic media
- Linking electronic displays and mobile camera devices
- Target acquisition with camera phones
- Tabletop interaction

Image Capturing without Image Processing

PhotoMap: Georeferenced Snapshots of “You are Here” Maps

- Problem: Standard maps often don’t show special areas such as parks, hiking trails, campuses
- Solution: Camera device with GPS positioning
  - Take image of paper map
  - Scroll to “You are here”
  - Phone associate map position and GPS position
  - Current position on photo updated by GPS

Cheverst, Schöning, Krüger, Rohs: Photomap: Snap, Grab and Walk away with a “You are Here” Map. MIRW 2008.

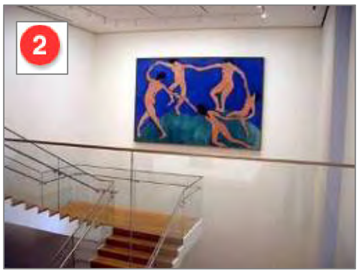
Server-based Image Recognition

Server-based Image Recognition

Source: Rahul Swaminathan, T-Labs

Server-based Image Recognition

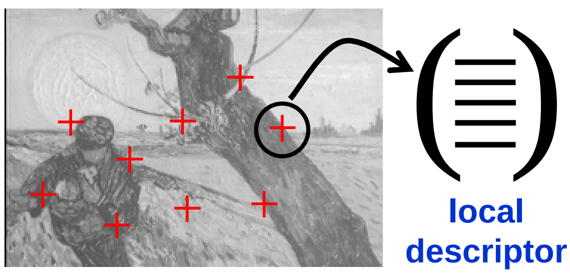
- Landmark recognition under varying illumination and pose
  - Time of day, weather conditions
- Creating landmark database for later use in system
  - Keeping database up-to-date
- Location to restrict search space
  - GPS, GSM cell id
- Applications
  1. Advertisements
  2. Museum guide
  3. Tourist guide



Source: Rahul Swaminathan, T-Labs

Standard Recognition Algorithms Example: SIFT

- Scale-invariant feature transform (SIFT) [Lowe, 1999]
  - Detect / describe local image features
  - Match detected features against database
- Based on "interest points" (characteristic locations)
  - Robust against changes in scale, rotation, viewpoint, illumination
  - Distinctive (representative for image they appear in)
  - Easy to extract from image
  - Easy to describe mathematically
- SIFT Approach
  1. Extraction of interest points
  2. Computation of local descriptors
  3. Determining correspondences
  4. Selection of similar images

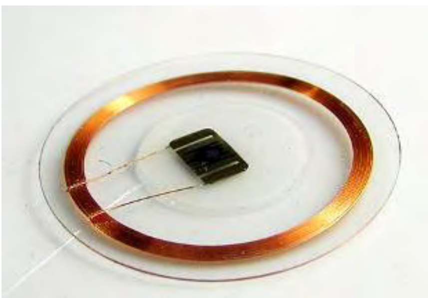


Mobile Tagging

Object Tagging
1D, 2D Barcodes and RFID/NFC

- 2D barcodes

- RFID/NFC readers



2D Barcodes (aka Visual Markers)

- Many different types
- Differences in
  - Application domain
  - Number of encoded bits
  - Robustness
- Low resolution CCD camera requires coarse grained code
- Arbitrary orientation because of camera mobility requires special code features

Data Matrix
TRIPcode
PDF417
QR Code
Philips Dot Code
UPS MaxiCode

QR Codes: Mass Market in Japan

QR Codes: Mass Market in Japan

- Used in train ads, business cards, coupon flyers, etc.
- 72% of Japanese users have phone with QR code reader
- 80% of customers with enabled phones used the feature (56% in 2004)
  - 87.4% scan codes in magazines
  - 40.1% scan codes in newspaper ads
  - 24.6% scan codes on posters

NWA QR code campaign billboard at Shinjuku station, October 2005

Receipt, Nov. 2007

QR Code Tombstone

- Tombstone series “Kuyou no mado” (”commemoration windows”)
- Access to the deceased person’s memorable photos and profiles
- Log feature records who visits when (families and relatives can share the history in future)
- Virtual grave visit feature by cellphone

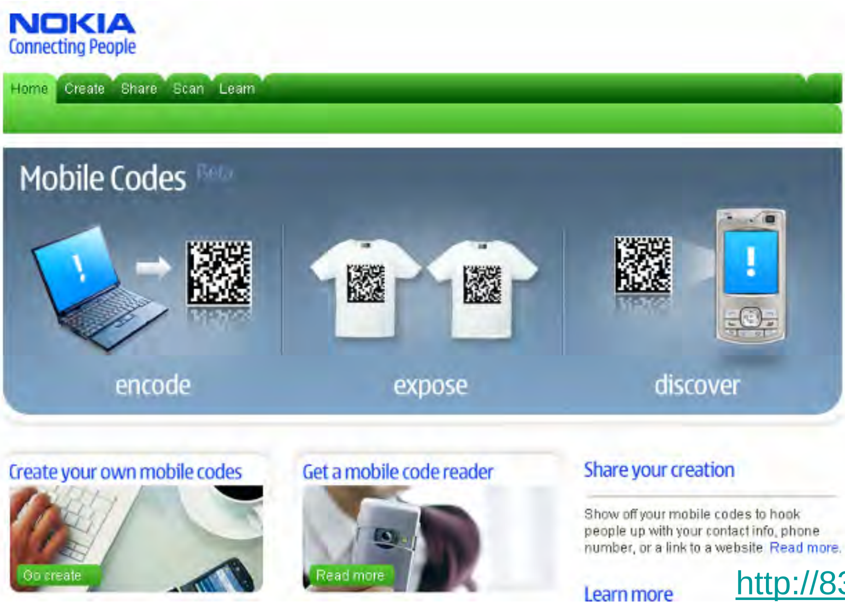
http://asiajin.com/blog/2008/03/13/2d-barcode-tombstone/tombstone-with-qr-code/

Germany: Newspapers start to use QR Codes in 2007

- Link to Web pages, movie ratings, movie trailers, online news
- But: Users have to download and install readers themselves

Some Nokia Phones have Pre-Installed 2D Barcode Readers

- Free online service to generate a code
- Content types: URL, phone number, or text



http://83.145.232.112/scan.htm

Mobile Tagging: Semapedia

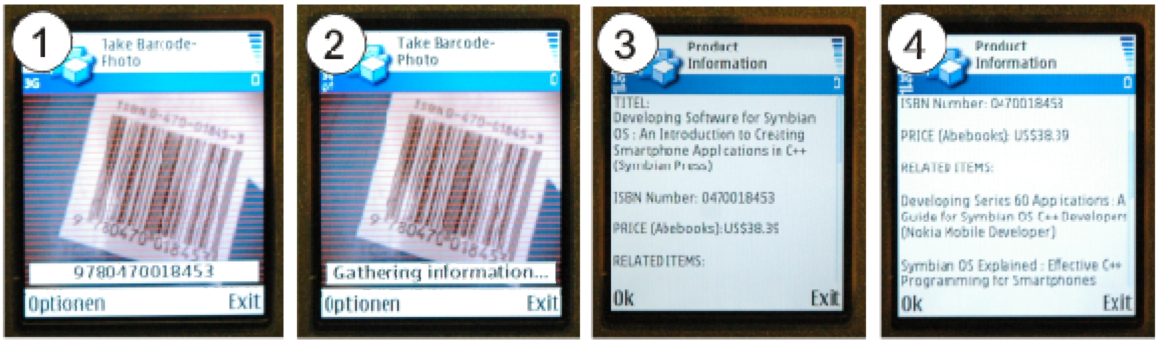
- Physically hyperlink places to Wikipedia
- Uses standard QR Code
- Website for creating Wikipedia URLs

MobileTagging: Semacode

- Linking people to Facebook by scanning “Semacode social card”
- Uses standard DataMatrix code
- apps.facebook.com/semacode

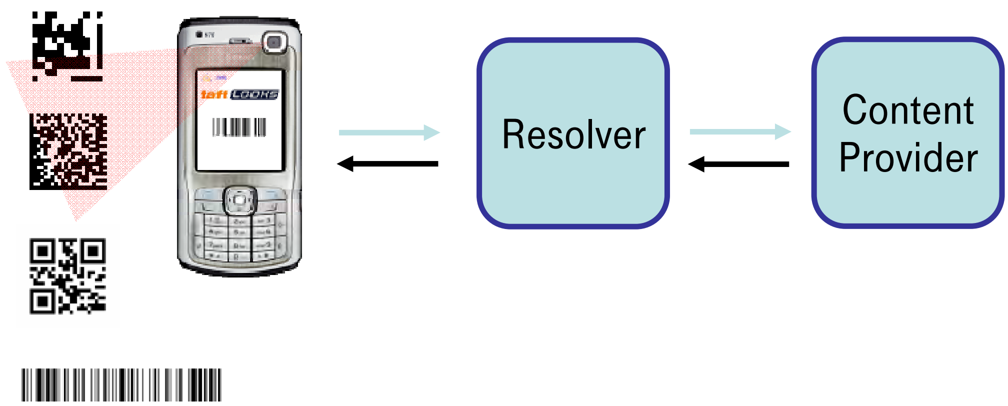
1D Barcode Recognition by Camera

- 1D barcodes on every retail item
- Camera resolution now sufficient to resolve lines
- Free toolkit (GPL): BaToo
  - people.inf.ethz.ch/adelmanr/batoo



Resolving Identifiers

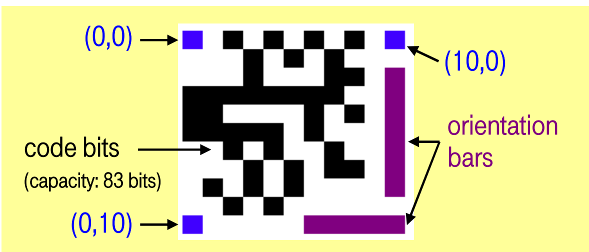
- Markers contain content or link to content
  - Direct (no resolver): store URL, phone number, text
  - Indirect (resolver): store identifier that resolver maps to content



Visual Codes for Camera Phones

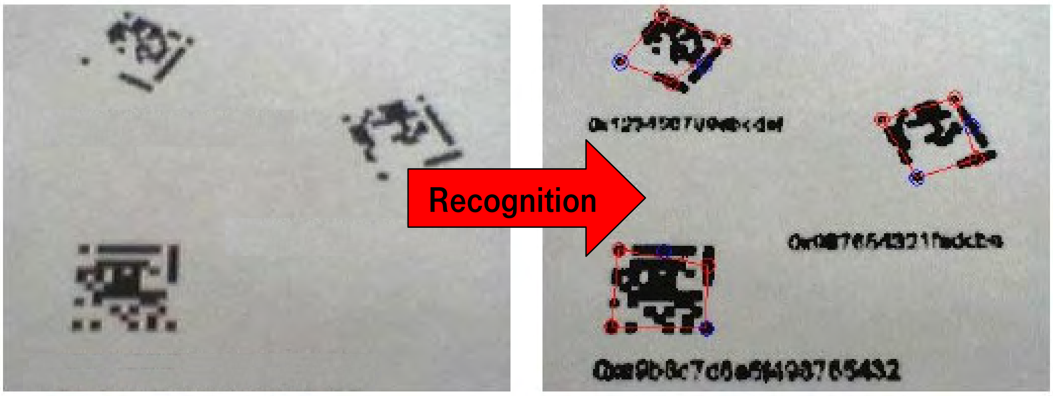
Visual Codes for Camera Phones

- For low-resolution phone cameras
  - Requires coarsely grained code
- Arbitrary orientation of code in the camera image
- Lightweight recognition algorithm
  - Real-time recognition in video stream
- Storage of IP address & port, Bluetooth address, UUIDs, EPCs



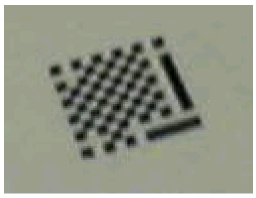
Low Quality Camera Images

- Low resolution
- Blurred edges
- Low contrast
- Uneven illumination
- Radial lens distortion (“barrel distortion”)

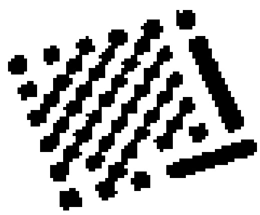


Grayscaling and Adaptive Thresholding

- Grayscaling: grey = (red + green) / 2
  - more efficient than
    $Y = 0.2126 \times red + 0.7152 \times green + 0.0722 \times blue$
  - good approximation
    Y = (218 * red + 732 * green + 74 * blue) >> 10

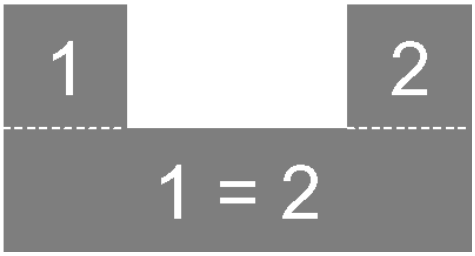


- Thresholding: Algorithm by Wellner
  - Traverse scan lines top to bottom
  - Adaptive threshold (moving average)
  - Modified to avoid floating point operations



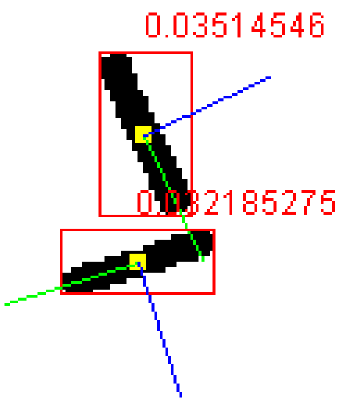
Identification of Connected Regions

- Standard two-phase labeling procedure
  - Run through all pixels, assign temporary labels, store label equivalences
  - With label equivalences, assign final labels



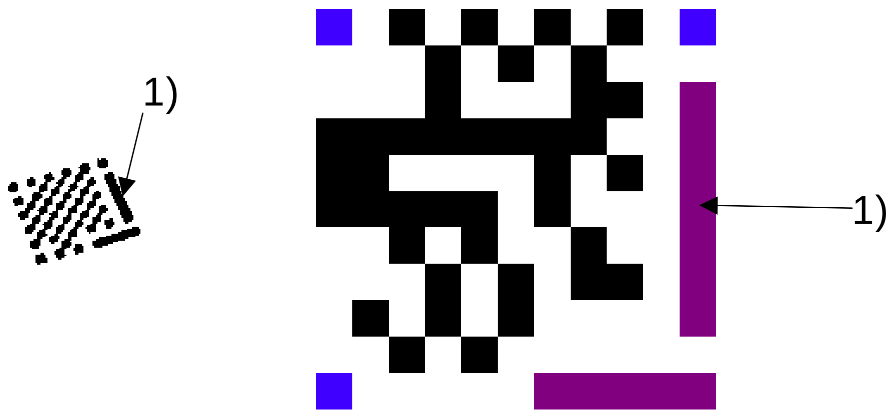
Calculate Region Shapes and Orientations

- Compute second-order moments
  - For symmetric regions: axes of symmetry
- Gives information about orientation and “ellipsity” of regions
  - ratio = 0 for lines, 1 for circles
- Example:



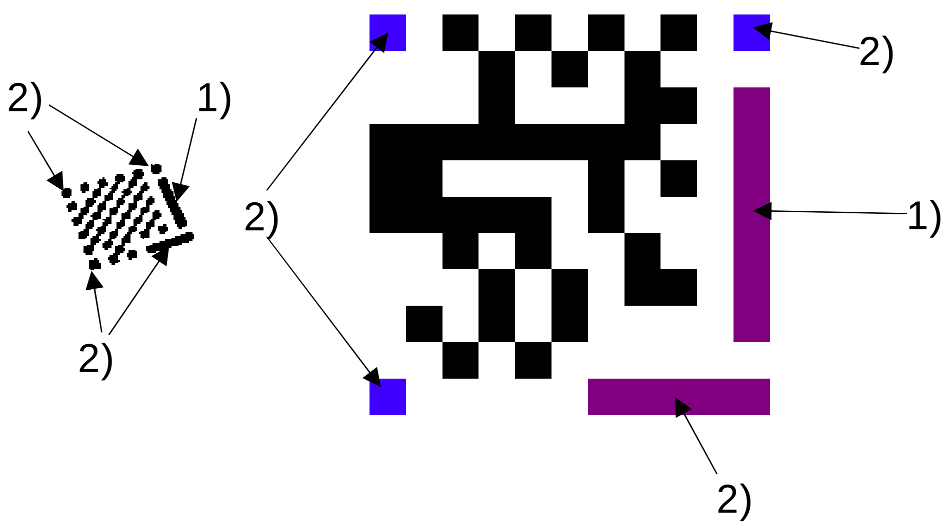
Locating Codes in the Camera Image

1) Search region that looks like a bar



Locating Codes in the Camera Image

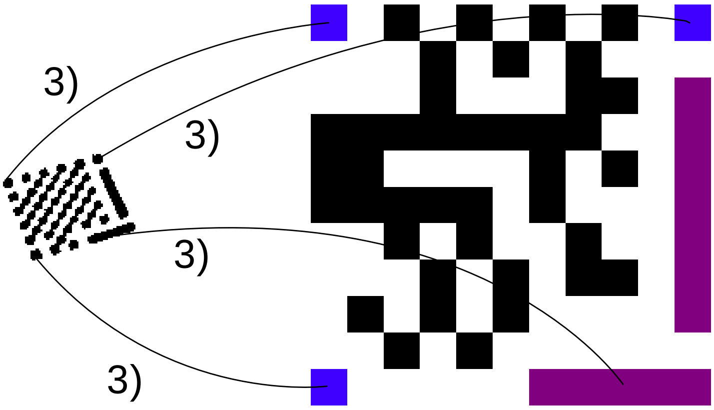
2) Check whether other features are present



Reading the Encoded Bits

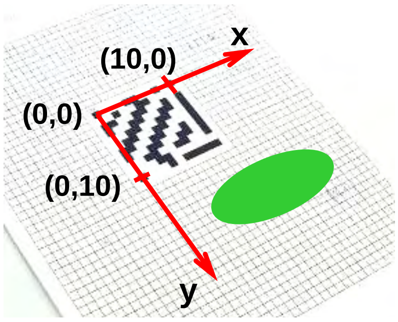
3) Distortion correction with projective mapping (homography)

4) Error detection with (83,76,3) linear code

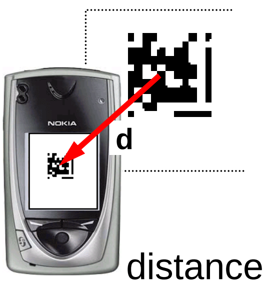


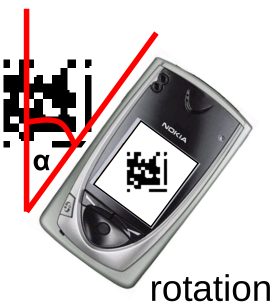
Visual Code Parameters

- Rotation, tilting, and distance
- Code coordinate system
- No camera calibration required
- Enables intuitive manipulation



code coordinate system

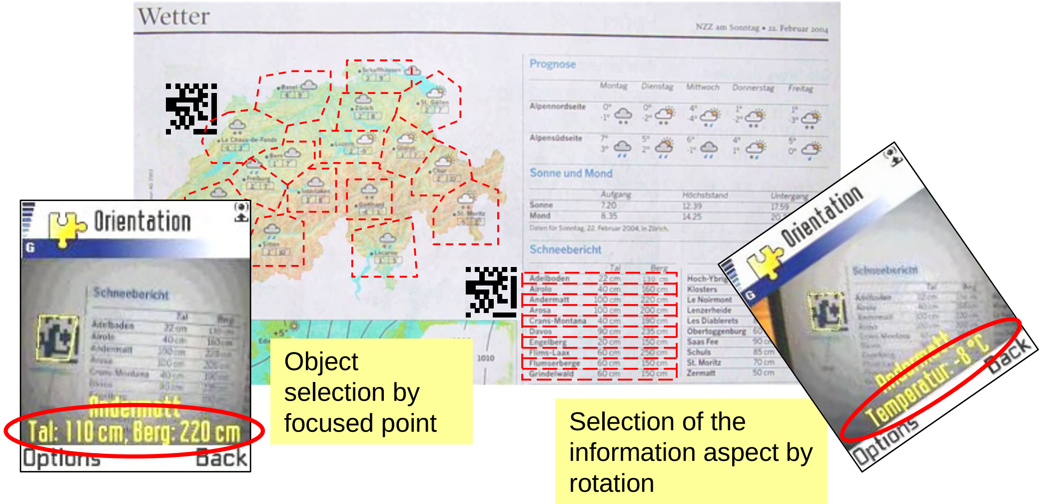




Michael Rohs: Real-World Interaction with Camera Phones. Proc. of UCS 2004.

Marker-based Interaction with Newspapers

- Current weather and snow conditions
- Combination of targeted object and rotation



Michael Rohs: Real-World Interaction with Camera Phones. Proc. of UCS 2004.

Handheld Augmented Reality Games on Product Packages: “Penalty Kick”

Video

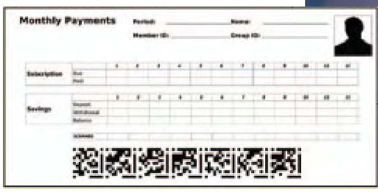
- Aim at goal
  - Device rotation = horizontal shot direction
  - Device tilting = vertical shot direction (flat or high)
- Kick the ball
  - Press joystick key
- Goalkeeper catches ball with some probability

Michael Rohs: Marker-Based Embodied Interaction for Handheld Augmented Reality Games. Journal of Virtual Reality and Broadcasting (JVRB), March 2007.

Academic Projects using Visual Codes

- Mitchell, Race, and Clarke: CANVIS: Context-Aware Network Visualisation using Smartphones. MobileHCI 2005
  – Real time monitoring and visualization of a campus network

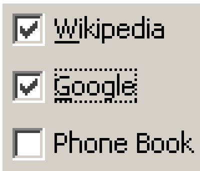
- Parikh: Using Mobile Phones for Secure, Distributed Document Processing in the Developing World. IEEE Pervasive Computing, 4(2):74
  – Embed processing commands into paper forms
  – Mobile phones more common than PCs

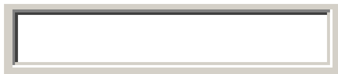


Augmented Reality Widgets

GUI Widgets

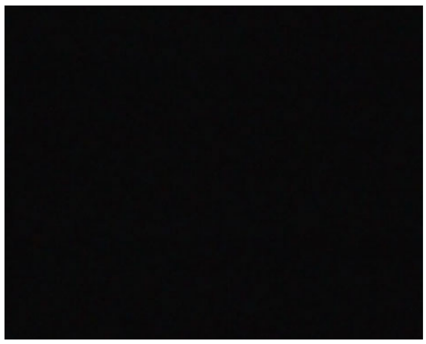
- Building blocks for creating graphical user interfaces
  - Buttons, check boxes, edit fields, tooltips...
- Generic, reusable, self-contained user interface elements
  - Define basic interaction metaphors across all applications
- Solve particular input problems
- Offer familiar affordances to the user





Magic Lens for AR Widgets

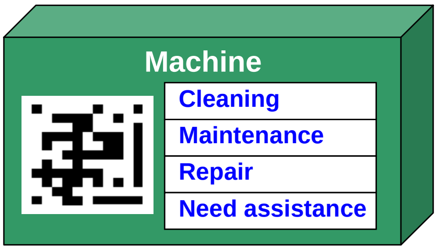
- Printable user interface elements
  - Embedded in user's environment
  - Entry point for interaction
  - Controlled via position, rotation, distance
- Background layer
  - Passive widget
- Overlay layer
  - Active Display
  - Camera phone as "see-through tool"

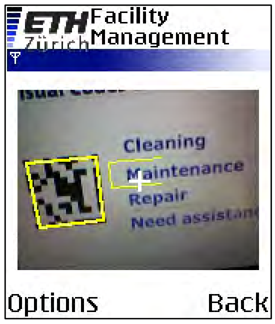


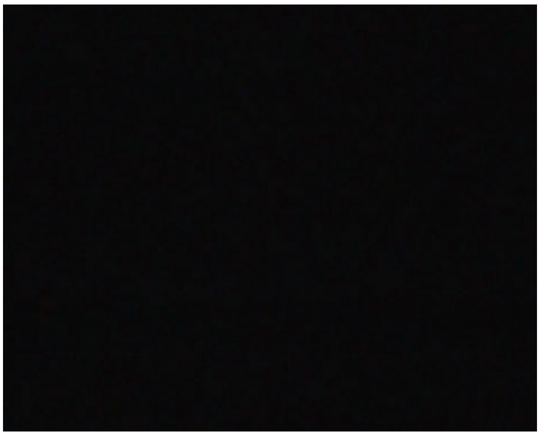
Michael Rohs: Visual Code Widgets for Marker-Based Interaction. Proc. of ICDCS 2005 Workshops.

Scenario: Facility Management and Field Service

- Scenario
  - Field engineer carries camera phone
  - Object has a visual code menu
  - User selects item to document work or request information
- Data generated upon selection
  - Code value, menu index
  - Device id, timestamp
- Automatically generated SMS
  - Send mode: immediate sending
  - Store mode: collecting items for later sending

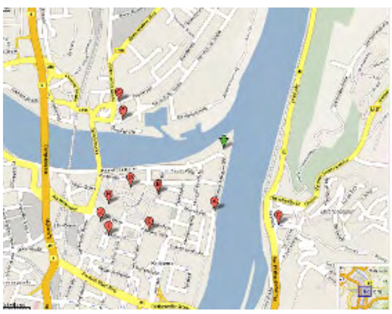


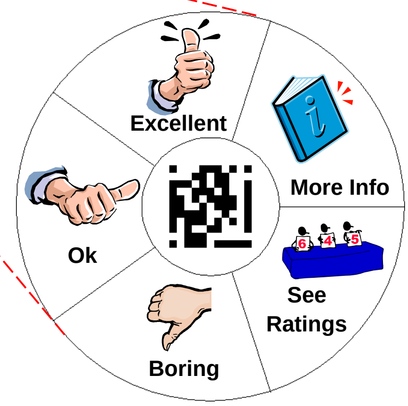




Scenario: Fairs, Exhibitions

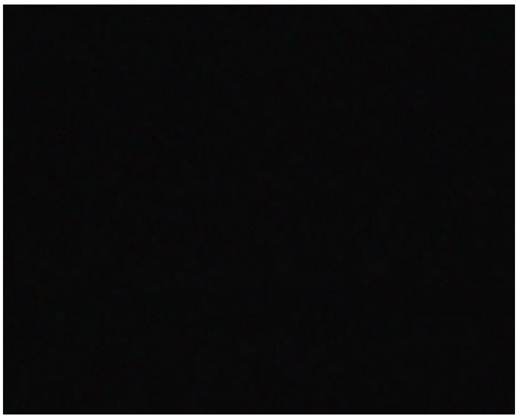
- Highlighting interesting exhibits
- Providing quick and easy ratings
- Instant transfer to my personal blog or community

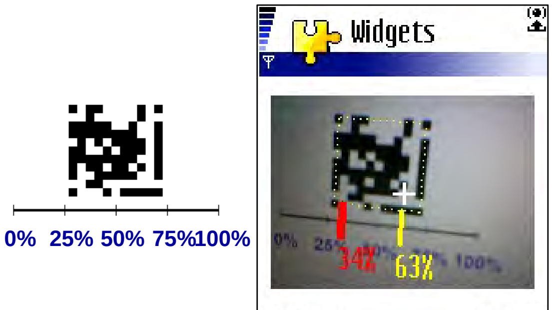




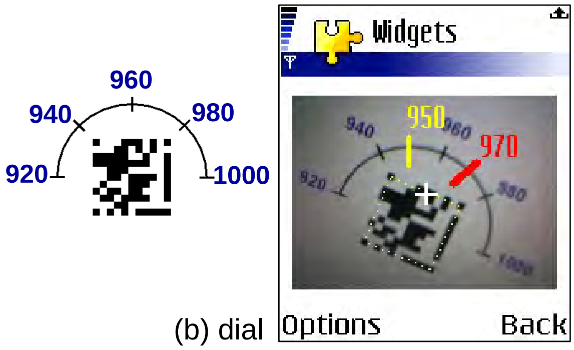
Sliders, Dials, Check Boxes, …

- “Bounded” data entry widget
  - Simple input of numeric data in predefined range
- Percentages or numeric scale
- Continuous or discrete input





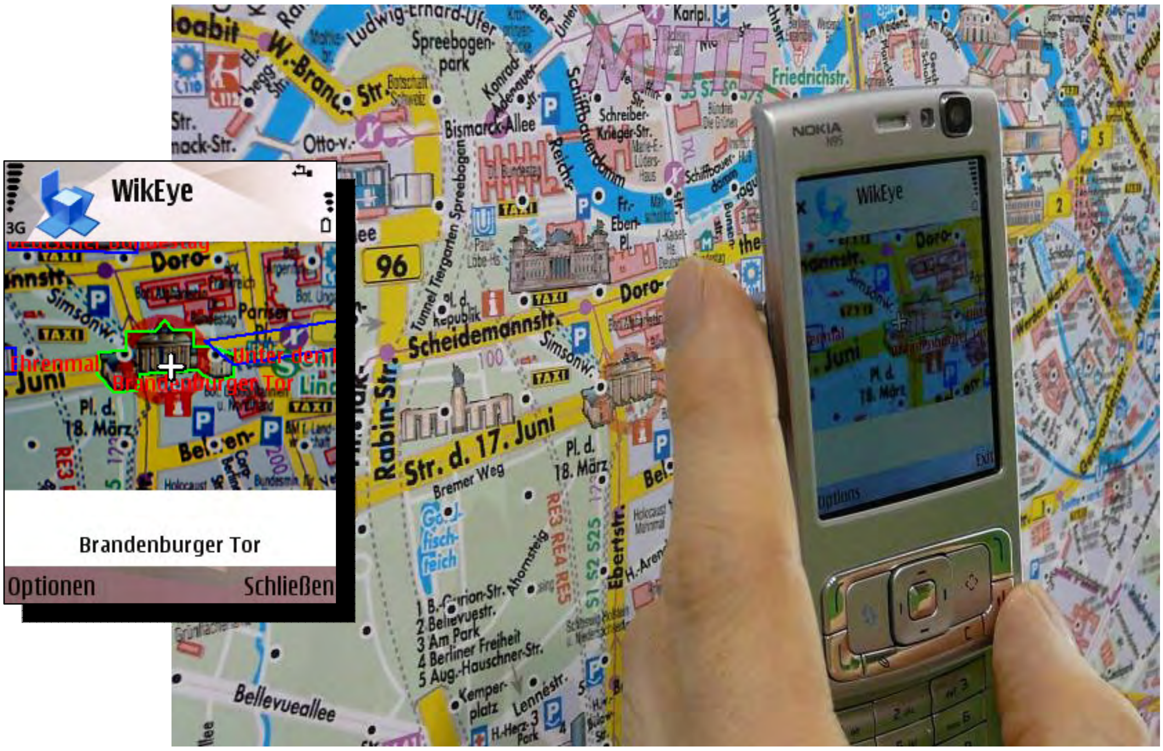
(a) horizontal slider



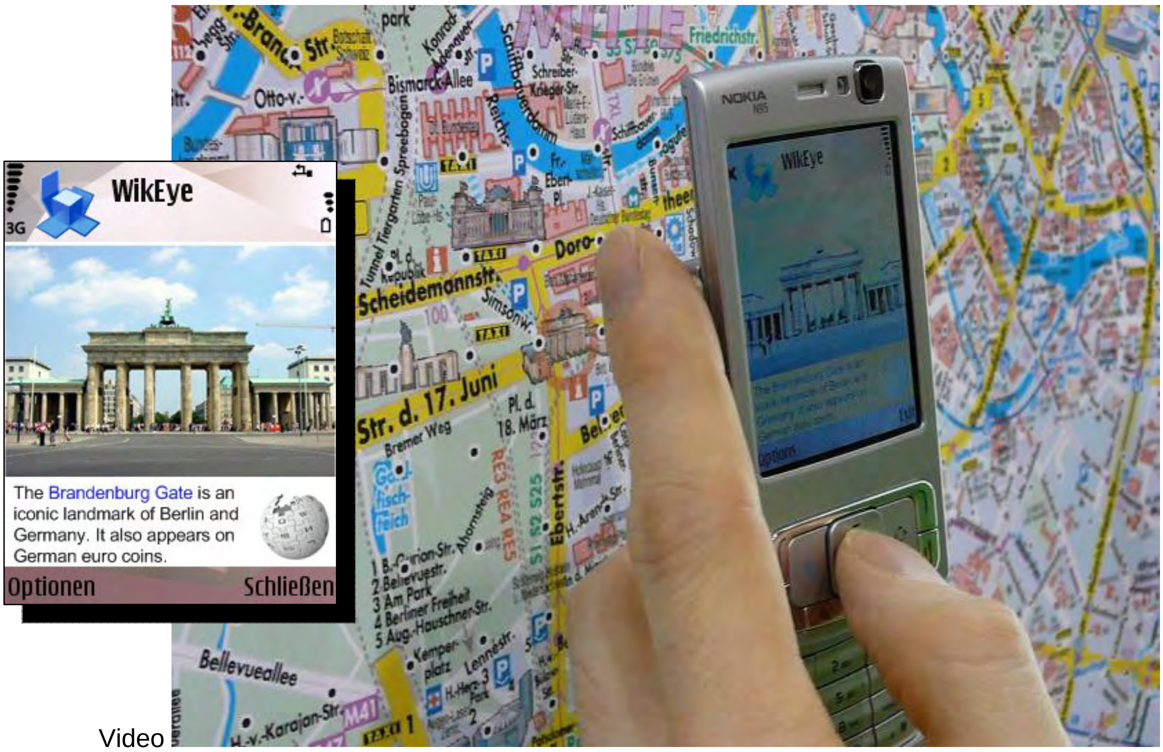
(b) dial

Camera Phones as See-Through Displays

Camera Phones as Magic Lenses

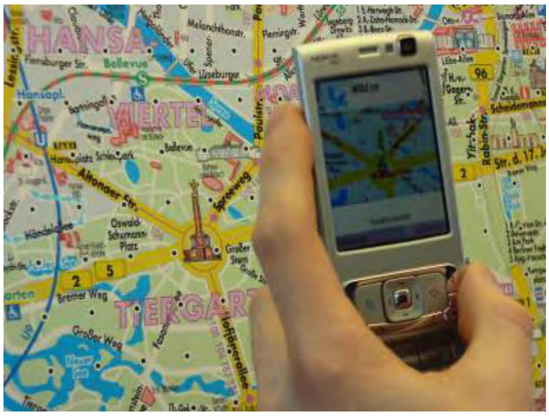


Camera Phones as Magic Lenses



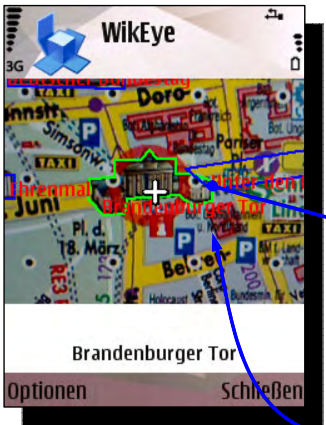
Video

Camera Phones as Magic Lenses for Large-Scale Paper Maps



- Paper maps
  - Large scale and high resolution
  - Available everywhere
  - But: only static, long-term information, not personalized
- Camera phones
  - Dynamic information: short-term, up-to-date, personalized
  - But: small display size, low resolution
- Camera phones as magic lenses for paper maps
  - Augmented reality for paper maps
  - Access information and services via paper map

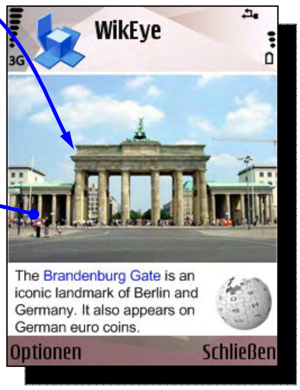
Wikipedia Content on Paper Maps



Computer-generated graphics overlaid over camera view of map.

link from map to Wikipedia article

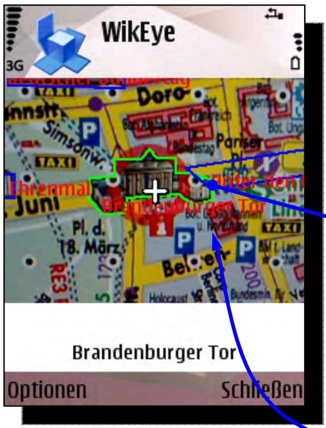
link back to physical map



Show Wikipedia content related to item on map.

Brent Hecht, Michael Rohs, Johannes Schöning, Antonio Krüger: Wikeye – Using Magic Lenses to Explore Georeferenced Wikipedia Content. PERMID 2007.

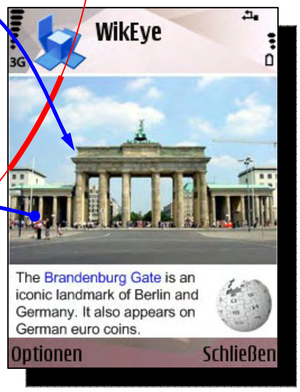
Wikipedia Content on Paper Maps



Computer-generated graphics overlaid over camera view of map.

link from map to Wikipedia article

link back to physical map

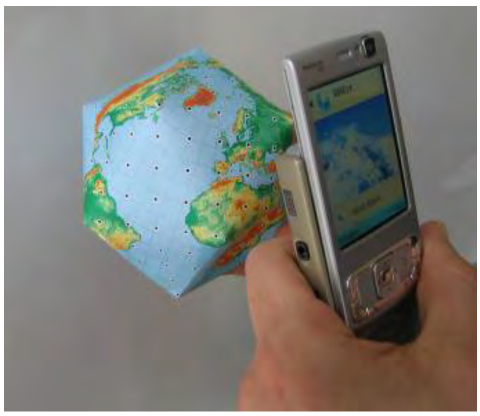


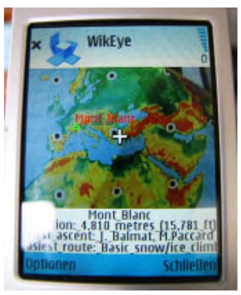
Show Wikipedia content related to item on map.

Brent Hecht, Michael Rohs, Johannes Schöning, Antonio Krüger: Wikeye – Using Magic Lenses to Explore Georeferenced Wikipedia Content. PERMID 2007.

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, time zones, etc.
- Applicable in educational scenarios





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

Real-Time Map Tracking Algorithm

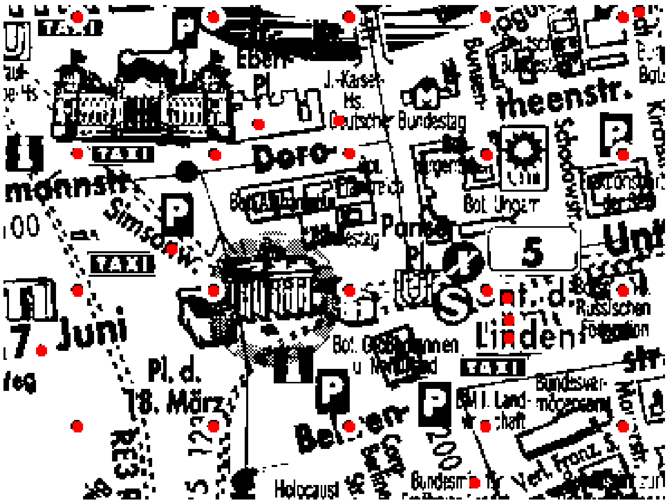
Michael Rohs, Johannes Schöning, Antonio Krüger, Brent Hecht: Towards Real-Time Markerless Tracking of Magic Lenses on Paper Maps. Pervasive 2007, Late Breaking Results, pp. 69-72.

Real-Time Map Tracking Algorithm

0. A regular map is overlaid over the map
   - Subdivides the map into square "patches"
   - A "fingerprint" is computed for each patch and stored as meta-information for the map
   - The "fingerprint" information initially has to be downloaded onto the phone

Real-Time Map Tracking Algorithm

1. Find map dot candidates
   - Black-and-white image with adaptive thresholding
   - Connected regions of a certain size and axis ratio are classified as potential map dots
     - False positives



Real-Time Map Tracking Algorithm

2. Find edges
   - Undirected graph with the map dot candidates as vertices
   - Stored in a hashtable for efficient lookup
   - Edge length constraint
   - Edges have a direction
     - "horizontal" ($\Delta x > \Delta y$)
     - "vertical" ($\Delta y \leq \Delta x$)
   - Role of vertex in edge
     - 0 = left, 1 = right,
       2 = top, 3 = bottom
   - Stored edge twice
     - left/top vertex lt
       hash key $k_{lt} = 4\, lt_{index} + lt_{role}$
     - right/bottom vertex rb
       hash key: $k_{rb} = 4\, rb_{index} + rb_{role}$

Real-Time Map Tracking Algorithm

3. Find patches
   - Identify the four corners of each correlation patch
   - Iterate over hashtable, look for suitable edges
   - Look for loops of length 4 of alternating horizontal and vertical edges
   - Vertex roles
     - left, right
     - top, bottom
     - right, left
     - bottom, top
   - Constraints
     - Length
     - Angle

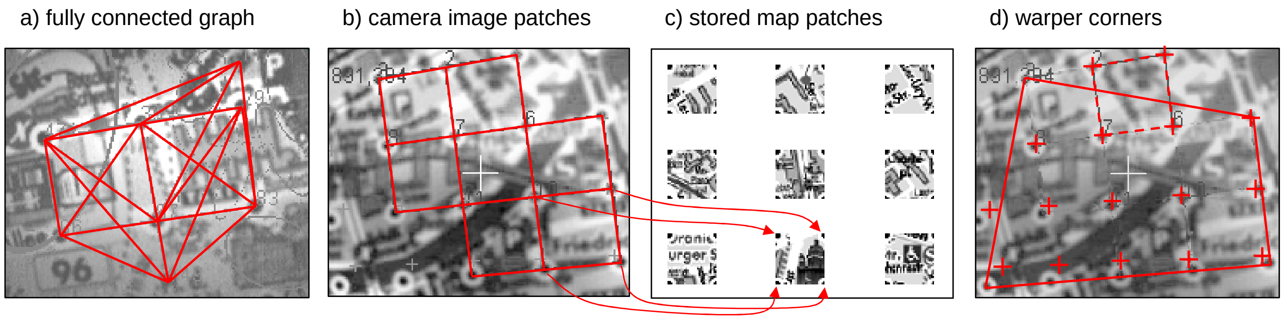
Real-Time Map Tracking Algorithm

4. Sample each patch
   - Compute projective mapping to a 12x12 pixel area
   - Take gray-value pixel samples
5. Compute correlations
   - Between image patch and map patch
6. Compute maximum correlation indices
   - Determine pairs of patches with highest correlation
7. Find reliable patch (voting)
   - Identify patches with correctly recognized position
8. Compute maximum warper
   - Compute perspective mapping for the graphical overlays

Real-Time Map Tracking Algorithm

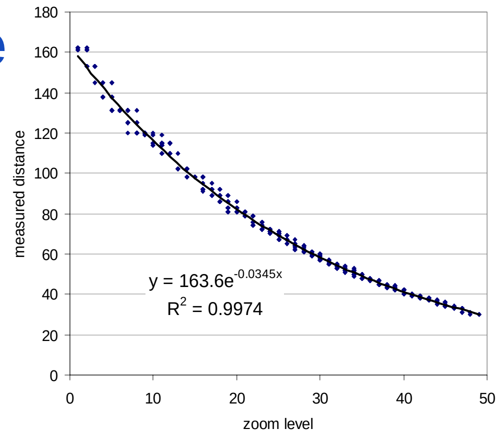
1. Find map dot candidates
2. Find edges
3. Find image patches
4. Sample each image patch (12x12 samples)
5. Compute cross-correlations between image and map patches
6. Compute indices of maximum correlation
7. Find reliable patch (majority voting)
8. Compute maximum warper

- 7-10 updates per second
- Limit search to 5x5 patch window

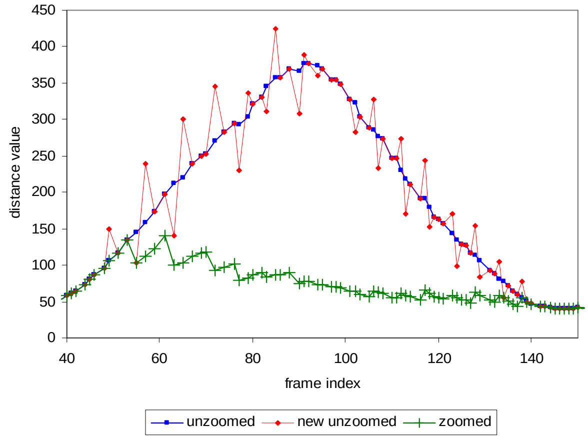


Extended Tracking Range

- Dynamic digital zoom
  - Continuously update zoom level
  - $d_{zoomed}(level) = a \exp^{\,b\ level}$
  - $d_{zoomed}(0) = a = d_{unzoomed}$
  - $d_{unzoomed} = d_{zoomed}(level) \exp^{\,-b\ level}$



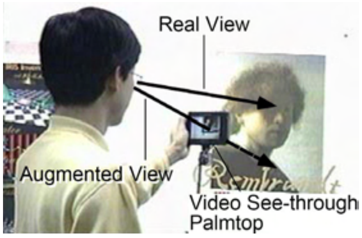
- Digital zoom not immediate
  - Delay of 2-5 frames
  - Compute distance for old and new setting
  - Choose smoothest curve
- Extended tracking range
  - 10 cm → 30-50 cm



Markerless Tracking for Mobile Devices

- Daniel Wagner et al.: Pose Tracking from Natural Features on Mobile Phones. ISMAR 2008.
- Real-time tracking of natural features on planar targets
  - ~10 fps on a Nokia N95
- Modification of SIFT and Ferns (based on local image features)
  - FAST corner detector
  - Not fully scale invariant like SIFT

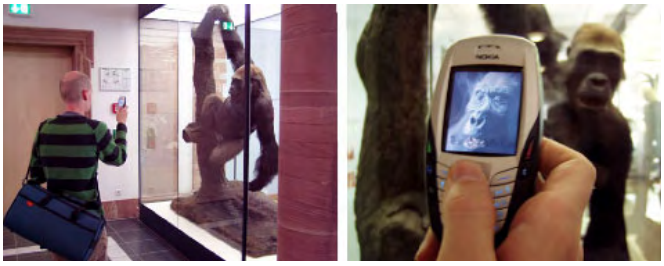
Mobile Augmented Reality



Source: Rekimoto: Magnifying Glass Approach to Augmented Reality Systems, 1995

- Video see-through augmentation with camera-equipped handheld devices
  - Handheld device as alternative to HMDs
- Align superimposed graphics with real-world view
  - Registration problem

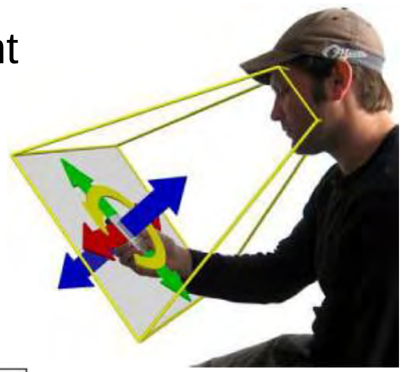

Source: Wagner: Handheld AR Displays, VR 2006

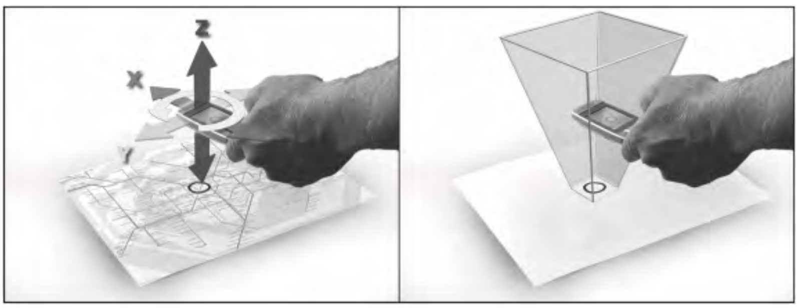

Source: Föckler: PhoneGuide, 2005

Input Devices based on Camera Input

Mixed Interaction Spaces (Hansen et al., 2005)

- Mixed: physical space for interaction in virtual space
- Visual tracking of a fixed reference point
  - Hand-drawn circle
  - Colored object
  - Face
- 4D input vector (device position and rotation in physical space)

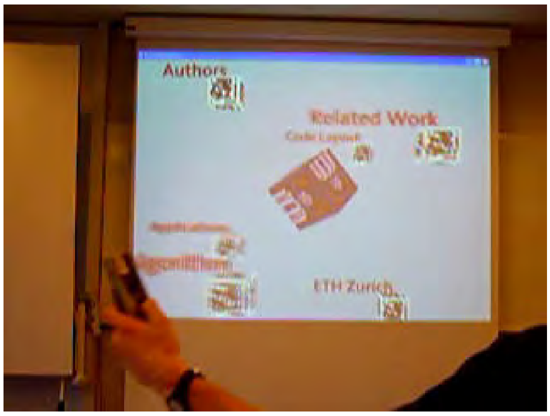


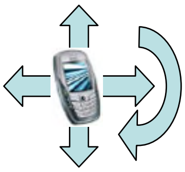


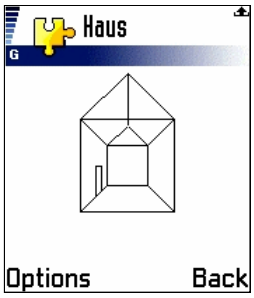
Source: Hansen, Eriksson, Lykke-Olesen: Mixed Interaction Space – Designing for Camera Based Interaction with Mobile Devices, CHI 2005

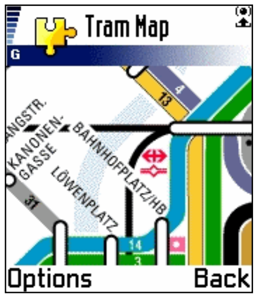
Optical Movement Detection (“Sweep”)

- Visual detection of device movement relative to the large display
- Continuous scrolling of screen contents
- Direct control of external displays
- 3 degrees of freedom (DOF)
  - x
  - y
  - θ



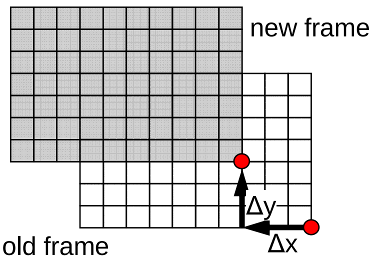


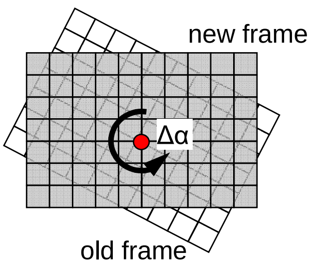


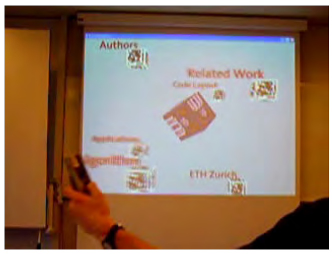


Rafael Ballagas, Michael Rohs, Jennifer G. Sheridan, Jan Borchers: Sweep and Point & Shoot: Phonecam-Based Interactions for Large Public Displays. Extended abstracts of CHI 2005.

Optical Movement Detection (“Sweep”)





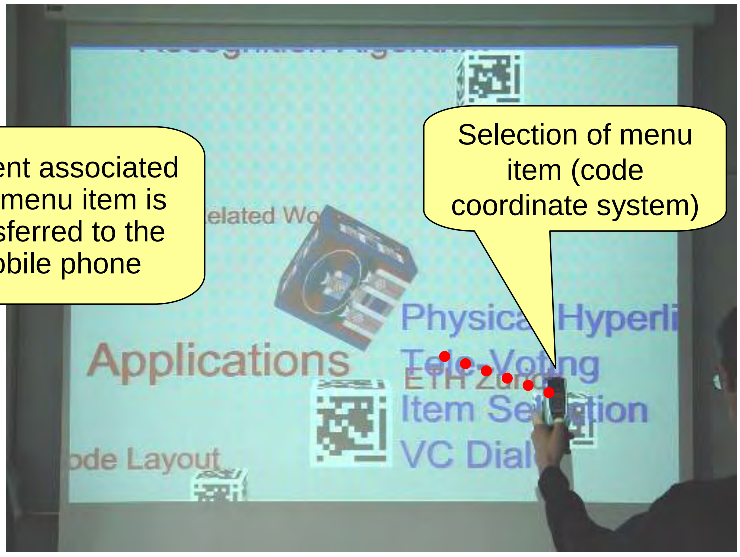


- Subdivide 176x144 pixel image in 8x8 pixels blocks
- Compute cross-correlation between adjacent frames
  - Frames are 33 ms apart (at 30 fps)
  - Sample spacing: 4 pixels
- Try a range of linear (Δx, Δy) offsets

$$r_t(dx, dy) = \frac{\sum_{y=0}^{h-1} \sum_{x=0}^{w-1} b_1(x, y) b_2(x + dx, y + dy)}{(w - |dx|)(h - |dy|)} \qquad (\Delta x, \Delta y) = \underset{dx, dy \in \{-4, \ldots, 4\}}{\operatorname{argmax}} r_t(dx, dy)$$

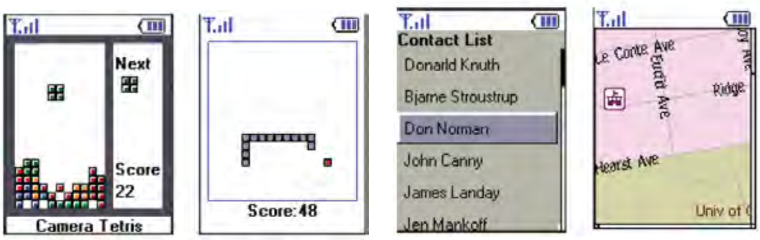
Interaction with Large Public Displays

- Large displays at public places
  - Train stations, air ports, museums, shopping malls
- Personal mobile devices for interaction with public displays
- Specific design criteria



TinyMotion: Camera Phone Based Motion Sensing (Jingtao Wang, Berkeley)

- Camera-based sensing of device motion
  - Detects horizontal, vertical, rotational, tilt
  - Controls scrolling, zooming, menu selection, cursor movement, gesture/handwriting input
- References
  - Wang, Zhai, Canny: Camera Phone Based Motion Sensing: Interaction Techniques, Applications and Performance Study, UIST 2006.
- http://tinymotion.org



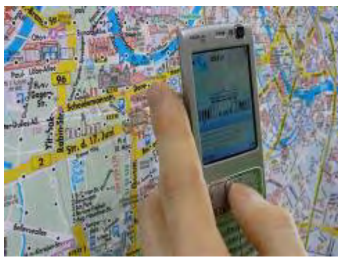
Source: Wang et al. TinyMotion: Camera Phone Based Interaction Methods. CHI 2006.

Target Acquisition with Camera Phones

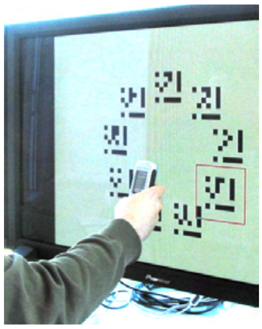
Michael Rohs and Antti Oulasvirta: Target Acquisition with Camera Phones when used as Magic Lenses. Proc. of CHI 2008, pp.1409-1418.

See-Through Interfaces for Camera Phones

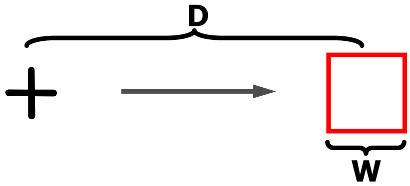
- Magic lens pointing
  - View targets through narrow viewport of device
- Pointing task performance
  - Analyzing target acquisition strategies
  - Speed and accuracy
  - Predictive model



Magic Lens Pointing Experiment



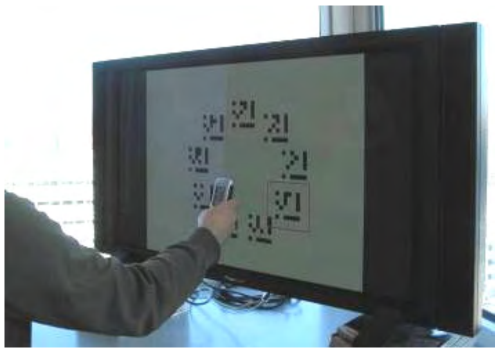
- Targets visible on background and through lens
  - Device tracked on plasma display of size 72x54 cm
- Cyclical multi-direction target acquisition (ISO 9241-9)
  - 9 targets on a circle, next one highlighted
  - W = 13-97 mm, D = 55-535 mm, 33 combinations
- 12 subjects x 33 conditions x 3 rounds x 9 selections



- Fitts' law: MT = a + b ID with ID = $\log_2(D / W + 1)$
- Fitts' law does not predict performance
  MT = 581 + 191 $\log_2(D / W + 1)$, $R^2 = 0.57$

...why?

Target Acquisition with Camera Phones

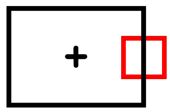


- Device movement in 3D space
- View selection
- Screen distance range
- System delay
- Maximum movement velocity
- Gaze deployment between display and background

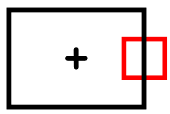
Analysis of Magic Lens Pointing Task

- Task:
  Move cursor onto target

- First phase: Target directly visible
  First task: Move lens over target



- Second phase: Target behind display
  Second task: Move crosshair over target



Analysis of Magic Lens Pointing Task

- Task:
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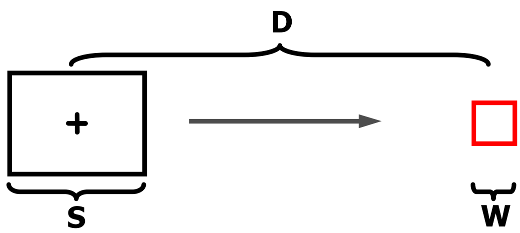
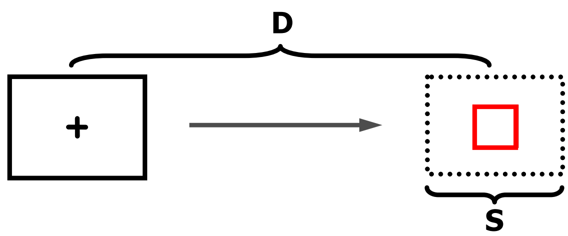
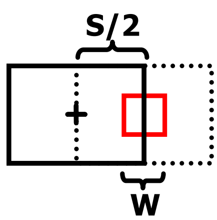


- First phase:
  Target directly visible
  $MT_p = a_p + b_p \log_2(D / S + 1)$



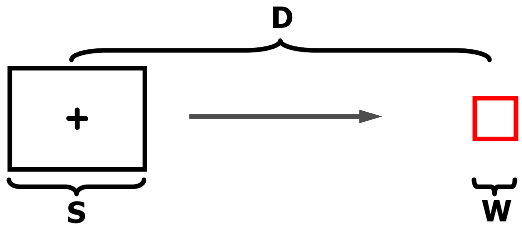
- Second phase:
  Target behind display
  $MT_v = a_v + b_v \log_2(S/2 / W + 1)$



Magic Lens Pointing Model

- First phase (physical pointing)
  $MT_p = a_p + b_p \log_2(D / S + 1)$
- Second phase (virtual pointing)
  $MT_v = a_v + b_v \log_2(S/2 / W + 1)$

- Two-component Fitts' law model
  $MT = a + b \log_2(D / S + 1) + c \log_2(S/2 / W + 1)$

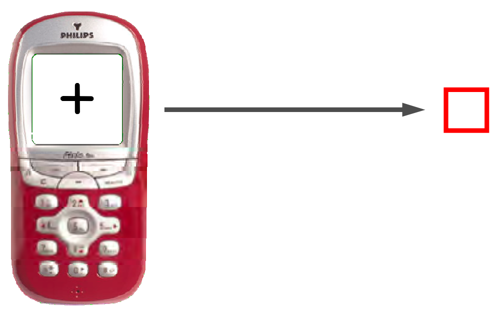


Control Loop in Physical Pointing

- Aimed movements require visual feedback
  – Movements >200 ms controlled by visual feedback
- Iterative corrections model [Crossman & Goodeve]
  – Ballistic submovements of constant time (135-290 ms)
  – Each submovement has distance error ε (4-7%)

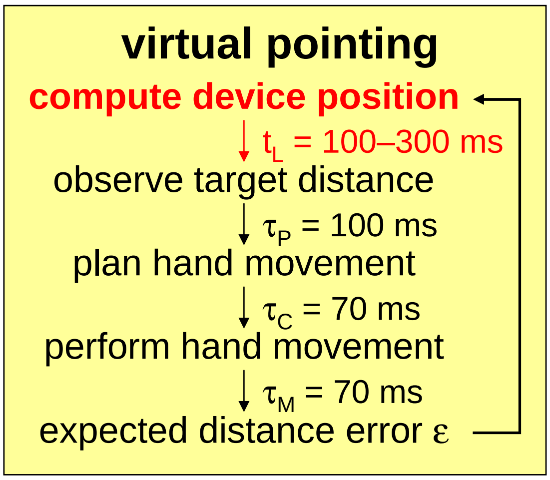
physical pointing

observe target distance
↓ τ_P = 100 ms
plan hand movement
↓ τ_C = 70 ms
perform hand movement
↓ τ_M = 70 ms
expected distance error ε



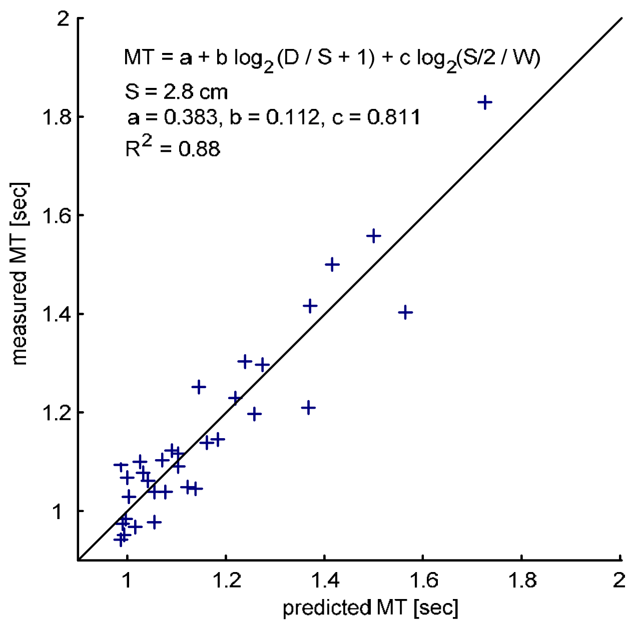
Control Loop in Virtual Pointing

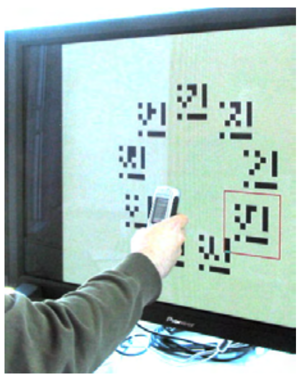
- Virtual pointing introduces delay in feedback loop
  - Submovement $t_H = \tau_P + \tau_C + \tau_M$
  - Machine lag t_L
- Rewrite two-part model as
  $MT = a + \beta\, t_H \log_2(D / S + 1) + \gamma\, (t_H + t_L) \log_2(S/2 / W + 1)$



Two-Part Fitts' Law Model of Magic Lens Pointing

- $MT = a + b \log_2(D / S + 1) + c \log_2(S/2 / W + 1)$
  $= 383 + 112 \log_2(D / S + 1) + 811 \log_2(S/2 / W + 1)$
- $R^2 = 0.88$





Model for Camera-Based Pointing

- Relevant for developing camera-based input devices

- Magic lens pointing not explainable by standard Fitts' law
- Different feedback loops
  - Initial physical pointing phase
  - Second virtual pointing phase

- Two-part Fitts' law model for magic lens pointing
- Predict pointing time for display size S and delay t_L

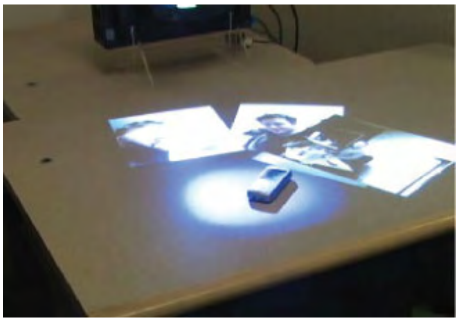
$$MT = a + b \log_2(D / S + 1) + c \log_2(S/2 / W + 1)$$

$$MT = a + \beta\, t_H \log_2(D / S + 1) + \gamma\, (t_H + t_L) \log_2(S/2 / W + 1)$$

Mobile Devices and Interactive Tabletops

BlueTable: Connecting Wireless Mobile Devices on Interactive Surfaces

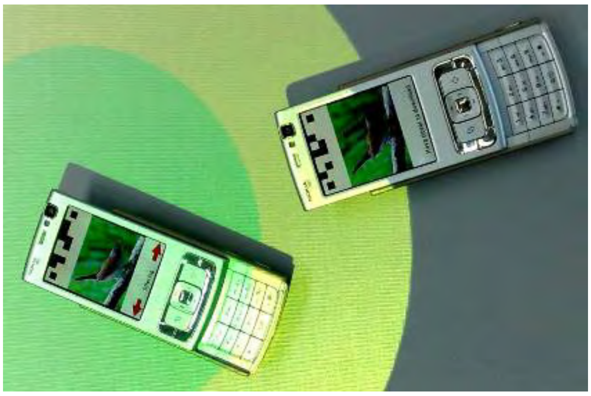
- Problem: Associating Bluetooth devices is cumbersome
- Solution:
  - Combining computer vision and Bluetooth technologies
  - Establish the connection by placing the device on a table surface
  - Exchange of photos by selecting and dragging them from device to another

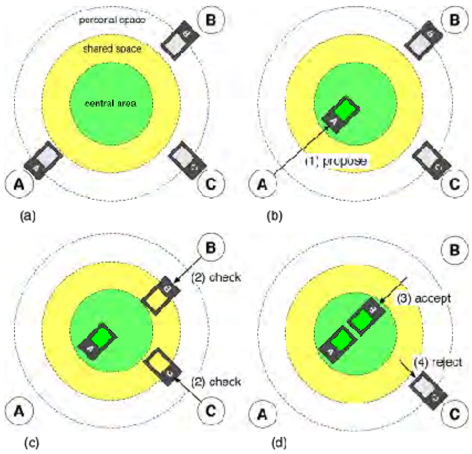


Source: Wilson and Sarin: BlueTable: Connecting Wireless Mobile Devices on Interactive Surfaces Using Vision-Based Handshaking, Graphics Interface 2007.

Mobile Devices and Interactive Tabletops

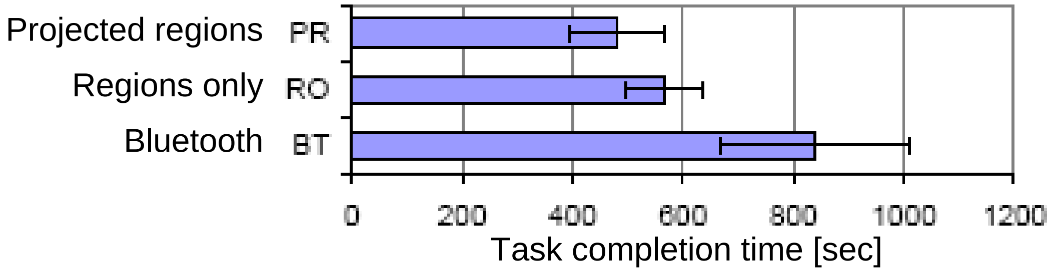
- Group of collocated users with shared goal
- Proximity regions around mobile devices
- Spatial arrangement reflects coordination state

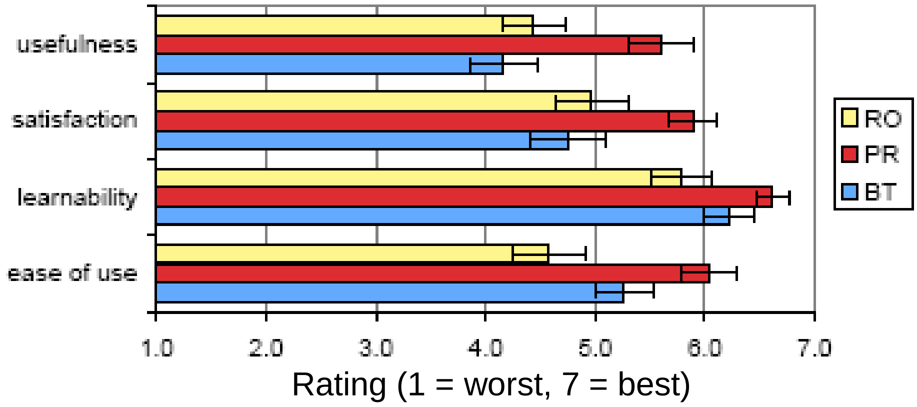




Kray, Rohs, Hook, Kratz: Group Coordination and Negotiation through Spatial Proximity Regions around Mobile Devices on Augmented Tabletops. IEEE Tabletop 2008.

Quantitative Results





Summary

- Linking physical objects to the virtual world
  - Objects around the user as part of the interface
- Mobile digital cameras are extremely rich sources of sensors data
  - Reliability, delay, dependence on lighting conditions
- Categories of camera-based interaction
  - Computational requirements, infrastructure requirements
- Creating interfaces from camera input
  - Many ways of approaching this
  - Keep limits of algorithms in mind

Thank you!

Dr. Michael Rohs
michael.rohs@telekom.de
www.deutsche-telekom-laboratories.de/~rohs

Deutsche Telekom Laboratories, TU Berlin

References (see slides for refs. as well)

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