CS 160: User Interface Design

Input Devices

02/16/11
Extension

Network router died tonight – website was inaccessible

Heuristic Evaluation due by 1pm, Thursday 2/17

(reading responses also ok for the next 24 hrs)
Human Info. Processor

Processors:
- Perceptual
- Cognitive
- Motor

Memory:
- Working memory
- Long-term memory

Unified model

Probably inaccurate
Predicts perf. well
Very influential
Perceptual Processor

**Cycle time**

Quantum experience: 100ms

Percept fusion
Working Memory

Access in chunks
Task dependent construct
7 +/- 2 (Miller)

Decay
Content dependant
1 chunk 73 sec
3 chunks 7 sec

Attention span
Interruptions > decay time
Motor Processor

Receive input from the cognitive processor
Execute motor programs
Pianist: up to 16 finger movements per second
Point of no-return for muscle action
Hick’s Law

Cost of taking a decision: \[ T = a + b \log_2(n + 1) \]
## Input Devices
Questions:

What (low-level) tasks are the users trying to accomplish with an input device?

How can we think about the space of possible input devices?

What interaction techniques are encouraged/discouraged by a particular device?
Important Tasks

Text Entry

Pointing/Marking

• Target acquisition
• Steering / positioning
• Freehand drawing
• Drawing lines
• Tracing and digitizing
• …
Text Entry: Keystroke Devices

Array of Discrete Inputs

Many variants of form and key layout

Can be one-handed or two

Wide range of sizes

Two-hand full keyboard is relatively standardized, Less standardization on others: Command keys, generic function keys, cursor movement, numeric keypad,...

Take advantage of procedural memory

Power law of practice

\[ T_n = T_1 n^{-a} + c \]
Keyboards
Key Layouts

QWERTY

! ` # $ % ^ & ( ) _ + = Q W E R T Y U I O P [ ]
A S D F G H J K L ;
Z X C V B N M , . : ?

Dvorak

! ` # $ % ^ & ( ) _ + = 
; ' . < > ? /
P Y F G C R L /
A O E U I D H T N S -
; ' Q J K X B M W V Z
Difficulty: Text Entry

Still very hard on mobile devices

Keyboards (on-screen and thumb)
Full hand-writing recognition
Graffiti
EdgeWrite
ShapeWriter
Mobile Text Entry: Keypads

Multi-tap mappings
Multiple presses per letter

Ambiguity resolution
One press per letter, dictionary lookup
Mobile Text Entry: Keypads

Chording

Multiple keys pressed simultaneously
$2^n$ combinations for n keys

Twiddler2, HandyKey
Mobile Text Entry: Soft Keys

Soft Keyboards

Benefits? Drawbacks?

To: stevejobs@apple.
Cc/Bcc, From: brentsheets@somewhere...
Subject:

Mactoids.com
EdgeWrite

Corner-based text input technique

Makes use of physical edges and corners to improve input time

Particularly effective for users with motor impairments

Edges provide stability

Implementable in many different input modalities

stylus, joysticks, trackball

Jacob Wobbrock, UIST 2003
Mobile Text Entry: Handwriting Recog.
Mobile Text Entry: Touch / Stylus

Stroke Entry Methods (e.g., Swype, ShapeWriter)
Mobile Text Entry: Touch / Stylus

Custom symbol sets improve recognition accuracy; appropriate for indirect (eyes-free) input
Which is fastest?

Comparison of Text Entry Techniques

words per minute (wpm)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Novice</th>
<th>Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Keyboard</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>Soft Keyboard</td>
<td>9</td>
<td>43</td>
</tr>
<tr>
<td>T9</td>
<td>0</td>
<td>46</td>
</tr>
<tr>
<td>Handwriting</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Multi-Press</td>
<td>7</td>
<td>27</td>
</tr>
</tbody>
</table>
What about Speech Recognition?

Dictation is faster than typing (~100 wpm)
What about Speech Recognition?

**Dictation is faster than typing (~100 wpm), BUT:**

Speech is different from written language:
Speaking in well-formed, complete, print-ready sentences is cognitively challenging

High cost of correcting errors through speech channel alone

Social awkwardness?
Pointing Devices

(cc) Flickr photo by Mike fj40
Mouse. Engelbart and English ~1964

slotted wheel (between emitter & detector)
Sensing: Rotary Encoder

High
Sensing: Fwd Rotation
Sensing: Backwd Rotation

Low  Oops!
Solution: Use two out-of-phase detectors
Sensing: Rotary Encoder

Low

High
Sensing: Rotary Encoder

Coding:
HH-> LH: dx = 1
HH-> HL: dx = -1
Transformation

c_{xt} = \max(0, \min(sw, c_{xt-1} + dx*cd))

c_{yt} = …

c_{xt}: cursor x position in screen coordinates at time t
dx: mouse x movement delta in mouse coordinates
sw: screen width
cd: control-display ratio

(dx,dy)
Device Abstraction

Click, DoubleClick, MouseUp, MouseDown, MouseMove …
What about optical mice?

Source: http://spritesmods.com/?art=mouseeye
Source: http://spritesmods.com/?art=mouseeye
What is sensed?

<table>
<thead>
<tr>
<th></th>
<th>Linear</th>
<th>Rotary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Position</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute</td>
<td>Position (P)</td>
<td>Rotation (R)</td>
</tr>
<tr>
<td>Relative</td>
<td>Movement (dP)</td>
<td>Delta rotation (dR)</td>
</tr>
<tr>
<td><strong>Force</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute</td>
<td>Force (F)</td>
<td>Torque (T)</td>
</tr>
<tr>
<td>Relative</td>
<td>Delta force (dF)</td>
<td>Delta torque (dT)</td>
</tr>
</tbody>
</table>

Other device properties:

**Indirect vs. Direct**
Direct: Input and output space are unified

**C:D Ratio**
For one unit of movement in physical space, how far does the cursor travel in display space?
Q: What is the C:D ratio for direct touch screen input?

**Device Acquisition Time**
Trackball, Trackpad
Trackpoint

Indirect, force sensing, velocity control

Nonlinear transfer function

Velocity

Force

(cc) Image by flickr user tsaiid
Mobile Pointing

D-Pad
(see: arrow keys)

Trackball

Direct touch
(see: Trackpad)

Stylus
Which is faster?

Which is faster?

Engelbart

Experiment: Mice are fastest!

Fitts’ Law

Time $T_{pos}$ to move the hand to target size $S$ which is distance $D$ away is given by:

$$T_{pos} = a + b \log_2 (D/S + 1)$$

Index of Difficulty (ID)

Only relative precision matters

$S = 4, D = 12$

$S = 2, D = 6$
Fitts’ Law

Time $T_{pos}$ to move the hand to target size $S$ which is distance $D$ away is given by:

$$T_{pos} = a + b \log_2 (D/S + 1)$$

Device Characteristics
(bandwidth of human muscle group & of device)

$a$: start/stop time
$b$: speed

Bandwidth of Human Muscle Groups

Fitts’ Law Example

Which will be faster on average?
pie menu (bigger targets & less distance)

Fitts’ Law in Windows & Mac OS

Windows 95: Missed by a pixel
Windows XP: Good to the last drop

The Apple menu in Mac OS X v10.4 Tiger.

Source: Jensen Harris, An Office User Interface Blog: Giving You Fitts. Microsoft, 2007; Apple
Fitts’ Law in Microsoft Office 2007

Larger, labeled controls can be clicked more quickly

Magic Corner: Office Button in the upper-left corner

Mini Toolbar: Close to the cursor

Everything is best for something and worst for something else.

- Bill Buxton
3-State Model of Input (Buxton)

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</tr>
<tr>
<td>2</td>
<td><em>Dragging</em>: Device motion moves objects on the screen.</td>
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(Table from Hinckley Reading)
Mouse

(Figure from Hinckley Reading)

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Touch Screen

(Figure from Hinckley Reading)

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Stylus on Tablet

(Figure from Hinckley Reading)

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Mouse, in more detail

1. **Hover**
   - $dx, dy$
   - $\Delta t > T_{out};$
   - $dx, dy < \varepsilon_{enter}$

2. **Drag**
   - $dx, dy$
   - $dx, dy > \varepsilon_{exit}$

1. **L Button Down**

2. **Left**
   - $dx, dy$
   - L Button Up (Click)

2. **Right**
   - $dx, dy$
   - R Button Up (R Click)

2. **Drag**
   - $dx, dy$
   - $dx, dy > \varepsilon_{drag}$

L Button Up (Drop)
(Multi-) Touch
Strengths

Direct input allows maximal screen space for mobile devices (ocular centrism).

More degrees of freedom.

“Virtual input devices” are adaptable.

No extra pieces to lose or break (styli!)
Challenges (from Buxton)

No tactile feedback.

Requires free use of (both) hands and eyes.

“Fat Finger” problems – precision & occlusion
Terminology (from Buxton)

- Touch-tablets vs Touch screens
- Single-finger vs multi-finger
- Multi-person vs multi-touch
- Points vs Postures
- Hands and fingers vs Objects
Multi-point Gestures

Select Single 1: tap

Select Single 2: lasso

Select Group 1: hold and tap

Select Group 2: Use Select Single 1, or Select Single 2 on all items in the group.

Move 1: drag

Move 2: jump

Pan: drag hand

Object jumps to index finger location.

Rotate: drag corner

Finger touches corner to rotate.

Cut: slash

Cuts current selection (made via Select Single or Select Group).

Paste 1: tap

Paste 2: drag from offscreen

Paste 3: Use Move 2, with off-screen source and on-screen destination.

Duplicate tap source and destination

Paste 2: Use Move 2, with off-screen source and on-screen destination.

After duplicating, source object is no longer selected.

Delete 1: drag offscreen

Delete 2: Use Move 2, with on-screen source and off-screen destination.

Accept: draw check

Reject: draw "X"

Reject 2: Reject 1: If rejecting an object/dialog with an on-screen representation, use Delete 1, or Delete 2.

Menu: pull out

Help: draw '?'

Undo: scratch out

Posture-based Interaction

THE MANUAL INPUT SESSIONS: "NEGDROP"
golan levin / zach lieberman . 2004
The “Fat Finger” Problem

Graphics: Patrick Baudisch, nanoTouch
A Software Solution

scenario 1:
ambiguous target
due to occlusion

(a) (b) (c) (d) (e)

Graphics: D. Vogel, P. Baudisch - Shift
A Hardware Solution: Use the Backside

Graphics: Patrick Baudisch, nanoTouch
Hybrids: Keyboards on Interactive Tables

B. Hartmann, M. Morris, H. Benko, A. Wilson: Augmenting Interactive Surfaces With Keyboards and Mice. UIST 2009
Hybrids: Multi-touch on Mice

Mouse 2.0: Multi-touch Meets the Mouse
Nicolas Villar, Shahram Izadi, Dan Rosenfeld, Hrvoje Benko, John Helmes, Jonathan Westhues, Steve Hodges, Eyal Ofek, Alex Butler, Xiang Cao and Billy Chen.
Next Time

No class on Monday – President’s Day!

Wednesday: Prototyping
Don’t forget to read and submit comment!
Due: Contextual Inquiry!
I think my keyboard is broken.

Whenever I have a few keys pressed down, some keys suddenly don’t work anymore; at other times ‘phantom’ characters appear.

What’s going on?
Key cap
Top conductive layer
Bottom conductive layer

Separating layer (with hole)
Key cap
Top conductive layer
Bottom conductive layer

Separating layer (with hole)
Row/Column Scanning

<table>
<thead>
<tr>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>W</td>
<td>E</td>
<td>R</td>
<td>T</td>
</tr>
<tr>
<td>A</td>
<td>S</td>
<td>D</td>
<td>F</td>
<td>G</td>
</tr>
<tr>
<td>Z</td>
<td>X</td>
<td>C</td>
<td>V</td>
<td>B</td>
</tr>
</tbody>
</table>

9 lines
20 keys
Closeup

C1

C2

R1

R2

90
One Key Down

C1

C2

R1

R2
One Key Down
3 Keys Down

C1

C2

R1

R2
3 Keys Down