User Interface Engineering – FS 2013

Interactive Surfaces & Gesture Based Interfaces
Classroom Visit – “Teaching at ETH”

- Didactics course: “Teaching at ETH: Committed and skilled”
- Today we have a number of visitors from the course
- Today’s class will be filmed
Remarks about Exercise

- Apologies for incomplete instructions in first assignment
- Hopefully Exercise 2 is much better
- Today the practical exercise will be in CNB D101
  - You will receive the hardware and assemble it (with help)
  - Today’s assignment is a two week assignment (no class next week)
  - There will be an interactive QA session next week during lecture and exercise slots
Feedback

User Interface Engineering Course - Feedback Form

Please use this form to let us know about things you want to see improved or you want to loop (e.g. faster pace, slower pace, more / less examples), topics you would like to see, etc.

Submit

Midterm

- Midterm date has been fixed
- **Nov 6\textsuperscript{th}** in the first hour of the lecture
- 20% of the total grade
- Questions can be about content from lecture slides or the exercises
Last Week – Fitts’ Law Examples – Mac OS X
Last Week – Fitts’ Law - Gmail

Dear class,

I’d like to remind everyone of the little extra exercise I gave you last week. If you have 5 minutes today, I would love to see some of your findings. If you haven’t done so already please email these to omar.hilliges@inf.ethz.ch.

Description:
Find uses of Fitts’ Law in modern software design. Email screenshot and a one paragraph explanation on how Fitts_Law (and Shannon’s formulation in particular) might have influenced design decisions.

We will discuss your examples in class.

Click here to Reply or Forward.

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Click here to Reply or Forward.
Microsoft Word 2007 Beta 2

Test

Introduction

Nulla pharetra, metus sed volutpat pretium, tortor metus luctus lectus, accumsan nonomma mi donec non ipsum. Suspendisse potenti. Sed nonummy, tellus vel gravida mattis, odio ipsum pretium ipsum, sed vehicula nunc pede at ut. Ut egestas, turpis a auctor erat interdum, nihil quam malesuada dolor, ut sed adipiscing lorem mi nec nunc. Suspendisse diam tortor, aliquet in, tincidunt et, dignissim sed, sapien. Sed auctor, utma sit amet malesuada mollis, tellus sapien luctus nibh, eget mattis nunc fermentum metus. Vivamus eu augue. Praesent ullamcorper. Proin
Last Week – Fitts’ Law Examples - Windows
Today

- Multi-touch Screens
- Interactive Surfaces (tables, walls etc.)
- Working principles
- Image processing

- You’re going to build one of these in the exercises
Motivation & Origins
Research Origins

- Multi-touch goes a long way back (ca. 1965)
- In many forms and with different applications in mind
- But it found widespread commercial success relatively fast

32 years 35 years
DigitalDesk

- Working prototype of vision based tabletop in 1991
- Top-down projection and camera
  - Tracks fingertips and scans physical objects
- Microphone was used for touch (tap) decision
- Various digital application scenarios that are aware of the physical world
  - Calculator
  - Spreadsheets
  - …
MetaDesk

- Back-projected digital table
- IR Camera tracks physical objects
- Physical icons are used as Tangible User Interface (TUI) to control on-screen objects
  - MIT dome invokes campus map; Ruler zooms and translates etc.
Digital Tables – Key Ideas

- Key ideas:
  - Bring physical and digital world together on the same (horizontal) surface
  - Use (both) hands for coarse input
  - Use stylus/dominant-hand for fine grained input
- But why?

- Describes how humans perceive and adapt to new information.
  - Assimilation (fitting new Info with pre-existing knowledge)
  - Accommodation (new information alters pre-existing knowledge schemas)
- Different developmental stages as children grow up:
  - **Sensorimotor stage** (0-2 years)
    - Understanding by manipulating
  - **Pre-operational stage** (2-7 years)
    - Egocentric and still dominated by physical world but can remember things without seeing (imagination)
    - Intuitive thought and reasoning starts (why questions)
  - **Concrete operational stage** (7-11 years)
    - No abstract, hypothetical thinking yet but appropriate use of logic begins
    - Can solve problems that pertain to concrete things or events
    - Can draw inference from observations and make generalizations
- **Formal operational Stage**
Empirical Background – Piaget’s Theory - Implications

- Visual context and representation makes concepts easier to grasp.
- Actions (functionality) can be discovered easier with visual context.
- Physical manipulation can help in understanding of abstract concepts.

- Physical / Visual representation are easier to process than textual representations.
Yves Guiard (1987) studied the role of the two hands in everyday tasks.

Bimanual interaction is divided asymmetrically between hands.

Hands can be regarded as motors in kinematic chain:
- Non-dominant hand provides a reference frame
- Hands interact on different granularity scales

RP = Reference Point; VP = Variable Position, LH, RH = Left Hand, Right Hand
Kinematic Chain – Frame of Reference

- Recordings of the same handwriting
- Relative to sheet of paper
- Relative to (fixed) table (obtained with carbon paper)
  - Slanted paper
  - 24cm text height
  - 16cm paper displacement
Kruger et al. (2003)

3 main roles of orientation:

- Comprehension
  - Ease of reading
  - Ease of task
  - Alternate perspective
- Coordination
  - Establishment of personal spaces
  - Establishment of group spaces
  - Ownership of objects
- Communication
  - Intentional communication
  - Independence of orientation
Digital Tables - Technology
HoloWall

- Jun Rekimoto’s HoloWall [UIST'97]
- Back projected setup
- IR illumination directed at diffusor screen
- Objects far from the surface are blurry / invisible
- Objects in contact with surface are in-focus
Low-Cost multi-touch sensor FTIR

http://www.youtube.com/watch?v=aoE6deG4AU

[J.Han, ACM UIST '05]
FTIR – Snell’s Law

Describes relationship between angle of incidence and refraction as rays of light pass through the interface of two isotropic materials

\[ \frac{\sin \theta_1}{\sin \theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1} \]

Setting \( \theta_2 = 90^\circ \) (\( \sin \theta_2 = 1 \)) the critical angle is \( \theta_c = \arcsin \frac{n_2}{n_1} \)

\[ n_{\text{air}} = 1 \]
\[ n_{\text{acrylic}} = 1.5 \]
FTIR – Han ‘05

- Frustrated Total Internal Reflection
  - Used in optical finger print scanners since the 1960s
- Optical waveguide is edge-lit by IR LEDs
- Light normally trapped in Acrylic due to TIR
- Object in optical contact with the sheet frustrates TIR
  - Light scatters out and is reflected towards camera underneath
Beyond The Pointer
Natural interactions
Surface input
Shape based Interactions

- Idea: model contact shape with many proxy objects (particles)
- Collisions obey shape of the contact (e.g., flat or side of the hand)
- Distribution of forces is modeled more accurately (e.g., conforms to 3D shape)
From Tracking to Flow
Cloth peeling and stacking
Beyond The Screen
Traditional tabletop setup

- Projector
- IR Illumination
- IR Pass Filter
- Camera
- IR Illumination
Electronically Switchable Diffusers

- A diffuse screen
- When voltage applied
  Diffuse -> Clear
- Switch between these states quickly
Projecting through the display
Projecting through the display
Sensing through the Display
virtual hand shadows
improve visual feedback
Sensing Pixels
Embedded Sensing

- Thin form factor optical sensing
- Array of IR transceivers embedded in LCD Sandwich
- IR travels through the LCD Matrix (in both directions)
- Low res image of IR reflective objects in front of the display
- Bi-cubic interpolation and filtering yields usable data

[ThinSight. Communications of the ACM ‘09]
PixelSense

- Samsung SUR40 (previously Microsoft Surface 2.0)
- Commercial version of ThinSight Technology
- Every Pixel has five components
  - RGB
  - IR transceiver
15 Minute Break
Image Processing for Touchscreens
Image Processing Pipeline I

- Input: rectified raw camera image
- Output: touch event + statistics

\[ B_g \]

\[ I(I_m, x), x = (u, v) \]

\[ I(F', x) := I(F, x) - I(B_g', x) \] 

\[ \begin{cases} 
1 \text{ if } I(F', x) \geq \tau_B, \\
0 \text{ otherwise} 
\end{cases} \]

\[ (x', y') \in \{(x - 1, y), (x + 1, y), (x, y - 1), (x, y + 1)\} \]
Connected Component Analysis
Connected Components Raster Scanning
Connectivity

- **4-connectivity**

\[(x’, y’) \in \{(x - 1, y), (x + 1, y), (x, y - 1), (x, y + 1)\}\]

- **8-connectivity**

\[(x’, y’) \in \{(x - 1, y), (x + 1, y), (x, y - 1), (x, y + 1),
(x - 1, y - 1), (x + 1, y - 1), (x - 1, y + 1), (x + 1, y + 1)\}\]
1. Design CCL algorithm:
   1. Finds connected islands of pixels in an binary image
   2. Each connected component has exactly one unique label once algorithm finishes

2. Two-Pass version is OK
   1. First-pass assigns labels to foreground pixels
   2. Record label equivalence as you go
   3. Second pass unifies equivalent labels

3. If you know the algorithm already: Think about single-pass algorithm
CCL – Time Allotment

- Work in groups of two (three also OK).
- You have 15 minutes to design your algorithm
  - 10 Minutes to discuss solution
  - 5 Minutes to create flowchart or pseudo code for presentation
- We will discuss results in plenum (20 min)

- Use pen & paper or blackboard if preferred
- You should have several images to try out your technique
1. Design CCL algorithm:
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3. If you know the algorithm already: Think about single-pass algorithm
Connected Components – Hints

- Pixels in the image are either foreground or background. Scan the image sequentially and assign a label for each connected foreground pixel.
- For each foreground pixel look at its direct neighbors and decide whether you should assign a new label, take the neighbors label or record equivalence between different labels.
- In the second pass over the image equivalent labels need to be unified so that each connected component only contains pixels of a single label.
Connected Components - Discussion
Connected Components Labeling – Stage One

scan image row by row

foreground pixel

check neighbors

neighbors labeled
assign neighbors’ (parent) label

no labeled neighbors
assign new label
Connected Components Labeling – Stage Two

- scan image row by row
- pixel labeled?
  - yes
    - entry in equivalence list?
      - yes
        - assign equivalent label
      - no
        - assign current label
  - no
    - find equivalent label
Connected Components – Take Home Message

- CCL is crucial algorithm in touch sensing pipeline
- Simple two-pass algorithm finds unique labels per component
- Efficient recording of label equivalences is important for good performance:
  - Union-Find disjoint-set data structure is very well suited
  - Other solutions exist but may be slow on real data
- Several alternative implementations exist
- Single-pass algorithms based on runs
- Contour tracing algorithms
Next Week

- No Class on 9.10.13
- Next Class 16.10.13
  - Camera based input
  - More image processing
  - Tracking
  - Filtering
Reading Suggestions


Connected Components Raster Scanning
CCL
Union Find

- Disjoint-set data structure (non-overlapping subsets)
- Very efficient for:
  - Find: Returns subset a given element is in
  - Union: Join two subsets into a new subset
- Can be used to implement CCL efficiently
  - When equivalence detected $\text{union}(\text{find}(\text{label}_{\text{curr}}), \text{find}(\text{label}_{\text{equiv}}))$
  - Second pass replaces label with $\text{find}(\text{label}_{\text{curr}})$
CCL – Contour Based method(s)

[Chang, F., Chen, C., Lu, C. A linear-time component-labeling algorithm using contour tracing technique. Computer Vision and Image Understanding (2004)]
Contour Tracing based Method

Contour tracing and label propagation algorithms [2], [4] are somewhat similar to searching and label propagation algorithms. They first search an unlabeled border pixel of a component, and they assign a new label to it. Then they trace the whole border of the components, and mark all pixels in the border with the same labels. Such processing are executed iteratively until there is no unlabeled border pixel in the image. Moreover, at each row, all pixels that are consecutive from a labeled border pixel are assigned the same label as the border pixel. They also process an image in an irregular way.