Authoring Sensor-Based Interactions by Demonstration with Direct Manipulation and Pattern Recognition

Björn Hartmann, Leith Abdulla
Manas Mittal, Scott R. Klemmer
How would you prototype...

...a workout monitoring system?

[Apple, Nike]
How would you explore...

...motion-based game controllers?
How would you build...

...a proximity-aware whiteboard?

[Ju, Lee, Akers]
Sensor-based Interaction Design
d.tools

[Hartmann et al., UIST ’06]
d.Tools
Student Project
Designing Sensor-based Interactions

- Prototype Application Logic
- Specify Relationship Between Sensor Data and Application Logic
- Provide Software Abstraction for Hardware
Types of Sensors

- Continuous
  - Force Sensitive Resistors
  - Phototransistors
  - Accelerometers
- Discrete
  - IR/Ultrasonic Rangers
- Categorical
  - RFID
Current Tools: Oscilloscopes
Current Tools: LabView
// detect accelerometer peaks

// read data sample
xVal[t++]=readA2DValue(xPin);

// look for changes in derivative
if(((xVal[t]-xVal[t-1]) >= 0 && (xVal[t-1]-xVal[t-2]) < 0)
   && ((xVal[t]-xVal[t-1]) < 0 && (xVal[t-1]-xVal[t-2]) >= 0)
   && ((xVal[t]-xVal[t-1]) < 0 && (xVal[t-1]-xVal[t-2]) >= 0))
   // peak detected
   // send message
   oscSendMessageInt("/x/peak",1);
else {
   // no peak
}

Accelerometer X axis

Accelerometer Y axis
Idea: Programming by Demonstration
Idea: Programming by Demonstration
Tacit Knowledge
Crux: Generalization
Crux: Generalization
Crux: Generalization
Exemplar

Demonstrate
Exemplar

Demonstrate

Edit
Exemplar

Demonstrate

Review

Edit
Exemplar UI
Exemplar UI

Incoming Data

[Graph showing data for /adc0, /adc1, /adc2, /adc3, /adc4, /adc5]

Filter for /adc0

- **Scale Y-Axis**
  - Invert Signal (x=-x)
  - Scale [0..1..2]

From: **Center**

- **Offset**
- **Smooth**

Amount of smoothing

- none
- lots

Signal Visualisation

Time scale:

Mouse mode: Drag, Draw

Play button

Event Type: Threshold, Pattern

Output continuous values to: None

max 0.30

min 0.15

Timeout
Exemplar UI

Incoming Data

Filter for /adc0

- Scale Y-Axis
- Invert Signal (x=-x)
- Scale [0..1..2]

From: Center

Offset

Smooth

Amount of smoothing

none lots

Signal Visualizations

Time scale:

Mouse mode: Drag Draw

Play

Event Type: Intersect

Output continuous values of: None

max 0.30

min 0.15
Exemplar UI
Exemplar UI
Exemplar UI
[Flash animations from the talk are not included in this presentation]
Dynamic Time Warping

Demonstration Signal

Matching Input Signal

[Sakoe, H. Chiba, S. ‘78]
Filters

- Offset
- Y-Axis Scaling
- Smoothing
- Rate of Change
Extensible Filter Set

```java
public float process(int time) {
    int width = 7;
    return 0;
}

private float median(int time, int width) {
    List<Float> list = new ArrayList<Float>();
    for(int i = 0; i < width; i++) {
        list.add(getInput(time - i));
    }
    Collections.sort(list);

    // Code for other filters...
}
```
## Understanding the Exemplar Approach

<table>
<thead>
<tr>
<th>What?</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Dimensions of Notation (CDN) Inspection</td>
<td>Analysis of Exemplar as a visual authoring environment</td>
</tr>
<tr>
<td>First-Use Laboratory Study</td>
<td>Threshold and usability</td>
</tr>
<tr>
<td>Class Deployment</td>
<td>Real-world stress test</td>
</tr>
<tr>
<td><strong>Used as Design Tools for</strong></td>
<td>Complexity ceiling for knowledgeable users</td>
</tr>
<tr>
<td><strong>“Building Upon Everyday Play”</strong></td>
<td></td>
</tr>
<tr>
<td><strong>CHI Interactivity Exhibit</strong></td>
<td></td>
</tr>
</tbody>
</table>
Lab Study

[sketches by Wendy Ju]
Lab Study

26 min

18 min

27 min

47 min

22 min

31 min

[sketches by Wendy Ju]
Mini Joystick
Bend Sensor taped to table

Navigation with Accelerometer
Navigation with XY Joystick
Test Play

time = 16 min
Mini Joystick
Bend Sensor taped to table

Trigger with Bend sensor
Test Play
Refine trigger detection
Test Play

time = 16 min
# Post-Test Questionnaire

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreases time to build prototypes</td>
<td>$\mu=4.8, \sigma=0.42$</td>
</tr>
<tr>
<td>Makes me experiment more</td>
<td>$\mu=4.7, \sigma=0.48$</td>
</tr>
<tr>
<td>Facilitates rapid modification</td>
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<tr>
<td>Teaches me how a sensor works</td>
<td>$\mu=4.3, \sigma=1.1$</td>
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<td>Helps to understand user experience</td>
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<tr>
<td>Helps me conduct usability tests</td>
<td>$\mu=4.2, \sigma=0.78$</td>
</tr>
<tr>
<td>Encourages more clever designs</td>
<td>$\mu=4.1, \sigma=1.1$</td>
</tr>
<tr>
<td>Decreases time to test prototypes</td>
<td>$\mu=4.1, \sigma=1.0$</td>
</tr>
<tr>
<td>Distracts from focus on design details</td>
<td>$\mu=2.6, \sigma=0.69$</td>
</tr>
<tr>
<td>I would build fewer prototypes</td>
<td>$\mu=2.4, \sigma=1.3$</td>
</tr>
<tr>
<td>Lengthens time required to program sensors</td>
<td>$\mu=1.5, \sigma=0.53$</td>
</tr>
</tbody>
</table>

*Likert scale ratings:* 1 2 3 4 5
# Post-Test Questionnaire

<table>
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<tr>
<th>Statement</th>
<th>Rating</th>
<th>Mean (μ)</th>
<th>Standard Deviation (σ)</th>
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<tr>
<td>Decreases time to build prototypes</td>
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<td>1.5</td>
<td>0.53</td>
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*Likert scale ratings:* 1-5
CHI Interactivity

[Control Freaks by Haiyan Zhang]
CHI Interactivity

Compulsory latency of pattern matching precludes use for fast-paced actions

Threshold crossed here

Pattern matched here

Time
## Related Work

<table>
<thead>
<tr>
<th>PBD Tools for Ubicomp</th>
<th>Musical Controller Design Tools</th>
<th>Commercial DSP Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Capella</td>
<td>HID Toolkit</td>
<td>LabView/ Lego Mindstorms NXT</td>
</tr>
<tr>
<td>[Dey et al., CHI 04]</td>
<td>[Steiner, NIME 05]</td>
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<tr>
<td>Crayons</td>
<td>MnM</td>
<td></td>
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<tr>
<td>[Fails &amp; Olsen, CHI 03]</td>
<td>[Bevilacqua et al., NIME 05]</td>
<td></td>
</tr>
<tr>
<td>Monet</td>
<td>FlexiGesture</td>
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</tr>
<tr>
<td>[Li, Landay, UIST 05]</td>
<td>[Merrill &amp; Paradiso, CHI 05]</td>
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<tr>
<td>Papier-Mâché</td>
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Related Work

A CAPella (Dey et al., CHI 04)
Related Work

FlexiGesture (Merrill CHI05)
Related Work

LabView
Related Work
Future Directions

Export: Generate code + specifications

Programming sensor networks by demonstration

d.mix: Programming by A Sample for Web Service APIs

Integration of direct manipulation environments with textual programming
Acknowledgments

We thank MediaX/DNP for funding, Intel for equipment donation, Wendy Ju for illustrations, David Merrill & Timo Arnall for photos.
Download Exemplar:
http://hci.stanford.edu/exemplar

CHI Interactivity “Building Upon Everyday Play”
Talk tomorrow, 11:30am, Room C2