Midway Design Review

Team SmartDesk
December 8, 2017
Meet the Team

Aidan Fitzpatrick
EE, Team Leader and Hardware Lead

Dan Mathieu
EE & CSE Software Lead

Tristan Koopman
EE Hardware Lead

John Melloni
CSE Website and Software Lead
Needs Analysis

• Problem Statement:
  • Difficult for users to be productive with a messy work environment.
  • SmartDesk eliminates need for physical resources by offering digital versions for both use and storage.
  • System maintains characteristics of a conventional desk while offering the functionality of a touchscreen that interfaces with your current computer.
  • Current market lacks cost-effective and durable touchscreens.
Proposed Solution

- LED's
- Clear Acrylic
- LCD Screen
- Back Casing
- Cameras

- IR Reflective Surface
- LCD
- IR Cameras, Raspberry Pi
System Specifications

1. Touch screen desk with accuracy up to a fingertip.
2. Design retains the versatility of a conventional desk.
3. Desk interfaces with a standard desktop computer via USB and HDMI.
4. System has applications which replace the need for physical resources.
5. Touch processing has real-time response.
6. Screen will have sufficient resolution and brightness.
7. Surface is resistant to scratches and spills.
8. Interface to control touch screen power.
Surface Capacitive touch is only capable of locating a single touch.

Projected Capacitive touch (PCAP) does not scale well. Indium Tin Oxide (ITO) is the transparent conductive material most commonly used.

ITO has a relatively high resistivity. As the size of the touch sensor increases, their electrode length increases as well, causing a higher resistance, leading to a higher time constant, resulting in a slower response and poor sensor performance.

Reach Technology’s 12.1” TS Development Kit costs $669.
Block Diagram

Diagram showing a block diagram for a system with various components such as a touch screen, LED array, acrylic sheet, LCD screen, camera, power switch, Raspberry Pi, and a PC with operating system and mouse driver.
Subsystem: IR LEDs and Acrylic

- Light is fed in via the edge of material and evenly emitted across the surface.
- The Acrylic is a transparent colorless material.
- The diffuser particles reflect the IR light up through the top surface of the sheet.
Subsystem: IR LEDs and Acrylic

Area to be illuminated

29 Inches

17 Inches

24 to 48 inches

12 to 24 inches*
Subsystem: LCD Screen

- Took apart screen
- Moved PCBs to the back of the desk
- Moved LEDs and diffuser
- Kept screen functionality in different orientation
Subsystem: Desk Structure

- Sloped vs. Flat Enclosure:
  - **Primary Goal**: Maintain sufficient leg room for user
  - **Secondary Goal**: Minimize number of cameras to lower overhead of concatenating images for processing = *Faster Response Time*
  - Using PS Eye 2.1mm wide angle lens which has 104° Field of View
Subsystem: Desk Structure

- **Approximate Flat Field of View Calculation:**

  ![Diagram of LCD screen with dimensions and calculations]

  \[
  \tan(52^\circ) = \frac{l}{4''} \quad \Rightarrow \quad l = 5.12''
  \]

  \[
  \text{FOV}_X = 2 \cdot l = 10.24''
  \]

  \[
  \frac{X}{\text{FOV}_X} = \frac{28.25''}{10.24''} = 2.76
  \]

  **3 cameras in X-direction**

  \[
  104^\circ \text{ in all directions:}
  \]

  \[
  \text{FOV}_Y = 2l = 10.24''
  \]

  \[
  \frac{Y}{\text{FOV}_Y} = \frac{16.5''}{10.24''} = 1.61
  \]

  **2 cameras in Y-direction**

  **6 Total Cameras**
Subsystem: Desk Structure

**Approximate Sloped Field of View Calculation**

- Through experimentation and measurement, 12” on back-end of slope leaves sufficient leg room

\[
\tan(\varphi) = \frac{16.5}{12} \quad \Rightarrow \varphi = 54^\circ
\]

**Issue that Arises with the Camera on an Angle:**

Resolution distribution no longer uniform.
Resolution Calculation

The resolution is the ratio between the actual length ($dL$) of the object (A) and its projected length ($dl$).

$$ r = \frac{dl}{dL} \quad (1) $$

The first term considers the orientation of the objects surface. The highest resolution can be achieved when the surface normal corresponds to the direction towards the perspective center (PC).

$$ dL = \frac{dl'}{\cos(\beta)} \quad (2) $$

The second term transforms the projected length into the range of the incident angle using the arc length formula.

$$ d\alpha = \frac{dl'}{H} \cos(\alpha) \quad (3) $$

Since the cameras selected for this project are wide angled, a wide angle model for $dl$ has been selected, where $f$ is focal length of the camera.

$$ dl = f \cos\left(\frac{\alpha}{2}\right) d\alpha \quad (4) $$

Plugging Eq2, Eq3, and Eq4 into Eq1, an equation for the resolution can be determined.

$$ r = \frac{dl}{dL} = \frac{f \cos\left(\frac{\alpha}{2}\right) d\alpha \cos(\beta)}{dl'} = \frac{f \cos\left(\frac{\alpha}{2}\right) \cos(\beta) \cos(\alpha)}{H} $$
Resolution Calculation

2D Resolution Map Pixels/cm

Height (cm) vs. Width (cm)
Subsystem: Image Processing

Input:
- Two wide angled PS Eye cameras equipped with an IR BPF and 2.1mm lens.

Processing:
- Raspberry Pi running OpenCV 3.3.1 and Python 3.5.3.

1. Camera Feed via USB at t=30μs
2. Concatenation at t=15ms
3. Time to concatenate 2 images averages ~15ms after 10 trials
4. IR Light
5. Image Processing
6. Coordinates
7. H(x)
8. User Touches Screen at t=0
9. Mouse Driver Converts Coordinates to Clicks at t=80ms
10. SimpleBlobDetector Library
11. Blobs Detected and Coordinates Sent to Mouse Driver at t=70ms
Subsystem: Image Processing

- Camera Feed via USB at \( t = 30\mu s \)
- IR Light
- User Touches Screen at \( t = 0 \)
- Image Processing \( H(x) \)
- Coordinates
- Mouse Driver Converts Coordinates to Clicks at \( t = 80ms \)
- SimpleBlobDetector Library
- Time to concatenate 2 images averages \( \sim 15ms \) after 10 trials
- Concatenation at \( t = 15ms \)
- Blobs Detected and Coordinates Sent to Mouse Driver at \( t = 70ms \)
MDR Deliverables & Demo

- Working Test Bed:
  - Acrylic and LED strip installed into the surface of the desk
  - LCD screen mounted underneath the acrylic with PCB relocation
  - LCD Screen functioning with proper backlighting and displaying computer duplicate
  - Camera(s) and Raspberry Pi mounted to a surface below the LCD screen that does not prohibit comfortable leg room.
  - Camera captures a single downward reflected IR touch-point
CDR Deliverables

- Full screen camera/touch coverage
- Single touch mapped to proper locations
- PCB designed for power and switching controls
- Handling of object subtraction (i.e. water bottle)
# Budget

## What’s already purchased?

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectre 32” TV</td>
<td>$119.00</td>
</tr>
<tr>
<td>IR LEDs</td>
<td>$29.90</td>
</tr>
<tr>
<td>Sony PS EYE Camera (2)</td>
<td>$3.98</td>
</tr>
<tr>
<td>IR BPF (2)</td>
<td>$10.00</td>
</tr>
<tr>
<td>m12x0.5 lens mount</td>
<td>$10.00</td>
</tr>
<tr>
<td>2.1mm m12 lens</td>
<td>$1.00</td>
</tr>
<tr>
<td>Raspberry Pi3</td>
<td>$34.79</td>
</tr>
<tr>
<td>Case for Pi3</td>
<td>$16.99</td>
</tr>
<tr>
<td>32GB SD Card</td>
<td>$12.99</td>
</tr>
<tr>
<td>Enlighten Acrylic</td>
<td>$114.50</td>
</tr>
<tr>
<td>Clear Acrylic</td>
<td>$12.36</td>
</tr>
<tr>
<td>Light Diffuser</td>
<td>$14.70</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$380.21</strong></td>
</tr>
</tbody>
</table>

## What’s left to be purchased?

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>m12x0.5 lens mount</td>
<td>$10.00</td>
</tr>
<tr>
<td>2.1mm m12 lens</td>
<td>$1.00</td>
</tr>
<tr>
<td>PCB Spin</td>
<td>~$40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>~$51</td>
</tr>
</tbody>
</table>

**Expected Total Cost:** $431.21
# Gantt Chart

<table>
<thead>
<tr>
<th>Week Beginning</th>
<th>12/10</th>
<th>12/24</th>
<th>1/7</th>
<th>1/21</th>
<th>2/4</th>
<th>2/18</th>
<th>3/4</th>
<th>3/18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single touch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T.K.</td>
<td>J.M.</td>
<td></td>
</tr>
<tr>
<td>PCB Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A.F.</td>
<td>D.M.</td>
<td></td>
</tr>
<tr>
<td>Power Switch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A.F.</td>
<td>T.K.</td>
<td></td>
</tr>
<tr>
<td>Object Subtraction</td>
<td></td>
<td></td>
<td></td>
<td>T.K.</td>
<td>J.M.</td>
<td>D.M.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multi-touch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T.K.</td>
<td>J.M.</td>
<td></td>
</tr>
<tr>
<td>Drag/Slides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D.M.</td>
<td></td>
</tr>
<tr>
<td>User Apps</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A.F.</td>
<td></td>
</tr>
</tbody>
</table>

Extra time allotted at the tail-end of the Gantt Chart for final touches

**FPR: 4/09 – 4/20**
Thank You!

ANY QUESTIONS?
Subsystem: LCD Screen

Sceptre 32" Class HD (720P) LED TV
Assumptions:
- USB 3.0 with 5gbps
- Worst case of image concatenation time modeled using MATLAB
- Data pipelines between applications are modeled as instantaneous
- Image processing running at 20fps
- Graph from human benchmark project with over 55 million data samples
ERROR: syntax error
OFFENDING COMMAND: --nostringval--
STACK:

ENDING COMMAND: --nostringval--
ERROR: syntax error