Smart Mirror

Group 8 – Fall ’16 / Spring ‘17
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Austin Keller – Electrical Engineering
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Daniel Yoder – Electrical Engineering
Project Introduction

• The Smart Mirror is a mirror which displays information to the user such as:
  – Time, Weather, Social Media, News Feed, etc.
• Improves upon a popular DIY project
• Incorporates computer vision technologies
Motivations

• Create a device the team would be excited to use
• Interest in computer vision technologies
• Develop skills in schematic and PCB design
• Develop skills in software architecture design and computer vision
Goals and Objectives

• Design a mirror to provide information relevant to the user
• Implement facial recognition software to determine user, thus which info to display
• Create an active device rather than a passive one
• A more user friendly UI system
• Be as power efficient as possible
## Project Specifications

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Modules</td>
<td>Amount</td>
<td>7 modules</td>
</tr>
<tr>
<td>Facial Recognition</td>
<td>Recognize Time</td>
<td>6 seconds</td>
</tr>
<tr>
<td>Power Supply</td>
<td>Input Voltage</td>
<td>12 Vdc</td>
</tr>
<tr>
<td>Low Power Mode</td>
<td>Power Saved</td>
<td>8 watts</td>
</tr>
<tr>
<td>Gesture Response</td>
<td>Time</td>
<td>0.5 seconds</td>
</tr>
<tr>
<td>Mirror</td>
<td>Weight</td>
<td>10 lbs. max</td>
</tr>
</tbody>
</table>
Physical Layout
Power System

• Powered from AC power socket
  – Use an AC/DC wall plug converter for 12V input

• Needs to provide 3 rails: 12V, 5V, 3.3V
  – 12V: LED Strips
  – 5V: ATMega328, Raspberry Pi, Gesture Sensor, LLC
  – 3.3V: LLC Circuit for communication

• Efficient power usage
Switching vs Linear Regulator

- 5V rail is the most demanding, most components need 5V
- Linear regulator would cause upwards of 14W of power
- Switching Regulator is a more efficient solution
## Regulator Selection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LM2596 (Switching)</th>
<th>TPS6213 (Switching)</th>
<th>L78S05 (Linear)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vin</td>
<td>4.5V-40V</td>
<td>3V-17V</td>
<td>10V-35V</td>
</tr>
<tr>
<td>Iout</td>
<td>3A</td>
<td>3A</td>
<td>2A</td>
</tr>
<tr>
<td>Efficiency</td>
<td>80%</td>
<td>82%</td>
<td>42%</td>
</tr>
<tr>
<td>Supporting Circuit</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Complexity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>$4.91</td>
<td>$2.51</td>
<td>$0.68</td>
</tr>
<tr>
<td>Size</td>
<td>14mmx10mm</td>
<td>3.1mmx3.1mm</td>
<td>10mmx29mm</td>
</tr>
</tbody>
</table>

![Image of LM2596 regulator](image1.png)

![Image of TPS6213 regulator](image2.png)

![Image of L78S05 regulator](image3.png)
3.3V Regulator

- 3.3V rail only used for LLC circuit, very low current draw and voltage difference
- Chose the MCP1700T Linear Regulator
- Smaller, cheaper, easier to
- Size: 3mmx2.5mm
Power Saving

• Save power by keeping LED’s off and dimming the backlight when mirror is not in use.
• If microcontroller determines room bright enough for face recognition, LED’s remain off.
# Power Saving

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Power (Watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED’s On, Display On, Face Recognition Running</td>
<td>15</td>
</tr>
<tr>
<td>LED’s On, Display On</td>
<td>14</td>
</tr>
<tr>
<td>Display On, Face Recognition Running</td>
<td>7.9</td>
</tr>
<tr>
<td>Display On</td>
<td>6.5</td>
</tr>
<tr>
<td>Low Power Mode</td>
<td>4</td>
</tr>
</tbody>
</table>

Accurate within 0.2%
Microcontroller

- **Speeds**
  - No intense need for very fast clock
- **Power Saving**
  - Less bits being transferred to/from Pi = Less power

<table>
<thead>
<tr>
<th></th>
<th>Atmega328P</th>
<th>MSP430</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clock Speed:</strong></td>
<td>20 MHz</td>
<td>25 MHz</td>
</tr>
<tr>
<td><strong>Package:</strong></td>
<td>Dual In-line</td>
<td>Surface Mount</td>
</tr>
<tr>
<td><strong>Core Size:</strong></td>
<td>8 bits</td>
<td>16 bits</td>
</tr>
</tbody>
</table>
Design Considerations

• Microcontroller choice:
  – Atmega328P-PU

• Perfect use for this project due to its simplicity and low power usage
  – Microcontroller is used for led control and sensor input/output

ATmega328P-PU
- Through-hole mount
- Larger package
- Less Analog Ports

ATmega328P-AU
- Surface Mount
- Smaller Package
- More Analog Ports
LED Lighting

- **LED Lighting**
  - Enhances ambient lighting for facial recognition
  - Aesthetic purposes

- **Power Saving**
  - One of the most efficient options
  - Next closest had 300 lumens/m

<table>
<thead>
<tr>
<th></th>
<th>Adafruit DotStar Digital LED Strip</th>
<th>Standard Density LED Flex Strips</th>
<th>Cool White LED Flexi-Strip</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Color:</strong></td>
<td>RGB</td>
<td>White</td>
<td>White</td>
</tr>
<tr>
<td><strong>Brightness:</strong></td>
<td>~419 Lumens</td>
<td>~300 Lumens</td>
<td>~600 Lumens</td>
</tr>
<tr>
<td><strong>Max Current Draw</strong></td>
<td>~60mA (per RGB LED)</td>
<td>~20mA (per RGB LED)</td>
<td>~20mA (per RGB LED)</td>
</tr>
</tbody>
</table>
LED Lighting

Front view of Smart Mirror
LED Lighting

LEDs full power (dark ambient lighting)  LEDs medium power (brighter ambient lighting)
# Microcomputer

- **Raspberry Pi Model 3B**
  - Powerful processor for facial recognition
- **Display**
  - Interfaces and powers display seamlessly

<table>
<thead>
<tr>
<th></th>
<th>TI Beaglebone Black</th>
<th>Raspberry Pi Model 2</th>
<th>Raspberry Pi Model 3B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price:</strong></td>
<td>$60.00</td>
<td>$35.00</td>
<td>$35.00</td>
</tr>
<tr>
<td><strong>Processor:</strong></td>
<td>AM3358 ARM Cortex A8 @ 1GHz</td>
<td>ARM Cortex-A7 @ 900MHz</td>
<td>LPDDR2 ARM Cortex A53 @ 1.2 GHz</td>
</tr>
<tr>
<td><strong>GPIO Pins:</strong></td>
<td>46</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>
Display

- 7 inch LCD display unit
  - Compatible with the Raspberry Pi 3 Model B
- The Smart Mirror *shall* be powered via a single cord
- Interfaces seamlessly with existing components chosen
- Also helps minimize the overall weight of the system

<table>
<thead>
<tr>
<th>7” inch display for Raspberry Pi3</th>
<th>Secondhand Computer Monitor</th>
<th>13.3 inch widescreen HDTV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost: $68.99</td>
<td>$&gt;30</td>
<td>$&gt;100</td>
</tr>
<tr>
<td>Size: 7-inch</td>
<td>Varies</td>
<td>13.3 inch</td>
</tr>
<tr>
<td>Power Source: Raspberry Pi</td>
<td>External</td>
<td>External</td>
</tr>
</tbody>
</table>
Presence Sensor

- 5v Input
- Infrared Distance sensing
  - 1in to 2ft
- Gesture Sensing
  - Left, Right, Up
- I2C serial
  - Refresh rate every 20ms
  - Interrupts

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Price</th>
<th>Range</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasonic Sensor HC-SR04</td>
<td>$15.00</td>
<td>13ft</td>
<td>Distance</td>
</tr>
<tr>
<td>Passive IR Motion Sensor</td>
<td>$10.00</td>
<td>20ft</td>
<td>True/False</td>
</tr>
<tr>
<td>ZX Distance Gesture Sensor</td>
<td>$25.00</td>
<td>2ft</td>
<td>Distance and Gestures</td>
</tr>
</tbody>
</table>
Camera

- Used for face recognition
- Small footprint
- Adequate resolution

<table>
<thead>
<tr>
<th></th>
<th>C920 Webcam</th>
<th>HP2100 Webcam</th>
<th>Rpi Camera Module v2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price:</td>
<td>$98.00</td>
<td>$30.00</td>
<td>$30.00</td>
</tr>
<tr>
<td>Resolution</td>
<td>15MP</td>
<td>8MP</td>
<td>8MP</td>
</tr>
<tr>
<td>Size:</td>
<td>7.5x2in</td>
<td>2.5x2.5in</td>
<td>25x25mm</td>
</tr>
<tr>
<td>Weight</td>
<td>450g</td>
<td>30g</td>
<td>3g</td>
</tr>
</tbody>
</table>
Load Sharing

- Sensor input
  - Gesture
  - Photoresistor
- LED Control
- Repeated polling

- Display
- Face Recognition
- Network Data
ATmega Activity Diagram

<table>
<thead>
<tr>
<th>GestureSensor</th>
<th>SleepHandler</th>
<th>MessageHandler</th>
<th>PhotoSensor</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gesture Interrupt Received</td>
<td>Disable Sleep</td>
<td>UART Startup Message to Pi</td>
<td>Take Light Level Reading</td>
<td>PWM LEDs - On</td>
</tr>
<tr>
<td>I2C Distance Reading</td>
<td>Enable Sleep</td>
<td>UART Sleep Message to Pi</td>
<td>Light Adequate?</td>
<td>PWM LEDs - Off</td>
</tr>
</tbody>
</table>

- Gesture Sensor
  - Gesture Interrupt Received
  - User Present?
    - Yes
    - No

- Sleep Handler
  - Disable Sleep
  - Enable Sleep

- Message Handler
  - UART Startup Message to Pi
  - UART Sleep Message to Pi

- Photo Sensor
  - Take Light Level Reading
  - Light Adequate?
    - Yes
    - No

- LED
  - PWM LEDs - On
  - PWM LEDs - Off
Face Recognition

• Detect the current user
• OpenCV 2.4 and Python 2.7
• Multi-stage process
  – Detect & Train
  – Identify & Recognize
• Haar Cascade Identifiers
  – Face, Eyes, Mouth
Feature Based

- Original image capture
- Greyscale
- Haar Cascade
- Crop
- Region based feature search
- Feature location validation
Feature Based

1. Identify the eyes and mouth
2. Calculate the midpoint
3. Rescale values based on regions

PersonalMetric = \frac{L1}{L2} * 100

- Typical Range: 75<M<100
- Highly dependent on face orientation
• Find the closest user
• Metrics are preconfigured during setup
• Send the ID to the framework

• Allow for a ±6.2% variability
  • Equates to ±6 metric points
Feature Based Results

Restitch the regions for verification

- Family Invariant
- Glasses Invariant
User Story

- As a user, I wish to view:
  - Time & Date
  - News/Social Feed
  - Calendar
  - Current Weather
  - Weather Forecast
Authorized User Use-Case

User Approaches Mirror

Camera Takes Photo

Facial Recognition Module

User's configuration file.

User Approaches Mirror

Algorithm analyzes face

If User exists, access their configuration array.

Configured modules are parsed and swapped.

Introduction

Hardware

Software

PCB Design

Administrative

Conclusion
Node.Js

• Utilizes the V8 Javascript Engine
• Event-Driven Architecture
• Good for persistent connections
• Allows code to be shared between browser and back-end
Node Package Manager

- Easily shares Node.JS modules
- Node Package Manager handles nested dependencies
- Most commonly used with Node.JS runtime environment
Angular 2

• Open sourced front-end web application framework

• Angular2 was released in May 2016
  – Good for small scale applications
  – Utilizes Typescript
  – Allows for dynamic loading
Module Swapping

- Provides a solution to user privacy
- Allows user to have more control over what they view via gestures
  - Cycle through each of the available modules to see content
- Saves space on the current 7 in. display
News Feed/Twitter Feed

- Mirror shows headlines based on RSS feed
- Shows recent tweets from user’s followings.
  - Amount of tweets shown are configurable
Message Datapath

- The Module runs the logic
- The Helper runs data acquisition scripts
- Response Time 0.5-1.0 sec
- Similar data path for camera

Raspberry Pi

- Software Framework
  - Module
  - Module Helper

Socket Connection sends json

ATmega 328

Display Output
Breadboard Testing

- Tested to ensure each subsystem function separately first, then began combining them together
- Operate all subsystems at same time to ensure no power or communication issues
Power System
LED Circuit
PCB Layout
Power: 12V → 3.3V and 5V
PCB Layout

Logic Level Converters
PCB Layout

Connections to Peripherals

4/26/2017

Group 8 - CECS
PCB Layout

Microcontroller/Debug Headers/Reset
PCB Layout
PCB Order

**Pros**
- 4-7 days to ship
- 5 boards for one price

**Cons**
- 12 days to ship
- Price per sq. in.

**Elecrow**
- 20% Quality Issues
- 3 boards
- Not in the U.S.

**OshPark**
- Not in the U.S.
PCB Layout

Backside of Smart Mirror
## Budget

<table>
<thead>
<tr>
<th>PART:</th>
<th>Vendor:</th>
<th>Budget:</th>
<th>Actual:</th>
<th>Over/Under</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-way Mirror</td>
<td>TWM LLC</td>
<td>$150.00</td>
<td>$68.43</td>
<td>$(81.57)</td>
</tr>
<tr>
<td>PCB Manuf.</td>
<td>Elecrow</td>
<td>$75.00</td>
<td>$27.55</td>
<td>$(47.45)</td>
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<tr>
<td>PCB Components</td>
<td>Various</td>
<td>$75.00</td>
<td>$50.00</td>
<td>$(25.00)</td>
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<tr>
<td>Display</td>
<td>Amazon</td>
<td>$40.00</td>
<td>$68.99</td>
<td>$28.99</td>
</tr>
<tr>
<td>Camera Module</td>
<td>Amazon</td>
<td>$50.00</td>
<td>$25.74</td>
<td>$(24.26)</td>
</tr>
<tr>
<td>Raspberry Pi 3</td>
<td>Amazon</td>
<td>$50.00</td>
<td>$35.70</td>
<td>$(14.30)</td>
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<tr>
<td>ZX Gesture Sensor</td>
<td>Sparkfun</td>
<td>$25.00</td>
<td>$24.95</td>
<td>$(0.05)</td>
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<tr>
<td>Atmega Microcont.</td>
<td>Amazon</td>
<td>$10.00</td>
<td>$2.23</td>
<td>$(7.77)</td>
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<tr>
<td>LED Strip</td>
<td>Adafruit</td>
<td>$30.00</td>
<td>$19.95</td>
<td>$(10.05)</td>
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<tr>
<td>Framing Materials</td>
<td>Home Depot</td>
<td>$40.00</td>
<td>$25.00</td>
<td>$(15.00)</td>
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<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>$545.00</strong></td>
<td><strong>$348.54</strong></td>
<td><strong>$(196.46)</strong></td>
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</table>
# Work Distribution

<table>
<thead>
<tr>
<th></th>
<th>Austin</th>
<th>Daniel</th>
<th>Kat</th>
<th>Reid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power System</td>
<td>P</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LED System</td>
<td>S</td>
<td>P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor Input</td>
<td></td>
<td></td>
<td>S</td>
<td>P</td>
</tr>
<tr>
<td>Face Recognition</td>
<td></td>
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<td>P</td>
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<tr>
<td>Architecture</td>
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<td>S</td>
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<td>P</td>
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<tr>
<td>PCB Design</td>
<td>S</td>
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<tr>
<td>Physical Design</td>
<td></td>
<td></td>
<td>P</td>
<td>S</td>
</tr>
</tbody>
</table>

P = Primary  
S = Secondary
Questions?