.

ECE 445 Design Document

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Interactive Mirror Display

Team 29

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1 - Introduction

1.1 - Objective:

Technology has become a ubiquitous presence in our lives. We have many devices which take up space and clutter up our living environments, providing us with convenient access to interesting features and functionalities in exchange. However, it can be hard to manage and find space for so many devices, especially those that present information visually.

We propose to address this issue by developing an interactive mirror display which provides context sensitive information and media access to the user through a discreet and unobtrusive device. We intend to integrate gesture recognition, through the use of visual sensors and OpenCV, and voice commands, through the use of Alexa integration, which will allow the user to interact with the device and access further information. The sensors will interface with a microcontroller, the user interface software will be run on a Raspberry Pi, and we will integrate a camera, microphone, and speakers.

1.2 - Background:

As technology is progressing, we are slowly entering a futuristic age. Smart devices are gaining popularity and are a part of people's daily lifestyles and their households. There is a clear interest from the public in these devices (51% of consumers in the United States are most excited about smart home technology), but many have concerns about cost, privacy and potential clutter with the accumulation of these devices[1]. We would like to design a smart mirror that can address some of these concerns. The appeal of a mirror is that it is already an everyday household object; it is discrete and concealed as a smart device. Furthermore, we want to be able to encompass many technologies into one to reduce clutter, so the mirror will be capable of presenting visual and audio content to the user directly from the same device. It will offer voice integration and gesture recognition in order to facilitate intuitive control of the device.

There are several other smart mirrors with voice integration in the market today, however they are often little more than large Android devices hidden behind a mirror and don't effectively take advantage of their mirror form factor. As a reach goal, we hope to make our mirror more innovative by using computer vision and machine learning to integrate the capability to detect certain visual features of the user's appearance on top of gesture recognition. Based on these detections, the mirror can offer commercial products that the user might be interested in. As for privacy concerns, the camera and microphone on the mirror will be under the complete control of the user through the settings and the use of a simple off switch. Overall, we want to implement a smart mirror that is very effective, user friendly and secure.

1.3 - High-level Requirements List:

- The mirror should be able to recognize gestures and perform the appropriate corresponding action.
- The mirror should be able to recognize speech and interpret specific voice commands.
- The mirror should have a functional and practical display, which adjusts accordingly in order to ensure the information is clearly visible.

2 - Design

The overall design of the device will be split into submodules which each enable a specific functionality. The user interface module will provide the hardware required to effectively communicate information to the user including a display and status LEDs. The audio I/O module will enable the user to interact with the device via voice commands through a microphone and will provide speakers through which the device can respond and provide audio media. The visual sensor module will make use of a camera, PIR sensor array, and proximity sensors to enable gesture detection and perform visual analysis on the user, as well as typical photo and video functionality. The control unit will consist of a microprocessor which will process input from the sensor modules and relay information to the Raspberry Pi which will run the virtual user interface software. The power module will ensure that the devices in the rest of the modules receive the power that they need to operate.

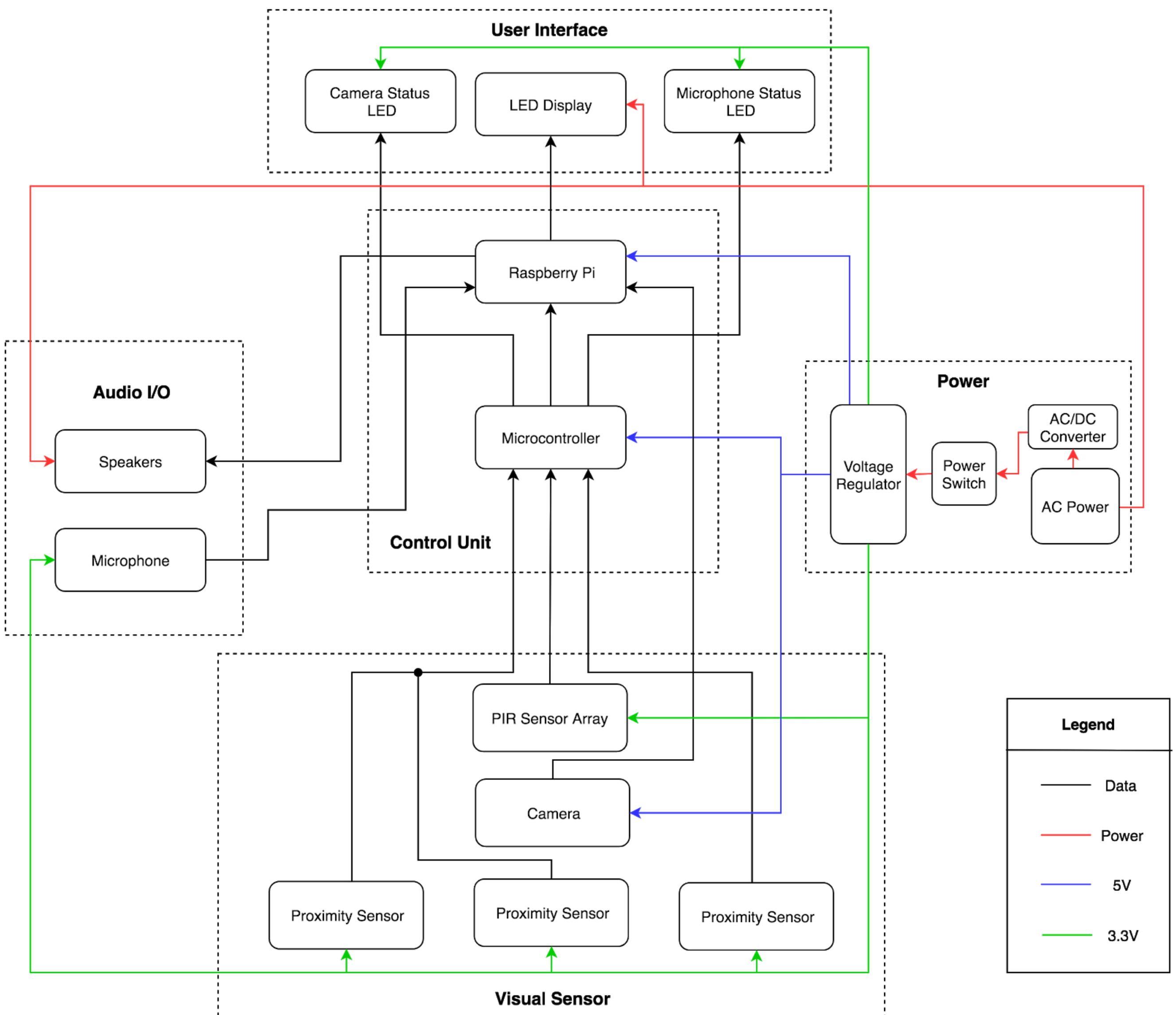

Figure 1. Block Diagram

The physical design of the device will consist of a single self-contained unit. The front will consist of a two way mirror surrounded by a bezel at the bottom of which the two status LEDs will be inlaid. The back of the device will consist of a monitor which will take up the upper portion of the display and a sensor module below which will include the camera, PIR sensors, proximity sensors, microphone, and speakers (if they are not included in the monitor). By placing the sensor module at the bottom of the device, we ensure that they will have an unobstructed view through the two way mirror while still being concealed effectively. The bottom of the frame will contain holes to ensure that sound travels to the microphone and from the speakers effectively as well as the power switch

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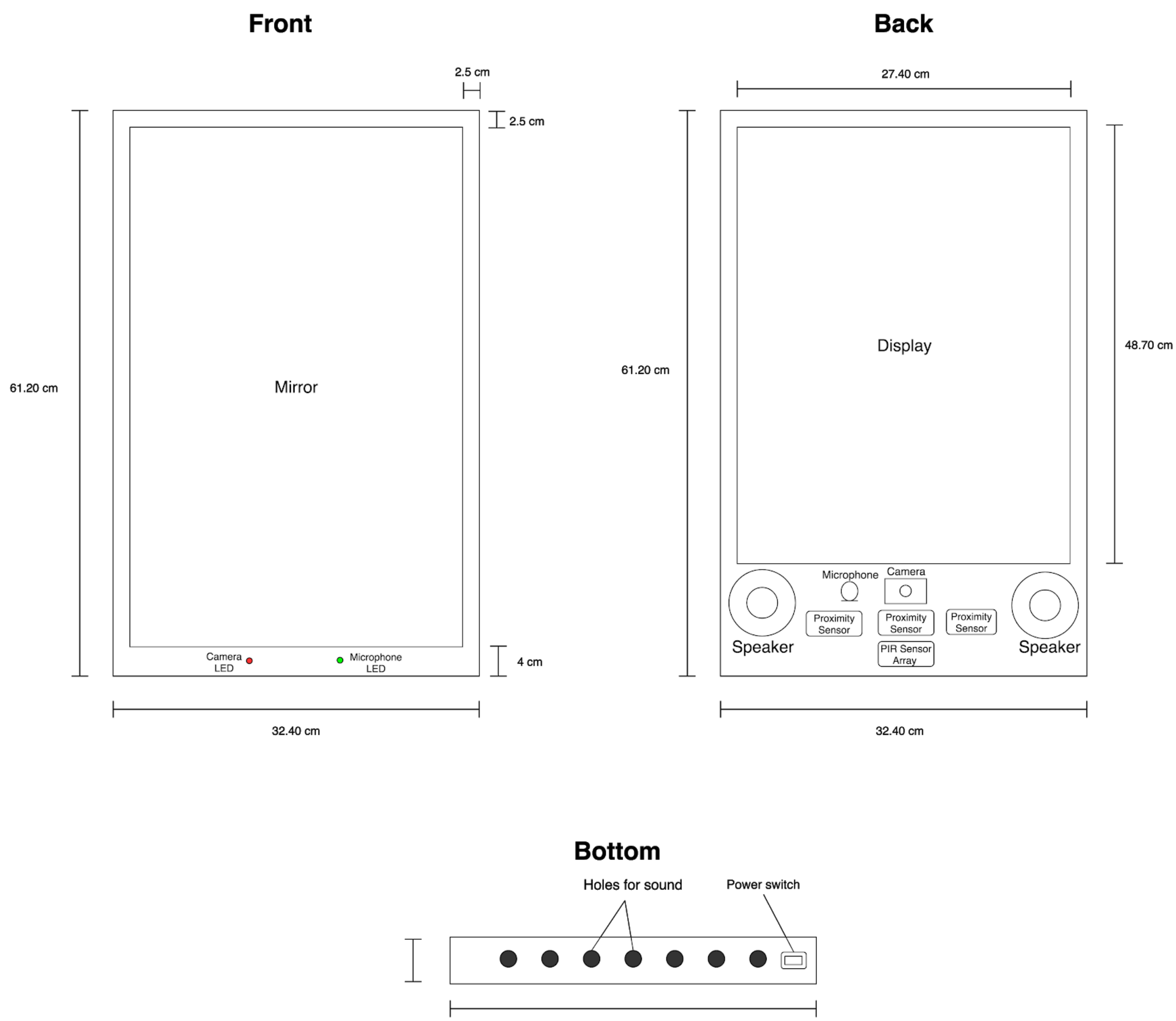

Figure 2. Physical Diagram

2.1 - Control Unit

The control unit will contain a microcontroller which will be responsible for coordinating the data flow between all of the sensors and outputs. It will process the data it receives and communicate with the Raspberry Pi which will be responsible for providing the virtual user interface.

2.1.1 - Microcontroller (ATmega328)

The microcontroller will run the application which displays information to the user via the LED display and reacts to the inputs provided through the sensors.

Table 1. Microcontroller Requirements and Verifications

Requirement	Verification
Operating voltage of 5V +/- 5%	1. Attach input leads to voltmeter 2. Observe and ensure that the value does not leave the range of 5V +/- 5%
Data rate between standard 9600 baud and 115200 baud.	1. Write simple program which sends data packets with alternating bit values 2. Attach data line to oscilloscope 3. Set oscilloscope to trigger on pulse 4. Measure duration of shortest pulse and ensure that the reciprocal falls between *9600 baud and 115200 baud*

2.2.3 - Raspberry Pi

The Raspberry pi will be responsible for running the virtual user interface which provides visual and audio media to the user. It will run an application which provides the full-featured user interface and will receive inputs from the microcontroller which communicate processed sensor data and controls.

Table 2. Raspberry Pi Requirements and Verifications

Requirement	Verification
Powered by 5.1V +/- 5%	1. Attach input leads to voltmeter 2. Observe and ensure that the value does not leave the range of 5.1V +/- 5%
Max current of 1A +/- 1%	1. Attach input leads to multimeter 2. Ensure that the current through the load is at 1A +/- 1% using a multimeter (positive lead attached to 10A and negative lead attached to COM) in series with a 12V battery

Communicates via USB and HDMI ports (UART) with speeds greater than 1 Mbps (raspberry pi has default baud rate of 115200)	1. Write simple program which sends data packets with alternating bit values 2. Attach data line to oscilloscope 3. Set oscilloscope to trigger on pulse 4. Measure duration of shortest pulse and ensure that the reciprocal is above 1,000,000 baud

2.2 - User Interface

2.2.1 - Display Monitor

The display monitor will be the main interface through which information and content will be provided to the user. Data will be supplied to the display from the Raspberry Pi, and power will be supplied through the wall outlet.

Table 3. Display Monitor Requirements and Verifications

Requirement	Verification
50mA +/- 1% to connect display to pi via HDMI port.	1. Attach input leads to ammeter 2. Ensure that the current through the load is at 50 mA +/- 1% using a multimeter (positive lead attached to 10A and negative lead attached to COM) in series with a 12V battery.
Power consumption of 22W +/- 5%	1. Test the power by plugging the monitor into a Kill a Watt meter 2. Make sure the power reading is 22W +/- 5%
Supports up to 1080p resolution	1. Check the on screen control in the settings of the display to check if 1080p is supported

2.2.2 - Camera Status LED

The camera status LED will indicate when the camera is currently enabled so that the user is always aware that it is watching.

Table 4. Camera Status LED Requirements and Verifications

Requirement	Verification
The status LED should be visible from 1 m away and have a drive current of 10mA	1. Set up test circuit shown in *Figure 3* to verify that current is between 10mA - 20mA 2. Ensure LED is visible from approximately 1m away

2.2.3 - Microphone Status LED

The microphone status LED will indicate when the microphone is currently enabled so that the user is always aware that it is listening.

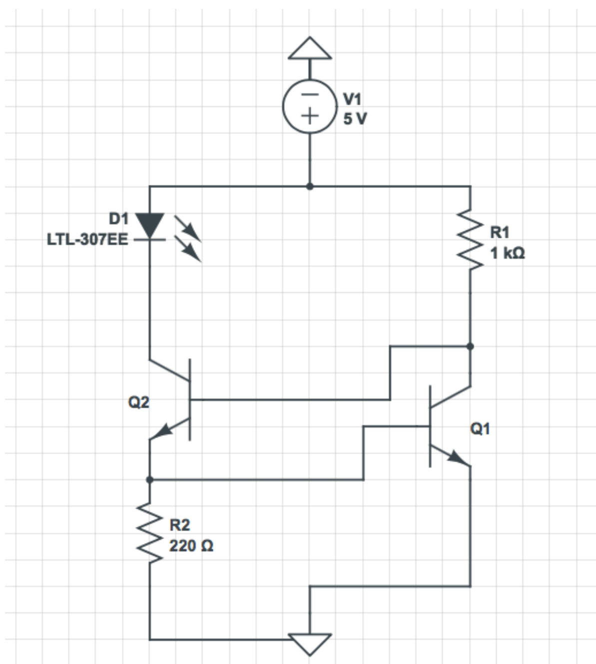

Figure 3. LED Test Circuit

Table 5. Microphone Status LED Requirements and Verifications

Requirement	Verification
The status LED should be visible from 1 m away and have a drive current of 10mA - 20mA	1. Set up test circuit shown in *Figure 3* to verify that current is between 10mA - 20mA 2. Ensure LED is visible from approximately 1m away

<u>3 - Audio I/O Module</u>

The audio module will take input through the microphone and output through the speakers in order to provide voice control and audio media playback capabilities.

2.3.1 - Microphone

The microphone will be used to collect data as the user speaks in order to process voice commands. It will send the data to the microcontroller and be powered through the power supply.

Table 6. Microphone Requirements and Verifications

Requirement	Verification
Audio bandwidth of 300 Hz - 5 kHz	1. Plug microphone in and play audio signals ranging from 300 Hz - 5 kHz 2. Check to see if microphone picks up those signals
Max current draw of 1A +/- 1%	1. Attach input leads to multimeter 2. Ensure that the current through the load is at 1A +/- 1% using a multimeter (positive lead attached to 10A and negative lead attached to COM) in series with a 12V battery

2.3.2 - Speakers

The speakers will output audio to the user including responses to voice commands and audio media. Data will be provided by the Raspberry Pi.

Table 7. Speakers Requirements and Verifications

Requirement	Verification
Integrated speakers in monitor (powered by monitor): sound should span 20Hz to 20kHz	1. Output an audio file to the monitor that has frequencies ranging from 20Hz to 20kHz

	2. Check to see if the speakers from the monitor successfully output all the audio and one can hear it

2.4 - Visual Sensor

The visual sensor system will provide various visual information to the processor in order to facilitate gesture recognition. These gestures will include swiping left, swiping right, swiping up, swiping down, and holding your hand in front of a sensor for a period of time.

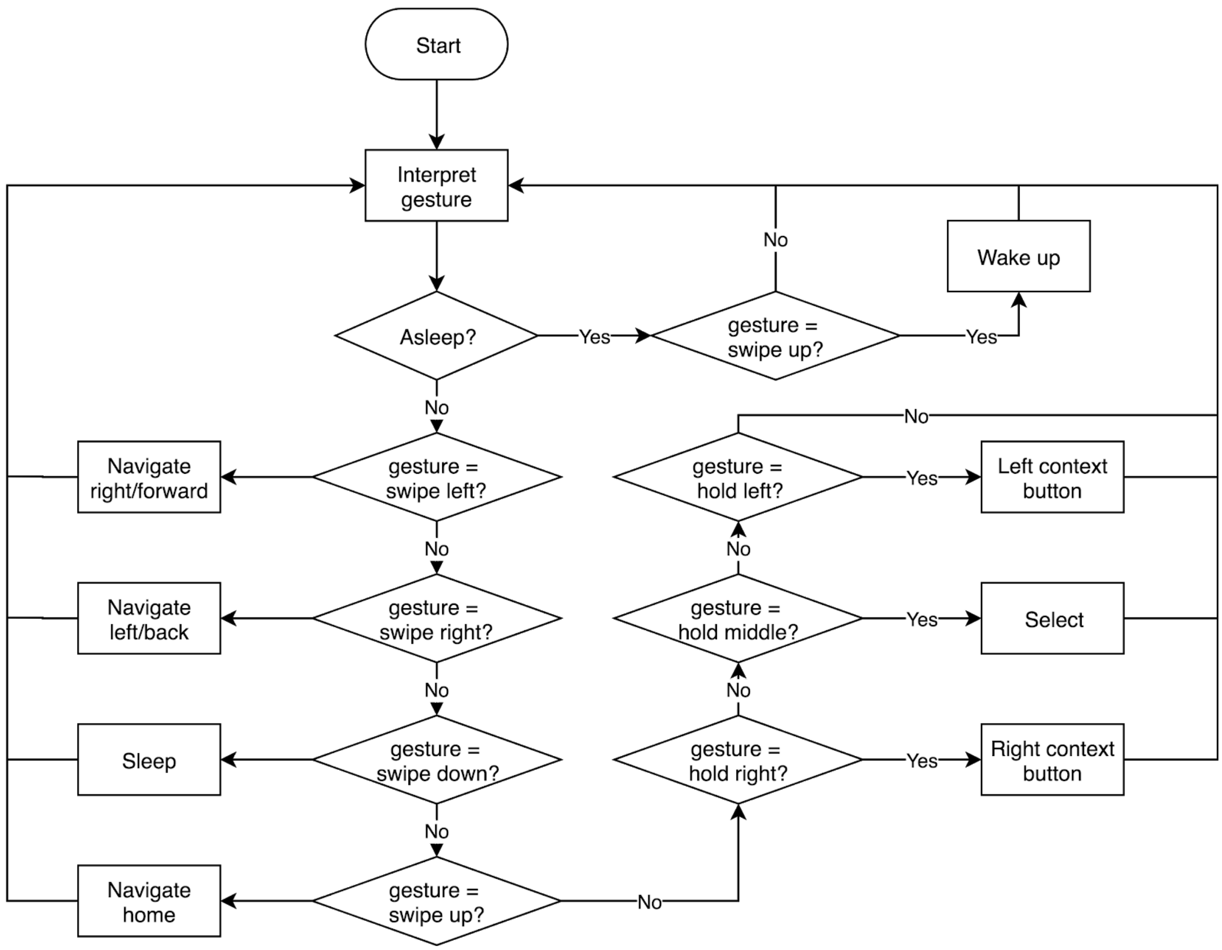

Figure 4. Gesture Control Algorithm

2.4.1 - Camera

The camera will provide a real time stream of visual information to the microprocessor which will be used to send pictures and videos. The feed will be sent to the Raspberry Pi for processing.

Table 8. Camera Requirements and Verifications

Requirement	Verification
Max current draw of 250mA +/- 1%	1. Attach input leads to multimeter 2. Ensure that the current through the load is at 250mA +/- 1% using a multimeter (positive lead attached to 10A and negative lead attached to COM) in series with a 12V battery
Pixel resolution between 2592x1944 pixels and 3280x2464 pixels	1. Take a picture using the camera 2. Check properties of the image file to verify pixel resolution matches the requirement
Can support 640p, 720p and up to 1080p video mode	1. Take a video using the camera 2. Check properties of the video file to verify resolution matches the requirement

2.4.2 - PIR Sensor Array

The PIR Sensor produces a low resolution infrared image of the scene in front of the sensor. We will be using an array of these sensors in order to detect motion: specifically hand gestures such as swipes.

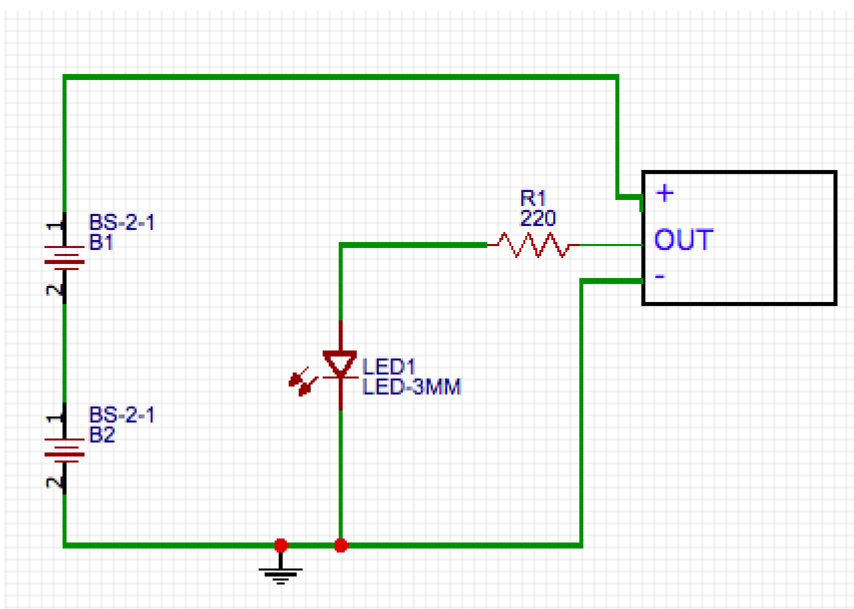

Figure 5. Visual Sensor Test Circuit

Table 9. PIR Sensor Requirements and Verifications

Requirement	Verification
Needs 5V +/- 1% power (powered by Arduino)	1. Attach input pin to voltmeter 2. Observe and ensure that the value does not leave the range of 5V +/- 1%
Can detect within a range from 20 cm to 1 m	1. Set up the circuit shown in *Figure 4* on a breadboard and wait 30-60s for the PIR to stabilize 2. During this time, the LED may blink - wait until the LED is off 3. Move around in front of the PIR sensor in the desired range. When the sensor detects motion, the output pin goes “high” to 3.3V and lights up the LED

2.4.23 - Proximity Sensors (VCNL4200)

The proximity sensors will be used to enable selection of the two auxiliary action buttons as well as to further improve swipe gesture detection. The data will be sent to the microcontroller.

Table 10. Proximity Sensor Requirements and Verifications

Requirement	Verification
Has a range from 0.1m to 1.5 m	1. Set up the circuit shown in *Figure 4* 2. Move object in front of sensor in the desired range. When the sensor detects motion, the output pin goes “high” to 3.3V and lights up the LED
Operation voltage from 2.5 to 3.6 V	1. Attach input leads to voltmeter 2. Observe and ensure that the value does not leave the range of 2.5V - 3.6V

2.5 - Power Module

The power module will be responsible for adapting the power provided by the wall outlet and supplying power to all of the other components.

2.5.1 - AC Power

AC power will be supplied via a wall outlet.

2.5.2 - AC/DC Power Converter

The power converter will convert the AC power supplied by the wall to DC power usable by the devices in our design.

Table 11. AC/DC Power Converter Requirements and Verifications

Requirement	Verification
Convert the 120V AC to 12V +/- 5% DC.	1. Attach input leads to voltmeter 2. Observe and ensure that the value does not leave the range of 120V +/- 5%

2.5.3 - Voltage Regulator

The voltage regulator will regulate the voltage supplied by the power converter at the specific voltages required for the various devices throughout the design.

Table 12. Voltage Regulator Requirements and Verifications

Requirement	Verification
Regulate the voltage to 5V +/- 5% for the microcontroller, raspberry pi, gesture sensor	1. Attach output to voltmeter 2. Observe and ensure that the value does not leave the range of 5V +/- 5%
Regulate the voltage to 3.3V +/- 5% for the status LEDs	1. Attach output to voltmeter 2. Observe and ensure that the value does not leave the range of 3.3V +/- 5%

2.5.4 - Power Switch

The power switch will turn the device completely on or off. The mirror may be woken with gestures and/or voice commands as well, but in order to eliminate privacy concerns and allow the users complete control over what features are enabled, the switch is provided to turn the whole device off when not in use.

Table 13. Power Switch Requirements and Verifications

Requirement	Verification
The power switch should power off the entire system	Once switch is flipped, ensure that all devices are no longer receiving power

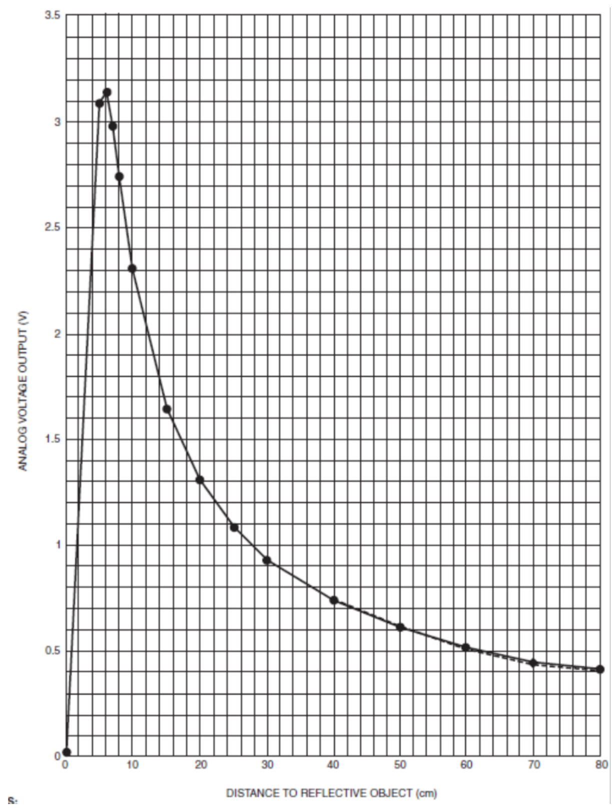

Figure 6. Plot of Distance vs. Voltage for a proximity sensor [4]

3 - Cost

3.1 - Cost Analysis

Part	Cost
Microcontroller (ATmega328) [5]	$1.96
Raspberry Pi 3 [6]	$35.00
Display Monitor	$50
Camera (Raspberry Pi Camera Module V2) [7]	$29.95
Microphone (Mini USB Microphone) [8]	$5.95
Proximity Sensors (VCNL4200) [9] x3	$8.85 ($2.95)
PIR Sensor (HC-SR501) [10] x5	$8.99
Assorted components	$9.30
Total:	**$150**

5 - Ethics and Safety

The ethical and safety concerns that our project presents relate to data management and privacy. As the ACM Code of Ethics (1.6) explains, we need to ensure that potential consumers know whether or not their personal information will be collected or monitored. To specifically address this issue, we will explicitly state how and when the mirror will be gathering and using information. To work towards the goal of full disclosure, we will incorporate LEDs used to alert the consumer that the mirror and/or camera is on. Additionally, we need to ensure that all data and metadata gathered will be kept confidential in order to comply with the ACM Code of Ethics (1.7). This means that we will not share data that can identify a consumer with third-parties (only specified personnel will have limited access), unless there is a clear violation of the law. In such a case, we will inform the consumer that their data may be shared with proper authorities.

Another concern we will be addressing is the security of our systems. The Interactive Mirror Display will have the potential ability to gather and monitor information about the consumer, we will be implementing certain security measures. In order to provide the consumer with a way to manage the usage of the mirror, we will be implementing a button to turn the mirror on or off. This provides a measure of physical security, and is simple enough for the general consumer to understand, which complies with the ACM Code of Ethics (2.9). Furthermore, we will be designing a system that implements common networking security protocols to ensure that all data being sent to a server is secured to a satisfactory level. In the case of a data breach, we will notify all parties affected in the "most expedient time possible and without unreasonable delay." By implementing and following these standards, we would be adhering to the Illinois Personal Information Protection Act (815 ILCS 530, et seq.) and the Federal Trade Commission Act (15 U.S. Code 41, et seq.).

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