ECE 445 Project Proposal

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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:

- All project components should fit within a $150 budget.
- The mirror should be able to recognize speech and gestures through the use of emitters and sensors. It should interpret these as commands and perform actions accordingly.
- 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, status LEDs, and a Raspberry Pi which will run the virtual user interface software. 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, gesture sensor, 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 in the user interface module so that the device can react appropriately. The power module will ensure that the devices in the rest of the modules receive the power that they need to operate.

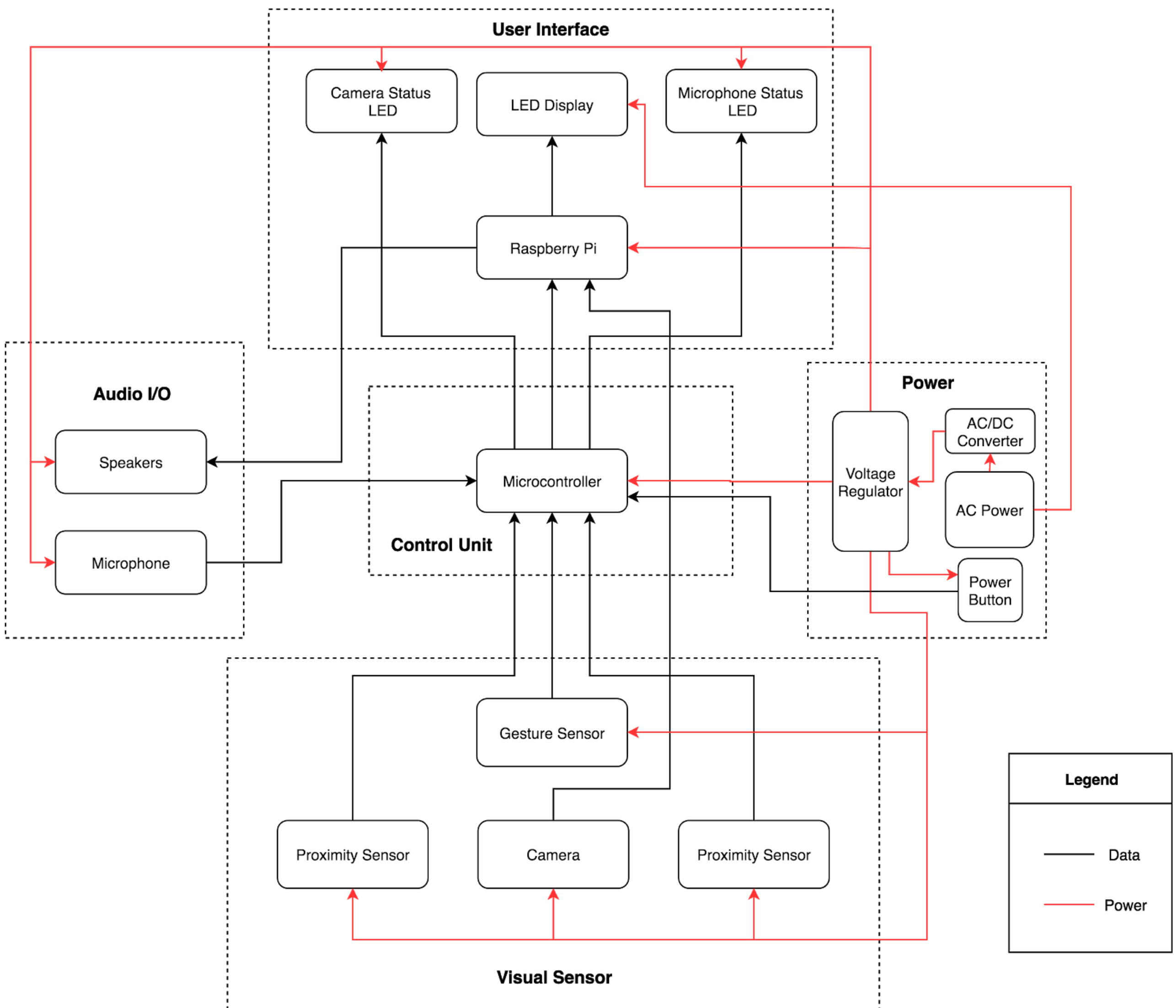

Figure 1. Block Diagram

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 and a power button 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, gesture sensor, 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.

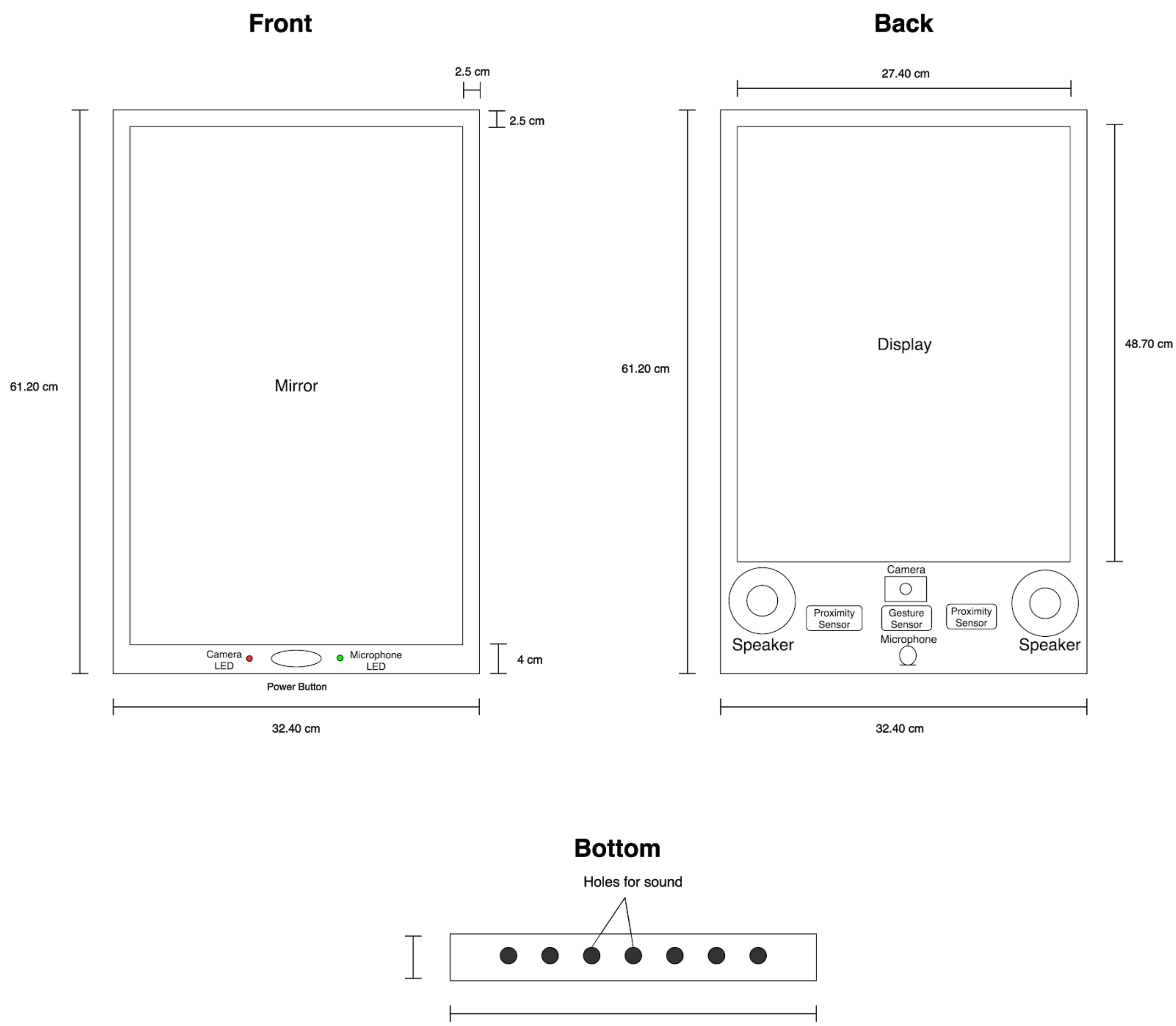

Figure 2. Physical Diagram

2.1 - Control Unit

The control unit will consist of 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 in order to enable interaction between the peripherals and 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.

Requirement 1: Operating voltage of 5 V +/- 5%
Requirement 2: Data rate between standard 9600 baud and 115200 baud.

2.2 - User Interface

2.2.1 - LED Display

The LED display 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.

Requirement 1: 50 mA to connect to pi via HDMI port.
Requirement 2: Size of 22", 22W +/- 5% power consumption, 1080p

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.

Requirement: The status LED should be visible from 3 m away and have a drive current of 10mA

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.

Requirement: The status LED should be visible from 3 m away and have a drive current of 10mA

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.

Requirement 1: Max current it can use is 1A; powered by 5.1 V +/- 5%
Requirement 2: Communicates via USB and HDMI ports (UART) with speeds greater than 4 Mbps (raspberry pi has default baud rate of 115200)

2.3 - Audio I/O Module

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.

Requirement: Audio bandwidth of 300 Hz - 5 kHz. Max current draw of 1A.

2.3.2 - Speakers

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

Requirement: Integrated speakers in monitor (powered by monitor): sound should span 20Hz to 20kHz

2.4 - Visual Sensor

The visual sensor system will provide various visual information to the processor in order to facilitate gesture recognition.

2.4.1 - Camera

The camera will provide a real time stream of visual information to the microprocessor which will be used to detect gestures and in any visual analysis AI that we incorporate. The feed will be sent to the Raspberry Pi for processing.

Requirement 1: Max current draw of 250 mA.
Requirement 2: Sensor resolution between 2592x1944 pixels and 3280x2464 pixels.
Requirement 3: Sensor image area of 3.76x2.74 mm and 3.68x2.76 mm.
Requirement 4: Can support up to 1080p video mode

2.4.2 - Gesture Sensor (APDS-9960 RGB and Gesture Sensor)

The gesture sensor will enable gesture recognition including swipes and selection. The data will be sent to the microcontroller.

Requirement 1: Needs 3.3V power (powered by Arduino)
Requirement 2: Has a range of 10-20 cm for swipe: 2 cm range for near gesture
Requirement 3: Data rate up to 400 kHz

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.

Requirement 1: Has a range from 0 to 1.5 m
Requirement 2: Operation voltage from 2.5 to 3.6 V

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.

Requirement: 120V at 60Hz

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.

Requirement: Convert the 120V AC to 12V +/- 5% DC.

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.

Requirement 1: Regulate the voltage to 5V for the microcontroller, raspberry pi, gesture sensor
Requirement 2: Regulate the voltage to 3.3V for the status LED's

2.5.4 - Power Button

The power button 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 button is provided as well.

Requirement: The width of the power button should be in between 1.5" to 3".

2.6 - Risk Analysis

The integration of gesture recognition poses a risk to the successful completion of our Interactive Mirror Display. The gesture sensor we are planning to incorporate is the APDS-9960 RGB and Gesture Sensor, which has a 10-20 cm range. The problem that arises from the use of this sensor is that the range may be too limited. Users may wish to utilize the Interactive Mirror Display at a distance greater than or equal to a meter. If this is the case, then the gesture sensor may pose an issue.

To combat the potential issue mentioned above, we will also incorporate proximity sensors. The proximity sensor we plan to use is the VCNL4200, which has a range of 0-1.5 m. The combination of the gesture sensor and the proximity sensors may help to reduce the risk of completion related to the range. However, the use of multiple sensors may present the risk of data interference.

3 - 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.).

References

[1] "Impact of Smart Home Technology - IoT Innovation", *IoT Innovation*, 2019. [Online]. Available: https://internet-of-things-innovation.com/insights/the-blog/impact-of-smart-home-technology/#.XFtTyxlKiqA. [Accessed: 06- Feb- 2019].

[2] acm.org, "ACM Code of Ethics", 2018. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 06- Feb- 2019].

[3] sparkfun.com, "APDS-9960 Digital Proximity, Ambient Light, RGB and Gesture Sensor Data Sheet", 2013. [Online]. Available: https://cdn.sparkfun.com/datasheets/Sensors/Proximity/apds9960.pdf