Theft Prevention Stand

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1. Introduction

1.1 Objective:
Cafes and Libraries are two common areas that students and workers use for working outside of their own houses or apartments. Since they work in these areas for up to hours at a time, they usually have to take a break for various reasons such as using the restroom, getting food, or just taking a break to get up and stretch. The issue with taking a break from the public workspace is that it is out in the open, and anyone could come and steal your belongings that are laid out. The problem that we are looking to prevent is the theft of one's personal belongings in a public workspace.

Our solution to this problem would be a portable, battery rechargeable security device that can stand on the table or workspace area that monitors the movement of people nearby. If movement is detected within a certain range then the device will emit a corresponding warning sound and flashing light. This is to account for general movement that may be detected from people walking near the workspace, but not getting within arms reach of the workspace to steal items. If movement is detected within a tighter range, the device will emit a louder and higher pitched sound and a red light will flash at a higher frequency. This security device would also be connected to an app that allows the user to arm and disarm the security measures and will notify the user when the device detects potential thieves.

1.2 Background:
Theft of belongings in a public space is a well known issue. People do not feel safe leaving their belongings alone even for a short trip to the bathroom without someone there to keep watch. The FBI reported that in 2018 only an average of 28.4% of lost belongings were ever recovered, 5.2% being office equipment and 11.4% miscellaneous, categories applicable to belongings one would leave alone in a public space. The Grainger Engineering Library is well known for having a high theft rate and patrons are constantly warned to keep their belongings attended at all times. Our project aims to provide users with the confidence that they will be able to leave their belongings alone for short periods of time without fear of being stolen from. We do not need to worry about the low recovery rate of belongings if we prevent them from being stolen in the first place.

1.3 High Level Requirements List:

- The device must be portable and must be able to be powered for at least 4 hours.
- The system can detect approaching objects within a range of 0-2 meters and activate the buzzer and LEDs based on the output from the sensors.
- The app will allow a user to arm or disarm the device at will as well as send a notification to the user whenever an approaching object is detected within either the warning or alarm range.

2. Design:

Physical Design:

Our project will consist of a cylindrical stand of about 0.25 meters in height and 0.09 meters in diameter. At the base of the stand will be a compartment that will hold our microcontroller and battery pack. Inside the body of the cylinder will be space for the wires from the attached electronics to run through to the microcontroller circuit. On the top of the stand we will have our motion sensor array. Our LEDs and buzzers will be attached to the outside of the body of the stand.

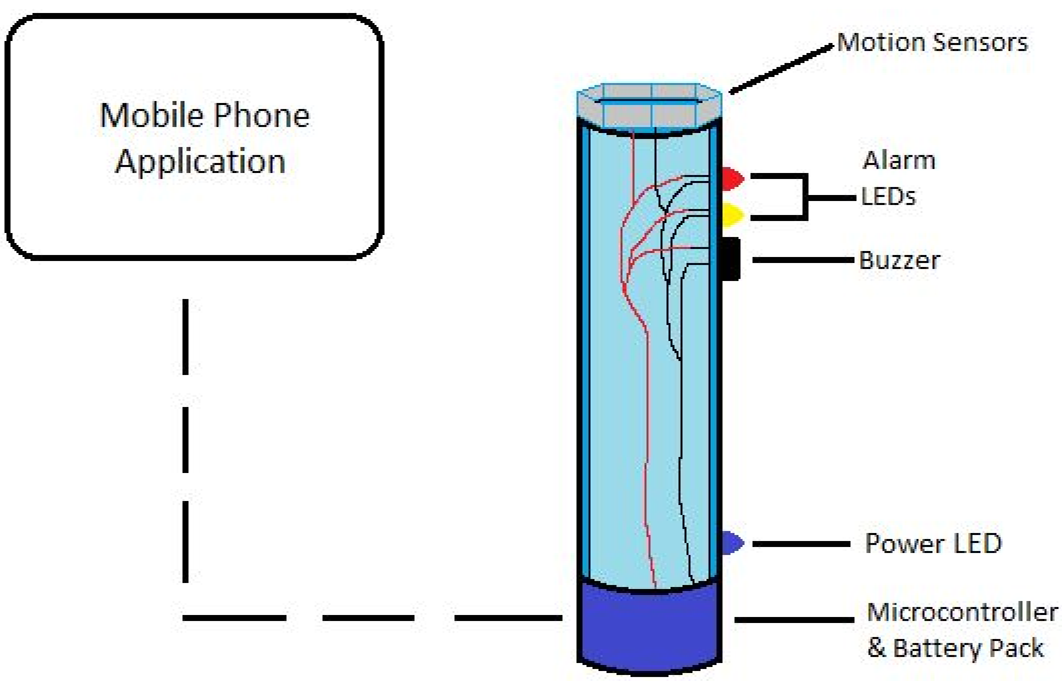

Figure 1: Physical Design

Block Diagram:
Our project requires four different subsystems for proper functionality: the power source subsystem, the sensor subsystem, the microcontroller subsystem, and the alarm subsystem. The power source ensures that every component receives the required amount of power necessary to run by drawing power from a battery pack. The sensor subsystem will provide the functionality for scanning for people approaching the stand and the belongings it is guarding. The alarm subsystem is used as a deterrent for thieves by scaring them and alerting any other people in the vicinity that a crime may be taking place. Lastly, the microcontroller system is in charge of taking the information given by the motion sensors and deciding whether to trigger the buzzers and LEDs on the stand. The Wi-Fi module in the microcontroller system is also responsible for alerting the associated phone app so that the user can be alerted as soon as a thief is detected.

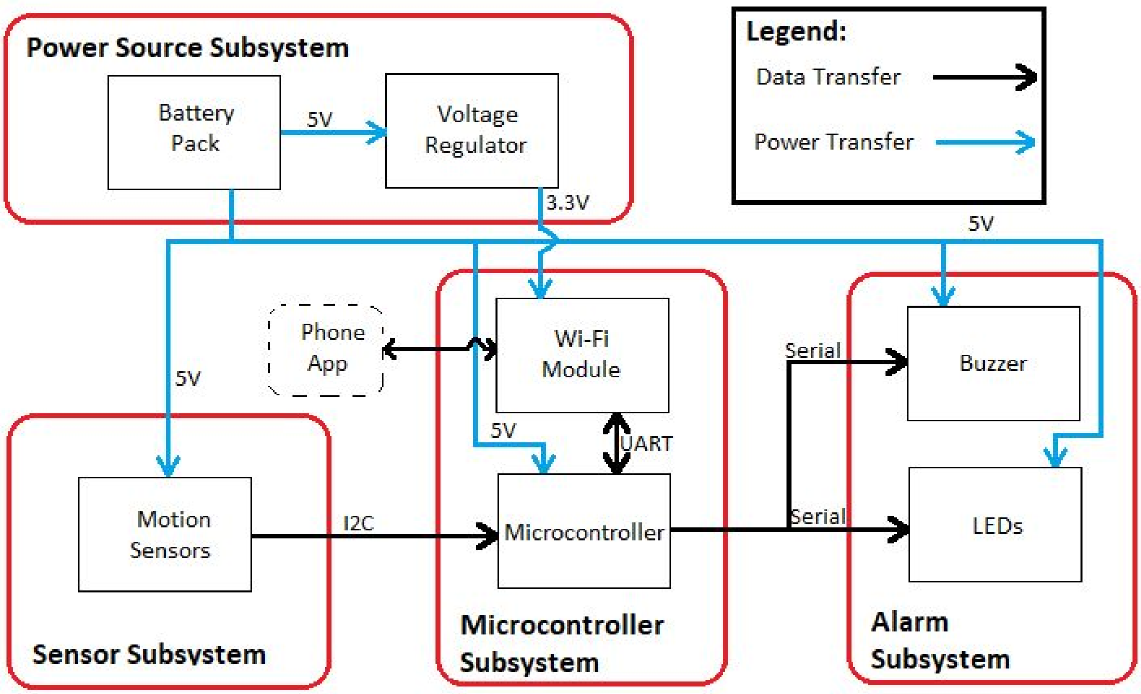

Figure 2: Block Diagram

2.1 Power Subsystem

A power supply is required in order to power up our device. Because our device is meant to be portable, we will use a simple battery pack that holds 4 AA batteries to supply our device with power. Adding up all of the current draw from our individual parts gives a total current draw of 459 mA so we need to make sure that our power source can supply this amount of current for the whole system.

Current Consumption:
Microcontroller: 9 mA
Wifi Module: 215 mA
Ultrasonic Distance Sensors: 15 mA x 12 = 180 mA
Buzzer: 15 mA
Yellow LED: 10 mA
Red LED: 10 mA
Blue LED: 20 mA
Total: 459 mA

2.1.1 Battery Pack

Our device will be powered by a battery pack which holds 4 AA batteries. This battery pack must supply enough power to allow our device to be on for at least 4 hours. A connected blue LED will alert the user when the batteries are starting to run low.

Requirements	Verification
1. Must store enough charge to provide at least 460 mA current at 5V (+/-5%) for at least 4 hours when turned on.	1. Connect the battery pack across a load resistor and use a multimeter to measure the current and voltage across the resistor

2.1.2 Voltage Regulator

This circuit will step down the 5V output of our battery to the required 3.3V input to power our Wifi Module. The regulator must also provide the required amount of current for our Wifi Module

Requirements	Verification
1. The voltage regulator must provide 3.3V +/- 5% from a 5V (+/-5%) input. 2. The voltage regulator must provide at least 215 mA of current.	1. Connect the Battery pack to the voltage regulator and measure the voltage output across a resistor load using a multimeter. 2. Connect the Battery pack to the voltage regulator and measure the current output across a resistor load using a multimeter.

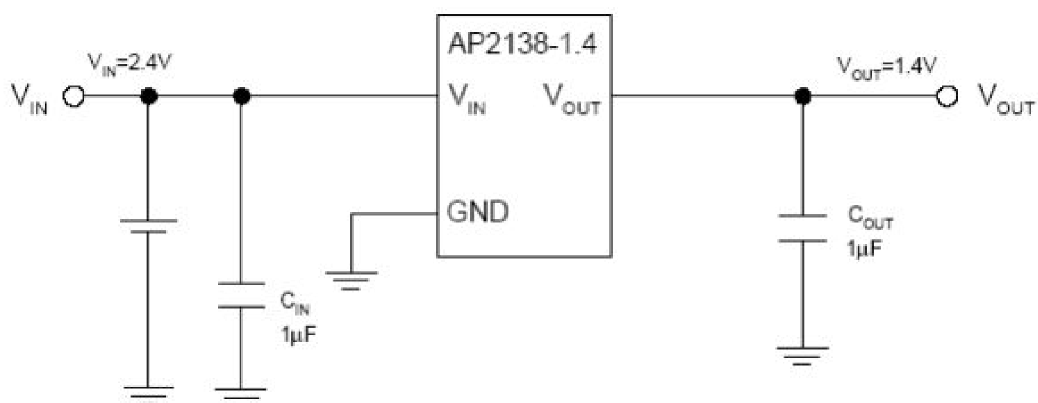

Figure 3: Voltage Regulator Circuit

2.2 Sensor Subsystem

In order to detect movement, we chose to use ultrasonic sensors, which detect movement by sending out a pulse and measuring the time it takes for the pulse to reflect back. We will use enough ultrasonic sensors to cover a 360° field of view.

2.2.1 Ultrasonic sensor

The ultrasonic sensors will check for approaching people, providing the information the microcontroller needs to decide whether to trigger the buzzer and LEDs or not. Releases a pulse by request and sends a signal to the microcontroller when the pulse returns.

Requirements	Verification
1. Detects people approaching within a 2.0 ± 0.1 meter radius	1. A. Write code to turn on an LED when the sensor detects movement within a range of 2 meters in front of it B. Stand outside of sensor's horizontal range C. Walk into its line of sight at a distance of 2 meters from it and look for LED response D. Walk back outside of sensor's horizontal range and re-enter at various distances within the 2 meter range from the sensor and check for LED response

2.3 Control Subsystem

In order to control when the alarm portion of the project is activated, the microcontroller is necessary to process the data provided by the ultrasonic sensors and signal the LEDs and buzzer to turn on. If a person is judged as having entered the warning range based on the sensor output, the microcontroller will trigger the warning pitch for the buzzer and the yellow LED while entering the alert range will trigger a higher pitch and the red LED. When triggered, an alert will be sent to the phone app associated with the project as well.

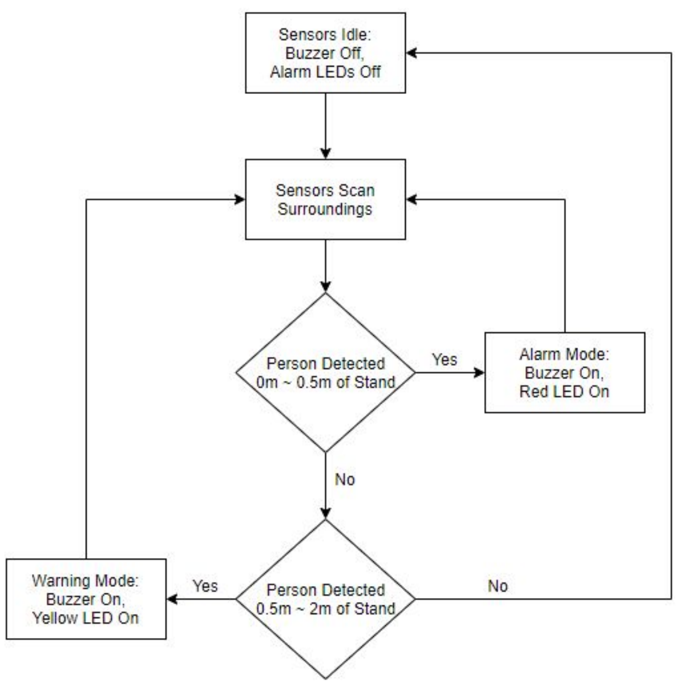

Figure 4: Software Flowchart

2.3.1 Microcontroller
Our microcontroller for this project will be the ATmega328p. It will communicate with the ultrasonic sensors using I2C protocol with the sensor as a slave. It will communicate with the Wi-Fi module through UART.

Requirements	Verification
1. Able to communicate over UART at speed of 115.2 kbps 2. Able to communicate using I2C protocol at rate of 400kHz	1. A. Establish connection between microcontroller and Putty terminal using an UART bridge B. Set Putty terminal to rate of 115.2kbaud C. Send and echo 50 characters D. Check to see that all characters have successfully been returned by terminal 2. A. Wire the ATmega328p for using I2C protocol [8] B. Use testing code to verify that I2C protocol works as advertised [8]

2.3.2 Wi-Fi Module
Our Wi-Fi module will be the ESP8266 chip. This chip will allow us to use Wi-Fi to communicate to the phone app associated with our project. It will communicate with the ATmega328p through UART.

Requirements	Verification
1. Able to communicate over IEEE 802.11 b/g/n at a rate higher than 100kbps 2. Able to communicate over UART	1. A. Assemble Wi-Fi module circuit according to specifications of datasheet B. Write necessary code to connect to a specified network [10] C. Print back the network name and IP address of the ESP8266 when successful 2. A. Establish connection between Putty terminal and ESP8266 using an UART bridge B. Set terminal to 115.2kbaud C. Type IP address of ESP8266 into browser D. Send characters through Putty and check browser to see if they are echoed properly

2.4 Alarm Subsystem

This alarm system is used to deter the possible thief and also alert others in the vicinity to the potential of a theft occurring. The buzzer will start emitting a sound when a person is detected within the warning zone while the yellow LED will light up. In the alarm phase the buzzer will emit a higher pitched sound and the red LED will start blinking rapidly.

2.4.1 Buzzer

A simple piezo buzzer with adjustable pitch will be used as a warning to approaching thieves. Buzzer will emit a lower pitch warning sound when a person is detected within the warning range and a higher pitch alarm sound when a person is detected within the alarm range.

Requirements	Verification
1. Pitch of buzzer can be adjusted through microcontroller code	1. A. Write code to set frequency of buzzer to increment over time B. Turn buzzer on with programmed code and listen for different pitches

2.4.2 LEDs

One yellow, one red, and one blue LED will be used as part of the warning to potential thieves. The yellow LED will be used for the warning and the red LED will be used for the alarm. The blue LED will tell us when the battery pack is beginning to run out of charge.

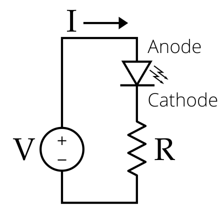

Figure 5: LED Circuit [13]

Requirements	Verification
1. LEDs must be visible from a distance of at least 3 meters with a current drive of 10mA for the yellow and red LEDs and 20mA for the blue LEDs.	1. A. Build circuit to power LED as according to figure 5 B. Set resistance to necessary value to provide 10mA or 20mA to LED depending on which LED is being tested (5V being used as V) C. Power the circuit and observe the LED from a distance of 3 meters to see if visible

2.5 Mobile Phone Application

An associated phone application will be used in order to remotely arm and disarm the stand as well as receive notifications whenever a possible thief is detected. The app will include a switch to turn the code for the stand on or off. When a thief is detected in either the warning or alarm ranges, the app will send a notification to the user depending on the level of threat.

Requirements	Verification
1. Switch in app is able to enable or disable the stand functionality 2. Notifications are sent to app's user when either alarm or warning are triggered	1. A. Stand outside of the stand's range while the switch is set to off. B. Set switch to on and walk towards stand until both warning and alarm modes are triggered C. Set switch to off while still in range and any activity by stand should stop 2. A. Check to see if notifications were sent when warning and alarm modes were triggered in previous verification steps

2.6 Risk/Tolerance Analysis:

A significant risk to our project's success is the ultrasonic sensor detection range. For our project to successfully notify the user when movement is detected, it must cover a 360 degree field of view. If there are any gaps in the sensing range then this means that someone could move within that gap of sensing range and there would be no movement detected. This is particularly challenging because in the case of ultrasonic sensors as a motion detector, the angle of detection is only 30 degrees.

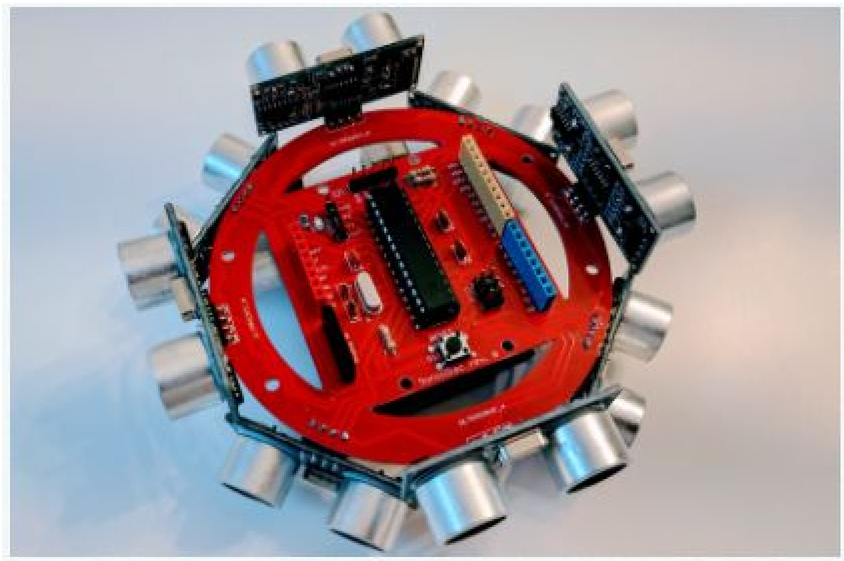

Figure 6: SonicDisc [9]

We had previously selected a part online called the SonicDisc, which had claimed to have full 360 degree sensing using 8 HC-SR04 sensors, but some analysis shows that this amount of sensors will not cover the full 360 degree range we want at a maximum range of 2 meters. At a distance of 2 meters, the circumference of the field of view would be:

Circumference = 2*π*radius = (2)(π)(2m radius) = 12.566 meters

We used some simple geometry to measure the effective circumference that 8 sensors would cover.

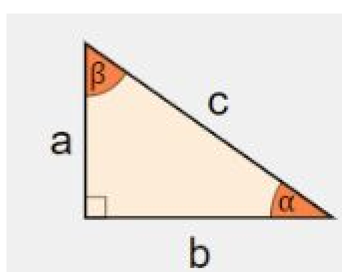

Figure 7: Right Triangle Calculations [14]

Our angle α = 15 degrees, b = 2 meters, and we want to solve for a.

Tan α = a/b => a = (2)(tan15) = 0.536 m.

Doubling the value of a to account for the full 30 degree range, we get about 1.072m of circumference for 1 sensor. Our total effective circumference for 8 sensors would be

(8)(1.072) = 8.576 m

which means that there is a gap of around 3.424 meters total of the circumference that someone could slip through undetected. Since the sensors are spaced out evenly, we divide this gap by 8 to get about 0.428 m between each sensor. In order to cover the full range, we need more sensors than the 8 provided with the SonicDisc. Assuming each sensor covers a range of 30 degrees, and we want to cover 360 degrees, we plan to use 12 sensors.

(360 degrees)/(30 degrees/sensor) = 12 sensors

Using the same steps as above but with 12 sensors instead of 8, we calculate an effective circumference of (12)(1.072) = 12.864 meters, which covers the full circumference of a 2m circle.

3 Project Differences:

3.1 Overview

The original project upon which we have based this project is called Warning Coverage. In essence, it is a blanket that is used to cover one's belongings, and when suspicious activity is detected, it takes several courses of preventative action. Firstly, it will loudly buzz to notify all of the people . Second, the internal twine will cinch the blanket shut, tightly protecting the contents inside. Lastly, and most importantly, it will notify a paired phone of the anomalous behaviour.

3.2 Analysis

Their project had three main high level requirements:

• Blanket must be foldable and portable so that it can be used on a daily basis and carried around by the user.

• Blanket's warning system must be able to catch the public's attention, in public places one of the ways to maximize safety is to draw public's attention.

• Blanket must be able to continuously work 12hrs without recharge.

In the interest of transparency, our project has only 4 hours of battery life, so in this way it is inferior to theirs. Our system is just as portable as theirs, being 0.25 m in height x 0.09 m in diameter and similarly shaped to a water bottle, which can easily fit into a backpack or onto any empty space on a table or desk. However, the ability to draw the public's attention is an area we feel we have greatly improved upon from their original design and concept. By principle, the warning coverage blanket has only as much range of area as the blanket can cover. So in theory, a potential thief could get as close as they wish to the user's belongings, and arouse no warning from their device. If they wished to steal something, they could simply take the blanket off or run off with the blanket. There is no advance warning that something is being stolen, no range of detection that has any sort of predictive abilities.

Our solution provides a range of detection. There are various levels of warning, from yellow to red lights and buzzers with increasing pitch, and these provide a buffer between the valuables and potential thieves. Even as they approach the objects, our design alerts the people in the surrounding areas. The yellow lights and the moderately pitched buzzer indicate a warning, and alert people in the area early. By the time the thief has reached close proximity (within 0.5 m), the red lights begin flashing and the pitch of the buzzer increases to high, sounding an alarm to the people nearby that a theft is happening. In a public place, there can often be great pressure to keep to yourself and not intervene, so the fact that our design has a greater range of effect than the blanket allows people more time to possibly take action and prevent theft.

4.1 Cost Analysis

4.1.1: Cost Table

Part	Vendor	Cost
ATMEGA328P-PU	Amazon	$5.99
Wifi Module - ESP8266	Sparkfun	$6.95
Ultrasonic Distance Sensor x 12	Sparkfun	$3.95 x 12 = $47.40
5V-3.3V Regulator	Digikey	$0.48
Battery Pack	Digikey	$2.95
Buzzer	Amazon	$5.99
Red LED	Digikey	$0.60
Yellow LED	Digikey	$0.58
Blue LED	RS	$0.48
Total Cost		$71.42

4.1.2: Labor

We have assumed a $35/hr salary working 10 hours a week for the 16 week semester for each member. ($35/hour) x 2.5 x 10(hrs/week) x 16 (weeks) x 3 = $42000

4.1.3: Grand Total

Our total costs are the costs of the parts added with the cost of labor which comes out to a grand total of $42071.42

4.2 Schedule:

Week #	Michael	Chris	Rob
1	Assemble team and think of ideas	Assemble team and think of ideas	Assemble team and think of ideas
2	Attend TA hours and have ideas critiqued	Work on Project Approval	Work on Project Approval
3	Proposal: Work on Block Diagram, Physical Design, Objective	Proposal: Risk Analysis, Functional Overview, Block Requirements	Proposal: Background, High Level Requirements, Ethics and Safety
4	Finish proposal work	Have proposal reviewed	Finish proposal work
5	Work on control system	Work on battery and power systems	Work on alarm subsystem
6	Design Document: High Level Requirements, Block Diagram, Physical Design, ControlSubsystem, Citations	Design Document: Problem and Solution Overview, Power Subsystem, Tolerance Analysis	Design Document: Alarm and Light subsystem, sensor subsystem, Ethics and Safety, Project differences, Cost Analysis
7	Begin arduino code	Order parts	Create enclosure specs and talk to machine shop
8	Set up wifi connectivity	Design PCB	Design PCB
9	Spring Break	Spring Break	Spring Break
10	Test control subsystem, begin work on app	Test power subsystem	Finish machine shop design, test alarm subsystem
11	Continue testing app	Test sensor subsystem	Test sensor subsystem
12	Integrate app with control subsystem	Integrate power subsystem with other subsystems	Get enclosure from machine shop
13	Test system as a whole	Test system as a whole	Integrate all components into enclosure
14	Prepare Demo	Prepare Demo	Prepare Demo
15	Prepare Presentation	Prepare Presentation	Prepare Presentation
16	Final Report	Final Report	Final Report

5. Ethics and Safety:

With any product relating to safety and security, there is some degree of danger or abuse that is present. Our product is designed to protect the users belongings from theft or harm, but it can also be abused to irritate others or to prevent them from using their belongings. Since the stand can be armed and disarmed remotely at any time, it is completely at the user's discretion where and when the stand may be used. For example, the user could place the stand near someone else's belongings, and then arm the system remotely. In doing this, the user could either scare the other person, or deter/prevent them from reaching their own belongings. This would also make it seem like the owner of these belongings is actually a thief trying to steal them, an action directly in violation of item 9 on the IEEE code of ethics [2]; to avoid injuring others, their property, reputation, or employment by false or malicious action. Also, people moving nearby the item could be misinterpreted as having malicious intent, and the alarm will go off regardless, which is not the intention of the stand.

In general, the stand's alarms and flashing could prove to be annoying to others nearby. If the lights flash fast enough, it could also endanger those with epilepsy, causing them to go into a seizure and require hospitalization. In addition, if the buzzer is too loud, then it could possibly cause hearing damage for those nearby. Depicted below are some common symptoms of epilepsy [6] as well as the dangers of exposure to loud noise [5]. Thankfully, our buzzer only goes up to 85 dB at the max, which is below the maximum safe exposure limit. Above 90 dB, one is susceptible to nausea, headaches, and hearing damage [7].

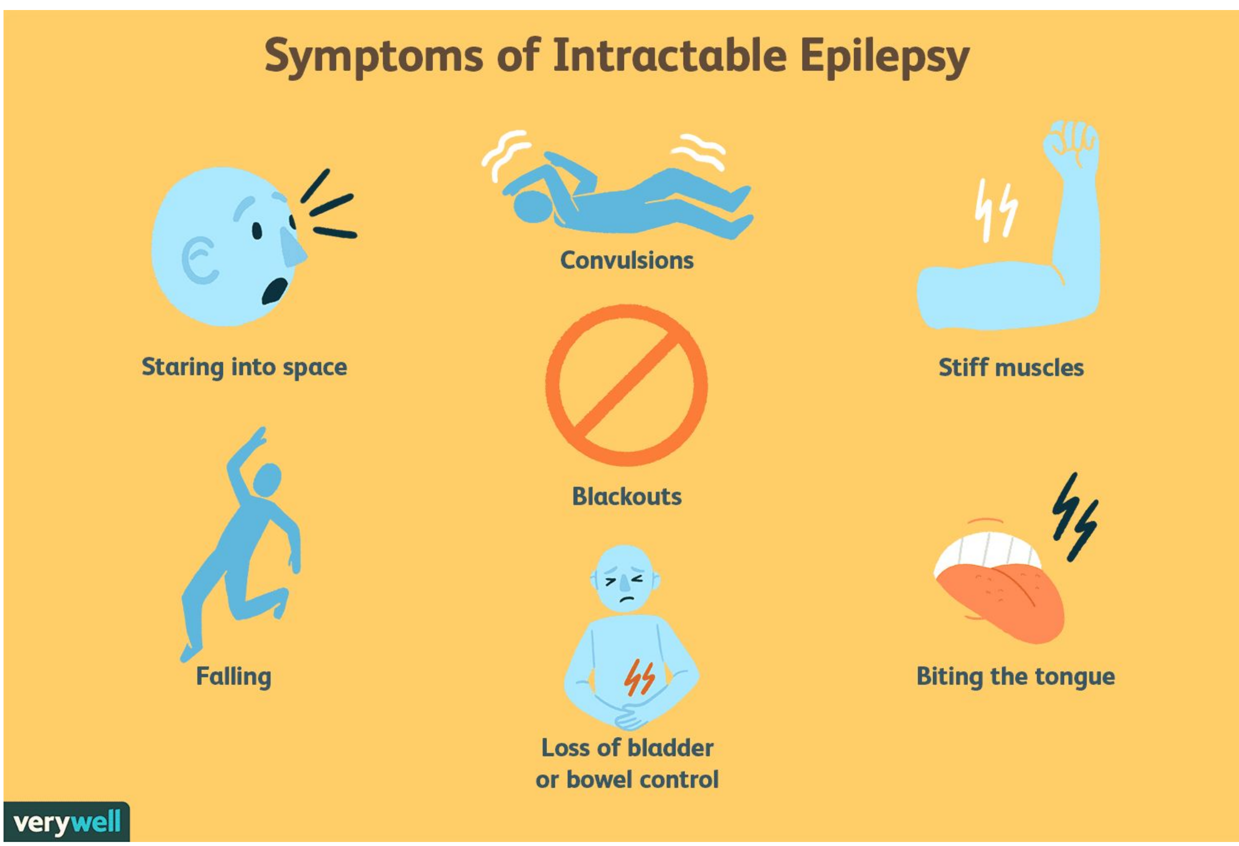

Figure 8: Symptoms of Epilepsy [6]

Figure 9: Noise Stress [5]

References:

[1] “Table 24 Property Stolen and Recovered.” *FBI*, [Online] https://ucr.fbi.gov/crime-in-the-u.s/2018/crime-in-the-u.s.-2018/tables/table-24/table-24.xls. Accessed 3 Apr. 2020.

[2] "IEEE Code Of Ethics". Ieee.Org, 2020, https://www.ieee.org/about/corporate/governance/p7-8.html. Accessed 13 Feb 2020.

[3] *DigiKey Electronics - Electronic Components Distributor*. [Online]. Available: https://www.digikey.com/products/en?mpart=3942&v=1528. [Accessed: 04-Apr-2020].

[4] *DigiKey Electronics - Electronic Components Distributor*. [Online]. Available: https://www.digikey.com/products/en?mpart=3859&v=1528. [Accessed: 04-Apr-2020].

[5] "Loud Noises: Health Dangers". *Healthline*, 2020, https://www.healthline.com/health-news/loud-noises-bad-for-your-health. Accessed 16 Apr 2020.

[6] "Intractable Epilepsy: Symptoms, Causes, And Treatment". Verywell Health, 2020, https://www.verywellhealth.com/intractable-epilepsy-4174278. Accessed 16 Apr 2020.

[7] CDC - Noise and Hearing Loss Prevention - Reducing Noise Exposure, Guidance and Regulations - NIOSH Workplace Safety and Health Topic. (2018, February 6). Retrieved from https://www.cdc.gov/niosh/topics/noise/reducenoiseexposure/regsguidance.html

[8] “Programming AVR I2C interface”. *Embedds*, [Online]. (2019, October 22). Retrieved from https://embedds.com/programming-avr-i2c-interface/

[9] Dimitris, “SonicDisc: A 360° ultrasonic scanner: Dimitris Platis - Software Engineer & Maker,” *Dimitris Platis*. [Online]. Available: https://platis.solutions/blog/2017/08/27/sonicdisc-360-ultrasonic-scanner/. [Accessed: 16-Apr-2020].

[10] “Establishing a Wi-Fi Connection”. Retrieved from https://tttapa.github.io/ESP8266/Chap07%20-%20Wi-Fi%20Connections.html

[11] “SonicDisc,” *PCBWay*. [Online]. Available: https://www.pcbway.com/project/shareproject/SonicDisc___A_360__ultrasonic_scanner.html. [Accessed: 16-Apr-2020].

[12] “AP2138N-3.3TRG1,” *DigiKey*. [Online]. Available: https://www.digikey.com/product-detail/en/diodes-incorporated/AP2138N-3-3TRG1/AP2138N-3-3TRG1DITR-ND/4470804. [Accessed: 16-Apr-2020].

[13] “LED Circuit” *Wikipedia.* [Online]. Retrieved from https://upload.wikimedia.org/wikipedia/commons/thumb/c/c9/LED_circuit.svg/200px-LED_circuit.svg.png

[14] “Right Triangle Side and Angle Calculator”. *OminCalculator.* [Online]. Retrieved from https://www.omnicalculator.com/math/right-triangle-side-angle