Automatic Candle

ECE 445 Design Document

Anders Cox, Armando Terrones, Kevin Thompson
Team 60
TA: Ruhao Xia
4/17/20

1 Introduction

1.1 Objective

The problem that we are addressing is the large amount of damages caused by . According to the NFPA, in recent years candles caused about 2% of household fires. Roughly 11% of these cases happen as a result of the user falling asleep with the candle still burning. In total, damages from candle accidents result in an annual loss of $268 million in property damages. [1] Of course, this hasn't stopped people from using candles and likely never will.

Our goal is to help reduce these statistics by designing a system which makes it easy to follow recommended candle safety guidelines. Our system will allow the user to place a candle on the base piece, and install a phone application. Once connected to the candle holder via bluetooth, the user can use the app to find and automatically light the wick. After a set timeout, or if the user wanders out of bluetooth range, the candle will automatically be extinguished.

1.2 Background

Candles have been around for a long time, and so of course there are a few key competitors in this market. The closest one would probably be the CandleWatch Automatic Candle Extinguisher [2], which will automatically extinguish a jar candle after about 4 hours by putting a lid on it. Other alternatives include flameless candles, which are recommended by the NFPA. However, our solution is novel because it isn't specifically designed around one type of candle, and it also provides the functionality for automatically lighting the candle. Of course, this approach is not quite as safe as the flameless alternatives, but many people dislike flameless candles because they don't provide the same strong scent that real candles do. Knowing this, we would say that our target audience are the people who want to practice safer candle usage, but don't want to give up using actual candles.

The solution proposed in a previous semester was very similar to the CandleWatch device. It was designed specifically for Jar candles, and only designed to extinguish. Our solution is clearly different from this, because we are trying to take an approach that works for many types of candles. Additionally, we are planning to provide functionality for igniting the candle, which is not possible with the design of the other solution.

1.3 Visual Aid

The design will include a base plate for holding the candle. An arm apparatus will be able to raise up above the candle and place the snuffer and arc lighter in position. These arms will need three degrees of motion in order to be able to guide both components to the wick accurately.

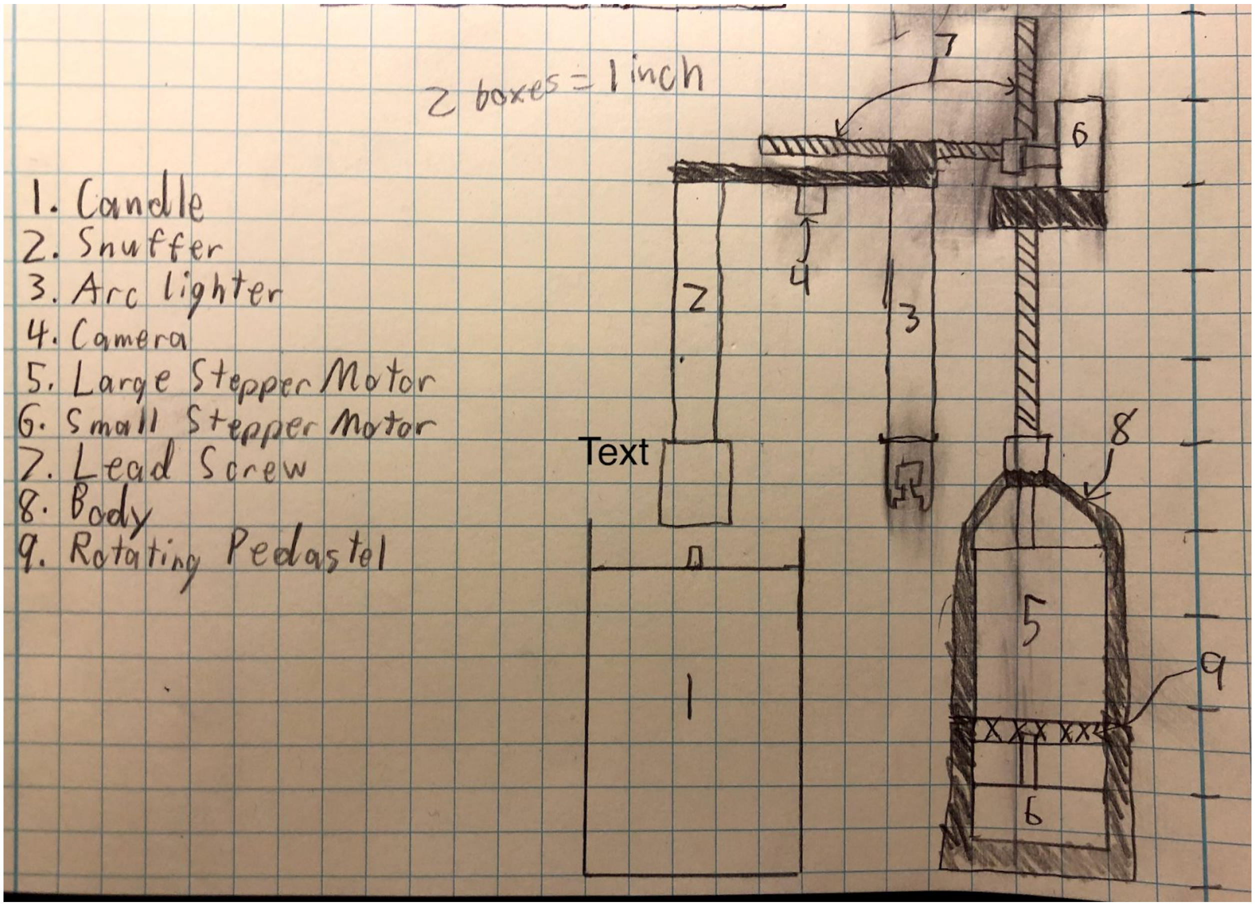

Figure 1. Physical Design

1.4 High-Level Requirements

- Must be able to detect if the candle is lit, with less <1% false negative rate.
- Must be able to extinguish a lit candle, with >90% success rate given an accurate wick position.
- Must be able to light an unlit candle, with >90% success given an accurate wick position.

2 Design

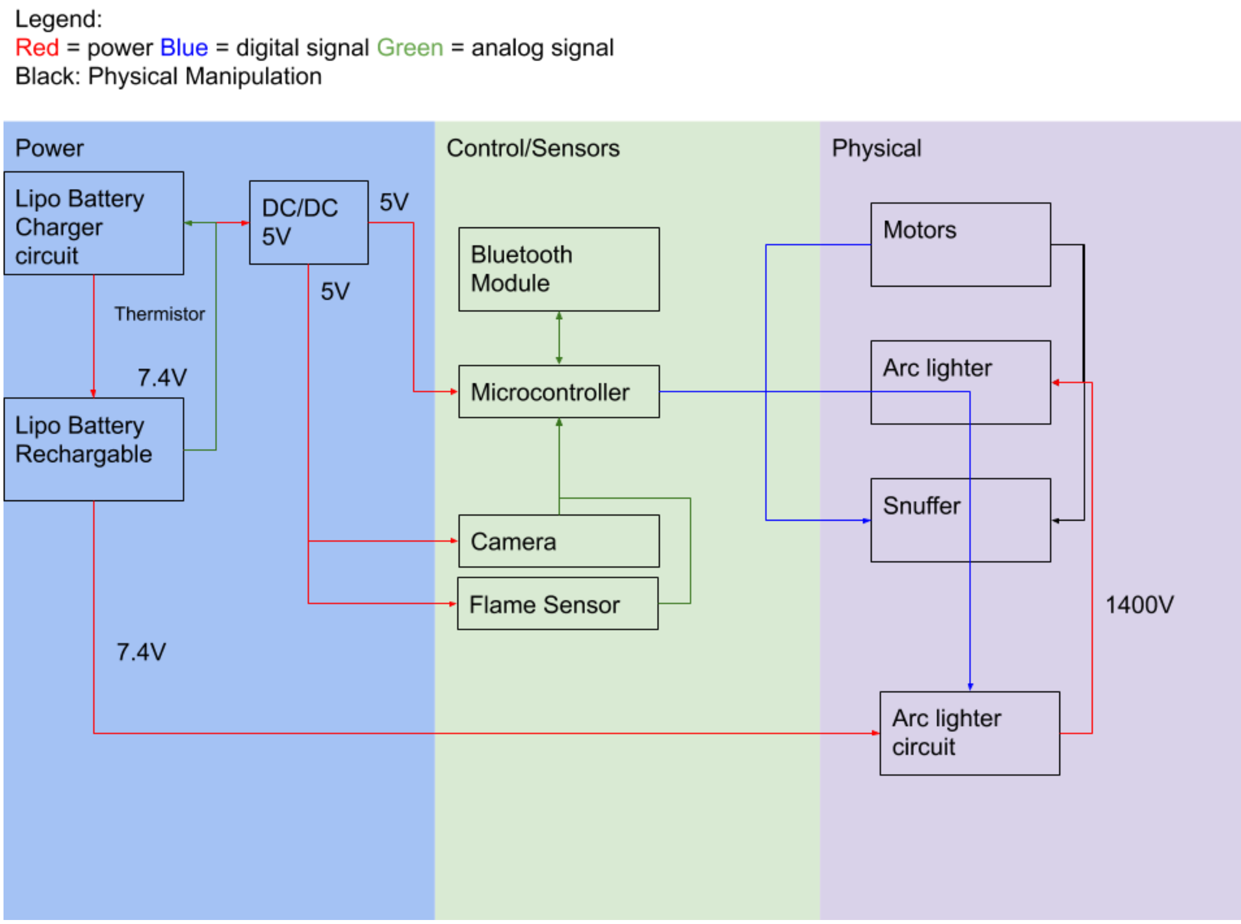

Figure 2. Block Diagram

2.1 Power Supply

A Power supply is necessary to operate all subsystems. The motors, sensors and microcontrollers all need power. Power will come from a battery and will be regulated for each subsystem to use.

2.1.1 Battery

Will provide the power needed to the rest of the system and be (rechargeable/replaceable).
Will be further regulated to usable voltages.

Requirement	Verification
1. Provide enough power for voltage regulator, controller, and motors. 2. Provide adequate power for *X* operating hours.	1,2. a. Connect battery to electronic load and test amperage out of battery at rated voltage. b. Hook up battery to test circuit A. Monitor battery in circuit over time to verify that adequate power is provided.

2.1.2 Battery charger

Will Charge the battery and provide protection to the battery to prevent over charging and imbalance in the LiPo cells.

Requirement	Verification
1. Charge battery safely[5] to at least 8V 2. Balance battery cells to within 1%	1. Connect battery charger to resistor to make sure output voltage and current are within safe charging parameters of battery (will be provided by battery manufacturer). 2. Connect battery to battery charger and measure voltage and current to ensure safe battery charging through multiple cycles. 3. Apply inconsistent voltage to battery cells within safe limits and measure voltage of cells when plugged into circuit to verify equalization.

2.1.3 Voltage regulator

Will regulate the battery voltage to usable voltages by the sensors and Control unit

Requirement	Verification
1. Provides 5v +/- 5% to all low voltage* components. 2. Can provide rated power to each low voltage* component while all components are operating **low voltage = less than 5V*	1. a. Connect to power supply set to 12v to input b. Connect electronic load to output c. Connect oscilloscope to output pin d. Monitor voltage across a range of currents up to maximum current draw to ensure criteria are met. e. Will also need to be tested while connected to AC/DC converter to ensure the entire power system is accurate. f. The same procedure will occur

2.2 Control Unit

2.2.1 Microcontroller

The microcontroller will interface with the bluetooth module to receive inputs from the user. It will then use user input as well as the sensor data to control the motor arms in order to perform the lighting and snuffing actions. The microcontroller is also responsible for snuffing the candle if the connection to the user is dropped or a timer expires.

Requirement	Verification
1. Can both send and receive with the Bluetooth controller through the serial interface at a baud rate of 9600. 2. Must be able to communicate with the camera over I2C at a baud rate of 9600. 3. Must be able to shut off the system if the battery gets too low in order to prevent damage to the battery.	1. a. Connect the controller to the GPIO pins on an Arduino board, configured for serial reading and writing. Set the baud rate to 9600. b. Generate and send 9.6 Kb of data from the Arduino to the microcontroller. c. Echo back the same data from the microcontroller back to the Arduino. d. Verify that the data transmitted matches the data received. 2. a. Connect the controller to the GPIO pins on an Arduino board, configured to use the I2C protocol. Set the baud rate to 9600. b. Generate and send 9.6 Kb of data from the Arduino to the microcontroller. c. Echo back the same data from the microcontroller back to the Arduino. d. Verify that the data transmitted matches the data received. 3. a. Supply monitor pin with a voltage below the operating limit and observe microcontroller measurement b. If correct measurement is seen then show the controller controlling the main battery relay disconnecting it from the rest of the system and show that the battery needs charging.

2.2.2 Bluetooth Module

The bluetooth module will allow the system to communicate with the users phone application and enable control. Bluetooth is a good choice for us because the user should always be present if a candle is lit. If the connection is lost, our system will begin the snuffing routine.

Requirement	Verification
1. Must be able to maintain a connection up to 10 meters away with open space between devices.	1. a. Connect the Bluetooth module to the GPIO pins on an Arduino. b. Run a simple ping-pong program on the Arduino to monitor the connection status of the bluetooth device. c. Connect to the bluetooth chip via cell phone. d. Measure 10 meters away from the bluetooth chip, and place the cell phone there. Ensure that the space between is free of obstacles. e. Monitor the connection status of the bluetooth device, and ensure that the connection is maintained for at least 30 minutes.

2.3 Sensors Unit

2.3.1 Flame Sensor

Flame sensors are simply photodetectors which are modified to specifically detect mid-length infrared beams. There are many of these designed for use with Arduinos, which should work well with our project.

Requirement	Verification
1. Must be able to detect if a candle wick, placed up to 12 inches from the sensor, is lit, with <0.1% false negatives.	1. a. Connect the flame sensor to an Arduino. Configure it to poll 10 times per second. b. Place a candle down and measure 6 inches above the wick. c. Mount the sensor at this position, and light the candle. d. Verify that the user flame is detected to the desired accuracy. Adjust thresholds as necessary. e. Repeat for distances of 8 inches, 10 inches, and 12 inches, until a constant threshold works for all distances.

2.3.2 Camera Module

The camera will mostly be used to interface with the user, and to allow us to precisely locate the wick on the candle. It will be controlled with our microcontroller, and therefore must be controllable via GPIO pins and a relatively simple communication protocol.

Requirement	Verification
1. Must have a high enough resolution that the user can identify the position of the wick in an image taken from 6 to 12 inches away.	1. a. Connect the camera module to an Arduino. b. Place a candle down and measure 6 inches above the wick. c. Mount the camera at this position, and use the Arduino to capture an image. d. Verify that the user can clearly see the wick in the image e. Repeat for distances of 8 inches, 10 inches, and 12 inches.

2.4 Arm Assembly

The arm assembly is responsible for bringing the snuffer, and arc lighter to the candle and positioning them so that they can complete their respective tasks.

2.4.1 Vertical Stepper Motor

Stepper motors are safe and easy to control motors that provide accurate position control in both directions. This will drive the vertical motion of the arm. We will be controlling this with a motor driver IC. This motor is much more accurate than necessary for our project, leading to the high tolerance and lack of lower bound for the step angle. These values are the listed values for this product [6].

Requirement	Verification
1. Must have Stall Torque of $6\ kg.cm\ +15\%/-15\%$ 2. Must have Step angle of $1.8\ Degrees\ +158\%$ a. If it has a smaller step angle, we will adjust the control, but it will not negatively affect the performance of the device	1. a. Program Motor to run constantly by PWM arduino program b. Connect motor to dynamometer or electric brake to provide precise loading of the motor c. Run motor at No-Load or low load. Increase the load until the motor is running at approximately half of No-load speed. Record this torque d. Take this torque point and the No-load speed and create a linear plot. The Y-intercept is the Stall Torque. 2. a. Attach a piece of bright tape to the motor shaft b. Mark starting position of the motor c. Program Motor to step 200 steps using an arduino PWM program d. Run the motor and mark the ending position of the bright tape e. Record this position in degrees relative to the start position. It should have traveled 360 degrees. f. Divide the position by the number of steps taken (30), and you have the step angle of the motor

2.4.2 Horizontal Stepper Motor

This motor will drive the horizontal motion of the arm, responsible for positioning the camera, snuffer, and lighter over the candle. This motor is responsible for moving a lighter load horizontally. This requires less torque, allowing this motor to be smaller and lighter than the vertical one.

Requirement	Verification
1. Must have Stall Torque of $1.325\ kg.cm\ +25\%/-25\%$ 2. Must have Step angle of $1.8\ Degrees\ +158\%$ a. If it has a smaller step angle, we will adjust the control, but it will not negatively affect the performance of the device	1. a. Program Motor to run constantly by PWM arduino program b. Connect motor to dynamometer or electric brake to provide precise loading of the motor c. Run motor at No-Load or low load. Increase the load until the motor is running at approximately half of No-load speed. Record this torque d. Take this torque point and the No-load speed and create a linear plot. The Y-intercept is the Stall Torque. 2. a. Attach a piece of bright tape to the motor shaft b. Mark starting position of the motor c. Program Motor to step 200 steps using an arduino PWM program d. Run the motor and mark the ending position of the bright tape e. Record this position in degrees relative to the start position. It should have traveled 360 degrees. f. Divide the position by the number of steps taken (30), and you have the step angle of the motor

2.4.3 Phi Stepper Motor

This motor will drive the Phi angle of the arm. This requires the most precision since it directly changes angle of the entire arm. It will connect to the frame of the arm. This type of rotation has much less friction and doesn't drive a load, meaning it can be small.

Requirement	**Verification**
1. Must have Stall Torque of $1.325\ kg.cm\ \ +25\%/-25\%$ 2. Must have Step angle of $1.8\ Degrees\ \ +15\%$ a. If it has a smaller step angle, we will adjust the control, but it will not negatively affect the performance of the device	1. a. Program Motor to run constantly by PWM arduino program b. Connect motor to dynamometer or electric brake to provide precise loading of the motor c. Run motor at No-Load or low load. Increase the load until the motor is running at approximately half of No-load speed. Record this torque d. Take this torque point and the No-load speed and create a linear plot. The Y-intercept is the Stall Torque. 2. a. Attach a piece of bright tape to the motor shaft b. Mark starting position of the motor c. Program Motor to step 200 steps using an arduino PWM program d. Run the motor and mark the ending position of the bright tape e. Record this position in degrees relative to the start position. It should have traveled 360 degrees. f. Divide the position by the number of steps taken (30), and you have the step angle of the motor

2.4.4 Snuffer

The snuffer is a long tube that will lower onto the wick to suffocate and extinguish it. It will have 1” of telescoping at the end to account for tiny errors in vertical positioning.

Requirement	Verification
1. Must be able to reliably extinguish wicks, with <1% error rate after covering the wick for 2 seconds a. Must be able to extinguish various wick sizes (<⅛”) b. Must be able to extinguish wicks when the telescoping is compressed	1. a. Light a candle, and wait 10 minutes until the wick is in a well-lit state b. Put the snuffer over the wick for 2 seconds to extinguish it c. Lift up the snuffer and check if the wick is extinguished d. Repeat above steps many times to establish an error rate with data e. Repeat above steps with different wick sizes, and with telescoping compressed

2.4.5 Arc Lighter

The arc lighter will be the component that lights the wick of the candle. It does this by creating an electric arc that can ignite wicks. This will be at high volts so precautions must be observed while testing.

Requirement	Verification
1. Must be able to light wicks of diameters between 1/16 inches and 1/8 inches with at least a 90% success rate	1. Set up a large resistor between leads of output and apply voltage to verify that High voltage will occur. 2. Set up a wick with diameter 1/16 inches, away from other materials. a. Position the arc lighter with terminals on either side of the wick. b. Apply voltage across the arc lighter for 3 seconds. c. Remove the arc lighter and visually confirm that the wick was lit. d. Extinguish the wick, then repeat using a wick with a diameter of 1/8 inch. e. Repeat above steps many times to establish a success rate with data

2.5 Schematic

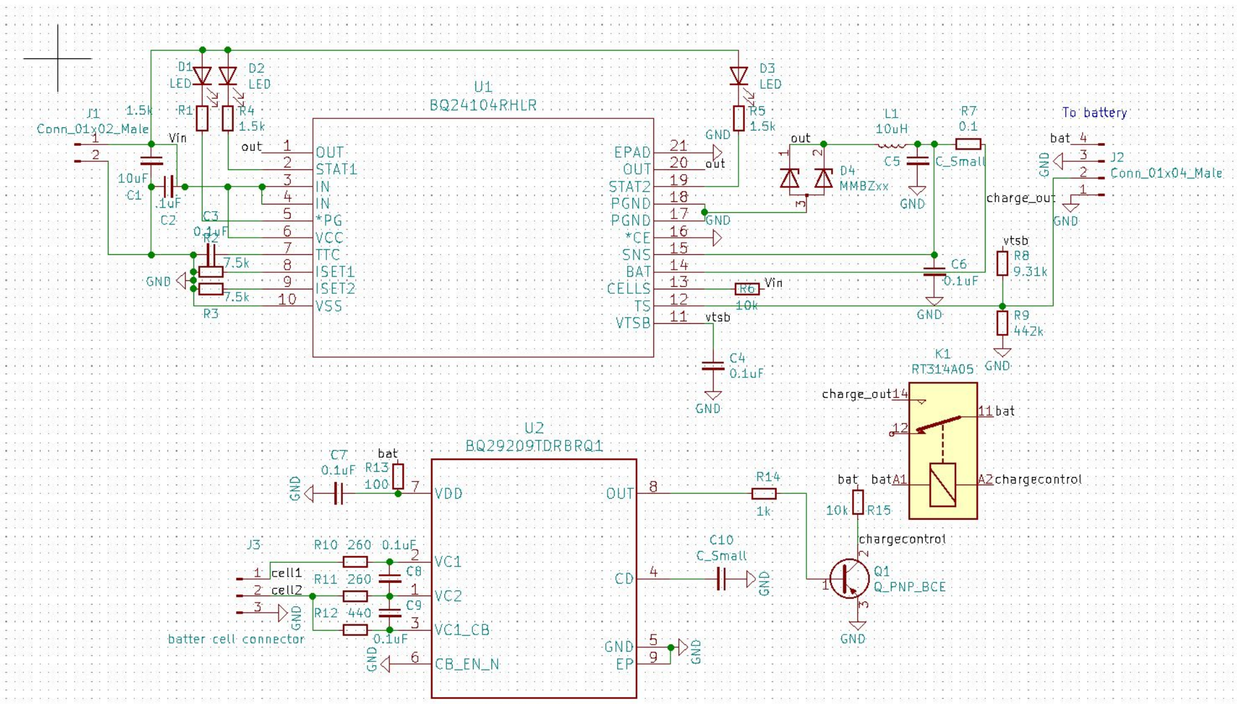

Figure 3. Battery Charger Circuit

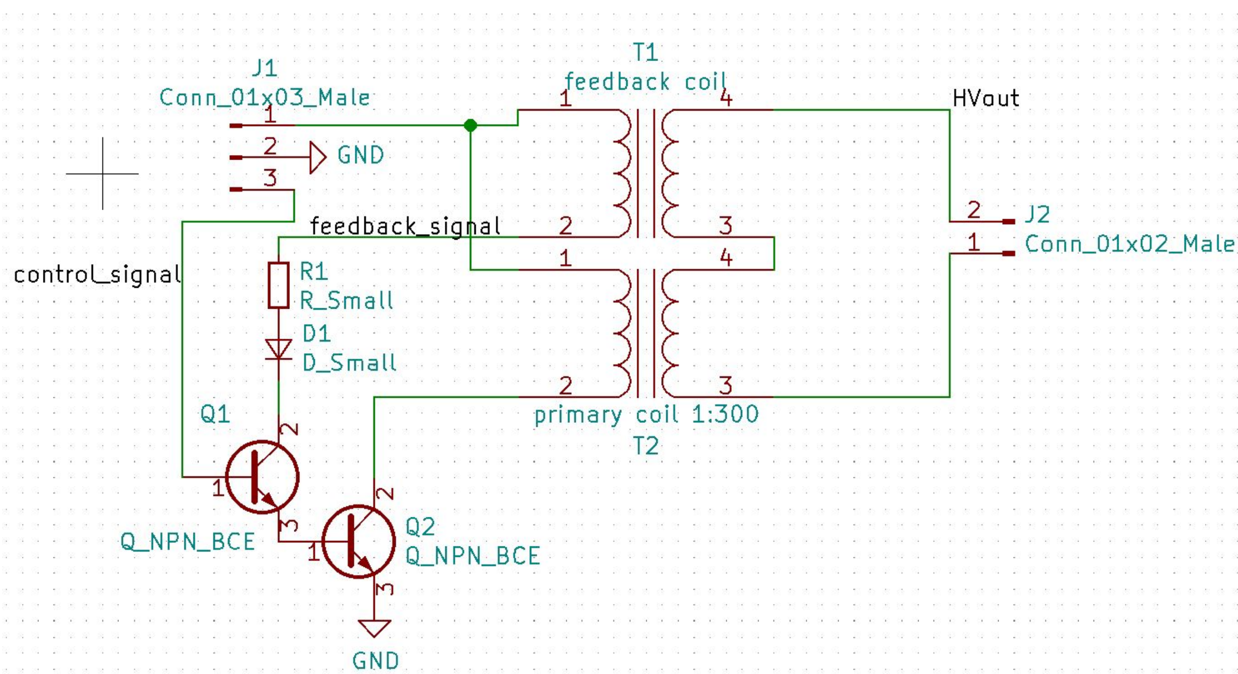

Figure 4. Arc Lighter Circuit

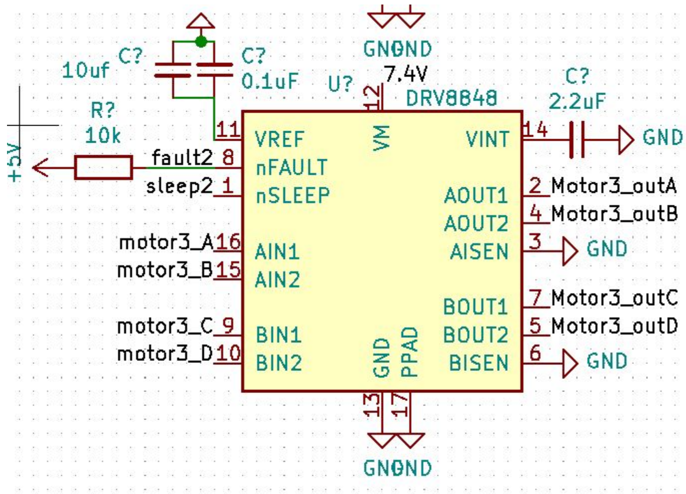

Figure 5. Motor driver

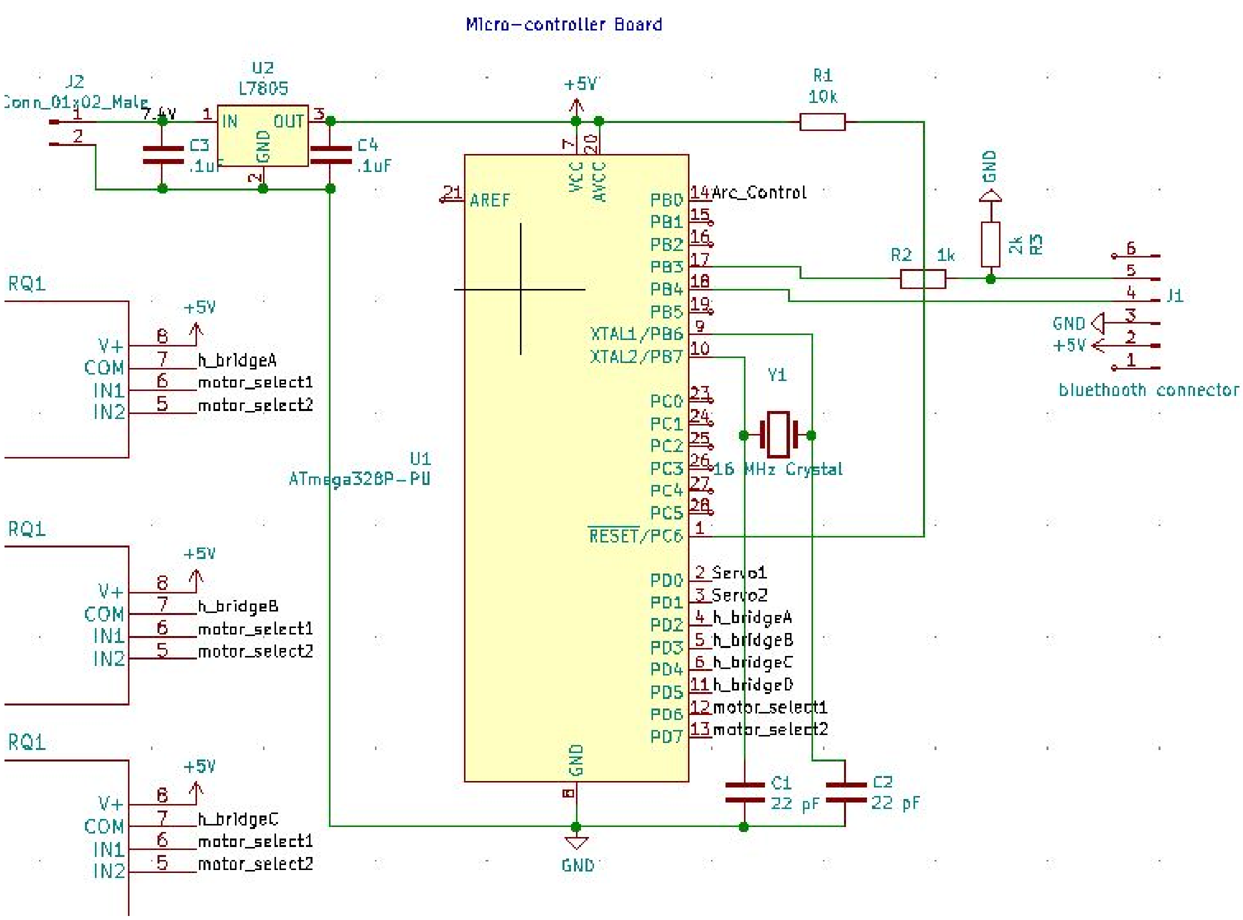

Figure 6. Microcontroller

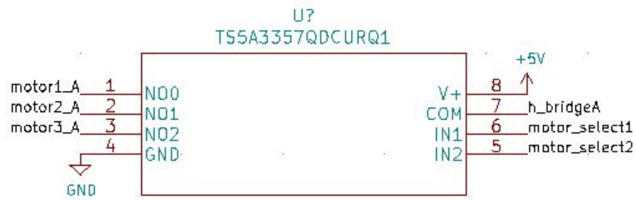

Figure 7. 3:1 Mux (Motor Select)

2.6 Tolerance Analysis

Automatically locating the position of the wick to light and extinguish it is central to this project. It is also the part which is most likely to cause the project to fail. However, given the tolerances of our motors and a couple extra design decisions, we are ensuring our ability to consistently find the position of the wick.

At the beginning of the lighting or snuffing phase, we are assuming that the camera is located directly above the candle wick. We are allowed to make this assumption, because the user is responsible for setting the candle wick position on their phone, and must verify that the camera has been centered over it before the device can be activated. We can also use some basic image processing to fine tune this positioning.

With the camera initialized directly over the wick, we begin the lighting process. First, we must adjust the length of the horizontal arm by a fixed amount of 1.25 inches. This will center the lighter where the camera was centered initially, which is directly above the wick. The motor that we are using for the horizontal driver is a stepper motor with 1.8° steps, which means it is accurate within 0.000315 inches. The arc lighter we are using is 0.1 Inches across, which means that the wick will necessarily fall under our arc lighter, as long as our distances are calibrated correctly.

With the horizontal position of the wick found fairly easily, we must also determine how far down the arm must lower in order to light the wick. After the lighter has been positioned over the wick, the camera has changed viewing angles. By comparing the views, we can compute the height of the wick. In the diagram below, P1 is the original position of the camera, P2 is the new position of the camera, P3 is the position of the wick, P4 is the farthest point on the table which camera can see from P2, and P5 is the point on the table directly below P2. h1 is the height of the camera, and h2 is the vertical distance from the candle to the wick. The distance between P1 and P2 is 1.25 inches. The angle between P4 and P5 is 12.5 degrees, which is half of the FOV of the camera[7]. The angle between P3 and P5 is given as θ.

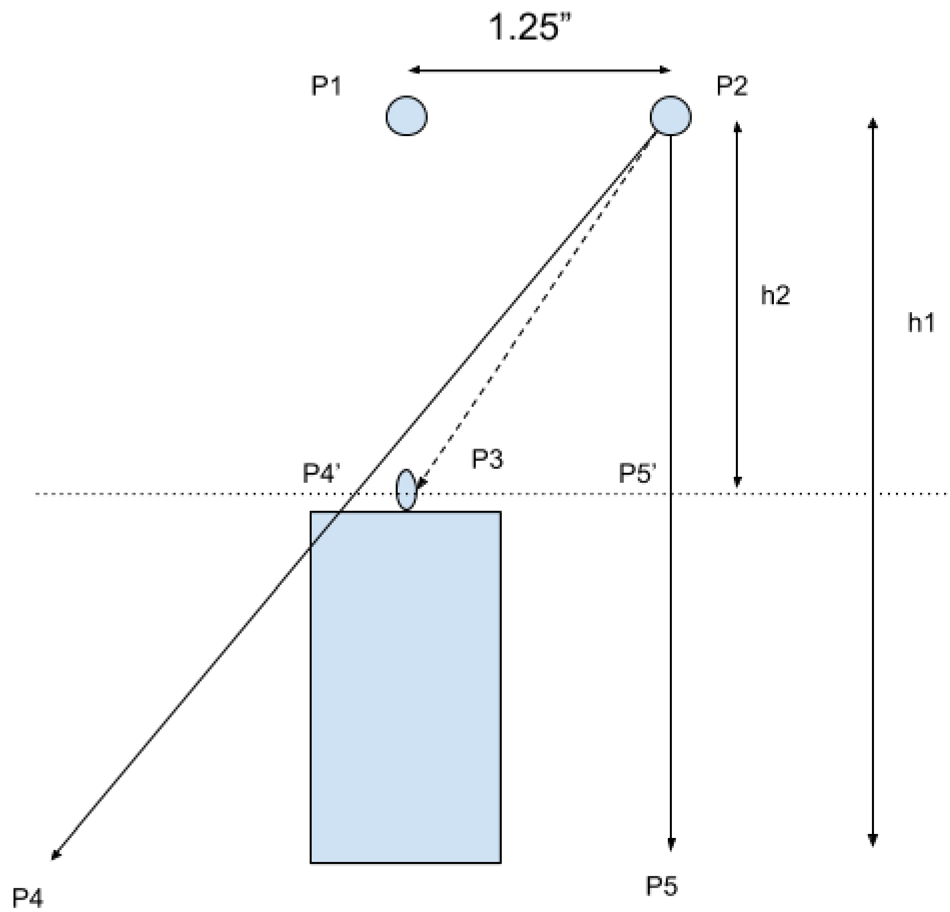

Figure 8. Camera Height Prediction Diagram

We need to solve for h2. Using the horizontal line drawn through the center of the candle wick, we can express this as:

(1) $h_2 = \frac{1.25}{tan(\theta)}$ inches.

This is a good start, but the camera only knows the position of the wick in terms of pixels, not by its angle. In order to get θ, we must also use the triangle formed by P4' and P5', which are the projections of P4 and P5 onto the horizontal line through the wick. Using these points, we can compare them as:

(2) $\frac{h_2\, tan(12.5°)}{h_2\, tan(\theta)} = \frac{320}{x}$

Where x is the number of pixels that the wick is away from the center of the new camera frame. 320 is used because the image is 640 pixels wide[7], and we are only looking at half of this width. This equation simply compares the ratios in inches to the ratios in pixels. Rearranging this for convenience gives:

(3) $tan(\theta) = \frac{x\, tan(12.5°)}{320}$

Substituting back into the original equation for h2 gives us:

(4) $h_2 = \frac{1.25}{\frac{x\,tan(12.5°)}{320}} = \frac{320\,(1.25)}{x\,tan(12.5°)}$

To perform the tolerance analysis for our heights predictions, we need to check the range of possible x values. The immediate upper limit is 320, since the image from our camera is only 640 pixels wide. The lower limit is determined by the smallest candle that our system allows. For simplicity, we will perform this analysis on a candle which is 0" tall. This means that h2 = h1 = 12", so solving for x in the last equation gives

(5) $x_{min} = \frac{320(1.25)}{12\,tan(12.5°)} = 154$ pixels.

Let $\widehat{h}_2$ be the predicted vertical distance to the wick, so the height error h_e is given by the equation:

(6) $h_e = |\widehat{h}_2 - h_2| = |\frac{320(1.25)}{\widehat{x}\,tan(12.5°)} - \frac{320(1.25)}{x\,tan(12.5°)}| = |\frac{320(1.25)}{(x+x_e)\,tan(12.5°)} - \frac{320(1.25)}{x\,tan(12.5°)}| = |\frac{-x_e}{x\,(x+x_e)}|\,\frac{320\,(1.25)}{tan(12.5°)}$

Where $\widehat{x}$ is the interpreted pixel displacement of the wick, and x is the real pixel displacement of the wick, and x_e is the difference between them.

Our system allows for a vertical error of 1", thanks to the telescoping appendages that house the lighter and extinguisher. To do this, we always lower 1" further than the calculated height. In the worst cases, the appendage doesn't telescope or it telescopes the full 2".

Evaluating for $h_e \leq 1$, with $x_e > 0$, we see that:

(7) $\frac{tan(12.5°)}{320\,(1.25)} \geq \frac{-x_e}{x\,(x+x_e)}$

We know that $x > 0$ and $x + x_e > 0$, so we can rearrange a little further to get:

(8) $\frac{tan(12.5°)\,(x^2 + x\,x_e)}{320\,(1.25)} + x_e = \frac{tan(12.5°)\,x^2}{320\,(1.25)} + \frac{tan(12.5°)\,x\,x_e}{320\,(1.25)} + x_e = \frac{tan(12.5°)\,x^2}{320\,(1.25)} + (\frac{tan(12.5°)\,x}{320\,(1.25)} + 1)\,x_e \geq 0$

(9) $(\frac{tan(12.5°)\,x + 320\,(1.25)}{320\,(1.25)})\,x_e \geq \frac{tan(12.5°)\,x^2}{320\,(1.25)}$

(10) $x_e \geq \frac{tan(12.5°)\,x^2}{tan(12.5°)\,x + 320\,(1.25)}$

If x_e is negative, then the result is similar:

(11) $x_e \geq \frac{tan(12.5°)\,x^2}{320\,(1.25)} / (\frac{tan(12.5°)\,x + 320\,(1.25)}{320\,(1.25)}) = \frac{tan(12.5°)\,x^2}{tan(12.5°)\,x + 320\,(1.25)}$

These are symmetrical, so we can simply look at the positive case. Plotting it gives the following graph:

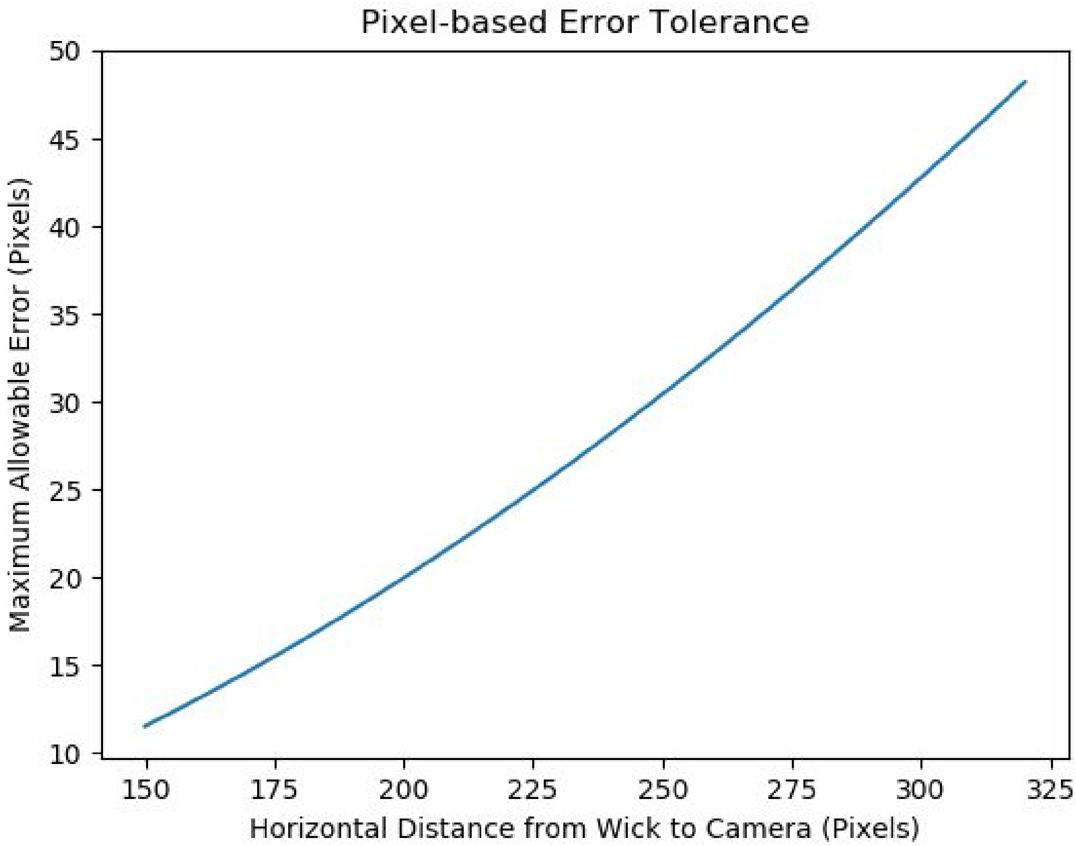

Figure 9. Pixel-based Error Tolerance Values

In the most conservative case, we are allowed at least 11 pixels of error before we risk missing the wick entirely, and the allowable error quickly grows. Our user interface will require the user to highlight an area with radius 10 pixels, which should ensure that we always fall within our allowable error bounds.

3 Project Differences

3.1 Overview

This project is an attempt to redesign a solution to a previously addressed problem. In a previous semester, a senior design team attempted to find the solution to unattended candles by designing a system to automatically extinguish candles after a set timeout. Their approach was to seal the candle, thereby starving it of air and causing it to extinguish itself.

We thought that the scope of this solution seemed too narrow, so we decided to try and find a solution that would work for a wide variety of candles, not just jar candles. The best way we could think of to accomplish this was to use a traditional snuffer, but add all of the sensors and motors necessary to make it work automatically. Because the action of snuffing and lighting a candle is very similar, we realized that our solution could also allow the user to automatically light a candle, given that certain safety measures are enforced.

The big tradeoff here is that our approach has a lot more moving parts and is obviously going to be more expensive. There is also a safety tradeoff, since we are now looking at igniting candles, not just snuffing an already lit candle.

3.2 Analysis

Our design is a clear improvement when it comes to scope. The solution that the previous team proposed requires that you use a specific type of candle. This limits the user base, since people who buy this system are expected to already own candles. People who own different types of candles, won't be able to use the previous team's approach. On the other hand, our system is designed specifically to accomodate all kinds of candles, limited mostly by size but not shape.

The previous approach is also limited in scope when it comes to the functionality of the project. It is only designed to put out candles, whereas our design is meant to ignite candles as well. We also designed this system with the intention that the user can control it from their phone, for ultimate convenience and feedback. A flame sensor can always alert the user if the candle has gone out unexpectedly, or if something went wrong when trying to light or snuff the candle.

The previous design did offer convenience in the way that it allowed the user to set a timer for the candle. However, we can also allow the user to set a timeout through the Android application. Further, we can allow the user to change the timer or immediately snuff the candle through the app. And, to ensure candle safety is followed, our system is meant to automatically snuff the candle when the user leaves bluetooth range. This is meant to accommodate the candle safety rule that you should always be in the room when burning a candle [1].

4 Cost and Schedule

4.1 Cost Analysis

Our fixed development costs are estimated to be $40/hour, 10 hours/week for 3 people. We consider approximately 70% of our final design this semester (16 weeks), neglecting the water pump:

$$3 \bullet \frac{\$40}{hour} \bullet \frac{10\ hours}{week} \bullet \frac{16\ weeks}{0.7} \bullet 2.5 = \$68,571.43 \quad (12)$$

Part	Cost (prototype)	Cost (bulk)
Bluetooth Module (Amazon; B071YJG8DR)	$7.99	$7.99
Camera Module (Amazon; B00TKXAGZM)	$10.99	$10.99
Flame Sensor Module (Newegg; 9SIAAZM4GR8884)	$1.99	$1.99
Microcontroller (Digikey; ATMega 328P-PU)	$2.08	$1.73
Large Stepper Motor (Amazon; Stepperonline Nema 17 Stepper Motor Bipolar 2A 59Ncm)	$15.99	$15.99
Small Stepper Motor (x2) (Amazon; Stepperonline Short Body Nema 17 Bipolar Stepper Motor 1A 18.4oz.in)	$27	$27
Battery (PRT-11856)	$15.95	$15.95
Assorted resistors, capacitors, ICs, crystals, sockets (Digikey;est.)	$20.00	$1.00
Mechanical Components and Housing	$50.00	$10.00

The estimated cost of our prototype is $141.99, so the estimated development cost is $68,713. If we were to produce a large number of such devices, the bulk pricing options we could find would bring this down to $92.04 per unit. This would lower substantially if we are able to get bulk prices on motors.

4.2 Schedule

Week	Anders	Armando	Kevin
1	Research and order power components	Research and order motor and mechanical components	Research and order sensors and microcontrollers
2	Verification of power system	Verification of motors	Collect code for testing components
3	First round of PCB design and ordering	Assemble first prototype of arm assembly	Verification of all sensors and microcontroller
4	Verification of lighting and snuffing subsystems	Verification of arm assembly and motion	Write code for the microcontroller's control flow
5	Second round of PCB ordering and design with continued testing of systems	Assemble first prototype of arm housing	Write code for android application
6	Final verification of power subsystems	Verification of full system using candles.	Begin collating data for Final Report
7	Verification that high level requirements were all met	Generate plots for final report and presentation	Ensure that verification for all components was completed
8	Prepare final presentation	Prepare final presentation	Prepare final presentation

5 Ethics and Safety

5.1 Safety

This project has little danger alone, but it is meant to be used with candles, a common household item that presents danger to both property and person. We will analyze the safety of our project when attached to a candle to get the most realistic sense of our project's hazards and how we combat them.

Candles have open flames in all types. Although jar candles and certain candle holders reduce the danger of this flame, they hold the same open flame hazards as other types. This flame can cause home fires. The National Candle Association has safety guidelines directed at customers to prevent many hazards associated with candles. We help address the crucial NCA guidelines [3], “do not burn a candle for longer than four hours and cool for at least two hours before relighting”, and , “never leave a burning candle unattended.” If a candle is on for too long, it’s flame becomes large and hot, leading to combustion of the table it rests on, or nearby flammable items. Our project has timers that will automatically put out candles after 4 hours. This both stops the candle from getting too hot, and ensures the candle is put out after four hours, reducing the dangerous consequences of forgetting about a lit candle. We also will put a timer on the candle that doesn’t allow it to be re-lit by our project until 2 hours have passed after it was last put out. Another cause of fires is the method of extinguishing the candle. Most people blow out candles with air. This is not safe due to the possibility of blowing the hot wax onto something flammable. We follow the NCA recommendation, “Usa a candle snuffer to extinguish a candle.” Our project uses a small snuffer to extinguish candles.

Open flames can also injure people directly when lighting and extinguishing a candle. Even when following the NCA guidelines of using long lighters or matches [3], a user could still burn themselves by accidentally touching the source of ignition on the lighter. People could also burn themselves on a snuffer since the snuffer usually gets hot when extinguishing a candle. Our project eliminates all that risk igniting the candle automatically with an arc lighter attached to a robotic arm. The user only needs to press a button to ignite the candle remotely, eliminating proximity of the user to the flame or heat. Another risk of injuring when using candles is the heating up of the candle holder during usage. Our project does not directly address this since the point of a candle is to heat wax and provide light. This safety will be left to the user to follow NCA guidelines.

Our device uses an electric arc lighter to ignite a candle wick. This leads to a shock hazard if a user touches the arc of the device when in use. We will address this by including warnings to keep away from the candle wick during ignition. We also will not start the arc lighter until it is in position to ignite the wick.

There is a danger associated with the moving arms of the device. They can knock over nearby objects and things can get caught in the spinning motors. We will address this by having all motors moving at very slow speed, and having covers. We will also limit the amount of required proximal clearance the device needs to operate.

5.2 Ethics

This project has ethical considerations dealing with its function of improving safety. This project claims to reduce the risks of using candles by both eliminating the direct user interaction with the flame, and by providing a safeguard against the dangers presented by forgotten lit candles. This can lead to violations of 2 different IEEE codes of ethics, #3: “to be honest and realistic in stating claims or estimates based on available data;” [4], and #9: “to avoid injuring others, their property, reputation, or employment by false or malicious action;” [4]. Addressing #3, our claims can easily be overstated to be the all inclusive candle management system which requires no oversight. This also addresses #9. These claims can give people the impression that they are completely safe if they just use our project. This can lead to potential injury and damage by false impressions. We will ensure that claims are clearly stated. We will emphasize that candles still require oversight, and are dangerous when used improperly. We will also reference the NCA guidelines throughout our user manual and packaging to promote safe candle usage.
There is a danger associated with the moving arms of the device. They can knock over nearby objects and things can get caught in the spinning motors. We will address this by having all motors moving at very slow speed, and having covers. We will also limit the amount of required proximal clearance the device needs to operate.

6 References

[1] “Candles,” *NFPA*. [Online]. Available: https://www.nfpa.org/Public-Education/Fire-causes-and-risks/Top-fire-causes/Candles. [Accessed: 04-Apr-2020].

[2] “Candlewatch Chrome Automatic Candle Extinguisher,” *Amazon*. [Online]. Available: https://www.amazon.com/Candlewatch-Chrome-Automatic-Candle-Extinguisher/dp/B006VYGEZ4/ref=cm_cr_arp_d_pdt_img_top?ie=UTF8. [Accessed: 03-Apr-2020].

[3] “Fire Safety & Candles,” *National Candle Association*, 2019. [Online]. Available: https://candles.org/fire-safety-candles/. [Accessed: 04-Apr-2020].

[4] “IEEE Code of Ethics,” *IEEE*, 25-Nov-2019. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 13-Feb-2020].

[5] “LiPo battery Safety safety - It’s worth your effort” [Online]. Available: https://www.helidirect.com/blogs/news/lipo-battery-safety-its-worth-your-effort.[Accessed: 06-Apr-2020].

[6] OSM Technology Staff, *Nema 17 Hybrid Stepper Motor*, Stepper Online, 2006. [Online]. Available: https://www.amazon.com/STEPPERONLINE-Stepper-Bipolar-Connector-compatible/dp/B00PNEQKC0/ref=sr_1_2?dchild=1&keywords=stepperonline+Nema+17+stepper+motor+bipolar+59Ncm&qid=1587182472&sr=8-2. [Accessed: 17-April-2020].

[7] Market, O., 2020. *OV7670 300KP VGA Camera Module Compatible With Arduino By Atomic Market*. [online] Atomic Market. Available at: https://www.atomicmarket.com/products/ov7670-300kp-vga-camera-module-compatiable-with-aurdino-by-atomic-market [Accessed 18 April 2020].