ECE 445 Spring 2019

OptiCane

Design Document

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1. Introduction

1.1 Objective

In 2016, it was estimated that 7,675,600 people between the ages of 16 and up suffer from a visual disability[1] and globally 36 million people are estimated to be blind[2]. As a result, many resort to using sighted guides, seeing eye dogs, white canes, or, in some cases, their remaining vision.

In a 2011 study conducted at the University of Santa Cruz, more than 300 legally blind or blind individuals were surveyed on the frequency of head and fall injuries. Of the entire sample group, 266 reported having experienced some type of fall injury[3]. The study suggests that the main causes for fall accidents can be attributed to unexpected obstacles or misjudgement of distances and angles [3].

Our proposed solution will enhance the user's interaction with the environment by utilizing sensors and haptic feedback to detect both the distance and size of an object while maintaining the same operation of the traditional white cane. By enhancing the original design of a white cane, we intend to allow the user who may be familiar with how to use a white cane to have a better understanding of his or her surroundings without a much greater learning curve.

1.2 Background

Although reliable, seeing eye dogs are estimated to cost anywhere up to $50,000[3] and are not covered by health insurance. In addition to their high cost, such companions require several years of training and other overhead costs associated with them. Sighted guides are required to be trained by licensed specialists and are either typically family members or volunteer based. With the white cane, the user has independence while travelling and can still develop a meaningful sense for the environment around him or her. Additionally, white canes help others around the user identify that he or she is visually impaired through its globally recognized design.

Current issues with the standard white cane are that it limits the user's ability to identify key features of the environment through strictly tapping, swinging, and moving the cane's tip against surfaces. Another issue that the traditional white cane has is that it is not as easy for it to identify the relative size or maneuverability of an object without audio cues (i.e. a hallway).

1.3 High Level Requirements

A. Each of the cane's sensors must be able to detect an object within 0 and 1.2 meters from itself. Additionally, the cane must be able to detect objects between 0 and 0.7 meters in vertical height with respect to the cane.

B. The power source must allow the OptiCane to have an operating time of at least 3 hours.

C. The feedback mechanism must vibrate with intensity corresponding to the detected object distance and with a pattern corresponding to the uppermost sensor which detects the object.

2. Design

Functional Overview

The final white cane assembly will be comprised of sensors, a microcontroller, and haptic feedback to the user. The LIDAR sensors mounted along the shaft of the cane will be detecting for obstructions that enter their respective field of view and will relay that information to a central microcontroller. After receiving the sensor data, the microcontroller will then process an appropriate haptic feedback to relay to a vibration motor that is fixed to a wearable bracelet for the user. The vibration in the motor will have an associated intensity and pattern depending on the distance between the sensors and the height of which sensors are detecting an object. For example, if an object is 0.2 meters away horizontally from the lowest sensor on the cane and the second sensor spaced above it also detects an object, the vibrating motor will have 2 pulsed vibrations at a respective intensity.

The walking stick will require four separate modules in order to function: the power supply, control unit, feedback module, and sensor module. This modular design will satisfy our high level requirements described in Section 1.3 above. With the microcontroller connecting all modules together and acting as the “brain” of the project, the necessary information will be taken from the laser sensor array and used to create an intuitive feedback system. A removable battery will power all components, and a single pole single throw (SPST) switch will allow the stick to be powered on and off. This will allow for a versatile, lightweight walking stick and wearable bracelet combination for the user.

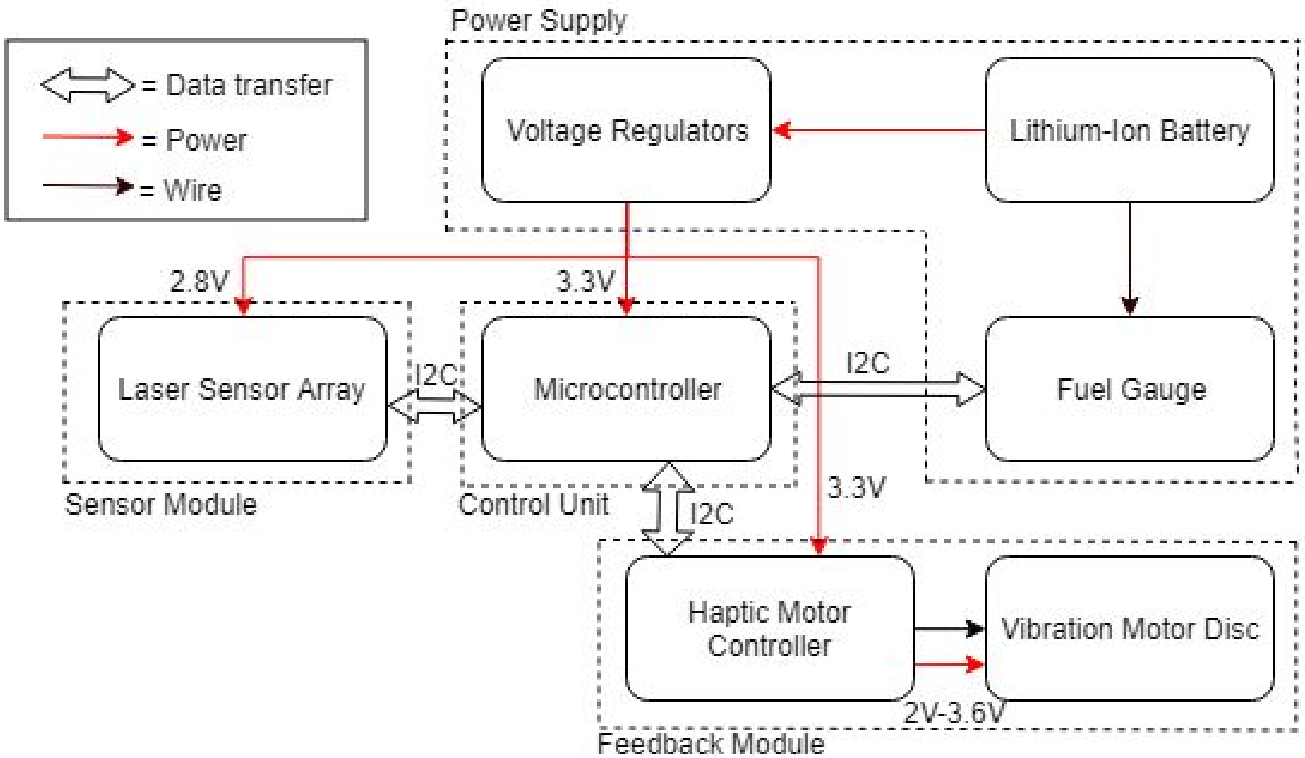

Figure 1. Block diagram for the OptiCane.

2.1 Power Unit

The purpose of the power unit is to supply the voltage required by each component of the design, such as the microcontroller, the sensors, and feedback module.

2.1.1 Lithium-Ion Battery

A 9V, 600 mAh Li-ion battery will be used to power all hardware components that go into the walking stick and bracelet. A T-clasp wire connector will be used to connect the battery, which will allow the battery to be easily removable from the stick for either replacement or recharging. The use of a battery to power the walking stick will allow greater mobility for the user.

2.1.2 Voltage Regulator

To regulate the amount of voltage the devices in each module, we will use several linear IC linear voltage regulators to provide a constant, fixed voltage to meet the power requirements for each device. In this way, we will prevent unstable voltage inputs that could create inefficiency and/or damage in our project. We plan on using several voltage regulators that will output 2.8V for our sensors and 3.3V for our motor controller as well as our microcontroller.

2.1.3 Battery Fuel Gauge

To monitor the power provided by the battery, we will use a lithium battery fuel gauge to ensure that the user will be notified when the power falls below a certain threshold. A 9V battery is considered to be discharged when it reaches 60% of its rated voltage, which would be 5.4V. When the battery discharges to this level, the fuel gauge will communicate with the microcontroller via I2C and send an alert. The microcontroller will then tell the motor driver to use a long vibration pattern to indicate to the user that battery power is running low.

2.2 Control Unit

The control unit of the project will consist of the microcontroller and all software components of the project. Data will be transferred to and from the microcontroller through I2C protocol for the sensor array as well as the motor driver.

2.2.1 Microcontroller

The control unit consists of the microcontroller, which will receive the necessary information from the sensors and, based on that information, will send the appropriate signals to the motor driver that control the vibrating discs for haptic feedback. We will implement the ATmega328 as the microcontroller in our project, which has support for I2C communication. The ATmega328P has 2 kB of SRAM and 32 kB of flash memory. We will be running the microcontroller at 3.3V and with a 11 MHz crystal oscillator.

2.3 Feedback Module

The feedback to the user will be given through the use of a wearable bracelet. The bracelet will contain a vibrating motor disc that will give feedback based on differing vibration intensities, as well as different vibration patterns. The vibration intensity will indicate the distance of the object from the user in that the vibration intensity will increase as the user moves closer to the object. Different vibration patterns will indicate which sensor along the stick detects an object, which will allow the user to get a rough estimate of the height of the object.

2.3.1 Haptic Motor Controller

This motor controller will communicate with the microcontroller via I2C protocol. The motor controller will allow for finer control over the vibration disk's vibration intensity as well as other vibrating effects that we may implement to improve user feedback. The motor driver will operate on a breakout board. The motor driver will also supply a varying voltage from 2V-3.6V to the motor disk in order for the disk to provide the necessary varying vibration intensities for feedback.

2.3.2 Vibration Motor Disk

The vibration disk will be contained within a wearable, waterproof bracelet to provide the user with the appropriate vibration pattern and intensity to indicate the object distance and height.

Sensor Number Starting from Bottom of Cane to Top	Vibration Pattern
1st sensor (bottom)	A single vibration separated by a pause.
2nd sensor	Two vibrations in quick succession separated by a pause.
3rd sensor	Three vibrations in quick succession separated by a pause.
4th sensor (top)	Four vibrations in quick succession separated by a pause.

Table 1. Sensor's corresponding vibration pattern for haptic feedback.

2.4 Sensor Module

The laser sensors we plan on using will be spaced along the walking stick, all facing in the same direction and angled outwards from the stick. Each sensor on the stick will correspond to a certain vibration pattern, which will give the user the pattern when an object is detected by that particular sensor. In this way, the user can get a rough estimate of the height of the object to determine whether the object can be stepped over or if they should walk around the object. The sensors includes a self contained microcontroller that analyze analog inputs from the optical sensor and outputs to pins via I2C protocol. Therefore we do not have to worry about technical details such as memory constraints.

2.5 Risk Analysis

The haptic feedback would be the most significant risk to the operational success of this product. The system governing the haptic feedback must be able to receive and process the information being relayed from the sensor data in order to appropriately determine the correct vibration patterns and intensities that will be given to the user as an object within detectable range. If the haptic feedback were to fail, the user would still be able to operationally use the white cane in its traditional sense, however the risk of not being able to detect objects will arise.

Ways in which the haptic feedback can fail are if the sensors do not respond correctly, the microcontroller does not correctly process the sensor data, or if the vibration motors do not operate correctly. In order to prevent this, we need to construct the proper housing for all wiring in order to protect the connections of the sensors and vibration motors to the microcontroller. Traditional white canes are constructed with with either fiberglass or aluminum, as their respective tensile strengths can withstand the impacts that the cane experience through its intended use. We plan to explore both of these materials as well as other options to maintain the durability and safety of the electrical devices we plan to use.

As previously mentioned, faulty sensors can also lead to inaccuracies in detection and haptic feedback delivered to the user. Each sensor will have to be tested for its range detection and its field of view in order to determine their associated tolerances as outlined in their datasheets. The vibration motors are also to be tested for their ability to have different settings based on various applied voltages in order to maintain consistent feedback for the proximity of the objects detected to the user.

2.6 Physical Design

Figure 2. 3D rendering of white cane assembly with wearable bracelet.

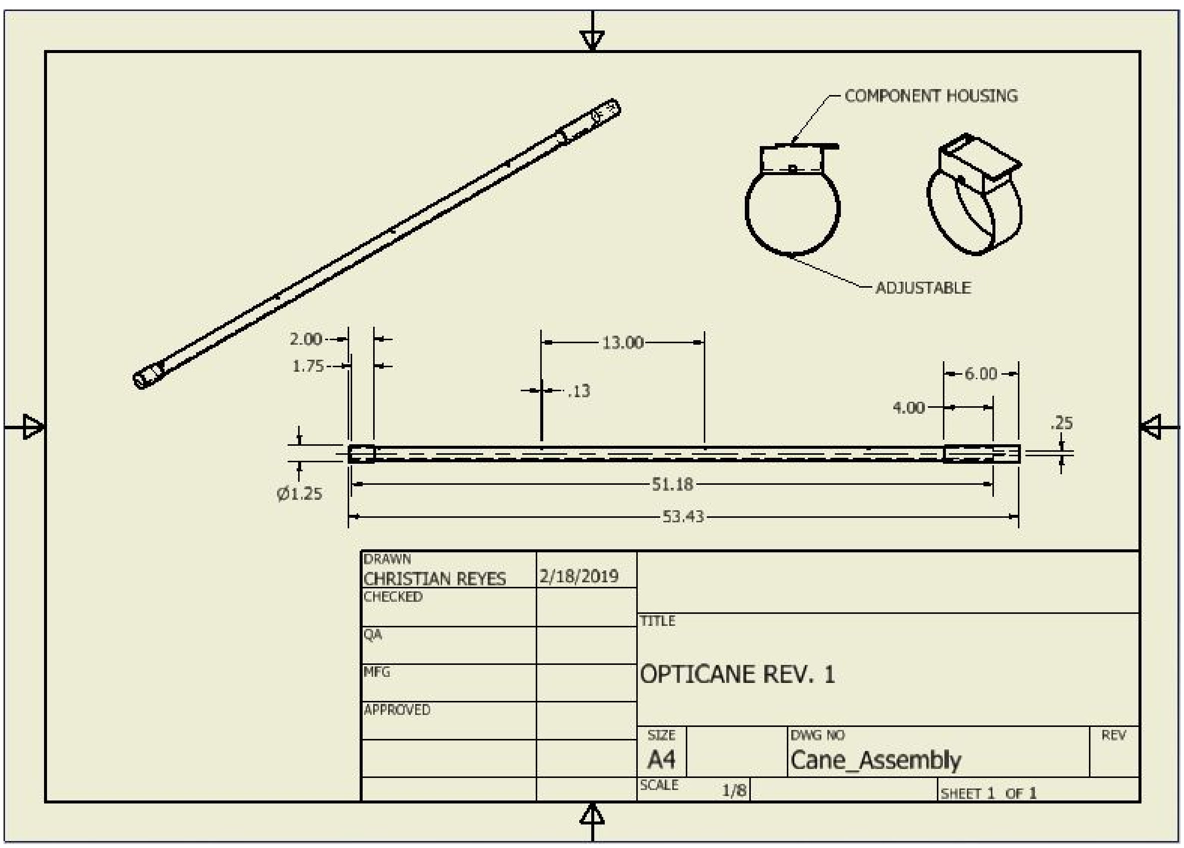

Figure 3. Dimensioned drawing of the cane assembly.

The physical design of the cane will be composed of an aluminum body with a plastic tip and rubberized handle. The wearable bracelet will house both the motor driver and the motor disc and will be connected to the other electronics though wiring. The bracelet will be constructed from waterproof fabric and will also be adjustable for the user through velcro straps.

2.7 Circuit Schematic

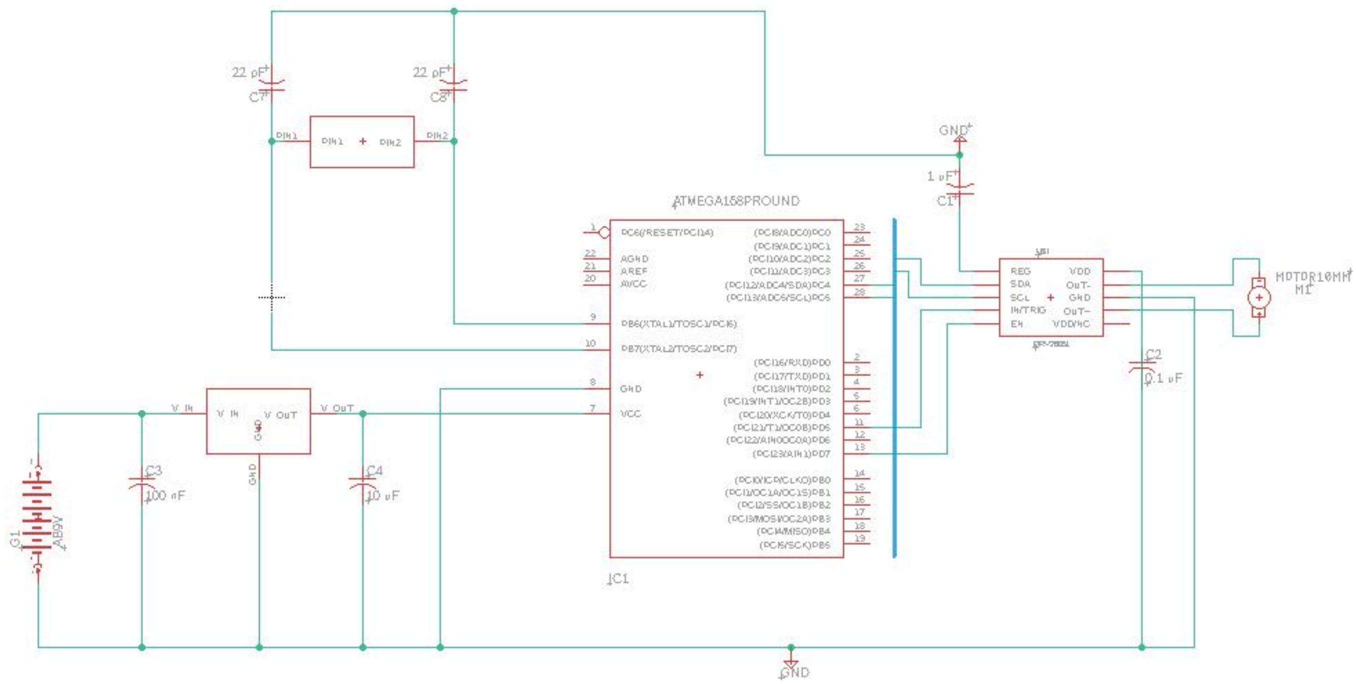

Figure 4. Main circuit schematic.

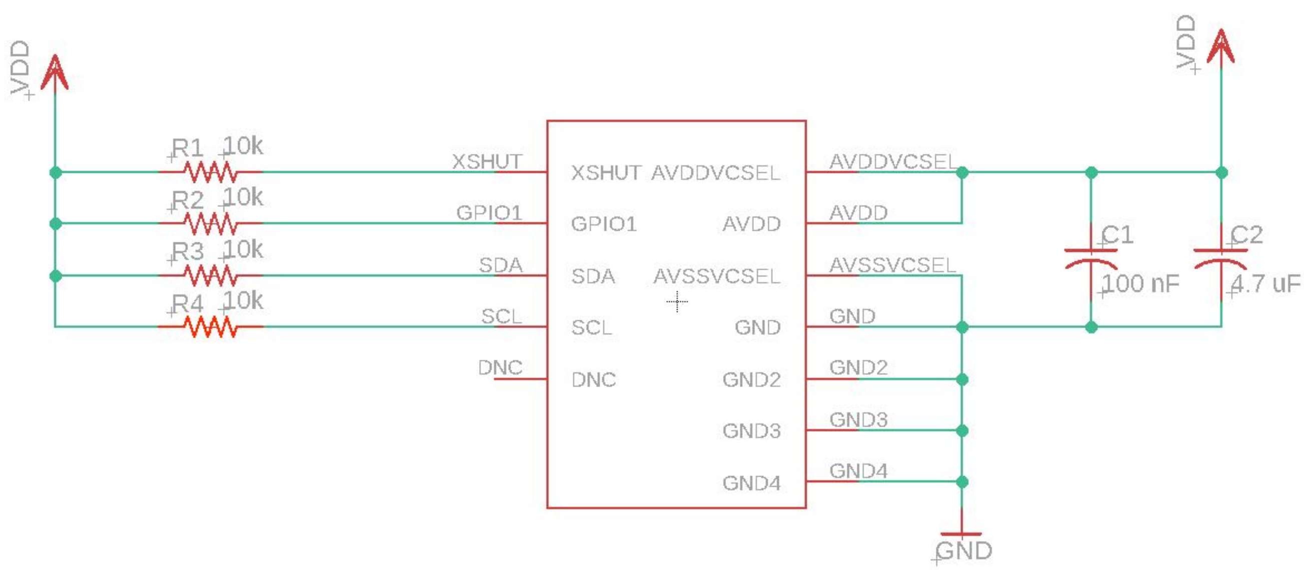

Figure 5. LIDAR sensor breakout board circuit schematic.

In Figure 4, the power supply, voltage regulator, crystal oscillator, microcontroller, haptic motor driver, and vibrating motor disk are shown. The power source that is present will be supplied by a 9V, 600mAh battery which will be controlled by a throw switch to allow the circuit to be powered on and off. The 9V from the battery is passed to a 3.3V voltage regulator, which will power the ATmega328p chip, haptic motor driver, and sensor array. Both the motor driver and the sensor array will communicate via the I2C bus that is coming from the ATmega328p's SDA and SCL pins.

In Figure 5, the schematic shows the connections necessary for breakout boards that will be mounted along the shaft of the white cane and contain each LIDAR sensor.

2.8 Software Flowchart

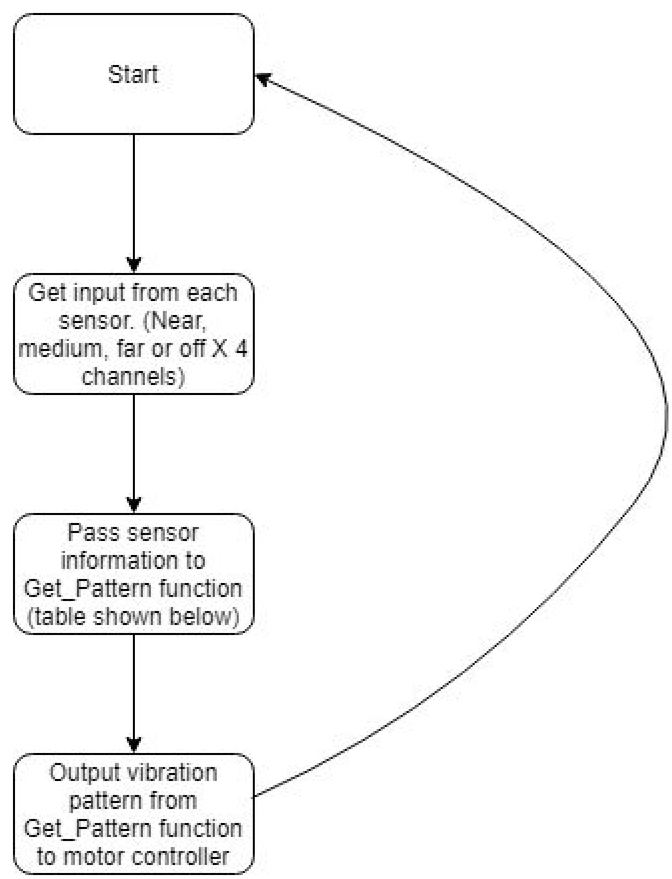

Figure 6. Software state diagram

The following chart shows the vibration patterns given the output from out sensors. The out of our sensors will be categorized into 3 distances: near, medium and far. The vibrations can take on 3 different intensities level 1-3, with 1 being the lowest and 3 being the highest intensity. These intensities will be controlled by the microcontroller outputting different voltages to the motor controller. The exact values of the distance ranges and vibration intensities will be determined after experimentation. The vibration pattern is played within half a second followed by a half second pause. These vibration patterns will distinguish between objects of different height and distance as well as stairs and curbs will objects behind them.

Sensor 1	Sensor 2	Sensor 3	Sensor 4	Vibration Pattern	Description of environment detected
Off	Off	Off	Off	No Vibration	No obstacle
Near	Off	Off	Off	1 short level 3	Near height 1 solid
Medium	Off	Off	Off	1 short level 2	Medium height 1 solid
Far	Off	Off	Off	1 short level 1	Far height 1 solid
Near	Near	Off	Off	2 short level 3	Near height 2 solid
Medium	Medium	Off	Off	2 short level 2	Medium height 2 solid
Far	Far	Off	Off	2 short level 1	Far height 2 solid
Near	Near	Near	Off	3 short level 3	Near height 3 solid
Medium	Medium	Medium	Off	3 short level 2	Medium height 3 solid
Far	Far	Far	Off	3 short level 1	Far height 3 solid
Near	Near	Near	Near	4 short level 3	Near height 4 solid
Medium	Medium	Medium	Medium	4 short level 2	Medium height 4 solid
Far	Far	Far	Far	4 short level 1	Far height 4 solid
Near	Near/Medium	Medium/Far	Far	5 short level 3	Near Stairs

Medium	Medium/Far	Medium/Far	Far	5 short level 2	Medium/Far Stairs
Near	Medium/Far	Off	Off	1 short level 3 then 1 long level 2	Near height 1 solid(curb) and Medium height 2 solid
Near	Medium/Far	Medium/Far	Off	1 short level 3 then 2 long level 2	Near height 1 solid(curb) and Medium height 3 solid
Near	Medium/Far	Medium/Far	Medium/Far	1 short level 3 then 1 long level 2	Near height 1 solid(curb) and Medium height 3 solid
Off	Near	Near/Off	Off	2 short level 3	Near height 2 table
Off	Medium	Medium/Far/ Off	Off	2 short level 2	Medium height 2 table
Off	Far	Far/Off	Off	2 short level 1	Far height 2 table
Off	Off	Near	Near/Medium /Far/Off	3 short level 3	Near height 3 table
Off	Off	Medium	Medium/Far/ Off	3 short level 2	Medium height 3 table
Off	Off	Far	Far/Off	3 short level 1	Far height 3 table
Off	Off	Off	Near	4 short level 3	Near height 4 table
Off	Off	Off	Medium	4 short level 2	Medium height 4 table
Off	Off	Off	Far	4 short level 1	Far height 4 table
Else	Else	Else	Else	# of short=highest sensor and level=closest distance sensed	Unknown environment

Table 4: Vibration patterns based on sensor output

2.9 Requirements and Verification

2.9.1 Power Unit

Requirements	Verification
Li-ion Battery : The battery should be able to provide the specified voltage for at least 3 hours while powering the Opticane.	Note: This requirement can only be verified after completing all other parts of the Opticane. 1. Attach the battery to the finished Opticane. Leave the Opticane on for 3 hours. 2. Probe the output of the 3.3V voltage regulator with a voltmeter. 3. This requirement is met if the voltmeter reads 3.3V(±5%)

2.9.2 Controller Unit

Requirements	Verification
Microcontroller interface: The microcontroller should be able to transfer I2C data from both the sensor array module and from the haptic motor driver at least 100 kbits/s according to I2C specifications.	1. Connect the sensors via the interface PCB to a pin on the ATmega328 chip. 2. Connect the vibration motors to the motor controller. 3. Connect the motor controller to a pin on the ATmega328 chip and power the motor controller with 3.3V (+/-0.3V). 4. Power the ATmega328 chip with a 3.3V (+/-0.3V) power supply. 5. Write and load a test code that reads from the sensor pins and write different level outputs onto the ATmega328 chip. 6. Run the code. 7. The requirement is verified when the console prints the sensors' outputs and the motors are vibrating at an increasing intensity.

2.9.3 Feedback Module

Requirements	Verification
Haptic motor and controller system: A: The haptic motor controller should be able to receive I2C data to the microcontroller at least 100kbits/s according to I2C specifications. The vibration motor should operate within a 2V-3.6V range, which will correspond to the intensity of the vibration we need for the user feedback. B: The feedback module must also be able to vibrate at predetermined patterns.	A: 1. Connect the motor controller to an output pin on the ATmega328 chip and power the motor controller with 2V-5.2V. 2. Power the ATmega328 chip with a 3.3V (+/-0.3V) power supply. 3. Write and load test code that writes different levels to the motor points onto the ATmega328 chip. 4. Run the code 5. The requirements are verified if the motors are vibrating at an varying intensity depending on the test code. B: 1. Change the code so that it supplies voltages at various patterns to the motor controller. Examples of patterns include 2 or 3 vibrations in quick succession followed by a long pause. 2. This requirement is met when the vibration motors correctly vibrate in the pattern specified by the code.

Requirements	Verification
Optical sensor array: A: The sensor array composed of 4 optical sensors should be able to detect objects within a FOV between 0 to 25 degrees. The sensor array should also be able to detect an object from 0 to 1.2m from each sensor and determine the distance of the object to each sensor.	All requirements: 1. Connect each sensor via the interface PCB and connect the PCB output to the microcontroller. 2. Connect each sensor to 2.8V±%5. 3. Load a test code which analog reads the outputs of the sensors and prints the

<u>B:</u> The sensor array must determine the relative height of the object based on how many sensors detect it with a tolerance of 1 more sensor up or down. <u>C:</u> The sensor array must correctly sense the location and range of an object with at least 90% accuracy	values of each sensor to the console with 33ms intervals 3. Place the sensor similar to the configuration shown in Figure 4 and in an open area of at least 2 m by 2 m. A: 1. Using a protractor or a compass to measure 25 degrees and mark two lines with masking tape from the sensor to 1 m(+-5cm) out in a V-shape with the sensor facing the center of the angle. Use a tape measure to precisely measure the distance. 2. The requirements are verified if the console reads different voltages when the test object enters and leaves the effective range. The range must be verified to be 1m(+-5cm). Also the outputs must correlate to the distance of the object from each sensor. B: 1. Move an object up and down in the effective range of the sensor array. 2. This requirement is met if each sensor outputs different values relative to the height of the object. It is within tolerance if the sensor above or below also reads the object. C: Using the data from part B, create 4 sections of vertical range depending on which sensors detect the object:height 1,2,3 or 4. Also create 3 sections of range depending on the distance from the array: near, medium or far. Place an object somewhere within the 1m and 25 degrees effective range and record if the output of the sensor array is correct with the actual placement of the object. Repeat for a large sample. This requirement is met if the sensor array is correct at least 90% of the time.

2.10 Tolerance Analysis

The component of our design that could potentially yield the most problems is connecting all of the slave devices to the master device (the ATmega328P microcontroller) and successfully communicating through I2C protocol. For the project, we plan on using 5 total slave devices for I2C protocol: the 4 laser sensors and the haptic motor controller. The master and slave devices transfer data and communicate through the SDA (serial data line) and the SCL (serial clock line). These lines are connected to ground through a transistor that acts as a switch. Because both SDA and SCL are open drain, pull-up resistors are needed to restore the lines high once they are pulled low. To prevent overheating, inefficiency, and damage to our devices, the pull-up resistors also need to have a high enough resistance to prevent a large current from going through the transistor controlling the SCL/SDA lines.

By looking at the I2C Specifications and User Manual, the maximum current possible across the SCL/SDA transistors is 3mA. Voltage drop across the transistors must also be limited with a maximum voltage of 0.4V for both standard and default modes of data transmission. We can use these maximum values as well as our I2C bus supply voltage value to calculate the minimum resistance needed to stay within the maximum current and voltage values. For our design, 3.3V will be used for the I2C bus supply voltage.

$$R_{min} = (V_{DD} - V_{max})/I_{max} = (3.3V-0.4V)/0.003A = 966.67\ \Omega$$

Therefore, the very minimum total resistance needed is 966.67Ω[6].

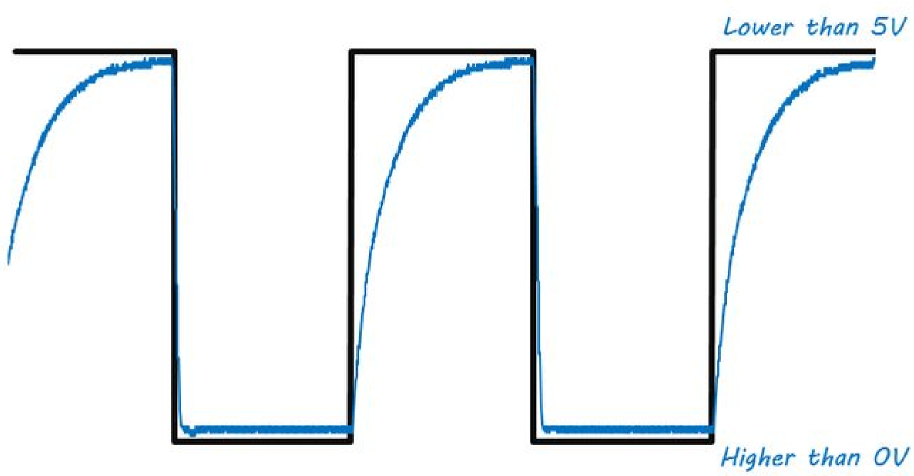

Figure 7. Good SCL/SDA model

The black signal represents an ideal digital signal caused by the transistor that acts as a switch across SCL/SDA and ground. The blue signal represents a good SCL/SDA signal that sweeps from 0V to 5V and fits within the ideal digital signal. This signal is when a proper pull-up resistor value is used and exceeds the minimum resistance to stay within the maximum voltage and current constraints for I2C[6].

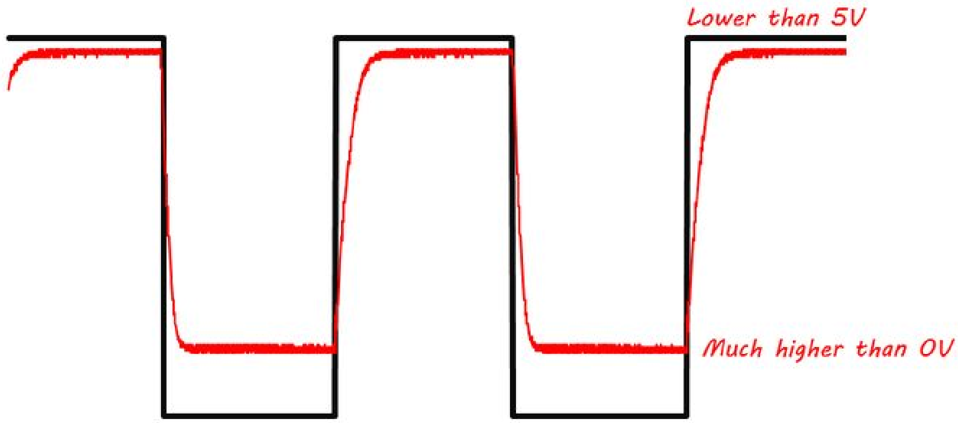

Figure 8. Poor SDA/SCL model

The red signal represents a bad SDA/SCL signal in that it does not sweep from 0V to 5V because the minimum pull-up resistance value has not been met.

Because we are planning on using breakout boards with resistors, all resistors on the breakout boards will be in parallel with each other, so the total resistance will be lowered and needs to be calculated to stay above the minimum resistance value of 966.67 Ω. The motor driver we plan on using has 2.2kΩ resistors on its breakout board, which means 2.2kΩ will be in parallel to the total resistance from the sensor breakout boards. According to the below calculations, if the sensor breakout board has 10kΩ resistors, and we have 4 breakout boards:

R(total for sensor breakout boards) = 1/(4 boards/10kohm) =2.5 kΩ.

From this calculation, we know that the total resistance from the sensor breakout boards alone will be 2.5kΩ. However, this resistance is in parallel with the 2.2kΩ from the motor controller breakout board. So we must calculate:

R(total) = R(2.5kΩ || 2.2kΩ) = 1170 Ω

Therefore, the total resistance of all I2C devices (sensors and motor controller) is 1.17kΩ and will exceed the minimum resistance of 966.67Ω.

2.11 Calculations and Measurements

2.11.1 Measurements

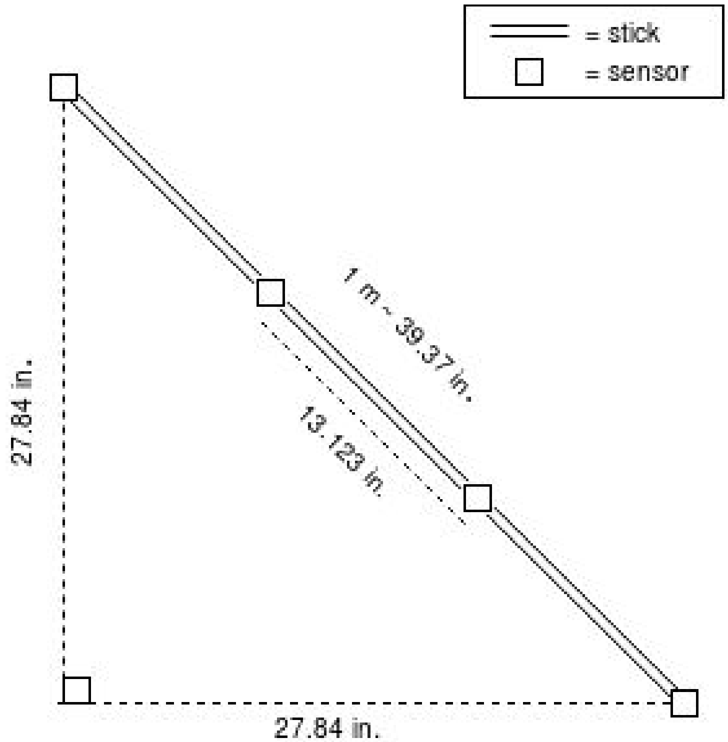

Figure 9. Dimensions for the spacing of the sensors. Sensors will be spaced ~13 inches along the walking stick from each other. This diagram does not include measurements for the handle of the walking stick (*see Figure 3*).

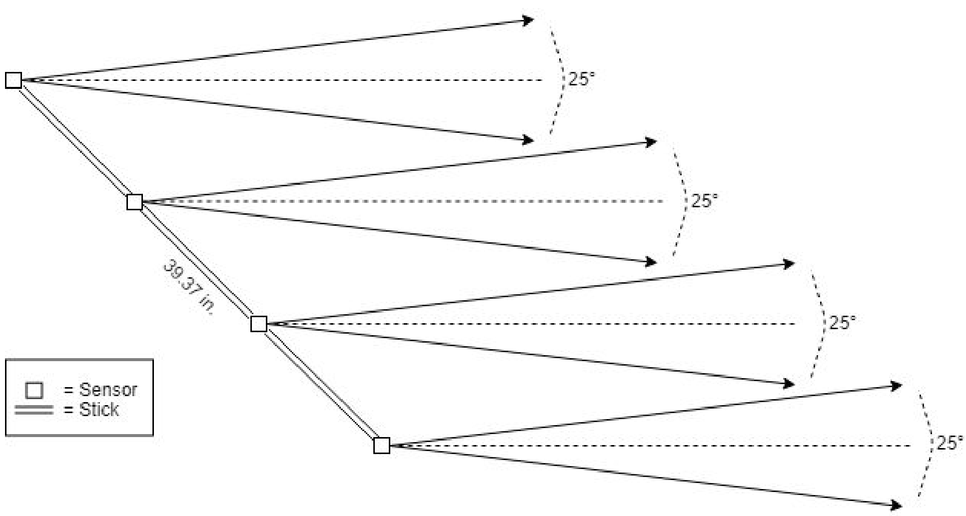

Figure 10. Sensors and their FOVs at the maximum detection distance of 1 meter (39.37 in.). FOVs of sensors do not overlap.

2.11.2 Plots and Calculations

Power Consumption and Battery Life

Device	Quantity	Current
Laser sensor (active ranging mode)	4	19 mA
Haptic Motor Driver (average battery current during operation)	1	2.5 mA
Motor Disc (maximum rated current)	1	60 mA
Microcontroller (11 MHz at 3.3V)	1	4 mA
Total		142.5 mA

Table 2. Current drawn by each device in our project. Used to calculate total power consumption.

Battery Life = capacity of battery in mAh/load current = 600 mAh/142.5 mA = 4.2 hours

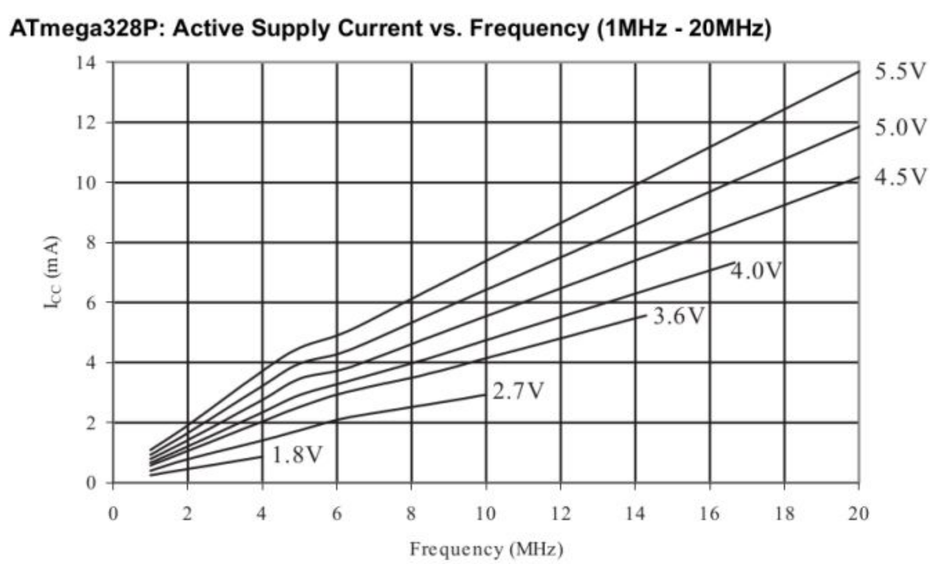

Figure 11. Active Supply Current vs Low Frequency. Used to calculate current consumption for the microcontroller running at 11 MHz and 3.3 V.

3. Cost and Schedule

3.1 Cost Analysis

The labor cost will be estimated using the average hourly wage of an entry level electrical engineer, which is $33/hour. The group consists of three people, and each member of the group will spend 12 hours/week on the project. We will consider the design and development phase to be 12 weeks.

Total Labor Cost = 3 people * $33/hour * 12 hours/week * 12 weeks = $14,256.00

Part Description	Quantity	Per Cost	Cost
Haptic Motor Driver (DRV2605L, Texas Instruments)	2	$7.95	$15.90
Vibrating Motor (SparkFun)	4	$2.15	$8.60
Laser Sensor (VL53L0X, STMicroelectronics)	6	$14.95	$89.70
9V, 600mAh Li-Ion Battery - 2 pack (Energizer)	1	$16.96	$16.96
Microcontroller (ATMega328P, Microchip Technology)	1	$2.08	$2.08
Assorted resistors, capacitors, ICs, crystal (Digikey)	---	---	$10.00
PCB (PCBway)	1	$10.00	$10.00
Total Parts Cost			$153.24

Table 3. Parts cost table.

We estimate that the materials to make the bracelet (waterproof fabric and velcro strap) will be $10.00. The unmodified aluminum walking stick itself will cost $14.99 (purchased through Amazon). Therefore, the total material cost will be $24.99.

The total cost of the project including labor cost, parts cost, and material cost will be **$14,434.23**.

3.2 Schedule

Week	Christian	Angela	Yu Xiao
2/11/19	Begin rough draft of circuit schematic.	Put together parts list for design.	Research material for walking stick/bracelet design.
2/18/19	Finalize circuit schematic. Work on design review presentation.	Finalize parts list. Work on design review presentation.	Turn in design document. Work on design review presentation.
2/25/19	Finalize and check 1st version PCB design. Order PCB on PCBway.	Order necessary parts and walking stick/bracelet material.	Research I2C protocol and laser sensor API documentation.
3/4/19	Load bootloader on ATmega328p chip. Start soldering onto PCB to run tests.	Test components on breadboard. Start soldering onto PCB to run tests.	Begin sensor testing and writing software for sensors.
3/11/19	Order 2nd version of PCB with revisions if necessary.	Give final revisions to machine shop for PCB housing and cane assembly.	Finalize version 1 of sensor controller code and test on microcontroller with vibration motors and sensor.
3/18/19	Spring break. Catch-up week if necessary.	Spring break. Catch-up week if necessary.	Spring break. Catch-up week if necessary.
3/25/19	Order final version of PCB with revisions if necessary. Work on the first prototype for bracelet.	Assemble and wire sensors on cane for first prototype for cane.	Begin working on version 2 of sensor code. Test code with first cane and bracelet prototype. Refine the code based on testing results.
4/1/19	Revise first prototype of bracelet if necessary. Test vibration motor through fabric of bracelet.	Test sensor placement/angle. Revise first prototype of cane if necessary.	Continue to test and refine code using prototype cane. Debug version 2 of sensor code.
4/8/19	Revise final prototype of bracelet. Integrate bracelet with cane system.	Revise final prototype of cane. Test final sensor distance ranges to meet requirements.	Test code with final bracelet and cane setup. Debug code as necessary
4/15/19	Make small revisions based on feedback from Mock Demo.	Prepare for demonstration and work on system integration and debugging if not completed.	Prepare for demonstration and work on system integration and debugging if not completed.
4/22/19	Begin final report. Prepare for Mock Presentation.	Work on final presentation.	Work on final presentation.
4/29/19	Final presentation	Final presentation	Final presentation

Table 5. Weekly task schedule for each project member.

4. Safety and Ethics

Our project is meant to be an extension to existing white canes. Our sensors will provide additional information that is to be used in tandem with information already received by sliding the cane across the ground. Our project is **NOT** meant to be a replacement with existing white canes.

Since our project aims to guide users around obstacles and through a safe path, we will not purposefully guide the user to dangerous locations, fabricate false informations about the surrounding environment or present information in a way to confuse the user. Furthermore our project is meant to be only used to navigation and not to be used as a weapon. Doing any of the above will infringe upon #8 and #9 of the IEEE code of ethics “to be honest and realistic in stating claims or estimates based on available data ” and “to avoid injuring others, their property, reputation, or employment by false or malicious action” respectively.

Some components of our project may be hazardous. The Lithium-ion battery used can cause energetic failure if exposed to fire or mechanical damage, overcharged, external short circuits and manufacturing defects [4]. Lithium-ion batteries have a safe charge temperature of 0°C to 45°C and a discharge temperature of -20°C to 60°C. Many of our components have strict safe operating voltages. We will use voltage regulators to ensure only the correct voltages are supplied. The LIDAR sensors will operate between 4.5V-5.5V. The vibrating motors will operate between 2-5V Although we do not expect hight power consumption in our projects we will use voltage regulators to ensure our battery is never charged over 5.1V.

The laser sensors we plan to use are considered class 1 lasers [5]. Our lasers cannot exceed the maximum permissible exposure when viewing with the naked eye or with the aid of typical magnifiers. However they are still potentially hazardous when viewed using telescopes or microscopes with sufficiently large aperture.

5. References

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[6] Bluedot, ‘How many Devices can you Connect to the I2C Bus?’. [Online]. Available: https://www.bluedot.space/tutorials/how-many-devices-can-you-connect-on-i2c-bus/ [Accessed: 20-February-2019].

6. Appendix

Laser Sensor Datasheet:

http://www.st.com/content/ccc/resource/technical/document/datasheet/group3/b2/1e/33/77/c6/92/47/6b/DM00279086/files/DM00279086.pdf/jcr:content/translations/en.DM00279086.pdf

Haptic Motor Driver Datasheet:

https://cdn.sparkfun.com/datasheets/Robotics/drv2605l.pdf

Vibrating Motor Disc:

https://cdn.sparkfun.com/datasheets/Robotics/B1034.FL45-00-015.pdf

ATMega328P Datasheet:

https://cdn.sparkfun.com/assets/c/a/8/e/4/Atmel-42735-8-bit-AVR-Microcontroller-ATmega328-328P_Datasheet.pdf?fbclid=IwAR1_w2gqvp3GUWK-siz1_DRUs5xwcgb-ZO9kI6PWYCZ6jBiT47qgcbTex4Q