OptiCane

ECE 445 Spring 2019

Design Review

Team 18:
Angela Park
Christian Reyes
Yu Zhang

TA: Anthony Caton

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-level 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, 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[4] 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

- 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.

- The Li-ion battery source along with the voltage regulator unit must be able to yield constant, fixed voltages as required per each device in our design (*see Figure 1).* The power source must have an operating time of at least 1 hour.

- The walking stick must provide the appropriate haptic feedback through a vibration based on the distance between the user and the object (in the form of varying intensity) and the height of the object detected (in the form of a given pattern). For example, an object that is between 0 and 0.2 meters between the lowest sensor and the tip but is also detected by two subsequent sensors placed above it (approximately 0.44 meters in vertical height) will give the user a stronger vibration intensity (characterized by the motor voltage) and provide 3 pulsed vibrations.

2 Design

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 based on a vibrating motor disk situated in a bracelet worn by the user. A removable battery will power all components and allow for a lightweight walking stick and wearable bracelet combination for the user.

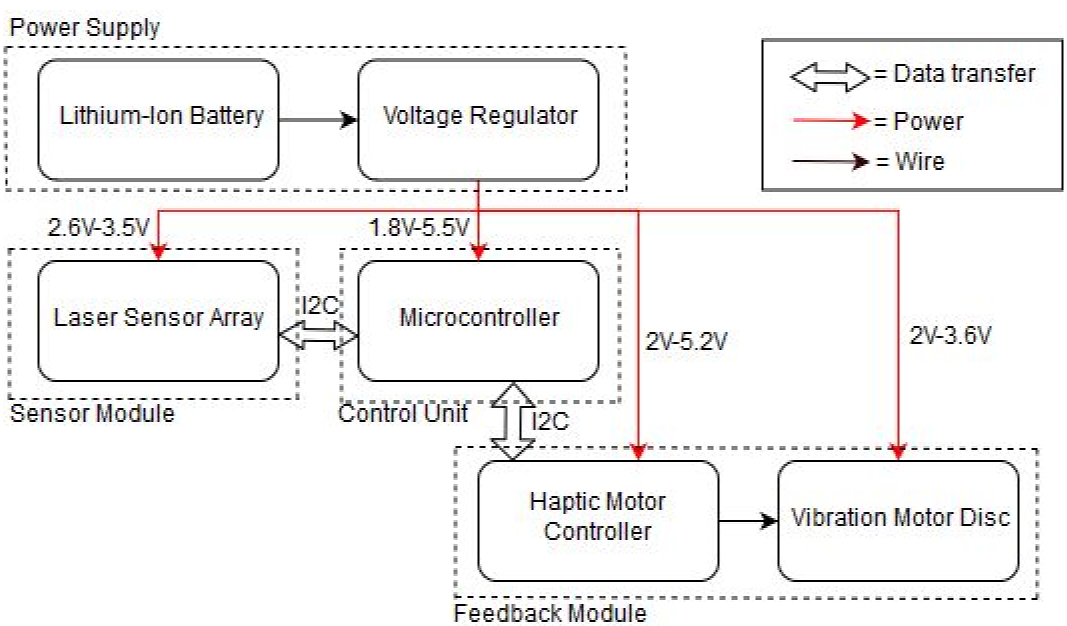

Figure 1. Block diagram for the OptiCane.

2.1 Power Supply

The purpose of the power supply is to power the other modules such as the microcontroller, the sensor array, 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.

Requirement: The Li-ion battery should be able to provide a voltage range from 2V-9V, depending on the power requirement of the necessary components in our design. The battery must be able to power the walking stick for at least 1 hour.

2.1.2 Voltage Regulator

To regulate the amount of power/voltage the devices in each module, we will use several linear IC 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 adjustable voltage regulators that have an output voltage range of 1.2V to 37V with a max output current of 1.5A.

Requirements: The IC voltage regulators need to be able to provide a stable, fixed voltage that is required for each device in our design.

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 plan on using 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. The recommended operating voltage range is 1.8V to 5.5V.

Requirements: The microcontroller should be able to simultaneously handle I2C data from both the sensor array module and from the haptic motor driver at around 3.4 Mbits/s according to I2C specifications.

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 operates on a voltage range of 2V-5.2V.

Requirement: The haptic motor controller should be able to receive I2C data to the microcontroller up to 3.4 Mbits/s according to I2C specifications.

2.3.2 Vibration Motor Disk

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

Requirement: 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.

2.4 Sensor Module

The laser sensors we plan on using will be arranged in a vertical stack spaced along the walking 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 analysis analog inputs form the optical sensor and outputs to pins via I2C protocol. Therefore we do not have to worry about technical details such as memory constraints.

Requirements 1: The sensor should be able to detect objects within a FOV between 0 to 25 degrees.
Requirement 2: The sensor array should be able to detect an object of a minimum of 1m away from the user.

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

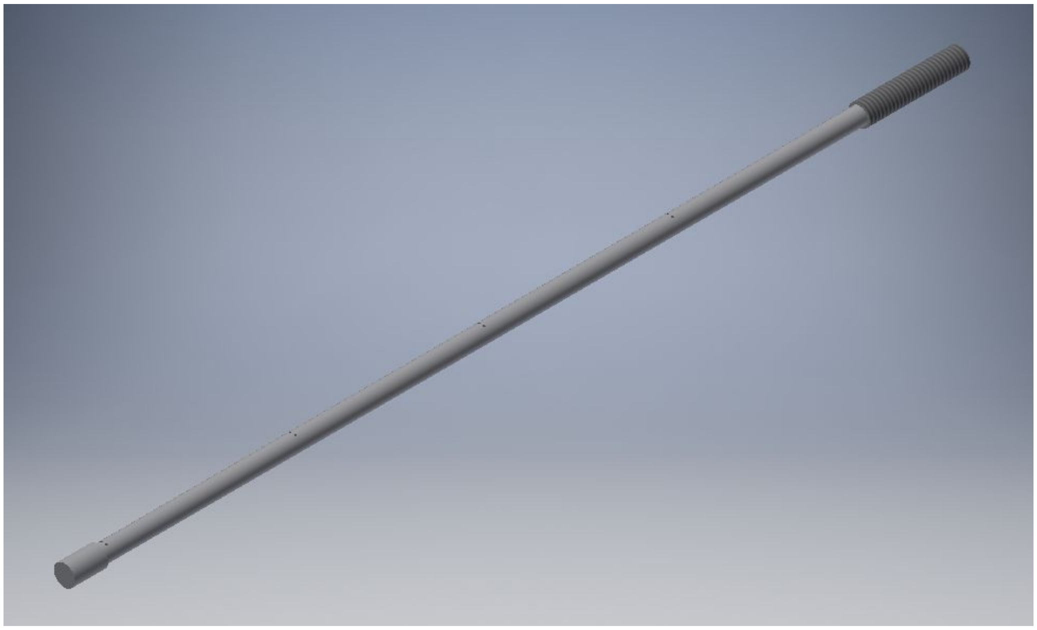

Figure 2. 3D rendering of the cane assembly

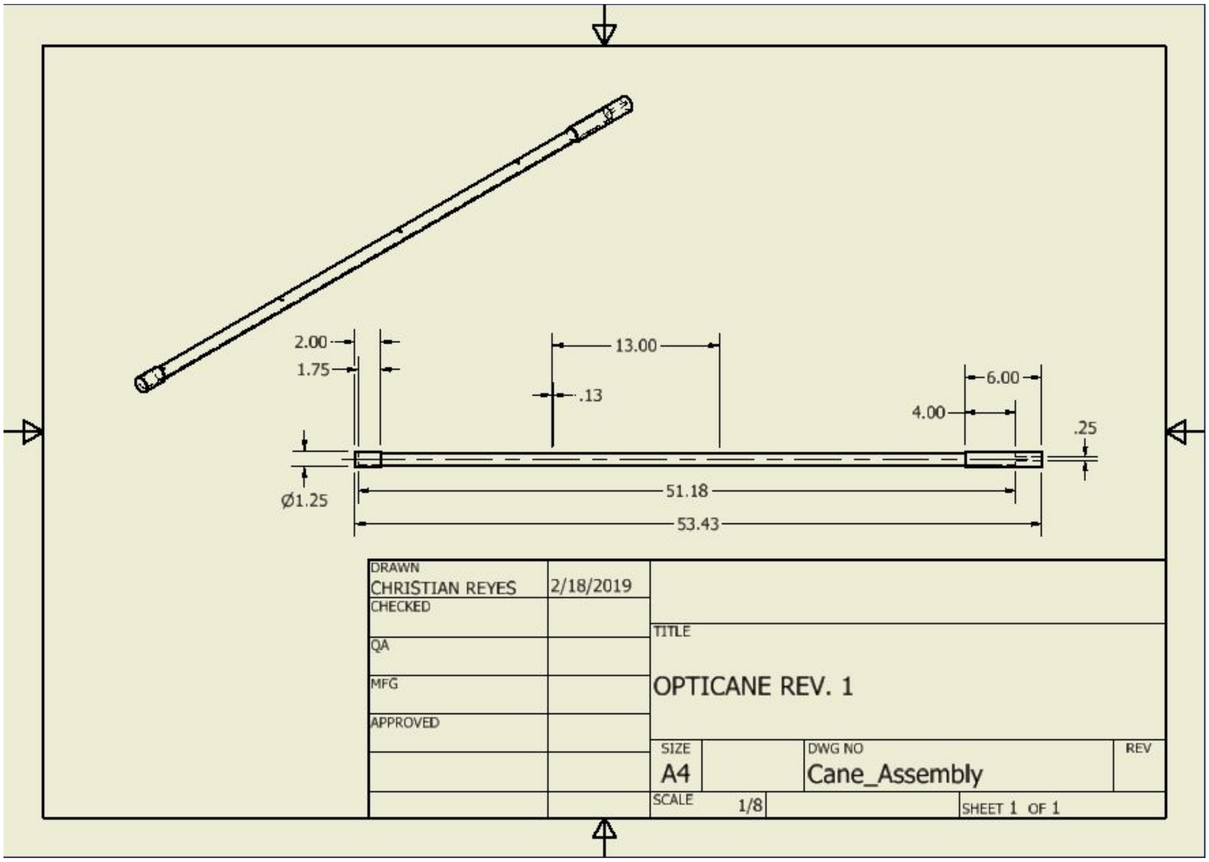

Figure 3. Dimensioned drawing of the cane assembly

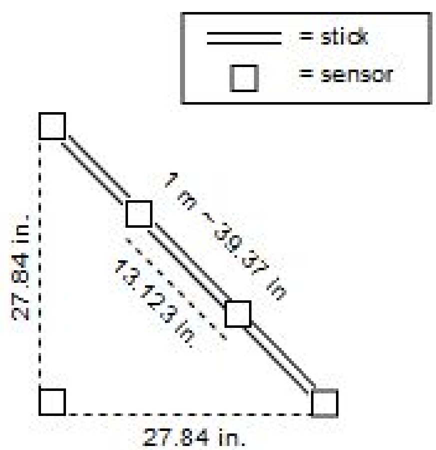

Figure 4. Shows dimensions on spacing of sensors along the stick. Does not include length of rubber tip at end of stick or length of handle.

Requirements and Verification

Power supply

Requirements	Verification
Lithium-Ion Battery: The Li-ion battery should be able to provide a voltage range from 2V-5V, depending on the power requirement of the necessary components in order to power the walking stick for at least 2 hours.	1. Fully charge the battery 2. Isolate the battery 3. Using a voltmeter probe each end of the battery. 4. Draw 200mA of current through the battery by any means (this is the current pulled by the microcontroller and it is the most of any device). 5. Measure the voltage of the battery and ensure that it is between 2V-5V 6. Leave the device on for 1 hour. 7. Measure the voltage of the battery again and ensure that it is still between 2V and 5V.

Controller Unit

Requirements	Verification
Microcontroller: Requirements: The microcontroller should be able to simultaneously handle I2C data from both the sensor array module and from the haptic motor driver at 3.4 Mbits/s according to I2C specifications. Additionally, if this requirement is met, the requirements for the feedback module and the sensor module are also met.	1. Connect the sensor via the interface PCB and connect the PCB to the corresponding input pin on the ATmega328 chip. 2. Connect the vibration motors to the motor controller. 3. Connect the motor controller to an output pin on the ATmega328 chip and power the motor controller with 2V-5.2V 4. Power the ATmega328 chip with a 5V (+/-0.5V) power supply.

	5. Load the test code provided below 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.
	
	<u>Pseudo test code:</u>
	
	Int motorVal=0;
	
	Void setup(){
	  pinMode(sensorPin, INPUT);
	  pinMode(motorPin, Output);
	}
	
	Void loop(){
	  sensorVal= analogRead(sensorPin);
	  Serial.println(sensorVal);
	
	  analogWrite(motorPin, motorVal)
	  If (motorVal>=255){
	    motorVal=0;
	  }
	  Else{
	    motorVal++;
	  }
	
	}

<u>Feedback Module</u>

Requirements	**Verifications**
<u>Haptic motor controller:</u> The haptic motor controller should be able to receive I2C data to the microcontroller up to 3.4 Mbits/s according to I2C specifications.	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 5V

<table>
<tr>
<td></td>
<td>(+/-0.5V) power supply.

3. Load the test code provided below onto the ATmega328 chip.

4. Run the code

5. The requirements are verified if the motors are vibrating at an increasing intensity.

<u>Pseudo test code:</u>

<pre>
Int motorVal=0;

Void setup(){
   pinMode(motorPin, Output);
}

Void loop(){
   analogWrite(motorPin, motorVal)
   If (motorVal>=255){
      motorVal=0;
   }
   Else{
      motorVal++;
   }

}
</pre>
</td>
</tr>
<tr>
<td><u>Vibration motor:</u> 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.</td>
<td>1. Connect the vibration to a variable power voltage source. And pull 40mA-60mA through it.

2. Set the variable power supply to sweep between 2V and 3.6V.

3. The requirement is met if the motor vibrates and its intensity varies depending on the supplied voltage.</td>
</tr>
</table>

Sensor module

Requirements	Verification
Optical sensor: 1: The sensor should be able to detect objects within a FOV between 0 to 25 degrees. 2. The sensor array should be able to detect an object of a minimum of 1m away from the user. This sensor	1. Connect the sensor via the interface PCB and connect the PCB output to a voltmeter. 2. Connect the sensor to a voltage supply at 2.6 to 3.5 V 3. Place the sensor 1 cm off the ground in an open area of at least 2 m by 2 m. 4. Using a protractor or a compass measure 25 degrees and mark two lines with masking tape from the sensor to 1 m out in a V-shape with the sensor facing the center of the angle. Use a tape measure to precisely measure the distance. 5. Move an object between the boundaries marked by the tape. 6. The requirements are verified if the voltmeter reads different voltages when the test object enters and leaves the effective range.

3 Cost and Schedule

3.1 Cost Analysis

The average hourly wage for an entry level electrical engineer is $33/hr.

3 people * $33/hr * 12 hrs/week * 12 weeks = $14,256

2 * $7.95 (haptic motor controller)
6 * $5.97 (VL53L0X laser sensors)
$10.00 (assorted resistors, capacitors, ICs)
$2.14 (ATmega328P microcontroller)

Total: $14,319.86

3.2 Schedule

Week	Christian	Angela	Yu Xiao
2/17/19	Work on design document.	Work on design document.	Work on design document.
2/24/19			Begin sensor testing and writing data analysis program version 1
3/3/19			Continue developing version 1 of program to analyze sensor data and output to motor controller
3/10/19			Finalize version 1 of sensor controller code and and prototype sensor code on microcontroller
3/17/19			Assemble and test first prototype of the cane
3/24/19			Begin working on version 2 of sensor code. Refine the code based on testing results
3/31/19			Continue to test and refine code using prototype cane
4/7/19			Begin assembly final version
4/14/19			
4/21/19			

4/28/19	Final presentation	Final presentation	Final presentation

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 [5]. 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. 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. 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.

Since our project is meant to be used outdoors it will be affected by elements such as rain, snow, puddles, mud etc. We will ensure that the project will be IP67 water resistant meaning it will be able to be submerged under 1 meter of water for up to 30 minutes..

5 References

[1] World Health Organization, ‘Vision 2020 The Right to Sight’, 2006. [Online]. Available: https://www.who.int/blindness/Vision2020_report.pdf. [Accessed: 3-February-2019].

[2] National Federation of the Blind, ‘Blindness Statistics’, 2019. [Online]. Available: https://nfb.org/resources/blindness-statistics. [Accessed: 3-February-2019].

[3] World Health Organization, ‘Blindness and vision impairment’, 2018. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment. [Accessed: 3-February-2019].

[4] Roberto Manducci and Sri Kurniawan, ‘Mobility-Related Accidents Experienced by People With Visual Impairment’, 2011. [Online]. Available: https://pdfs.semanticscholar.org/609b/3d62282eaa5c2e4a89c803c0b401a789e27d.pdf. [Accessed: 4-February-2019].

[5] Mikolajczak C., Kahn M., White K., Long R.T., ‘Lithium-ion batteries hazard and use assessment’, 2011. [Online]. Available: http://www.prba.org/wp-content/uploads/Exponent_Report_for_NFPA_-_20111.pdf. [Accessed: 4-February-2019].

References

[1] National Federation of the Blind, ‘Blindness Statistics’, 2019. [Online]. Available: https://nfb.org/resources/blindness-statistics. [Accessed: 3-February-2019].

[2] World Health Organization, ‘Blindness and vision impairment’, 2018. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment. [Accessed: 3-February-2019].

[3] Roberto Manducci and Sri Kurniawan, ‘Mobility-Related Accidents Experienced by People With Visual Impairment’, 2011. [Online]. Available: https://pdfs.semanticscholar.org/609b/3d62282eaa5c2e4a89c803c0b401a789e27d.pdf. [Accessed: 4-February-2019].

[4] Mikolajczak C., Kahn M., White K., Long R.T., ‘Lithium-ion batteries hazard and use assessment’, 2011. [Online]. Available: http://www.prba.org/wp-content/uploads/Exponent_Report_for_NFPA_-_20111.pdf. [Accessed: 4-February-2019].