OptiCane

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1 Introduction

1.1 Objective

The World Health Organization defines blindness as having a visual acuity of less than 3/60, or a corresponding visual loss of less than 10°, in the better eye with the best possible correction[1]. In 2016, it was estimated that 7,675,600 people between the ages of 16 and up suffer from a visual disability[2] and globally 36 million people are estimated to be blind[3]. 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[4]. The study suggests that the main causes for fall accidents can be attributed to unexpected obstacles or misjudgement of distances and angles [4].

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). 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.

1.3 High Level Requirements

- The walking stick must be able to detect objects within a distance of at least 1m from the user.

- The walking stick must be able to detect the height of the object at a minimum of 0.7m from the ground.

- 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 within 1m from the user that is detected by 4 sensors will have the highest intensity available from the vibration motor with 4 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 removeable, rechargeable battery will power all components and allow for a lightweight walking stick and wearable bracelet combination for the user.

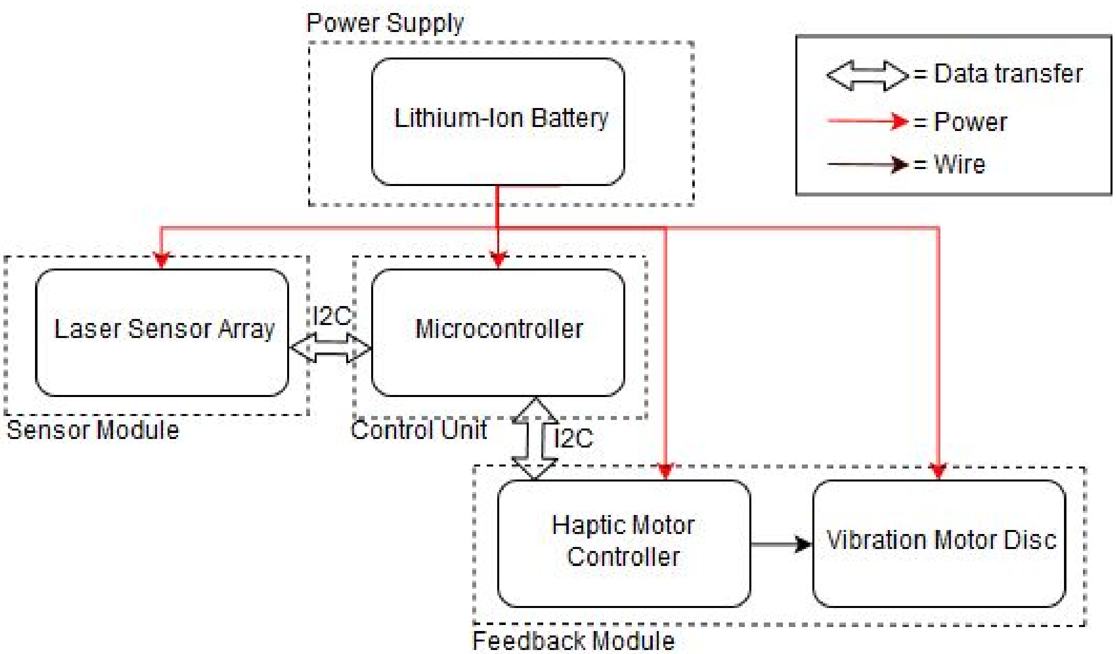

Figure 1. Shows the block diagram for our proposed project.

2.1 Power Supply

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

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. The battery will be rechargeable through the use of a battery charging port. 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 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-5V, depending on the power requirement of the necessary components in order to power the walking stick for at least 2 hours.

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 sent to the microcontroller through I2C protocol from 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 haptic feedback to the user through the use of vibrating motors.

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.

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.

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.

3 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 ro 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.

References

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[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].