Initial Project Documentation

Batpack

A companion for the visually impaired that uses an array of sensors to increase the mobility and spatial awareness of the individual.

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1. Introduction

Recent years have seen technology growing in leaps and bounds. Indeed, Moore's law has ensured that we are surrounded by evidence of always smaller, and always faster devices. However, one area that has remained relatively stagnant has been gadgets to aid the visually impaired. With no recent innovations in this field, blind individuals have been forced to utilize the so-called 'walking stick'. Not only does the walking stick hamper an individual's use of a hand (and usually their dominant hand), but this clunky, obtrusive method of facilitating mobility for blind people has been unchanged for hundreds of years. With recent updates to technology, and especially the small cost of ranging finding sensors, we believe it's time to rethink this device. Using modern components, our aim is to build a device which offers not only the same benefits of the walking stick with none of the disadvantages, but also provides new innovations to aid the visually impaired in their day to day lives.

2. Goals

For our envisioned device, referred to from here on as Spot, to truly innovate in this area, it is not enough to simply provide distance information to the user. For Spot to be truly innovative, it needs to provide the entire package. The device must be light, portable, as unobtrusive to the user as possible, easy to use, and most of all intuitive. While most common electronic devices communicate with their users through sight, Spot must utilize other methods of communication to provide feedback that feels natural and useful to the visually impaired.

To accomplish these goals, Spot will come in two separate modules - a haptic feedback belt worn around the midriff, and a similar laser/optical feedback system built into a pair of goggles. The haptic feedback belt will be outfitted with both ultrasonic sensors and vibrating units. These two components, when paired together, will be used to indicate the direction and distance of any surrounding objects. This should provide the user with a lightweight method of naturally feeling their surrounding, thus greatly facilitating their mobility without hampering the user or impeding the use of either hand.

The goggles module will provide a method of gauging the distance of objects that are further away with higher resolution. Now instead of pointing a stick to feel objects within close range, users should be able to simply point their heads in a direction and know with high resolution how far away an object is. Additionally, a small camera will be placed on the goggles to aid the detection of street corners and sidewalks. This component will be designed to detect the edges of sidewalks and streets to notify the user if they veer off the path. This additional feature provides the user security in knowing that they are in a safe location while Spot is being used.

In conclusion, while all the technical and qualitative goals for this device are paramount to its success, ultimately there is one test the device must pass. That test being 'Does Spot increase the quality of life for visually impaired individuals?' Our goal is to test this assertion with real-life examples. By bringing in individuals that are visually impaired, we will have the benefit of live feedback during and after the design process. Our hope is that continuous real-life testing of the device will ultimately secure it's position as a tool for increasing the quality of life for it's users.

3. Specifications & Requirements

The specifications below represent the minimum requirements that need to be meet for the project in order to create a functional and comfortable device to use for a visually impaired person.

- Unit Housing
  - Dimensions : Less than 12” x 12” x 12”
  - Weight : Less than 2lbs
- Micro-Controller
  - I/O : I2C and SPI Communication Protocols
  - Power : Less than 1.5W
- Ultrasonic Sensor
  - Distance : More than 2m
- Laser Sensor
  - Distance : More than 5m
- Vibration Unit(s)
  - Power : Less than 0.1W
- Camera
  - Resolution : Compatible for Computer Vision Detection
  - Frame Rate : At least 120Hz
- Battery Supply
  - Capacity : At least 2000mAh
  - Rechargeable : Yes

4. House of Quality

				↑				
			↑		↑			
		↑		↑		↑		
					↑		↑	
		↑						

		Cost	Weight	Dimensions	Sensor Range	Computer Vision	Point Sensor Laser
		-	-	-	+	+	+
Ease of Use	+		↓	↓	↑	↑	↑
Battery Life	+	↑	↑	↑	↓	↓	↓
Portability	+		↓	↓			
Cost	-	↑↑	↑	↑	↑	↑	↑
Sensor Range	+	↑			↑↑		↑
Sensitivity	+	↑			↑	↑	↑
Accuracy	+	↑			↑	↑	↑
Targets for Engineering Requirements		<$500	<5W	Fit in Duffel Bag	5m-10m	Sense grass vs sidewalk	10m range, sense dist.

Legend	
↑	Positive Correlation
↑↑	Strong PC
↓	Negative Correlation
+	Positive Polarity
-	Negative Polarity

5. Block Diagrams

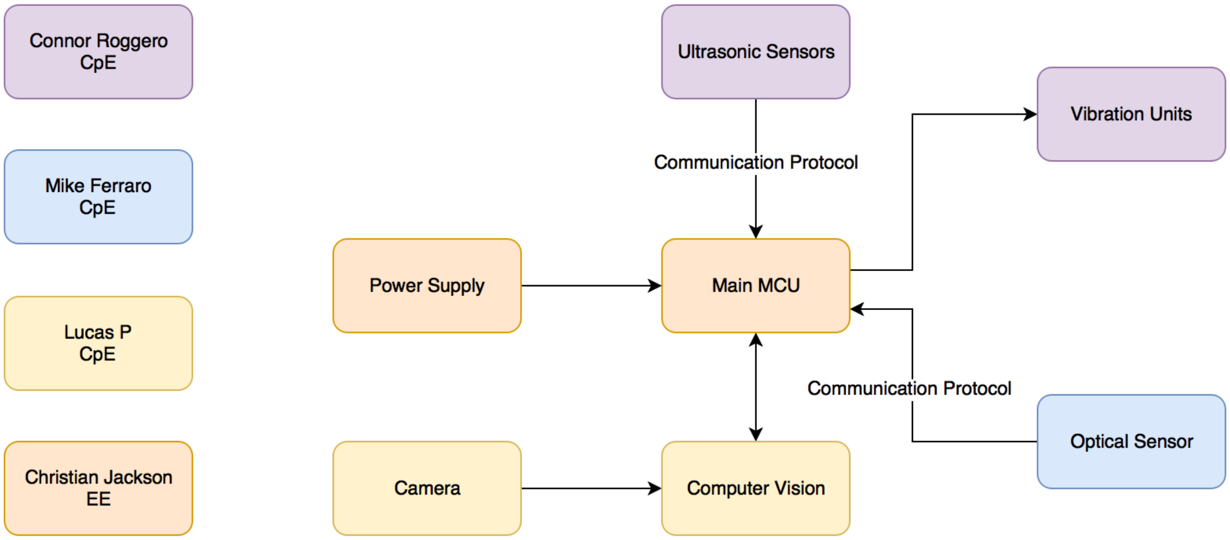


Figure 1. High Level Design Layout

6. Budget

Part Description	**Quantity**	**Price ($)**	**Manufacturer**
Optical Sensor	**1**	**$150 each**	**Sparkfun Electronics**
Ultrasonic Sensor	**4**	**$40 each**	**Parallax**
Camera	**1**	**$40 - $200**	**Unknown**
Total:	**6**	**$350 - $510**	N/A

The design will have multiple sensors in it to track everything going on around the user. The final product will cost roughly up to $600 to make. This does not include the sensors we plan to purchase for testing and comparing to the other pieces. The overall budget of the project will come close to $800-$1000. Specifications of the pieces will be added later on.

7. Milestones

Table 1. Project Milestones

Destriction	Semester	Start	End	Duration	Days until Due	Percent Complete
Brainstorm Senior Design Ideas	Summer	5/22/17	5/26/17	4 Days	Past	100%
Confirm Project Idea	Summer	5/27/17	5/27/17	Due	Past	100%
Goals and Objectives for Project	Summer	5/29/17	6/1/17	3 Days	Past	100%
Initial Project Documentation	Summer	6/2/17	6/2/17	Due	1	100%
Meeting with Professor	Summer	6/6/17	6/6/17	Due	5	0%
Research sensor technology	Summer	6/3/17	6/20/17	17 Days	19	0%
Research sensor communication protocols	Summer	6/3/17	6/20/17	17 Days	19	0%
60 Page Documentation Draft	Summer	7/7/17	7/7/17	Due	36	0%
100 Page Documentation Submission	Summer	7/21/17	7/21/17	Due	50	0%
Final Documentation Due SD1	Summer	8/1/17	8/1/17	Due	61	0%
Finalize Components	Summer	7/21/17	8/1/17	11 Days	61	0%
PCB Layout	Summer	7/20/17	7/31/17	11 Days	60	0%
Research Coding languages	Summer	7/1/17	7/20/17	19 Days	49	0%
Assign Programming tasks	Summer	7/21/17	7/30/17	9 Days	59	0%

Order Components	Break	8/7/17	8/11/17	4 Days	71	0%
Initial Testing	Fall	8/21/17	8/26/17	5 Days	86	0%
Build Prototype	Fall	8/27/17	9/16/17	20 Days	107	0%
Test & Debug Prototype	Fall	9/17/17	10/28/17	41 Days	149	0%
Final Documentation Due SD2	Fall	11/11/17	11/25/17	14 Days	177	0%
Finalize Project	Fall	10/29/17	11/25/17	27 Days	177	0%

8. Considerations

Considerations for Range Finding Sensors

There are a few things we must consider when designing Spot. Because the device relies so heavily on range finding sensors, it is essential we have a strong understanding of how these components work. For the ultrasonic distance sensor, the sensor sends out an ultrasonic burst, known as a chirp. This transmission will hit an object and reflect the sound back to the receiver, called an echo. The pulse width corresponds with the distance from the object.

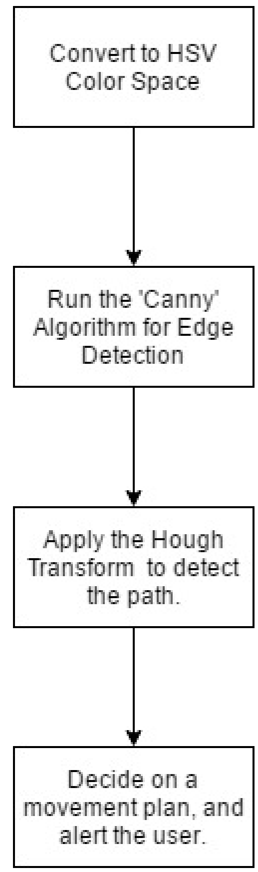
The laser sensor utilizes the same idea, but is more precise for longer distances. The component calculates the distance by sending out pulses of infrared light. Once the laser beam hits the object, the beam will reflect back to the sensor. The time of flight will give us an idea on how to measure the distance.

Provided below is a list of additional considerations we must keep in mind during the design process:

- The position of the object we are shooting the signal at. Each sensor comes with specifications of the range it can read from. We must make sure we are in that target range when doing calculations.
- When sending out the signal, if the angle between the sensor and the object is below a certain amount (roughly 45 degrees), the sound will not be reflected back to the receiver. Fortunately the user can just turn the product easily to fix this issue.
- The object's size. For ultrasonic sensor, the object must be a certain size, or it will not be able to reflect the sound back.
- The material of what we are pointing the sensor at. Some sensors have an issue with reflecting the sound. For example if the surface is soft, some of the sound is absorbed. Thus, you may have an issue finding your favorite stuffed animal.

- The outside world. This can include rain and outside temperature. These can have an effect on the speed of sound in the air, causing delays or inaccurate readings.

Considerations for the Optical Algorithm



The purpose of the optical algorithm is to use computer vision to facilitate mobility on sidewalks for the blind. More specifically, the algorithms seeks to detect the edges of the sidewalk, and notify the user if they veer too much from the path. However, while there have been rapid advances in the field of computer vision in recent years, there is still no (open source) foolproof algorithm to do this. As with any Computer Vision algorithm, there are several considerations which may hinder the algorithms efficacy, including but not limited to:

- Reflective surfaces in the camera view.
- Time of day, which may affect the lighting condition.
- Different patterns which may appear in different sidewalk constructions.
- Reflective materials or other obstructions in the camera view.
- Camera lens specifications, which may alter the image.

To combat these hindrances, the algorithm will make use of the most modern computer vision filters and algorithms available to the public. An estimated flowchart of these filters and algorithms is provided to the right. As can be seen, the first step will including converting to the HSV color space and generating masks based on color. This will help reduce the effect that lighting saturation has on the image, and will allow us to filter based only on color and not level of brightness. Next, the Canny algorithm will be run to find large changes of gradient in the image. If the image was masked correctly in the previous step, then it should be easy to detect where the sidewalk ends and the grass begins. To filter out other noise and detect the both straight edges of the sidewalk, the Hough transform is applied to the output from the Canny Algorithm, and this final step will allow us to see the angle and direction of the sidewalk. With this information, we are confident that the device will be able to make it’s best attempt at providing the user with a walkable path.

9. The Design

The key idea behind this product is to let the user be hands free when walking around. The product will include a belt piece and goggles for the user to wear. Through the interaction of the two, the user will be guided through society with ease.

The belt piece will be equipped with multiple ultrasonic sensors to prevent the user from running into objects. Each of the sensors will be equipped with a vibrator, that will vibrate stronger when objects appear to be closer. Meaning you can detect multiple things around you. For example, if there was a person standing to the right of you one foot away and an ice cream stand standing three feet away from you to the left, the user would feel a stronger vibration on there right side of their body then their left (which has a small vibration to inform the user something is still there). This gives them a full 360 degrees of recognition, almost like eyes in the back of your head!

The goggles will be implemented with a extremely precise optical sensor. It will be able to handle a larger distance than the ultrasonic sensor. Additionally the user will be able to point their head in any direction they want to find the object. Now coming back to the previous example, the user could turn their head to the icecream stand to find exactly where it is and walk to it for a delicious treat. Another beneficiary this brings is the distance the user can scan is now much longer than their walking stick. He or she will now have more time to react to the situation ahead. This can be extremely helpful when walking across a street with cars driving around. What if they were crossing the street, when allowed and a car came around the corner running the red light? The user will hear a car approaching and turn their head to see the terrible driver with a distance much longer than their walking stick, possibly saving their life.

As discussed previously, there will be a camera attached to the goggles as well as to act as their eyes. The idea behind the camera is for ground detection. For example, this will differentiate the difference between the sidewalk and grass, keeping the user on path. Normally all of this is done with the walking stick. Continuing with the previous example, say the ice cream stand is actually across a patch of grass and the line starts a few people back, the user would identify the difference in ground detection and walk around it, looking for the back of the line by scanning for opening in the line.

There are thousands of different types of sensors and cameras available, and we plan to experiment with multiple ones to find the right one for this device. We want to meet our specifications, as listed above. The key to all of this is how we connect all the pieces together to the PCB design, which will be handled by Christian and Mike. One important thing we need to keep in mind is the fact that some pieces will not work with others due to compatibility issues. The product we find best for the situation might not be compatible with the other best pieces we found, meaning some tradeoffs will need to be done. This is why the budget cost could be expected up to $1000 due to buying multiple products for testing, even though they aren’t all being used.