The Echo Belt: Navigation Technology for the Visually Impaired

Markus Kunej

Purpose

The objective of this project was to design, develop and program a discrete, non-intrusive and hands-free navigation device for the visually impaired to reduce the stress caused from travelling on foot, and therefore, improve their quality of life.

Hypothesis

If a navigational device for the visually impaired which features ultrasonic technology and vibration motors is constructed into a belt, then users' ability to accurately determine the direction and distance of obstacles would improve after a brief training exercise. This is because there are touch receptors all throughout the body, including the stomach and back, and the vibration motors provide precise haptic feedback by varying their strength based on the distance of the obstacles.

Background

Visual impairment or low vision is a severe reduction in vision that cannot be corrected with standard glasses and reduces a person's ability to function at certain or all tasks. The World Health Organization (WHO) defines impaired vision in five categories:

- Low vision 1 is a best corrected visual acuity of 20/70.
- Low vision 2 starts at 20/200.
- Blindness 3 is below 20/400.
- Blindness 4 is worse than 5/300.
- Blindness 5 is no light perception at all.

The visually impaired makes up a large portion of Canada's population. There are approximately half a million Canadians living with significant vision loss, and 5.5 million more with a major eye disease that could cause visual impairment. Other factors leading to a dramatic increase of the number of people with sight problems in Canada includes a doubling of the senior population (65 years and older) in the next 25 years and a growing incidence of key underlying causes of vision loss, such as obesity and diabetes.

Approximately half of Canadian working-age adults with vision loss struggle to make ends meet on $20,000 a year or less. People with vision loss are also at a greater risk of social isolation and reduced community participation. They live with an overall lower quality of life compared to Canadians with normal vision.

Current Solutions

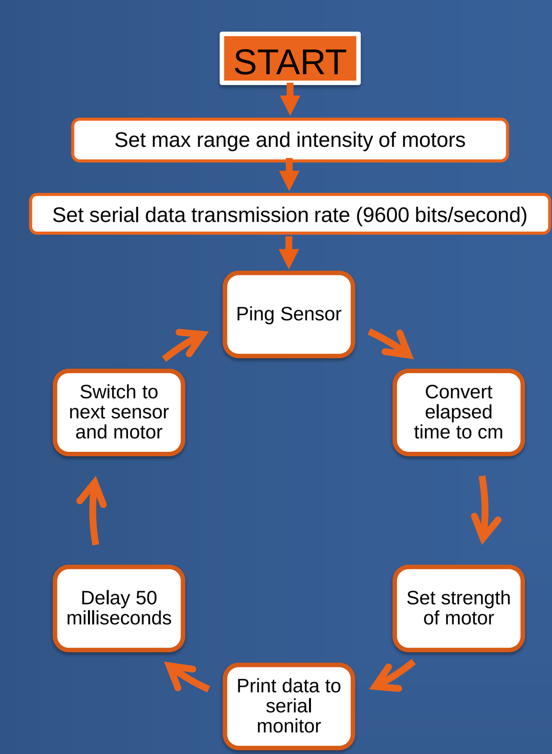
The two most commonly used navigational devices for the visually impaired are the white cane and guide dog.
While both of these devices enable those with visual impairment to travel independently, they suffer from some drawbacks: they only provide obstacle feedback in a single direction at any given time, they require the use of at least one hand, and they can be intrusive to pedestrians. They also make the user easily identified as visually impaired, which is important for other pedestrians, but also makes them targets of crime. The rate of serious violent crime for persons with disabilities (12.7 per 1,000) was more than three times the rate for persons without disabilities (3.9 per 1,000) in 2010 to 2014.

Materials

- Arduino Uno
- Arduino Nano
- 6 x Ultrasonic Sensor (HC-SR04)
- 6 x Mini Vibration Motor - 10mm
- 6 x Diode
- 6 x NPN Transistor (PN2222)
- 6 x Resistor (1K Ω)
- Jumper Wire
- Breadboard
- Wire Cutters
- Soldering Iron
- Solder
- Electrical Tape
- PCB Board
- Plastic Battery Storage Case (4 x AA)
- Multimeter
- 28 AWG Copper Electrical Wire (Several colours)
- Belt
- Velcro
- Needle and thread

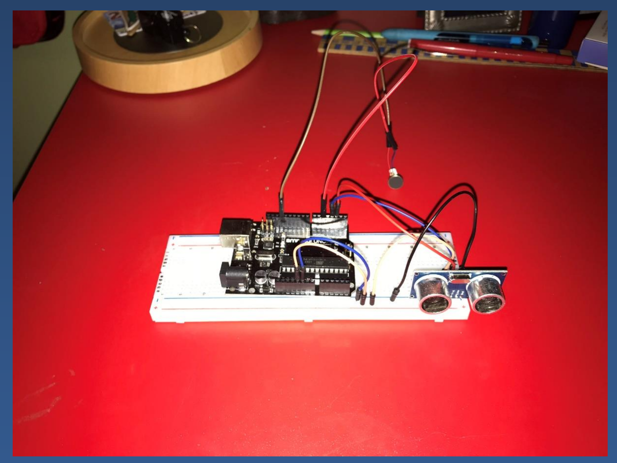
Software

The final program, as well as test programs, were developed in the Arduino Windows Application using the Arduino Language (subset of C/C++).
Algorithm:

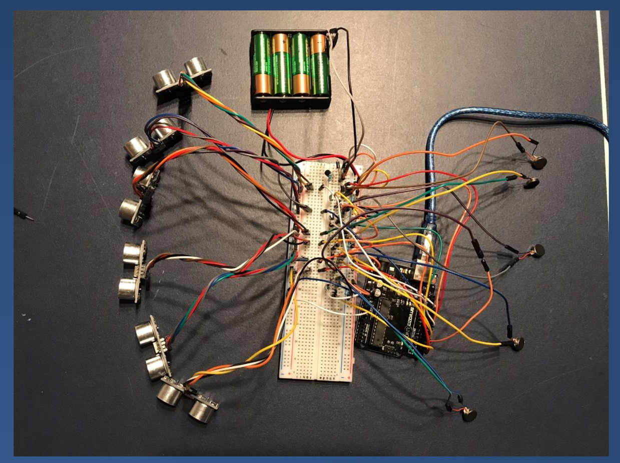


Design

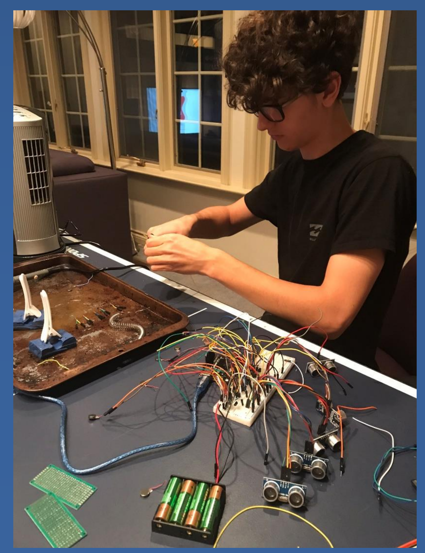
Product construction procedure available in written report



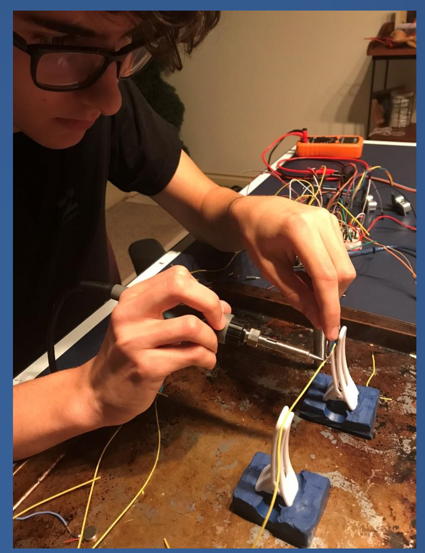
An early prototype



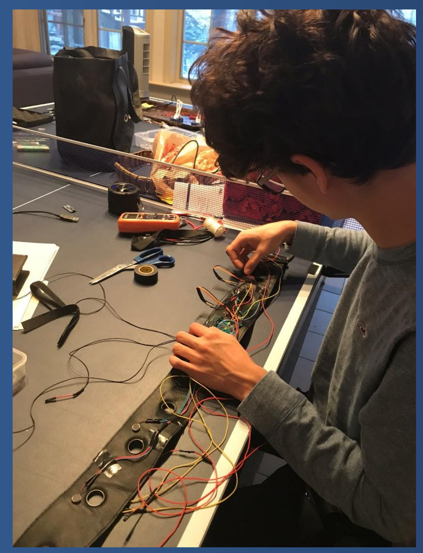
Final design on breadboard



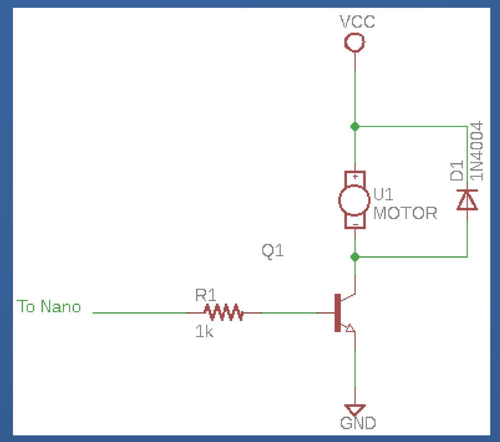
Stripping the ends off of wires



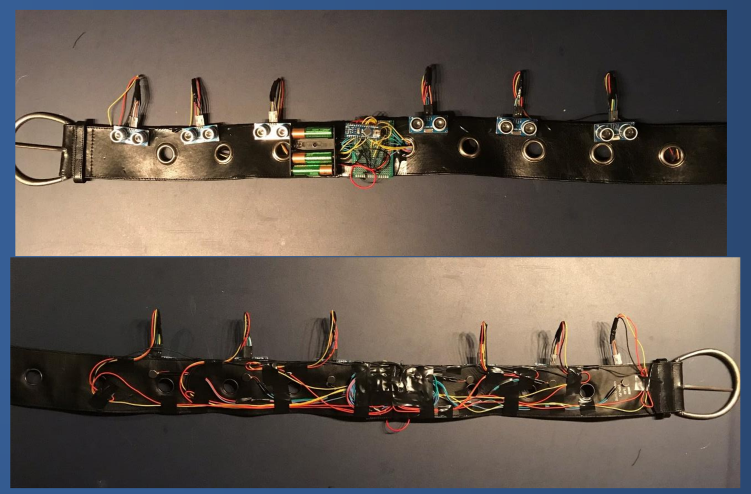
Soldering two wires together



Putting the belt together



Schematic of motor module on circuit board



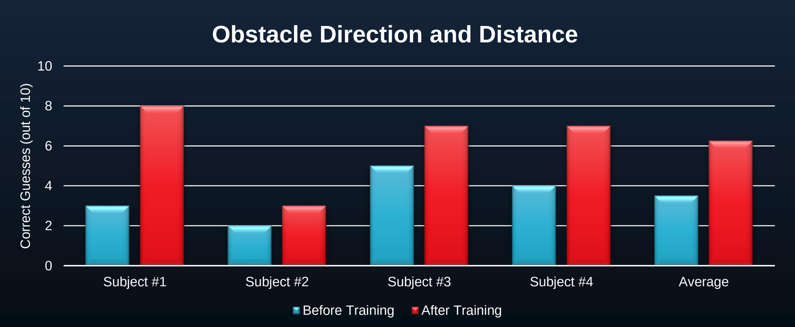
The "Echo Belt" (outside & inside)

Testing

1. Using masking tape, an "X" was marked on the floor, with the area around it cleared.
2. Dashes of masking tape were stuck in front of each of the 6 ultrasonic sensors, at distances of 0.5m, 1.0m, and 1.5m.
3. Participants were asked to put on the device and stand on a marked spot.
4. Participants were then blindfolded.
5. Music was played in the background to allow obstacles to be placed without warning the user.
6. Participants counted down from ten while an obstacle was placed, using a predetermined list, somewhere on one of the pieces of tape.
7. The participant guessed the direction (e.g. front left) and the distance of the obstacle.
8. The participant's guess is recorded.
9. Steps 6-8 were repeated nine times, each using a different obstacle direction and distance.
10. Participants then went through a brief "training" exercise where they got to experience the feedback of the motors at the three distances in every direction.
11. The experiment (steps 6-9) was then repeated, using different predetermined directions and distances from the initial test.
12. The participant's guesses were recorded.

Testing Area

Results



Conclusions

The results supported the original hypothesis, where by using ultrasonic sensors and vibrations motors which vary their intensity according to the distance of an obstacles, users' ability to determine the direction and distance of an obstacle while using the Echo Belt improved after a brief training exercise. The device was very successful in allowing users to determine the direction of an obstacle, where after the training exercise, users correctly guessed the direction 100% of the time. Although users couldn't predict the obstacle's distance with as high of an accuracy (62.5% of the time), most incorrect guesses were within 0.5m of the correct distance. Also, users shared feedback that some motors were stronger than others, which is likely due to the quality of the parts. The device was easy for users to pick up, since with about only 10 minutes of use, users' ability to determine an obstacles direction and distance almost doubled. With continued use of the device, users will have more experience with determining the different intensities of the motors, and their ability to judge an objects distance would likely improve as well.

Applications

The "Echo Belt" would benefit anyone suffering from visual impairment, especially those with less severe vision loss, since it is discrete and non-intrusive for others. Furthermore, the total cost of the device is under $40, making it highly affordable. The "Echo Belt" requires very little no to training to operate, while other alternatives require weeks of training to use. It functions well to detect obstacles not only in front of the user, but all around, similar to how people with normal vision can see out of their peripheral or turn their head at a moment's notice. Users could avoid obstacles which are approaching from behind, something which would be otherwise impossible to do. By having both hands free, the user has a more "natural" walking experience, where they could better greet people, order food, carry objects, and perform other daily tasks. By making foot travel a less stressful task for the visually impaired, their quality of life will be improved and can be better integrated into society from the functionality and ease of use of this device.

Future Directions

Future development of the "Echo Belt" would include new hardware and features to make the device even more functional.
This includes:

- Creating a user control system to set the range, intensity, and to power off the unit.
- Adding more ultrasonic sensors and vibration motors to achieve a full 360° field of view.
- Purchasing higher quality vibration motors to improve the precision of the haptic feedback.
- Developing wristbands featuring this technology to detect obstacles beside the user.
- Installing two adjustable clips on the sides, which allows the belt to be readjusted at two points and therefore no re-aligning would be required.

To detect tripping hazards which are lower than thigh height, such as curbs or bumps, this system could be implemented in the toes of people's shoes. By attaching a GPS module to the device, the belt could connect with the user's smartphone to give directions in the form of vibrations.

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