P.A.V.L: Personal Assistance for the Visually Limited

New Mexico

Supercomputing Challenge

Final Report

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Team 39

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Abstract

Our team focused on finding solutions for helping blind people avoid obstacles. Specifically, we wanted to create an easy, inexpensive device that would help people with visual impairments navigate their surroundings. Currently, such devices are often cost prohibitive for many users. Our goal was to get our device to cost under $300. Using ultrasound sensors and a battery pack, we created and tested a device that sensed obstacles in its path and audibly alerted the user. We modeled an agent in Netlogo navigating a simulated world with obstacles. Its goal was to avoid obstacles and not run into walls. Then, a robot was created which would allow for simulation of the Netlogo model in real life. A third round of testing was performed on human subjects, who were blindfolded and had the sensors attached via two sensors on sunglasses, and sensor on the forehead, belt, or knee. The sunglasses with sensor attached proved to be most effective, and minimized collisions. In all cases, collisions below waist level with small objects proved most common; this is due to sensor orientation and can be alleviated using a combination of sensor locations.

Introduction

1.1. Motivation

Roughly 285 million people worldwide are visually impaired. About 90% of those people live in low-income situations. Despite this, most electronic sight devices on the market today are extremely expensive, costing on average between $1500 and $2000. It is estimated blindness costs the economy $20 billion annually in economic damages and 350,000 years in productivity each year. The cost is significant and most of all a burden on those in developing countries, who cannot afford electronic sight devices, even if they are available.

1.2. Ultrasonic Sensing

The Ultrasonic sensors used operate on the same fundamental principles as echolocation works on. The Sensor operates at 11494 Hz, taking a reading once every 35 milliseconds. The sensor has a confidence of +/- 3 cm, allowing for precise readings even at distances of about 2.5 meters. The sensors sends out a sound wave, and objects reflect the waves sent out to them. The sensor then transmits to the CPU the start time of the original wave, as well as the response time. The distance to the object can then be determined by multiplying the speed of the wave by the time interval and dividing by two.

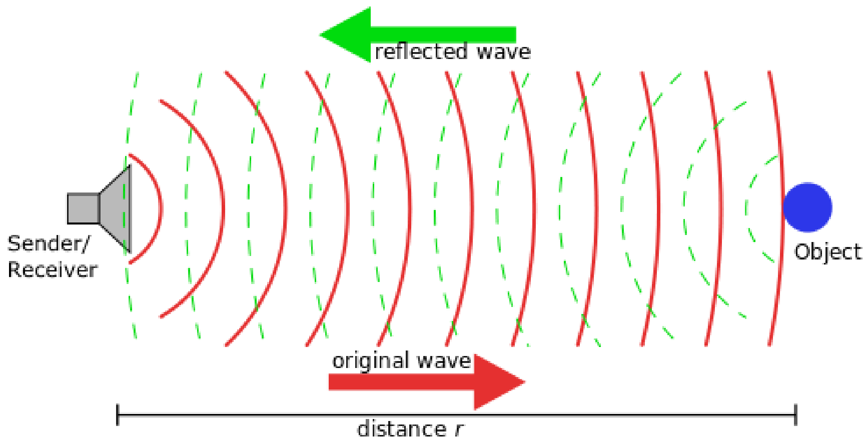

Figure 1. Diagram showing sensor operation methodology.

1.3. Objectives

- To create a device that is economically affordable for assisting visually handicapped people with navigating their surroundings
- To model this device in an agent-based environment to prove the concept
- To perform same robotic testing proving the concept in physical surroundings
- To perform human testing demonstrating proof of concept for the device

Materials and Methods

2.1. Computational Simulation.

The proposed mechanism was first tested through creation of an agent-based simulation written in NetLogo. Obstacles were created, and the agent would scan ahead (as if with a sensor) to find the obstacles. The agent would then turn to avoid the obstacle. The walls were imported via a png image file representing Las Cruces High School. Obstacles were then randomly scattered throughout the imported environment. Creation of this simulation in NetLogo allowed for the use of importing the image file of the physical obstacle course that a real robot and human test subject would later maneuver. Thus the entire system of a robot or test subject was sufficiently modeled in a real-world obstacle setting.

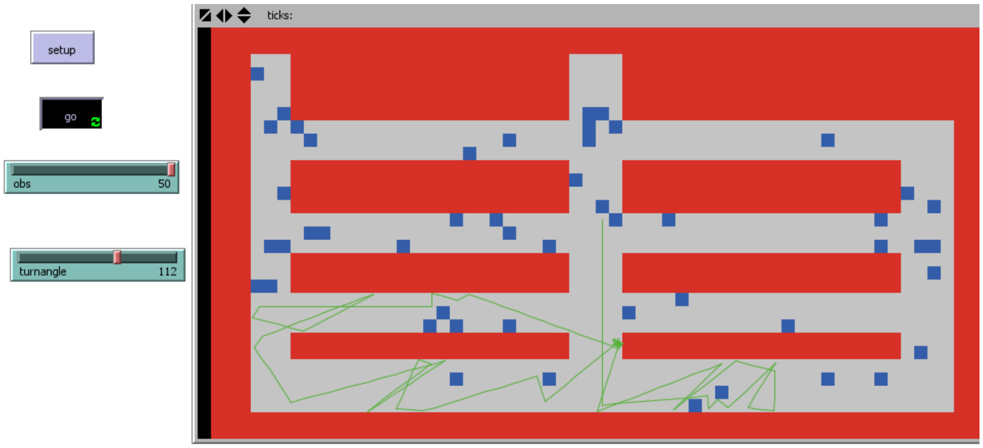

Figure 2. Screenshot of the NetLogo program running. The agent would turn in response to obstacles and walls.

2.2. Robotic experimental testing.

The validity of the design was initially tested through creation of a robot. In response to obstacles, the robot would stop, turn to the side, test for obstacles, and repeat the commands. The robot was built using Lego Technique pieces, was powered via two servo motors, and a smart brick with a 32-bit Atmel main microcontroller with 256 KB flash memory and 64 KB RAM as well as an 8-bit Atmel microcontroller operating at 4 MHz, with 4 KB flash memory and 512 Bytes RAM. An ultrasound sensor was used for detection of objects.

The robot was constructed with a total of four wheels. The two back wheels were attached to motors, which allowed for turning of the robot as well as calculation of distance traveled and degree of turning. The front wheels were attached to free floating axils, allowing for movement in all directions.

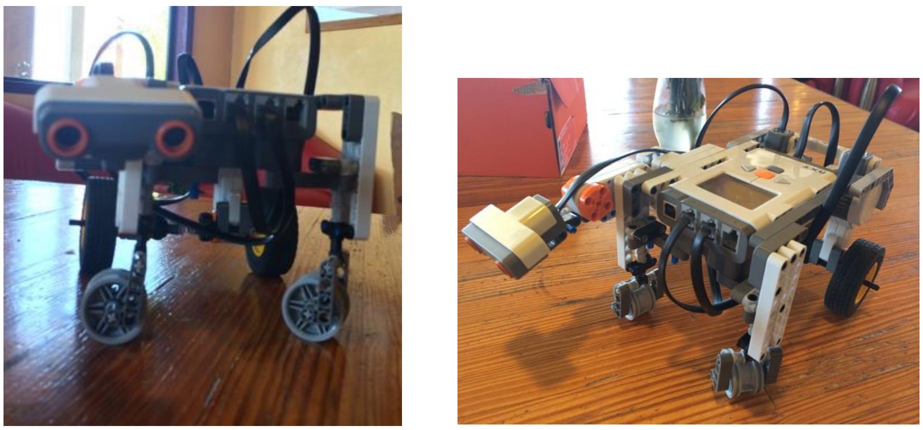

Figure 3. A forward view of the robot (left), and a view showing the entire robot (right).

Programming was performed in NXT-G, which is based on the LabVIEW programming language. The entire program was in an infinite loop, and included a number of pathways: (1) the robot would sense if there was an object in front of it. If not, (2) the robot would turn its ultrasound sensor and test for more objects. The robot would then (3) move its ultrasound sensor to its starting position and proceed forward if no objects were detected. If objects were detected at either the initial or secondary testing the robot would stop, turn, test for objects, and proceed forward if clear. If not, the robot would continue turning until an obstacle-free direction was found. The robot would then repeat this algorithm until stopped by the user. If at any time the robot would not encounter an object, it would play an audio file pronouncing, “You’re good”, and upon encountering objects would pronounce “Watch out”.

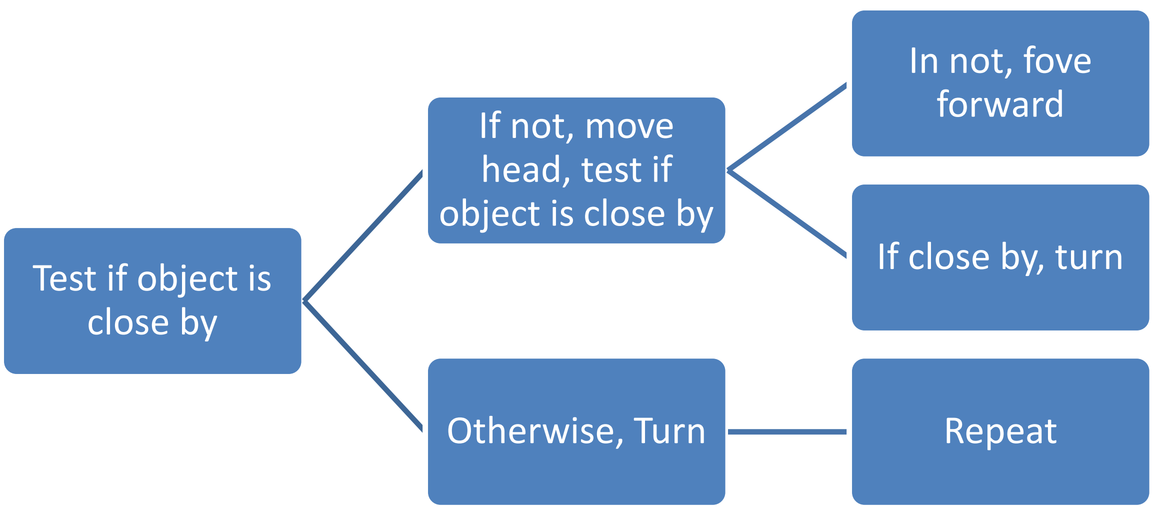

Figure 4. The infinite loop algorithm. Object vicinity to the robot is tested repeatedly).

2.3. Human Forehead Sensor.

In order to test the practicality of the design, two approaches were used with attaching the ultrasonic sensor to test subjects. The sensor was (1) attached to test subjects' foreheads, and (2) the sensor was attached to test subjects' belts, at waist level.

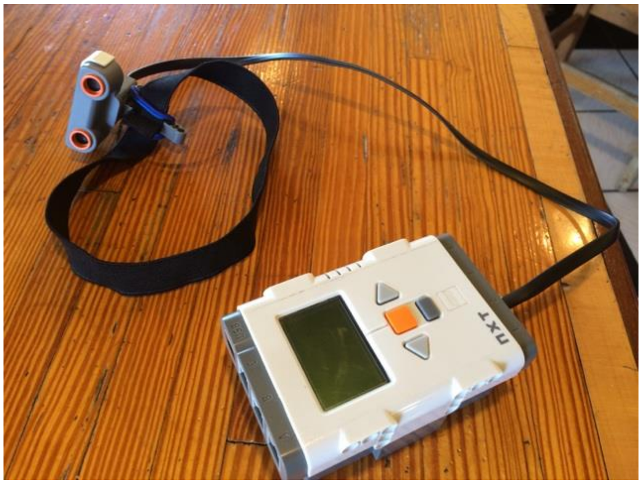

Figure 5. The single sensor attached to an elastic headband (top left)

The test subjects' were blindfolded, and guided by the sensor, and one of the authors for safety reasons. The sensor was attached by an elastic strap, and connected the controlling element which had a built in speaker. In response to obstacles such as walls, people, chairs, and tables, “Watch out!” would be played, while in response to a clear route “You’re good” was played.

Results and Discussion

3.1 NetLogo 5.1.0 Simulation

The stimulation consisted of a NetLogo program with a downloaded “map” that contained hallways and obstacles through which the agent had to maneuver. The agent was asked to look to the patch ahead of it to determine whether or not an obstacle or wall lay ahead of it. The agent would then either continue forward if it determined the area ahead of it was clear or turn away from the obstacle blocking it and attempt to find another path. The simulation mimics a similar environment to the *P.A.V.L.* which was later tested. Though the agent manages to detect walls and obstacles that are directly in front of it, corners are a problem for the agent to detect.

3.2 Motorized robot: P.A.V.L.

P.A.V.L.’s initial testing took place in a 4m by 4m area that was filled with obstacles in form approximately 30 cm high obstacles around which our robot could navigate.

At first P.A.V.L. navigation techniques were unsuccessful. The motorized robot knocked over several of the obstacles during each run. Though P.A.V.L. could see and avoid the object that were directly in front of it, it tended to run through cups that were slightly to the side of it. Through more careful movement, consisting of testing for objects before turning to move from existing obstacles, it was possible to minimize this issue.

3.3 Single sensor testing

As expected, the different placements of the single sensor produced a wide variety of results with some being far more effective than others. Our initial subject, male, and 193 cm tall, had the ultrasound sensor strapped to his head and maneuvered for 30 mins., at walking speed, around the various hallways and classrooms within Las Cruces High School. Within the 30 min test subject 1 experienced 2 corner collisions and 0 frontal collisions with objects above waist level, 1 collision directly at waist level and 14 collisions with objects below waist level. Our second subject, female, and 168 cm tall also had the ultrasound sensor strapped to her head, maneuvering the same areas for the same time slot. With this different subject there was only 1 corner collision and 0 frontal collisions with objects above waist level though there was an increased number of below waist collisions, with 17 below waist level collisions and 2 waist level collisions. The same subject was used to conduct a test with the sensor attached at the waist. Though this placement fixed the problems with collisions at waist level, with 1 waist level collision and 2 below waist level collisions it drastically increased with 18 corner collisions and 2 frontal collisions. The placement of the sensor on the waist also took away much of the mobility that the sensor on the head maintained as the head and subsequently the sensor could be turned and directed in multiple ways whereas the waist sensor could not be so easily manipulated.

3.4 Double sensor testing

The final test we ran consisted of two ultrasound sensors attached to a pair of glasses with test subject 1 being used. This test yielded the most favorable results with only 1 corner collision, 0 frontal collisions, 3 waist level collisions and 4 below waist level collisions throughout an identical testing period.

3.5 Problems Throughout

We encountered the same issues with our NetLogo simulation and our actual testing. Though P.A.V.L. is able to detect object in front of the user we have still encountered many problems with corners in all aspects of our project. Though the agent in our program and our sensors can spot object in front of them with hardly any problem, corners are P.A.V.L.'s biggest weakness.

We also encountered issues with navigating around corners. We found P.A.V.L. had difficulty detecting objects that are near the ground or below the subjects waist level. In our experimenting we found that the most collisions occurred with objects that were below or at waist level. This can be remedied in part by the user moving their head up and down and effectively allowing the sensors to gain different perspectives of their environment, however this can be tiresome and inaccurate.

P.A.V.L. is also far from discreet at the current time. He still announces his directions out loud instead of to the person using him and both the volume and the spoken directions are noticeable and irritating. Volume could be turned down to a much more discreet level or a Bluetooth ear piece could be wirelessly connected to P.A.V.L. insuring that the subject wearing P.A.V.L. would hear the instructions. The manner in which the instructions are given is also adjustable. Though at the present time P.A.V.L. announces "Watch out!" to warn of object in front of it, while in response to a clear route "You're good" is played, the directions themselves can be easily reprogramed to announce whatever the owner of P.A.V.L. decided.

Conclusions

In doing this project, we have created a cheap and technologically simple design that can assist the visually impaired go about their daily lives. The total cost for the battery pack, two sensors, and glasses is about $250, which is about 6 times less expensive than most devices on the market today. Ultimately, the cost could be halved through the use of non-commercial parts leading to even further economic benefit for the users. The most successful design features two ultrasonic sensors attached to a pair of glasses, with each sensor on a side rim. Sharp corners and low-lying obstacles below the sensors' field of vision proved to be the hardest obstacles to avoid. Sharp corner collisions were predicted to be the weakness of the system in a Netlogo simulation, and both the created independently-moving robot and human test subjects had the same issue. Further expansion of the system to include more sensors should prove more successful, though this will come with an increased cost.

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