Problem – According to the World Health Organization, 161 million people worldwide have a visual impairment. And out of these, 37 million people are blind. Furthermore, in the U.S. alone 93,600 school age children are blind. Can a portable sonar-based device be created to aid the visually impaired by replacing the walking stick and its capabilities, such as detecting stairs and walls of any material?

Engineering Goal- Build a portable sonar-based device, for the visually impaired, that will alert the user through a vibrating motor when he or she is approaching a wall or a step in an indoor setting. Make the device less than $100 to produce, small in size, and easy to use. Refine and modify the device into the smallest, least expensive, and most efficient state possible.

Materials List-

- 16 mhz crystal – 1
- 22 pF ceramic disc capacitor – 2
- 5v regulator – 1
- 9v battery connector – 1
- Adhesive Tape – 5cm
- Arduino Duemilanove - 1
- Atmega328 - 1
- Drill – 1
- Electrical wires – 9m
- Glue – 2mL
- Lexan – 300cm2
- Pen cap – 3
- HC-SR04 ultrasonic module - 3
- Shoe - 2
- Shrink tubing – 20cm
- Small Printed circuit board - 1
- Soldering iron - 1
- Switch - 1
- Thin Solder – 40cm
- Various construction materials (glass, concrete, brick, etc.) – 400cm2
- Velcro – 4cm
- Vibrating motor – 3

Procedure-

1. Write a program in C based Arduino language which will control 3 HC-SR04 ultrasonic sensors and respectively send out a medium electric pulse to corresponding vibrating motor when the corresponding ultrasonic distance module is within 100 centimeters from an object and a high electric pulse when the distance is within 50 centimeters.
2. Transfer the program to the atmega328 on the Arduino testing board
3. Test its functionality
4. Revise program if needed
5. Remove the atmega328

6. Solder each vibrating motor to 2 thin electrical wires
7. Cover the motors loosely with pencaps for protection
8. Cover the soldering and the pencaps with shrink tubing for protection
9. Plan out how the device will fit on the PCB

10. Solder electrical wires, components, and the distance modules, switches, ultrasonic sensors, and the atmega328
11. Cover exposed soldering with shrink tubing
12. Retest its functionality
13. Using the drill cut the lexan into rectangles to make 2 boxes, one large enough for 1 ultrasonic sensor with the vibrating motor and the other just large enough to house 2 of the ultrasonic sensors, the main PCB and the battery
14. Drill holes for the transmitters, receivers, wires, and switch (be sure that the sensors will be spaced 45o from each other)
15. Glue the pieces together with the components inside, leaving one side open.
16. Using adhesive tape, make a small latch on top of the opening for the battery
17. Attach Velcro to the shoe and the casing
18. Test its functionality and its accuracy
19. Write observations on its ease of use
20. Revise program to alter the trigger distance if needed

Procedure for writing a program

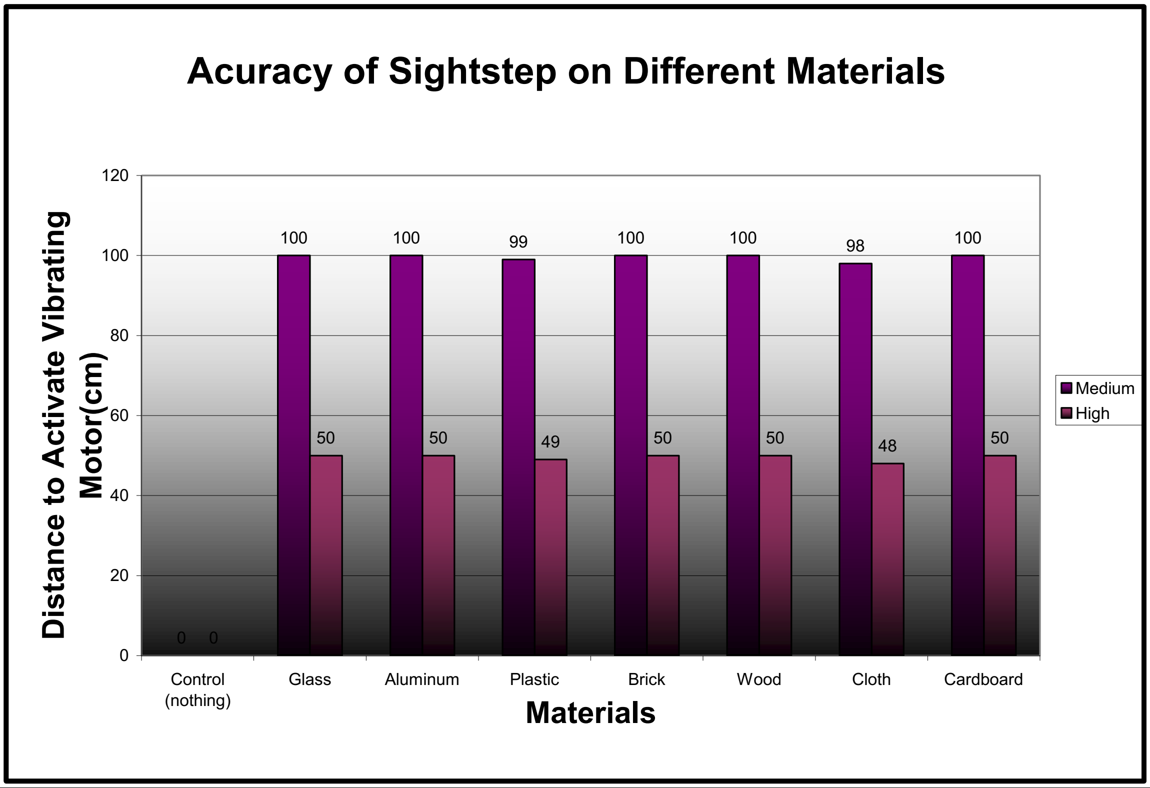
1. Research how the language works and what syntax it follows
2. Study sample programs for better understanding
3. Buy and download all of the necessary equipment (Bootloaders, programming chips, etc.)
4. Write the program in the allowed syntax (For my program, I had to name pins being used, write "if" functions to control the vibrating motor when the distance was within certain parameters, and define output power to the motor.)
5. Build the written program
6. Make sure that no errors are given back
7. If there are errors, usually something is wrong with the syntax and that section of the program must be rewritten in a different format
8. Once the program is free of errors, upload the program onto the programming chip
9. Retest the program using the chip to ensure that it is functional
10. Alter the program again if changes need to be made (For my program, I had to constantly alter the program to find an acceptable output power for the vibrating motor's medium setting.)

Procedure for Data-

1. Mark off 50cm and 100cm on level ground with a piece of tape on both sides
2. Use small weights to weigh down two small cardboard boxes

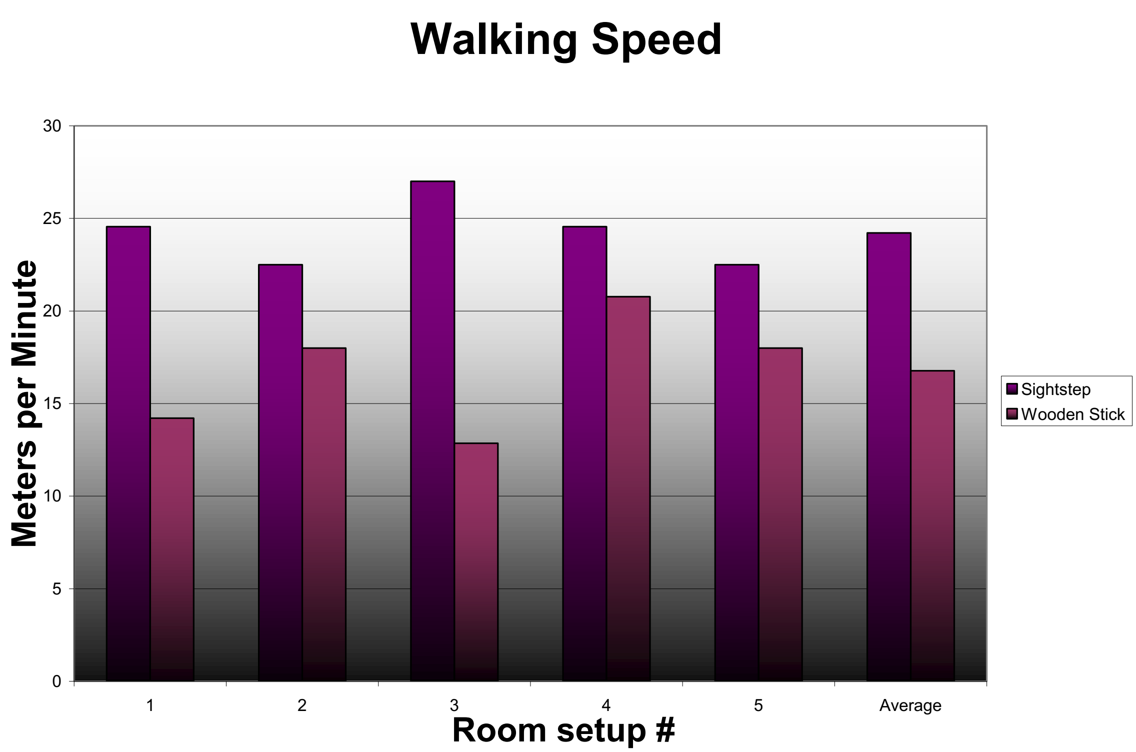
3. Place these boxes on the edges of the line, leaving 80cm of space between them
4. Place the shoe with the device on the other side.
5. Face the front sensor so it is pointed between the two boxes
6. Move the shoe back and forth around the 100cm line until it reacts and turns on the motor
7. Record the maximum distance required to activate the vibrating motor
8. repeat step 6 and 7 at the 50cm line
9. Place a sheet of glass between the two boxes, using them as supports
10. Repeat steps 5-7
11. Place a sheet of aluminum between the two boxes, using them as supports
12. Repeat steps 5-7
13. Place a sheet of plastic between the two boxes, using them as supports
14. Repeat steps 5-7
15. Place a brick between the two boxes, using them as supports
16. Repeat steps 5-7
17. Place a sheet of wood between the two boxes, using them as supports
18. Repeat steps 5-7
19. Place a sheet of cloth between the two boxes, using them as supports
20. Repeat steps 5-7
21. Place a sheet of cardboard between the two boxes, using them as supports
22. Repeat steps 5-7
23. Repeat steps 6-21 using the 50cm line
24. Mark off a 3.7x2.55 meter room
25. Mark off an exit and an entrance on opposite sides with 4.5 meters in between them
26. Obtain 3 cardboard boxes. One 19x90cm, one 17x38cm, and one 40x49cm.
27. Using these boxes, create 5 randomized "rooms", each of which has the boxes at least 60cm apart from one another. These boxes represent household furniture.
28. Allow yourself 2 minutes to become acquainted with the device.
29. Blindfold yourself and turn on the device.
30. Have an assistant randomly set up one of the 5 rooms without your knowledge of which room was chosen.
31. Relying on the device, attempt to reach the exit in a reasonable amount of time (less than 30 seconds), without hitting any of the boxes with your feet.
32. Have your assistant record the time, corresponding room number, and where you hit any boxes.
33. Repeat steps 25-31 with the other 4 rooms.
34. Repeat steps 24-32 using a wooden stick
35. Research the range of prices and sizes for a walking stick from www.walking-canes.net
36. Add up the amounts of money spent on the components used in the device.
37. Measure the size of the device
38. Compare the device with the walking stick

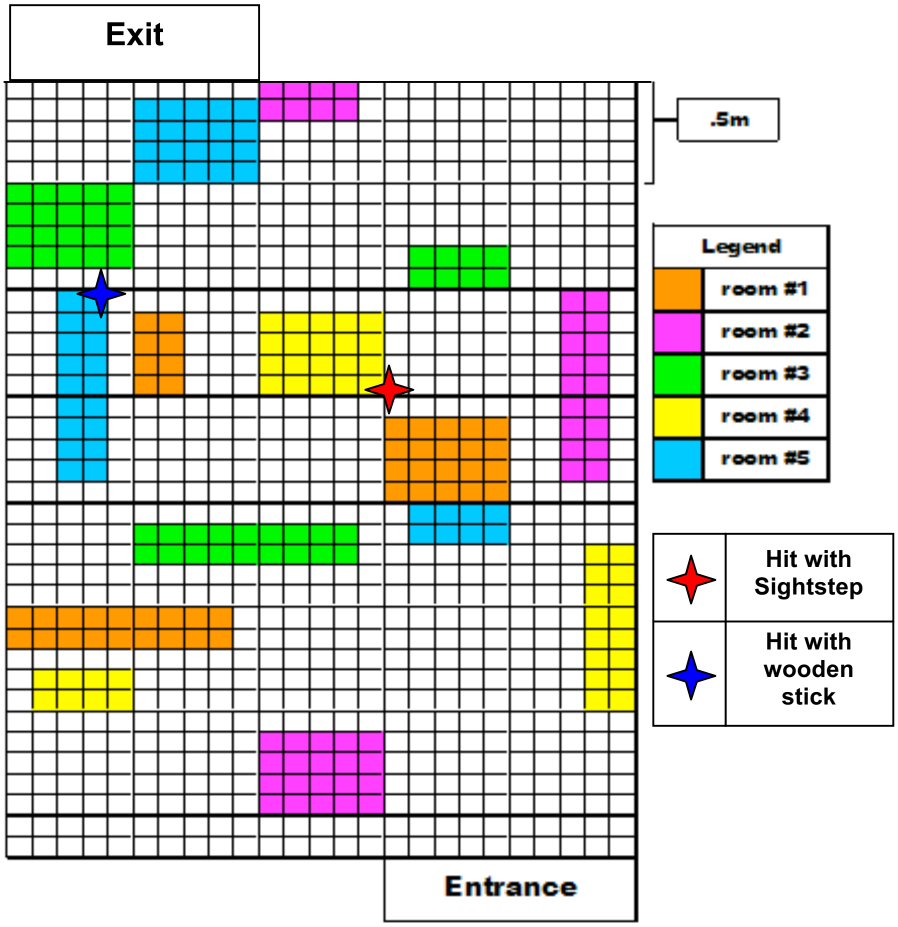
Data:



Materials	Control (nothing)	Glass	Aluminum	Plastic	Brick	Wood	Cloth	Cardboard
Distance to Activate Vibrating Motor (cm)	does not exist	100	100	99	100	100	98	100
Distance to Activate Vibrating Motor on High(cm)	does not exist	50	50	49	50	50	48	50


Time to Walk Across a 3.7m by 2.55m Room with Obstacles While Using Sightstep
Seconds to Reach the Exit
25
20
15
10
5
0
1
2
3
4
5
Average
Room Setup #
Sightstep
Wooden Stick


Walking Speed
Meters per Minute
30
25
20
15
10
5
0
1
2
3
4
5
Average
Room setup #
Sightstep
Wooden Stick



Room Setup	1	2	3	4	5	Average
Time to Reach Exit with Sightstep (sec)	11	12	10	11	12	11.2
Time to Reach Exit with wooden stick (sec)	19	15	21	13	15	16.6
Pace of walking for Sightstep (m/min)	24.55	22.5	27	24.55	22.5	24.22
Pace of walking for wooden stick (m/min)	14.21	18	12.86	20.77	18	16.77

Costs for Sightstep

16mhz crystal - $0.49
22pF capacitors - $0.29
5v regulator - $0.49
9v battery connector - $0.20
Adhesive tape - $0.01
Atmega328- $5.50
Electrical wires - $2.50
Glue - $0.02
Lexan- $3.00
PCB - $0.30
Shrink tubing - $0.20
Solder - $0.05
Switch - $0.49
Ultrasonic sensors - $22.80
Velcro - $0.05
Vibrating motors- $2.97
TOTAL-$36.39

Sightstep	Walking Cane
-Costs: $36.39 -Size: 8cm by 8cm by 3cm -201 grams -Does not require use of hands	-Costs: $22.30-$63.99 (walking-canes.net) -Size: 1.5meters by 5cm diameter -Requires use of hands

Data analysis: The data from the accuracy test would suggest that Sightstep will work quite consistently on almost all materials that it would encounter in a real-world setting. The glass, aluminum, plastic, and wood tests showed that Sightstep would react when it was 48-50 cm and 98-100 cm away from the target object. These materials were chosen to be tested because they are primary building materials which one would come across everyday in the suburbs. The cloth test was chosen to resemble clothed people. The test suggests that even on free-flowing, porous, and unstructured materials, Sightstep could still perform quite accurately. The reason for the slight deviations in the trigger distance for cloth is most likely due to the curves and depressions of the cloth disturbing the path of the ultrasonic pulse. The slight deviations in the plastic test are most likely due to the fact that the plastic was textured and did not have a consistently smooth surface. The cardboard test suggested that even on fragile and lightweight materials, sound would still be reflected to the sensor. Later on, cardboard boxes were used for the ease of use and the degree to accuracy test.

The ease of use test was designed to note how one's pace would be affected by using Sightstep. After 2 minutes of getting accustomed to using Sightstep, the experimenter attempted five times to traverse 4.5 meters with a set of 3 randomly placed cardboard boxes in a timely manner. Then, the experimentor redid the same tests with a 110 cm long wooden stick. In both experiments a cardboard box was hit once, however, the Sightstep test suggests that using Sightstep is actually quicker than using a walking stick, most likely due to the size of the walking stick. Furthermore perhaps with more time allotted to become acquainted with Sightstep, the pace would quicken.

The degree to accuracy test shows that although it won't be completely accurate, Sightstep does work as aslong as the object is within 80 degrees left or right from the sensor.

The comparison statistics between the walking cane and the Sightstep indicate that Sightstep is within the price range of walking canes; however, Sightstep is much smaller than the cane, as it is more compact, and doesn't require the use of hands.

Conclusion- In this project, a practical replacement for the blind walking cane was created by utilizing ultra-sonic technology. This device, named Sightstep, could consistently react to approaching objects, such as a wall or a step. To create sightstep, a program was written in Arduino programming language, which is based off of C and C++. This program sent pulses to 3 ultra-sonic sensors, which relay feedback information in microseconds. The program converted the feedback into centimeters. Then, using this incremented data, the program would turn on 3 vibrating motors to a medium setting to alert the user when an object was within 100cm of an object and a high setting when an object was within 50cm of an object. Using the Atmega328 programming chip, the electrical components used in this program were compiled onto a printed circuit board and encased in a small container which could fit over a shoe.

The testing with this product indicates that Sightstep is consistent with nearly all materials. With every material tested, Sightstep reacted when the material was close to 100cm away for the medium setting and 50cm away for the high setting, with a variation of 2cm. Sightstep reacted 100% of the cases when it was directly facing the material. This suggests that ultra-sonic technology is viable for fulfilling the capabilities of a walking cane. There are few instances in which this ultra-sonic sensor would provide a false negative. If this object is tilted outside of 80 degrees left or right so that the ultra-sonic sound waves would bounce away from the sensor, then a false feedback could occur. Also, Ultrasonic technology is not helpful in searching for tiny objects, such as wires or thin poles.

The statistics comparing the Sightstep and the walking cane suggest that the Sightstep would be a better choice due to its decreased size and due to the fact that it does not require the use of hands to operate. Its cost is around the same as that of an average walking cane. Furthermore, during the testing, Sightstep proved to allow the experimenter to move 7.45 meters per minute faster than a walking stick would.

In the future, Sightstep will be continuously revised to bring it to the most efficient, user-friendly, and inexpensive state possible. For instance, a custom-made printed circuit board may be used. The 9v battery could be replaced with button cell batteries which are much smaller and lighter. A tougher and slimmer casing will be made to add even more protection to Sightstep. New features will be added to the program. Another sensor could be added to detect depressions in the land. Also, cheaper or bulk materials will be used to bring the price of Sightstep down.