AN ULTRASONIC BASED
NAVIGATION AID FOR THE BLIND

A Project Report

Submitted by

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in partial fulfilment of requirements for the award of the degree of

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CERTIFICATE

This is to certify that the project entitled: **An Ultrasonic Based Navigation Aid for the Blind** being submitted to the **Indian Institute of Technology, Madras, by Pradyumna R. Patwadkar** in fulfilment of the requirement for the award of **Bachelor of Technology and Master of Technology in Electrical Engineering** is a bonafide record of project work carried out by him under my guidance and supervision at this institute

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Date: May 2019

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Pradyumna Patwadkar

ABSTRACT

It is no person's choice to be born blind, yet a few unfortunate percentage of us have to endure the pain throught their lives. Navigation is one of the most important tasks in our lives and being independent at it would empower the blind. Hence the need to research in this field and come up with an easy to use solution as a navigation aid.

The biggest problem with the presently available technology is that the aid generally gives the blind person's identity away. The research involved exploring different methods currently used, and coming up with a system design which is cost effective and full proof for navigation. The design approach was to integrate ultrasonic sensors in commonly used clothing items and things we wear often like belt, bag pack, waist bag etc. It involved deriving information about the environment and informing the user.

The system works with 4 sensors in different positions and is able to detect obstacles like walls, doors, even stairs and pot holes to alert the user on a timely basis. The user of the system would not need to use a blind stick maintaining the confidentiality of their identity. Concluding, methods have been identified how the designed system can be integrated with other existing technology to make the experience even more sophisticated for the user.

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1. Introduction

1.1 Motivation:

Blindness or visual impairment is a condition that affects many persons around the world. According to the World Health Organization (WHO) in 2012, out of 7 billion global population there were over 285 million visually impaired people and 39 million were totally blind and this number is growing at an alarming rate [1]. This condition leads to the loss of the precious sense of vision to such a degree that makes the concerned person handicapped due to the need for guidance or assistance, specifically affecting the mobility of the person. This dependence causes the blind people most of the time to be withdrawn from the society because they feel that people and the society are prejudiced and they may be treated differently. Blind person do not need pity, but require empathy, so as to mingle in the society. Hence blind people need an assistive device that will allow blind user to navigate freely and this requirement has become crucial.

Guidance by other humans, with good vision, or specially trained dogs is an obvious solution to help blind persons navigate their way around both in the house as well as outside the house. However, dependence on other humans is highly demanding and constraining in many ways. Trained dogs are very helpful however they have limitations that include inability to interpret what the blind persons really wants and identifying objects. This is in addition to the continuous care cost for the dog. Among devices, the long cane is by far the most popular mobility device for the blind [2]. Unfortunately, all of these methods give away the identity of the blind person which means that when people interact with the person, their behavior is different.

Some technological solutions have been introduced recently to help blind persons navigate independently. Many of those solutions rely on Global Positioning System (GPS) technology to identify the position and orientation of the blind person. While such systems are suitable for outdoor navigation, due to the need for line of sight access to satellites, they still need additional components to improve on the resolution and proximity detection to prevent collision of the blind persons with other objects and hence subject his/her life to danger.

Blind humans have been known to use echolocation to "see" their environment but this is difficult for everyone to learn. This master's thesis explores this principle by presenting the development of a system with ultrasonic sensors to mimic echolocation with which the user can use to navigate with ease. The goal has been to attain a simple user experience without giving away the user identity. The idea is that a navigation aid able to do this should have a fair chance of being successful on the market.

1.2 Scope of Work:

The main objective of the project is to develop a navigation aid and a methodology for it to be developed into a product. The process of objectives will be as follows

- Research and explore the existing methods available for navigation for the blind
- Identify their drawbacks
- Explore different sensors and test them
- Design the most effective system and test the system for different situations

- Integrate the system assembly to day to day wear to make it incognito
- Identify the drawbacks and future scope of improvement for the system

1.3 Organization of Thesis

The report is divided into 6 chapters of which the first chapter gives an introduction of the project, the motivation behind it, and its objectives. Chapter 2 deals with a literature review of available technology and literature. Chapter 3 looks at the theory behind the choice of sensor, the theory of how the sensors work, what is the system proposed and the reasons behind this being the exact assembly. Chapter 4 deals with results of test of the system for various obstacles which the user would encounter in everyday use. Chapter 5 is about conclusions of this project, drawbacks with this assembly and future scope of improvement. Chapter 6 contains all references.

2. Literature Review

One of the major proposed methods for navigation is using GPS. [3] Presents a system that will enable a blind or visually impaired person to navigate independently inside an enclosed environment such as the home. The system integrates wireless communication technologies, path planning, sensors and other technologies to build a compact portable navigation system. The elements required to perform the guidance process include defining the destination or target, identifying the current position of the blind person and finally determining the best path to be taken to reach the desired destination. In order to identify user position, the guidance system utilizes localization engine technique that continuously updates the server with the user location. A digital compass located in the push mobile cart enables the system to identify the user orientation. The proximity sensors incorporated in the mobile push cart enable the detection of obstacles. The user of the guidance system pushes the cart that houses hardware components in front of him/her while walking. The cart rolls on passive wheels that support its weight during regular operation. Also the wheels are equipped with encoders to determine the relative motion of the user. This information is used to refine the system localization process.

[4] This study proposes a simple smartphone-based guiding system for solving the navigation problems for visually impaired people and achieving obstacle avoidance to enable visually impaired people to travel smoothly from a beginning point to a destination with greater awareness of their surroundings. In this study, a computer image recognition system and smartphone application were integrated to form a simple assisted guiding system. When the system begins to operate, the smartphone captures the scene in front of the user and sends the captured images to the backend server to be processed. The

backend server uses the faster region convolutional neural network algorithm to recognize multiple obstacles in every image, and it subsequently sends the results back to the smartphone. The results of obstacle recognition in this study reached 60%, which is sufficient for assisting visually impaired people in realizing the types and locations of obstacles around them.

[5] The researchers worked towards the development of a miniaturized, wearable sensor device to enhance safety during ambulation for persons who are blind. This system warns the blind user when they are about to hit an obstacle at head level, in time to avoid a collision. With respect to existing Electronic Travel Aids, this device is “minimalistic”: rather than attempting to provide rich information about the environment, the proposed system simply emits a warning signal (in acoustic and/or tactile form) when a hazard is detected. The sensor, which uses two ultrasonic transducers for obstacle localization, can be mounted on one’s shirt pocket or disguised as a brooch. Special care is devoted to optimizing the devices’ performance (in terms of range accuracy and detection / false alarm rate) and to minimizing form factor and power consumption. This looked at building a more simplistic model for solving a particular problem.

[6] Uses a stick equipped with ultra-sonic sensors, GPS and audio output system. The stick contains GPS which will have SD memory card which used to store different locations. The user can set the location by voice and the GPS will guide the person to his/her distention. This system will also provide the speed and the remaining distance to reach the destination. When the ultra-sonic sensors detect any obstacle directly the voice system will activate the caution voice. This system can be classified as a low cost system affordable by the user. In addition to that, it can provide a voice guide for the user with

greatest possible accuracy. The system uses the ARM processor which has more memory space, so that the operating speed is high. However, this system cannot operate indoors because there will be no signal for the GPS system. The accuracy of the GPS signal need to be improved because it only can be controlled within 5 meters radios. Finally, the blind person needs to be trained on the system so that he or she can use it effectively.

[7] An advanced blind stick system was proposed that allows visually challenged people to navigate with ease using advanced technology. The blind stick is integrated with ultrasonic sensor along with light and water sensing. The project first uses ultrasonic sensors to detect obstacles ahead using ultrasonic waves. On sensing obstacles the sensor passes this data to the microcontroller. The microcontroller then processes this data and calculates if the obstacle is close enough. If the obstacle is not that close the circuit does nothing. If the obstacle is close the microcontroller sends a signal to sound a buzzer. It also detects and sounds a different buzzer if it where detects water and alerts the blind. One more feature is that it allows the blind to detect if there is light or darkness in the room. The system has one more advanced feature integrated to help the blind find their stick if they forget they kept it. A wireless RF based remote is used for this purpose. Pressing the remote button sounds a buzzer on the stick which helps the blind person to find their stick. Thus this system allows for obstacle detection as well as finding stick if misplaced by visually disabled people.

[8] The aid consists of a microcontroller, an accelerometer, a footswitch, a speech synthesizer, a hexadecimal keypad, a mode switch, two ultrasonic sensors, two vibrators and a power switch. The system is divided into the obstacle detection containing two ultrasonic transmitters-receivers and two vibrators. It can detect the presence of any

obstacle within the specified measurement range of approximately 0.03 to 6 meters. It operates by sending out a pulse of ultrasound. Eventually the pulse is reflected from a solid object in the path of the pulse. The time between the outgoing pulse being transmitted and its echo being received corresponds to the distance between the transmitter and the object or the obstacle. This information is then relayed to the blind the form of a vibration. An increase of distance to an obstacle results in a decrease in vibration, while a decrease of distance results in an increase in vibration. The other part of the system records the instructions to a particular route which can be accessed by the user.

All of these system had some common drawbacks. All the solutions with a blind stick gave away the fact that the person was blind. This is something I am looking to correct. The one's which only worked with GPS had problems with objects in close proximity that might be relevant to the user. The smartphone system needed network available to process the data via cloud and send it back which is not something to be assumed during all parts of the day. None of the above research looked at covering all the relevant region to a person moving around which is essentially the region a few meters ahead of the user covering the width of the user and their height. With the system I am targeting to design to cover and detect obstacles in the area of concern for the user. I also attempt to make this system real time with future scope to be integrated with other existing solutions.

Table summarizing advantages and disadvantages of a scheme using a particular type of sensor:

Scheme (major sensor)	**Advantages**	**Disadvantages**
GPS	User knows can know their orientation in a completely unknown environment	No information shared about objects around the user, nor their proximities
Lidar sensor	Accurate, information about the proximity of objects is conveyed, , can be used in day and night, large range	Expensive, ineffective during rain, objects are not identified
Ultrasonic sensor	Accurate, cheap, easy to interface, information about the proximity of objects is conveyed, can be used in day and night	Sensing affected by soft objects, less range, objects are not identified
IR sensor	Low power requirement	Affected by dust, smoke, changes in air, objects are not identified
Camera	Objects are identified, captures the whole environment information	Higher computation time, complex algorithms to process large data, less ease in distance detection

The future scope includes possible integration of the proposed system with GPS and Camera giving the maximum advantages possible to approach a more complete solution to the navigation problem.

3. Ultrasonic Based Proposed System

3.1 Ultrasonic Sensors

[9] Ultrasonic sensors measure distance by using ultrasonic waves. The sensor head emits an ultrasonic wave and receives the wave reflected back from the target. Ultrasonic Sensors measure the distance to the target by measuring the time between the emission and reception.

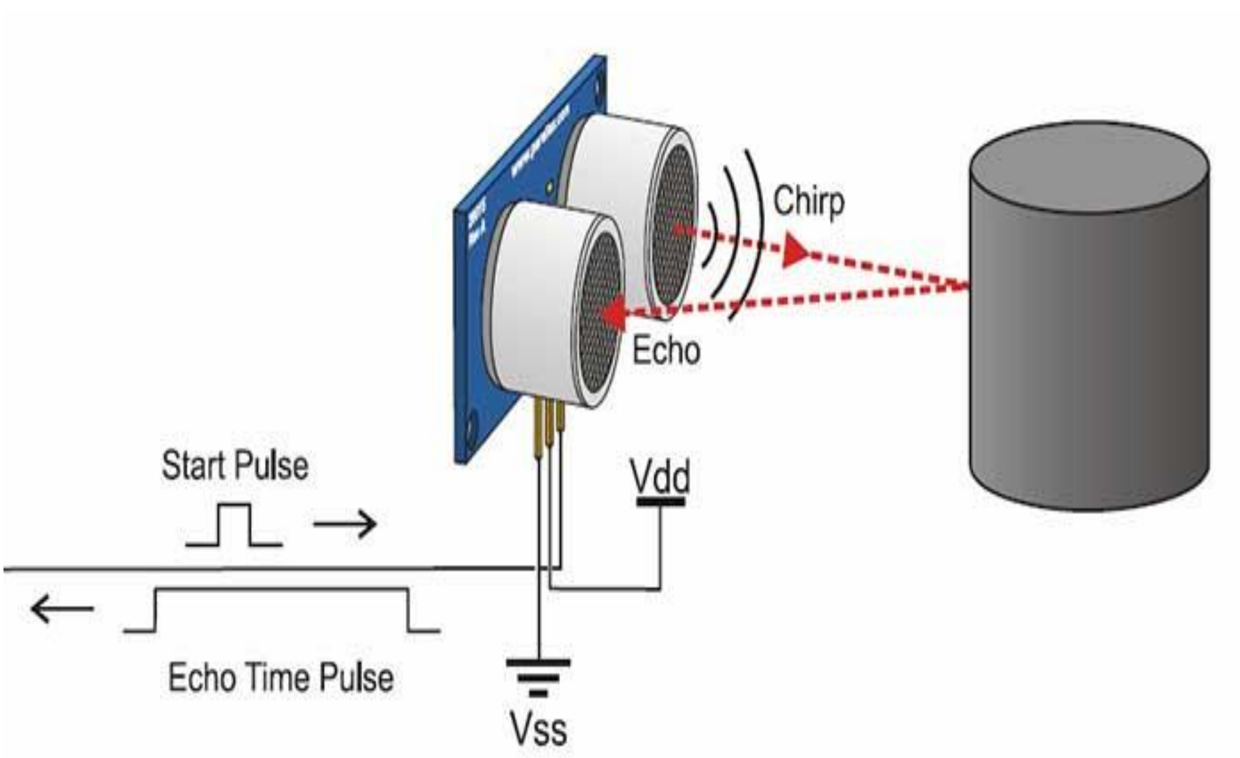


Fig 3.1 Working of an Ultrasonic Sensor

Distance calculation:

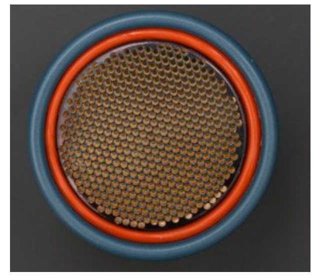
Distance L = 1/2 × T × C where L is the distance, T is the time between the emission and reception, and C is the sonic speed. (The value is multiplied by 1/2 because T is the time for go-and-return distance.)

3.2 Why Ultrasonic sensors?

- The ultrasonic sensor has high frequency, high sensitivity and high penetrating power therefore it can easily detect the external or deep objects.
- These sensors easily interface with microcontroller or any type of controller
- These sensors have greater accuracy then other methods for measuring the thickness and depth of parallel surface.
- These sensors could easily sense the nature, shape and orientation of that specific objects which is within the area of these sensors. [10]
- There sensors are easy to use, not dangerous during operation for nearby objects, person, equipment or material
- The wideness of the beam angle make them better suited for covering the required area
- These sensors are cost effective and inexpensive in comparison to lidar sensors
- These sensors are tolerant to changes in light, dust in the air, smoke etc. which gives them a major relative advantage against IR sensors. [11]

3.3 Sensors Used

URM06 - Analog Ultrasonic sensor provides very short to long-range detection and ranging from 20cm - 10m. It comes with analog interface and works at high output acoustic power. The ultrasonic sensor detects objects with 1cm resolution. The URM06 has 15 degree beam angle which has excellent receive sensitivity. This sensitivity makes it ideal to detect the unevenness of the ground.



HC-SR04 – [12] The HC-SR04 ultrasonic sensor uses sonar to determine the distance to an object like bats or dolphins do. Ranging from 10cm-400cm non-contact distance sensing capabilities and accuracy up to 2cm. It is extremely cheap at Rs.99 per piece hence it has been used in both set of sensors.

3.4 Proposed System

The system consists of 2 sets of sensors, Set 1 and Set 2. Set 1 deals with all obstacles above the waist level and Set 2 deals with all obstacles below the waist level including changes in level of the ground. Both the sensors used in Set 1 are HC-SR04, whereas Set 2 consists of 1 HC-SR04 sensor and 1 URM 06 sensor. Set 1 is integrated with a regular bag pack and Set 2 is integrated with a waist bag.

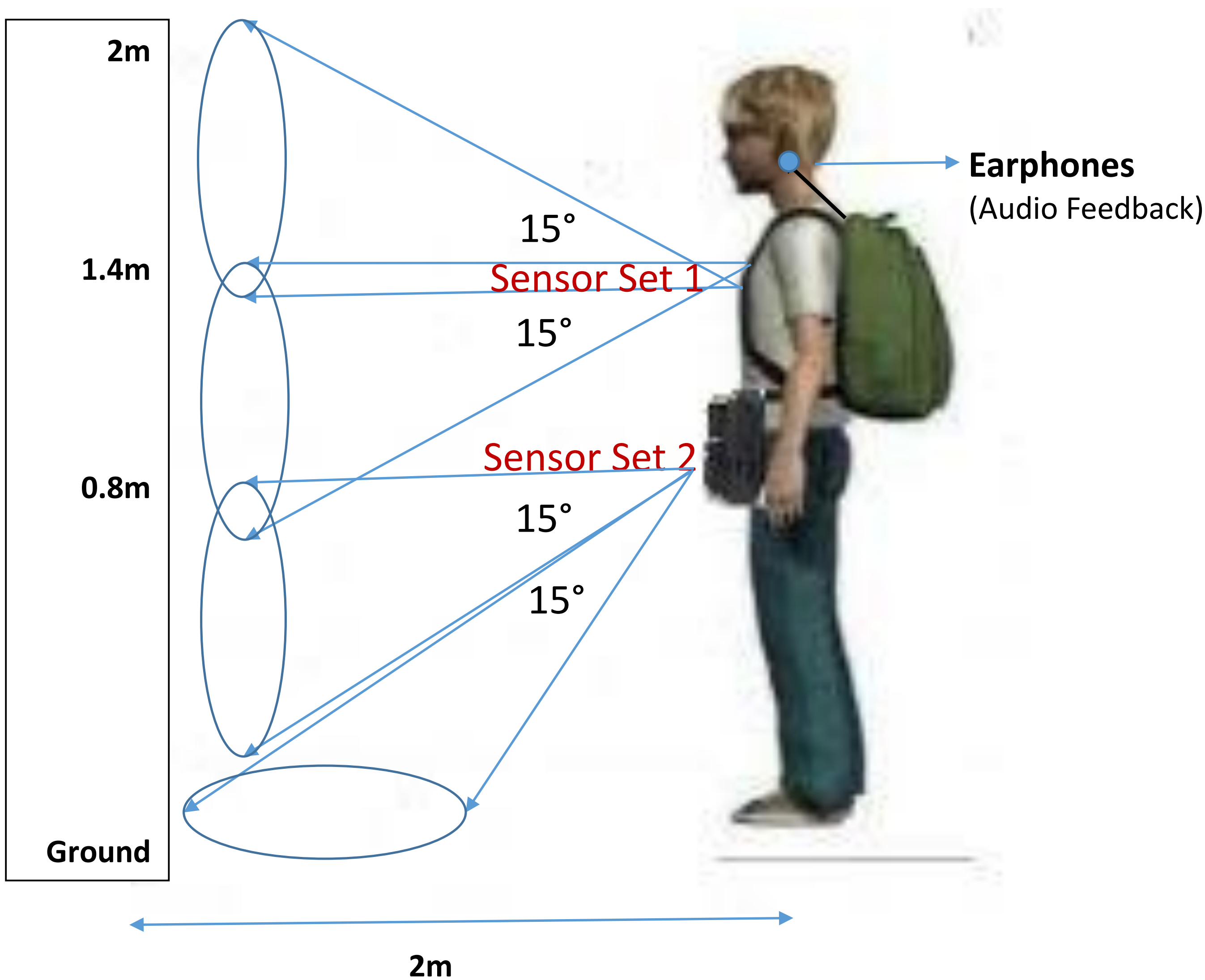


Fig 3.2 Side view of the area covered by the Sensor Sets 1 and 2

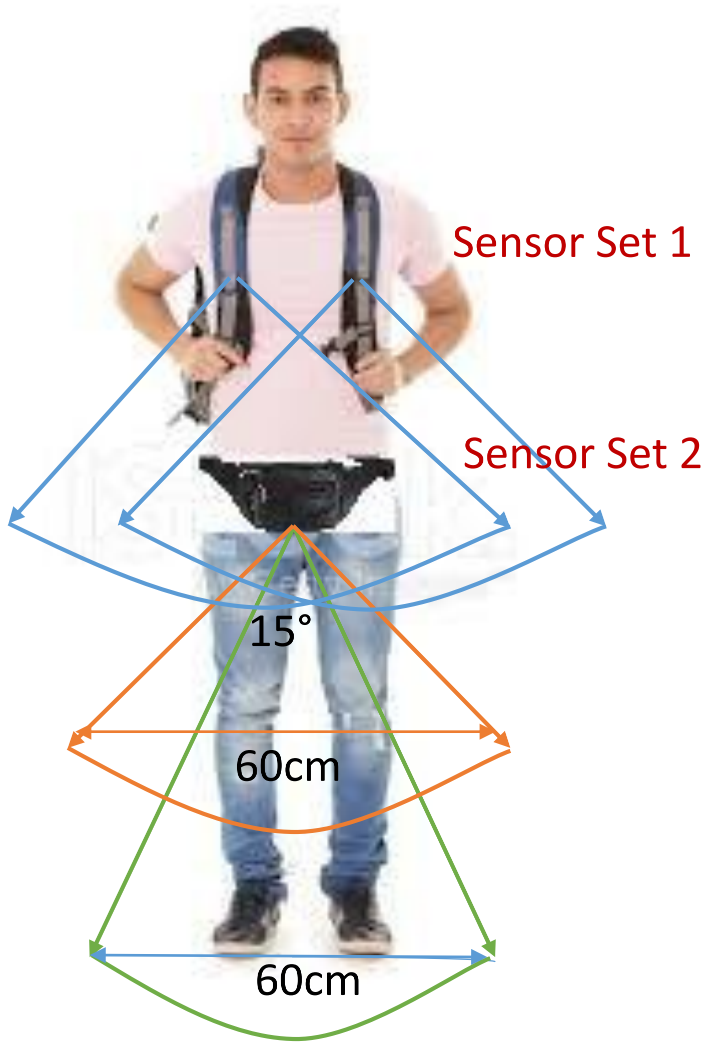


Fig 3.3 Front view of the area covered by the Sensor Sets 1 and 2

Each sensor covers a horizontal length of 60cm at a distance of 2m away from the user. These areas cover nearly 20 cm more than the average shoulder hence would successfully detect any obstacles in front of the user.

Fig 3.4 System Set 1

Fig 3.5 System Set 2

3.5 Why this assembly?

1. **Region Covered:** This assembly is most importantly covering all the area relevant to the user. When we are walking we can see all obstacles in front of us, be it a pot hole on the ground, or stairs or an obstruction near the head region so this is exactly what this system works like. Vertically the Sensor Set 1 covers all obstacles from 0.8 m to 2 m. The Sensor Set 2 covers all obstacles (below the waist level) from the ground to 1 m.

2. **Obstacle detection:** The increased sensitivity for the URM6 sensor means that even a small change in ground level is detected easily. The sensors are able to detect all common obstacles that might fall the way of the user when commuting.

3. **Optimal number of sensors:** The task was to design a system with the minimum number of sensors to make the system easy to use and also to make it cost effective. This task was done with just 4 sensors without compromising on the effectiveness of the system. Too many sensors would make the system complicated.

4. **Ease of integrating:** This system of sensors can be easily integrated with something a person uses often in their daily life. A waist bag and a bag pack will not make the user feel awkward and not give away their identity.

3.6 System Flow Block Diagram:

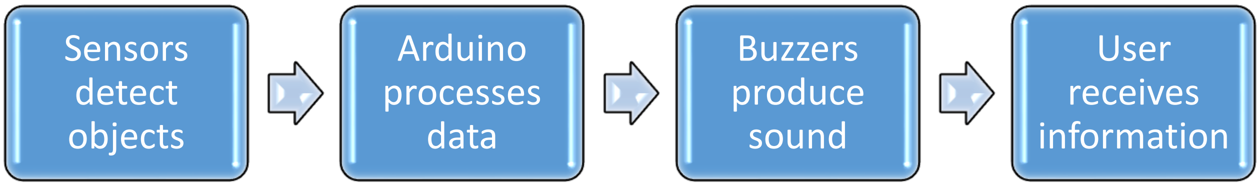


Fig3.6 Block Diagram of the System

The system functioning has 4 main steps. A pulse is sent after every 10 microsecond to trigger the input pins of the sensors. When an echo is received, the time taken is measured and thus distance is calculated. For the URM06, it gives the output in an analog voltage form which can be easily converted to the distance by measuring the voltage from the analog pin of the Arduino. For the other sensors, the digital pins are used to both trigger and get the echo. Once the distance values are calculated, a sound output is created with the use of buzzers. The frequency of the tones produced is inversely proportional to the distance from the nearest object. Thus when an object is close by, the high frequency will alert the user to stop and change direction. With a separate buzzer for each sensor the user knows which area the obstacle lies in. Finally the user can process the information and make a decision.

4. Results

4.1 Methodology

The method to test the system was practical. All major situations which will recur when navigation are tested and also objects which could come in the path of the user. Also detection ranges have been found out as to how far the particular sensor is able to detect the object. The URM06 sensor was tested to detect pot holes, stairs (both going up and down) whereas the HC-SR04 sensor was tested to detect walls, pillars, humans.

4.2 Detection of stairs going up

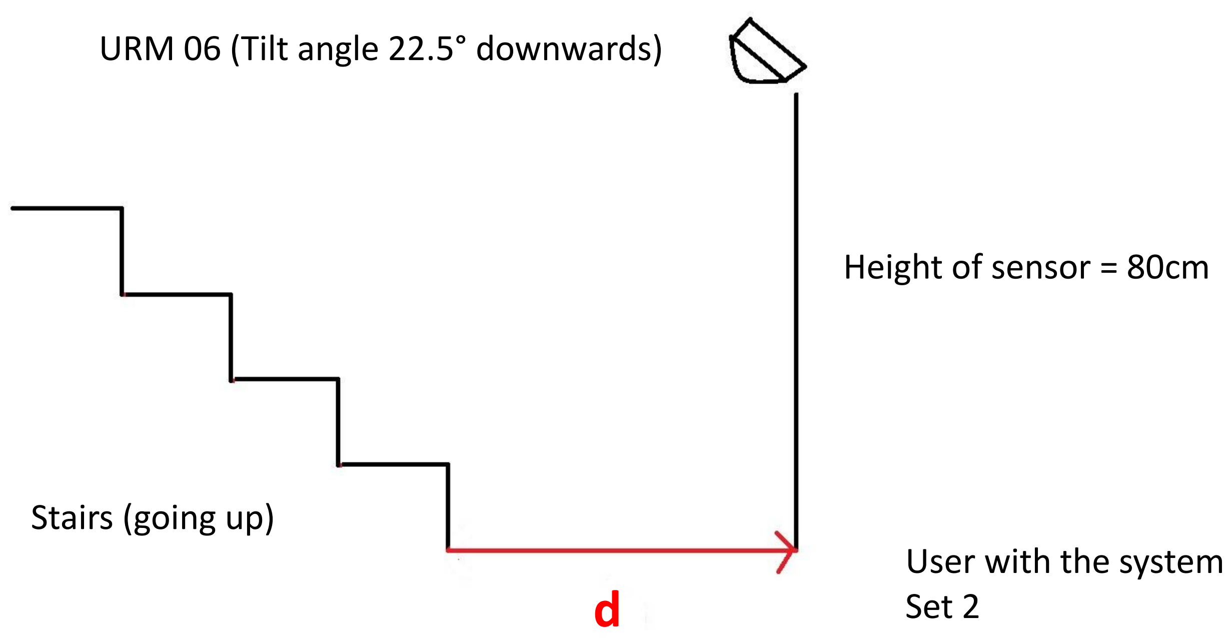


Fig 4.1 Assembly for detection of Stairs going up

The URM06 is tested for detecting stairs going up in steps of 15cm from a height of 80cm (which is the height it will be at when worn by the user).

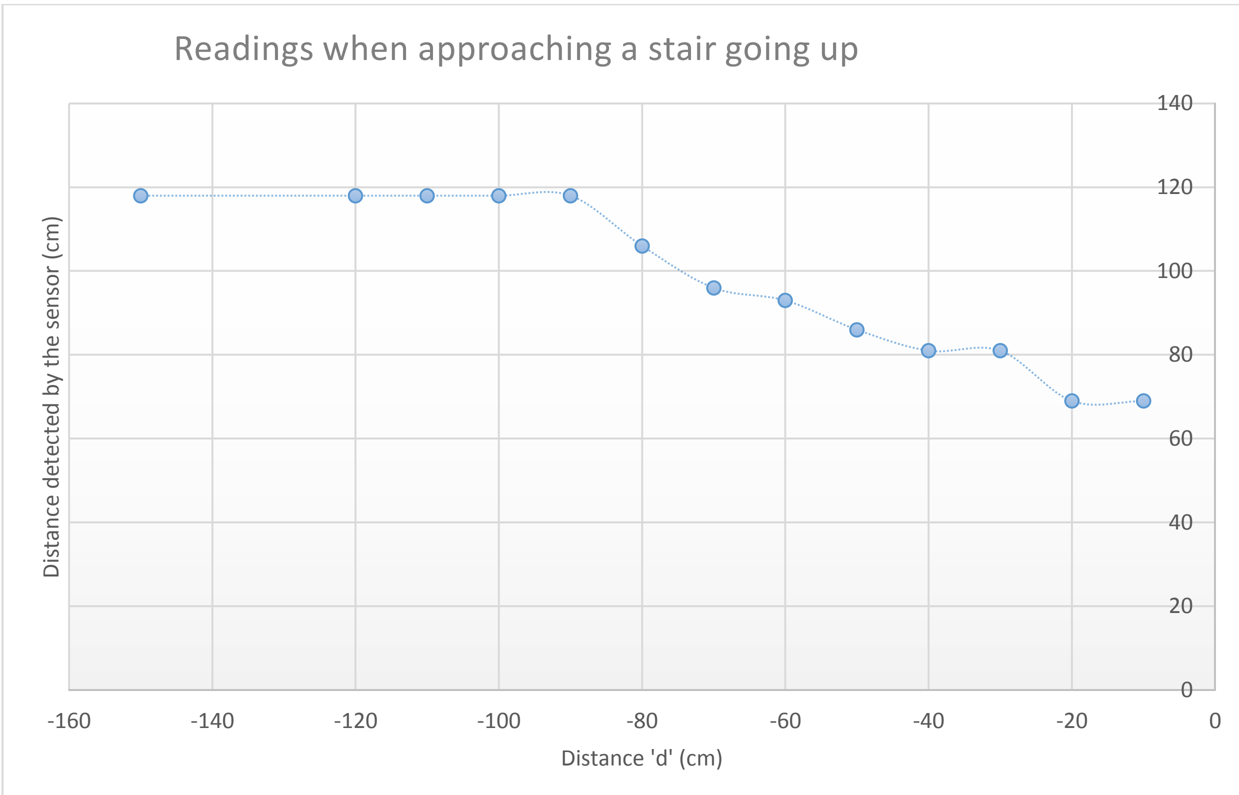


Fig 4.2 Readings when approaching stairs going up

The graph shows that the sensor detects the stairs almost 1m away from the user. With each step the user takes closer to the stairs, the distance reading from the sensor drops. Finally this reading reaches close to 70cm when the user is about to reach the stairs because the echo reflected back from the stairs takes much less time because of the decrease in distance from it.

4.3 Detection of Stairs going down

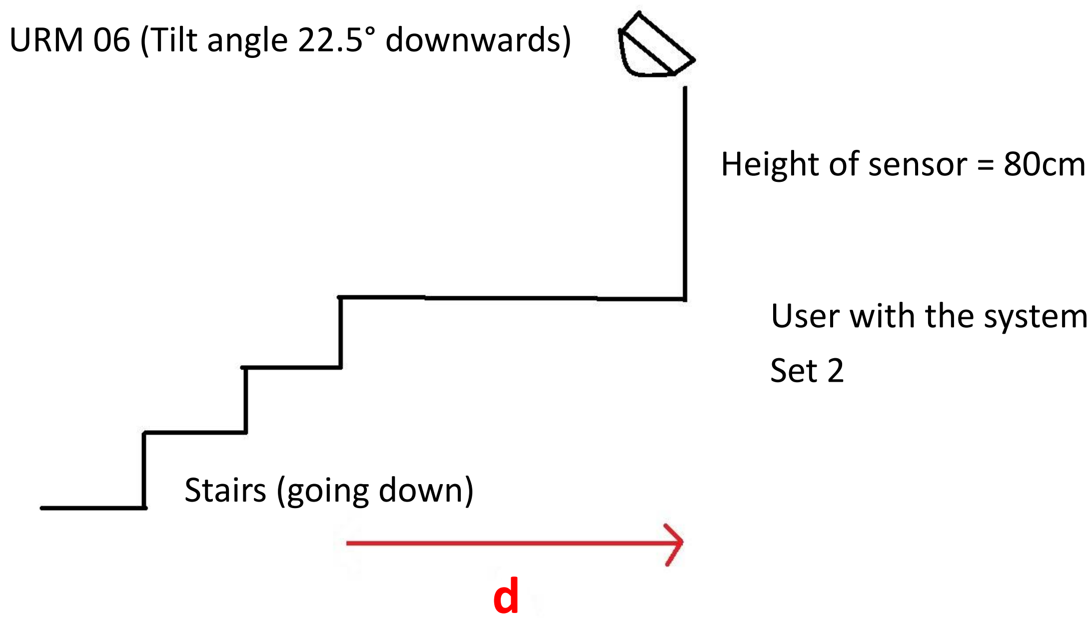


Fig 4.3 Assembly for detection of Stairs going down

The URM06 is tested for detecting stairs going down in steps of 15cm from a height of 80cm (which is the height it will be at when worn by the user).

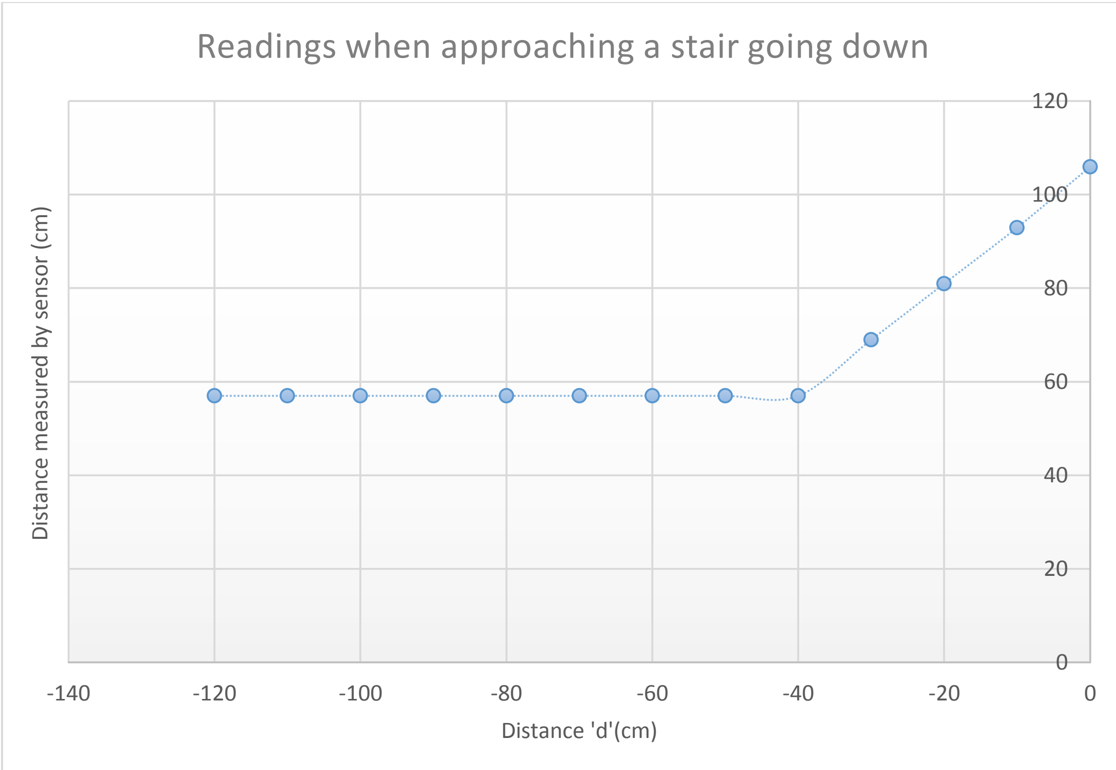


Fig 4.4 Readings when approaching Stairs going down

The graph shows that the sensor detects the stairs almost 40cm away from the user. With each step the user takes closer to the stairs, the distance reading from the sensor increases. Finally this reading reaches close to 110cm when the user is about to reach the stairs because the echo reflected back from the stairs takes much longer to reach the sensor due to increased distance from it.

4.4 Detection of a Pot hole

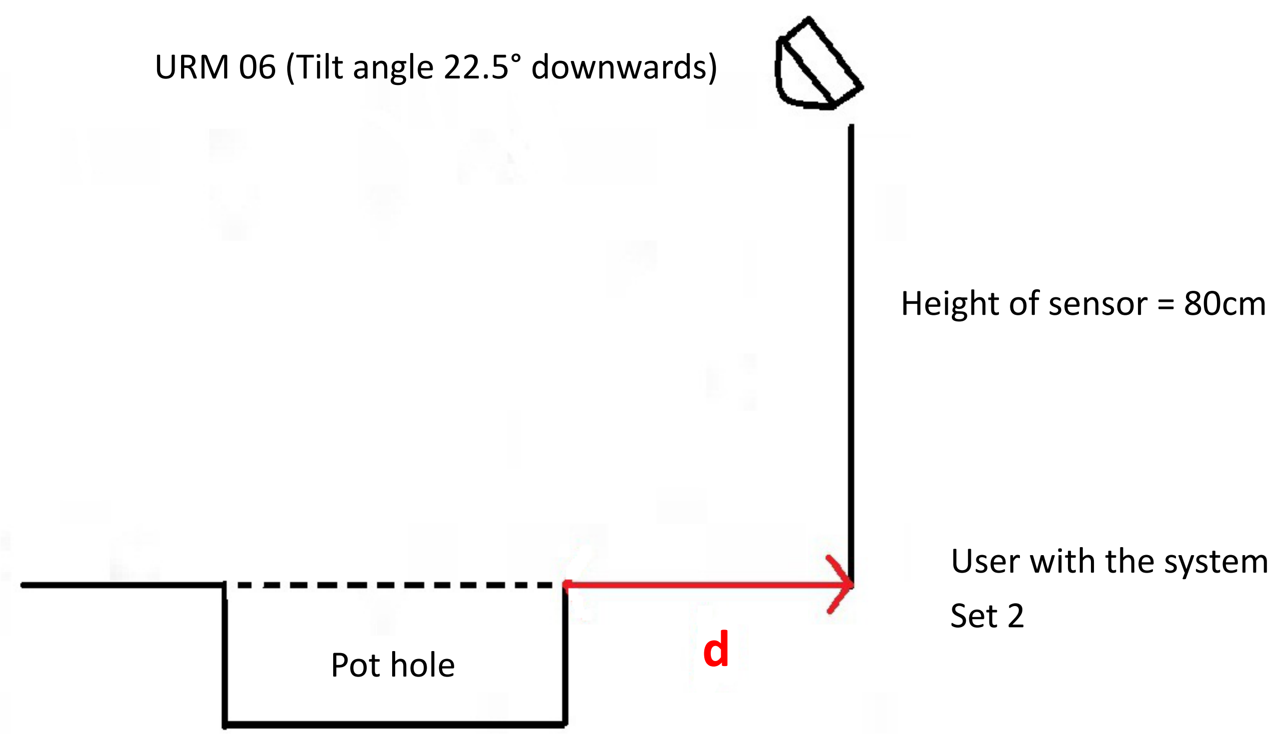


Fig 4.5 Assembly for detection of a Pot hole

The URM06 is tested for detecting pot hole of height 30cm from a height of 80cm (which is the height it will be at when worn by the user). The test was done by taking 2 readings for the same distance; one with the cardboard box closed (meaning no pot hole) and the other with an open box (pot hole).

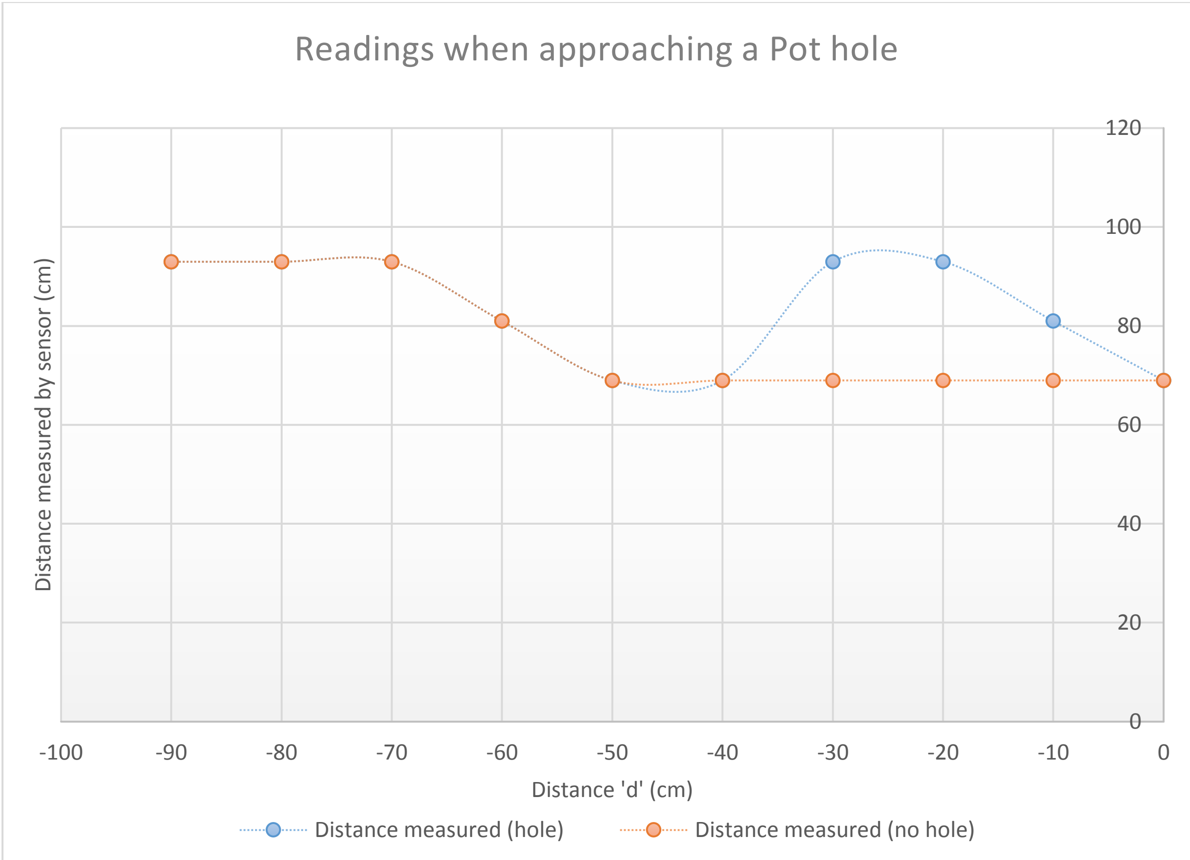


Fig 4.6 Readings when approaching a Pot hole

The graph shows that the sensor detects the pot hole almost 40cm away from the user. There is a difference of readings when the user goes closer to the pot hole. The red line indicated the reading taken when there is no hole and the blue one indicated the readings taken with a pot hole. Finally this reading increases when the user is about to reach the pot hole because the echo reflected back takes much longer to reach the sensor due to increased distance from it. Whereas the readings no change when there is no pot hole.

4.5 Readings when approaching different obstacles

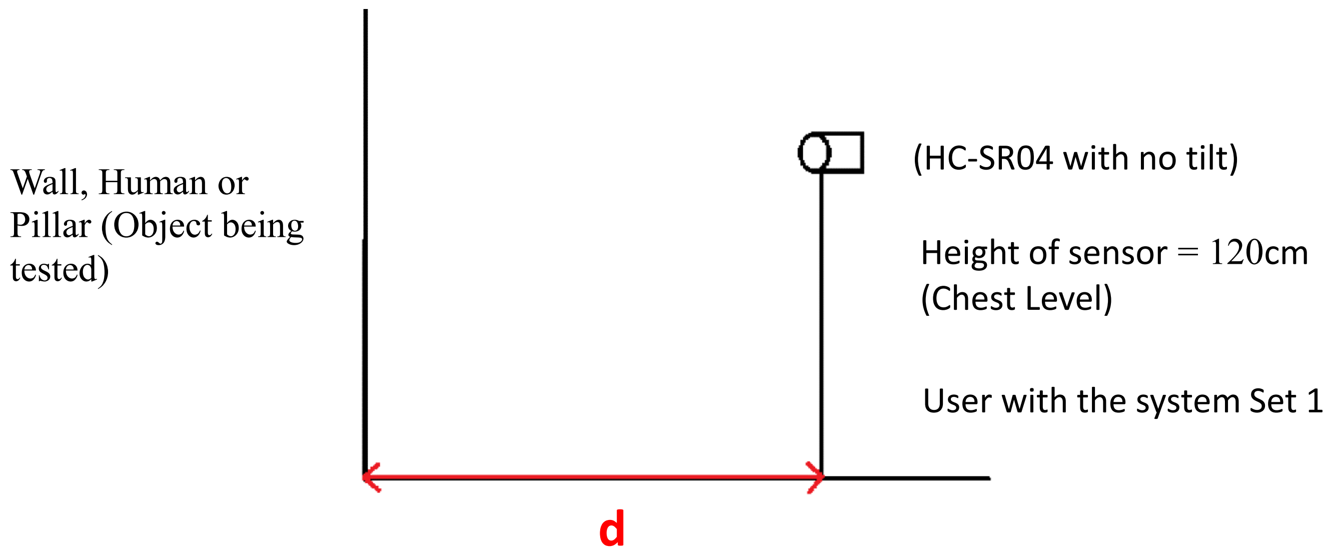


Fig 4.7 Assembly for detection of Wall, Human and Pillar

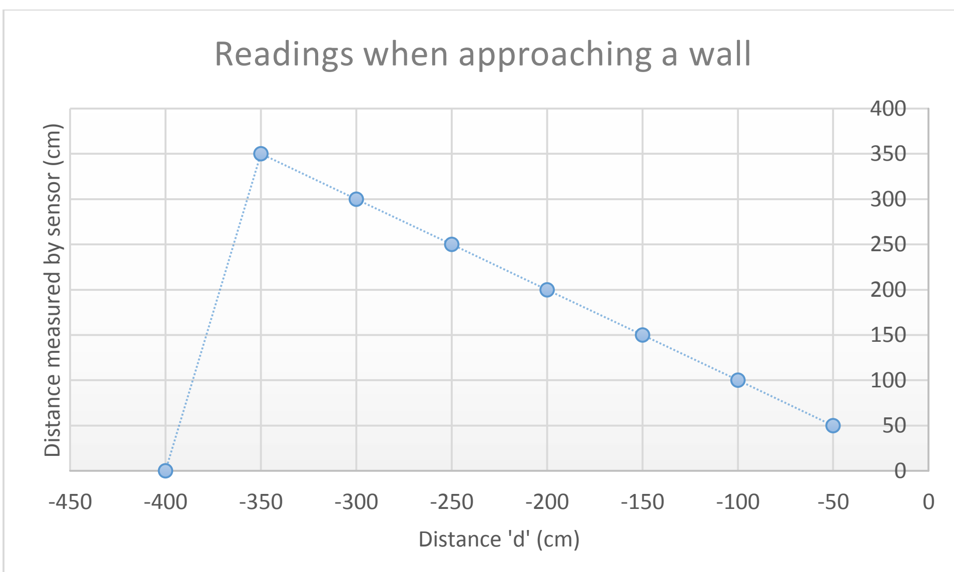


Fig 4.8 Readings when approaching a wall

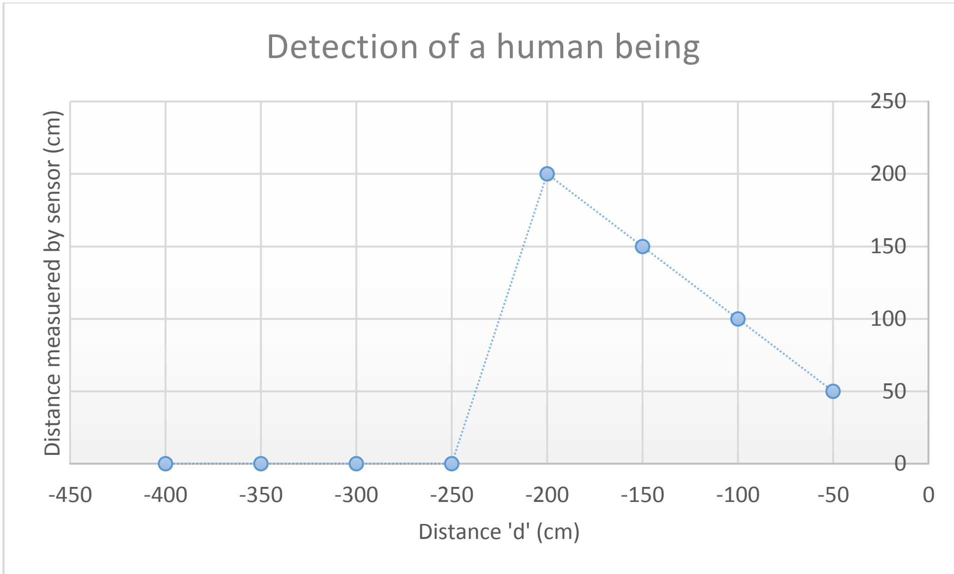


Fig 4.9 Readings when approaching a human

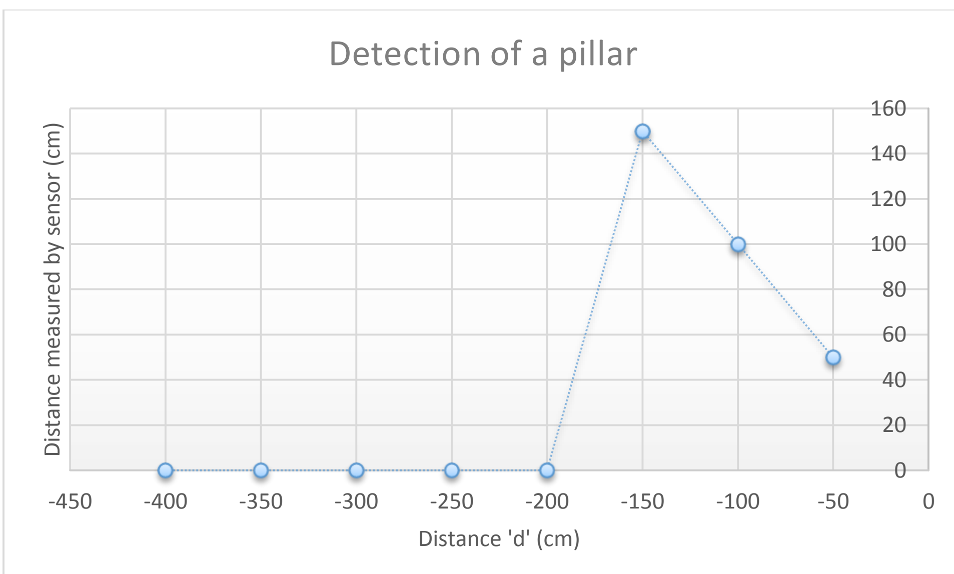


Fig 4.10 Readings when approaching a pillar

The graphs shows different ranges at which different objects are detected. Walls are detected at 4m distance away because of the width of the wall, it is easily detectable. Whereas a human can only be detected at 2m away from the user and a pillar can be detected 1.5 m away.

5. Conclusions

5.1 Summary of results

The proposed navigation aid has been developed in order to enhance the independent mobility of blind individuals. The system is able to detect all the obstacles it has been tested for. It is specifically useful for detection of stairs, pot holes or any unevenness in the ground surface. It was also able to detect other obstacles like chairs, tables, buckets etc. Although the system detects the nearest obstacles, it cannot solve the blinds' ultimate problem of the Environment perception. But thus far the results obtained are encouraging and further testing on more blind people shall be implemented in the near future. I hope that this aid will be an effective, low-cost solution for reducing navigation problems for blind users.

5.2 Drawbacks of the System

- Sensing accuracy of ultrasonic sensors is affected by soft materials - Objects covered in a very soft fabric absorb more sound waves making it hard for the sensor to see the target.
- Sensing accuracy of ultrasonic sensors is also affected by changes in temperature of 5-10 degrees

- The HC-SR04 sensor has a maximum detection range of 4 m hence objects approaching the user fast like a car for example might not be detected until it’s too late.
- The system may not convenient to use when at home, in an office or places where the laptop bag doesn’t blend in.
- The system gives user only information about proximity to an object but cannot specially identify the object.

5.3 Future Scope of Improvement:

- Integration with a GPS – the system can be integrated with GPS. This would provide navigation to the user to move from a place to another. Combining this with the information about proximities of objects, the user could receive very detailed navigation instructions. [13]
- Integration with a camera – a camera could give information about the objects around the user. Once these changes are integrated, the model could be developed into a product.

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