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Ultrasonic Sensor Based Haptic Feedback Navigational System for Deaf - Blind People

G. Saravanan, K. Devibalan

Abstract*: Deaf-Blindness is a rare collective disorder that affects nearly 3.5 million people in today's world. The improvement restricts the usage of two senses and by large impacts a person's navigational capability. A variety of aid devices are used to tackle such a disability. But one common drawback that setback them is their inability to address the collective disorder. The proposed project aims at overcoming the aforementioned drawback with the help of ultrasonic sensors and haptic feedback in the form of vibrations. These sensors and feedback mechanisms are to be controlled by a microcontroller in an Arduino. Further, a rechargeable battery shall be used to accommodate the power requirements which emphasizes on energy efficiency. The project commits to limit space constraints by proposing a compact handle design and maximizes its cost efficiency such that it is affordable for everyone equally.

***Keywords* : Deaf-blindness, SONAR, path guidance**

I. INTRODUCTION

Deaf-Blindness is rare disorder that affects a significantly small percentage of our population. It is very rare that a person is born with this disability, but the chances that a person develops deafness or blindness in course of life is highly plausible. When that happens, if the person is already blind or deaf then he ends up with deaf-blindness. Navigational assistance has been a revolutionary technological innovation since its inception. The primary aim of such aid is to provide a seamless method of path guidance based on effective understanding of the environment. In its raw form the end user expects this form of assistance to provide him with the knowledge of objects in the environment in the predefined path to his destination. This brings us to the requirement of developing an efficient solution that enables a disabled person to use navigational assistance without any hassle. The proposed product focuses on providing a novel navigational assistance mechanism in an indoor environment that uses the concept of Sound Navigation and Ranging (SONAR) and haptic feedback. SONAR is implemented using ultrasonic transducers and haptic feedbacks in the form of vibrations are provided.

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Dr. G. Saravanan, Department of Electronics and Communication Engineering, Sri sai Ram Institute of Technology,Chennai,India. Email: saravanang.ece@sairamit.edu.in

K. Devibalan, Department of Electronics and Communication Engineering , Sri Sairam Engineering College,Chennai, India. Email: devibalan.ece@sairam.edu.in

II. LITERATURE SURVEY

Assistance devices conventionally use a signal or indication of some sort to inform the user about any obstruction in their path. In the vast number of technical articles, papers and experiments that have been studied, it was found that there is no concrete system that aims at providing assistance that is independent of auditory feedbacks. In the conducted survey a detailed account on the existing systems, their drawbacks would be elucidated along with discussion on research carried out in this domain. The most widely used aid device is the Guide Stick or the White Cane which is primarily hand held and extends till the surface of floor. Despite its universal popularity, the major disadvantage is its restricted usage capability. The stick does not inform the user about objects above the knee level. Also it requires the user to continuously tap around that might wear out the user over a period of time. The other alternative guiding mechanisms include, guide Dogs, GPS enabled Wheel Chair, Guiding Bots. Guide Dogs have proven to be a faithful and effective companion, but it requires a lot of training and a period of getting accustomed to which might reduce the usage efficiency.

In a study conducted by Mohamed Fezari *et al.* (2007) from University of Annaba, Ultrasonic transducers have been integrated with various conventional aid devices and their operational response was recorded. The sensors were controlled by a microcontroller and the feedback was given as auditory response with the help of speech synthesizer.

Another study carried out by Ramiro Velázquez *et al.* (2003) from Laboratoire de Robotique de Paris discussed an Intelligent Glass that records the environment in real time and provides an environmental perception to the wearer in the form of interactive Tactile Interface exploiting the concept of Man- Machine Interaction. The important understanding from this study is the need to provide the wearer with an understanding of his environment. [6]

The third study surveyed was by Kyle Curham *et al.* (2012) from University of South Florida focussed on providing Haptic Feedback to the disabled person in the form vibrations. This research also used the concept of SONAR and the working device was proposed as a hand mounted unit.

The results of this study tell the importance of device portability and handling ease. [2]

Finally Mahidi Safaa A. *et al.* (2012) from Technical Institute of Babylon, Iraq worked on a handheld device for obstacle detection using SONAR. The concept of Handheld was adopted from the two research works mentioned above as it gives more degree of freedom and ease of usage. [3]

Therefore, based on the survey conducted it was concluded that a handheld device would be the most compact design and haptic feedback in the form of vibrations would efficiently guide a deaf-blind person to navigate through the environment.

III. DESIGN

A. Functional Description

The working of the proposed system is explained below in the form of functional block diagram. The proposed system consists of a cluster of ultrasonic sensor. The Ultrasonic sensor is used to detect objects or obstacles present in the environment.

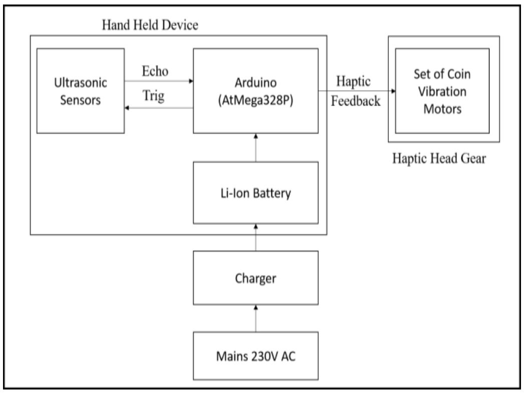


Fig. 3.1 Ultrasonic Transducer

The ultrasonic sensor HC SR-04 consists of four pins TRIGGER, ECHO, VCC and GND, Vcc is the input voltage given to the sensor at 5V.GND is connected to the ground of the Arduino. TRIGGER is the input signal given to the sensor to generate the pulse. The output of the sensor id collected through the ECHO pin.

B. Working

After connecting the HC SR04 to the Arduino a small pulse of 10uS width is sent through the trigger. This generates eight 40KHZ pulses to be sent through the TX of the sensor. The RX detects the first ultrasonic burst to return to the sensor and transmits it to the Arduino through the ECHO pin. The Arduino includes a function to calculate the
ToF and the corresponding distance from the ToF value, accessed using an ultrasonic library.

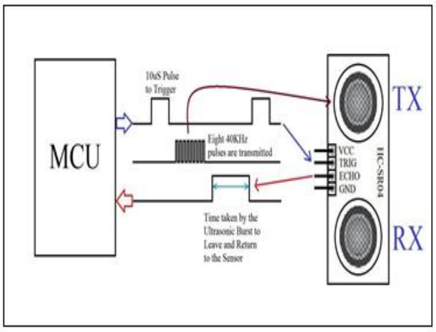


Fig 3.2.Working of HC-SR04

C. Brushless Button Motors for Haptic Feedback

Most vibration motors consist of a small electrical motor that drives an unbalanced weight. The motor is a DC current brushless motor of coin type. Brushless motors bring extended motor life and eliminate Radio Frequency Interference (RFI) by their lack of sparks. In this design, the rotor assembly includes the magnet as well as the weight that provides the vibration during rotation. The relatively bulky coils are moved to the stator, where they are connected to the controlling IC.

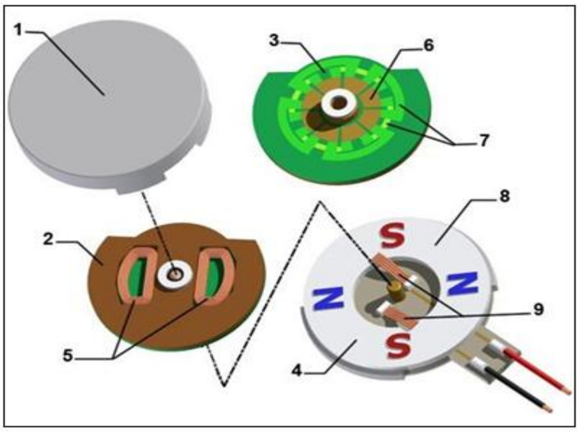


Fig.3.3. Brushless Coin Vibration Motor

E. Schematic Design

The schematic diagram shows the integrated version of the ultrasonic sensor with the arduino. The power given to the ultrasonic sensors can be given from the arduino or directly from a battery. The trigger input is given to the sensor for which an echo output is generated .All echo outputs from the sensors are collected and the appropriate feedback is given to the vibrotactors. Here the Brushless motor or Vibrotactor is substituted with LEDs of various colours to provide an analogy to show the functioning of the vibrotactor since it is working cannot be shown properly in a simulation.

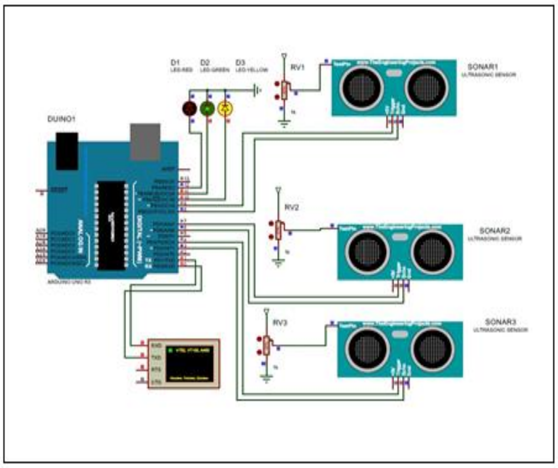


Fig. 3.4. Schematic Representation of HC-SR04 Connected with Arduino

The unique feature of this product is its design novelty and ranging capacity. The design is such that it can accommodate three sensors that detect objects in three spatial regions with respect to the human body.

Ranging capacity by extension becomes more efficient and ensures zero sensor collision. In addition to that, all the three sensors are centrally controlled by an ATMega328P microcontroller present in an Arduino UNO prototyping board. Furthermore the device is powered by an internal rechargeable Li-Ion battery. The paper discusses the design, development and implementation of the aforementioned concept. Moreover the complete testing procedure is explained with a detailed analysis of the results followed by an appropriate conclusion about the performance. In order to corroborate the practical results, detailed simulations are done in PROTEUS ISIS that provides similar results that are fairly comparable.

IV. FLOW CHART

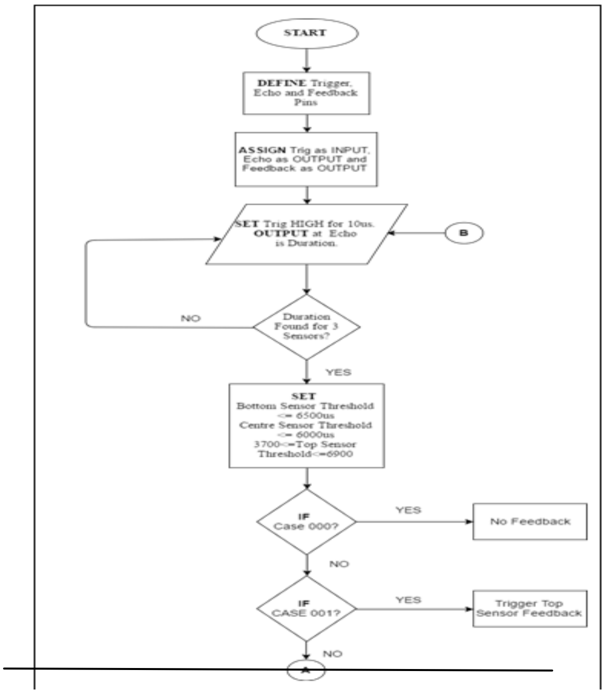
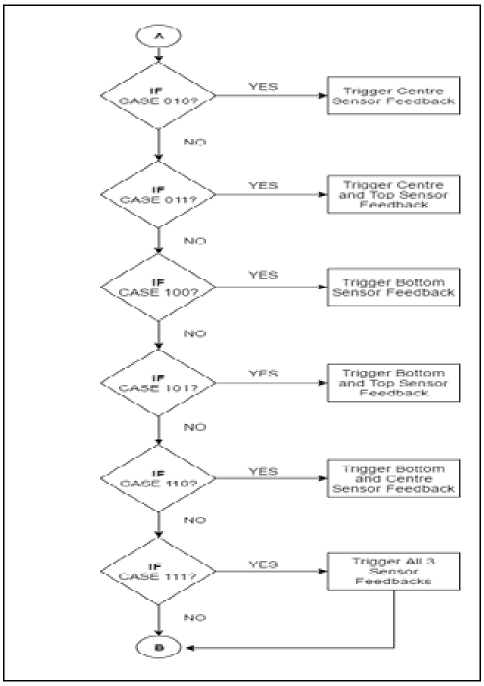


Fig.4.1. Operation Flow



V. EIGHT CASE ANALYSIS

Table 5.1 Eight Cases Input for the Device

S.No.	CASE(B,C,T)	Description	Output
1	0	All sensors do not detect obstacles.	There is no feedback to the user.
2	1	The obstacle is detected only by the top sensor.	The top sensor feedback vibrates.
3	10	The obstacle is detected only by the middle sensor.	The middle sensor feedback vibrates
4	11	The obstacle is detected by the top and middle sensors.	The feedback for both middle and top sensor vibrates.
5	100	The obstacle is detected by bottom sensor.	The bottom sensor feedback vibrates.
6	101	The obstacle is detected by both bottom and top sensors.	The feedback for both bottom and top sensor vibrates.
7	110	The obstacle is detected by both bottom and middle sensors.	The feedback for bottom and middle sensor vibrates.
8	111	All sensors detect the obstacle.	The feedback of all sensors vibrates

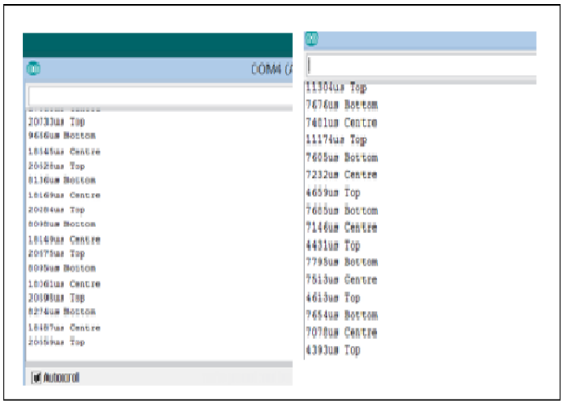
VI. RESULT AND DISCUSSION

Extensive testing was performed upon each of the module that comprises the device and device itself. The simulation for each sub-section of the device provided the ideal results and the implementation of the same provided the actual working results. The simulation and real time working have comparable results. The sensors were individually tested to record their ToF output and the three sensors together were tested with the 8 case scenario. The results obtained in each of the case gave the insight of correct execution path being followed and the output was more than satisfactory in each of the cases.

The device was tested as a whole in two circumstances, with and without obstacles. The performance was found to be fairly efficient and the subjects reported a positive user experience. The charger module upon testing gave a constant 7.35V at 70mA under charging condition and 2mA pull down at cut off. The battery was found to be fully charged in 4 hours duration and lasted up to 6 hours of continuous usage.

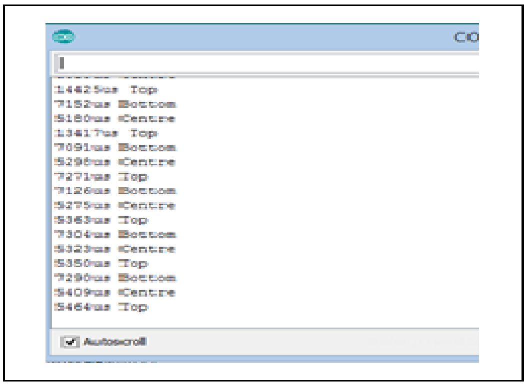
The casing design was implemented in Aluminium sheet metal owing to its light weight characteristic and easy malleability. The efficiency of the design was found to be good and the subjects found it easy to handle without any hindrance.

A. Test Case Results

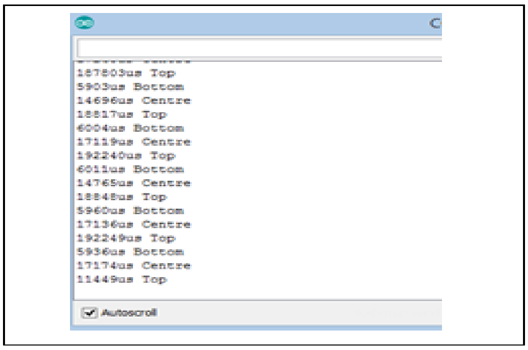


Test Case 000 & Test case 001

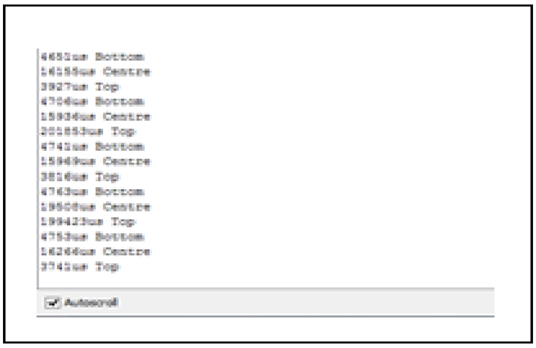
Test Case 010



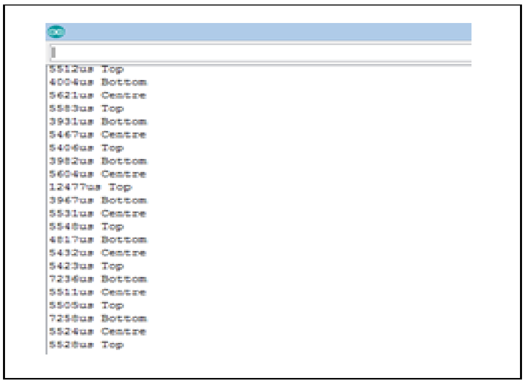
Test Case 011



Test Case 100



Test Case 101



Test Case 110

VII. CONCLUSION

It is therefore concluded that the device implemented for the purpose of navigational assistance in an indoor environment for the deaf-blind people is working satisfactorily meeting its result commitment. The device has been tested and can be produced at an industrial scale at an affordable price as a ready-to-use product for the end user.

VIII. FUTURE WORK

The proposed device aids in complete navigation only in an indoor environment. The device fails to meet its purpose in an outdoor environment owing to the randomness of that space. The scope of development is plenty and the device's functionality can be extended to meet its performance goal in an outdoor dynamic environment. This can be made possible by tracking objects in real time using ToF cameras and processing them. The process shall involve identifying their movement and predicting the next step and accordingly giving a feed back to the user. This involves real time Digital Image Processing and high speed sensors. A device with such a technology can ably assist any one in need without any hassle in an outdoor environment. Lastly, the device which is implemented using sheet metal can be manufactured using Polyethylene Terephthalate (PET) for better durability, insulation and handling ease.

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AUTHORS PROFILE

Dr.G.Saravanan obtained his Ph.D. in the field of Wireless Sensor Networks. And currently he is working as an Associate Professor in the Department of Electronics and Communication Engineering. His research areas are Sensor Networks & Wireless Communication. He has published many papers in International Journals.

K.Devibalan has completed his Master's in the field of Communication systems. He is pursuing Ph.D. in Anna University. And he is currently working as an Assistant Professor in the Department of Electronics and Communication Engineering.