Smart and Cost-Effective Device for Visually Impaired People

Syed Saim, Tooba Khan, Hassan Ali, Fahad Shamim

***Abstract:** Mobility and navigation are always challenging for visually impaired people. The daily life activities of these persons are hampered because of their inability to conceive, identify or locate things. Many researchers have developed different devices for blind people using the concept of echolocation. However, those devices could not benefit blind persons living in an undeveloped areas because of too much complexity, cost, inability to detect trenches, and vulnerability. This study aims to address the design and development of a smart device that can efficiently detect trenches and obstacles. The 3D model of the prototype is designed using Fusion 360 software. The ultrasonic sensors will be used in measuring the distance and if the user is near any obstacle or trench then Arduino nano will send recorded voices to warn the user. The voices will pass through the process of amplification and using a 433MHz Radio Frequency (RF) transmitter these recorded voices will go to the 433MHz receiver set inside the 3D-Printed earphones. The electrical signal received by the 433MHZ RF receiver is then changed into sound using the speaker. Based on the questionnaire of the trial prototype, 94.64% of respondents stated that the designed device is wearable, reliable, cost-effective, and easy to use.*

***Keywords**: Echolocation, Mobility, Navigation, 3-D Printing*

I. INTRODUCTION

Blindness is the most painful and the worst form of vision impairment. In light of the statistic of the Global Burden of Disease (GDB), 2017 report globally almost 48.2 million people were blind and also 39.2 million people were suffering from severe vision loss [1]. 90% of visually impaired people live in low and middle-income countries, meaning that their access to preventive care education, curative services, and quality rehabilitation is not available at a moderate cost [2]. It was also observed that almost 82% of people with blindness are over 50 years old whereas 28% of them are in their working years, which has an impact on their productive life [3]. Numerous research articles have been published on smart shoes for the detection of obstacles in front of the user and warning the user by using mobile applications [4] [5] [6] [7].

Manuscript received on 22 October 2022 | Revised Manuscript received on 13 November 2022 | Manuscript Accepted on 15 November 2022 | Manuscript published on 30 November 2022.
*Correspondence Author (s)
Syed Saim*, Department of Biomedical Engineering, Salim Habib University, Karachi, Pakistan. Email: syedsaimshah9090@gmail.com
Tooba Khan, Department of Biomedical Engineering, Salim Habib University, Karachi, Pakistan. Email: toobakhan@shu.edu.pk
Hassan Ali, Department of Biomedical Engineering, Salim Habib University, Karachi, Pakistan. Email: hassanali@shu.edu.pk
Dr. Fahad Shamim, IBET, Liaquat University of Medical and Health Sciences, Jamshoro, Pakistan. Email: fahadshamem@gmail.com

© The Authors. Published by Lattice Science Publication (LSP). This is an open-access article under the CC-BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Whilst there has been extensive research on smart shoes, usage in the developing world has been limited due to the lack of knowledge and training on the proper usage of these devices. Furthermore, in mountainous areas, these smart shoes do not prove much effective because there are trenches and the visually impaired person could fall and be seriously injured. Smart shoes are vulnerable as the electronic components can be damaged by water and other environmental factors and this could lead to improper functioning. The cost of commercially available smart shoes is also very high and people cannot afford them. The new aids or technologies, when available are either too expensive ($ 3000 and above), or affordable ($200) but with limited task functions only [8].

This work aims to develop a low-cost, light weighted, highly accurate, and well-protected device that will detect the obstacles in front of the user and warn the user through the earphones using a wireless radio waves communication system. The prime feature of this system will be that it will provide the distance of obstacles in inches and also it will detect the trenches and warn the user by providing the depth of trenches in inches using pre-recorded voices. Many devices for blind people are already available in the market but this device will be unique because of its working, its structure, and its accuracy. The prototype will be the practical application of integrated knowledge of programming, echolocation, signal processing, and electromagnetic communication.

II. METHODOLOGY

A. Components

The following Components are used in this Smart Device:

- Arduino Nano
- Two HC-SRO4 Ultrasonic Sensors
- 433 MHz Radio Frequency(RF) Module
- 9V DC Power Source
- A speaker of 8Ω
- LM358 Audio Amplifier
- Some Resistors (kΩ) and Capacitors (nF)
- Polylactic Acid (PLA)

B. Design

The 3-D Model of this smart device is designed on AutoCAD Fusion 360 software. The Arduino nano amplifier circuit and a power source are placed inside the 3-D printed model. One ultrasonic sensor is placed on the ground side of this model which will help in detecting the trenches. Another ultrasonic sensor is facing the front side and will help in detecting front obstacles.

These ultrasonic sensors will measure the distance and if the user is near any obstacle or trench then Arduino nano will send pre-recorded voices to warn the user. The recorded voices will further pass through the process of amplification and filtration and then using a 433 MHz Radio Frequency (RF) transmitter these pre-recorded voices will go to a 433MHz receiver set inside the 3D-Printed earphones. The electrical signals received by the 433MHZ RF receiver are then changed into sound using the speaker. The interaction of various components of a system is indicated by the following 3D-Model Designed on Tinkercad Software.

Figures (1) and (2) are indicating the basic prototype of a smart device. Figure (1) is showing the top view of the prototype and RF in it stands for the Radio Frequency transmitter while figure (2) is showing the front view of the prototype. This is just a model. The actual 3-D Printed body of the smart device will be designed on AutoCAD Software.

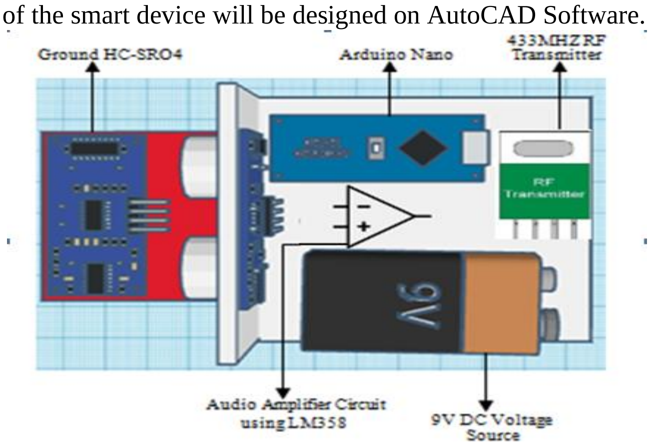

Fig. 1. Top View of Smart Device Designed on Tinkercad

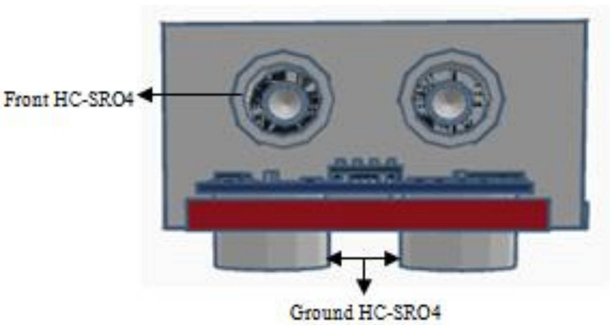

Fig. 2. Front View of Smart Device Designed on Tinkercad

C. 3-D Modelling on AutoCad

The compact smart device is being modeled on the AutoCAD Fusion 360 Software as illustrated in Fig.3. There are six parts of this smart device and that is front, ground, left, right, top and back. All these parts have been designed using 2-D sketching and are then converted into 3-D models using extruding and pull tools. The ground part is being designed using two rectangles having dimensions of 70mm x 70mm and 50mm x 49.8mm respectively. The large rectangle will serve as a base for Arduino nano, power source, RF transmitter, and amplifier circuit. In the small rectangle, two circles having a diameter of 17mm are drawn and they are placed at a distance of 27mm. Then using the pull tool of AutoCAD this 2-D sketch is converted into a 3-D Model. Ground HC-SRO4 sensor will be placed in a small rectangle and its two heads will emerge out from those holes that are being created using two circles of 17mm diameter. The front part also has two rectangles having the dimension of 70mm x 40mm and 50mm x 28.5mm. Two circles are again drawn on the front side having a diameter of 17mm and the distance between these two circles is 27mm. By pulling, this 2-D sketch is converted into a 3-D model. The front HC-SRO4 will be placed on the front side and its head will emerge from the holes created using circles. The Left and right parts are modeled just by drawing rectangles having dimensions of 62mm x 40mm. The back part has dimensions of 70mm x 40mm. The top part of the Smart Device has dimensions of 70mm x 40mm. Furthermore, the front part is cut with the help of a rectangle having the dimension of 4mm x 3mm, so that a connection between ground HCSRO4 and the Arduino nano could be established. The shape was designed using AutoCAD's basic tools but its significance is its dimension. Every component is exactly fit into it and no extra space is used by any part, so that smart device could take up less space on shoes. Earphones are also designed using AutoCAD.

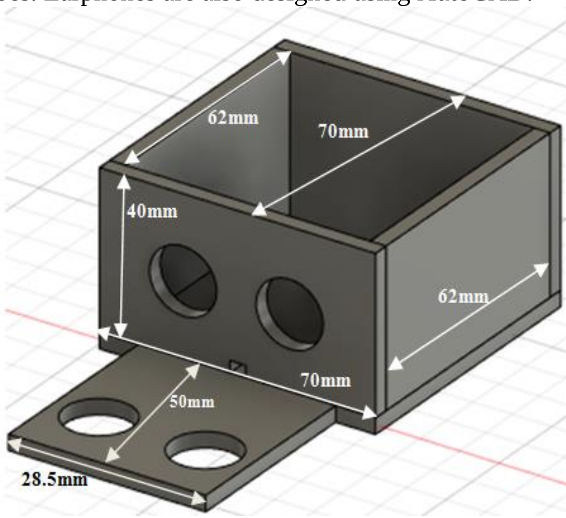

Fig. 3. 3-D Model of Smart Device Designed on AutoCad

III. IMPLEMENTATION

While using contactless sensors such as ultrasonic sensors, the time of flight method is a preferred choice for distance measurements [9]. Time of Flight is the time taken by ultrasonic waves after emitting from the ultrasonic sensor and then returning back to the ultrasonic sensor after being reflected from some physical object. HC-SR04 ultrasonic sensor has a working voltage of 5V DC, 15mA of operating current, an operating frequency of 40kHz, a maximum distance of 400cm, a minimum distance of 2cm, an angle measurement of 15° and a weight of 20 grams [10]. This ultrasonic sensor is 98-100% accurate while having a precision of 100% [11]. Ultrasonic waves are emitted from the ultrasonic sensor when the trigger pin of HC-SRO4 is given high voltage using a microcontroller. These ultrasonic waves will go away from the sensor and after hitting some solid object ultrasonic waves are reflected back to ultrasonic sensor and using the echo pin of the HC-SRO4 microcontroller picks the time of flight of ultrasonic waves in microseconds.

Retrieval Number:100.1/ijpmh.A1022113122
DOI:10.54105/ijpmh.A1022.113122
Journal Website: www.ijpmh.latticescipub.com

Published By:
Lattice Science Publication (LSP)
© Copyright: All rights reserved.

We have learned in physics that distance covered per unit of time is speed as stated in equation 1.

$$s=d/t \qquad (1)$$

Here, s is the speed of sound, d is the distance covered by sound wave and t is the time of flight. As the speed of sound is 343m/s and the time of flight can be obtained through an echo pin then after rearranging the above equation, we can easily calculate the distance covered by sound waves. But we have to divide this distance by 2 because it takes half the time of flight while traveling from the sensor to the object. The distance obtained using this method will be in SI unit i.e. meter; we will convert this distance into inches.

Both distances obtained from the front and ground HC-SRO4 sensor will be then analyzed using a microcontroller. If the distance between the smart device and the ground will greater than six inches or if the distance between the smart device and the front obstacle will less than seven inches then using recorded voices in the Arduino library i.e. "Talkie.h" ,"Front ,Danger, Red, Alert" and "Ground, Danger ,Red, Alert" voices will be sent by the microcontroller to the speaker. Arduino has different built-in libraries which provide extra functionalities for different uses. Talkie.h is a software implementation of the Texas Instruments speech synthesis architecture and contains over 1000 different words that can be used for Arduino [12]. Moreover, using words in talkie library, the microcontroller will also send the distance of obstacles from the device and the depth of trenches in inches in the form of audio signals so that the user could easily overcome this situation. The audio signals generated by the microcontroller will be amplified using an LM358 operational amplifier because signals have very low amplitude and then the filtration process is done to reduce the noise. After filtration, audio signals will reach to 433MHz Radio Frequency (RF) transmitter that will send audio signals to the 433MHz RF receiver wirelessly. Radiofrequency transmission is more reliable than Infrared transmission because it uses a selected frequency and the effect of noise can be reduced to much extent. 433MHz transmitter will send data through radiowaves using the technique of amplitude modulation. The data can be transmitted to a minimum of three meters using this RF transmitter [13]. RF Receiver in 3-D printed earphones will receive modulated RF signal and then demodulate it. After demodulation of the audio signal, it will be fed into the speaker which will change this signal into sound. In this way, the sound will directly reach the ear canal of the user.

A. Calculations

For detecting the distance between the HC-SRO4 and ultrasonic waves reflecting body, the following calculations have been done in the source code:

Travel Time = pulse In (Echo Pin, HIGH);

Since TravelTime obtained from HC-SRO4's echo pin is in microseconds so we will convert it into seconds.

Time of Flight (t)= TravelTime/1000000

The speed of Sound is 767.29 miles per hour which is equal to 343 meters per second.

By rearranging (1) distance can be calculated as:

$$d=sxt$$

Distance obtained through the above relation is two times than the actual distance between the ultrasonic reflecting body and HC-SRO4:

So, d will be:

$$d= (s \times t)/2 \qquad (1.1)$$

The distance (d) here is in meters which is the bigger unit so we will convert it into inches.

For, distance in inches we will simply use the value of s=13503.97 inches/second, in (1.1).

In this way, the distance between the reflecting body and HC-SRO4 could be obtained in inches.

B. Block Diagram

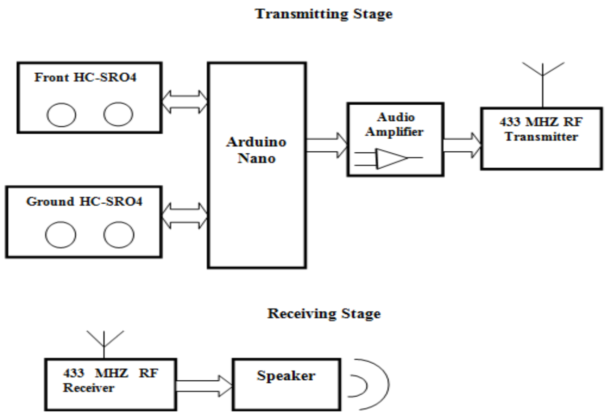

Fig. 4. Block Diagram of the Complete System

IV. RESULT AND DISCUSSION

A. Testing and Evaluation of Prototype

The prototype was tested on ten subjects i.e. five subjects were the inhabitants of a mountainous area (Kashmir) and the remaining five subjects used to live in a plain area (Karachi, Pakistan). All ten respondents tested the smart device three times at different places and gave their valuable feedback by filling out a questionnaire. The testing can be seen in Fig 5.

The main motive of the questionnaire is to check the reliability and usefulness of the smart device

TABLE 1. QUESTIONNAIRE

No.	Questionnaire	Rating			
		VG	G	NG	B
1	Smart Device informed you about the existence of the obstacles	8	1	1	
2)	Smart Devices warned you about trenches in your path by providing the exact depth	8	1		1
3)	The process of the response time of smart devices was fast	6	1	2	1
4)	The prototype is easy to use	9	1		
5)	The voice from the speaker of the earphone giving you information was clear and audible	8	1		1
6)	This prototype is light to lift	10			
7)	Smart Device is affordable	8	1	1	
8)	Smart Device is reliable	7	2		1
	Total Points	4800	400	100	0
		5300			

*VG=Very Good, G=Good, NG= Not Good, B=Bad

© Copyright: All rights reserved.

The result from Table 1 is processed by the Likert Scale. Based on table 1, the first column (VG) has a value equal to 75, the second column (G) is equal to 50, the third column (NG) is equal to 25, and the last column (B) is equal to zero[14]. The formula for measuring the validity of the result is:

Average Score=Total Score/Total No. of Items (2)

The total score could be obtained by multiplying the total answers of the questionnaire of the column with the value of each column. We obtained a total score of 5300. The total No. of items is equal to 80 (Eight questions, multiplied by ten users). Putting values in 2, we get:

Average Score=5300/80=66.25

% Score can be calculated by using relation 3:

% Score= (Average Score*100)/Ideal Score (3)

% Score= (66.25*100)/70=94.64%

By evaluating, we can categorize this smart device into the “Good” category. This indicates that smart device is in the level category of row (76%-100%) [15]. We used cost-effective RF Modules and common amplifiers for communications, and we also used only those electronic components which were necessary, such as Arduino nano instead of other expensive microcontrollers and this factor contributed much to making smart devices economical.

We can say that our smart device is reliable, user-friendly, and cost-effective having a cost of nearly $12.

Fig. 5. Implementation of Smart Device on Shoes

V. CONCLUSION AND SIGNIFICANCE

Based on the testing and analysis of the result, we categorize this Smart Device into the “**Good**” category and we concluded that the smart device proposed in this paper has the following characteristics:

- It can easily detect obstacles and trenches with high accuracy.
- It is cheaper than the devices already available in the market.
- It is well protected inside the eye-catching 3-D model.
- This device is easy to use by pressing just one button.
- This device is wearable and detachable.
- Smart Device is also portable and has low power consumption.
- Many important concepts of Electronics, Mechanics, Electromagnetic Communication, 3-D Modeling, and Programming can be understood by reading the literature on this Smart Device.

This paper also illustrates that theoretical concepts of Biomedical Engineering are helpful in solving different real-world problems.

ACKNOWLEDGMENT

We thank Dr. Muhammad Hussain Habib (Salim Habib University, Karachi) and Mr. Ahmed Saleh Raja (Steps College, Rawalpindi) for motivating and supporting us. We will always remember their efforts, prayers, support, and contribution to our research work.

REFERENCES

1. Hassan, Bilal, Ramsha Ahmed, Bo Li, Ayesha Noor, and Zahid ul Hassan. "A comprehensive study capturing vision loss burden in Pakistan (1990-2025): Findings from the Global Burden of Disease (GBD) 2017 study." PloS one 14, no. 5 (2019): e0216492. [CrossRef]
2. Burton, Matthew J., Hannah B. Faal, Jacqueline Ramke, Thulasiraj Ravilla, Peter Holland, Ningli Wang, Sheila K. West, Rupert RA Bourne, Nathan G. Congdon, and Allen Foster. "Announcing the Lancet global health Commission on global eye health." The Lancet Global Health 7, no. 12 (2019): e1612-e1613. [CrossRef]
3. R. Abi Zeid Daou, J. Chehada, G. Abou Hayder, A. Hayek, J. Boercsoek and J. J. S. Olmedo, "Design and Implementation of Smart Shoes for Blind and Visually Impaired People for More Secure Movements," 2020 32nd International Conference on Microelectronics (ICM), 2020, pp. 1-6, doi: 10.1109/ICM50269.2020.9331779 [CrossRef]
4. Malumbres, M. P., P. Pablo Garrido, Carlos T. Calafate, and Jose Oliver. "Underwater wireless networking technologies." Encyclopedia of information science and echnology (2009): 3864-3958. [CrossRef]
5. Hakobyan, Lilit, Jo Lumsden, Dympna O’Sullivan, and Hannah Bartlett. "Mobile assistive technologies for the visually impaired." Survey of ophthalmology 58, no. 6 (2013): 513-528. [CrossRef]
6. Guerrero, Luis A., Francisco Vasquez, and Sergio F. Ochoa. "An indoor navigation system for the visually impaired." Sensors 12, no. 6 (2012): 8236-8258. [CrossRef]
7. Mohapatra, Saurav, Subham Rout, Varun Tripathi, Tanish Saxena, and Yepuganti Karuna. "Smart walking stick for blind integrated with SOS navigation system." In 2018 2nd International Conference on Trends in Electronics and Informatics (ICOEI), pp. 441-447. IEEE, 2018. [CrossRef]
8. Sudharani, B., K. Lokanath, G. Bhavya, K. Hema Priya, K. Venkat, and G. Revanth Sri Chandu. "SMART GLASSES FOR VISUALLY CHALLENGED PEOPLE USING FACIAL RECOGNITION."
9. B. Mustapha, A. Zayegh and R. K. Begg, "Ultrasonic and Infrared Sensors Performance in a Wireless Obstacle Detection System," 2013 1st International Conference on Artificial Intelligence, Modelling and Simulation, 2013, pp. 487-492, doi: 10.1109/AIMS.2013.89. [CrossRef]
10. Al Tahtawi, Adnan Rafi. "Kalman filter algorithm design for hc-sr04 ultrasonic sensor data acquisition system." IJITEE (International Journal of Information Technology and Electrical Engineering) 2, no. 1 (2018): 15-19. [CrossRef]
11. Bongolan, Riyadh Renzo S. "ULTRASONIC DISTANCE MEASURING DEVICE." (2019).
12. Dandanell, Josefin, and Agnes Henriksson. "Brailled: A Braille translation aid." (2021).
13. Guna, T., S. Manojkumar, R. Hamsa Krishna, S. Nitesh, and R. Gayathri Ms. "WIRELESS COMMUNICATION USING 433 MHz TRANS RECEIVER."
14. Mutiara, Giva Andriana, Gita Indah Hapsari, and Ramanta Rijalul. "Smart guide extension for blind cane." In 2016 4th International Conference on Information and Communication Technology (ICoICT), pp. 1-6. IEEE, 2016. [CrossRef]
15. Hapsari, Gita Indah, Giva Andriana Mutiara, and Dicky Tiara Kusumah. "Smart cane location guide for blind using GPS." In 2017 5th International Conference on Information and Communication Technology (ICoIC7), pp. 1-6. IEEE, 2017. [CrossRef]

© Copyright: All rights reserved.

AUTHORS PROFILE

Syed Saim is a student of Biomedical Engineering in Salim Habib University (SHU), Karachi Pakistan having excellent C.G.P.A. (4/4) in academics (54/138 Credit Hours Completed).He has strong interest in **Biosignal Processing**, Modelling and Simulation, Biomaterials, Biomechanics, electromagnetism, Biosensors and, 3-D Printing. He is an enthusiastic and always tries to find the solution of different real-world problems using theoretical concepts of engineering and life sciences. Mr. Saim is very passionate in performing biomedical engineering research. He is motivated in updating his research skills through continuous reading of research articles and other literary books and currently, his research work has been accepted for presentation in renowned international conferences. As a General Secretary of Arts and Literature Society SHU, he is spreading the message of innovation and creativity with his pen and has organized webinars on the topic of "Basics of Research". He has excellent verbal and written communications skills and has won several honorary awards in the field of Biomedical Engineering and Literature.

Engr. Tooba is currently working as a lecturer in the Department of Biomedical Engineerng, Salim Habib University. She has completed her bachelor's degree in Biomedical Engineering from NEDUET, Karachi in 2019 and secured 2nd position in her batch. She has completed her masters in Biomedical Engineering with the specialization in Biomaterials from NEDUET, Karachi in 2021. Her masters' research work was focused on the Fabrication of PVA/BG composite for wound healing applications. She has supervised various students' projects in the field of Biomaterials, Biomechanics, Electronics etc. She also has an experience of supervising Final Year design projects. She is also an active member of SHU Final Year Project Committee.

Engr. Hassan is currently working as a lecturer in the Department of Biomedical Engineering, Salim Habib University. He has earned the undergraduate and post-graduate degree in the field of Biomedical engineering with specialization. He is now perusing PhD in the same discipline. He has published several research articles in international conferences. He has more than 10 years of teaching and research experience. His research interests include Modeling and Simulation, Rehabilitation Engineering, Biomaterials and BioInstrumentation.

Dr. Fahad Shamim is a Biomedical Engineer and has completed his masters in medical electronics and physics. His PhD is in NMRR and NMRI and currently he is working as an assistant professor at the institute of biomedical enginnering and technology, LUMHS, Jamshoro. His research areas include Magnetic Resonance Imaging, Bio Instrumentation, Medical Electronics and Biomechanics.

Retrieval Number:100.1/ijpmh.A1022113122
DOI:10.54105/ijpmh.A1022.113122
Journal Website: www.ijpmh.latticescipub.com

Published By:
Lattice Science Publication (LSP)
© Copyright: All rights reserved.