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Development of Smart Intelligent Walking Aid 3rd Eye for the Blind Using Ultrasonic Sensor

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Abstract

Laser cane, traditional white cane, guide dog, Mowat sensor, talking signs and sonar systems have been used by those who are visually impaired (blind) but possesses some drawbacks. The main focus of this research is to develop a device meant for the blind in order to navigate nearby obstacles called "Third eye" that will notify the blind of any obstruction ahead by signaling a beep or vibration with design, experimental and implementation analysis. Third Eye is a wearable device based on five modules that is built from an Arduino Pro Mini 328-15/16MHz board equipped with ultrasonic sensors, vibrating motor, buzzer, power bank, battery etc. The device was subjected to test on a visually impaired person. Findings revealed that as the distance between the blind and obstacles decreases, the intensity of the vibration and the device's beeping rate increases. Third Eye device proved effective, requires little training to use and enhances confidence of the user thereby giving it an edge.

Keywords: *Arduino, Wearable band, Buzzer, Blind people, Traditional white cane*

1. INTRODUCTION

The eye is an organ of vision in the body, an important part of human physiology. The eyes play a vital role in the lives of humans because about 83% of information from the environment is obtained through the eyes [1]. Blindness is a state of lacking visual perception due to physiological or neurological factors [31], [32]. The inability to see could be partial or total blindness. Lack of vision affects emotional, personal and professional relationships, making a significant difference in the performance of everyday adventure/ routines [2].

Blindness could be partial or total; Partial blindness represents the lack of integration in the growth of the optic nerves or visual centre of the eyes, and total or complete blindness is the full absence of visual light perception. The World Health Organisation (WHO) estimated that around 39 million people are blind [3] and about 285 million people are visually impaired [29]. Every 5 seconds, someone somewhere in the world goes blind, and according to scientific research, 20% of all blindness is neither curable nor preventable[4]. Also in the United States, around 7 million people are blind of which 10% are between the ages of 4 and 20 with a further 10% of those ages registered at schools. This ratio is expected to double by 2030 [28]. Since early 1950s, several efforts have been put in place in providing travel aids for visually impaired people and more devices have been in development. They ranged from the simple cane [30], guide dog [33], k-sonar cane [34], and locomotor device [36] to advanced electronic aids [5]. This and many more reasons prompted this study.

Blind people oftentimes depend on other people for their locomotion. Moving around is a very big challenge for the blind, because they cannot depend on their own eyes thereby facing many difficulties. The use of the blind stick and other traditional instruments do not provide accurate detection of obstacles; it is inefficient and cannot be totally relied upon. To assist blind persons, the right technology could be used to overcome the challenges of movement to avoid any obstacle on the way. Technology can be used for a blind person to walk safely and reduce dangers while walking. "Third eye for the blind" is an innovation which assists blind people to navigate with speed and confidence by detecting nearby obstacles with the help of ultrasonic waves,

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notifying them with buzzer sound and vibration. When multiple sensors are installed on the blind people, they do not need to scan their area to walk. This study focuses on developing a Smart Intelligent Walking Aid 3rd Eye for the Blind using an ultrasonic sensor.

2. RELATED WORKS

2.1 The Path Force Feedback Belt

The feedback belt includes a comparative survey of wearable and portable assistive technologies for visually impaired people which demonstrate the advancement of assistive technology for this population. Aside from the difficulties of identification, picture processing takes time and demands a large amount of memory [6]. This study gives a set of necessary rules for creating assistive devices and the features described to ensure optimal performance and an effective computer interaction scheme with the blind person.

2.2 Electronic Long Cane for Locomotion

A belt-for-blind for those who are visually impaired was designed based on the specification of the ultrasonic sensors, a mathematical model was constructed to determine the optimal orientation of the sensors for detecting stairs and holes [7]. This prototype is incapable of distinguishing between animate and inanimate barriers. The goal of this study was to see if enough data could be acquired from an ultrasonic sensor to generate a stair and a hole using a mathematical model. It was successful at the stages of experimentation/ setup, terrain identification and performance analysis. “Intelligent walking stick for elderly and blind” is more advanced, cheap to acquire, easy to maintain and durable than the conventional ones. With the aid of a smart walking stick, the blind and elderly people can advance more than 15-20% travel speed, reduce minor collisions, do not lose their way, and increase safety and confidence. Blind/elderly persons can move confidently without any dependence on another person with the help of this smart stick [13]. Others include the works of [22] and [23] which made use of a walking stick.

2.3 Antenna Design for Tongue Electrotactile Assistive Device for the Blind and Visually Impaired

This study provides an innovative technology that is user-friendly for visually impaired people to access public transportation and learn[8]. Furthermore, the suggested approach allows them to be always informed of their health status. The system directs the user in both familiar and unfamiliar situations. However, it is not cost-effective. It only enables one-way communication and has a very limited range of identification.

2.4 Some Map Matching Algorithms for Personal Navigation Assistants

The system employed the Atmega-328 microcontroller, a high-performance 8-bit AVR RISC-based microcontroller and an

Ultrasonic Range Finder Distance Sensor Module to detect distance. It has two modes, the first of which converts system information to audio in various noises. It was difficult for the blind person to distinguish between the two sounds, one for free travel direction and the other for barred travel direction. Another issue was that the system did not know the user's current location [9]. Other researches on navigation are the works of [21, 25, 26, 27, 31, 37 and 35].

2.5 Radio Frequency Identification Walking Stick

The goal of this research is to create a product that will be extremely valuable to persons who are blind. They suggested two distinct forms of noise. The main disadvantage of this work is the identification of the sound [10]. Findings show that more improvement will need to be done because the blind was unable to distinguish between sounds. Other researches on radio frequency can be found in [21, 24 and 25].

2.6 Finger Reader: A Wearable Device to Support text Reading on the Go

The study reviewed a Smart Stick. The Stick uses an ultrasonic sensor to measure the distance between objects and the smart working stick [11]. Also, the wearable device was employed by some researchers such as [17, 18, 19 and, 20].

2.7 Development of an Ultrasonic Cane as a Navigation Aid for the Blind People

The study investigated the creation of the Smart Cane device for sensing things and producing correct navigation instructions. Its limitation is that the sensor will not detect till you are 0.5 cm or closer to an object, which is too close for a blind person to notice[21], and the detector's buzzer will not stop warning unless it is manually turned off by a third party [12]. The study [15] designed and fabricated a simple yet effective ultrasonic-based intelligent walking staff (iWalk) for the visually impaired persons that can detect physical obstacles and waterlogs within 100cm with different sound of the buzzer for each type of obstacle. In another study, IR sensor, Arduino UNO, ultrasonic sensor, voice playback module, LCD show and voltage controller were utilized. Arduino is a microcontroller that can perform all estimations fast and rapidly with incredible exactness [16].

2.8 Third Eye Navigator for Visually Challenged

The study successfully tested the text and temperature data to voice using raspberry pi. The study revealed that the android application for bus tracking systems helps the visually challenged to access public transport independently. The tangible reader helps to learn effectively without guidance. Also, android application for health monitoring system helps the visually impaired to be aware of their health condition [14], [34].

3. SYSTEM DESIGN

This study consists of two parts. First, creating portable suitcases and designing intelligent work aids for the visually impaired. Second, to detect obstacles using multiple sensors. It includes circuit simulation, circuit building, the manufacture of parts of the coating device and the operation of attaching the circuit to the coating. Building an "Intelligent Walking Aid Third Eye for the Visually Impaired" was carried out in five steps:

i. Printed Circuit Board (PCB) Design
ii. Software design, printing, and etching on PCB
iii. Soldering to circuit boards
iv. Inspection and results
v. Charger Package / Case

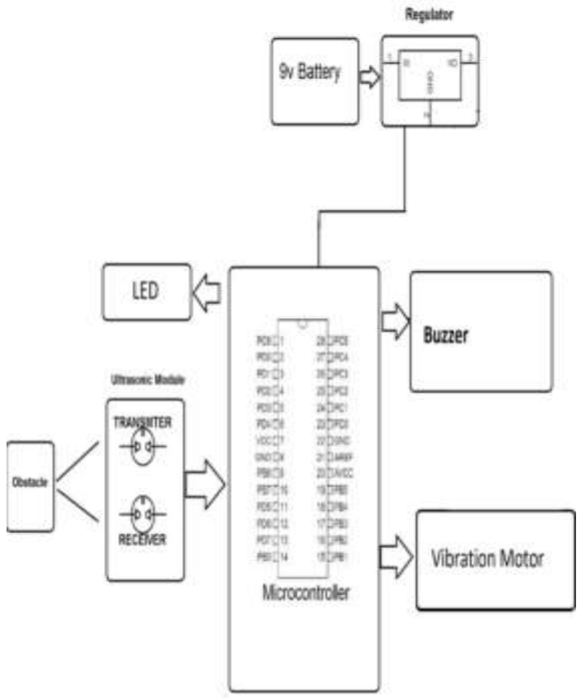

Figure 1: Block Diagram for Third Eye Device
Source: Adapted from https://nevonprojects.com/third-eye-for-blind-ultrasonic-vibrator-glove/

This block diagram (figure 1) of the Third Eye device consists of an Arduino UNO microcontroller, ultrasonic sensor, breadboard, buzzer (that detects boundaries and notifies the person approximately about the obstacle ahead), jumper cables, pink LEDs, switches, energy banks, male and female header pins. It includes a few elastic frames and a tool decal that holds the tool as a strap for the person to wear the Arduino incorporated improvement surroundings. The diagram explains how the third eye operates and the gadget in its simplicity when used by a visually impaired person. The 9v battery powers the device which aid the buzzer to produce a beep sound whenever an obstacle is detected, vibration motor informs the user about an obstacle detected using the ultrasonic sensors thereby making the ultrasonic module (transmitter and receiver) to give signal to the user on the location of the obstacle ahead.

3.1 Equipment and Technologies

Each component has been individually tested to ensure it is in good condition before being assembled on the board. The main test performed on these components is a continuity test done with a multimeter type of transistor. Polarity tests are also performed on several components such as diodes, capacitors, and transistors. The following components were used to implement the system:

1. **Arduino UNO Microcontroller:** The Arduino Uno is an open-source microcontroller board designed by Arduino.cc that is based on the Microchip ATmega328P microprocessor. The board has a number of digital and analog input/output (I/O) pins that can be used to connect to various expansion boards (shields) and other circuits.

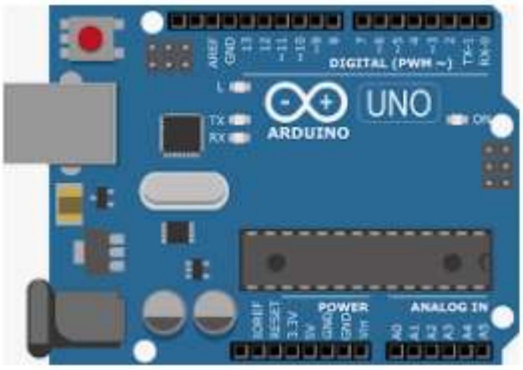

Figure 2: Arduino UNO Microcontroller
Source: https://www.arduino.cc/

2. **Ultrasonic Sensor:** An ultrasonic sensor is a device that uses ultrasonic sound waves to determine the distance between two objects. An ultrasonic sensor employs a transducer to send and receive ultrasonic pulses that relay information about the proximity of an item.

Figure 3:Ultrasonic Sensor
Source: http://wiki.sunfounder.cc/index.php?title=Ultrasonic_Module

3. **Breadboard:** A thin plastic board used to connect electrical components (transistors, resistors, chips, etc.). Breadboards are used to produce electronic circuit prototypes and can be utilized for future applications.

Figure 4: Breadboard
Source: Adapted from https://en.wikipedia.org/wiki/File:400_points_breadboard.jpg

4. **Buzzer:** An electrical gadget that emits a buzzing sound and is used to signal.

Figure 5: A Buzzer
Source: Adapted from https://create.arduino.cc/projecthub/SURYATEJA/use-a-buzzer-module-piezo-speaker-using-arduino-uno-89df45

5. **5mm Red LED:** This simple red 5mm LED has a rated forward current of 20mA and a typical forward voltage of 2.0V.

Figure 6: A Red LED
Source: Adapted https://www.petervis.com/electronics/led/led-resistor-calculator.html

6. **Slide Switch:** A slide switch is a mechanical switch that glides from the open (off) position to the closed (on) position, allowing

control of a circuit's current flow without the need for manual splicing or cutting of wire.

Figure 7: Slide Switch
Source:https://uk.rs-online.com/web/c/switches/toggle-switches-slide-switches/slide-switches/

7. **Connector Strip:** An insulated bar with a set of screws to which wires are connected.

Figure8: Connector Strip
Source: Adapted https://www.tlc-direct.co.uk/Main_Index/Boxes_and_Enclosures_Index/Connector_Strips/index.html

8. **Jumper Wire:** A jumper is a pair of prongs that serve as electrical contact points on a computer motherboard or adapter card.

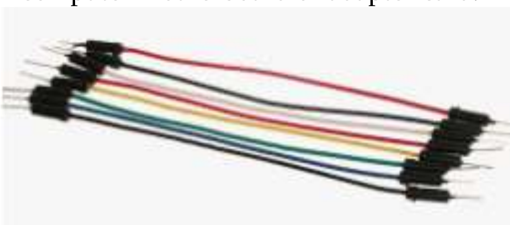

Figure 9: Jumper Wire
Source: Adapted from
https://en.m.wikipedia.org/wiki/Jump_wire

9. **Power Bank:** This is a portable gadget that can store electricity for charging phones, cameras, laptop computers, and other electronic devices.

Figure 10: Power Bank
Source: Adapted
https://en.wiktionary.org/wiki/powerbanks#English

10. **Vibrator:** A device that converts a constant current into an oscillating current by the use of repeatedly repeated impulses.

Figure 11: A Vibrator
Source:
https://cdn.shopify.com/s/files/1/2311/3697/products/vibration-motor-motors-robotics-generic-oem-cool-components_173_455x342.jpg?v=1537312751

3.2 System Testing

This involves testing all circuits and thus checking for faults such as short circuits, conduction currents, and splices of unwanted links. We insert the correct IC pin layout and check that the ICs of these pin numbers are inserted into their proper base. After testing, crosscut was done before turning on the system.
The navigation mantle will allow visually impaired people to perceive obstacles within 270° at an angle of 45° from the right and 45° from the left. The definition of 270° angle detection with transmitter 400ST160 and receiver 400SR160 is used. Sensors are used for operating frequency, diameter and beam angle. The operating frequency is 40kHz. Since the frequency is generated by a 40kHz crystal oscillator, the 40kHz frequency is selected as the operating frequency. The diameter of the ultrasonic sensor is 16mm, which is the largest

among other sensor models that have a logically large detection area. The radiation angle of the transmitter is about 45°. Proteus software is used to design, evaluate and analyze both preliminary activities and results for each part of the system. Proteus has allowed the system to be tested and modified before the actual circuit is installed until accurate and expected results are obtained.

4. IMPLEMENTATION AND EVALUATION

The evaluation showed that the components used for construction are mainly not static. The electronic data book has played an important role in determining which other components are available in the absence of them. The following observations were made during the testing of the designed equipment.

4.1 Casing and Packaging

A 3D plastic sheet is designed on a system using Magic drawing software and printed with a 3D printer. We have made sure that the purchased box contains a ground wire for good grounding.

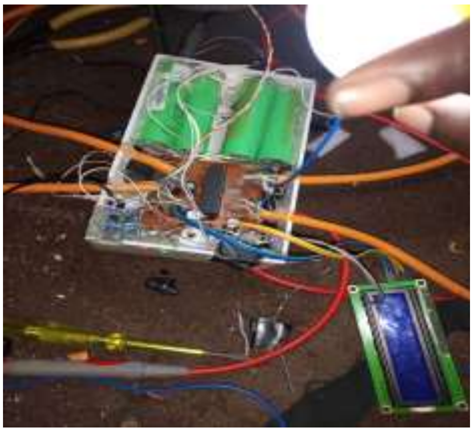

Figure 12: Designed Casing for the Device Using 3D Printer

4.2 Assembling of Section

Different sections had been assembled collectively inside the casing nicely and punctiliously to keep away from destroying the circuit arrangements. We additionally ensured that the assembling does now no longer create a hazard for quick circuits and so, we related the circuit to a floor wire. It is frequently less difficult while assembling the additives at the board to erect them in line with their peak. That is, the bottom additives first, commonly the resistor and different tiny ones, while others with better peaks follow. Care was taken in getting the polarity of additives, like diode, electrolytic capacitor, etc., earlier than they had been soldered at the panel. In addition, the polarization of the transistor changed explicitly. The use of an IC holder saves from hazard that could be because of extreme heat while soldering the IC. The pins of the incorporated circuit and its connectivity with different additives was configured.

Figure 13: Final testing with eyes covered using the device for navigation.

4.3 Comparison of Scenarios According to Position of Obstacle

To compare the outcomes of the scenarios according to the obstacle location, the first three examples are given to explain the situations. For example, consider that the obstacle is located at (0, 60), (0++, 60) and (0, 60). The position "(0, 60)" specifies the centre of the obstacle at position 0 relative to the axis of rotation and 60cm from the axis of rotation. The position "(0++, 60)" specifies the obstacle boundary located at position 0 to the right of the x-axis and 60cm from the y-axis. In contrast, "(0, 60)" specifies the object contour located at position 0 to the left of the x-axis and 60cm from the cab.

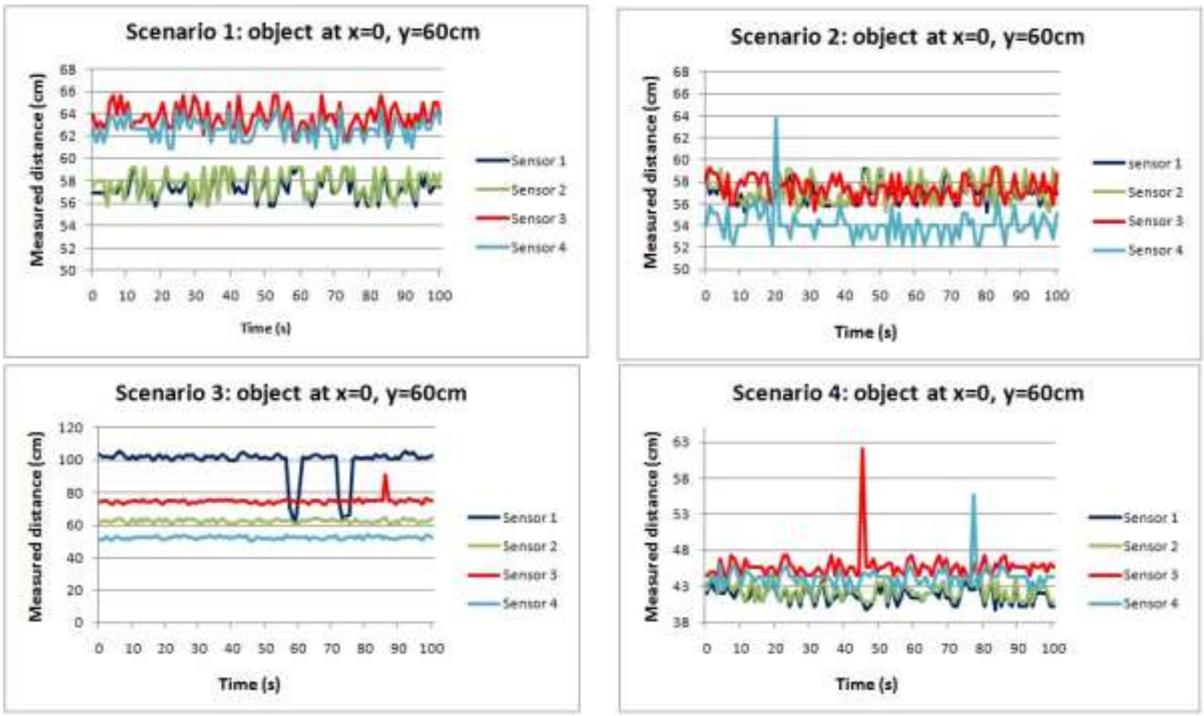

Figure 14: Comparison of scenarios when object locates at x=0, y=60cm

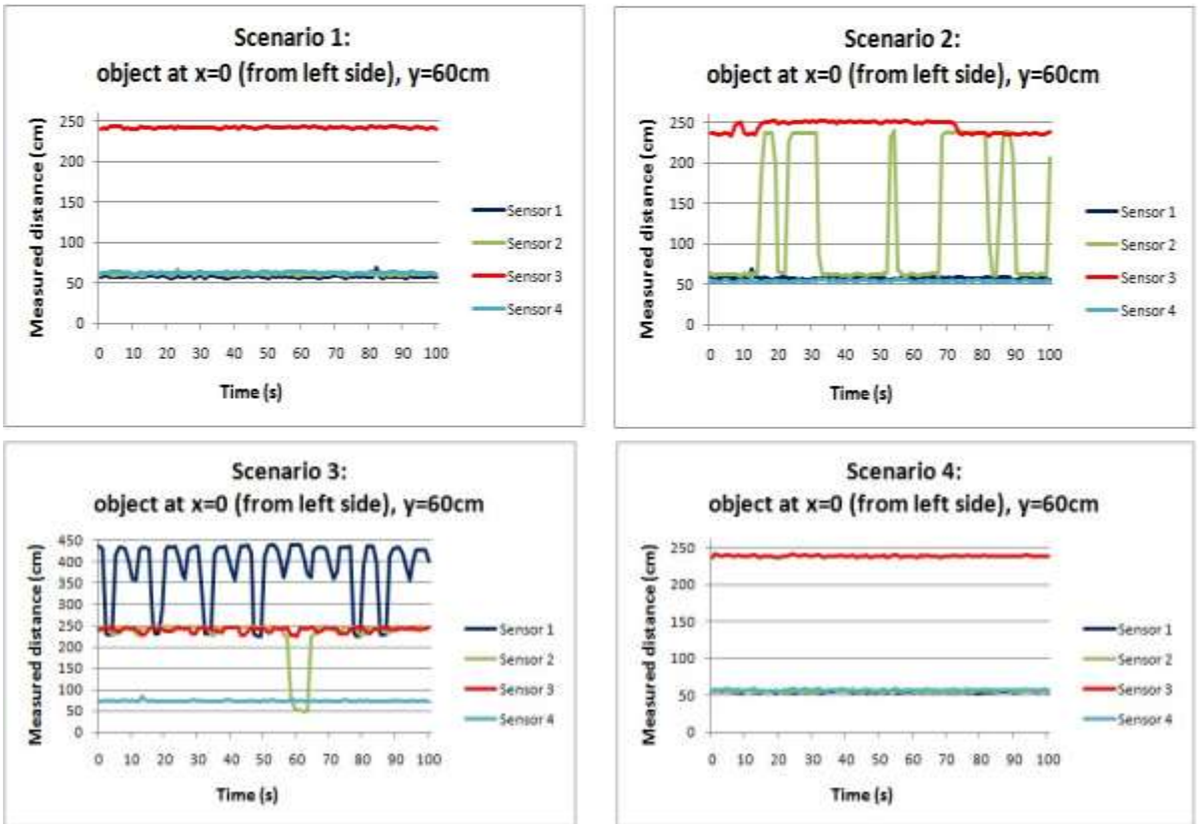

Figure 15: Comparison of scenarios when object locates at x=0 (from left side), y=60cm

If this obstacle is located at x = 0 (from the left), then y = 60cm; the expected result should be that the sensors shown on the left side will read the object's position. On the other hand, considering the assumed law and the distance between the sensors and the obstacle, the sensors on the right side can detect the position of the obstacle.

According to Figure 15, scenario 1 and scenario 4 correctly detected obstacles. As expected, in addition to sensor 3 (the right sensor), sensor 1 (bottom left sensor), sensor 2 (bottom right sensor) and sensor 4 (top left sensor) correctly detected the position of the obstacle. However, with scenario 2, only the sensors on the left side detected obstacles. Similarly, scenario 3 once again recorded the worst results.

When the obstacle is located at x = 0 (from the right), then y = 60cm; sometimes the expected results must be reversed from the information described above. From Figure 16, in all situations, the right sensors (sensor 2 and sensor 3) detected an exact opposite position, except for scenarios 1 and 4, roughly. It is clear, however, that Scenario 4's reading is unstable. In summary, as described above, analyzing each obstacle position in the work area separately is not sufficient and easy to determine which the best is. Therefore, for the comparison between scenarios, all data taken by each evaluator in each scenario has been carefully analyzed.

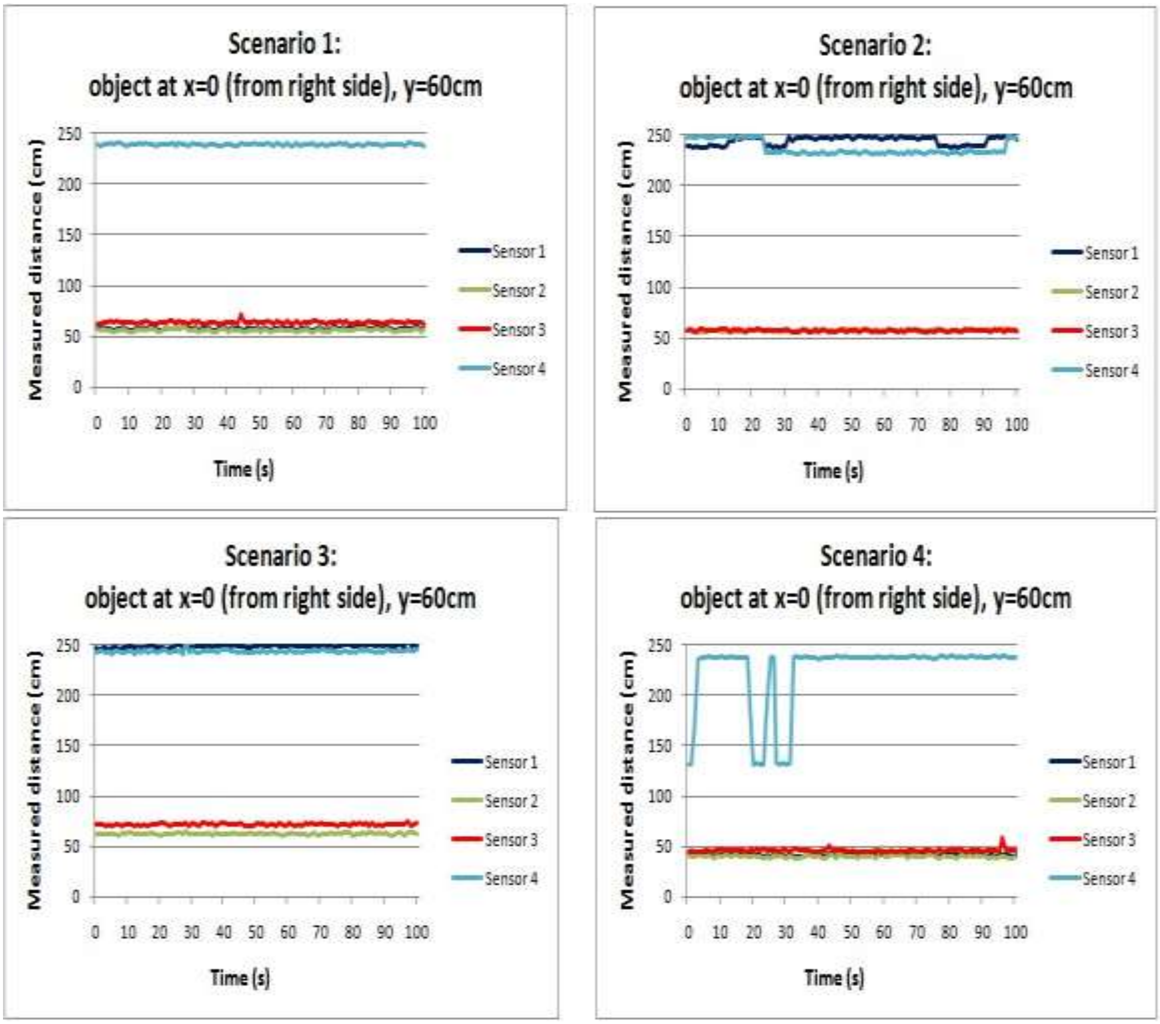

Figure 16**:** Comparison of scenarios when object locates at x=0 (from right side),y=60cm

5. CONCLUSION

This study designed and architects a new concept of embedded device-based virtual eyes for the blind. The result indicates that the system was efficient, had unique capabilities in identifying the source and distance of the objects that may encounter the visually impaired. This is in line with the result of [39],[40] gadget developed for the blind is light weight, effective and portable. The applicability in the study of [38] revealed a device for the blind which gives accurate location awareness and confidence for guiding the visually impaired people. The buzzer used in [41] was found to be very effective in producing signals which was fine tuned to produce good output. The device in this study can scan and detect obstacles in areas such as left, right and in front of the visually impaired person according to his height/depth. With this device, blind people will be able to move from place to place without direct assistance. The system was designed, implemented and evaluated to be absolutely reliable for the locomotion of the visually impaired. The real-time result of this device is very encouraging; it revealed 93% accuracy in detecting different shapes, materials and distances. The result also showed that the element is effective in determining the origin and distance of objects that may confront blind people. This device can eliminate several challenges that blind people face. The device responds to the user in all the challenges that are faced by blind people with the help of the Ultrasonic sensors and the microcontroller.

6. REFERENCES

[1] N. Sahoo, H. Lin & Y. Chang (2019), ‘‘Design and Implementation of a Walking Stick Aid for Visually Challenged People’’ *Sensors Journal: 19 -130.*

[2] D. Plikynas, A. Žvironas, A. Budrionis & M. Gudauskis (2020), “Indoor Navigation Systems for Visually Impaired Persons: Mapping the Features of Existing Technologies to User Needs”, *Sensors Journal, 2020 ISSN: 20, 636.*

[3] World Health Organization (2017), “Blind Statics Record,” In Proceedings of the India Educators Conference (TIIEC), Bangalore, India, (April 2017): 38–43.

[4] V. Patel (2015) “The digitalization of the walking stick for the blind’’, *International Journal of Scientific &Engineering Research, Volume, Issue 4, ISSN 2229 – 5518.*

[5] J. F. Oliveira (2013), “The path force feedback belt,” In Proceedings of the 8th *International Conference on Information Technology in Asia (CITA), Kuching, Malaysia.*

[6] J. F Oliveira (2013) “The Path Force Feedback Belt,” In Proceedings of the 8th *International Conference on Information Technology in Asia (CITA), Kuching, Malaysia.*

[7] R. Fonseca (2011) “Electronic Long Cane for Locomotion Improving on Visual Impaired People: A Case Study,” *In Proceedings of the 2011 Pan American Health Care Exchanges (PAHCE), Rio de Janeiro, Brazil.*

[8] T. H. Nguyen, T. L. Le, T. T. H. Tran, N. Vuillerme & T. P. Vuong (2013) “Antenna Design For Tongue Electrotactile Assistive Device for the Blind and Visually-Impaired,” *In Proceedings of the 7th European Conference on Antennas and Propagation (EuCAP), Gothenburg, Sweden: 1183–1186.*

[9] C. E. White, D. Bernstein & A. L. Kornhauser (2000), “Some Map Matching Algorithms for Personal Navigation Assistants,” *Trans. Res. C Emerg. Tech. 8: 91–108.*

[10] M. F. Saaid, I. Ismail & M. Z. H. Noor, (2009), “Radio Frequency Identification Walking Stick (RFIWS): A Device for the Blind,” *In Proceedings of the 5th International Colloquium on Signal Processing & Its Applications, Kuala Lumpur, Malaysia*.

[11] R. Shilkrot, J. Huber, C. Liu, P. Maes & S.C. Nanayakkara, (2016),“Fingerreader: A Wearable Device to Support text Reading on the Go,” *In Proceedings of The CHI’14 Extended Abstracts on Human Factors in Computing Systems, Toronto, ON, Canada.*

[12] K. Kumar, B. Champaty, K. Uvanesh, R. Chachan, K. Pal & A. Anis (2014), “Development of an Ultrasonic Cane as a Navigation Aid for the Blind People,” *In Proceedings of the 2014 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT), Kanyakumari District, India.*

[13] S. Singh & B. Singh (2020), “Intelligent Walking Stick for Elderly and Blind people’’, *International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 9 Issue 03.*

[14] S. Deepa, T. S. Maheshwari, G. Jancy Rani & A. Jayasri, (2018), “Third Eye Navigator for Visually Challenged”, *International Journal of Advanced Research in Science, Engineering and Technology Vol. 5, Issue 4.*

[15] R. F. Olanrewaju, R. Mohd, L. A. Muhammad, M. Rehab & F. E. Fajingbesi (2018), “Design and Fabrication of an Intelligent Walking Staff for Visually Impaired Subject”, *Indonesian Journal of Electrical Engineering and Computer Science Vol. 10, No. 1, pp. 266 - 270 ISSN: 2502-4752.*

[16] T. Tirupal, B. Venkata Murali, M. Sandeep, K. Sunil Kumar & C. Uday Kumar (2021),"Smart Blind Stick Using Ultrasonic Sensor", *Journal of Remote Sensing GIS & Technology Volume-7, Issue-2: 34-42.*

[17] R. Tapua, B. Mocanua & T. Zaharia(2018),"Wearable assistive devices for visually impaired: a state of the art survey", Pattern Recognition Letters, *Elsevier Journal, pp 1-18.*

[18] S. Chen, D. Yao, H. Cao & C. Shen, (2019),"A Novel Approach to Wearable Image Recognition Systems to Aid Visually Impaired People", *MDPI Journal for Applied. Sci., 9, 3350;* PP 1-20.

[19] A. D. P. dos Santos, A. H. G. Suzuki, F. O Medola & A. Vaezipour (2021) "A Systematic Review of Wearable Devices for Orientation and Mobility of Adults with Visual Impairment and Blindness", *IEEE Access Journal, volume XX.*

[20] Z. Chen, X. Liu, M. Kojima, Q. Huang, & T. Arai. (2021),"A Wearable Navigation Device for Visually Impaired People Based on the Real-Time Semantic Visual SLAM System", *Sensors Journal, ISSN 21, 1536, pp 1 -14.*

[21] W. Sakpere, M. Adeyeye-Oshin, & N. B. W. Mlitwa (2017),"A state-of-the-art survey of indoor positioning and navigation systems and technologies", South African Computer Journal (SACJ), vol 29, no 3,pp. 145-197.

[22] M. Islam, M. Sheikh Sadi, K. Z. Zamli & M. Ahmed, (2019), "Developing Walking Assistants for Visually Impaired People: A Review", *IEEE Sensors Journal, Vol. 19, NO. 8, pp 2814 - 2825.*

[23] M. A. Kollathodi, R. Drolla & S. A. Kumar (2018),"Smart Walking Stick for the Visually Challenged", *Indonesian Journal of Electrical Engineering and Computer Science Vol. 12, No. 3, pp. 1282 - 1288.*

[24] S. Shoval, I. Ulrich, & J. Borenstien, (2003), "Nav Belt and the Guide Cane," *IEEE Transactions on Robotics & Automation, Vol. 10, No. 1, pp 9-20.*

[25] W. E. Sakpere, N. B. W. Mlitwa, & M. Adeyeye-Oshin (2017), "Towards an efficient indoor navigation system: a near field communication approach", *Journal of Engineering, Design and Technology (JEDT), vol 15, no 4,pp. 505-527.*

[26] S. Sabarish. (2013) "Navigation Tool for Visually Challenged using Microcontroller", *International Journal of Engineering and Advanced Technology (IJEAT),* 2, No.4: 139-143.

[27] L. Wee & M. K. H. Leung, (2013): "SINVI: Smart Indoor Navigation for the Visually Impaired Control, *Automation," Robotics and Vision Conference, 2:1072 – 1077.*

[28] R. Dhod, G. Singh, G. Singh, & M. Kaur (2017), "Low cost GPS and GSM based navigational aid for visually impaired people," Wireless Pers. Commun., vol. 92, no. 4, pp. 1575–1589.

[29] D. Pascolini and S. P. Mariotti (2012), ''Global estimates of visual impairment: 2010,'' *Brit. J. Ophthalmology, vol. 96, no. 5, pp. 614–618.*

[30] H. Zhang & C. Ye, (2017) "An indoor wayfinding system based on geometric features aided graph SLAM for the visually impaired," *IEEE Trans. Neural Syst. Rehabil. Eng., vol. 25, no. 9, pp. 1592–1604.*

[31] S. L. Joseph et al.,(2011) "Being aware of the world: Toward using social media to support the blind with navigation," *IEEE Trans. Human-Mach. Syst., vol. 45*, no. 3, pp. 399–405, Jun. 2015.

[32] M. Bousbia-Salah, M. Bettayeb & A. Larbi, "A navigation aid for blind people," J. *Intell. Robot. Syst., vol. 64, nos. 3–4, pp. 387–400.*

[33] R. Jafri, R. L. Campos, S. A. Ali & H. R. Arabnia (2018), "Visual and infrared sensor data-based obstacle detection for the visually impaired using the Google project tango tablet development kit and the unity engine," *IEEE Access, vol. 6, pp. 443–454.*

[34] M. A. Hersh & M. A. Johnson (2008), Assistive Technology for Visually Impaired and Blind People. London, U.K.: Springer-Verlag.

[35] Wu, Y.; Zhu, H.; Du, Q.; Tang, S. (2019), A Survey of the Research Status of Pedestrian Dead Reckoning Systems Based on Inertial Sensors. Int. J. Autom. Comput.: 16, 65–83.

[36] W. Elmannai & K. Elleithy (2017), "Sensor-based assistive devices for visually-impaired people: Current status, challenges, and future directions," *Sensors, vol. 17, no. 3, pp. 565–606.*

[37] F. Zafari, A. Gkelias & K. A. Leung (2019), Survey of Indoor Localization Systems and Technologies. *IEEE Commun. Surv. Tutor, 21, 2568–2599.*

[38] K. Chen, V. Plaza-Leiva, B. C. Min, A. Steinfeld, & M. B. Dias, ''NavCue: Context immersive navigation assistance for blind travelers,'' in Proc. 11th ACM/IEEE *Int. Conf. Hum.-Robot Interact. (HRI), Mar. 2016, p. 559.*

[39] P. Marzec & A. Kos, ''Low energy precise navigation system for the blind with infrared sensors,'' in Proc. MIXDES 26th *Int. Conf. Mixed Design Integr. Circuits Syst.,* Jun. 2019, pp. 394–397.

[40] K. Viswanathan & S. Sengupta, ''Blind navigation proposal using SONAR,'' in Proc. *IEEE Bombay Sect. Symp. (IBSS), Sep. 2015*, pp. 1–6.