American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-4, pp-122-131
www.ajer.org
Research Paper Open Access

Wearable Obstacle for Visually Impaired: Distance, Reflectivity, and Energy Absorption Evaluation

Onwuagba C.J.[1], Achumba I.E.[2], Nosiri O.C.[3], Dike D.O.[4]
[1,2,3,4] *Department of Electrical and Electronic Engineering, Federal University of Technology, Owerri, Nigeria*

ABSTRACT: *An infrared – based wearable indoor obstacle detector for the visually impaired was designed and implemented. Then, the significant effects and the relationship between the angle of incidence and distance traveled by the infrared rays, energy consumption and reflectivity of the surface, and battery life of the device, were compared using Matlab. The investigation was based on angle range of 0° to 45° and distance range of 50cmto10m. It was found that, at smaller angle, the distance travelled increased and more energy was consumed thereby reducing the battery life. Based on the above stated design considerations, the infrared device was implemented and sampled at an angle of 20° and 45° in order to show the effect of intensity and object distance to energy consumption rate. At an angle of 20°, at a distance of 0.4m, the energy consumed was 5J, at a distance of 0.5m, the energy consumed was 3J, at a distance of 0.8m, the energy consumed was 1J, at a distance of 1.2m, the energy consumed was 0.5J and at a distance of 2.7m, the energy consumed was 0.1J. Then, for an angle of 45°, at a distance of 0.1m, the energy consumed was 5J, at a distance of 0.16m, the energy consumed was 3J, at a distance of 0.26m, the energy consumed was 1J, at a distance of 0.42m, the energy consumed was 0.5J and at a distance of 0.8m, the energy consumed was 0.1J. The reflectivity of different surface properties was also evaluated. It was observed that Yellow Smooth Body (YSB) reflected more than other surfaces at an intensity of 0.99 (W/M^2) while the Black-Surface (BS) reflected less at an intensity of 0.1(W/M^2).*

Keywords: *Obstacle detector, Infrared Sensor, Distance measurement, Reflectivity, Energy Consumption.*

I. INTRODUCTION

Individuals are often faced with various health challenges, such as visual impairment. Visual impairment is the inability to see or to see properly. It occurs in several ways such as poor sight, albinism, hereditary, old age, infections and as a result of poor public health awareness [1].For example, in Nigeria it is estimated that 1.13million individuals aged 40 years are currently visually impaired in Nigeria and 2.7 million adults aged 40 years are estimated to have moderate visual impairment[2].Often, the visually impaired require some sort of aid to enable them undertake their Activities of Daily Living (ADL). Activities of Daily Living include eating, bathing, washing, dressing, walking about e.t.c. The major challenge of the visually impaired is ambulation. Due to their inability to see or see properly, they tend to regularly collide with obstacles in their paths thereby reducing their self-esteem and confidence. Also, this collision may lead to various degrees of injuries from minor to grievous. Consequently, they are dependent on people to help them move around. The collision could also lead to falls and fatality, hence there is need for a walking aid that would promote ambulation and enhance independency. There are different types of existing walking aids such as the white stick, pathfinder, ultrasonic cane, sensor stick, smart cane, intelligent walking stick, smart stick for the blind, among others. These existing walking aids have a number of limitations: high rate of energy consumption, faster battery drain, detection of the rear view and weight of the device. A walking aid to address these limitations has been designed and implemented. The work presented in this paper is focused on the testing and evaluation of the walking aid.

II. RELATED WORK

This section presents the review of related work in order to put the work presented in this paper into perspective. A Miniguide travel Aid for the Visually Impaired was presented in [3]. The handheld electronic aid assists people moving within an environment. It uses ultrasonic echo-location to detect objects, and sends out ultrasonic beams that bounce off objects in the environment, and the senor picks up the reflected beams. It is used as a secondary aid to compliment the walking cane. One of the limitations of the miniguide is its inability to detect drop off or uneven surfaces. [4] worked on Sensor Stick Walking Aid for the Visually Impaired using ultrasonic sensor for obstacle detection. The aim for using ultrasonic sensor was to achieve long distance obstacle detection rather than short distances. In addition, the device incorporated a sound alert system of buzzer and vibrator. A Smart Cane Mobility Aid for the Visually Impaired was presented in [5]. The device incorporates an ultrasonic sensor which has a highest maximum distance of 2m. The limitation of this device is the battery life span. The battery only last for four hours of continuous use and this causes a usability problem when the visually impaired find themselves in situations requiring prolonged use of the mobility aid.

An Intelligent Walking Stick (INSTICK)by [6] senses and detects obstacle based on using ultrasonic signal. The user is alerted by means of tactile vibration. The strength of the vibration was said to be inversely proportional to the distance of the user from the object detected. The major limitation of the Instick was non-miniaturization of the device and also, obstacle above the knee level cannot be detected..

[7], in their article titled "A Smart Stick for the Blind", designed a Smart Stick device for the user. The smart stick incorporated a Global Positioning System (GPS) for outdoor activities due to the line of sight access to the satellite. This device incorporated an Ultrasonic sensor for far distance measurement thereby finding it difficult for short distance measurement. The proximity problem tends to endanger the life of the visual impaired and still make them live a life of dependency.

In [8], "An Obstacle Detector for the Visually Impaired" was developed. An Infrared sensor was used for the detection of obstacles at short distances. In the design, three sensors where incorporated and none was designed to address the rear view which helps to prevent back injury. Audio voice alert system was not incorporated in the design.

The existing work mostly used ultrasonic sensors for obstacle detection. Ultrasonic sensors are mostly suitable for outdoor long distance detection. Also, the existing works suffer from very short battery life and lacked the facility for rear-view obstacle detection. Rear-view obstacle detection is critical in situations where the wearer needs to take steps backward. The weight of the device posed a major problem thereby making it uneasy for the visually impaired. The work presented in this paper is focused on addressing these research gaps.

III. METHODOLOGY

This section presents the details for the realization of the wearable indoor hardware device. The device was designed to be worn on the wrist. The choice of wrist as the placement location for the device was informed by literature. Various researchers investigated the best placement location for monitoring and obstacle detection using sensor- based devices and the wrist was found to be most appropriate [9].

3.1 Design Consideration

A number of factors were put into consideration during the design process. The minimum energy absorption value of 0.1J was determined. Energy absorption at the minimum possible level helps to elongate battery life and reduce energy consumption. Reflectivities of different materials were considered because different surfaces have different reflectivity and also the amount of energy absorbed differs. For instance, black objects absorb more energy than any other surface properties. The battery size depends on the capacity of the battery required for the fabrication of the device. The higher the capacity of the battery the bigger the size of the battery and the more space it will occupy in the device. This will also impact on the size of the device. Nokia BL-5CA was used in this design because it has a dimension of 53×33.9×5.6m, resistance of 47kΩ, voltage of 3.7V and its weight is only 18g.The device should operate within a temperature range of 18°C to 70°C which is the specified temperature range of operation for the infrared sensor. The sensor response should be fast enough so that no delay is experienced between the time an obstacle is sensed and the time the user is notified of the obstacle. The device should be as small as possible (miniaturized), not cumbersome or inconveniencing to wear. Also, the device should be easily usably without requiring any special skills. Some of these factors such as battery life, energy absorbed, reflectivity and distance constitute the operational parameters for evaluation purposes.

3.2 Hardware Design

In the hardware design, a number of components were used including infrared sensor, audio system, vibrator, buzzer, Secured Digital (SD) card and microcontroller. The SD card was interfaced with the microcontroller chip through Serial Peripheral Interface (SPI). Also, connected to the microcontroller are the buzzer, audio and the vibrator. Fig. 1 shows the block diagram of the hardware highlighting the interconnection of the various system modules.

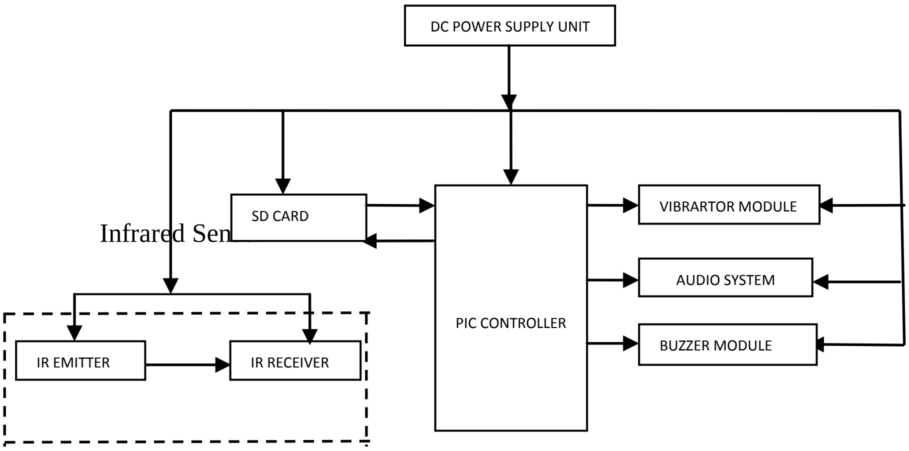


Fig. 1 Hardware Block Diagram

An IR sensor consists of a pair of an IR LED and a photodiode which are collectively called a photo-coupler or an opto-coupler. The four IR sensors are positioned 45° apart as shown in Fig. 2. This is to facilitate obstacle detection in the front, right hand side, left side and rear side. The operational mode of the Infrared sensor is to emit an infrared signal, then infrared signal is reflected back from the surface on which it is incident then, reflected signal is received by the infrared receiver which is the photodiode. The IR emitter consists of the 555timer and the LED. The 555timer is used to generate the 38kHz needed by the LED. Infrared light need to be modulated at 38kHz and then made co-linear. The emitted signal is then sent to the receiver which is the photodiode. The photodiode sends this signal to the microcontroller by making its pin LOW as shown in Fig. 2. The PIC16F876A microcontroller was deployed for the hardware design. In the hardware design, embedded software was developed using embedded C language and burnt into the microcontroller.

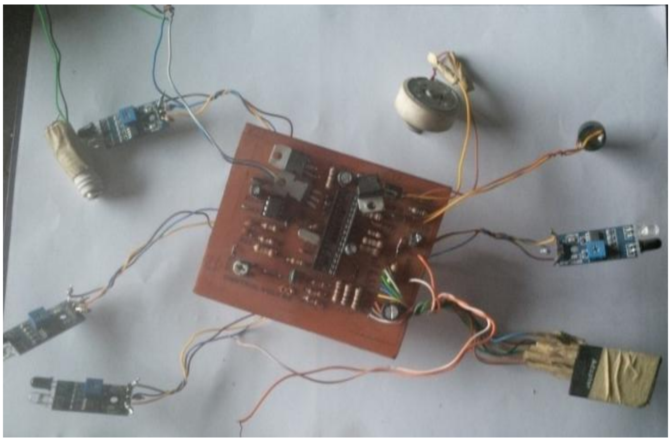


Fig. 2 Wearable Obstacle Detector Circuit

3.3 Software Design

This section presents the software aspect of the work with respect to design, development, and deployment. The software design algorithm is highlighted in Fig. 3. The figure shows a flowchart of the design. The flowchart indicates four possible sections of an endless loop. The first section which is Pin RB4 responds when the pin goes LOW and the microcontroller communicates with the buzzer, vibrator and the voice system to alert the user. The microcontroller communicates with the other sections when pin RB4 goes high. However, the implication of this flowchart is that if RB4 is always LOW, then pins RB5-7 will never be checked. Therefore, pin RB5-7 is checked when pin RB4 goes High.

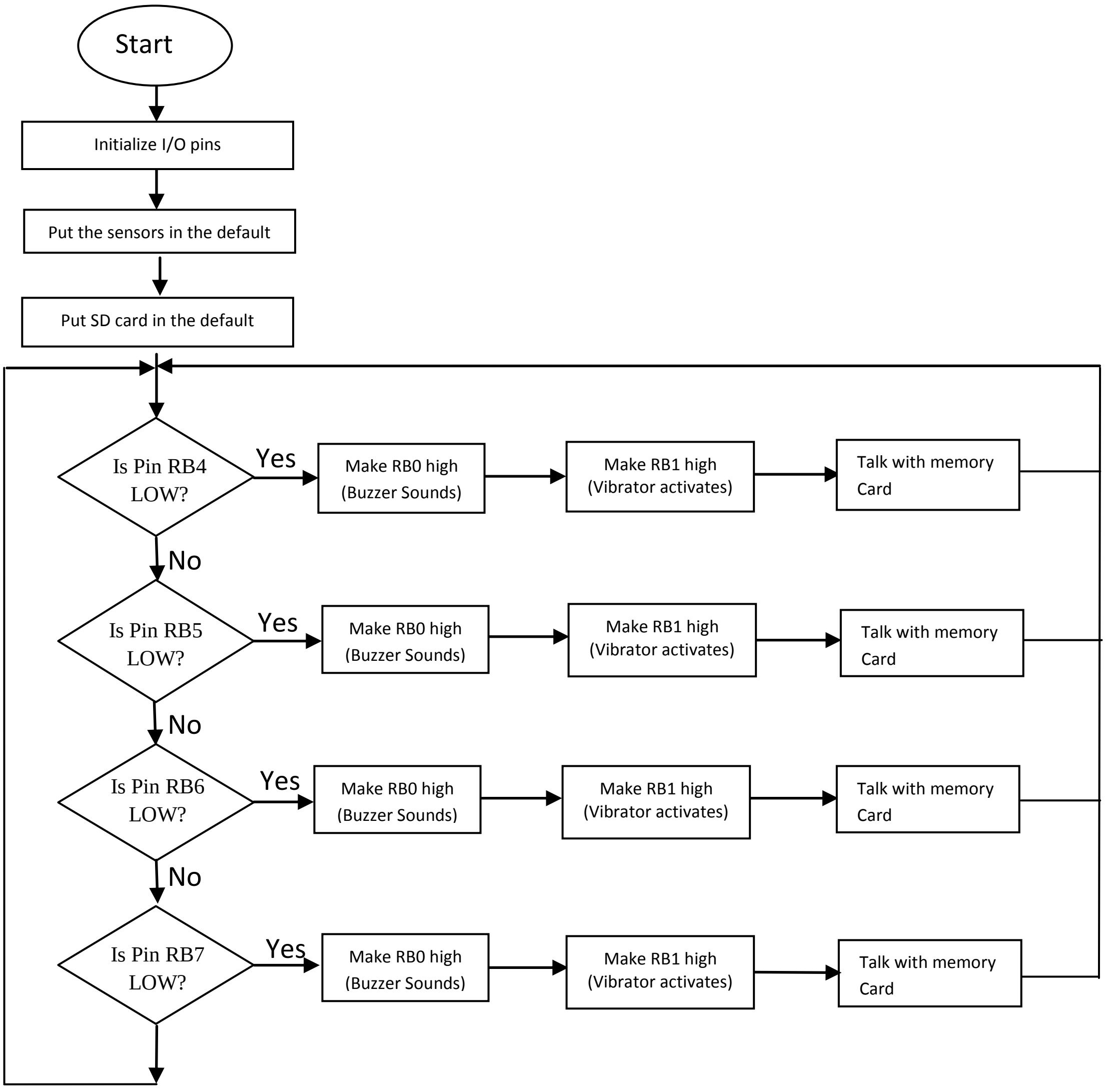


Fig. 3 Flow chart of the Obstacle Detector for the Visually Impaired System.

3.4 System and Parameter Evaluation

Infrared (IR) sensors are widely used as a proximity sensor and for obstacle avoidance. They offer lower cost and faster response times than ultrasonic sensors. The process of measuring distance to an obstacle by using IR sensors can be divided into three steps which are:[10]

- Determine the surface property of the obstacle to detect. This is because when light is incident on a surface, some portion of it scatters or absorbed and the rest of the energy is reflected. Different surface scatters, absorb and reflect light in different portions. It is obvious that black surface will absorb more light than a white surface, and a shiny smooth surface will reflect more energy than a rough surface. This can be seen in the reflectivity of the object.
- The angle of orientation of the surface relative to the sensor is determined. It is determined to simplify the calculation of the surface properties and the distance of an obstacle. The maximum reading of the sensor will always occur at an angle of 0°.
- The distance to the object should be determined. This is calculated from the information obtained from the intensity and angle of orientation of the surface relative to the sensor.

The phong model can provide a simplified description of this effect in four constants: C_0, C_1, C_2 and n. The phong equation for intensity, I, reflected from a surface is shown [10]

$$I = C_0 (\mu_s, \mu_n) + C_1 (\mu_r, \mu_v)^n + C_2 \quad (1)$$

Where μ_s, μ_n μ_r, and μ_v are the light source, surface normal, reflected and viewing vector, respectively. This can be shown in figure 4

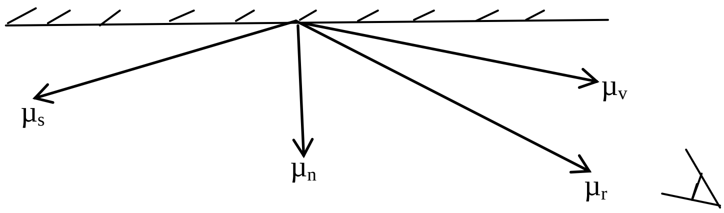


Fig. 4 Angle between the light source, surface normal, reflected and viewing vector [10]

An Infrared sensor emitting Infrared energy and the interaction of the energy with a flat surface is shown in Fig. 5. When comparing Fig. 4 and Fig. 5, one can determine the value of (μ_s, μ_n) and (μ_r, μ_v). The angle between the source vector and the normal vector of the surface is α. Also, if one assumes that the emitter and receiver are in the same position, then the angle between the viewing vector and the reflected vector is 2α. Therefore, equation 1 becomes

$$I = C_0\cos(\alpha) + C_1\cos(2\alpha) \quad (2)$$

Also, the energy absorbed by the photodiode is a function of the intensity (I), distance travelled (2L) and the area (A) of the sensor as shown in equation 3.

$$E=\frac{IA}{(2L)^2} \quad (3)$$

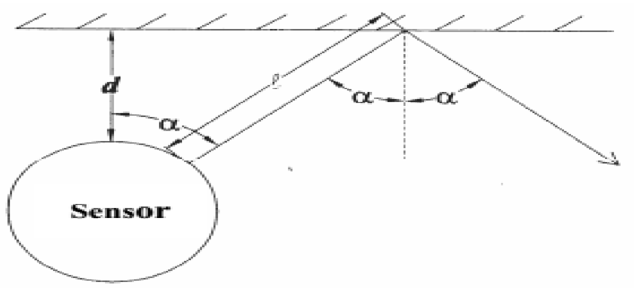


Fig. 5 Emission and Reflection of an Infrared Signal by Sensor [10]

Fig. 5 indicates that, L can be expressed in terms of distance to object (d), angle (α) and the radius of the sensor (r).

$$L = \frac{d}{\cos(\alpha)} + r\left(\frac{1}{\cos(\alpha)} - 1\right) \quad (4)$$

Combining equations2,3, 4, with the assumption that $C_2 = 0$, $n = 1$ and A is constant, the energy absorbed by the sensor can be expressed as

$$E=\frac{C0\cos(\alpha)+C1\cos(\alpha)}{\left[\frac{d}{\cos(\alpha)}+r\left[\frac{1}{\cos(\alpha)}-1\right]^2} \quad (5)$$

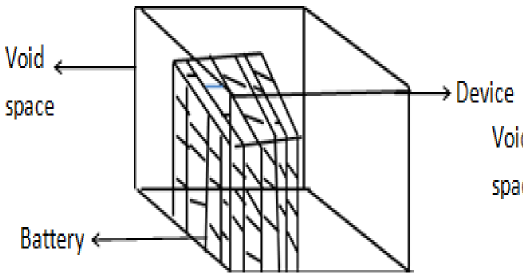
Finally, C_0 and C_1 in Fig. 5 indicate the Infrared characteristics of an obstacle.

Also, after obtaining the surface and the relative angle of the surface, it becomes easier to calculate the distance from equation 5, the distance (d) can be expressed as:

$$d=r(\cos(\alpha)-1)+\cos(\alpha)\sqrt{\frac{C0\cos(\alpha)+C1\cos(2\alpha)}{E}} \quad (6)$$

3.5 Battery Capacity, Size, and Weight

Aside the circuit panel and covering of the device, the major component that contributes to the size of the device is the battery size. Every component can assume a constant size apart from the battery size. The higher the capacity, the bigger the size of the device and the greater the area occupied by the device. There are different sizes of battery and each battery assumes a particular shape which will account for the area occupied. For the purpose of this work, the battery used is a Nokia battery. The weight and dimension of the equipment is dependent on the arrangement and number of the battery needed for the device fabrication. The weight increases as the dimension increases. This can be shown in Figs. 6 and 7.



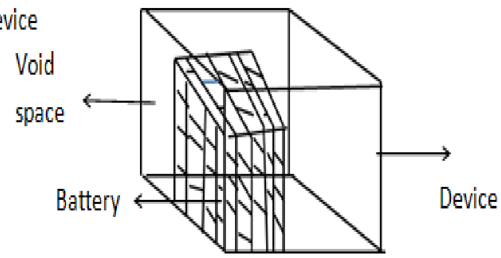


Fig. 6 Device with a higher battery capacity and height and higher number of batteries

Fig. 7 Device with a lower battery capacity, height and lower number of batteries

The total weight of the device is the weight of the number of individual battery used (W_b), the weight of the protective cover used (W_c) and the weight of the other components in the device (W_o) which can be seen as a constant. It can be expressed as

$$W_T = nW_b + W_c + W_o \tag{7}$$

Where W_T is the total weight of the device and n is the number of the battery. This is to say that the total weight of the device changes as the weight of the battery and the weight of the protective covering changes with respect to the number of battery used. The size of the battery also account for the battery capacity. To increase the battery capacity, the size of the battery needs to be increased. Assuming Ce is the battery capacity for each battery, it can be concluded that the total battery capacity, G, of the device is given as

$$G = nCe \tag{8}$$

Substituting equation 8 into 7 we can account for the weight of the device based on the battery capacity we are intended for the device.

$$W_T = \left(\frac{G}{C_e}\right)W_b + W_c + W_o \tag{9}$$

3.6 Device Sensitivity

The sensitivity of the device has to do with device behaviour with respect to the object detection. The device is designed in such a way that when object is closer to it, the sensor triggers more. The triggering of the device requires consumes more energy. The relationship for the sensitivity of the object can be seen as

$$\delta = \frac{Ea}{d} \tag{10}$$

Where δ = Sensitivity of the object, E_a = Energy absorbed, d = Distance to the object

The relationship shows that as the distance increases, the sensitivity of the device reduces, while as the energy absorbed increases, the sensitivity increases.

IV. RESULTS AND DISCUSSION

The Snapshot of the circuit simulation is shown in Fig. 8. This paragraph gives a summary functional description of the system. The Infrared Sensor comprises the IR emitter (LED) and the receiver (Photodiode) which is known as the Opto-coupler. The IR transmitters consist of the 555 timer and the LED. The 555 timer is used to generate the 38KHz needed by the LED. Infrared light was modulated at 38 KHz and then made co-linear. The generated signal was transmitted to the photodiode receiver. The photodiode sends the signal to the microcontroller by making its pin LOW. The microcontroller receives the signal and sends feedback to the buzzer, vibrator and the audio speaker by making its pin HIGH. In the case of audio speaker, the microcontroller communicates with the Secure Digital card by enabling the Chip Select (CS) and then sends a serial data to the memory by using serial data input pin. Once this data is sent, the memory card sends on response to the microcontroller using serial data output pin. The microcontroller now sends the pre-recorded voice to the push up amplifier and then disables the chip select. This functional description of the system is necessary in order to appreciate the result of the work. The simulation was done in order to evaluate the functional behavior of the system. The simulation of the result shows that the system is working perfectly well. The waveform showing the different results of Infrared sensor, SD card, Vibrator and audio system were shown on the oscilloscope.

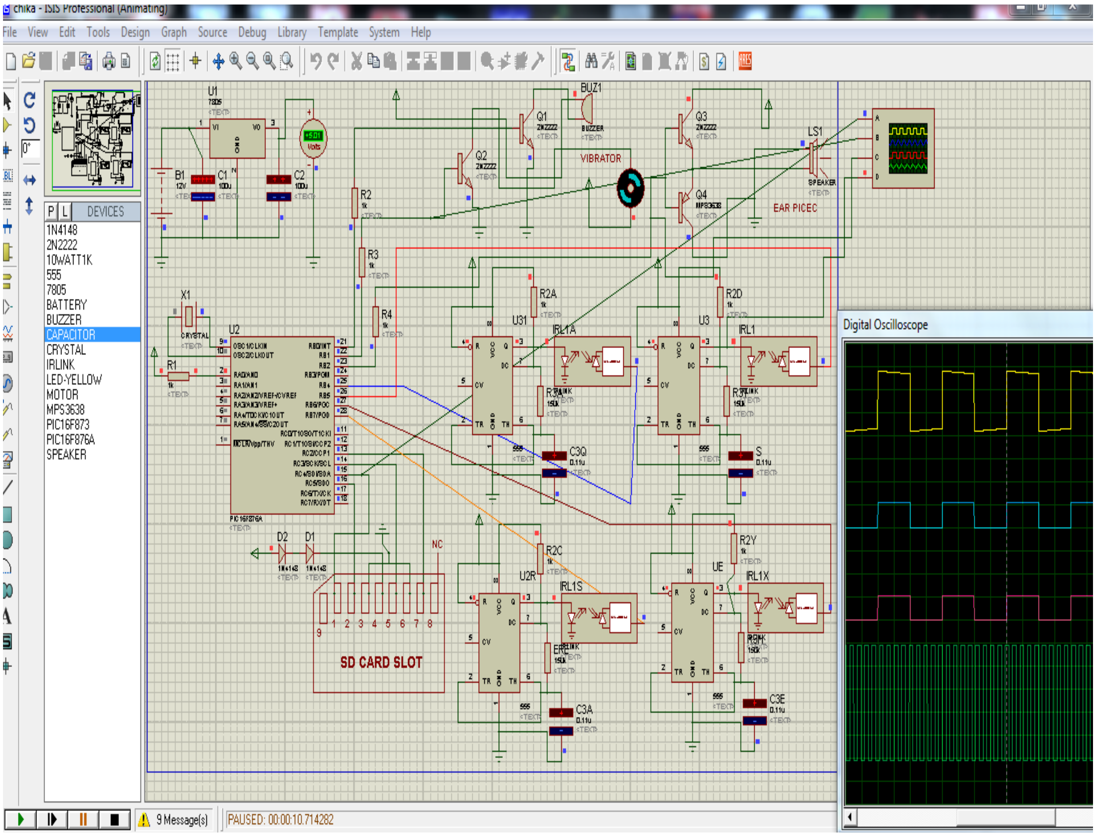


Fig. 8 Circuit simulation of obstacle detection for the visually impaired

Two angles were compared in the course of the design; the angles are 20° and 45° respectively as shown in tables 1 and 2. Table 1 shows angle of 20°, the distance and the energy absorbed. The table which indicates that, at a distance of 0.4m, energy of 5J was absorbed and at a distance of 2.7m energy absorbed was 0.1J. This shows clearly that smaller angles absorb more energy at shorter distances and less at longer distance.

Table 1 Comparison of distance with angle of 20° for different energy consumed.

Angle	Distance(m)	Energy consumption (J)
20°	0.4m	5J
20°	0.5m	3J
20°	0.8m	1J
20°	1.2m	0.5J
20°	2.7m	0.1J

Table 2 shows angle 45°, the distance and the energy absorbed. The table which indicates that, at a distance of 0.11m, energy of 5J was absorbed and at a distance of 0.8m energy absorbed was 0.1J. This shows clearly that larger angles absorb less energy at not very far distances compared to 20°.

Table 2 Comparison of distance with angle of 45° for different energy consumed.

Angle	Distance(m)	Energy consumption (J)
45°	0.11m	5J
45°	0.16m	3J
45°	0.26m	1J
45°	0.42m	0.5J
45°	0.8m	0.1J

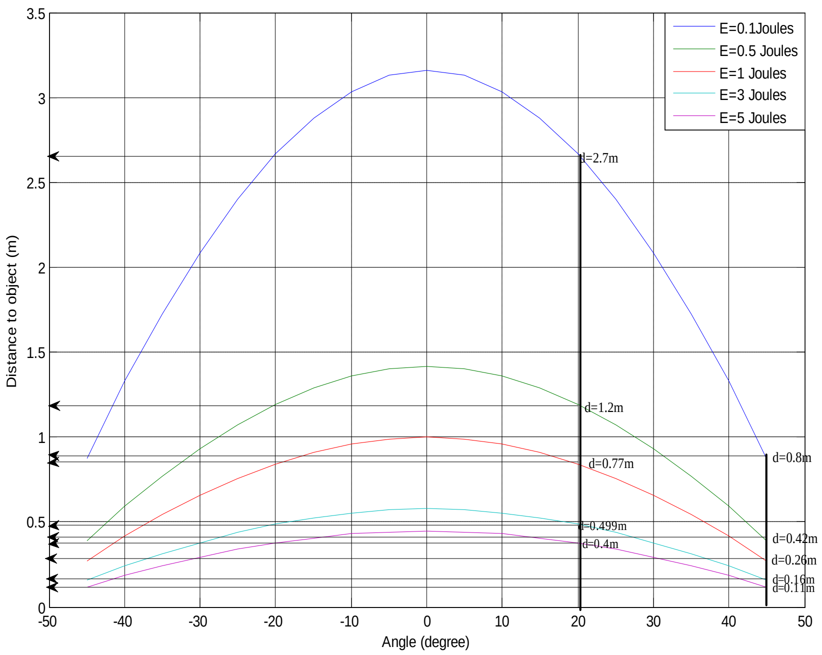


Fig. 9: Comparison of distance with angle for different energy absorbed

Fig. 9 represents a graph showing the effects of angle relative to the distances for different energy absorbed. From the figure, it depicts that the distance decreases progressively as the energy absorbed increases. This becomes paramount as it serves as a design template. The graphical interpretations from Fig. 9 show that to achieve a shorter distance with low energy consumption, it is necessary to increase the angle.

The properties of a material greatly affect the behaviour of the infrared ray. This is due to the absorption of some of the ray on the surface of the material while other materials reflect. Fig. 10 shows the reflectivity of six surface properties i.e Yellow Smooth Body (YSB), Light Gray Body (LGB), Brown Body (BB), Wooden Panel (WP), Concrete Wall (CW) and Black Smooth Body (BSB).

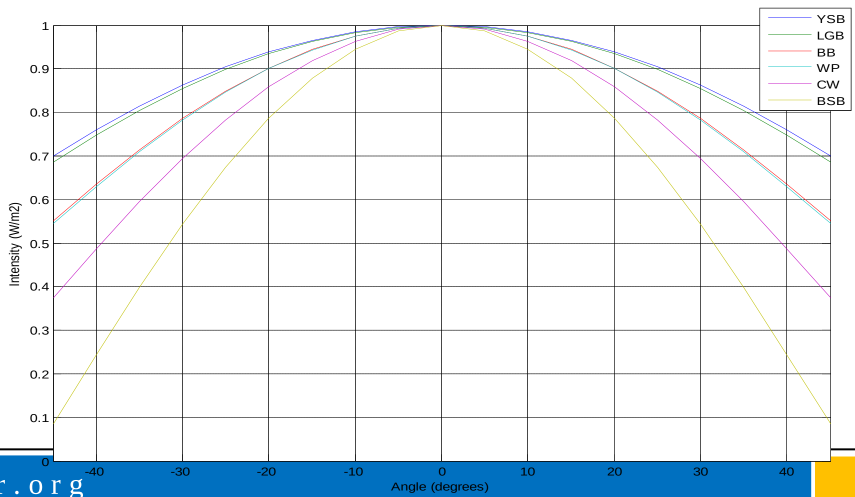


Fig. 10: Comparison of Intensity and angle for different surface properties for a distance of 0.8m.

From the bar chart in Fig. 11, it can be seen that the yellow surface have a higher reflectivity than other surface properties. Black body absorbs so much of the infrared ray which means that to detect an object from a distance above 0.8m it will require greater intensity of the rays and as a result demanding energy from the battery.

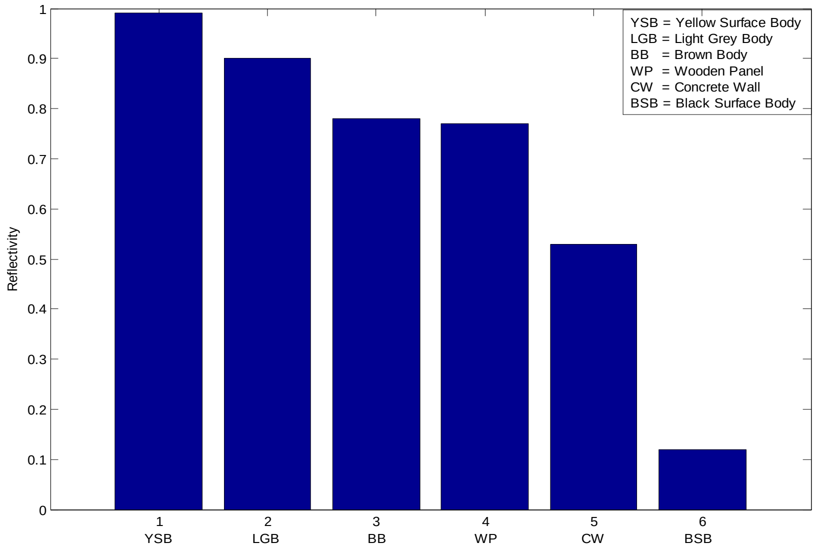


Fig. 11: Reflectivity of different surface properties

V. CONCLUSION

An indoor wearable obstacle detector has been designed, implemented, and evaluated with respect to its functionality, effectiveness, reflectivity, battery life, energy absorption and object detection distance. The device has been found to meet its design considerations of reflectivity of material, battery capacity, size and weight, performance, installation and usage. It is reconfigurable and easy to use with extended battery life. It does not require any special skills or training to use.

For evaluation purposes, the device was simulated at the design phase and was subject to use various test. The simulated results showed that all the modules and the system as a unit were working as desired. The reflectivity test indicated that light coloured objects are more detectable than dark coloured objects. Battery life test indicated that the incident angle on closer objects (that is objects within smaller distance) are often ($\geq 40°$) resulting in lower intensity rays and lower energy absorption of 0.1J by the device form the reflected rays at a short distance. This result promotes longer battery life. On the other hand, the incident angle with farther objects (that is objects within longer distances) are often $\leq 35°$ resulting in higher intensity rays hitting the object and higher energy absorption of 0.1J at longer distance.

VI. RECOMMENDATION

The system is specifically designed to detect objects at closer distance. The work presented forms various contributions to knowledge in the areas of longer battery life for the device, easily detectable object surface colour and the determination of object position and direction. The following recommendations are outlined for further development of the work:

1. Apart from infrared sensor, ultrasonic sensor should be integrated to form a hybrid system so as to alternately detect both long and short distances and also evaluate how the workability of the sensors affects the battery life of the device.
2. More research should be done on how to remedy the high absorption rate of black objects so as to ensure constant reflection of objects irrespective of their colour.

REFERENCES

[1]. Visual Impairment, https://en.wikipedia.org/wiki/Visual_impairment/, accessed, March 2015.

[2]. Nigeria National Blindness and Visual Impairment Survey, https://iceh.lshtm.ac.uk/nigeria-national-blindness-and-visual-impairment-survey/, accessed, February 2017.
[3]. Miniguide, an ultrasonic mobility aid, http:// www.gdp-research.com.au/minig_1.htm/, accessed, March 2015.
[4]. L.Zaratang, and D. Kimbi,. Sensor Stick Walking Aid for the Blinds, International Journal of Research in Engineering and Science, 3(3),2015, 58-60.
[5]. K. Sung Yeon and C. Kwangsu, Usability and Design Guidelines of Smart Canes for Users with Visual Impairments , international Journal of Design, 7(3),2013,99-110.
[6]. R. Khlaikhayai, C. Pavaganun, B. Mangalabruks and P. Yupapin,. An Intelligent Walking Stick for the Elderly and Blind Safety Protection, 2nd International Science, Social Science, Engineering and Energy Conference. 2012, 313-316.
[7]. A,Sakhare, and S. Dambhare, Smart Stick for Blind Obstacle Detection, Artificial Vision and Real-time Assistance via GPS, 2nd National Conference on Information and Communication Technology (NCICT), 2011, 31-33.
[8]. C. Iheweaba, N. Nwachukwu and O. Iheakweaba, Design and implementation of an embedded obstacle detector for the visually impaired,International conference on embedded systems and applications, 2013, 41-47.
[9]. A.Özdemir, An Analysis on Sensor Locations of the Human Bodyfor Wearable Fall Detection Devices,www.mdpi.com/1424-8220/16/8/1161/pdf / accessed, February 2017.
[10]. M.Tarek, Using Ultrasonic and Infrared Sensors for distance measurement, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, 3(3), 2009, 267-272.