Indonesian Journal of Electrical Engineering and Computer Science
Vol. 10, No. 1, April 2018, pp. 266~270
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v10.i1.pp266-270

Design and Fabrication of an Intelligent Walking Staff for Visually Impaired Subjects

Rashidah Funke Olanrewaju, Muhammad Luqman Azzaki Mohd Radzi, Mariam Rehab, Fawwaz Eniola Fajingbesi
Department of Electrical and Computer Engineering, International Islamic University Malaysia, Malaysia

Article Info

Article history:

Received Jan 10, 2018
Revised Mar 10, 2018
Accepted Mar 24, 2018

Keywords:

Walking Staff
Visually Impaired
Ultrasonic Sensor
Water Sensor
Wireless RF Remote Control

ABSTRACT

The joy we derive from our ability to commute and interact freely with the world as a result of our possession of sight with the naked eyes are enormous however the Visually impaired people find great difficulty in moving around freely without a human guide, especially in a new terrain. This research reports the design and fabrication process of an intelligent walking staff (iWalk) specially designed for the visually disabled individuals to argument their loss of sight, improve and ease their navigation. iWalk was designed around water and ultrasonic sensors to detect obstacles and water ahead. iWalk also has a wireless RF remote control buzzer for localization and detection in case it gets misplaced. The proposed system operability and efficiency was adequately tested using physical dataset composed of randomized locations with random obstacles and water. The proposed algorithm achieves an overall efficiency of 90% detection rate for water and ultrasonic sensor and 85.75% for the RF wireless remote control.

Corresponding Author:

Rashidah Funke Olanrewaju,
Department of Electrical and Computer Engineering,
International Islamic University Malaysia,
Malaysia.
Email: frashidah@iium.edu.my

1. INTRODUCTION

The World Health Organization statistics of 2017 puts global visually impaired subjects on the average of 285 million, with about 39 million totally blind and around 246 million having low vision [1]. This group of people without external aids don’t have the luxury of conducting basic living need and activities with ease most especially those related to navigation or relocation to new environments. A visually impaired subject is always bound to disorientation in new environment as obstacles in navigational pathway are ever changing and not static once they left their comfort zones. The conventional solutions with most of this group are the use of guidance dogs or humans as a guide. This method is expensive and very difficult to maintain and sometime unreliable due to the life factors of the guide itself. An alternative to dogs and human guides is the use of a stick or cane to detect an object without any prior information about the environmental situation.

In developed and developing nations, tactile pathways have been incorporated for the visually impaired subjects using sidewalk path. However, they sometimes visit recreational places where small and large obstacles, ponds and water puddles are commonly found along their route. Furthermore, there are cases where they misplace their walking staff making it difficult to commute or locate the staff even inside their comfort zones. Hence, the design of an Intelligent Walking Staff was considered to guide the visually impaired from tangible obstacles as well as water around their pathway and also enable them locate their staff should it be misplaced. Although there have been quite a number of research [2-9] in providing aids to this cluster of people however this design offers simplicity and affordability. The walking stick is made up of an ultrasonic sensor due to its reliability and outstanding versatility. The devices are also tremendously robust so that it can function even in the most terrible situation. The ultrasonic sensor is the most suitable option to be integrated with the walking stick to serve as traveling aid for visually impaired people. Additionally, the walking stick comes with a remote control, which is used to track and locate the misplaced stick.

2. RESEARCH METHOD

The iWalk staff was designed around three basic principle that enables its visually impaired user locate his/her staff and navigate the environment around physically tangible obstacles and water logs. The operation process is illustrated in Figure 1.

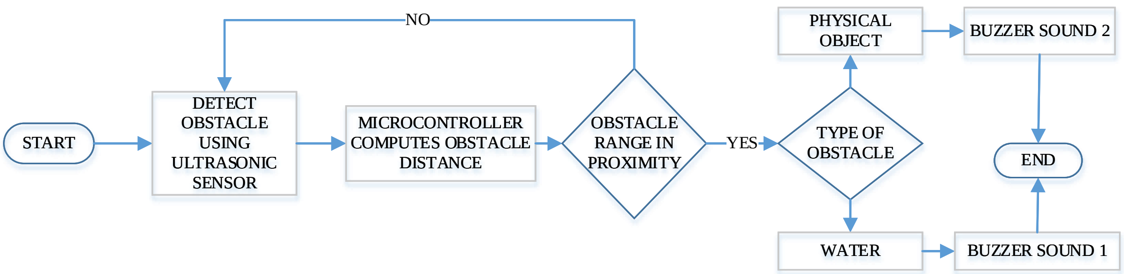

Figure 1. iWalk System Operation Flowchart

2.1. Ultrasonic Sensor Module

The ultrasonic proximity sensors, is predesigned sonic transceiver that permits the interchange transmission and receiving of sound waves. The transducer emits sonic waves which are either absorbed or reflected by an object back to the transducer. The ultrasonic sensor toggles between transmitter and receiver mode when producing sound waves. The time elapsed between the emission and feedback reception of the waves is proportional to the gap of the object from the detector. In this research, the ultrasonic sensor is connected to an Arduino UNO microcontroller board [10] as shown in Figure 2(A). The V_{cc} pin of the ultrasonic transducer is combined with a 5V pin of Arduino board. The ground pin connects the components. The trigger pin of the ultrasonic sensor is connected to the pin number 12 of Arduino while the echo pin of the sensor is linked with pin number 10 of the Arduino board. The buzzer's positive terminal is connected to the pin number 11 of the Arduino board, and the negative terminal is connected to ground. The Arduino is programmed such that the speaker will beep faster if the object is closer to the sensor. The speed of the beeping sound of the speaker can be adjusted by increasing or decreasing the delay in the coding. For this research, the ultrasonic sensor was set to detect an object 100 cm ahead of the user. The buzzer will beep more frequently as the object and the staff gets closer and the range decreases between 60cm-70cm.

2.2. Grove Water Sensor Module

The Grove water sensor module detect the presence of water using exposed PCB traces. It indicate whether the sensor is dry, damp or completely immersed into water by measuring the conductivity change at the exposed segment. As depicted in Figure 2(B), the V_{cc} pin of the sensor is connected to 3.3 V pin of the Arduino board while the D8 pin of Arduino Uno is connected to SIG pin of the sensor as both ground pins were connected. The water sensor was tested to detect the presence of water on the surface of the floor and so the algorithm was also fine-tuned after each test for higher sensitivity. The test for the water sensor involved walking with the walking stick towards the puddle of water on the outdoor surface causing the buzzer to sound rapidly.

2.3. Wireless RF Remote Control Module

The wireless RF remote control module consist of a transmitter and a receiver that could be place over 100m apart as shown in Figure 2 (C). By pressing a button on the remote control, the receiver kit initiate a signal on the corresponding buzzer to alert the visually impaired user about the location of the iWalk staff. The Arduino Uno and the wireless RF remote control receiver are powered up by a 9V battery and 12V battery respectively. Both the batteries are expected to last around 2-3 months, depending on the usage.

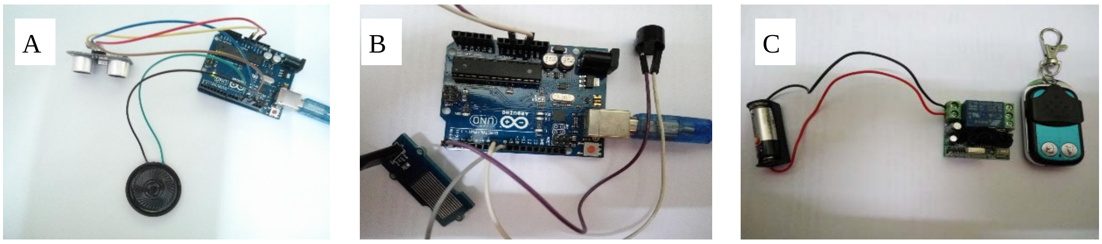

Figure 2. iWalk individual components: (A) Ultrasonic sensor and Arduino Uno connection (B) Integration of grove water sensor, Arduino Uno connections and Wireless RF remote control switch and (C) Wireless RF remote control transmitter and receiver

3. RESULTS AND ANALYSIS

The efficiency of the system was tested by measuring the accuracy of the sensors for detecting the distance between objects and the device after successive training and fine-tuning of the algorithm have been done for the proper calibration. As shown in Figure 3 (A) and Figure 3 (B), the water sensitivity and the physical object proximity test was carried out respectively.

Figure 3. iWalk System Test: (A) Water Sensor Test (B) Obstacle Proximity Test

The system accuracy was calculated using the confusion matrix truth table where:

$$System\ accuracy = \frac{\sum Tp+\sum Tn}{\sum Tp+\sum Tn+\sum Fp+\sum Fn} \quad (1)$$

Table 1. iWalk Obstacle Test Result

		Distance Measurement Test			
Distance	No. of Test	True positive (obstacle correctly identified)	False positive (obstacle distance wrongly classified)	True negative (obstacle distance not wrongly classified)	False negative (obstacle wrongly identified)
100 cm	10	100%	0%	100%	0%
95 cm	10	90%	10%	90 %	10%
90 cm	10	80 %	0%	100%	20%
85 cm	10	80%	0%	100%	20%
80 cm	10	80%	20%	80%	20%
Total	50	430	30	470	70
Material		Water Sensor Test			
Water	10	90%	0%	0%	0%
Oil	10	0%	100%	0 %	0%
Total	20	90	100	0	0
Distance		Wireless RF Remote Control Switch Test			
0.5 m	10	100%	0%	100%	0%
1 m	10	90%	0%	100 %	10%
1.5.m	10	70 %	10%	90%	30%
2 m	10	60%	0%	100%	40%
Total	40	320	10	390	80

$$Ultrasonic\ sensor\ accuracy = \frac{430 + 470}{430 + 470 + 30 + 70}$$

$$\therefore\ Ultrasonic\ sensor\ accuracy = \ 90.0\%$$

$$Water\ sensor\ accuracy = \frac{90}{100}$$

$$\therefore Water\ sensor\ accuracy = 90.0\%$$

$$Wireless\ RF\ accuracy = \frac{320 + 390}{320 + 390 + 10 + 80} = 88.75\%$$

$$\therefore Wireless\ RF\ accuracy = \ 88.75\%$$

From the results in Table 1, it can be seen that average distance measurement of the ultrasonic sensor show nominal deviation from the actual distance with accuracy of 90.0%. Each test was conducted multiple times with minimum mean value of 20 samples to check the algorithm response and verify the buzzer sound with higher frequency as obstacle distance is reduced. The ultrasonic sensor was placed above the water sensor to avoid the presence of water that may cause damage the circuitry. The groove water sensor test was performed, and the water sensor reacted to the presence of water. The water sensor was also tested to detect the presence of another liquid such as oil. Also, from Table I above, it is evident that the sensor can't detect all forms of the liquid, as the sensor did not respond to the presence of oil. Notably, the buzzer sound for the water sensor is set differently to avoid confusion and the partial code responsible for handling those routine is shown in Figure 4. The buzzer in the water sensor beeps faster, and the buzzer sound is a little bit slower than ultrasonic sensor. The water sensor is placed below the ultrasonic sensor and the receiver of RF on the walking stick. The water sensor was not put on the bottom of the walking stick to avoid any damage to the circuit that may have been caused by the rough surface or high level of water. The wireless RF remote control switch is evaluated by placing the walking stick in one place, then pressing the switch on the remote control and trying to go as far as possible while listening to the sound of the buzzer. The maximum range of the buzzer that could be heard was observed to be 2.0 m. This limitation is totally due to the audibility of the buzzer and not the wireless range of the RF controller. The sound of the buzzer for the RF receiver is also slower than the ultrasonic buzzer and the water sensor. To sound the buzzer rapidly, buttons A and B could be pressed simultaneously so that the user can hear the sound of buzzer more naturally. On the walking stick, the wireless RF receiver was placed between the ultrasonic sensor and the water sensor.

```
#define GroveSensor 8
#define PiezoBuzzer 7
int buzzerPin = 11;
int trigPin = 12;
int echoPin = 10;

void setup() {
  Serial.begin (9600);
  pinMode(PiezoBuzzer, OUTPUT
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(GroveSensor, INPUT)
}
```

```
void loop() {
  if (digitalRead(GroveSensor) == LOI

    digitalWrite(PiezoBuzzer, HIGH);
    delay(10);
    digitalWrite(PiezoBuzzer, LOW);
    delay(20);
  } else {
    digitalWrite(PiezoBuzzer, LOW);

  }
  long duration, distance;
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
  distance = (duration / 2) / 29.1;
  Serial.print(distance);
  Serial.println(" cm");
```

```
if (distance >= 17 && distance <= 27)
{ int freq = 1000;
  tone(buzzerPin, freq);
  delay(100);
  noTone(buzzerPin);
  delay(200);
}
if (distance > 27 && distance <= 57)
{ int freq = 1000;
  tone(buzzerPin, freq);
  delay(200);
  noTone(buzzerPin);
  delay(200);
}

else if (distance >= 400 || distance <= 0
  Serial.println("Out of range");
}

}
```

Figure 4. iWalk Buzzer Configuration Code

4. CONCLUSION

This work proposed, design and fabricated a simple yet effective ultrasonic-based intelligent walking staff (iWalk) for visually impaired subject that is capable of detecting physical obstacles and water logs within 100cm with a different sound of buzzer for each type of obstacle. The obstacle detection accuracy was computed to a 90.00% accuracy using confusion matrix. The reduced value in the accuracy can be ascribe to the limitations with the water sensor and also some from the ultrasonic sensor selected. The selected water sensor also can only detect water up to 5cm^3 just to avoid any short circuit to the water sensor. Hence, the sensor is not suitable to be used in heavy rain. The iWalk also has remote control feature for locating the walking stick when misplaced with a recorded 88.75% accuracy. The system improvement can also be made based on the already proposed design using higher order algorithms for obstacle computation and validations such as genetic algorithm or artificial neural network.

ACKNOWLEDGMENT

This work was partially supported by Ministry of Higher Education Malaysia (Kementerian Pendidikan Tinggi) under Research Initiative Grant Scheme (RIGS) number RIGS 16-357-0521.

References

[1] Vision impairment and blindness, World Health Organization, 2017. [Online]. Available: http://www.who.int/mediacentre/factsheets/fs282/en. [Accessed: 12- Oct- 2017].

[2] G. Gayathri, M. Vishnupriya, R. Nandhini and M.M. Banupriya. Smart walking stick for visually impaired, *International Journal of Engineering and Computer Science (IJECS),* vol. 3, no. 3, pp.4057-4061, 2014.

[3] O.B. Al-Barrm and J. Vinouth, 3D ultrasonic stick for blind, *International Journal of Latest Trends in Engineering and Technology (IJLTET),* vol. 3, no. 3, pp. 108-114, 2014.

[4] P. Sharma and S.L. Shimi. Design and development of virtual eye for the blind, *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering,* vol. 3, no.3, pp. 26-33, 2015.

[5] T.A. Ueda and L.V. de Araújo. *Virtual walking stick: Mobile application to assist visually impaired people to walking safely*. Universal Access in Human-Computer Interaction, International Conference on, Springer, Cham, pp. 803-813, 2014.

[6] V. Patel, The Digitalization of the Walking Stick for the Blind. *International Journal of Scientific & Engineering Research,* Volume 6, Issue 4, 1142-1145, 2015.

[7] C. Furlan And V. Su, Sonar Walking Stick. San Luis Obispo: Electrical Engineering Department, California Polytechnic University, 2014.

[8] P. Bhardwaj and J. Singh, Design and development of secure navigation system for visually impaired people, *International Journal of Computer Science & Information Technology*, vol. 5, no. 4, pp. 159-164, 2013

[9] Rashidah FO, Fajingbesi FE, Mahmoud SM. *Automated bank note identification system for visually impaired subjects in Malaysia.* 6th International Conference on Computer and Communication Engineering (ICCCE 2016), 25th-27th July 2016, Kuala Lumpur.

[10] Gunawan, T. S., Munir, Y. M. S., Kartiwi, M., & Mansor, H. (2018). Design and Implementation of Portable Outdoor Air Quality Measurement Systemn using Arduino. International Journal of Electrical and Computer Engineering (IJECE), 8(1).