IOT Bracelets for Guiding Blind People in an Indoor Environment

Ahmad Abusukhon

***Abstract*— Every day, we engage in a variety of activities such as shopping, reading, swimming, and so on. Many people in our community, however, are unable to participate in such activities, due to a variety of eye problems. Directing a blind person to the optimal position (the center of a spot where there is enough space in all directions such that a blind person avoids various obstacles) is a challenge. This paper proposes wireless bracelets that are able to guide a blind person to the optimal position. The proposed system employs ultrasonic sensors in order to detect various obstacles in an indoor environment. It also makes use of the Firebase database and NodeMCU WiFi module to enable real-time communication with a blind individual. Furthermore, the suggested system includes a novel fall-detection mechanism. The proposed Internet of Things (IoT) system is evaluated in an indoor environment. Experiment results showed that the proposed system could efficiently direct a blind person to the optimal position. In comparison to the current state of the art, the proposed system is simpler, less expensive, and more efficient in determining the optimal position to which a blind person must navigate.**

***Index terms*— Internet of Things (IoT) bracelets, IoT navigation system, visually impaired, real-time communications, NodeMCU, Firebase database.**

I. INTRODUCTION

A large number of people in our community are unable to carry out their everyday activities in a normal manner. These people have lost touch with one of their most vital senses for navigating their way through life. This is the sensation of seeing. Blindness is defined as “lacking visual perception due to physiological and/or neurological factors” [1]. Recently, the World Health Organization (WHO) revealed that there are 2.2 billion people suffering from various kinds of vision impairment [2]. When traveling in an indoor environment, a blind person must contend with a variety of obstacles such as room furniture, walls, stairs, and other hazards, exposing oneself to a variety of dangers. To avoid these obstacles, the blind rely on caregivers to lead them down the right path. Because caregivers are not always accessible, an IoT system that allows a blind person to travel safely to a specific destination is required. Here, we describe some of the challenges associated with guiding blind people along their path, as well as the challenges that this paper attempts to address.

Manuscript received December 14, 2022; revised January 10, 2023. Date of publication April 14, 2023. Date of current version April 14, 2023. The associate editor prof. Luigi Patrono has been coordinating the review of this manuscript and approved it for publication.

Author is with the Department of Computer Science, Al-Zaytoonah University of Jordan, Jordan (e-mail:ahmad.abusukhon@zuj.edu.jo).

Digital Object Identifier (DOI): 10.24138/jcomss-2022-0160

In [2], [3], the authors stated that the most difficult challenges for blind people are related to safe and effective navigation. Furthermore, a blind person's inability to perceive items in their environment is described as a difficult or herculean task. [4]. Mainly, there are two types of navigation, namely, indoor and outdoor navigation [5]. Indoor positioning is more challenging than outdoor positioning [6]. One solution to the above challenges is the use of the Internet of Things (IoT). The IoT is composed of four modules: the data-gathering module, the data-storage module, the communication module, and the data-retrieving and processing module. A group of sensors represents the data-gathering module, which is used to collect data from the environment. The data-storage module is in charge of storing the sensor’s data in the cloud. The communication module handles data transfer between the NodeMCU board, the Firebase database, and a mobile phone. The IoT is defined by the IEEE [7] and others [8], [9] as follows: The IoT is a complicated network of intelligent objects that are managed over the Internet.

Designing an IoT system that serves blind people in an indoor environment is more complicated than designing one that serves them in an outdoor environment [10].

One of the challenges for blind travelers is checking the ground plane. Checking the ground plane includes the ability to recognize various obstacles (such as steps and ramps) and their positions [11], [12]. In [13], the authors proposed wearable smart glasses and an intelligent walking stick for blind people. In a similar work [14], the authors developed a wearable vision assistance system that detects various objects based on a binocular vision sensor, which is used to capture images at a specific frequency. In [15], the authors investigated tracking the blind way using beacons that are placed at specific locations. The authors in [16] suggested an IoT system that is made up of a smart stick and a mobile application. In [17], the authors proposed a new indoor navigation method based on visual light communication technology. In [18], the authors proposed the “virtual eye” system. In their system, the blind’s stick is equipped with a USB camera and ultrasonic sensors. The camera captures an image, and then this image is analyzed using the You Only Look Once (YOLO) classifier.

In [19], a Global Position System – Global System for Mobile (GPS-GSM) module and the ultrasonic sensors are used in order to help blind people avoid obstacles in an outdoor environment. In [20], the authors proposed an IoT system for detecting obstacles and holes based on a laser sensor that detects holes at night and in the daylight. The authors in [21], [5], [22] recommended that when designing new assistive technology for blind people, the cost, simplicity, reliability,

robust navigation with a short response time, and device weight must be taken into consideration so that the assistive devices are economically accessible to blind people.
Following the introduction, the rest of this paper is organized as follows: Section II describes the related work. Section III describes the proposed system and the research methodology. Section IV describes the system evaluation and testing in a real-time environment. Section V describes the conclusion and future work.

II. Related Work

This section describes various navigation techniques used to aid blind people in avoiding obstacles along their path. In [23], the authors proposed wearable glasses and a walking assistant design based on the ultrasonic sensor. In [24], the authors replaced a blind's man cane with an IoT prototype in order to reduce the total cost. The proposed prototype is able to detect obstacles (using an ultrasonic sensor that is affixed to the blind's glasses) and warn blind people about these obstacles via smart phone. In [5], the authors innovated a blind stand that is provided by an Arduino Uno Microcontroller (AUM) and ultrasonic sensors associated with a voice module in order to guide blind people. The authors in [16], [18], and [25-31] proposed work similar to the work proposed in [5]. In [26], the authors proposed an IoT stick that is able to detect obstacles within 4 meters based on an ultrasonic sensor and a vibrator motor. The stick vibrates as an indicator when a blind person is confronted with an obstacle. In [27], the authors proposed a stick that is able to discover obstacles (using an ultrasonic sensor) and then send a signal to a buzzer and a vibrator. In [28], the authors proposed a smart stick for the visually impaired. This stick is equipped with ultrasonic sensors for detecting obstacles and potholes). The ultrasonic sensor is placed on the stick at an angle of 30. To achieve safety for blind people, the authors in [32] proposed a navigation system via the web. Their system is based on image processing techniques and the use of IR sensors. They developed mathematical equations for calculating the distance between a blind person and an obstacle using two cameras where the epipolar plane cuts through image planes. However, this system is inefficient when using cameras, since cameras are sensitive to various environmental distortions such as dust, smoke, fog, and vapor, and they do not work perfectly at night. In [30], the authors proposed a prototype model (an Electronic Traveling Aid (ETA)) for assisting blind people. In their system, they proposed to attach the ultrasonic sensor to the blind person's shoe. When an obstacle is detected, a blind person receives an audio message.

The above survey shows that most of the recent papers are focusing on improving the design and features of the smart stick using sensors and cameras. Other papers, on the other hand, are focusing on using artificial intelligence with the IoT to provide solutions for the blind's problems and difficulties [33]. Using artificial intelligence is not the focus of this paper.

The research problem of this paper is how to design a simple, cheap, and real-time IoT system, which is able to keep a blind person in the optimal position with respect to the locations of various obstacles in an indoor environment? The goal is to enable a blind person to navigate safely along her or his path. To tackle this problem, we propose an efficient IoT system for guiding blind people in an indoor environment. The proposed system is IoT bracelets (IoT-Brac), which are able to precisely detect obstacles and direct a blind person to the optimal position. The proposed system is based on the ultrasonic sensors, the NodeMCU ESP8266 WiFi communication module (NodeMCU 1.0 (ESP-12E Module), and the Firebase platform as a real-time database. The proposed system is a couple of wireless bracelets, which a blind person wears in both hands. Our proposed system can be used for both an indoor and an outdoor environment. We focus on an indoor environment, however, because it is straightforward to test different scenarios for identifying barriers by modifying the position of such obstacles, allowing us to simply update our algorithm. Some previous work proposed guiding a blind person to a specific direction after a specific time (for example, a blind person may receive an audio message saying, "After 2 minutes, go to the right") [34]). Since a blind person cannot precisely determine the time (e.g. two minutes in the above message), a blind person may go to the right before or after the set time, causing him to struggle with an obstacle and fall. To overcome this con, our system sends a blind person an audio message telling him about the direction (e.g., right) and the magnitude of the optimal position (e.g., how many steps a blind person should move). For example, the proposed system sends a message saying: "Go to the right after 3 steps" instead of saying: "After 2 minutes go to the right" as described in [34]. Thus, compared to the work done in [34], our technique is more accurate in selecting the optimal position. In addition, our system differs from the work in [34] in that it detects falls using the left and right bracelets. In addition, our system is simpler than the system proposed in [32]. In [32], the authors calculated the distance between a blind individual and an obstruction using two cameras and difficult mathematical formula. The approach suggested in [32] is inaccurate, though, because cameras are susceptible to a variety of environmental distortions such dust, smoke, fog, and vapor, and they perform less than optimally at night. Besides, in the previous work, a walking stick is used for detecting obstacles along a blind person's path. Aside from that, a blind person has had to deal with certain embarrassing situations, such as hitting a walker's leg with a stick and being injured by hitting barriers [34]. Our design differs from the design in [34]. Our design is wireless IoT bracelets that a blind person can easily wear, and thus avoid the above embarrassing situations. Table I compares various techniques (including our proposed IoT system) with respect to the technique used in the paper, the system's cost, the scope of the system (indoor or outdoor), the system's cons (dentoed as "-") and pros (dentoed as "+") and the delay for both calculations and message receipt. In Table I, the cost is approximately calculated based on the hardware used in each paper. This is because the authors of these papers did not calculate the total cost of their systems. Table I is one of the contributions to this paper. In Table I, we calculate the delay time for both calculations and message receipt. Our proposed system performs better than the system proposed in [34] in terms of delay time (communication delay and message receipt dealy). However, it was difficult to compare the other papers listed in Table I with the proposed system since the original authors did not calculate the delay time.

TABLE I
A COMPARISON BETWEEN VARIOUS TECHNIQUES AND THE PROPOSED SYSTEM BASED ON VARIOUS FACTORS

Paper Ref.	The Technique	Cost	Scope	Pros (+) and Cons (-)	Dealy time
[27]	A stick (with an ultrasonic sensor and an Arduino Nano) is used to detect an obstacle.	≈ $102	Indoor /out door	(-) Unable to direct a blind person to the optimal position. (+) Stick finder: help the person to find his stick	-Not calculated by the authors
[5]	A stick (with ultrasonic sensors and an infrared sensor) is used for detecting obstacles and creating audio messages.	≈ $39	Indoor /outdoor	(-) Unable to direct a blind person to the optimal position. (+) Water sensor for detecting puddles. (+) light weight	-Not calculated by the authors (the authors mentioned that "response time is short" without measuring it.
[35]	A color-based technique that uses a camera and machine learning for guiding blind people.	$0 (Except for mobile phone, no other hardware was used.)	In door	(-) Produced inaccurate results. (-) Influenced by distortions such as dust and fog. (-) Unable to guide a blind person to the optimal position. (+) retrieves information about directions using color targets	-Not calculated by the authors. The authors mentioned that " for time processing, the mobile application (GuiderMoi) has the advantage of being in real time" without measuring the processing time.
[34]	The system captures an image of an obstacle, analyzes this image, and then it takes an action. The navigation is executed using the GPS module.	≈ $113	Indoor/ out door	(-) Unable to guide a blind person to the optimal position. (-) Weight =1Kg. (+) Use night vision camera	- Calculation time = 2-3 seconds. -Time for sending message = 10-12 seconds
[24]	Detecting obstacles using ultrasonic sensors and then keeping the locations of these obstacles in a database using a mobile application for future detection.	≈ $50	Indoor/ outdoor	(-) If the location of an obstacle is changed, the system produces false alarm. (-) Unable to guide a blind person to the optimal position. It just uses the words (East, West, etc.) (+) Recording the obstacle's Location	-Not calculated by the authors
[28]	Detecting various obstacles using three ultrasonic sensors affixed to a stick at various angles.	≈ $96	Indoor/ outdoor	(-) Unable to guide a blind person to the optimal position. (+) pot-hole detection	-Not calculated by the authors
[23]	Wearable glasses and walking assistant devices were developed in order to guide a blind person.	≈ $52	Indoor/ outdoor	(-) Unable to guide a blind person to the optimal position. (+) data are collected and analyzed by the clouds computing center	-Not calculated by the authors.
The proposed system	IoT bracelets that are able to detect obstacles in three directions left, right and forward simultaneously and calculate the optimal position to which a blind person must be directed.	≈ $29	indoor	(+) The proposed system is able to guide a blind person to the optimal position. (-) Tested for indoor environment only.	Dealy time (milliSeconds): Calculation = 0.0174 milliseconds. Message receipt = 0.24567 milliseconds Writing data to firebase database = 683.2 milliseconds

TABLE II
THE ESTIMATED COST OF THE STATE-OF-THE-ART TECHNIQUES AND THE PROPOSED SYSTEM (PRICES ARE BASED ON THE HARDWARE USED IN EACH PAPER)

Paper Ref.	Hardware used in the paper	Price ($)
[27]	Arduino Nano	26
	Vibration motor	20
	Portable hand cane walking stick (110 m)	19
	DC 12-24V 22H RF wireless remote control switch system.	14
	Buzzer (tatoko)DC 3-24V)	10
	9V batteries (8 pack 9V)	11
	Ultrasonic sensor	2
	Total cost	$102
[5]	Two ultrasonic sensor	4
	Arduino Uno	27
	ISD 1820 voice module (Ximimark sound voice module)	7
	Infraread sensor	0.5
	Total cost	$39
[35]	No hardware	0
	Total cost	$0
[34]	Raspberry pi3 B+ module	30
	Night vision raspberry pi	22
	Global Positioning System (GPS) receiving module navigation tracker developer test kit	10
	Batteries	11
	L298N IC motor drive module	11
	Press button	2
	Power bank (5V/2.1A)	27
	Total cost	$113
[24]	DSD TECH HC-05 Bluetooth	10
	Ultrasonic sensor	2
	Arduino Uno REV3	27
	Working voltage	11
	Total cost	$50
[28]	Three ultrasonic sensors	6
	Arduino Uno R3	27
	HiLetgo HC-05 wireless Bluetooth RF.	10
	Two buzzers	20
	Two vibration motors	22
	Batteries	11
	Total cost	$96
[23]	Five ultrasonic sensors	10
	GPS receiving module navigator tracker	10
	Zigbee module	5
	Arduino Uno	27
	Total cost	$52
[24]	DSD Tech HC-05 Bluetooth	10
	Ultrasonic sensor	2
	Arduino Uno REV3	27
	Working voltage	11
	Total cost	$50
The proposed system	NodeMCU (two nodes)	10
	Four ultrasonic sensors	8
	Batteries	11
	Total cost	$29

Table II describes the hardware and the cost of the systems proposed in the previous work as well as the hardware and the cost of the proposed system. Fig. 1, compares the proposed system with various IoT systems proposed in the previous work with respect to system's cost. Fig. 2, describes a block diagram of the proposed system.

As described in Fig. 1, our proposed system outperformed the other proposed systems in terms of cost in U.S. dollars. Details about this cost are shown in Table I and Table II. Besides, unlike the previous work ([13-16], [18], [19], [23], and [25-31]), the proposed IoT system is able to detect obstacles in various directions simultaneously, decide which path (D) a blind person should take, and then guide a blind person to the optimal position using Equations 1 and 2. Furthermore, our work is simpler than the work proposed in [32] since it does not use complicated mathematical equations for calculating the distance between a blind person and an obstacle. Using complicated mathematical equations slows down the real-time systems such as the one we propose in this paper. Besides, our system is not sensitive to various environmental distortions such as dust and smoke, and it works perfectly at night. In [35], the authors proposed a mobile application for guiding a blind person to various directions based on colored benchmarks (targets). The drawback to their system is that their system did not solve the mobility problem (also known as wayfinding).

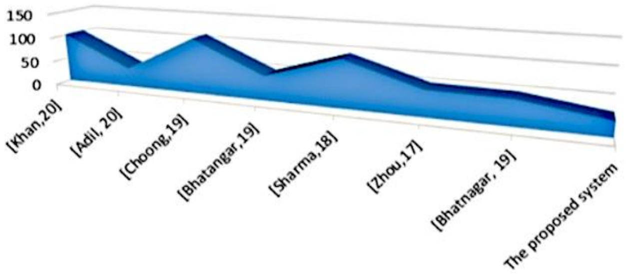

Fig. 1. A comparison between the proposed system and the state-of-the-art in terms of system's cost.

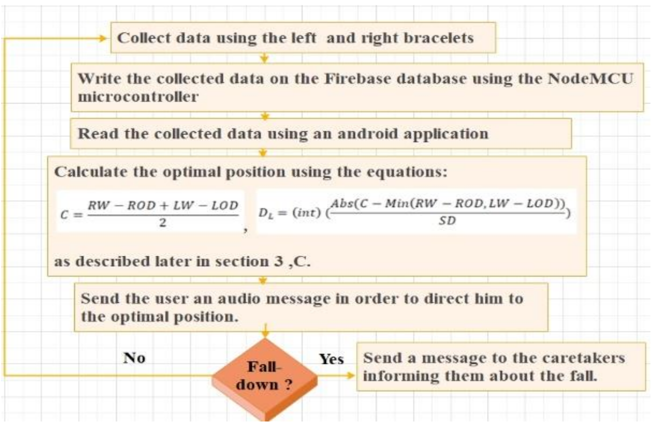

Fig. 2. A block diagram of the proposed IoT system.

The wayfinding problem is "the global problem of planning and following routes from place to place" [36]. However, our system solves this problem since it is able to guide a blind person to various directions using the left and right bracelets and a mobile application. Compared with the state-of-the-art, the proposed system is simpler and more accurate than the other systems since it directs a blind person to the optimal position. Besides, it introduces a novel way for detecting falls using the ultrasonic sensors.

III. The Proposed System

In this section, we describe the proposed IoT system (as shown in Fig. 2) and the pseudo code.

A. *The Research Methodology*

The proposed IoT system consists of two bracelets that guide a blind person along his path while avoiding various obstacles. Our system consists of the following modules: the data-gathering module (a set of ultrasonic sensors), the data storage module (the Firebase database), the communication module (the NodeMCU 1.0 (ESP-12E Module), and the data retrieving and processing module (an Android application). In this paper, we use the HC-SR04 ultrasonic distance sensor. This low-cost sensor offers non-contact measurement functionality ranging from 2 cm to 400 cm with a ranging accuracy of up to 3 mm. An ultrasonic transmitter, a receiver, and a control circuit are all included in each HC-SR04 module. The NodeMCU 1.0 (ESP-12E Module) is a wireless communications and Wi-Fi chip platform that is widely used in mobile devices and Internet of Things applications. The HC-SR04 sensors are used for gathering information from an indoor environment. These sensors are affixed to both bracelets at angle 30 in order to detect objects of various lengths [28]. In general, the sensing angle of the HC-SR04 is 30-degree cone and the angle of effect is 15-degree cone. However, a blind person can detect objects of varying lengths by moving his hands up and down, left and right. Besides, the HC-SR04 is used in our system since it can detect objects located in a wide range (from 2 cm to 400 cm) and it is accurate to the nearest 0.3 cm as we mentioned earlier. In our system, the ultrasonic sensors are used to read information about various obstacles that are allocated in various directions (e.g., left, right and forward). After that, the information is stored in the Firebase database in the cloud, and then our Android application simultaneously reads the values stored in the Firebase database and calculates the optimal position. When the optimal position is calculated, the proposed system sends an audio message in order to guide a blind person to that position. We use the Firebase database since it is a real-time database (it can store and synchronize app data in real-time). Furthermore, it includes features that will help us develop the proposed system in the future, such as GPS-location-tracking of the blind person. Besides, Firebase's features such as Firebase Machine Learning (ML) can be used for calssifying various directions (e.g. left, right) that a blind person should follow and addressing various fall situations correctly. This enhancement requires storing data about the blind person's location in a database for further use. Other features of the Firebase database include:

1) Built-in Analytics (observing user behavior and measuring various user characteristics).
2) Cloud messaging (which allows us to deliver and receive messages in a more reliable way across platforms). The proposed system is tested and evaluated in an indoor environment for various cases where various obstacles are located in various positions in the living room. For each case, a suitable audio message is sent to a blind person (via a headphone) in order to guide him to the optimal position. Next, we describe the pseudo code of the proposed system. We describe the navigation system and the fall detection system. Table III, shows the notations used for describing our system.

<u>The pseudo code:</u>

Step 1: The Bootstrap Configuration
- (a) *Set the threshold of the ultrasonic sensor* US_{TH} *=30 cm.*
- (b) *Set the step distance SD = 30 cm.*

Step 2: The Navigation System –IoT bracelets
- (a) *Define the function Calculate*D_L*(RW-ROD, LW-LOD) that calculates the* D_L *value based on the RW-ROD and LW-LOD values gathered from the left and right bracelets as follows:*

Function CalculateD_L *(RW-ROD, LW-LOD)*
{
1) *Measure the distance (X) between O and the RW-ROD.*
2) *Store X in the Firebase database with the help of the NodeMCU module.*
3) *Measure the distance (Y) between O and the LW-LOD.*

4) *Store Y in the Firebase database with the help of the NodeMCU module.*
5) *Measure the distance (F_R) between O and the RW-FOD.*
6) *Store F_R in the Firebase database with the help of the NodeMCU module.*
7) *Measure the distance (F_L) between O and the LW-FOD.*
8) *Store F_L in the Firebase database with the help of the NodeMCU module.*
9) *Calculate:*
   a) $C = (X+Y)/2$
   b) $D_L = (int)(Abs(C-Min(X,Y))/SD)$
10) *Return D_L, F_R, F_L*

}

(b) *Define the Function getDirection (X, Y, D_L, F_L, F_R).*

```
{
    // This function steers a blind person to the right direction (e.g.,
    // left, right, forward, and //backward) in order to avoid various
    // O. It //receives the parameters: X, Y, D_L, F_L and F_R. These
    // parameters are retrieved from the //Firebase database using
    //our Android //application. The function works as follows:
If (X > Y)
    Send the audio message "Move D_L steps to the right."
Else
    Send the audio message "Move D_L steps to the left."
If ((F_L >= US_TH) AND (F_R >= US_TH))
    Send the audio message "Move forward one step."
Else if ((F_L < US_TH) OR (F_R < US_TH))
    {
    Send the audio message "Move backward one step."
    Call the Function CalculateD_L (X,Y)
    Call the Function getDirection (X, Y, D_L, F_L, F_R).
    }
}
```

Step 3: *Falls Detection*

1) *Read the RW-ROD and LW-LOD values using the left and right bracelets.*
2) *Store the RW-ROD and LW-LOD values in the Firebase database.*
3) *Read the RW-ROD and LW-LOD values from the Firebase database using an Android application.*
4) *While ((RW-ROD >=2000) OR (LW-LOD >= 2000))*
   {
   Send a text message to the caretakers telling them that a fall has occurred.

}

Note that in the proposed system, the left and right bracelets are connected to various NodeMCU boards. For the above algorithm, we calculate two types of delays: the calculation delay time (the time required to perform the calculations that are described in the above pseudocode) and the message recipe delay time (the time required to read data from the firebase and then choose the suitable audio message to be sent to the blind person.) Next, we describe the proposed navigation system.

B. *The Proposed Navigation System (NS)*

In this section, we describe the proposed IoT system for guiding a blind person along his path. In our system, the Firebase platform is used for data storage. The Firebase platform provides a set of developer solutions that accelerate the integration of the cloud-based features into Web and mobile applications. To deal with Firebase, a Google account and a Firebase project are required [37]. Fig. 3, describes the structure of our real-time database that we built using the Firebase platform. The database consists of a root node (we call it the "BNS" node) and a set of sub-nodes as follows: the "LeftBracelet" node, which includes two sub-nodes, namely, the "LW-FOD" and the "LW-LOD". The "RightBracelet" node, which includes two sub-nodes, namely, the "RW-FOD" and the "RW-ROD". The shortcut "LW" refers to "Left Wrist", the "RW" refers to "Right Wrist", the "FOD" refers to "Forward Obstacle Detector", and the "LOD" refers to "Left Obstacle Detector". The above database is connected with the NodeMCU ESP8266 module, which is responsible for sending data to the Firebase database. The NodeMCU is an open source platform, which is based on the ESP8266. The NodeMCU connects objects using the Wi-Fi protocol. The NodeMCU is used as a microcontroller, which provides features such as the GPIO and PWM pins. In fact, it contains 13 GPIO pins and 10 PWM channels. Besides, it can be programmed with the Arduino IDE and acts as an access point [38]. The NodeMCU is connected with a nine volt-battery using a battery connector and the HW-131 power supply module. The HW-131 is connected to the NodeMCU using a USB cable. Besides, the NodeMCU is connected to the left and right bracelets using the jumper wires. In the proposed system, the right bracelet reads data from two ultrasonic sensors, one of these sensors is affixed to the front of the bracelet and the other sensor is affixed to the right-hand side of the bracelet. Similarly, the left bracelet reads data from two ultrasonic sensors, one of them is affixed to the front of the bracelet and the other is affixed to the left-hand side of the bracelet. Data collected by the left and right bracelets are stored in the Firebase database.

Fig. 4 describes the left and right bracelets before packaging and Fig. 5 describes them after packaging.

TABLE III
THE NOTATIONS USED FOR DESCRIBING THE PROPOSED IOT BRACELETS

The shortcut	The meaning
SD	The step distance (in this paper, SD =30 cm)
USH	The value of the ultrasonic sensor. When the ultrasonic sensor touches the ground or is directed to open space the value read by this sensor is greater than 2000.
US_{TH}	The ultrasonic sensor threshold = 30 cm.
RW-ROD	The Right Wrist- Right Obstacles Detector
RW-FOD	The Right Wrist- Forward Obstacles Detector
LW-LOD	The Left Wrist- Left Obstacles Detector
LW-FOD	The Left Wrist- Forward Obstacles Detector.
O	An obstacle.
D_L	How many SD steps a blind person should move toward the optimal position.
X	The distance between an obstacle O and the RW-ROD.
Y	The distance between an obstacle O and the LW-LOD
C	The central position between two obstacles, O1 and O2
F_R	The distance between an obstacle O and the RW-FOD.
F_L	The distance between an obstacle O and the LW-FOD

Fig. 3. The Firebase database structure of the proposed IoT system.

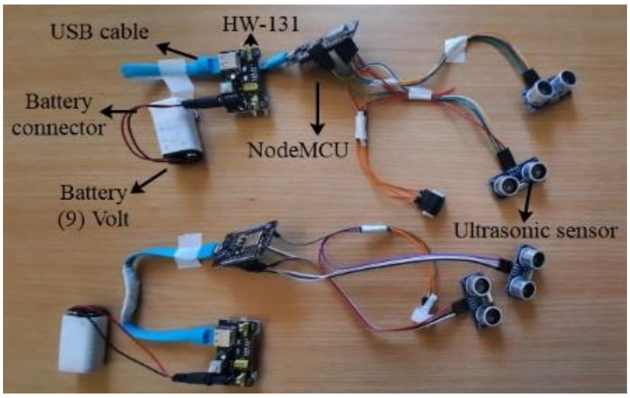

Fig. 4. The left and right bracelets before packaging.

In Fig. 5, the ultrasonic sensors are connected to various NodeMCU boards as follows: the RW-ROD and RW-FOD are connected to the right NodeMCU board, and the LW-LOD and LW-FOD are connected to the left NodeMCU board. The RW-ROD is connected to the right NodeMCU as follows: the “Trig” pin is connected to pin D5 on the NodeMCU board, the “Echo” pin is connected to D6 pin, the “GND” is connected to “G” pin, and the “VCC” is connected to VU pin on the NodeMCU board. The RW-FOD is connected in a similar way, except that the “Trig” pin is connected to pin D0, and the “Echo” pin is connected to pin D1 on the NodeMCU board. The LW-LOD and LW-FOD are also connected to the left NodeMCU board in a similar way, except that the “Trig” and “Echo” pins of the LW-LOD are connected to the pins D7 and D8, respectively, and the pins “Trig” and “Echo” of the LW-FOD are connected to the pins D2 and D3, respectively.

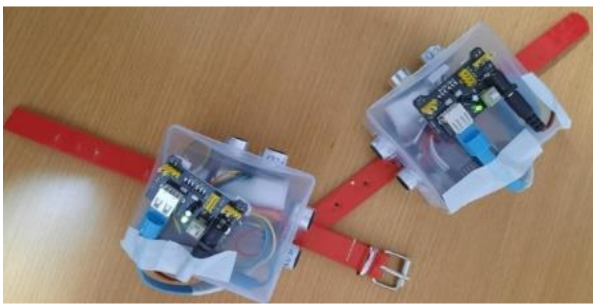

Fig. 5. The left and right bracelets after packaging.

To store the collected data in the Firebase database, we develop NodeMCU code that is able to connect to the Firebase database. Four things are needed to establish a connection with the Firebase database, namely, a URL to the host on which the database is located (usually, a URL ends with “firebaseio.com”), the firebase authentication code, the router name (i.e., the access point name), and the router password. Besides, we include the following libraries in the code: the #include <ESP8266WiFi.h> and #include <FirebaseArduino.h>. On top of that, we create an Android application (using Android Studio Arctic Fox 2020.3.1 Patch 1) that can connect to the Firebase database and read the information (gathered by the left and right bracelets) from the Firebase database. Each sub-node in the database receives its value online from a particular sensor, as shown in Fig. 6.

Fig. 6. Filling the data gathered by various sensors into the Firebase database.

For example, in Fig. 6, the sub-node “LW-FOD” gets the value 37 cm from the forward ultrasonic sensor that is affixe to the front of the left bracelet. The sub-node “LW-LOD” gets the value 20 cm from the ultrasonic sensor that is affixed to the left-hand side of the left bracelet. To retrieve data from the Firebase database instantaneously, we develop an Android application that is able to connect with the Firebase database and retrieve the data collected by the left and right bracelets. Fig. 7 describes our real-time system where the data read from the Firebase database are displayed on the user’s mobile instantaneously. The mobile phone of a blind person uses the data listed in Fig. 7 to produce audio messages that a blind person can hear. Besides, the proposed system is used for detecting falls. The blind individual is subject to many risks while moving around including falls. We utilize an ultrasonic merit for detecting falls as follows: when an ultrasonic sensor touches the ground, it records a value ≥ 2000. Thus, when a blind person falls and the ultrasonic sensors (the RW-ROD and the LW-LOD sensors) touch the ground, then the values recorded on the Firebase database are greater than or equal to 2000, which is an indicator that a blind person is fell down.

Fig. 7. The proposed IoT system is a real-time system – The same data are shown on the Firebase database’s monitor and the Android’s monitor simultaneously.

C. Calculating the Optimal Position

In this section, we describe how the proposed system calculates the optimal position to which a blind person is directed. Fig. 8, describes a study case where there are various obstacles, O, along the blind person's path. In Fig. *8,* a blind person wears the proposed bracelets, and there are three obstacles along his path, namely, O1, O2 and O3. The variables X, Y, and Z represent the distances between O1, O2, and O3 and a blind person respectively.

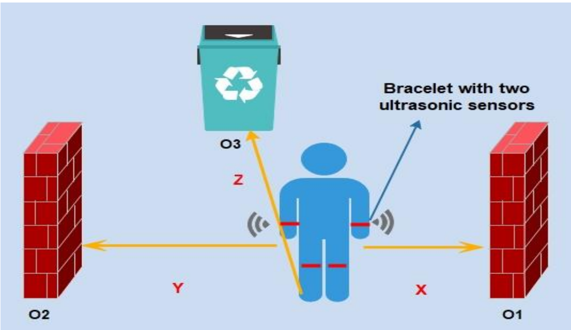

Fig. 8. A scenario for the existence of obstacles in various locations.

In the proposed system, in order to facilitate a blind person's movements and allow him to precisely estimate the distance required to be moved; we propose the Step Distance (SD) measuement. Using the SD measurement, as described in Fig. 9, is more accurate than using time measurement (e.g., "After three minutes move to the left"). The SD distance vary from one person to another. However, in this paper, we measured SD of the person who tested our proposed system and we found that the SD was 30 cm. In this context, our work is more accurate than the work proposed in [34]. This is because a blind person uses the SD measurment daily in his life, and she or he is more familiar with the SD measurement than time measurement.

Thus, instead of saying: "After two minutes go to the right" [34], we say, for example, "After two SDs go to the right" or "Go to the right two SDs", and so on. In [34], if a blind person could not determine the time exactly (i.e., there was a wrong estimation), then he might struggle with some obstacles. In this paper, the general format of the command we send to a blind person is "Go to D D_L SD". Where, D is the direction (e.g., left,

Fig. 9. The Step Distance (SD) of the tester equals 30 cm

right, forward and backward) and D_L is the distance (measured in SD). Here, we have to determine the D and D_L values based on the locations of various O along the path. This is done in order to guide a blind person to the optimal position. The D_L is calculated as follows: suppose that a blind person wears the bracelets on both wrists, in this case, we have four ultrasonic sensors affixed to the bracelets, namely, the RW-ROD, the RW-FOD, the LW-LOD and the LW-FOD. Now, suppose that there are three obstacles, namely, O1, O2, and O3 (as described in Fig. 8), where O1 is located at the right-hand side of the blind, O2 is located at the left-hand side of the blind. Besides, suppose that the distance between the right wrist and O1 is RW-ROD (X in Fig 8). Also, suppose that the distance between the left-wrist and O2 is LW-LOD (Y in Fig. 8). Then, our strategy is to keep a blind person in the middle of the distance between O1 and O2 (i.e. the center point of O1 and O2). We formulate the center point (C) as described in Eq. 1.

$$C = \frac{RW-ROD+LW-LOD}{2} \tag{1}$$

Now, in order to calculate D_L (also we call it "the optimal position"), we find the minimum value of the RW-ROD and LW-LOD (i.e. min (RW-ROD, LW-LOD), then we subtract this value from the center point, C, and then the result is divided by SD. Thus,

$$D_L = (int)\ (\frac{Abs(C-Min(RW-ROD,LW-LOD))}{SD}) \tag{2}$$

where, the (int) rounds any value to an integer value, and the Abs() function returns the absolute value. Now, in order to determine the direction (i.e. left, right, etc.), we find the maximum value of RW-ROD, and LW-LOD, and if RW-ROD is greater than LW-LOD, then a blind person is asked to move to the right. Otherwise, he is asked to move to the left. Now, let us demonstrate the following scenarios:

The first scenario: suppose that a blind person is moving along a narrow path where the distance between the left bracelet and O1 is one SD and the distance between the right bracelet and O2 is one SD. In this case, the optimal position, D_L, is reached after zero SD as described below:

$$C = \frac{(30+30)}{2} = 30$$

Thus,

$$D_L = (int)(\frac{|\,30-30|}{30} = 0\ SD$$

This signifies that a blind person should continue going forward without turning left or right. Thus, the audio message sent to his mobile phone is "Move forward." However, before sending this message, our Android application, checks if the value of the "LW-FOD" and "RW-FOD" are greater than one SD in order to avoid potential hazards that may be in front of the blind person. The second scenario: suppose that the NodeMCU board receives the following data from the left and right bracelets: LW-FOD = 37 cm, LW-LOD = 100 cm, RW-FOD = 48 cm and RW-ROD = 20 cm, our mobile application reads these data from the Firebase database, and it determines the direction (D) and calculates the D_L value as well, as follows

$$C = \frac{(100+20)}{2} = 60$$

Thus,

$$D_L = (int)(\frac{|60 - 20|}{30} \approx 1\, SD$$

The D_L value in the above calculations is (40 / 30) = 1.3. Since the fraction 0.3 is less than 0.5, it is ignored; thus, the function (int) returns "1". Now, in order to determine the D value, we find the maximum value of the LW-LOD and RW-ROD. In our scenario, the D value is a message saying, "Move to the left."

```
var db= FirebaseDatabase.getInstance().reference
var rightplayer = MediaPlayer.create( context: this,R.raw.right)
var forwardplayer = MediaPlayer.create( context: this,R.raw.forward)
var backplayer = MediaPlayer.create( context: this,R.raw.backward)
var leftplayer = MediaPlayer.create( context: this,R.raw.left)
override fun onDataChange(snapshot: DataSnapshot) {
    val srrod = snapshot.child( path: "RightBracelet").child( path: "RW-ROD").value.toString()
    val srfod = snapshot.child( path: "RightBracelet").child( path: "RW-FOD").value.toString()
    val sllod = snapshot.child( path: "LeftBracelet").child( path: "LW-LOD").value.toString()
    val slfod = snapshot.child( path: "LeftBracelet").child( path: "LW-FOD").value.toString()
```

Fig. 10. Code segment of the Android application

This is because the LW-LOD is greater than the RW-ROD. Now, if the two previous audio messages are combined, the final message becomes "Move to the left one SD". This audio message is sent to the user's mobile phone. Fig. 10, is an Android sketch that shows the statements used for creating an instance of the Firebase database. It also describes four audio files namely, the "rightplayer" (it informs the blind person to move right), the "forwardplayer" (it informs the blind person to move forward), the "backplayer" (it informs the blind person to move backward), and the "leftplayer" (it informs the blind person to move left). Furthermore, the code describes how we monitor any changes in the values RW-ROD, RW-FOD, LW-LOD, and LW-FOD. To do so, we construct a listener on the root node level (i.e. the BNS node). The event listener monitors any changes in the values of RW-ROD, RW-FOD, LW-LOD, and LW-FOD. Thus, if any value of the above values is changed, then the calculations for D and D_L are re-executed.

The Figures 11 and 12 show various scenarios for guiding a blind person using our Android application. In Fig. 11, a blind person receives an audio message through the headphones of his mobile phone. The audio message asks a blind person to move one-step (one SD) to the left based on the sensors values retrieved from the Firebase database. This decision (i.e. moving to the left one-step) is taken based on the calculations of D and D_L values as described in Eq. 2. Note that RW-ROD = 28, and LW-LOD = 86, and thus, a blind person should move to the left since the LW-LOD is greater than the RW-ROD. In Fig. 12 the values of the forward sensors RW-FOD and LW-FOD are less than 30 cm. In this case, the proposed system recognizes that there are obstacles in front of a blind person; therefore, it asks him to move backward. Fig.12 describes the Firebase database when the audio message "Go backward one SD" is sent to a blind person. In Fig. 13, the blind person is asked to move forward. An audio message is sent to his mobile phone's headphone. Note that in Fig 13, the sensors values are all greater than 30 cm and thus, it is safe to move forward since there are no obstacles in any direction within the range of 30 cm.

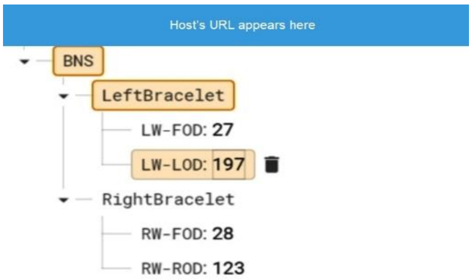

Fig. 11. The audio message "Go left one step."

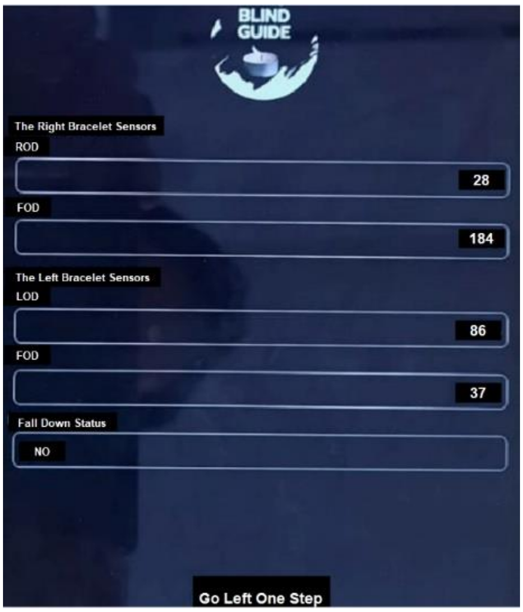

Fig. 12. The Firebase database state when a blind person receives the audio message "Go backward one SD."

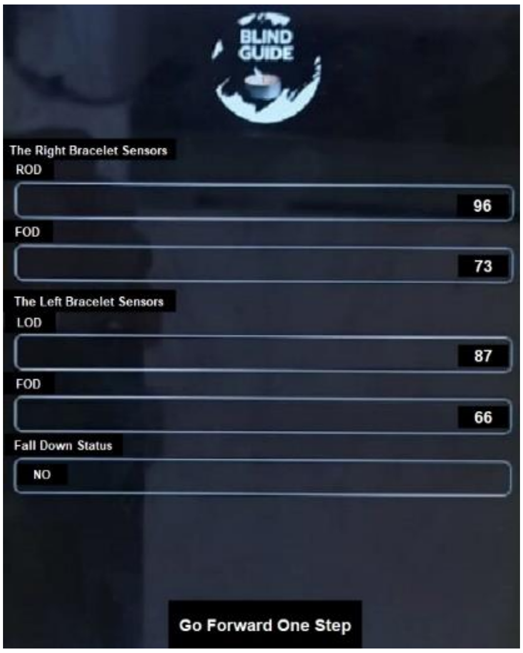

Fig. 13. The audio message "Go forward one step".

IV. The Evaluation of the Proposed System

In this section, we evaluate and test the proposed system in an indoor environment where obstacles are located at various positions. We test various scenarios as described in the Figures 14, 15, 16, and 17.

Fig. 14. Testing the Navigation System (NS) – chair obstacle.

Fig. 15. Testing the Navigation System (NS) – door obstacle

Fig. 16. Testing the Navigation System (NS) – lamp obstacle.

Fig. 17. Testing the Navigation System (NS) – tree obstacle.

In Fig. 14, the blind person receives an audio message asking him to move to the left one-step (one SD) since a chair is located on his right-hand side. In Fig. 15, the blind person is asked to move backward one-step (SD) since a door is located in front of him. In Fig. 16, the blind person is asked to move backward since a lamb is located in front of him. In Fig. 17, the blind person is asked to move to the left one-step since there is a tree located on his right-hand side. Table IV describes various scenarios for testing our proposed system in an indoor environment where the tester wears the bracelets and faces various obstacles.

TABLE IV
TESTING THE NAVIGATION SYSTEM FOR VARIOUS OBSTACLES

Obstacle Name	Ref. Fig.	RW-ROD	RW-FOD	LW-LOD	LW-FOD	Decision
Tree (to the right)	16	29	240	260	240	Move to the left 4 SD.
Door (in front)	14	250	270	70	28	Move backward one SD, then move 3 SD to the right
Chair (in front)	13	350	27	245	220	Move backward one SD, then move 2 SD to the right
A Lamp and a wall (in front)	15	197	29	180	40	Move backward one SD, then move one SD to the right.

We calculate the Delay Time (D_T) for both: the Delay of Calculations (D_C) and the Delay of message Receipt (D_R) in milliseconds as described in Eq. 3.

$$D_T = D_C + D_R \tag{3}$$

In our experiments we find that D_C = 0.0174 milliseconds and the average D_R = 0.24567 milliseconds. Thus, D_T = 0.26307 milliseconds. Besides, we calculate the average delay time of writing data to a firebase database, which is equal to 683.2 milliseconds as described in Table I. The D_T in [34] equals 15 seconds. However, the D_T of our proposed system equals ≈ 0.3 second. Thus, our system performs better than the work in [34] in terms of delay time. Besides, the LW-LOD and the RW-ROD values can be used for detecting falls. If a blind person struggles with an obstacle, then a fall may occur. In this context, we propose to use the ultrasonic sensor for detecting falls. When the ultrasonic sensor touches the ground surface, or directed to the open space, then the value of an ultrasonic sensor is greater than 2000. We use this merit for detecting falls. When a blind person falls, his or her hand may touch the ground, and thus the ultrasonic sensor touches the ground recording a value greater than 2000. Fig. 18 describes this situation.

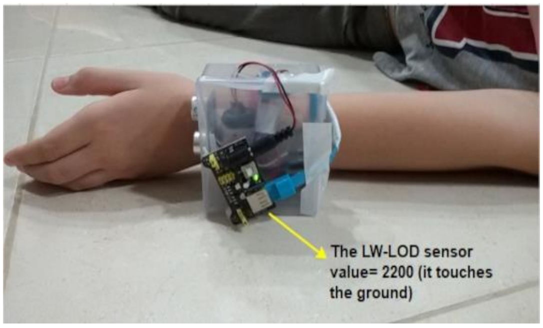

Fig. 18. Fall detection using the left bracelet

V. CONCLUDING REMARKS

In this paper, IoT bracelets are proposed for directing a blind person's steps and detecting falls. The proposed navigation system is based on a set of ultrasonic sensors, the NodeMCU board, the Firebase database, and a mobile application. Compared with the state-of-the-art, the proposed system is cheaper, simpler, and more accurate than the other systems since it directs a blind person to the optimal position. Furthermore, the proposed system required less delay time than other work. In addition, unlike the previous work, the proposed system is able to detect falls using the left and right bracelets. The proposed system is tested and evaluated in an indoor environment using the NodeMCU module that uses the Wi-Fi protocol and a real-time database called the Firebase database where various obstacles are located in various locations. The proposed navigation system is designed to keep a blind person safe while traveling by directing him to the optimal position between various obstacles (e.g. O1 and O2). In future, we propose to develop the proposed system to be able to work in an outdoor environment using the Global System for Mobile Communications (GSM) enhanced with security[39][40]. In addition, various algorithms can be employed for recognizing various objects [41][42]. Besides, the proposed IoT system can be enhanced to provide the ability to use the vibration sensor's value as an indicator for sending messages or warnings to the blind person. In this case, if an obstacle is discovered, the bracelets that a blind person is wearing (either the left or the right bracelet) vibrate, telling him to go in a specific direction.

ACKNOWLEDGEMENTS

The author would like to thank Al-Zaytoonah University of Jordan for their financial support and encouragement.

REFERENCES

[1] BrailleWorks Famous People with Visual Impairments. [Online]. Available at: https://brailleworks.com/braille-resources/famous-people-with-visual-impairments/. [[Accessed on 19-12-2020].

[2] K. Bineeth, S. Raju, and E.S. Frode *Tools and Technologies for Blind and Visually Impaired Navigation Support: A Review, IETE Technical Review,* Vol. 0, no. 0, 1-16, 2020. doi: 10.1080/02564602.2020.1819893.

[3] A. G. Nicholas, and G. E. Legge *Blind navigation and the role of technology*. "The Engineering Handbook of Smart Technology for Aging, Disability, and Independence". Chap.25, 479–500. 2008. doi: 10.1002/9780470379424.ch25

[4] S. Bhole, and A. Dhok A. *Deep Learning based Object Detection and Recognition Framework for the Visually-Impaired*. In Proc. 2020 Fourth International Conference on Computing Methodologies and Communication (ICCMC), Erode, India, April 2020, 725-728. doi: 10.1109/ICCMC48092.2020.ICCMC-000135

[5] Md. Adil, T. Rafa, J. Ferdoush, A. Mahmud and A. Pathak *An IoT based Voice Controlled Blind Stick to Guide Blind People*. International journal of engineering inventions. Vol. 9, no. 1, 9-14. 2020.

[6] A. Jayakody, C.I. Meegama, H.U. Pinnawalage, R.M.H.N Muwenwella, and S.C. Dalpathado *AVII [Assist Vision Impaired Individual]: An Intelligent Indoor Navigation System for the Vision Impaired Individuals with VLC*. In Proc. 2016 IEEE International Conference on Information and Automation for Sustainability (ICIAfS), Galle, 2016, June, 1-6. doi: 10.1109/ICIAFS.2016.7946526

[7] X. Liu, and O. Baiocchi *A comparison of the definitions for smart sensors, smart objects and Things in IoT*. In Proc. 2016 IEEE 7th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), Nov. 2016, 1–4. doi: 10.1109/IEMCON.2016.7746311

[8] S. Madakam, R. Ramaswamy, S. Tripathi *Internet of Things (IoT): A literature review*. J. Computer and Communication, Vol. 3, no. 3, 164-173, 2015. doi:10.4236/jcc.2015.35021

[9] S. Chen, H. Xu, D. Liu, B. Hu and H. Wang *A vision of IoT: applications, challenges, and opportunities with china perspective*. IEEE Internet of Things Journal, Vol. 1, no. 4, 349-359. 2014. doi: 10.1109/JIOT.2014.2337336

[10] A. Alnafessah, M. Al-Ammar, S. Al-Hadhrami, A. Al-Salman, and Al-H. Khalifa *Developing an Ultra Wideband Indoor Navigation System for Visually Impaired People*. International Journal of Distributed Sensor Networks, Vol. 12, no. 7, 1-15, 2016. doi:10.1177/155014776152342.

[11] L. Deverell, S. Bentley, L. Ayton, C. Delany and J. Keeffe *Effective mobility framework: A tool for designing comprehensive O&M outcomes research.* International Journal of Orientation & Mobility, Vol. 7, no. 1, 74–86. 2017. doi:10.21307/ijom-2017-059.

[12] O.O Olakanmi *A Multidimensional Walking Aid for Visually Impaired Using Ultrasonic Sensors Network with Voice Guidance.* I.J. Intelligent Systems and Applications, Vol. 6, no. 8, 53-59, 2014. doi:10.5815/ijisa.2014.08.06.

[13] l. Chen, J. Su, M. Chen, W. Chang, C. Yang and C. Sie *An Implementation of an Intelligent Assistance System for Visually Impaired/Blind People*. In Proc. 2019 IEEE International Conference on Consumer Electronics (ICCE), Las Vegas, NV, USA, March, 1-2, 2019. doi: 10.1109/ICCE.2019.8661943.

[14] B. Jiang, J. Yang, Z. Lv and H. Song *Wearable Vision Assistance System Based on Binocular Sensors for Visually Impaired Users.* In IEEE Internet of Things Journal, Vol. 6, no. 2, 1375-1383, 2019. doi: 10.1109/JIOT.2018.2842229.

[15] "Wayfindr LA Metro Trial Report" [Online] available at: http://www.wayfindr.net/wp-content/uploads/2020/01/ Wayfindr-LA-Metro-Trial-Report.pdf, Accessed on 20-05-2021, 2019.

[16] M. Dimpal, P. Meshram, S. Bhelkar, S. Padhye, S. Kotangale and R. Deshmukh *Blind's Mate - A Navigation System for Blind People*. International Journal of Scientific Research in Science and Technology. Vol 6, no. 2, 230-235, 2019. doi:10.32628/IJSRST196244.

[17] M. Nakajima and S. Haruyama *New indoor navigation system for visually impaired people using visible light communication*. J Wireless Com Network. Vol. 37, 1-10, 2013. doi:10.1186/1687-1499-2013-37

[18] K. Niveditha, PD. Kavya, P. Nivedha *Virtual Eye for Blind using IOT.* International Journal of Engineering Research & Technology (IJERT). Vol. 8, no. 11, 116-121, 2020. doi: 10.17577/IJERTCONV8IS11027

[19] M.P. Agrawal and A.R. Gupta *Smart Stick for the Blind and Visually Impaired People.* In Proc. 2018 Second International Conference on Inventive Communication and Computational Technologies (ICICCT), Coimbatore, Sep. 2018, 542-545. doi: 10.1109/ICICCT.2018.8473344.

[20] M.M. Billah, Z.M. Yusof, K. Kadir, A.M.M Ali, H. Nasir and A. Sunni, *Experimental investigation of a novel walking stick in avoidance drop-off for visually impaired people.* Cogent Engineering. Vol. 6, no.1, 1-22, 2019. https://doi.org/10.1080/23311916.2019.1692468.

[21] A.B.C Chai, B.T. Lau, Z. Pan, A.W. Chai, L. Deverell, A.A. Mahmud, C. McCarthy and D. Meyer *Comprehensive Literature Reviews on Ground Plane Checking for the Visually Impaired*. Chapter 4. In: Paiva S. (eds) Technological Trends in Improved Mobility of the Visually Impaired. EAI/Springer Innovations in Communication and Computing. Springer, Cham. 85-103, 2020. doi:10.1007/978-3-030-16450-8_4

[22] N. Sahoo, H.W. Lin and Y.H. Chang *Design and Implementation of a Walking Stick Aid for Visually Challenged People*. Sensors (Basel, Switzerland), Vol. 19, no. 1, 1-17, 2019. doi: 10.3390/s19010130

[23] M. Zhou, W. Li, and B. Zhou *An IoT System Design for Blind.* In Proc. of the 14th Web Information Systems and Applications Conference (WISA), Liuzhou, April 90-92, 2017. doi: 10.1109/WISA.2017.72
[24] V. Bhatnagar, R. Chandra and V. Jain *IoT Based Alert System for Visually Impaired Persons. Communications in Computer and Information Science*. Springer Nature Singapore Pte Ltd. A. K. Somani et al. (Eds.): ICETCE, 2019, CCIS 985, 216–223. 2019. doi:10.1007/978-981-13-8300-7_18
[25] A. Nada, S. Mashali, M.A. Fakhr and A.F. Seddik *Effective Fast Response Smart Stick for Blind People*. In Proc. of the Second Intl. Conf. on Advances in Bio-Informatics and Environmental Engineering - ICABEE 2015, USA, 5-11, 2015. doi: 10.15224/978-1-63248-043-9-29.
[26] N. Loganathan, K. Lakshmi, N. Chandrasekaran, S.R. Cibisakaravarthi, R.H. Priyanga and K.H. Varthini *Smart Stick for Blind People*. In Proc. 6th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 65-67, 2020. doi: 10.1109/ICACCS48705.2020.9074374.
[27] N.S. Khan, A.A. Gaud, H.R. Khanvilkar and R.N. Shelar *Design and modification of smart stick for visually impaired with stick finder*. International Journal of Advance Research, Ideas and Innovations in Technology, Vol. 6, no. 2. 326-328, 2020.
[28] H. Sharma, M. Tripathi, A. Kumarnd and M.S. Gaur *Embedded Assistive Stick for Visually Impaired Persons*, In Proc. 2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Bangalore, Oct. 2018, 1-6. doi: 10.1109/ICCCNT.2018.8493707.
[29] W.J. Chang, L.B. Chen, M.C. Chen, J.P. Su, C.Y. Sie and C.H. Yang *Design and Implementation of an Intelligent Assistive System for Visually Impaired People for Aerial Obstacle Avoidance and Fall Detection*. IEEE Sensors Journal, Vol. 20, no. 17, 10199-10210, 2020. doi: 10.1109/JSEN.2020.2990609.
[30] M. Ramamurthy, V. Naveen, K. Mithun, R. Nivas *IOT Based Assistive Technologies for Visually Impaired Persons*. International Journal of Pure and Applied Mathematics.Vol 119, no. 12, 647-652, 2018.
[31] A. Ashraf, S. Noor, M. Arslan Farooq, A. Ali, A. Hasham *Iot Empowered Smart Stick Assistance for Visually Impaired People.* International Journal of Scientific and Technology Research. Vol. 9, no. 10, 356-360, 2020.
[32] P.S. Ranaweera, S.H.R. Madhuranga, H. F. A. S. Fonseka and D. M. L. D. Karunathilaka *Electronic travel aid system for visually impaired people.* In Proc. of the 5th International Conference on Information and Communication Technology (ICoIC7), Melaka, Malaysia, Oct. 2017, 1-6. doi: 10.1109/ICoICT.2017.8074700.
[33] S. Tayyaba, M.W. Ashraf, T. Alquthami, Z. Ahmad, S. Manzoor *Fuzzy-Based Approach Using IoT Devices for Smart Home to Assist Blind People for Navigation*. Sensors. Vol. 20, no. 13, 1-12, 2020. doi: 10.3390/s20133674.
[34] L.T. Choong, M.K.V. Vardhana *Smart Assisting Visually Impaired Stick (SAVIS).* International Journal of Engineering Research & Technology (IJERT). Vol. 8, no, 12, 78-84, 2019. doi:10.17577/IJERTV8IS120045.
[35] H. Jabnoun, M.A. Hashish, F. Benzarti *Mobile Assistive Application for Blind People in Indoor Navigation.* In: Jmaiel M., Mokhtari M., Abdulrazak B., Aloulou H., Kallel S. (eds) The Impact of Digital Technologies on Public Health in Developed and Developing Countries. ICOST 2020. Lecture Notes in Computer Science. Vol. 12157. Springer, Cham. 395–403, 2020. https://doi.org/10.1007/978-3-030-51517-1_36.
[36] Y. Zhao, E. Kupferstein, B.V. Castro, S. Feiner and S. Azenkot *Designing AR Visualizations to Facilitate Stair Navigation for People with Low Vision.* In Proc. of the 32nd Annual ACM Symposium on User Interface Software and Technology (UIST '19). Association for Computing Machinery, New York, NY, USA,20-23,Oct. 2019, 387–402. 2019. https://doi.org/10.1145/3332165.3347906
[37] N. Smyth "Firebase Essentials Android" 1st edition. eBookFrenzy. https://www.ebookfrenzy.com/pdf_previews/FirebaseEssentialsAndroidPreview.pdf. [Accessed on 12-09-2021].
[38] S. Hosseini "Getting Started w/ NodeMCU ESP8266 on Arduino IDE". [online] https://electropeak.com/learn/nodemcu-esp8266-on-arduino-ide/. [Accessed on 09-09-2021].
[39] Z. Mohammad, A. Abusukhon and T. A. Qattam, *A Survey of Authenticated Key Agreement Protocols for Securing IoT*, 2019 IEEE Jordan International Joint Conference on Electrical Engineering and Information Technology (JEEIT), Amman, Jordan, 2019, pp. 425-430, doi: 10.1109/JEEIT.2019.8717529.
[40] A. Abusukhon, Z. Mohammad and A. Al-Thaher *An authenticated, secure, and mutable multiple-session-keys protocol based on elliptic curve cryptography and text-to-image encryption algorithm*. Concurrency and Computation: Practice and Experience. Vol 34, issue no 4,pp. e6649, 2022. https://doi.org/10.1002/cpe.6649
[41] M. Rifaee, M. Al Rawajbeh, B. AlOkosh, F. Abdel-Fattah *A new approach to recognize human face under unconstrained environment*, International Journal of Advances in Soft Computing and its Application, 14, 2(2022), 1-13. doi: 10.15849/IJASCA.220720.01
[42] Z. Oufqir, L. Binan, A. EL ABDERRAHMANI and K. Satori *Deep Learning for the Improvement of Object Detection in Augmented Reality*, International Journal of Advances in Soft Computing and its Application, 13, 3(2021), 129-143. doi: 10.15849/IJASCA.211128.10

Ahmad Abusukhon is an Associate Prof. in Computer Science. He was awarded a Ph.D. degree in Computer Science from the University of Sunderland in the United Kingdom (UK) in 2009. He worked for Al-Zaytoonah University of Jordan from 2009 until now. During this period, he supervised many undergraduate and graduate students (Master's degree) in the fields of cryptography and the Internet of Things (IoT). He published dozens of papers in international journals and conferences and published many books in the field of computer science. His research interests include the IoT, cryptography, distributed systems, and network security. Dr. Abusukhon has been granted the fund for various projects in the field of power conservation using IoT. He has been on the organizing committees of many IEEE conferences, acting as special session chair. Furthermore, he is acting as a local managing editor for the International Journal of Advances in Soft Computing and its Applications in 2019.