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Wearable Navigation Assistance System for the Blind and Visually Impaired

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***Abstract*— The blind people cannot get information of their surrounding environment for example they cannot see any obstacles and hazards in their path. They have no information of objects in their surroundings and direction which is essential for travelling. According to World Health Organization (WHO) report there are 285 million visually impaired people among which 39 million are totally blind. The estimated number of blind people in Pakistan is 1.14 million. Blind people mostly use a white cane or a guide dog for their assistance. However, these techniques are limited as they do not guarantee risk avoidance for the blind people. Many researchers are working on assistance of blind people and have developed several devices including infrared cane, ultrasonic sensors, voice assisted navigation cane and laser-based walker assistance to name a few. Nevertheless, all these schemes are marred by limitations and as such are not utilised in real life. An assistance system was developed in this research work which is based on ultrasonic sensors for obstacle detection. The ultrasonic sensors along with a vibration device and a buzzer are placed on multiple places in a wearable jacket. Sensors scan the environment of user and inform them through vibration and buzzer sound when the sensor detects any obstacle.**

Keywords*— *Blind, Visually Impaired, Navigation Assistance, Infrared Cane, Ultrasonic Sensor, Wearable Technology.

I. Introduction

According to World Health Organization (WHO) report there are 285 million visually impaired people around the world, out of which 39 million are blind [1]. According to WHO the number of blind people will increase and will double by 2020. The estimated number of blind people in Pakistan are 1.14 million [2]. It is difficult to move or walk for blind people as they have no information about their environment.

They usually use a white cane or a guide dog for their assistance. However, these methods are limited because they do not guarantee saving blind people from risks. Previously developed assistance systems for blind people include infrared cane-based assistance, ultrasonic cane-based assistance, voice assisted navigation cane, laser-based walker assistance [3-6]. There are some advantages of these systems but they also possess some limitations. For example, in infrared cane-based assistance infrared has short range for detecting obstacle, produces unfavourable results in the dark. In ultrasonic cane-based assistance, ultrasonic sensors are used to detect obstacles and it gives information to vibration devices which is fixed on top of the cane and vibrates when obstacle is detected. As the cane can only scan a limited area as compared to a human being, it is limited in its functionality.

In laser-based walker assistance they use two lasers to scan the environment to detect any obstacles. One laser is fixed and the other is rotated by a servo motor. There is one belt of five vibrator motors which give feedback to users when an obstacle is detected. In this assistance system, the lasers are used which may harm other people if it strikes them in their eyes or skin.

An assistance system is proposed in this research work which is aimed in assisting blind people, which will be based on ultrasonic sensors. The ultrasonic sensors are highly beneficial as presented in the works of Adarsh et al. in [7] and Burnett in [8]. These sensors can be placed on a jacket. Ultrasonic sensors with vibrator and buzzer are placed on multiple body parts like on both hands, on both legs and on head at front, vibrator will also be attached with each sensor. The sensors scan environment of user. When ultrasonic sensor detects any obstacle in range of 50cm, it informs the user through vibration and buzzer depending upon which sensor detects the obstacle aiding the user in changing their direction.

II. Literature Review

It is difficult, nearly impossible, for blind people to walk without an aid . Even with an aid such as a white cane or a guide dog can be sometimes inconvenient, uncomfortable, and perhaps inaccurate in avoiding obstacles.

Priya et al. in [9] developed a smart glasses-based assistance system for blind people. It utilises object and face recognition for navigation. This system helps the user in recognition of objects and people in front of them. This system is limited to the recognition of those people or objects which are already stored in the system database.

Praveen et al. proposed a navigation assistance system for blind people based on image processing. The front environment is captured by a camera, followed by image resizing and conversion to grayscale [10]. The obstacle is detected by utilising canny edge detection and morphological operations [11]. The height of the obstacle is found through Vanishing Point Estimation (VPE) technique. Saffoury et al. in [12] designed assistance system for blind people based on laser pointer and android smart phone. The obstacle in front of the user is detected through laser light triangulation and image processing.

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GPS based navigation systems have also been developed including the works of Wang et al. in [13] and Balachandran et al. in [14]. In their system, they used Differential Global Positioning Systems (DGPS) module. DGPS system is used to provide positional corrections to GPS (Global Positioning System) signals and improve location accuracy.

Krishnan et al. in [15] designed a smart walking stick for visually impaired people which detect and identify obstacles through ultrasonic sensor, image processing and smart phone app for GPS and maps which is used to provide assistance. Ding et al. in [16] proposed a system which is based on Radio Frequency Identification (RFID), mobile communication and warless technologies. This system consists of RFID tags, an RFID reader which is integrated into the cane and the mobile phone. By this system, the user can know their location or locate their building.

All these literature reviews include topics of an Infrared base cane assistive system, Ultrasonic cane for blind people, Smart walker for blind people based on laser sensors, Voice assisted navigation cane are discussed below.

A. Infrared Base Cane Assistive System

Several infrared base blind assistive systems are developed in which the obstacles are detected through infrared sensors. Nada et al. in [3] developed a smart stick assistive system in which two infrared sensors are installed on a stick. These sensors detect the obstacles and send the signal to the microcontroller. The microcontroller generates an audio message. In infrared cane-based assistance infrared sensor have a short range for detecting the obstacles, have bad results at dark environment.

B. Infrared Base Head Hat and Mini Hand Stick Assistive System

Al-Fahoum et al. in [4] developed an assistive system, in which infrared sensors are installed on a head hat and on small hand stick. These sensors act as a radar. When the obstacle is detected, send the signal to a PIC microcontroller. PIC microcontroller informs the user through a buzzer and a vibrator motor about obstacles.

C. Ultrasonic Based Smart Cane

The Smart Cane by Wahab et al. in [5] and Agarwal et al. in [17] is designed to help blind people navigate safely and quickly among obstacles and other hazards using ultrasonic sensors shown in Figure 1. As a cane can only scan a limited area as compared to human body area. So, this is not helpful for blind people.

Fig. 1. Figure 1 Ultrasonic Based Smart Cane by Wahab et al. in [5] and Agarwal et al. in [17].

D. Laser Based Smart Walker

Wachaja et al. in [6] presented a smart walker for blind people with walking disabilities shown in Figure 2. In laser-based walker assistance, they use two lasers to scan the environment to detect any obstacles, one laser is fixed and the other is moving through servo motor, there is one belt of five vibrator motors which give feedback to users when the obstacle is detected. In this assistance system, the lasers are used which is harmful to others eyes and skin as laser damage eyes and skin.

Fig. 2. Figure 2 Smart Walker Wachaja et al. in [6].

III. Methodology

The methodology is expected to be achieved through the following steps as shown in Figure 3. Literature Review is explained in above section 2.

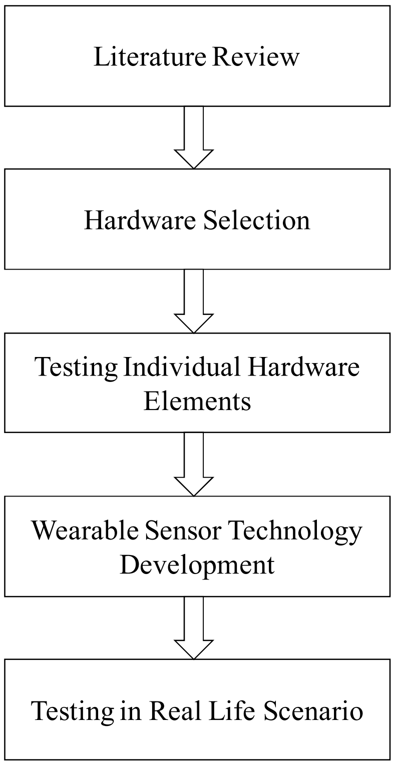


Figure 3 Methodology of the proposed research work.

IV. Hardware Selection

A. Sensor Selection

As this all project is based on detection so its first part of the design to find a correct sensor that fulfils our requirement and can easily available in the market. For this, our efforts are split into looking at verity possible type of sensors.

- Infrared Sensor
- Laser
- Ultrasonic Sensor
- Temperature Sensor

Our first impression is to use the infrared sensor or the ultrasonic sensor. As it is mainly used for detection objects, movement. But infrared sensor has some disadvantages. Infrared sensors cannot work in a dark environment and have poor result when there is no light. Laser sensor cannot be used for this project as it is harmful for humans, can damage their skin and eyes. After eliminating other option, we turned to research ultrasonic sensor because it is completely insensitive to hindering factors like Light, Dust, Smoke, Mist, Vapor, Lint Etc. we select HC-SR04 ultrasonic sensor from ultrasonic sensors family. Because it is easily available in the market, it has good a range of 2cm to 400cm. As this is generally used in detection and robotic projects so their many helpful articles and blogs about sensor and how to use it.

HC-SR04 has 4 pins, Trig, Echo, Vcc, and Gnd. Trig pin is to enable Transmitter of the sensor and the Echo pin is to enable the receiver of a sensor. It has two openings at front, one is called transmitter and the other is called receiver. The transmitter transmits sound waves and the receiver receive that waves after striking back from an object Electronics, S. in [18].

The ultrasonic sensor HC-SR04 has opted for the following reasons.

- This ultrasonic sensor has range from 2cm to 400 cm.
- The sound waves produced by the transmitter of the sensor is 40kHz, which is non-human audible.
- It will not be affected by any other noise like cars etc. because these noises have the frequency of few hundreds.
- It will not be affected by light, unlike the infrared sensor.

Figure 4 Ultrasonic Sensor HC-SR04 Electronics, S. in [18].

B. Microcontroller Selection

There are several microcontrollers available to operate ultrasonic sensor HC-SR04 like Arduino UNO, TI MSP430, Raspberry Pi Model B+, Arduino Mega ETC. Based on our experience, requirement and research Arduino UNO R3 is the best. Arduino UNO provides an easy way to operate Ultrasonic sensors and vibrator device. It has 16 digital input-output pins and 6 analog input/output pins which can easily fulfil our requirements. Furthermore, Arduino UNO has a 16 MHz oscillator. It has a USB connector port from which it can easily connect to a computer to burn code through Arduino software. Arduino UNO R3 has two types of memory Data memory and Program memory. Program memory consists of flash memory which is 32KB, 0.5 KB used by bootloader. Flash memory is Non-Volatile. Data memory consist of SRAM 2KB and EEPROM 1KBImpatto Zero®, L.i [19].

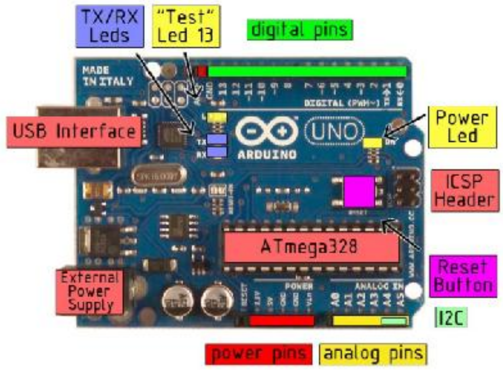


Figure 5 Arduino UNO R3Impatto Zero®, L.i [19]

C. User Informing Medium Selection

When the ultrasonic sensor detects an obstacle, then there must be medium to inform the user. Our first selection is the ISD1820 voice recording module. This module records only one message at a time up to 10 Seconds. As we have five sensors, then we have to use five modules. Each message duration is about 5 Seconds so it takes a lot of time at each sensor to detect an obstacle and inform the user. Then we find a good informing medium which is mostly used by blind assistance system is vibrating device. After research, we select coin flat vibrator Machinery, J. in [20]. A vibrator is placed with each sensor i.e. on both legs, on both hands and, on the forehead at front.

Figure 6 Coin Flat Vibrator Machinery, J. in [20]

V. Testing Individual Hardware

In this process, a prototype is developed which is consist of one sensor, one Buzzer and, one Vibrator. The reason of this prototype is to test the Ultrasonic sensor detecting procedure and range, Buzzer and Vibrator. In this prototype Arduino UNO R3 is used, it has an ATmega328P Microcontroller. Arduino UNO R3 has 16 Digital input/output pins, 6 analog input/output pins. Arduino IDE software is used to program Arduino UNO R3. The prototype of 1 sensor is shown in Figure 7. When the ultrasonic sensor detects any obstacle in range of 50cm the Buzzer and Vibrating device will ON for 1 second. The distance from a sensor to object can be found from below formula.

Distance= (Duration Time/2) *(Speed of Sound)

Duration time is the time of sound waves travel from the sensor transmitter to object and then back to the receiver of a sensor. This time will be divided by 2 because of two-time travel of sound waves from the transmitter to object and then back to a receiver.

The speed of sound in normal air is 340m/s to 343m/s. In this project 340m/s is used, m/s is converted to cm/µs as the sensor record the time in microseconds. The speed of sound in cm/µs is 0.034 cm/µs

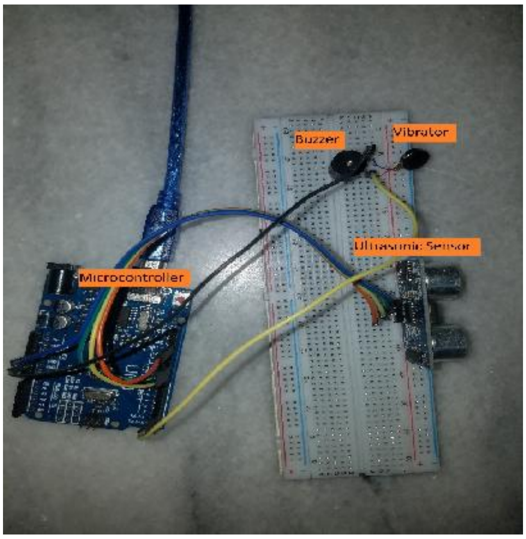


Figure 7 Prototype of 1 sensor

VI. Wearable Sensor Technology Development

In this process sensor module is designed which can be placed of multiple parts of human body like on both hands, on both legs and one on the head at front. Each sensor module consists of a sensor, vibrator and, buzzer as shown in Figure 8. Microcontroller and power source will be placed in the pocket of a jacket. When the sensor detects an obstacle in range of 50cm, it will automatically inform user through vibrating depend upon which sensor detect obstacle and buzzer

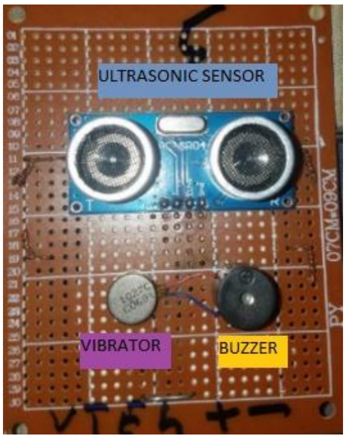


Figure 8 Sensor Module

A. *Inter-Sensor Interference*

As in this system, 5 sensors are to have connected with Arduino UNO R3. When 5 sensors are connected to Arduino UNO R3 then these sensors will receive transmitted signals of each other's and inter-sensor interference problem will occur due to which system will generate a false instruction. For solving such problem, a mechanism is created, all sensor will enable in series instead of parallel i.e. one after other. 250 milliseconds of delay are placed before enabling of each a sensor. The reason of 250 milliseconds delay is to prevent other sensors from receiving each other signals. As shown below Table 1. 1 second is given to informing the user for every sensor. So, each sensor will enable 1.25 second after the other sensor, will scan their environment and give information to the microcontroller. Algorithm program code is given below in Table 1.

TABLE I. PROGRAM CODE FOR SOLVING PROBLEM DUE TO MULTI SENSORS.

```
delay(250);

digitalWrite(trig1Pin, HIGH);   delayMicroseconds(10);   // trig pin of sensor 1 wil be ON for 10µs

digitalWrite(trig1Pin, LOW);   // after 250ms the trig pin wil be off

duration1 = pulseIn(echo1Pin, HIGH);   // Reads the echoPin, returns the sound wave travel time in microseconds Calculating the distance

distance1= (duration1*0.034)/2;   // 0.034= (340*100cm)/1000000microsecond

if (distance1 <= 50 && distance1 >= 0) // if distance is less then 50cm led will glow else it will be off

{ analogWrite(led1Pin,255);  delay(1000);  }

    else { analogWrite(led1Pin, 0); }
```

B. *Final prototype*

For testing individual hardware final prototype is developed. In the final prototype as shown in Figure 10 the buzzer and vibrator are replaced with LED. Final Prototype has 5 sensors 5 LEDs as shown in Figure 10. Every sensor starts with the delay of 0.250 seconds to prevent every sensor from receiving other sensor signals. Trigger pin of every sensor enables for 10µs. In this 10µs each sensor generates the signal. This signal bounces back and receives the receiver side of the sensor. The buzzer and vibrating device (which is here used as informing medium for user) enable for 1 second when an obstacle is detected. Total 1.250 seconds is taken by each sensor.

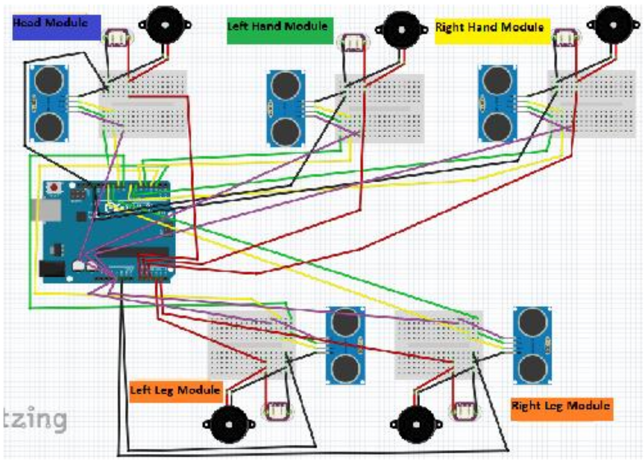


Figure 9 Wiring Diagram of Final Prototype

Figure 9 shows the wiring diagram of final prototype. As the sensor has 4 pins Trig, Echo, GND and, VCC. In wiring diagram, green wires represent the Trig wires of the sensor which are connected to 2,4,6,8,10 pins of microcontroller from head module to right leg module. The yellow wires represent Echo wires of sensor. These yellow wires are connected to 3,5,7,9,11 pins of microcontroller from head module to right leg module. The black wires represent GND wires which are connected to GND pin of microcontroller, and the purple wires represent VCC wires which are connected to a 5V pin of the microcontroller. Buzzer and Vibrator, their VCC pin (red wire) are connected to A1, A2, A3, A4, A5 pins of microcontroller from head module to right leg module as shown in Figure 9 and their GND pins (black wire) are connected to GND pin of Microcontroller.

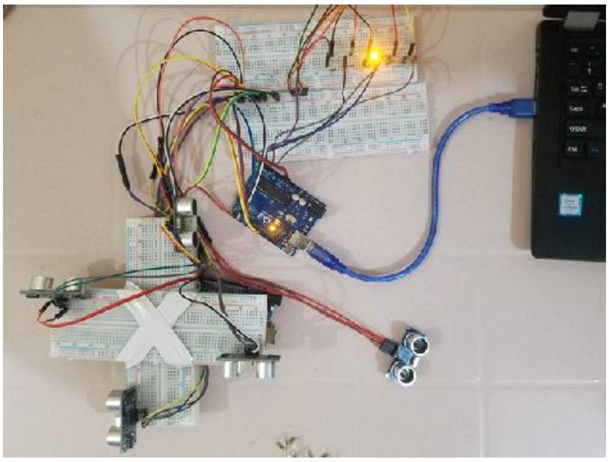


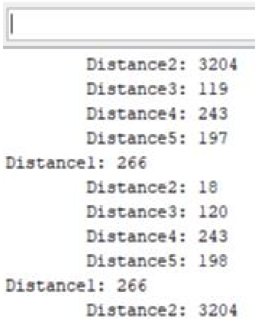
Figure 10 Circuit of final prototype

C. *Testing in Real Life Scenario*

In this phase, the prototype was tested to make sure it works correctly. The results of this testing are discussed in Section 7.

VII. Results and Analysis

The prototype system was tested for real life scenarios. For real life scenarios all the sensors of final prototype are replaced with sensor module to make it wearable. Each sensor module consists of sensor, buzzer and vibrator as shown in Figure 7. Range of sensor detection is set at 50cm. The sensors would detect an obstacle in front of them within the range of 50cm. The sensor's ability to accurately gauge the distance was tested and the result is taken on serial monitor of Arduino IDE shown in Figure 11.



```
        Distance2: 3204
        Distance3: 119
        Distance4: 243
        Distance5: 197
Distance1: 266
        Distance2: 18
        Distance3: 120
        Distance4: 243
        Distance5: 198
Distance1: 266
        Distance2: 3204
```

Figure 11 Result of final Prototype

The method and formula of distance finding from sensor to obstacle already discussed in section 5 and section 6.B. Distance 1 showing measured distance of head sensor module, distance 2 showing measured distance of right-hand sensor module, distance 3 showing measured distance of left-hand sensor module, Distance 4 showing measured distance of right leg sensor module and distance 5 showing measured distance of left leg sensor module. In testing, the assistance system would successfully turn on vibrator and buzzer corresponding to each sensor after detecting an obstacle in front of them within a range of 50cm.

Placing the ultrasonic sensor modules on different places of a human body (head, left and right hand and on both legs) are as shown in Figure 12 - 15

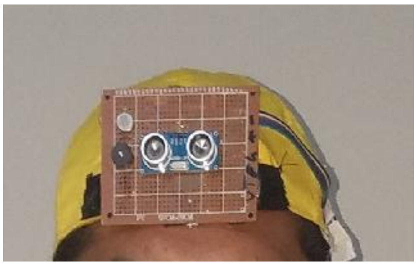


Figure 12 Ultrasonic sensors placed on the head

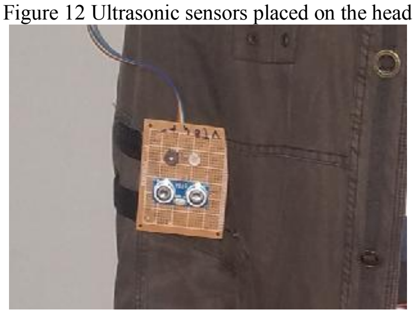


Figure 13 Ultrasonic sensors placed on the right arm

Figure 14 Ultrasonic sensors placed on the left arm

Figure 15 Ultrasonic sensors placed on both legs

As shown in Figure 16 ultrasonic sensors are placed on multi parts of the human body (on the head at front, left and right hand and on the left and right legs through a wearable jacket.

Figure 16 For testing ultrasonic sensors placed on human body

VIII. CONCLUSIONS

An assistance system was designed and developed in this research work. It is based on ultrasonic sensors for detecting obstacles in the path. These sensors with vibrating device and buzzer have been be placed on multiple places on a jacket. The sensors scan the environment of the user and inform him through vibration and buzzer. The system aid in the movement for blind people by scanning their environment through object detection and guiding them to a safe path. From the experiments, it was revealed that the developed prototype achieves its objectives with adequate accuracy. In the future, it is aimed that an image processing obstacle and person recognition be employed for tacking further real-life problems associated with the travel of blind people.

IX. FUTURE WORK

In the future, we will extend this work to investigate more efficient techniques of obstacle detection through image processing. With image processing, the assistance system will be faster than present ultrasonic based assistance. Present ultrasonic based assistance system each sensor takes 1.25 second to scan front environment so all five sensors take 6.25 seconds. This 6.25 second of time can be minimized with image processing. We will further try to extend this work to utilize the GPS module. A GPS module can be installed to give information to the user about a location and can also give direction to the user about the desired location through voice messages.

Currently, in this system, ultrasonic sensors are used for object detection. Ultrasonic sensor faces some difficulties in detection of objects having sharp edges or triangle shaped objects. This research does not deal with such type of objects and overfilled areas. In the future, we will try to solve this problem through image processing.

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