Assistive Infrared Sensor Based Smart Stick for Blind People

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***Abstract*—Blind people need some aid to feel safe while moving. Smart stick comes as a proposed solution to improve the mobility of both blind and visually impaired people. Stick solution use different technologies like ultrasonic, infrared and laser but they still have drawbacks. In this paper we propose, light weight, cheap, user friendly, fast response and low power consumption, smart stick based on infrared technology. A pair of infrared sensors can detect stair-cases and other obstacles presence in the user path, within a range of two meters. The experimental results achieve good accuracy and the stick is able to detect all of obstacles.**

Keywords—Blind people; Electronic cane; Infrared (IR) sensor; Obstacles detector; visually impaired people

I. Introduction

A report by World Health Organization (WHO) and International Agency for Prevention of Blindness (IAPB) [1] stated that there are approximately 285 million persons around the world who are visually impaired, out of which 39 million are completely blind. Africa and other developing countries represent 90% of this statistics. Egypt specifically has one million blind, out of which 14% are children. According to WHO and IAPB, the number of blind people will increase worldwide to reach the double by 2020.

It is difficult for blind people to move or live without help. So, they usually use white cane to guide them during moving. Although it might be helpful, it doesn't guarantee saving blind people from risks. These traditional ways can be used for low-level obstacles detection only.

Electronic Travel Aids (ETAs) devices have been introduced recently to be a mobility aid for the blind people. ETAs are devices contain sensors that alert the blind about obstacles existence through vibration and sound [2], [3]. Such devices increase the blind's self-confidence and provide safety, as they give the necessary help to the blind to facilitate their movement in unfamiliar environment. Several visual aid devices have been developed [4], [5]. There are three types of aid: devices are used to locate the blind in case he got lost like those containing GPS [6]. Others devices are used to guide his path via detecting land-marking like near-infrared (IR) light or radio frequencies [7], [8]. Alternatively instead of guiding his path, devices might protect him hitting obstacles like those using ultrasonic sensor like K sonar [9], Ultra cane [10], Miniguide [11], Palmsonar [12], Ultra-Body-Guard [13], and iSonic cane [14]. Laser devices like C-5 Laser Cane [15], Teletact [16] and CCD camera input systems like v0ICe [17], NAVI [18], AudioMan [19], SoundView [20].

Our work aims at providing blind with the third type of aid. The proposed system detects obstacles in his path and produce appropriate alert to save him from hitting obstacles. The infrared sensors are used in this paper because they are small, cheap, have specific spectrum, and have low power consumption.

Such devices are based on producing beams of ultrasound, infrared or laser light: Then, the device receives reflected waves, and produces either an audio or tactile stimulus in response to nearby objects. The intensity of the sound or tactile vibration is proportional to the distance of the pointed object. As a result many important problems are frequently cited:

Firstly, Ultrasonic devices have big size, high weight, and high power consumption. They are limited due to multiple reflections, laser has a very narrow spectrum so it collect information about very narrow area that are not large enough to be free paths. Therefore, they detect a lot of useless information as mentioned by [21]. IR sensor beam is intermediate in width between laser and ultrasonic, low power consumption and low cost compared to laser and ultrasonic sensors.

Secondly, Solution based on sound confusing and difficult to understand [22] as well as solution based on tactile stimulation as mentioned by [23].

The proposed system provides the following features

- Cheap mobility sticks with total cost not exceeding $120.
- Light weight components integrated to the stick which makes it user friendly.
- Fast response of obstacles in near range and up to 200 cm using IR sensors
- Avoidance confusion by playing comprehensible speech message through an earphone.
- Detection of stairs and its direction (upward and downward) stairs

- Low power consumption and battery life up to 14 hours before recharge.

The paper is organized as follows: Section II presents the proposed system. Experiment and Results is presented in Section III. Finally, conclusion and recommendation is shown in Section IV.

II. THE PROPOSED SYSTEM

The block diagram of the proposed system as shown in Fig.1, is basically an embedded system integrating the following components: pair of infrared sensor, the horizontal one to detect obstacles in front of the blind in the range of 200 cm, the inclined infrared sensor to detect obstacles on floor, upward and downward stairs. Both infrared sensors collect real time data and send it to 16F877A microcontroller to process this data.

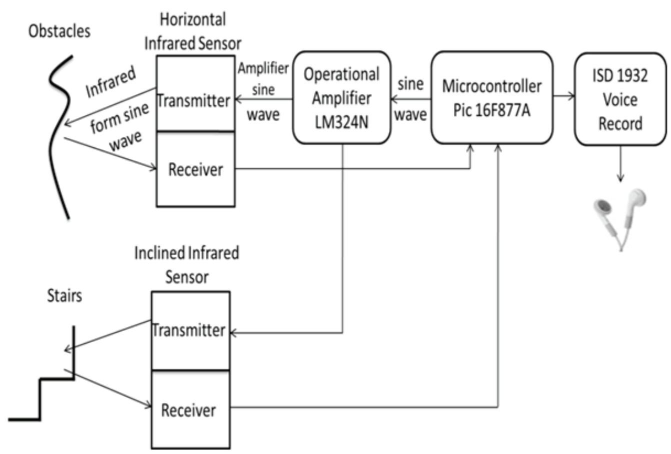


Fig. 1. The block diagram of proposed device

When the infrared signal is received at the microcontroller, it begins to compare between transmitted and received signals to identify obstacles standing in the way of the blind. If the microcontroller finds a difference in the form and amplitude of transmitted and received signals, it invokes the appropriate speech warning message stored in ISD 1932 through an earphone.

The whole system is powered using 5V power supply and it is simulated by using Proteus software [24]. The program code was written by using C language. The following subsections will discuss each block in more details.

A. Microcontroller PIC 16F877A

Researchers in [22, 25] used the microcontroller 16F877A. A microcontroller unit abbreviated MCU [26] is a small computer modeled on a single integrated circuit containing processor core, memory, 2 capture/compare/PWM functions, programmable input/output peripherals, and 8 channels of 10-bit Analog-to-Digital (A/D) converter. It also includes a chip named ROM, as well as a typically small volume of RAM. Microcontrollers are designed for embedded applications.

PIC 16F877A is made by Microchip technology as it's a family of modified Harvard architecture microcontrollers, derived from the PIC1650.PICs are widely used due to the following reasons:

- Low cost.
- Wide availability.
- Can be programmed by free tools.
- Can be re-programming with flash memory capability.

One of the PIC 16F877A main advantages is that each pin shares more than one function. It also contains a 40 pin out and many internal peripherals. The 40 pins can be used as multi-function if more than one external device is attached to MC.

As shown in Fig.2. When the MCU starts by generating the pulse that will drive the infrared emitters. After receiving the reflected wave, the A/D converter of MCU will read and convert the received analog wave from each infrared receiver into a digital signal.

If the received signal comes from the horizontal sensor, MCU will calculate the distance between the stick and obstacle.

If the inclined sensor received the signal, MCU will calculate average of the signal shape and its amplitude to detect the presence of stairs and direction of stairs (upward or downward).

After calculating the required information, MCU invokes the appropriate speech warning message through an earphone.

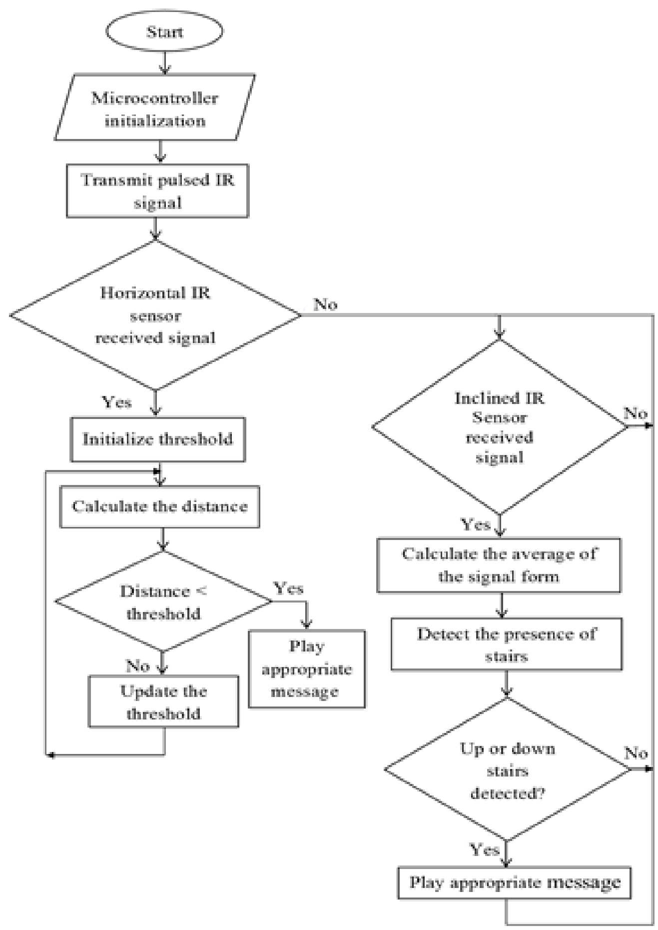


Fig. 2. Flowchart of the proposed system

B. Infrared Sensors

In our system, two infrared sensors are used; horizontal and inclined. The horizontal IR sensor is located under the hand stick at height of 90 cm to scan the area in front of the blind, whereas, the inclined IR sensor is located at height of 75 cm as shown in Fig.3.

The main concept of operation is as follow: a pulse of IR signal is transmitted by the transmitter, and then the signal travels out in the environment. In case of no obstacle, the signal is never reflected, and there is no received signal at the IR receiver but the receiver still can get a very weak noise signal from the environment. In case of finding an obstacle, the signal is reflected back to the receiver.

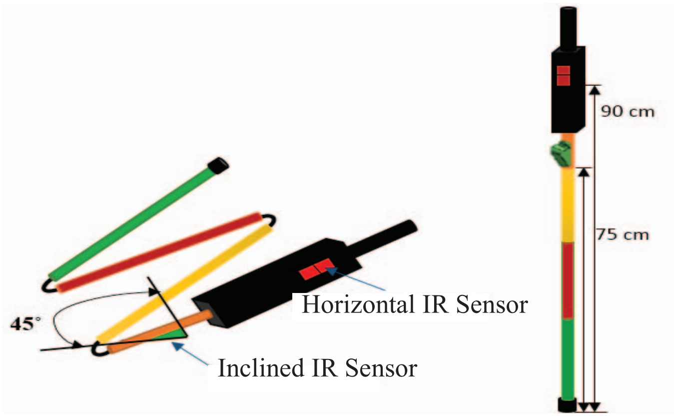


Fig. 3. Design of smart stick

As illustrated in Fig. 4, α is the angle between the transmitter path to obstacle and the reflected path to receiver, and β is the angle between transmitter path to obstacle and the distance between transmitter and receiver, α increase as the obstacle exist near to the sensor and vice versa.

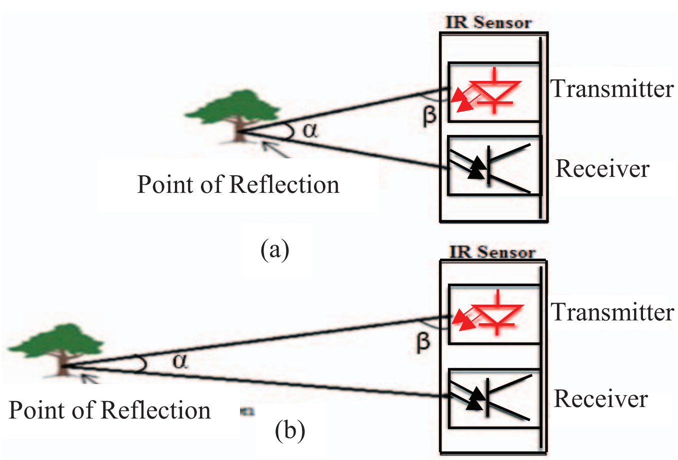


Fig. 4. Different angles with different distances (a) Near obstacle (b) Far obstacle

The IR transmitter contains: IR photodiode and an optical lens while the IR receiver contains an optical lens and a linear Charge Coupled Device (CCD) array detector.

When the transmitter emits IR wave, it goes through the transmitter's optical lens and hits the obstacle then reflects back. The intensity of reflected wave varies according to the obstacle surface and the distance of obstacle from sensor.

Then, the reflected wave is bundled by receiver optical lens and the receiver store information about obstacle surface and distance, in CCD array (full part of CCD represented by 'y') in Fig.5.

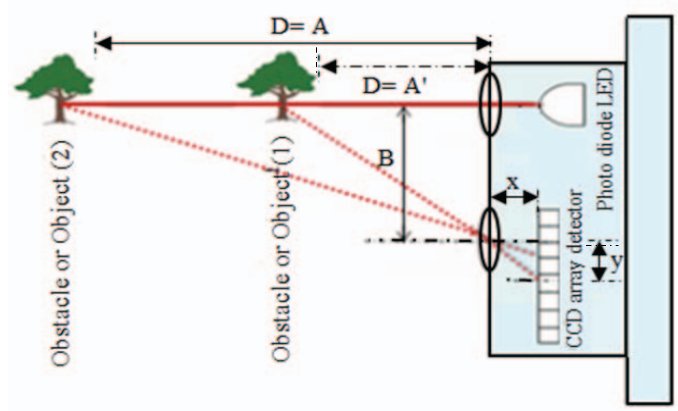


Fig. 5. Measure of distances between obstacles and individual elements in IR sensor at cases of: (1) Near obstacle, (2) Far obstacle

Upon receiving a wave from an obstacle and storing the obstacle information and converting to digital information by A/D converter. The MCU will compute a distance D.

D value will differ according to the obstacle distance to IR sensor as in Fig.5, D = A' for near obstacle and D = A for far obstacle based on the equation (1).

$$\frac{D}{B} = \frac{x}{y} \qquad \textit{Thus}$$

$$D = \frac{B \times x}{y} \tag{1}$$

Where B is the distance between the transmitter and the receiver, x is the focal length of the lens and y represents the amount of captured received wave.

Fig. 6 presents how infrared sensors interface with a PIC16F877A microcontroller.

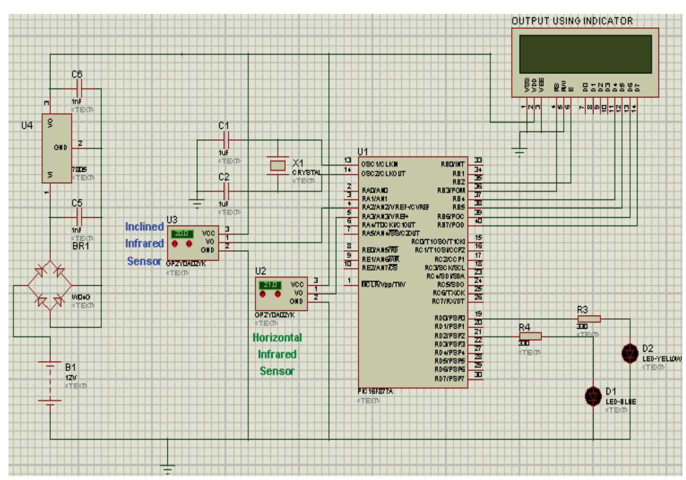


Fig. 6. The whole circuit design using Proteus simulation

Upon distance calculation, MCU invokes the corresponding message.

C. Message Recording

The proposed device uses ISD1932 [27] circuit that contains a multiple-message recording- and playback device. This circuit can record up to 64 seconds per message. It includes microphone inputs and speaker outputs as shown in Fig. 7.

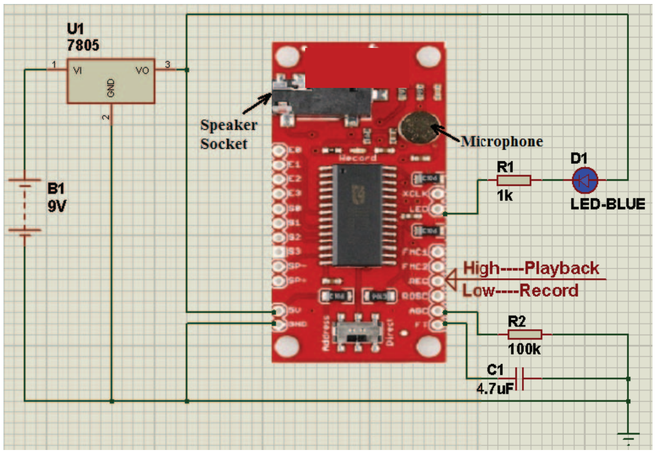


Fig. 7. Voice recorder circuit

In the proposed system, six different speech warning messages are recorded as listed in Table 1 to alert the user. To decrease recording duration to 21.2sec per message, a capacitor of 4.7 µF and an external resistor of 100KΩ are added.

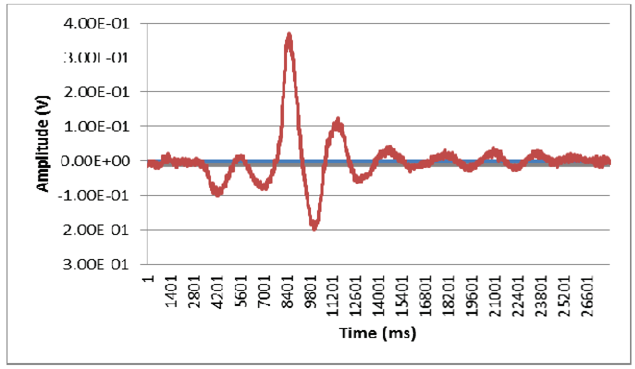
TABLE I. SPEECH WARNING MESSAGES

Serial	Speech warning message	Duration (sec)	Obstacle distance to generate the message
1	"Obstacle is at 20 cm approximately"	0.5 sec	Less than 20 cm
2	"Obstacle is at 50 cm approximately"	0.6 sec	21 cm to 50 cm
3	"Obstacle is at 75 cm approximately"	0.57 sec	51 cm to 100 cm
4	"Obstacle is at 150 m approximately"	0.61 sec	101 cm to 200 cm
5	"Attention there are upward stairs"	0.4 sec	In range 80 cm
6	"Attention there are downward stairs"	0.4 sec	In range 80 cm

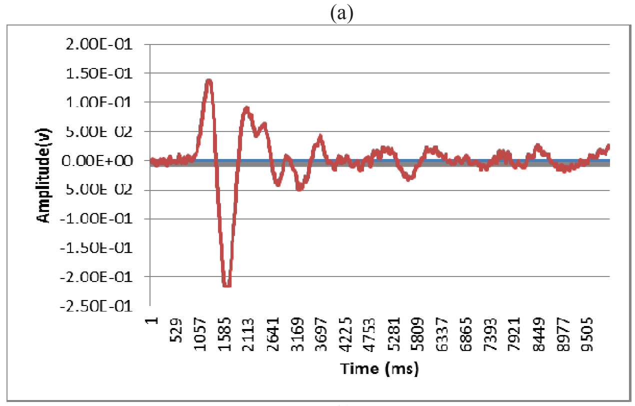
III. EXPERIMENT AND RESULTS

A. Stairs detection expermient

Two experiments are done; the first was a validation test in lab and the second was a real test outside and inside buildings. In the lab valid test, a simple stairs models are built with 2 steps and output of inclined sensor is connected to oscilloscope to notice the variation in received signal. In the case of stairs presence a different form and amplitude signal than the transmitted signal is received as shown in Fig.8a and Fig.8b. The received signal in case of upward stairs ranged from-0.198V to 0.73V with average 0.086V while downward stairs range from 0.138V to -0.215V with average -0.038V. When the MCU computes the average, it checks any negative or positive variations as shown in Fig.9.



(a)



(b)

Fig. 8. Received signal in inclined infrared sensor (a) Stairs up signal case (b) Stairs down signal case

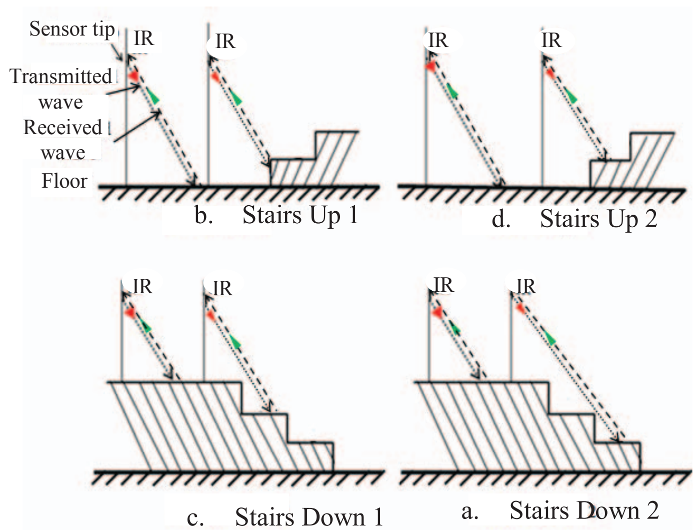
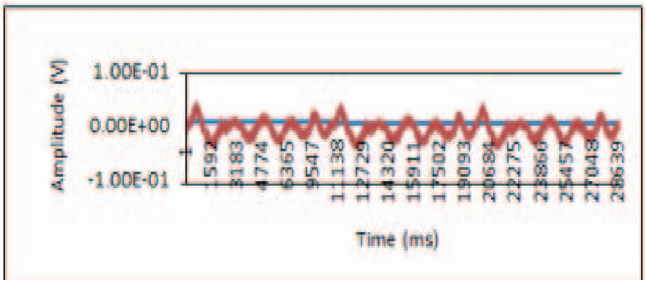


Fig. 9. Inclined infrared sensor in environment

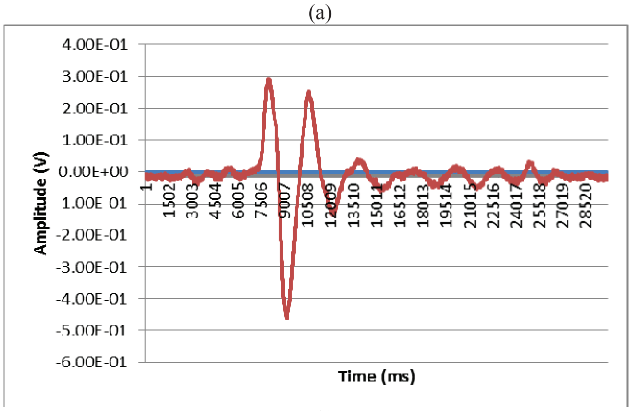
Additionally MCU can detect how far the stairs are from the blind by checking the amount of variation of average received signal which increases the blind approaches the stairs. We check the whole operation using voice kit and able to validate that the correct speech warning messages were spoken via earphone.

B. Obstacle detection experiment

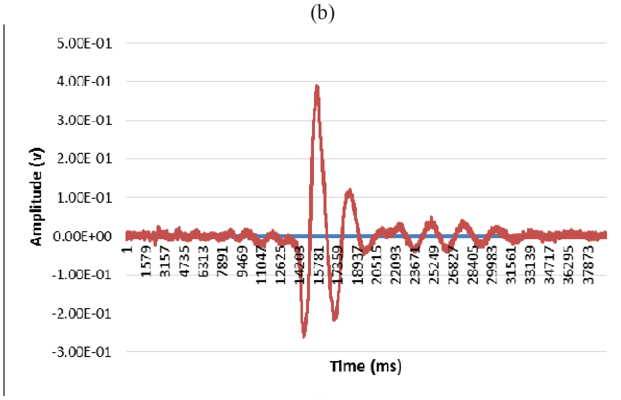
Obstacles are either low obstacle located on the floor in the path of the blind or high level obstacles in front of him. In lab, different types of obstacles at various distances and heights are placed, and then the sensor is connected to oscilloscope to observe the received signal variation. In the case of no obstacles on floor or in front of him, we receive almost no signal. The environmental noise show on the oscilloscope as a very weak signal as shown in Fig. 10a. In case of an obstacle exist in front of him a received signal by horizontal sensor with amplitude higher than that received signal by inclined sensor in case of low obstacle on the floor as shown in Fig.10b and Fig.10c



(a)



(b)



(c)

Fig. 10. Received signal in infrared sensors (a) No obstacle (b) Obstacle in front of the blind (c) Obstacle in the floor

We also checked the detection using the speech warning message kit and were able to validate the product on of corresponding speech message.

Real experiment was held by a group of six blind people to test the obstacles detection using the stick. Eight obstacles with different heights were placed in their walking path.

Most of obstacles were detected and the appropriate messages were heard by them as they reported although some were not taking enough space away from the obstacle. Therefore, they sometimes touched the obstacle edge so these instances were considered as unintended error. The results of complete avoidance of hitting detected obstacles are shown in Fig.11.

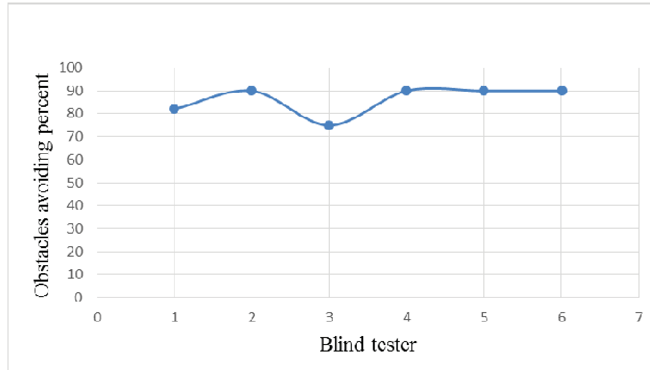


Fig. 11. Obstacles avoiding perecent vs blind tester

IV. Conclusion and Future Work

In this paper, a solution is proposed to help blind to move safely and detect obstacles in their path. Solution was composed of a foldable stick with a pair of IR sensors mounted on it. Connected to an earphone to alert the blind with speech warning message about the detected obstacles. The horizontal sensor was able to detect high level obstacles whereas the inclined sensor was able to detect the low level obstacles on floor and stairs case. Additionally, it can identify the type of the stairs (upward and downward) and appropriate message are played back through earphone using ISD1932 flash memory. The feedback from the real test was positive because all of obstacles can be detect although the avoidance accuracy was ranging from 75% to 90%.

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