Smart Assistive Shoes with Internet of Things Implementation for Visually Impaired People

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Abstract. Visually impaired people usually have a lot of difficulties involved in interacting with their environment. Physical movement is a major challenge for them, because it can be tricky to make a distinction about where they are and how they can move from one place to another. In this project, smart assistive shoes with Internet of Things (IoT) implementation is designed. These shoes are equipped with ultrasonic sensors and vibration motors that can warn users about obstacles. Next, the IoT system is implemented using Adafruit IO and If This, Then That (IFTTT) to transfer data between Google Assistant and buzzer for shoes position finder purposes. NodeMCU allows the buzzer on shoes to be controlled by the Internet using its WiFi module which is connected to the mobile phone hotspots. As a result, shoes with an obstacle detection system which can detect obstacles within 20 cm distance and shoes position finder using Google Assistant are designed. In conclusion, hopefully these shoes will become one of the alternatives to aid the independent movement of the visually impaired people in the future.

1. Introduction
Visually impaired is what experts describe as any form of vision loss whether it's someone who can't see at all or someone with a partial vision loss [1]. A partial vision loss is also known as legally blind. They are not completely blind but they did not have enough vision to see things clearly. As a result, there are many things that need to be considered in living their daily life. Most of them did not have problems moving around their house as they tend to memorize the place and route. Therefore, we should be careful to not move any objects without asking. Walking outdoors is another challenge for them since they cannot memorize all the routes taken unless they use the same routes every day. Even if they remember the roads taken, they still need to be careful of unexpected obstacles near them [2].

However, as the industrial and technology development keeps increasing in our country, we managed to gain knowledge about one of the most useful devices which are sensors. Sensors are implemented in devices and tools to improve the mobility for visually impaired people [3]. It helps to detect the obstacles automatically using ultrasonic sensors. As an example, instead of using a guide dog and white cane, a smart cane with a sensor has been designed.

In addition, a technological paradigm shift seems to be taking place in manufacturing
companies recently which is Industry 4.0 [4-5]. Technology helps the visually impaired people to interact with the environment. The process of communication and information transmission has become very rapid, which has greatly influenced human life, thereby increasing the means of entertainment and comfort and reducing misery and hardship in many ways. For example, the Internet of Things (IoT) in communication systems, the Cloud for online data storage and Augmented Reality in the education system.

The Internet of Things is the world's next big digital revolution in the advertising of different goods [6]. All is connected to the Internet with the control and monitoring of parameters from anywhere. The Internet of Things is today the most up-to-date technology alongside wearables and robotics. The network of physical objects embedded with circuitry, software, sensors and networking helps it to gain greater value and operate by exchanging data with the manufacturer, operator or other network devices. Through its embedded computing device, each item is uniquely recognizable but is able to communicate within the current Internet infrastructure.

One of the smart devices designed to help visually impaired people is smart stick [7]. Smart stick is not a wearable device and needs users to carry or hold it all the time. Thus, users cannot use their hands freely. Also, there is a higher possibility for users to lose or misplace it by mistakes in an outdoor environment and not be able to find it by themselves. However, all the limitations mentioned when using the smart stick can be solved with the smart assistive shoes with the implementation of IoT. The smart assistive shoes are a wearable device and equipped with the application to find the position of the shoes using the Internet. Therefore, users can use their hands freely and will be able to find the position of the shoes with the help of equipped features.

2. Literature Review

Most of the methods in the previous works are about obstacle detection using smart devices to improve the use of white cane by visually impaired people. Other than that, there are tracking systems, image detection and emergency alert systems. However, all the systems in the previous works have their own limitations.

In [8], a smart shoe prototype that could connect to a smartphone through Bluetooth and deliver navigational information via a vibration unit placed around the shoe. Information for both outdoor and indoor navigation can be supplied using Google's navigation database. However, when using Bluetooth, the connection cannot function well if the smartphone and shoes are far from each other.

Meanwhile, a device that leads the user by detecting obstructions within the stick's range is designed in [9]. With the help of several sensors implanted in it, it would identify any obstructions in the road. The microcontroller will retrieve data and transmit it as vibrations, alerting the user to potential roadblocks. Unfortunately, users still need to hold the stick all the time while walking. Therefore, only one hand can be used for other purposes or kept free.

As for previous work stated in [10], the project used ultrasonic sensors as aid in measuring the distance between obstacles in a blind person's walk. This device assists the user in receiving the best possible track in the form of audio. The sensors are built into the shoe, allowing the blind person to not only identify impediments in front of them, but also detect any large pits along the road. In case of emergency, it also has a panic button that can send SMS. Anyhow, this shoe is not suitable to be used during outdoor activities because the output voice for the alert system may not be heard due to noisy environments.

Then, a custom-made shoe that includes features such as object identification, image recognition and real-time navigation to the target destination with obstacle detection and warning has been proposed in [11]. As a result, this technology will assist blind and visually impaired people in walking and exploring unaided without the need for physical assistance. Even so, the hardware used more space as there is more than one module which are WiFi module and Bluetooth module to be implemented together with Raspberry-Pi.

For the last review of the previous work in [12], a vibration sensor is used to sense any obstacle.
In the headset, customers can hear the guide's instructions. An ultrasonic sensor on the stick is utilized to detect the impediment, which is detected by the camera. The image is transferred to the microcontroller, which determines the object's kind, and then it is communicated as a voice command via the Raspberry Pi's speaker or earbuds. GPS interface is used to identify the exact location. However, this project used Raspberry Pi which is an expensive development board.

3. Methodology

3.1. Schematic Circuit
For the obstacle detection system, NodeMCU is used as a microcontroller for the circuit. Two ultrasonic sensors are used to detect obstacles on the ground and two mini disc vibrating motors will help to alert users about the obstacles near them. These motors will vibrate according to the direction of the obstacles detected.

Also, NodeMCU will provide an Internet connection between smartphones with the hardware components using the WiFi module embedded on the chip. The buzzer is used as output for the shoes position finder system. It allows users to locate the shoes with the help of an IoT system and buzzer. The schematic circuit that involves both obstacle detection and shoes position finder system can be referred to in Figure 1.

![Figure 1. The schematic circuit for hardware components.](image-url)

3.2. Arduino IDE Software
The Arduino Integrated Development Environment or Arduino Software (IDE) contains a code writing text editor, a text console, a message field, a common function button toolbar and a set of menus. To install programs and communicate with them, it connects to the Arduino and Genuino hardware. This is where all the codes to set up an Internet connection, obstacle detection system and shoes position finder system are integrated.

3.3. Process Flow of the Project
The flowchart of the project starts from the setup of the Internet with hotspots from mobile phones. There are two main flows in the flowchart shown in Figure 2. First is the obstacle detection system and the other one is the shoes position finder system. Both of the systems will be integrated together and the final output is the vibration motor to alert users on the obstacles detected and the buzzer to find the position of the shoes.
4. Results and Discussion

4.1. Smart Shoes Prototype

A fully designed prototype equipped with an obstacle detection system and shoes position finder has been built. In Figure 3, the front view of the smart shoes is shown. It can be seen that there are two ultrasonic sensors placed in front and at the side of the shoes. As for Figure 4, it shows the top view of the smart shoes where the connection of the circuit with the NodeMCU can be seen. The NodeMCU has been placed inside the shoe tongue.
4.2. Obstacle Detection System
In the test, LEDs are used to replace the vibrating motor because the size of wire is too small to be connected to the circuit. Therefore, it needs to be soldered by using a device in the laboratory. Since the implementation process cannot be done in the laboratory, the vibrating motors are replaced with the LEDs for the test only.

During the test, the power is being supplied by the computer via USB. In Figure 5 (a), the test is carried out by placing the obstacle 30 cm away from the ultrasonic sensor. The LED does not light up. Then, the obstacle is placed 5 cm away from the ultrasonic sensor. The LED turned on as in Figure 5 (b). This proves that the obstacle detection system works as expected.
4.3. Test for Obstacle Detection System

The test is done to investigate whether the obstacle detection system is functioning properly by walking with the shoes. The data of the distance calculated using the ultrasonic sensor are uploaded directly to the Google Sheets using the IFTTT service. The plotted graphs in Figure 6 and Figure 7 show the data for 15 minutes only.

![Figure 5. Test for obstacle detection system (a) Obstacle’s position is 30cm away from the sensor. (b) Obstacle’s position is 5 cm from the sensor.](image)

![Figure 6. The LED behaviour with front obstacle](image)

![Figure 7. The LED behaviour with right side obstacle](image)
Figure 6 and Figure 7 depict the behaviour of LEDs when an obstruction is detected after 15 minutes of testing. When an obstacle is less than 20 cm away from the sensor, the LED will display value 1. If the obstacle is 20 cm away from the sensor, the LED will display value 0.

4.4. Shoes Position Finder
The shoes position finder started with the setup of the Internet connection. After the Internet has been connected, users can start to find the position of the shoes. Users can initiate the Google Assistant by saying ‘OK Google’. Then, users need to say the phrase that has been set in IFTTT as shown in Figure 8 (a). In this case, the phrase is ‘Find my shoes’. There are several phrases that can be set. After that, Google Assistant will also give a reply as what has been set which is ‘OK! Listen to the buzzer’. The moment when Google Assistant gives a reply, the buzzer will turn on and that is how users will find the shoe’s position.

After confirming the position of the shoes, users again will initiate the Google Assistant using the same way which is by saying ‘OK Google’. Then, users can say ‘I found it, thank you’ to terminate the system. The buzzer will turn off when Google Assistant give a reply ‘OK! Good Job’ as in Figure 8 (b). Hence, the shoes position finder system is fully terminated.

![Image](image-url)

**Figure 8.** (a) Smartphone’s screen during shoes position finder system is initiated (b) Smartphone’s screen when shoes position finder system is terminated

5. Conclusion
As a conclusion, a prototype of smart shoes using NodeMCU equipped with an obstacle detection system using ultrasonic sensors and vibrating motors has been built. In addition, to improve the existing smart shoes, a feature of the shoes position finder has been added. Also, a speech-recognition application, Google Assistant has been used as a shoes position finder with the help of an IoT system using Adafruit IO and IFTTT services. Last but not least, the use of an IoT system in an ordinary shoe is effective as long as there is an Internet connection. This allows users to find the position of shoes over a long distance. Therefore, these shoes are expected to increase mobility among the visually impaired society in the future with all the abilities and features on them. Moreover, as shoes are wearable devices, users can use their hands freely instead of walking with a cane and holding it all the time.

For future work, a mobile application is completely linked with the maps and ready to be used as a navigation system with built in speech recognition. Also, the applications will be integrated with the hardware component via Internet connection. Last but not least, all the hardware components are implemented on the shoes to alert users for obstacle detection and navigate them in the direction of their destination.
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