Development and Analysis of Rechargeable Smart-Shoe for Visually Impaired People

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Abstract

The eyes are referred to as the "windows of the soul," which emphasizes their significance. The eye is a critical element of the human body that allows a person to see and understand his environment. Blindness makes it difficult for a person to perform daily tasks. Technological advancements facilitate communication between visually impaired individuals and their environment. In this paper, we introduced an application called SMART-SHOE, which serves as a helping hand for the visually impaired, using innovative solutions to reduce their challenges. The user is required to wear the shoes during the procedure. When sensors detect an obstruction, the user will be notified via the Android system they are using. The proposed device can detect significant obstacles in a very short duration of time. It takes around 3.08 minutes on average and detects about 89.5% of obstacles.

Keywords
Smart-shoe, visually impaired people, Arduino, Bluetooth module, GPS.

1. Introduction
People with disabilities such as blindness, low vision, visual impairment, and vision loss encounter substantial obstacles that impact their physical, mental, social, and economic well-being. These challenges decrease their quality of life and hinder their ability to engage in essential daily activities, with navigation and mobility being particularly crucial.

The World Health Organization (WHO) released its inaugural global report on vision on October 8, 2019, revealing that approximately 2.2 billion individuals worldwide experience vision impairments. The majority of these individuals could attain normal vision through the use of eyeglasses, contact lenses, or refractive surgery. A significant proportion, approximately 85%, of visually impaired people reside in low- and middle-income nations. Age-related cataract is the primary cause of blindness, accounting for 79% of all cases. Cataract surgery and the correction of refractive errors are considered highly cost-effective healthcare interventions. During a discussion, it was highlighted by experts that approximately 750,000 individuals in Bangladesh are currently experiencing blindness. Dr. Golam Mostafa, the Director of the National Eye Care Line and the National Institute of Ophthalmology and Hospital (NIOH), emphasized in his presentation that around 1.5 million children in Bangladesh are affected by low vision, a condition that can be prevented with appropriate intervention.

Many blind people rely on travel aids to get around in unfamiliar places. We demonstrate the Smart-shoes project, which allows visually impaired people with mobility issues to avoid obstacles. Our system identifies obstacles such as curbs, stairwells in the ground, and even moving objects using existing robotics technology, and sends obstacle information via haptic feedback (vibrations and beeps). Our system enables human users to travel safely in both indoor and outdoor areas, according to preliminary tests.

Numerous aids have been created to assist individuals with visual impairments in navigating with ease. Various organizations have devoted considerable efforts over an extended period to produce affordable and efficiently structured devices for this purpose. The combined use of several types of sensors, notably the active-passive combination, can provide a lot of value to a full and reliable obstacle detection sensing system. A technique based on the major challenge is to create algorithms that are reliable enough to recognize and alert the user of any obstacles that may occur in front of them on the road. The activities related to this field can be summarized as follows.

(Discant et al. 2007) provided an overview of various sensor types, encompassing both active and passive sensors. It also sheds light on other sensing systems that make use of these sensors in conjunction (Baharuddin Mustapha et al., 2013). This research presented the utilization of ultrasonic and infrared sensors to measure distances in the development of an obstacle detection system tailored for elderly individuals and those with visual impairments. The findings reveal that when it comes to output voltage measurements, ultrasonic and infrared sensors have different features. Ultrasonic sensors produce linear output representations, but infrared sensors produce nonlinear representations. Both sensors can detect an impediment with a precision of 95 to 99 percent at distances within their useful range (B Mustapha et al. 2013). A motion-supporting device is presented that can be utilized to assist in navigating around the environment and avoiding collisions with obstructions (Lakde & Prasad 2015). It gives a full summary of the convention of navigation systems for individuals with impaired vision as an artistic method. As a result of prohibitive costs, accuracy, and user efficiency needs, the achievement of usability for large-scale navigation systems is lacking (Bousbia-Salah et al. 2007). A blind person's ultrasonic sensor-based navigation system consists of microcontrollers with synthetic speech output and portability to assist the user around obstacles while they ponder and update their next step (Mahmud et al. 2014). Ultrasonic sensors were used to detect obstructions in a vibration and voice-operated navigation system. Because visually impaired people have a stronger sense of hearing and perception than the general public. As a result, this system provides alerts via vibration and audio input. The system can be utilized for both inside and outside navigation, with an emphasis on continuously sensing surrounding impediments and notifying users via vibration and voice input.

2. Problem Statement

This research offers an initial model and system design for a smart electronic assistive device specifically designed for individuals with visual impairments. This system uses a microprocessor, an ultrasonic sensor, a smartphone (GSM Module), and a vibratory circuit to provide overall measures for object detection, human detection, and real-time assistance. The goal of this work is to create an Electronic Traveling Aid (ETA) kit that will help blind persons in finding an obstacle-free path. This ETA is permanently attached to the shoe. When an object is recognized near the shoe and a person approaches, the vibrating circuit informs them, as well as in advance through the use of speakers or headphones, a spoken command is provided with the aid of an Android application. Here, the major criterion is power supply, so the shoe is incorporated with a self-power generation unit to eliminate the need for a power backup. People who wear navigation-enabled shoes can receive signals from the footwear indicating when to move, which direction to proceed, and whether to take a left or right step. A GPS system will guide him to the destination. To notify a blind person, the control unit vibrates in accordance with the route coordinates in the shoes. As a result, the visually impaired person moves in the vibration's direction.

In this work, the system is designed to be capable of moving in open areas. On the roads, there'll be more open space. So, the blind people need to adjust according to the roads. Therefore, the Smart-shoe will react according to the open space on the road. Moreover, we've practically applied our method to blind people on open roads. They've successfully overcome the obstacles using this method in open spaces.

3. System Setup

The various components employed in this research, as well as their interdependencies.

1. **IR and US Sensors**: These components detect approaching obstacles.
2. **Arduino Nano:** The sensors and Bluetooth module are embedded in this component.
3. **Bluetooth Module:** This module is used to send data from the Arduino to the smartphone.
4. **Android Application:** This component collects all incoming data and produces the required output.
5. **Google Maps:** The Android app uses this API to run in the background.

Arduino is an accessible and open-source electronics platform that consists of user-friendly hardware and software. Arduino boards have the capability to perceive inputs from various sources, such as light sensors or buttons, and convert them into outputs that can perform actions like driving a motor, activating an LED, or sharing information online. In Figure 1, an Arduino Nano is shown which is installed on the top part of the Smart-shoe. Bluetooth module controls Bluetooth connection with the device which is shown in Figure 2, In the Smart-shoe system, the HCSR04 Ultrasonic sensor interface Arduino is shown in Figure 3, Apart from the 433 MHz Wireless Serial Transceiver Module 1, Bluetooth Module, and other Smart-shoes components such as Cables, Vibration motor, LED, Beeper, and so on were used.

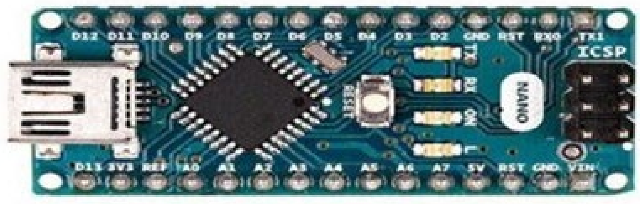

Figure 1. Arduino Nano

The target audience for this product consists of individuals who are visually impaired or blind and require assistance with navigation. The idea is to utilize everyday attire, particularly shoes, to guide users to their destinations while also alerting them to obstacles in their path. The product doesn't offer instructions on how to bypass obstacles; rather, it outlines a method for informing the user about the obstacle's presence so that they can adjust their next step accordingly. This device represents a technological innovation that enables visually impaired individuals to navigate using only their smartphones and footwear, without the need for additional external tools. It functions as an audio navigating system that receives information from sensors attached to the user's shoes and outputs auditory instructions and vibrations from the shoes. Figure 4, shows a beeper that will alert the user. The application created for the purpose must also have a Google Maps interface to provide real-time navigation.

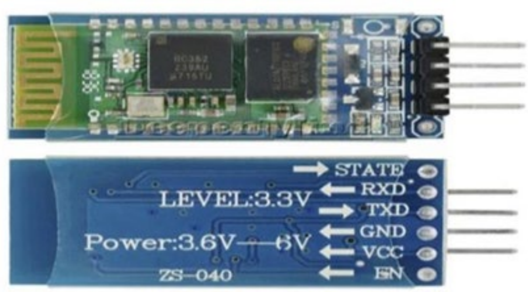

Figure 2. Bluetooth Module

Figure 3. HC-SR04 Ultrasonic sensor interface Arduino

Figure 4. Beeper

The following important functions are initiated and performed by this product:

1. Use the Google API for internal navigation.
2. Employing voice commands to read and guide the route from the starting point to the destination.
3. Object detection and classification near the user.
4. Intuit the user's current location and any nearby obstacles, as well as their type, using spoken commands.

The proposed system's real-time processing implementation could be the most crucial. The program should be capable of processing barriers observed by the sensors in real-time. It's of utmost importance to swiftly detect, process, and transmit this information to the Android device via Bluetooth. The computations must be reduced to a bare minimum to maximize the lifespan of the batteries in the shoes. To warn the user of any potential impediments, the text-to-speech conversion must be completed in the shortest time possible. All the time saved during processing would become irrelevant if the text-to-speech conversion is inefficient, so no delays can be tolerated. All of the obstacle detection equipment, such as sensors and Arduino Nano, will be installed in each shoe with batteries attached, increasing the possibility of losing equipment strength if not used properly and owing to the Smart-shoes severe wear and strain. Water percolation must be prevented as much as possible in order to maintain a well-working system. The shoes were equipped with various sensors, as shown in Figure 5, to detect obstacles in front of or beside the user. After the installation of the devices, the shoes weighed around 0.955 kg whereas before installment the weight was 0.75 kg.

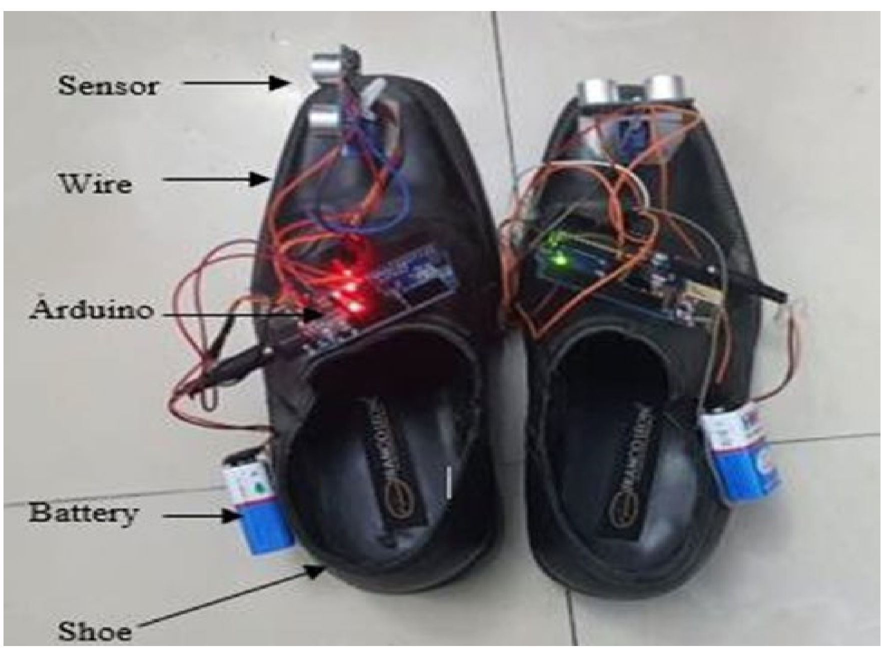

Figure 5. Proposed Smart shoe.

When an obstacle is detected within a 5-meter range, the Smart-shoes emit a beeping sound that serves as an alert. The interesting feature here is that the intensity of the beep increases as the obstacle approaches closer, providing users with a clear auditory cue about the proximity of the obstruction. If an obstacle is detected within a mere 2 meters, the beeping becomes notably louder, and a tactile component comes into play. The vibrating sensor is activated at this point, enabling the user not only to hear but also physically feel the presence of the obstacle. This dual-alert system enhances the user's awareness of their surroundings, ensuring a high level of safety. The sequential steps followed by Smart-shoe to detect obstacles are visually depicted in Figure 6, offering a comprehensive overview of this innovative technology's functionality.

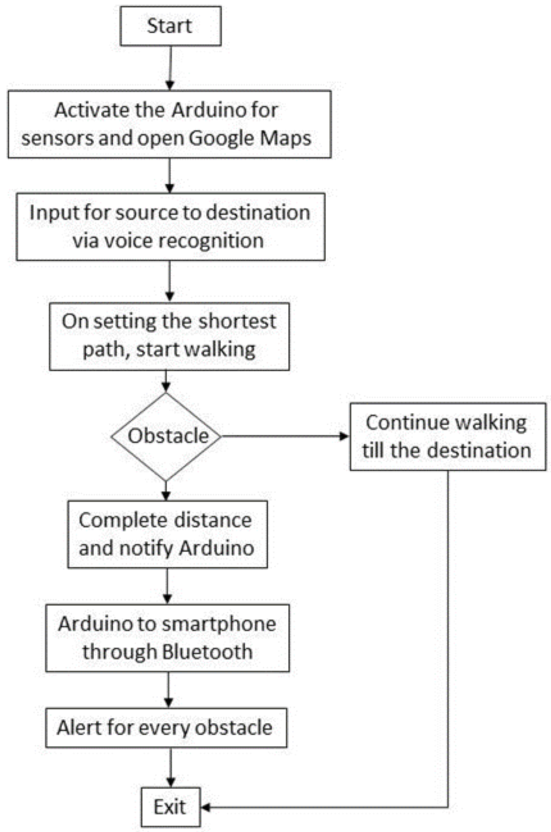

Figure 6. Flow diagram

The functionality and user-friendliness of this program for visually impaired individuals are centered on three key elements: voice commands, hard-coded keys, and text-to-speech conversion. These components collectively empower users to navigate with confidence and independence. The integration of the Google Maps navigation system plays a pivotal role in this solution. It not only furnishes users with their desired routes but does so without necessitating them to seek instructions or assistance. This seamless and intuitive navigation system leverages cutting-edge technology to provide real-time guidance.

Moreover, the program incorporates an advanced obstacle-detection system that serves as a crucial safety feature. It ensures that any obstructions along the user's path are not only detected but also communicated to the user in a logical and clear manner. This proactive approach enables individuals with visual impairments to make informed decisions and take appropriate action, enhancing their overall mobility and safety.

4. Results and Discussion

The robustness of the Smart-shoe's obstacle detection capabilities becomes even more apparent when we delve into the data. This extensive study not only considered regular settings but also examined the performance in crowded environments, mimicking real-world scenarios. The findings reveal that the device encountered obstacles 179 times within this varied context, consistently delivering an impressive average response time of 3.08 seconds.

Figure 7, a visual representation of the device's accuracy, provides a striking visual testament to its efficacy. The graph clearly illustrates a significantly high rate of obstacle detection, reinforcing the Smart-shoe's value as a dependable aid for users in various situations, whether navigating familiar paths or bustling, dynamic environments.

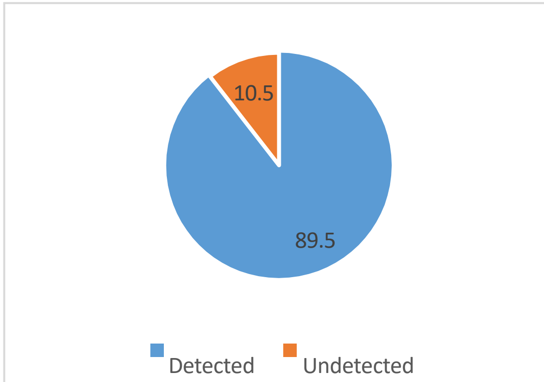

Figure 7. Percentage of obstacle detection

In Table 1, it is shown that in the ordinary mode, the user's average obstacle apprehension distance was 105 centimeters, whereas in crowd mode, it was 48 centimeters.

Table 1. Mean Distance for Detecting Obstacles

Mode	Distance obstacles apprehension
Regular (0 cm-200 cm)	105
Crowd (0 cm-100 cm	48

After evaluating the outcomes of various methods explored in this study, this paper introduces a system of intelligent footwear designed to aid visually impaired individuals in detecting obstacles and navigating their surroundings. These smart shoes are constructed using Arduino, an embedded device. By utilizing the GPS module, the Smart shoe system will be able to direct the user to an obstacle-free route to their desired destination in the future. The suggested system will operate automatically, taking into account real-time pathways and obstacles encountered during the journey. The obstacles will be handled through the algorithm pre-programmed within Arduino, initiating communication via the Android interface. The sensors will detect the obstacle and output values, allowing the obstacle's distance from the sensors to be calculated. Arduino will simplify the data processing and transmit it to the smartphone via an interface device that relies on the information obtained from the sensors.

5. Conclusion

This research offers a potential solution to address the mobility challenges encountered by individuals with visual impairments in Bangladesh. Using a text-to-speech technique, the user can audibly perceive distances from their current location, which can be especially beneficial when an online connection is not available, enhancing usability. The integration of an API enables the background operation of a Google Maps application to aid in navigation by detecting obstacles. However, it's worth noting that the device has certain limitations, such as occasional difficulty in detecting small objects with limited surface area, like gravel, wires, or small bricks.

While these Smart-shoes facilitate a visually impaired individual's experience by providing enhanced perception, hearing, and mobility, they are not without their constraints. To enhance detection capabilities, it is proposed that the number of sensors within the shoes be increased and distributed throughout the design. This, however, comes with the trade-off of increased shoe weight. Therefore, further research is warranted to develop an optimal solution that balances accuracy and weight. Additionally, the device's response time could be reduced to a mere second by modifying the Bluetooth module, as it can occasionally exhibit slower response times. Continued investigation in these areas will contribute to a more effective and efficient solution for visually impaired individuals.(Celik & Ersozlu, 2009).

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Biography

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