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Design Development and Implementation of IOT Based Smart Shoe for Visually Impaired People

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ABSTRACT

This paper presents an innovative technology called the "smart shoe," designed to assist people with visual or hearing impairments in navigating their surroundings more easily. Equipped with advanced sensors and mini-computers, the shoe can detect uneven surfaces or obstacles in the wearer's path. It provides feedback through vibrations or sound alerts to help guide them. Developed with ease of use and practicality in mind, this device aims to empower users, fostering greater confidence and independence. The goal of this technology is to create a more inclusive and secure environment for those with sensory challenges.

Keywords: Assistive Technology, Smart Wearables, Obstacle Detection, Accessibility & Inclusive Mobility

I. INTRODUCTION

All Lately, developments in assistive technologies have allowed for significant improvements in life quality of visually disabled people. According to World Health Organization estimates, more than 285 million people worldwide suffer from some degree of vision impairment and up to 39 million people are completely blind [1]. Traditional aids like white canes and guide dogs are effective but offer little to no feedback and require a lot of active interaction with the environment. These limitations have led researchers to design smarter and wearable assistive technologies through smart assistive shoes, which can make navigation and mobility more intuitive and less intrusive.

In smart assistive shoes, advanced sensor systems are used, such as ultrasonic sensors, vibrators, and buzzers, to detect objects and thus avoid hazardous situations [2]. Further extended utility of the shoes is by piezoelectric sensors that convert walking mechanical energy into electrical energy, thus enabling efficient provision of power and sustainable battery use [3].

Studies have shown that these smart shoes increase mobility and independence for visually impaired persons. The ultrasonic sensors, located in the footwear, can detect collision threats and alert the user through the transmission of various kinds of vibrations and sounds. In this way, the new form of assistive technology has greater promises not only to increase mobility but also to reduce dependency upon traditional aids [5].

The aim of this paper is to develop a less dependent, user-friendly, and sustainable assistive technologies to revolutionize interaction between visually impaired people and their environment.

II. LITERATURE REVIEW

This paper introduces a smart shoe equipped with ultrasonic sensors, vibration sensors, and Bluetooth connectivity. These shoes help guide users to their destinations while alerting them to obstacles in their path through vibration feedback. However, the current design has some limitations such as, it lacks a feature for water detection, which poses a risk of damage to the components if exposed to moisture. Additionally, it does not include the ability to count the number of steps remaining before reaching an obstacle. Further improvements are needed to address these gaps [6].

The study found that the developed support system is highly effective in detecting obstacles and helping visually impaired individuals navigate safely to their destinations. By maximizing the capabilities of ultrasonic sensors, the system greatly improves mobility for blind and visually impaired users, enabling safer and more independent travel. Notably, its user-friendly design eliminates the need for carrying bulky equipment over long distances and requires no special training to use, making it a practical solution for everyday use.[7]

The proposed system integrates both hardware and software into an embedded solution designed to serve as a smart navigational aid for visually impaired individuals. It not only detects obstacles and wet surfaces but also includes a fall detection feature. If a fall occurs, it can pinpoint the user's location and send an alert to a caregiver or healthcare professional through a dedicated smartphone app, ensuring timely assistance.[8]

The proposed navigation assistance system is designed as a smart embedded solution that blends hardware and software to support blind and visually impaired users. Its main functions include detecting obstacles, identifying wet surfaces, and locating the user in case of a fall, with alerts sent through a smartphone app. Additionally, the shoes are equipped with vibration alerts, making them useful for individuals who are deaf, as they might not hear an audible buzzer.[9]

This paper incorporates piezoelectric sensors which are materials that produce an electric charge when subjected to mechanical stress or deformation, and can also respond to electric signals by changing shape. This approach is aimed at conserving energy and creating a more sustainable smart shoe solution.[10]

III. DESIGN AND SPECIFICATION

The primary objective of this paper is to implement obstacle detection using an ultrasonic sensor, coupled with auditory and tactile feedback mechanisms. The project utilizes an Arduino Uno microcontroller to interface with the sensors and manage the detection process.

The ultrasonic sensor is employed to identify obstacles within a range of 50 from its position. Upon detecting an obstacle, the system triggers both an auditory alert via a buzzer and a tactile alert through a vibrating motor. These alerts serve to promptly notify individuals of obstacles obstructing their path, enhancing situational awareness and promoting safety.

Furthermore, a piezoelectric sensor is integrated into the system to harness and convert pressure exerted into electric energy. This feature extends the battery life of the device, ensuring prolonged operation without frequent recharging or replacement.

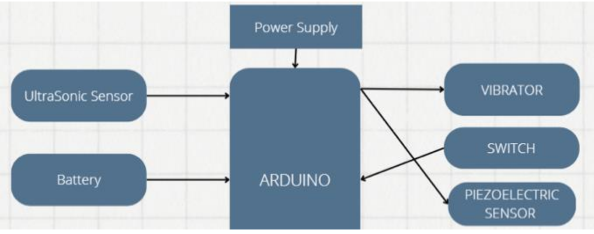

Fig. 1. Block Diagram of Smart Shoe

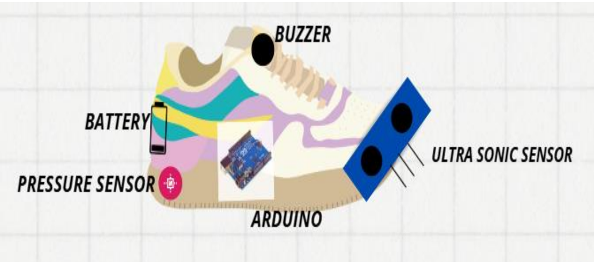

Fig. 2. Model of Smart Shoe

A. Algorithm

First we define the pins for ultrasonic sensors - such as the trigger pin, trigPin, and echo pin, echoPin. Next we specify the pins for the buzzer, buzzerPin and for the vibration motor, vibrationPin. Set up trigPin as an output and echoPin as an input. Similarly, set up pins of the buzzer and vibration motor as an output, ensure that the buzzer and vibration motor are initially in "off" state. Therefore, serial communication is initiated at a baud rate of 9600 to transfer data.

In the main loop, first clear the trigger pin by setting it to LOW for 2 microseconds. Then send an ultrasonic pulse by setting the trigger pin HIGH for 10 microseconds and then back to LOW. Then take the pulseIn() function with the echo pin and calculate the distance from the pulse duration coming from the echo pin using the appropriate formula.

Check whether the sensed distance is smaller than 50 centimetres. If it is, turn both of the outputs - buzzer and vibration motor. Else, send a signal to enter off the two outputs. Add a 100 millisecond delay before proceeding with the measurement cycle again.

B. Equations

Distance Measurement using Ultrasonic Sensor

The ultrasonic sensor calculates the distance to an obstacle using the time it takes for the ultrasonic pulse to return after hitting an object. The distance (d) can be calculated using:

Where, v is the speed of sound in air (approximately 343 meters per second at room temperature).

t is the time taken for the echo to return.

The division by 2 accounts for the pulse traveling to the object and back.

$$d = (v * t)/2 \tag{1}$$

Vibration Motor Activation Based on Distance

To activate the vibration motor based on the distance detected this equation can be used.

Where, Imax is the maximum intensity of the vibration.

D is the measured distance to the obstacle.

d_{max} is the maximum range for detecting obstacles (e.g., 50 cm).

$$Vibration\ Intensity = \begin{cases} I_{\max} \times \left(1 - \frac{d}{d_{\max}}\right), & if\ d \leq d_{max} \\ 0, & if\ d > d_{max} \end{cases} \tag{2}$$

Energy Harvesting using Piezoelectric Sensor

The energy (E) generated by a piezoelectric sensor when the user steps on it can be calculated Where, k is the stiffness constant of the piezoelectric material.x is the displacement (or compression) due to the force applied when stepping.

$$E = \frac{1}{2} * K * x^2 \quad (3)$$

Battery Life Calculation

To calculate the estimated battery life (T) of the smart shoe, you can use the equation:

Where,$C_{battery}$ is the capacity of the battery in milliampere-hours (mAh).I_{draw} is the average current draw of the system in milliamperes (mA).

$$T = \frac{C_{battery}}{I_{draw}} \quad (4)$$

Haptic Feedback Signal

The intensity of haptic feedback (Vh) provided by the vibration motor based on proximity to an obstacle can be modelled

Where,V_{max} is the maximum voltage applied to the vibration motor.d is the distance to the detected object.dc is a constant that determines the sensitivity range of the haptic feedback.

$$v_h = V_{max} * e^{-d/dc} \quad (5)$$

Signal Processing

Calculating the signal to noise ratio

Where,SNR: Signal-to-noise ratio (dB).P_{signal}: Power of the desired signal (Watts).P_{noise}: Power of the noise (Watts)

$$SNR = 10\log_{10}\left(\frac{P_{signal}}{P_{noise}}\right) \quad (6)$$

Vibration Frequency for Feedback

Determines the optimal frequency for vibration feedback to alert the user using -

Where,f_v: Vibration frequency (Hz).k: Stiffness of the vibration motor (N/m).m: Mass of the vibrating element (kg)

$$f_v = \left(\frac{1}{2}\pi\right)\sqrt{\frac{k}{m}} \quad (7)$$

Piezoelectric Power Generation

It calculates the electrical power generated by piezoelectric sensors embedded in the shoe.

Where,P: Power generated (Watts).k: Piezoelectric constant (Farads).V: Voltage generated (Volts).f: Frequency of foot impact (steps per second)

$$P = \frac{1}{2} * k * V^2 * f \quad (8)$$

C. Components

The ultrasonic sensor serves as the cornerstone of the smart shoe system's proximity detection capabilities. Utilizing ultrasonic waves, the sensor measures the time taken for these waves to bounce back after being emitted, thus accurately determining the distance between the shoe and nearby objects. This functionality is invaluable in scenarios such as obstacle detection, pedestrian awareness, and environment mapping. By providing real-time distance data, the ultrasonic sensor enhances user safety and spatial awareness, particularly in crowded or dynamic environments.

TABLE I COMPONENTS USED

Sno	Components	Values
1.	Ultrasonic Sensor	Distance Measurement
2.	Buzzer	Audio Feedback
3.	Vibration Motor	Haptic Feedback
4.	Piezoelectric Sensor	Mechanical Energy To Electrical Energy
5.	Microcontroller/Arduino Uno	Processing Unit

Integrated into the smart shoe system, the buzzer acts as an auditory feedback mechanism, alerting the user to critical events, notifications, and alarms. By converting electrical signals into sound waves through rapid vibration, the buzzer delivers clear and discernible alerts, even in noisy or distracting environments. Its role in providing immediate, real-time feedback enhances user awareness and responsiveness, promoting safety and situational awareness during various activities, such as walking, running, or navigating unfamiliar terrain.

The vibration motor plays a pivotal role in augmenting the user experience through tactile feedback. By generating controlled vibrations, the motor provides subtle yet effective cues and notifications to the wearer of the smart shoe. These tactile sensations can convey a wide range of information, including directional guidance, alerts for navigation or obstacle avoidance, and feedback on user interactions. The vibration motor's ability to deliver haptic feedback enhances user engagement and interaction, particularly in scenarios where auditory or visual feedback may be inadequate or impractical.

Incorporating a piezoelectric sensor into the smart shoe system enables the detection and measurement of pressure exerted on the shoe's surface during movement. This sensor converts mechanical stress or pressure into electrical signals, allowing for real-time monitoring of foot pressure distribution, gait analysis, and activity tracking. By capturing biomechanical data related to foot movement and posture, the piezoelectric sensor facilitates insights into user behavior, performance, and potential injury risks. Its applications span a wide range of domains, including sports biomechanics, physical therapy, and ergonomic design.

Central to the operation of the smart shoe system is the microcontroller, serving as the brain that orchestrates the functionalities of all integrated components. The microcontroller processes sensor data, executes control algorithms, and manages communication between various system elements. Leveraging an Arduino microcontroller platform offers advantages such as flexibility, ease of programming, and compatibility with a vast array of sensors and peripherals. Its role in enabling rapid prototyping, development, and customization makes it an ideal choice for wearable technology applications, including smart shoe systems.

IV. RESULTS and DISCUSSION

The Smart Shoe for visually impaired individuals represents a significant advancement in embedded system technology, integrating both hardware and software to create an accessible and user-friendly solution. At its core, the system relies on an array of sensors that play a crucial role in guiding users, making it a powerful tool for those with visual impairments. The seamless interaction between these components provides a dependable, hands-free navigational aid that enhances safety and independence. Compared to the existing solutions this smart shoe is sustainable and less intrusive.

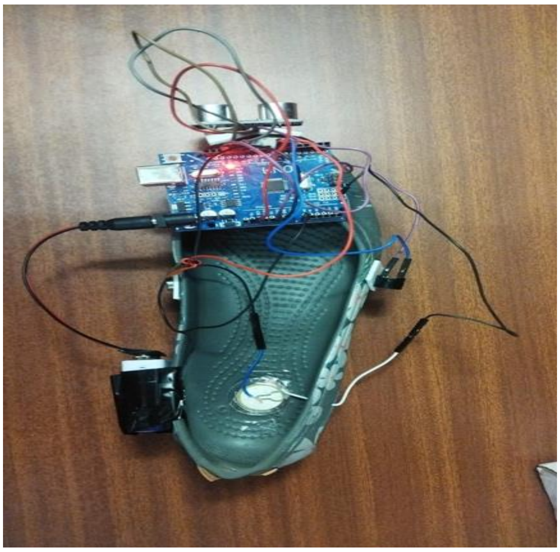

Fig. 3. Top view of the prototyped shoe

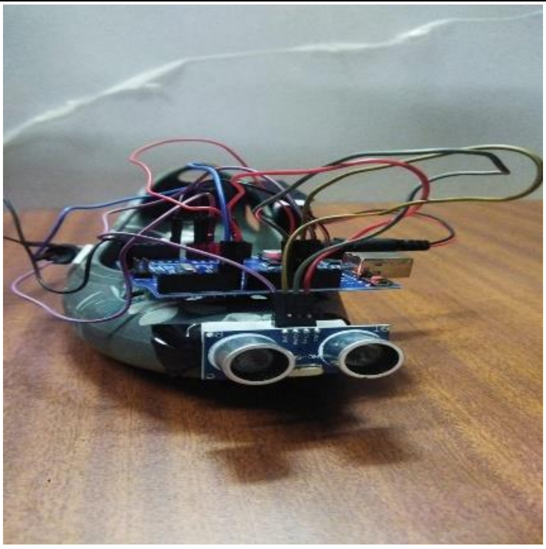

Fig. 4. Front view of the prototyped shoe

V. CONCLUSION

By addressing some of the everyday challenges faced by the visually impaired, such as detecting obstacles, wet surfaces, and falls, this project has the potential to greatly improve their quality of life. The ability to receive immediate alerts and guidance not only increases their mobility but also helps build confidence in navigating unfamiliar environments. Additionally, its design eliminates the need for complex or cumbersome equipment, focusing instead on practical, wearable technology that requires minimal training.

Overall, this smart shoe system stands out as an innovative solution capable of addressing the unique needs of the visually impaired community. By leveraging sensor technology and smart design, it offers a sustainable, efficient, and user-centred approach to assistive technology, opening the door to more independent and safer travel experiences.

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