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Article

Arduino-Based Smart Boot Guidance System for Visually Impaired Ladies

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Abstract: This research introduces an embedded-based assistive system designed to support visually impaired and blind individuals in their daily mobility. The proposed "Smart Boot Guidance System" integrates both hardware and software components to enhance safety and independence. The system utilizes ultrasonic sensors, a microcontroller (Arduino Nano), and a buzzer to detect obstacles, identify slippery surfaces, and recognize falls. When a fall or obstacle is detected, an alert signal is sent to notify a responsible person. The prototype aims to provide a low-cost, compact, and reliable solution that ensures electrical safety and usability in real-life scenarios. Preliminary testing demonstrated promising results in obstacle detection and fall alerts. Future work will focus on incorporating additional sensors to increase measurement accuracy and minimize false alarms, as well as evaluating the system on a larger sample population to further improve its performance and reliability.

Keywords: Smart Boot, Visually Impaired, Embedded System, Ultrasonic Sensor, Arduino

1. Introduction

Vision is regarded as the most essential human sense, as nearly 83% of the information a person receives from the environment comes through sight. This sense allows individuals to perform their daily activities effectively by helping them move safely within their surroundings, engage in social communication, carry out tasks, obtain information, and detect potential hazards. Therefore, the absence of vision severely affects an individual's quality of life and psychological well-being.

People with visual impairments (VIP) encounter significant challenges in their everyday lives, including reduced independence and self-confidence, since they are often unable to perform many routine activities without assistance. Unaccompanied visually impaired individuals are at a high risk of accidents and injuries, as they may not be aware of obstacles or dangers in their path. Furthermore, this condition imposes a heavy financial burden on both families and governments.

For example, in the United States, statistics show that the unemployment rate among blind individuals is extremely high — approximately 75% of working-age blind people struggle to secure jobs. Additionally, only around 10% of blind children receive proper education and learn Braille, leaving many without literacy skills. To help visually impaired

individuals lead more independent and productive lives, families and authorities spend significant amounts on specialized care and training. This includes the involvement of various professionals such as Braille instructors, psychologists, mobility and orientation trainers, and vision rehabilitation therapists — though their numbers often fall short of meeting the real demand.

According to the World Health Organization (WHO), about 1.3 billion people worldwide suffer from some degree of vision impairment, including 36 million who are completely blind, 188.5 million with mild impairment, and 217 million with moderate to severe impairment. Roughly 80% of these cases are considered preventable. The majority of visually impaired individuals are over the age of 50, and around 87% of blind people live in low-income or developing regions. By the year 2050, the number of people with vision impairment is expected to triple due to factors such as global population growth, longer life expectancy, and the improved survival rate of premature infants. The figure below (Figure 1) shows the percentage of blind people across the globe.
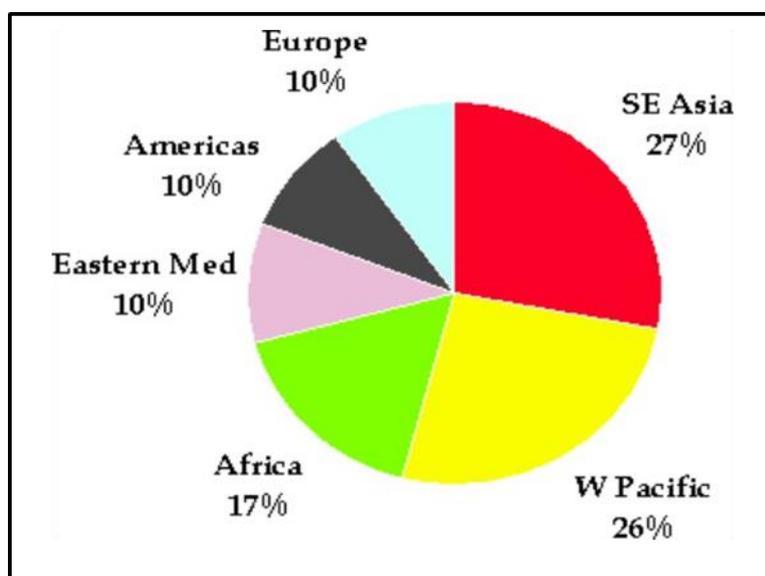
Figure 1. A pie chart showing blind people across the world.

Literature review

• Kiran Rakshana R and Chitra C et al. developed a system designed to enable visually impaired individuals to listen to the contents of printed or text-based images. The system is built using a camera, microphone, ultrasonic sensor, Raspberry Pi, earphones, and a vibration motor. It operates through three major components: a voice search module, an image processing module, and a speech processing module.

The first module, voice search, uses keyword-based voice commands—the user speaks a keyword which is received and processed by the Raspberry Pi. The second stage involves image capture and text extraction using Optical Character Recognition (OCR). The extracted text is then transformed into speech through a Text-to-Speech (TTS) synthesizer. The image processing pipeline includes several stages such as binarization, noise reduction, de-skewing, segmentation, and feature extraction, all of which ensure accurate text retrieval.

Additionally, the system integrates ultrasonic sensors to detect nearby obstacles, alerting users via vibration signals, which helps prevent collisions. This allows visually impaired individuals to read books and recognize text from images effectively. However, the system lacks emotion detection and can only recognize predefined text stored in the system's database.

- Vipul Samalam et al. proposed a Speech Assistance System using OCR for the Visually Impaired, developed at Vivekananda Education Society's Institute of Technology. This camera-based assistive device helps visually impaired users read printed materials, such as labels, notes, and product packaging. The system employs a camera, a microphone, a Raspberry Pi, OCR, and a Text-to-Speech (TTS) synthesizer.

The process begins when the camera captures an image, which is then processed using OCR technology. The binarization step converts grayscale images into binary form, facilitating object detection and shape analysis. The text extracted through segmentation and feature extraction is subsequently transformed into speech via the TTS module.

Although effective in text recognition, the system cannot interpret images or detect numerical data, limiting its range of applications.

- Christos Liambas et al. introduced an autonomous mobile reading system capable of dictating text from documents using an image-processing-based algorithm. The setup incorporates a Raspberry Pi 2B, camera-mounted glasses, a Bluetooth headset, Optical Character Recognition (OCR), and a Text-to-Speech (TTS) engine.

The algorithm follows three major steps: calibration, line separation, and data preparation for OCR and TTS. During calibration, the camera captures video frames and guides the user through audio instructions to correctly position the document (ensuring both pages are visible). The line separation stage then identifies the lines of text on each page. Finally, OCR reads each character, and the text is converted into audio output using the TTS module, which is played through earphones.

Despite its efficiency, the system cannot recognize handwritten content, mathematical formulas, or text displayed on screens such as monitors or newspapers.

2. Materials and Methods

Materials (Hardware Components)

The smart boot system was built using the following main hardware components:

1. Ultrasonic sensor

An ultrasonic sensor is a device that determines the distance between itself and an object by utilizing ultrasonic sound waves. It operates through a transducer that both emits and receives ultrasonic pulses, which provide information regarding the object's distance. High-frequency sound waves are reflected off surfaces, creating unique echo patterns that help in measurement.

Working Principle of Ultrasonic Sensors:

Ultrasonic sensors function by generating sound waves at frequencies higher than the human hearing range. The transducer serves as both the transmitter and receiver of these waves. In many cases, a single transducer is used to send an ultrasonic pulse and then capture its echo. The sensor calculates the distance to the object by measuring the time interval between the emission of the pulse and the reception of its reflected signal.
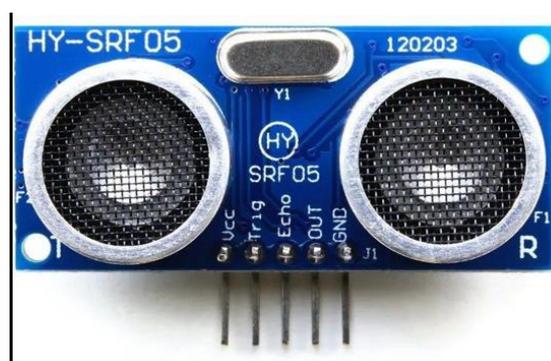

Figure 2. Ultrasonic sensor.

2. Arduino Nano

The Arduino Nano is a compact, fully functional, and breadboard-compatible microcontroller board built around the ATmega328 (Arduino Nano 3.x). It provides nearly the same capabilities as the standard Arduino board but comes in a smaller form factor. Unlike the regular version, it does not include a DC power jack and instead connects using a Mini-B USB cable.
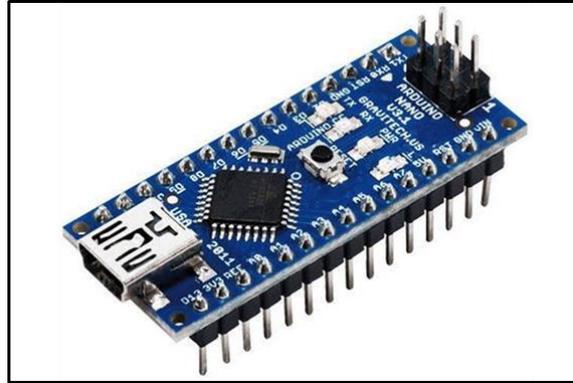

Figure 3. Arduino Nano.

3. Buzzer 9V

A 9V buzzer is an audio signaling component that can be mechanical, electromechanical, magnetic, electromagnetic, electroacoustic, or piezoelectric in nature. It produces sound when powered by an electrical signal and can be operated using an oscillating electronic circuit or another type of audio source. The components mentioned here are intended solely for hobby electronics or DIY projects.

Figure 4. Buzzer 9V.

4. Battery

Duracell Plus Power 9V batteries provide dependable, long-lasting energy for a wide range of devices. These versatile batteries are designed to deliver consistent performance, making them ideal for everyday use. They are particularly suitable for powering devices such as motorized toys, flashlights, portable gaming consoles, remote controls, CD players, and other household electronics that require reliable power.
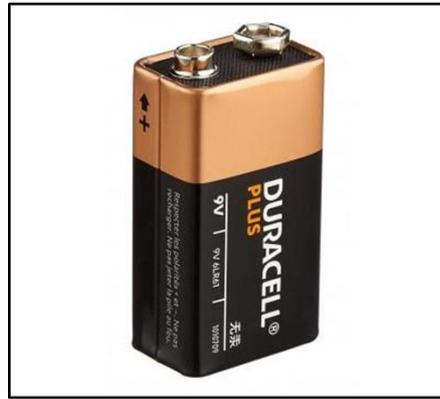
Figure 5. Battery.

5. Jumper wire

A jumper wire is an electrical conductor, or a set of conductors within a cable, equipped with connectors or pins at both ends. It is commonly used to establish temporary connections between components in electronic circuits or breadboard setups.

Figure 6. Jumper Wire.

6. Plastic Box

It is used to connect and integrate all the components inside the box, allowing signals and power to flow between them efficiently.

Methods

Overview

This study presents the design and implementation of a smart wearable system in the form of a boot, intended to assist visually impaired individuals in obstacle detection. The system was developed using an Arduino Nano microcontroller, ultrasonic sensors, and a buzzer to provide real-time audio feedback. The overall goal was to build a compact, low-cost, and user-friendly device that improves mobility safety.

System Design Procedure

The proposed method consists of several stages that integrate hardware assembly, software development, and practical testing.

1) Sensor Placement and Detection

An ultrasonic sensor was positioned on the front section of the boot to continuously monitor the distance between the user and potential obstacles.

The sensor operates by transmitting ultrasonic sound waves and calculating the time delay of the returning echo to determine the obstacle's distance.

2) Signal Processing

The Arduino Nano serves as the control unit of the system. It receives the distance data from the sensor and processes it using the programmed algorithm.

The distance is calculated by the equation:

$$\text{Distance (cm)} = \frac{\text{Time} \times 0.034}{2}$$

150–100 cm → slow beep

100–50 cm → moderate beep

less than 50 cm → rapid beep

This variation in sound frequency helps the user recognize the proximity of obstacles.

3) Feedback Mechanism

A 9V buzzer was utilized to provide audible alerts. The buzzer's frequency changes proportionally with the obstacle's distance. This auditory feedback ensures that the user receives a clear and immediate warning in different environments.

4) Power Source and Circuit Assembly

All electronic components (sensor, Arduino, and buzzer) were connected using jumper wires and powered by a 9V battery.

To ensure safety and durability, the circuit was enclosed inside a plastic case integrated into the boot's design, allowing comfort and mobility.

As shown in Figure 8, all the components are arranged neatly inside the boot to ensure protection and functionality.
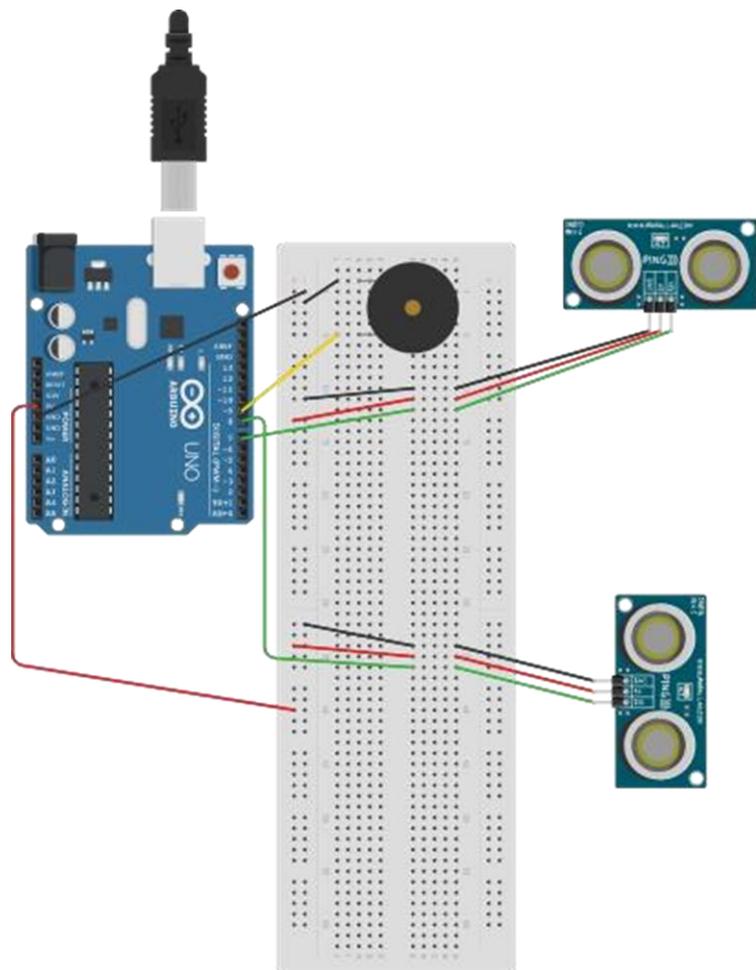

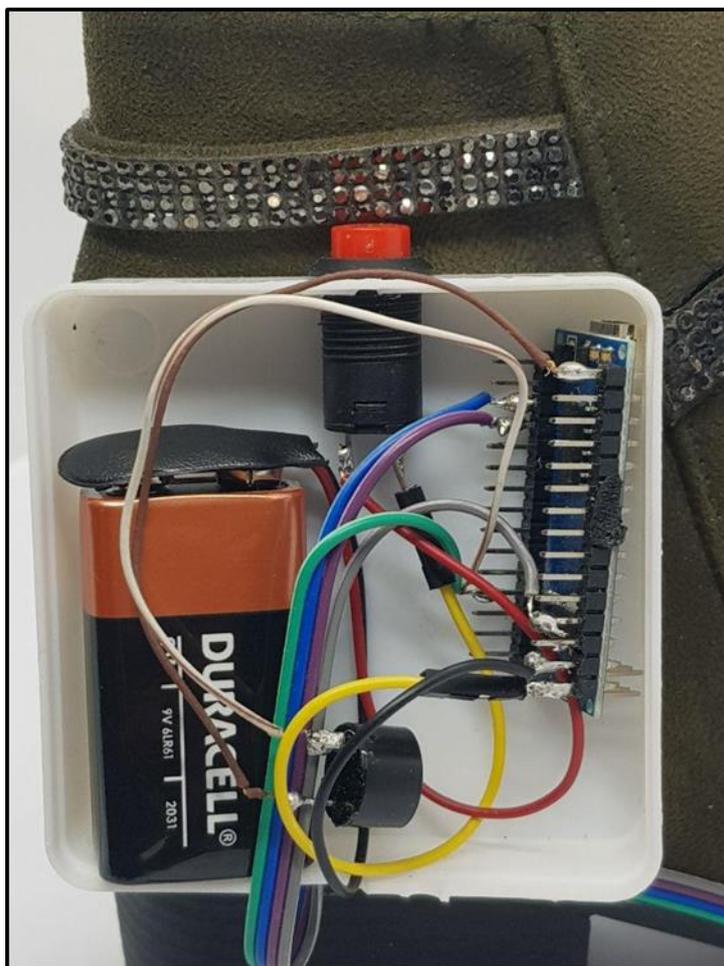**Figure 7.** Block Diagram of the Proposed Smart Boot Guidance System.

Figure 8. Smart Boot Inside View.

Software Implementation

The system was programmed through the Arduino IDE, which provides a user-friendly environment for coding and debugging.

The algorithm was written in C++ and uploaded to the Arduino Nano. The code controls the ultrasonic sensor and buzzer behavior according to the measured distance. Serial communication was used for testing and calibration during development.

Testing and Validation

The prototype was tested under different real-life conditions by placing obstacles at various distances ranging from 10 cm to 150 cm.

Each test confirmed that:

- The sensor accurately measured the distance.
- The buzzer responded promptly with distinct tones for different proximity levels.
- The system remained stable and power-efficient during continuous use.
- These results indicate that the proposed method successfully achieved real-time obstacle detection and reliable feedback suitable for visually impaired users.

3. Results and Discussion

The developed smart boot prototype was successfully tested in various indoor and outdoor environments to evaluate its obstacle detection performance. The ultrasonic sensor accurately measured distances within a range of 10 cm to 150 cm, providing reliable feedback through the buzzer. The response time of the system was minimal, allowing users to receive alerts promptly when approaching obstacles. Experimental results showed that

the buzzer's sound frequency effectively indicated the proximity level, helping visually impaired users to interpret their surroundings. The system demonstrated high stability and power efficiency during continuous operation, with no signal loss or malfunction observed. Furthermore, the compact integration of components ensured comfort and portability when worn for extended periods. The discussion highlights that this embedded design provides a cost-effective and user-friendly mobility aid. Overall, the results confirm that the proposed smart boot enhances navigation safety and independence for visually impaired individuals.

4. Conclusions

The proposed system presents an embedded-based solution that integrates both hardware and software components to serve as an assistive technology for individuals who are blind or visually impaired. The system is designed to detect obstacles, identify slippery surfaces, and monitor accidental falls, sending an alert notification to a designated contact in case of an emergency.

The developed prototype successfully achieved the creation of a low-cost, independent, and electrically safe pair of smart shoes intended to assist visually impaired and blind users by preventing collisions and providing support during falls. Moreover, future work aims to test the prototype on a larger user group to assess performance, identify potential limitations, and enhance system reliability in upcoming versions.

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