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OBSTACLE DETECTION FOR VISUALLY IMPAIRED PEOPLE USING IOT

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ABSTRACT

Obstacle detection is one of the most critical challenges faced by visually impaired people, especially in unfamiliar environments where it becomes difficult and dangerous to navigate. This research proposes an IoT-based smart assistance system that aids mobility, safety, and independence in blind users through real-time obstacle detection and alerting. The proposed system integrates ultrasonic sensors with a microcontroller, such as Arduino or NodeMCU, and wireless communication modules to scan a user's surroundings continuously. If an obstacle is detected in a specified range, the system would send feedback via vibration or audio alerts directly to ensure the swift response of the user against the chances of collision. It also connects the module to an IoT-enabled cloud platform for remote monitoring, data logging, and future scalability for advanced features like GPS-based navigation, emergency alerts, and caregiver communication. The compact, wearble design aims to ensure comfort

and convenience while maintaining accurate detection performance. Experimental results confirm that the system efficiently identifies obstacles of various sizes and distances in different environmental conditions, whether dynamic or poor light, which essentially enhances the safety and situational awareness of users. This research points to the potential that IoT technologies have in delivering cost-effective, reliable, and user-friendly assistive devices for visually impaired individuals. The proposed solution, with sensor-based detection integrated into intelligent communication and real-time feedback, will contribute to enhancing independent mobility and improving the quality of life among the blind.

KEYWORDS : Obstacle detection, visually impaired, ultrasonic sensors, real-time alerting, wearable device, assistive technology.

Introduction

The integration of technology in health and assistance sectors has proven to be one of the most revolutionary ideas in the 21st century so far. The populations that derive benefits from these ideas include those that are visually impaired, in which their mobility and freedom are hampered due to their inability to detect objects around them. As estimated by World Health, more than 285 million people in the world are visually impaired, out of which 39 million are completely blind. For completely blind people, it is risky and problematic to move around in crowded and even familiar areas around them. The current aids used by these people, which include white sticks and guide dogs, are limited in their range and adaptability to different environments.

Internet of Things (IoT) is found to have become an innovative approach for linking physical objects and communication networks for real-time information and analysis. When considering the use of assistive technology, IoT brings its own merits such as simple integration of sensor modules, constant observation and tracking systems with less power consumption and flexible architecture adaptable to personal needs and requirements. With the use of IoT-assisted systems and solutions, there is scope to develop wearable and portable assistive technology solutions capable of identifying roadblocks and notifying users with appropriate audio and vibration responses based on environmental inputs and conditions. These solutions are capable of covering extended functionality with greater adaptability than existing solutions for a holistic and reliable experience for visually challenged people in terms of navigation systems and solutions.

Obstacle detection in visually impaired individuals is a multidisciplinary integration of sensing technologies, microcontroller technology, and communications technology together with human-centered designs. Various technologies like ultrasonic sensors, infrared modules, LiDAR, and computer vision are used in detecting environmental space information. Microcontroller technology like Arduino or Raspberry Pi is the central computation system in this scenario, allowing the system to instantly process the selected environmental information. Technologies like Bluetooth communications, Wi-Fi communications, or LoRa communications enable networking between devices as well as cloud services, allowing the system to achieve complex functionalities like data logging, analytics, and detection in a centralized manner. However, the critical aspect in this technology is not just networking and integrating various technologies together; instead, the focus should be on maximizing portability, battery life, price, and comfort to visually impaired individuals. In addition to this, there should be a focus on how much the visually impaired understand information, to avoid causing unnecessary distractions.

This research paper, entitled “Obstacle Detection for Blinded Peoples using IoT”, aims to provide a solution for the issues above by introducing a novel approach for real-time obstacle detection and warning using a slipper-based IoT system. In contrast to other existing tools for the visually impaired, such as the white cane, this system for the first time proposes the integration of intelligent sensors into a pair of shoes for the purpose of monitoring the path continuously without the use of additional gadgets or assistance from a separate device held in the hands constantly for support and references. This research tackles not only the technical development of the system but also the aspects of comfort and affordability for a more feasible solution for the visually impaired using the proposed slipper system over the existing tools for the time being.

Related Works

Nur Azira Jasman et. al. [1] describes an obstacle detection system for blind individuals incorporating an ESP32 microcontroller, ultrasonic and PIR sensors, and a smartphone application designed using MIT App Inventor. The system has an accuracy level of above 89% to detect an obstacle, angle, and puddle, along with real-time voice assistance for navigation. Sangam Malla et. al. [2] introduces an Internet of Things (IoT) Smart Blind Stick containing Arduino UNO and ultrasonic, infrared, moisture-sensing, and light sensors as well as the Viola-

Jones algorithm that assists through voice notification via a headset regarding obstructions, water, and environmental factors for the visually impaired. Sunnia Ikram et. al. [3] proposed a smart knee glove designed with ultrasonic sensors, PIR sensors, Arduino Uno, IoT technology, and machine learning classifiers is presented. By utilizing a voting classifier, a total accuracy of 88.34% is obtained at a distance of 4 meters, along with audio alerts to improve the mobility and independence of visually impaired persons. Muhammad Siddique Farooq et al. [4] introduces an IoT-based intelligent stick that includes an ultrasonic sensor, water sensor, GPS/GSM, and an object recognition camera. The device also allows the user to choose either a vibrating signal option or a vocal reminder option, in addition to its location tracking facility and emergency SMS service. It is light in weight, waterproof, and adjustable. Xinnan Leong et. al. [5] proposed work describes smart glasses that incorporate Raspberry Pi, a camera, and a pre-trained CNN for the visually impaired. The proposed assistive system recognizes objects and calculates distances, providing the user with auditory or tactile feedback. The proposed assistive solution is portable, hence useful for independence. P. Vennila et. al. [6] proposed work creates a smart IoT navigation solution with an ESP32 microcontroller, ultrasonic, and PIR sensors, and a mobile application developed using MIT App Inventor. It offers accurate results with over 87% accuracy up to a distance of 490 cm and angles of 90°, providing real-time voice notifications for visually impaired persons. Ahmed Mueen et. al. [7] presented for research aims to incorporate a fog-based IoT cloud navigation system for the blind and visually impaired. This system aims to incorporate the concept of Bald Eagle Search for route identification, the YOLOv3 Tiny algorithm for multiple obstacles, and the A3C algorithm utilizing the concept of reinforcement learning. Sunnia Ikram et. al. [8] examines the application of deep learning-based obstacle detection systems enabled by the IoT, YOLOv3, MobileNetv3, RetinaNet, and Faster R-CNN models, designed to aid the visually impaired. It is found that YOLOv3 has 86% precision in the resultant application compared to other models. Mohammad Marufur Rahman et. al. [9] proposes a wearable e-guidance system for the visually impaired based on the use of ultrasonic sensors, PIR motion sensor, accelerometer, ESP32 microcontroller, Bluetooth module, and smartphone application. It gives 88.34% accuracy for the identification of obstacles, humps, fall, and moving objects, along with alerts to guardians. Zahraa A. Ali et. al. [10] introduces a visually impaired persons, two affordable obstacle detection tools, a smart belt and a smart stick, have been designed and analyzed in this paper. Compared to a conventional white stick, it was observed that the belt exhibited greater accuracy regarding obstacle avoidance, while the stick was easier to use. Shubham Suman et. al. [11] presented for the first time in this paper is Vision Navigator, a system integrating a Smart-fold Cane and a Smart-alert Walker for the visually impaired. Under the SSD-RNN architecture, the system identifies and predicts the type of obstacles for auditory signal production. This yields accurate results of up to 85.54% for both indoor and outdoor environments. Wasiq Khan et. al. [12] introduces SOMAVIP, which represents the Smart Outdoor Mobility framework designed for the visually impaired. The ObDtM model, based on their own custom dataset. of eight dangerous objects using deep transfer learning with YOLOv5 and Mask R-CNN, achieved 87% mAP. However, the model has been integrated with the IoT concept and the smart city infrastructure. Salam Dhou et. al. [13] presents the idea of an IoT-assisted smart cane with the mobile sensor unit incorporating ultrasonic sensors, acceleromet.er/gyroscope, GPS, cameras, and Raspberry Pi. Housing machine learning algorithms, the classification of obstacles takes place, while notification messages alert the user as well as the caregivers. This assists visually impaired persons in navigating independently while ensuring safety. Usman Masud et. al. [14] proposes a smart assisting system for blind people using Raspberry Pi and Arduino with ultrasonic sensors and cameras, which classify scenes and identify obstacles using object detection techniques related to Viola-Jones and TensorFlow. Shahzadi Tayyaba et. al. [15] proposed an IoT-based smart home navigation system for the blind using ultrasonic sensors, Bluetooth devices, and fuzzy logic controllers has been proposed that utilizes inputs regarding obstacle distances, direction, and locations to produce sound commands. The Mamdani model simulation proved safe indoor movement and obstacle avoidance. Md. Atikur Rahman et. al. [16] introduces an assistive technology for the visually impaired using IoT technology in collaboration with laser sensor technology, Pi camera technology, SSD-MobileNet, and SIFT techniques for recognizing objects as well as currencies. Other features include fall detection, location identification by GPS technology, and transmitting data in IoT technology. The testing resulted in accuracy rates of almost 89%. Ahmad Abusukhon et. al. [17] proposes the use of affordable IOT bracelets with ultrasonic sensors, NodeMCU, and the Firebase platform to aid the visually impaired in navigating indoors. The proposed system can detect obstacles, compute optimal positions, and give audio directions for the visually impaired to follow. The proposed system has a fall detection mechanism with a delay of milliseconds, a cost of $29, and has better simplicity, efficiency, and accuracy than the existing systems for the visually impaired. N.M.A.Nazri et. al. [18] introduces a smart cane with ultrasonic sensors designed to detect obstacles, water sensors to detect puddles, and GPS tracking using Blynk is introduced. The prototype was tested on ten users to improve navigation safety in outdoor environments. Future improvements include the addition of multi-angle sensors, artificial intelligence algorithms to detect obstacles, more robust alert signals, and the ability to connect to IoT technology. Md. Atiqur Rahman et. al. [19] presents an IoT-based solution for blinds using Raspberry Pi, stereo cameras, ultrasonic sensors, YOLO object and currency recognition, face recognition, OCR, and speech processing. The proposed system combines GPS, cloud, and web applications and provides accurate indoor and outdoor guidance, perception, and monitoring of guardians. Abhijit Pathak et. al. [20] presents a voice-controlled blind stick based on IoT and Arduino UNO with ultrasonic sensor, infrared sensor, water sensor, and ISD1820 voice module is introduced. Obstacles, stairs, and puddles are identified up to 4 meters with voice notification. Prototype had accuracy of 83% with low-cost assistance service for visually impaired persons. Krupal Jivrajani et. al. [21] proposes the design of an A IoT-based smart stick that incorporates the functionalities of obstacle detection, object recognition, currency recognition, health tracking, GPS tracking, and emergency notification systems for the benefit of the visually impaired. The proposed smart stick has the potential to offer enhanced mobility, safety, and quality of life to the visually impaired. The proposed smart stick utilizes the concepts of deep learning and IoT to provide. Jong Hyeok Han et. al. [22] proposed study, a walking assistance system using a deep learning approach, combining the use of ultrasonic sensors, camera, and YOLOv2 for the recognition of obstacles, is described. It provides sound and touch feedback, reaching a high accuracy of 82% for all objects. Muhammad Irfan Yazid et. al. [23] discusses the development of an obstacle detection cap for the visually impaired using ESP32, ultrasonic sensors, warning alarms, and the GPS system connected to the Telegram app. The system has been tested among the students and has proved effective for the detection of obstacles ranging from 2-300 cm and the accurate location-tracking system. Anamika Maurya et. al. [24] presents an obstacle detection system based on HGSO C R Deep CNN. Videos are transmitted through HGSO, taking into account distance, energy, and delay, and are then processed for frame extraction, feature extraction, segmentation, and classification. Experiments showed a classification accuracy of 85.9%, a high value for sens, spec, throughput, and low value for delay. Pratik Kharat et. al. [25] introduces a new project called "Visioner." It is a smart stick for the visually impaired that uses IoT, Arduino Uno, LiDAR, ESP32-CAM, and YOLOv4. The prototype was accurate, inexpensive, and power-efficient, making it a remarkable improvement over previous solutions to aid visually impaired persons. Nitin Kumar et. al. [26] proposes the design of a deep learning-based navigation aid for the visually impaired using YOLOv5 incorporated within the wearable mask and the smart cane. With the combination of vision detection capabilities, GPS tracking systems, and ultrasonic technologies, the proposed algorithm provided an overall accuracy rate of 79.24%. Yashvi Khera et. al. [27] proposed an IoT-based smart blind guiding system utilizing ultrasonic sensors, vibration, buzzer, GPS, GSM, and PIR sensors. This will improve safe mobility, obstacle detection, emergency notifications, tracking, and social distancing in the era of COVID, allowing blind people to move about independently and safely. Akkasha Latif et. al. [28] proposed smart knee gloves that use ultrasonic sensors and cameras to detect obstacles for the visually impaired. The proposed work preprocesses data from the sensors, reduces noise, classifies the type of obstacle using the AlexNet model, and notifies the user through vibration or sound notifications. Additionally, the authors have proposed path planning using the A* algorithm, which helps improve the mobility and freedom of the visually impaired person. Wei You Tana et. al. [29] proposes the development of wearable blind people's guidance devices using a stabilizer system and sensor arrays. The proposed design includes a wearable ultrasonic and PIR sensor-enabled belt connected to wristbands, which offers blind and deaf-blind individuals tactile and visual indications. The results include less than 10.38% error, accurate human detection, and improved movement and independence for the blind. Hala S. Abuelmakarem et. al. [30] proposes an IoT-based smart cane for visually impaired people, incorporating ultrasonic, water, and flame sensors with Arduino control. The smart cane has been able to detect obstacles, stairs, and dangers and give audio signals. Family members can track users through Blynk mobile app. Accuracy, cost-effectiveness, and increased independence were achieved as mentioned in Table 2.1.

Table 2.1 Summary of the Existing Study

Ref No.	Author Name	Sensor Type	Communication Technology	Problem Identifier
[1]	Nur Azira Jasman	HC-SR04	ESP32 microcontroller, Bluetooth	Accuracy issues in prior systems
[2]	Sangam Malla	HC-SR04, IRFC-51	Arduino UNO R3 microcontroller, Bluetooth	Need for independence in unfamiliar environments
[3]	Sunnia Ikram	PIR Sensor	Wi-Fi, Arduino Uno R3 microcontroller, Firebase cloud	Need for extended detection range

[4]	Muhammad Farooq	JSN-SR04T, Raspberry Pi	Panic button, SIM800L	Hazard detection gaps
[5]	Xinnan Leong	Ultrasonic sensor	Raspberry Pi, CNN	Limitations of traditional aids
[6]	P. Vennila	HC-SR04, PIR Sensor	Bluetooth, Smartphone integration	Accuracy gaps in prior systems
[7]	Ahmed Mueen	Ultrasonic sensor	IoT-cloud environment, YOLOv3 Tiny	High latency in cloud-only systems
[8]	Sunnia Ikram	Ultrasonic sensors	Bluetooth, Mobile application	Limitations of traditional aids
[9]	Mohammad Ma rufur Rahman	HC-SR501, HC-SR04	Bluetooth, ESP32 microcontroller	Safety gaps
[10]	Zahraa A. Ali	HC-SR04	Raspberry Pi	Limitations of traditional white cane
[11]	Shubham Suman	Ultrasonic sensors	Arduino board, Bluetooth	Vision Navigator
[12]	Wasiq Khan	ultrasonic sensor	YOLOv5, Mask R-CNN	Obstacle detection gaps
[13]	Salam Dhou	HC-SR04, MPU6050	Firebase cloud, Bluetooth, Wi-Fi	Limitations of existing smart canes
[14]	Usman Masud	HC-SR04	Raspberry Pi, Arduino Uno	Technical challenges
[15]	Shahzadi Tayyaba	Ultrasonic sensor	Bluetooth, WPAN	Obstacle detection gaps
[16]	Md. Atikur Rahman	VL53L1X (Laser Sensors)	Bluetooth, Google Coral Dev Module	High risk of injury/mortality from falls.
[17]	Ahmad Abusukhon	HC-SR04	ESP-12E, WiFi	Indoor Navigation Difficulty
[18]	N.M.A.Nazri	HY-SRF05	ESP8266 Wi-Fi	Water Puddle Hazard
[19]	Md. Atiqur Rahman	HC-SR04	Raspberry Pi	Accuracy gaps in prior systems
[20]	Abhijit Pathak	HC-SR04	Arduino UNO, Bluetooth	Water Puddle Hazards
[21]	Krupal Jivrajani	HC-SR04	Raspberry Pi, Bluetooth	Earlier sticks lacked multi-functionality
[22]	Jong Hyeok Han	Ultrasonic Sensor	Voice Assistance, YOLOv2 CNN	Detect only ground-level obstacles.
[23]	Muhammad Irfan Yazid	HC-SR04	ESP32 Microcontroller, Wi-Fi	Cannot detect obstacles above waist level.
[24]	Anamika Maurya	Ultrasonic Sensor	IoT Framework, Wi-Fi	Limited accuracy in object recognition.

[25]	Pratik Kharat	ESP32-CAM	Arduino Uno, Bluetooth	Lack of real-time obstacle classification.
[26]	Nitin Kumar	HC-SR04	Raspberry Pi, YOLOv5	White cane detects only ground-level obstacles
[27]	Yashvi Khera	Ultrasonic Sensors	Raspberry Pi	Hazard detection gaps
[28]	Akkasha Latif	HC-SR501	Raspberry Pi, AlexNet CNN	White cane misses upper-body hazards.
[29]	Wei You Tana	RCWL-1601	ESP32 Microcontrollers	Unreliable Data in Different Environments
[30]	Hala S. Abuelmakarem	Ultrasonic Sensors	Arduino Uno, Wi-Fi	White canes cannot detect water pits, fire hazards.

METHODOLOGY

This section describes the design, development, and functioning of a shoe-worn obstacle detection system for the visually impaired during navigation have been discussed. The system comprises an ultrasonic sensor, Arduino, and a buzzer, which helps to provide alerts acoustically for the visually impaired. The system operates on the principle that it detects obstacles using its ultrasonic sensor, which then triggers the buzzer.

3.1 System Architecture

The proposed system would be a wearable assistive device based on a shoe system. The system would integrate an ultrasonic sensing module, a processing module, and an alert system. The ultrasonic module would be responsible for continuously sensing and calculating the distance to a nearby obstacle in front of the user. The Arduino processing module would be responsible for processing the data from the ultrasonic module and alerting the user through a buzzer if a nearby obstacle exists below a predefined distance as mentioned in Figure 3.1.

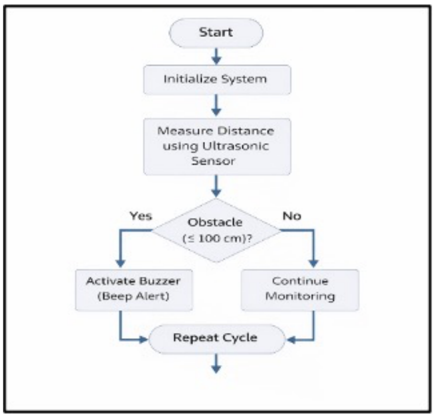

Figure 3.1 Flow Diagram of Obstacle Detection Process

Figure 3.2 Shoe Based Obstacle Detection System

3.2 Hardware Components

Following is the hardware used to implement the system as mentioned in Figure 3.2.

Arduino Board:

The Arduino board will be a circuit for the central processing unit. It should receive distance data coming from the ultrasonic sensor, process the data, and provide the control on the buzzer within the logics of the obstacle detection.

Ultrasonic Sensor:

It sends out ultrasonic waves and detects the reflected echos from objects through the ultrasonic sensor. By calculating the time it takes for an echo to come back, the distance between the user and any obstacle can be detected. It allows for precise, contactless measurements in the area of distance.

Passive Buzzer:

One passive buzzer has been used to realize audio warnings. In case of obstacle detection, the warning sounds from the buzzer thus create sound-based feedback to assist the user regarding the object proximity.

Jumper Wires:

Jumper wires are utilized to connect the Arduino board with the ultrasonic sensor and buzzer for flexible and easy integration into the circuit as mentioned in Figure 3.3.

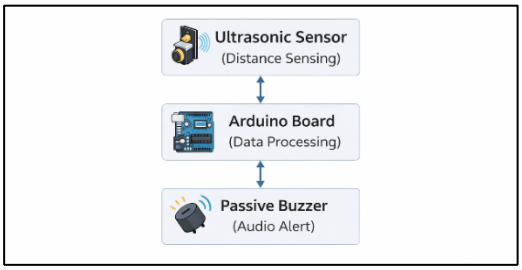

Figure 3.3 System Architecture Diagram

3.3 System Implementation

The ultrasonic sensor keeps sending out ultrasonic pulses in the forward direction of the shoe. In this process, when it detects an obstacle, some of the pulse bounces back to the sensor. The Arduino calculates the distance of the obstacle through the echo signal that comes after the sent ultrasonic pulse. The code then asks for an audio signal for alerting the user if the detected distance is within the defined detection range. This process happens again and again to ensure real-time obstacle detection as mentioned in Figure 3.4.

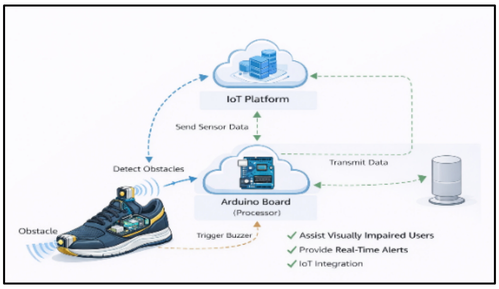

Figure 3.4 Proposed System Architecture

3.4 Obstacle Detection Algorithm

Algorithm 3.1 Shoe-Based Obstacle Detection Using Ultrasonic Sensor

Algorithm: Obstacle Detection and Alert System
Input: Ultrasonic Echo Time
Output: Audio Alert (Buzzer)
Step 1: Initialize Arduino board
Step 2: Initialize ultrasonic sensor and buzzer
Step 3: Set threshold distance D = 100 cm
Step 4: Loop continuously
    Step 4.1: Trigger ultrasonic pulse
    Step 4.2: Measure echo time
    Step 4.3: Calculate distance:
        "Distance = " ("Time" ×"Speed of Sound")/2
    Step 4.4: If Distance ≤ D then
            Activate buzzer
            Set beep rate based on distance
        Else
            Turn off buzzer
    Step 4.5: Repeat loop
End Algorithm

This algorithm 3.1 sets up an Arduino system with an ultrasonic sensor and a buzzer to sense obstacles. It constantly calculates the echo time to determine distances. When there are objects within 100cm distance, it turns on the buzzer at different beep intervals for audio signals.

3.4 Obstacle Detection and Alert Mechanism

It is configured that the system will identify the obstacle up to 100 cm. And the distance if identified, will drive the buzzer on. The alerting pattern with the buzzer depends on the obstacle distance:

Beep rate faster; an obstacle is nearer.

Slower beep rate indicates obstacle is farther away.

This distance-based alert mechanism supports the user in understanding obstacle proximity. The distance threshold was experimentally selected based on user safety and comfort, ensuring sufficient reaction time for obstacle avoidance.

3.5 IoT Integration

The proposed system currently performs local obstacle detection and alert generation using an ultrasonic sensor and Arduino controller, the overall architecture is designed to be IoT-ready. The system can be easily extended by integrating wireless communication modules such as ESP8266 or ESP32 to transmit sensor data to a cloud platform for remote monitoring, data logging, and performance analysis. This IoT integration enables future enhancements including caregiver notifications, mobility pattern analysis, emergency alerts, and GPS-based navigation support. Hence, the proposed smart shoe system aligns with the principles of the Internet of Things by enabling connectivity, scalability, and intelligent assistive services for visually impaired users.

4. RESULTS AND DISCUSSION

4.1 Result Analysis

The designed shoe-based obstacle detection system was tested to ensure its functionality in supporting the visually impaired in their path navigation. A test was conducted by positioning the obstacles at a range of 20 cm to 100 cm ahead of the user. The ultrasonic sensor correctly identified the obstacles within the designed range and continuously supplied the data to the Arduino controller as mentioned in Figure 4.1.

Figure 4.1 Indoor Detection of Proposed System

Table 4.1 The indoor experiment image proves the working of the proposed ultrasonic obstacle detection system using the shoe in the real world. The ultrasonic signals sent by the shoe detect the nearby obstacles in an indoor setup like chairs, tables, bags, and upright fans as mentioned in Figure 4.2.

Table 4.1 Indoor Obstacle Detection Accuracy

Obstacle Type	Detection Accuracy (%)
Chair	96.4
Table	95.6
Bag	94.6
Fan	93.9
Wall	98.3
Cupboard	97.1

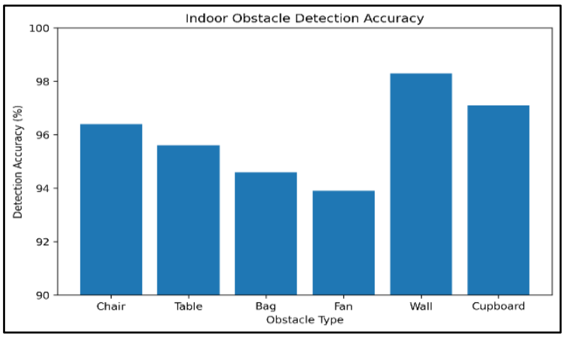

Figure 4.2 Indoor Obstacle Detection Accuracy Chart

Figure 4.2 depicts indoor obstacle detection for different objects. It can be observed that there is high accuracy for walls and cupboards, and slightly reduced accuracy for smaller objects such as a bag and a fan. Overall, the system performs in a reliable and consistent way for different indoor obstacles.

Obstacle Type	Detection Accuracy (%)
Moving Vechicle (Car)	94.2
Two – Wheeler (Bike)	93.6
Roadside Pole	95.1
Road Divider / Curb	96.8
Static Object (Stone/Barrier)	97.5
Average Accuracy	95.5

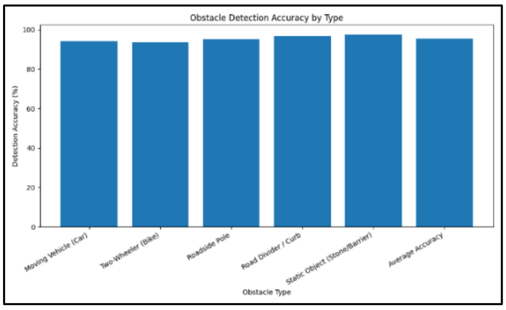

Figure 4.3 Outdoor Detection of Proposed System

Figure 4.3 To demonstrate the usefulness of the ultrasonic obstacle detection system designed on a shoe. Ultrasonic waves sent from the shoe help in detecting vehicles and other objects near the person and allow them to alert visually impaired persons through audio as mentioned in Figure 4.4.

Table 4.2 Outdoor Obstacle Detection Accuracy

Metric	White Cane Stick	Smart Shoe
System Type	Manual Assistive device	IoT-enable Wearable assistive device
Detection Method	Physical contact	Ultrasonic Sensor
Sensors Used	None	Ultrasonic Sensor
Microcontroller	Not applicable	Arduino
Alert Mechanism	User perception through touch	Alert using buzzer(distance-based)
Hands-free Operation	No	Yes
Real-time Detection	Limited	Yes

Figure 4.4 Outdoor Obstacle Detection Accuracy Chart

4.2 Result Discussion

The system demonstrated stable performance under varying lighting conditions, confirming that ultrasonic sensing is unaffected by illumination changes. Indeed, it has been verified that the ultrasonic sensor works perfectly for detecting solid objects in front of the user as mentioned in Table 4.3.

Table 4.3 Comparison of Existing and Proposed System

Metric	White Cane Stick	Smart Shoe
System Type	Manual Assistive device	IoT-enable Wearable assistive device
Detection Method	Physical contact	Ultrasonic Sensor
Sensors Used	None	Ultrasonic Sensor
Microcontroller	Not applicable	Arduino

Alert Mechanism	User perception through touch	Alert using buzzer(distance-based)
Hands-free Operation	No	Yes
Real-time Detection	Limited	Yes

Obviously, this comparison in Table 4.4 shows that the proposed smart shoe system outperforms the traditional white cane stick. While a white cane relies solely on physical contact and user experience, the smart shoe offers contactless ultrasonic sensing, real-time obstacle detection, and audio feedback. A wearable design ensures hands-free operation, improved safety, and higher accuracy. It achieves 98.3% indoors and 95.5% outdoors. Besides, the proposed system can be scaled into IoT in the future, making it more intelligent and reliable as an assistive solution for the visually impaired.

Table 4.4 Comparison of Existing and Proposed System

System	Indoor Detection Accuracy (%)	Outdoor Detection Accuracy (%)
Existing System (White Cane Stick)	70%	65%
Proposed System (Smart Shoe)	98.3%	95.5%

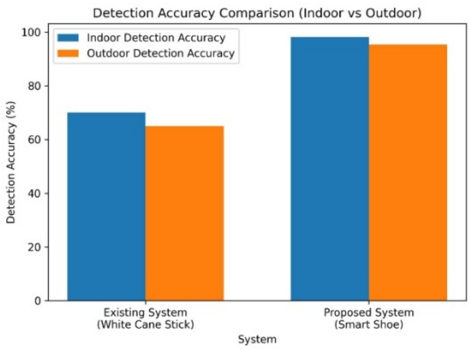

Figure 4.5 Comparison of Existing & Proposed System

This figure 4.5 illustrates the accuracy of existing and proposed systems for both indoor and outdoor settings. It can be observed that the proposed system of the smart shoe performs accurately compared to the conventional white cane stick, and its performance in both indoor and outdoor settings is better for obstacle detection.

5. FUTURE WORK

While this proposed shoe-based obstacle detection lays a very concrete foundation for assistive navigation, some enhancements may still be pursued in the future. This may include incorporating other sensors that could provide multisensory feedback-infrared sensors or vibration motors that would give more accuracy in the detection of obstacles while also providing alternative methods of alerts.

In the future, the development might also be directed at enhancing the detection capability to identify different types of obstacles, like stairs, pits, slopes, or moving objects. Multiple sensors mounted at different angles can enable the detection of obstacles not only in front but also on either side, thus improving user safety in crowded environments.

Another enhancement is the need to optimize power consumption and hardware size. Utilization of low-power microcontrollers coupled with compact components can be made to improve battery life and comfort. A lightweight and energy-efficient design would make the system more suitable for long-term daily use.

Also, whereas the current system is designed to operate independently, prospective improvements might include optional IoT integration for recording data and analyzing performance. Such enhancements could enable continued research and optimization of the system, while keeping the core functionality focused on real-time obstacle detection.

6. CONCLUSION

The proposed system is IoT-scalable and can be extended into a fully connected assistive platform with cloud-based monitoring and intelligent services. This study has demonstrated the design and development of an obstacle detection system through a shoe-based solution targeting visually impaired persons when navigating. This project has employed an ultrasonic sensor to detect an obstacle, an Arduino controller to interpret data on distance, and a buzzer to give an alert signal. Additionally, portability, convenience, and comfort of use have been accomplished through a wearable device.

Experimentation has shown that it has the ability to detect obstacles up to a range of 100 cm and give auditory feedback. The alert system based on the range of the obstacle enables users to know the proximity of the obstacle and thus improve navigation safety.

The system is cost-effective and quite easy to implement and can be used both indoors and outdoors. The system is able to operate independently without the use of other devices.

In general, the shoe-based obstacle detection system provides an effective assistive solution for visually impaired people to increase independent mobility. With further improvement, this system can act as an important assistance in real-life navigation.

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