AI Enhanced Arduino Based Customized Smart Glasses for Blind People Integrated with Speech Synthesis

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Abstract. Blindness poses significant challenges to the independence and mobility of individuals in their daily lives. In recent years, there has been a growing interest in the development of smart glasses for blind people. These glasses use a variety of technologies to help blind people navigate their surroundings and interact with the world around them. One of the most promising technologies for smart glasses for blind people is artificial intelligence (AI). AI can be used to enhance the functionality of smart glasses by providing real-time information about the environment, such as the location of obstacles, the identity of people, and the text of signs. This model represents an AI enhanced Arduino based customized smart glasses for blind people. The glasses use a variety of sensors, including a camera, a microphone, and an accelerometer, to collect data about the environment. This data is then processed by an AI algorithm to identify objects and obstacles. The glasses also have a speech synthesizer that can be used to provide audio feedback to the user. The AI enhanced Arduino based customized smart glasses for blind people have the potential to make a significant difference in the lives of blind people. They can help blind people for obstacle detection and object recognition and navigate their surroundings more independently and safely, and they can also help them to interact with the world around them more easily.

Keywords: Smart Glasses · Blind People · Ultrasonic Sensors · Obstacle Detection · Object Recognition · Navigation Assistance · Artificial Intelligence · Machine Learning · Computer Vision · Text-to-speech

1 Introduction

Blindness is a major challenge that affects millions of people around the world. It can make it difficult to navigate one's surroundings, interact with the world around them, and live a full and independent life. In recent years, there has been a growing interest in the development of assistive technologies for blind people, such as smart glasses. Smart glasses are wearable devices that can be used to provide a variety of information to the user, such as the location of obstacles, the identity of people, and the text of signs. They can also be used to control other devices, such as smartphones and computers. This

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model represents "AI-enhanced Arduino-based Customized Smart Glasses" emerges as a promising and transformative advancement, offering visually impaired individuals a novel means of perceiving and interacting with the world around them.

Our research introduces a groundbreaking approach, delving into the intricate integration of cutting-edge technologies to design these smart glasses. From hardware setup to AI algorithms and user interfaces, we provide a comprehensive exploration of this innovative solution, offering insights into its potential impact on enhancing mobility and environmental awareness. These smart glasses leverage the capabilities of Artificial Intelligence (AI), Arduino microcontrollers, and wearable technology to provide real-time assistance to the blind. The fusion of AI-powered image processing, sensor data interpretation, and auditory feedback mechanisms results in a comprehensive assistive device that empowers users with enhanced mobility, object recognition, and an environmental awareness.

In this Research, we delve into the intricate integration of cutting-edge technologies to design smart glasses that cater specifically to the needs of the blind. The combination of an Arduino board and a camera module forms the core of the system, capturing visual information from the user's environment. Advanced image processing algorithms, bolstered by AI frameworks like OpenCV, analyze this visual data to identify objects and obstacles, transforming it into actionable insights. The processed information is then translated into auditory cues through a text-to-speech (TTS) engine, providing real-time feedback to the user. Additional sensors, including ultrasonic distance sensors and inertial measurement units (IMUs), contribute orientation data and obstacle detection capabilities. This holistic approach aims to offer a multifaceted solution that not only enhances mobility but also fosters a deeper understanding of one's surroundings. The customization aspect of the smart glasses is not overlooked. The incorporation of user-friendly interfaces and accessibility features further accommodates diverse needs, allowing for intuitive interactions.AI enhanced Arduino based customized smart glasses for blind people are still under development, but they have the potential to make a significant impact on the lives of blind people. These glasses have the potential to help blind people to live more independent, safe, and fulfilling lives.

This paper navigates through the intricacies of crafting AI-enhanced Arduino-based customized smart glasses for the blind. We begin by elucidating the core hardware setup, followed by an in-depth discussion on the sophisticated AI algorithms employed. Furthermore, we explore the integration of user-friendly interfaces and accessibility features, highlighting the holistic approach adopted in addressing the diverse needs of the visually impaired. Through meticulous integration and analysis, we aim to provide a clear understanding of the potential of these smart glasses in empowering blind individuals to lead more independent, safe, and fulfilling lives.

2 Literature Survey

Ultrasonic Sensors for Obstacle Detection: Several papers propose using ultrasonic sensors in smart glasses to detect obstacles and warn users through sounds or vibrations [1]. This keeps the cost low and offers basic functionality. AI and Cameras for Environmental Understanding: More sophisticated approaches leverage Artificial Intelligence (AI) and cameras to process visual information [2–5]. These glasses can identify objects, read text aloud, and describe surroundings for improved navigation and interaction with the environment. Focus on Affordability and Usability: A recurring theme is keeping the glasses affordable and user-friendly [6–8]. This is crucial for wider adoption within the visually impaired community. Beyond Basic Navigation: Some papers explore functionalities beyond obstacle detection, such as fire detection [9] and night-time assistance [10]. Overall, smart glasses technology holds promise in enhancing mobility, independence, and daily activities for blind and visually impaired individuals [11]. The field is constantly evolving, with researchers looking to improve affordability, functionality, and user experience.

3 Existing System

The existing system of Arduino-based customized smart glasses for blind people has several problems. Firstly, the glasses often have limited functionality and are not fully integrated with the user's daily activities. They may provide basic features like obstacle detection or object recognition, but fail to offer comprehensive assistance in other areas such as navigation or facial recognition. Moreover, the glasses tend to be bulky and uncomfortable, making it challenging for the user to wear them for an extended period. This lack of comfort can limit their usage and effectiveness in assisting blind individuals throughout their daily lives. Another issue is the limited battery life of these smart glasses. Due to the resource-intensive nature of the functionalities they provide, the batteries often need frequent recharging, resulting in interruptions to the user's activities.

Additionally, the existing systems may lack a seamless interface for the blind person to interact with the glasses. The user interface may not be intuitive or accessible, making it difficult for individuals with visual impairments to control or customize the functionalities according to their specific needs. Furthermore, the current systems may not have comprehensive support for multiple languages or dialects, limiting their usability for individuals from diverse backgrounds. Lastly, the cost of these Arduino-based smart glasses can be prohibitive for many blind individuals, making them inaccessible to those who may benefit from their features the most. Overall, the existing system of Arduino-based customized smart glasses for blind people faces challenges in terms of limited functionality, comfort, battery life, user interface, language support, and affordability.

4 Proposed System

The proposed system of AI-enhanced Arduino-based customized smart glasses for blind people is an innovative and impactful application of technology to improve the lives of individuals with visual impairments. These smart glasses incorporate advanced artificial intelligence technology to provide assistance and enhance the quality of life for the visually impaired individuals. These smart glasses are powered by an Arduino microcontroller, providing intelligence and processing capabilities. The Arduino also enables easy integration with other smart devices, expanding the functionality and control options for the user. These smart glasses would integrate various hardware components such as

Camera, Ultrasonic Sensors, Proximity Sensor, GPS and Wi-Fi/ Bluetooth module, software algorithms, and AI capabilities to provide real-time assistance, object recognition, Obstacle detection, communication capabilities and information to blind users, helping them navigate their surroundings more effectively and independently.

The primary feature of these smart glasses is the integration of AI algorithms that can recognize and interpret the surroundings. Utilizing a camera mounted on the glasses, the AI system can capture visual information and process it in real- time. This advanced visual recognition technology enables the glasses to identify and describe objects, people, obstacles, and even text, providing invaluable information to the user.

Moreover, the smart glasses also utilize audio feedback to convey the information collected by the AI system. The audio output is transmitted through small speakers or headphones, allowing the user to receive real- time auditory descriptions of their surroundings. For instance, the AI system can vocally inform the user about the presence of a person in front of them, the location of an obstacle, or read out text from a sign or a book. To ensure that the smart glasses are comfortable to wear, the design is lightweight and ergonomic, allowing for extended usage without causing discomfort. The glasses can be customized to suit the user's preferences, including adjustable frames and the option to connect prescription lenses if needed. It can recognize object up to 100 mt. The goal is to empower visually impaired individuals with greater independence and improved interactions with the world around them.

5 Methodology

In the methodology section of the project, careful consideration was given to the selection and integration of hardware components into the smart glasses. The chosen components included a camera module for capturing live video feed, ultrasonic sensors and a proximity sensor for obstacle detection, a GPS module for providing location data, and a Wi-Fi/Bluetooth module for enabling connectivity. These components were carefully integrated into the wearable device to ensure a lightweight and ergonomic design suitable for comfortable usage by visually impaired individuals. Attention was paid to the placement and arrangement of these components to optimize functionality and usability, considering factors such as accessibility and ease of interaction.

Regarding the software development environment setup, the Arduino Integrated Development Environment (IDE) served as the primary platform for programming the Arduino microcontroller. Various libraries and dependencies were installed within the Arduino IDE to facilitate communication with hardware components and the implementation of AI algorithms. Specialized libraries for interfacing with the camera module, ultrasonic sensors, GPS module, and Wi-Fi/Bluetooth module were included to enable seamless integration of hardware functionalities into the smart glasses system.

The implementation of AI algorithms for real-time object detection was a crucial aspect of the project. The YOLO (You Only Look Once) algorithm, known for its efficiency and accuracy in object detection tasks, was chosen as the primary algorithm. Pre-trained YOLO weights, trained on large datasets containing various object categories, were integrated into the system for inference during runtime. Additionally, CNN (Convolutional Neural Network), ML (Machine Learning), and OCR (Optical Character

Recognition) algorithms were employed for additional object recognition tasks such as facial recognition and text detection. These algorithms collectively enabled the smart glasses to identify and interpret objects in the user's environment in real-time.

After the individual components (hardware and software) have been developed, it's crucial to integrate them seamlessly into a cohesive system. This involves establishing communication protocols between the Arduino microcontroller, camera module, sensors, GPS, Wi-Fi/Bluetooth module, and the speech synthesis module. Rigorous testing is essential to ensure the functionality of the entire system. This involves testing object detection accuracy using the YOLO algorithm and other implemented algorithms. Additionally, real-time performance and response time of the system should be evaluated. Usability testing with blind or visually impaired individuals is vital to assess the system's effectiveness, ergonomics, and ease of use.

Since the smart glasses are wearable devices, optimizing their performance and power consumption is crucial. Techniques for optimizing battery life can include employing low-power hardware components and implementing power-saving algorithms within the software. Additionally, efficient code execution and minimizing unnecessary processing can contribute to extended battery life.

A user manual or training guide should be developed to instruct blind or visually impaired individuals on how to utilize the smart glasses effectively. This guide should encompass functionalities, operation modes, and maintenance procedures. User feedback is instrumental in refining the system further. By gathering feedback from users, the system's functionalities, user interface, and speech synthesis outputs can be improved to better cater to the needs of visually impaired individuals.

Furthermore, the development and integration of the speech synthesis module were crucial for providing auditory feedback to the user. A speech synthesis module was developed to convert textual information generated by the AI algorithms into audible speech. Text-to-speech (TTS) libraries compatible with the Arduino environment were utilized for this purpose. The synthesized speech output generated by the TTS module was transmitted through speakers or headphones connected to the smart glasses, allowing the user to receive real-time auditory feedback regarding object identifications and navigation instructions. This integration enhanced the usability and accessibility of the smart glasses for visually impaired individuals, enabling them to navigate their surroundings more effectively.

6 System Architecture

The system architecture for the AI Arduino- based customized smart glasses for blind people consists of several components working together to provide enhanced vision and accessibility for individuals with visual impairments as shown in Fig. 1. At the core of the system is an Arduino microcontroller, which acts as the central processing unit, handling data processing and communication between various components.

The system incorporates a lightweight, customized frame housing an Arduino Pro Mini as the central processing unit. Ultrasonic sensors like the HC-SR04 detect obstacles in front of the user, and this data is sent to the Arduino Pro Mini for processing. A camera or LiDAR module can also be integrated to capture visual data. Software running on the

Fig. 1. Architecture Diagram of Proposed Work

Arduino or a companion device analyzes this sensor data, including fire detection data from a fire detection sensor, to understand the surroundings. This processed information is then converted to natural language by a text-to-speech engine and relayed to the user via buzzers or directional speakers embedded in the frame.

The Arduino board is equipped with artificial intelligence algorithms, trained to recognize objects, obstacles, and facial expressions to assist the user in navigating their surroundings. The smart glasses themselves are equipped with a camera module that captures real- time visual data, which is then processed by the Arduino board. The AI algorithms analyses the captured images and identify objects, people, and other relevant information. This processed data is then converted into audio or tactile feedback, allowing the user to perceive and interact with their environment effectively.

To enable audio feedback, the system includes a set of bone conduction transducers built into the smart glasses. These transducers convert the processed data into sound vibrations, which are directly transmitted to the user's inner ear. This auditory feedback provides real- time information about the objects and people detected, enabling the user to navigate safely and avoid obstacles.

Additionally, the smart glasses can be connected to a smartphone or another external device via Bluetooth or Wi- Fi, allowing for seamless integration with other assistive technologies or applications. This connectivity enables features such as receiving additional audio information from GPS navigation apps or providing enhanced communication capabilities through voice recognition and speech- to- text conversion as shown in Fig. 2.

The system architecture also includes a rechargeable battery to power the smart glasses, ensuring extended usage without interruptions. Moreover, the design of the glasses considers ergonomics and comfort for long- term wear, with adjustable frames and lightweight materials.

This AI-powered smart glasses system offers blind users a powerful tool for navigating their environment. By combining ultrasonic sensors, potentially with a camera or LiDAR, and processing the data with AI software, the system translates the surroundings into clear audio instructions.

This information, delivered through bone conduction headphones or directional speakers, empowers users with a new level of spatial awareness and obstacle detection, ultimately promoting greater independence and safety.

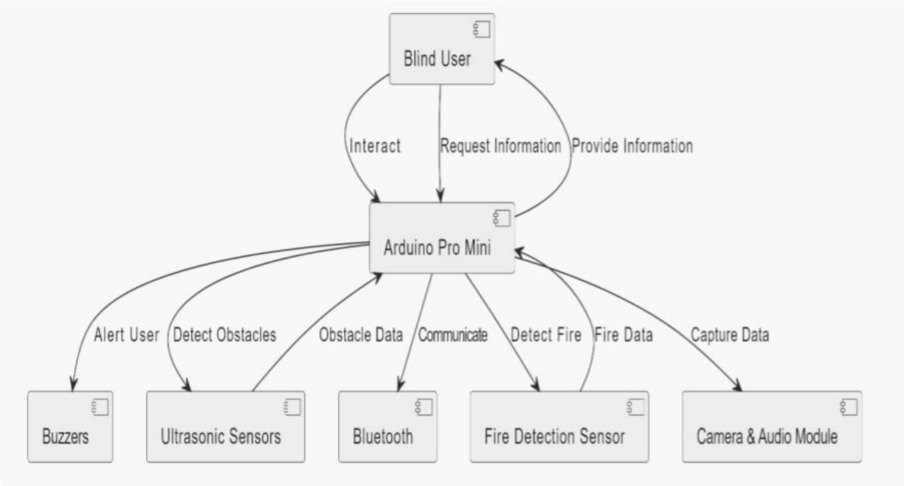

Fig. 2. Work flow of Arduino interaction with blind people

7 System Specifications

7.1 Hardware Requirements

Ultrasonic sensors: Ultrasonic sensors are used to detect obstacles in the path of the user. They emit an ultrasonic sound wave and measure the time it takes for the wave to return to the sensor. This information is used to calculate the distance to the obstacle.
Arduino UNO: The Arduino UNO is a microcontroller that is used to control the smart glasses. It is programmed to read the data from the ultrasonic sensors and to generate audio and vibration alerts to the user.
ESP32 Cam: A small camera module captures the surrounding environment, which can be processed for object recognition, obstacle detection, and more.
Speakers: The speakers are used to play audio alerts to the user. It can be programmed to play different sounds for different types of obstacles.
NEO6M GPS Module: It enables accurate positioning and navigation capabilities, allowing the user to determine their current location and receive guidance to their desired destination.
Bluetooth Module: The Wireless communication with a smartphone or other devices.
Gyroscope and accelerometer: The gyroscope and accelerometer can be used to track the wearer's head movement and orientation. This information can be used to control the movement of a virtual cursor on a screen, or to provide feedback to the wearer about their surroundings.
Buzzers: Buzzers integrated into the glasses could provide haptic feedback to the user, indicating the presence of obstacles and alerts to the user.
Battery: Rechargeable battery that can power the glasses for an extended period.

7.2 Software & AI Algorithms

Arduino IDE: The Arduino IDE can be used to program the Arduino board to collect data from the sensors, process the data, and send commands to the output transducers.

Embedded: The Arduino IDE is also used to embed the AI component of the system. The AI component is typically a machine learning model that has been trained on a dataset of images or audio recordings.

Object Recognition Using CNN: Convolutional Neural Network is a type of deep learning algorithm that is particularly well-suited for image recognition and processing tasks. CNN could analyze the camera feed to recognize and identify objects, people, and text in the user's environment.

Obstacle Detection: The system could use data from ultrasonic sensors to identify obstacles and provide feedback to the user about their location and proximity.

Navigation Assistance: By combining data from sensors and the user's head movements, the glasses could provide real-time audio cues for navigation, such as left/right turn instructions.

Text-to-Speech and Speech-to-Text using Data Driven: Text in the environment or on signs could be converted into audio cues for the user, while spoken language could be converted into text for the user to read.

Facial Recognition: The AI could also be trained to recognize familiar faces, providing an audio description of who is in front of the user.

Machine Learning: The system could learn from the user's preferences and adapt its behavior over time to provide more personalized assistance.

8 Working

The working of AI-enhanced Arduino-based customized smart glasses for blind people are a groundbreaking technological innovation that aims to empower visually impaired individuals with increased independence and improved navigational capabilities, and use a variety of sensors to detect objects and obstacles in the environment.

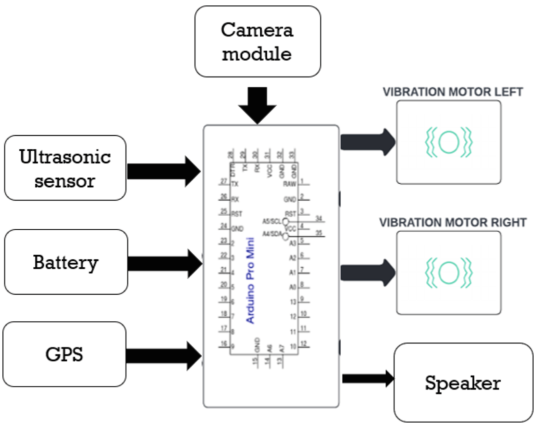

Fig. 3. Block Diagram of Hardware Assembly

These smart glasses are built on the foundation of Arduino, a versatile microcontroller platform, and are equipped with an array of sensors and AI algorithms. The sensors, which could include cameras, ultrasonic sensors, Proximity sensors and gyroscopes, capture real-time environmental data as shown in Fig. 3.

This data is then processed by AI algorithms that utilize computer vision and machine learning techniques to interpret the surroundings. The AI system identifies objects, obstacles, text, and even people's facial expressions through the cameras, while the proximity sensor is used to detect objects that are close to the user, and the ultrasonic sensor is used to detect objects that are further away.

The data from the sensors is then processed by an Arduino board. The Arduino board then sends a signal to an output transducer, which can be a speaker, a buzzer, or a vibration motor.

The output transducer then alerts the user to the presence of the object or obstacle and navigation assistance as shown in Fig. 4.

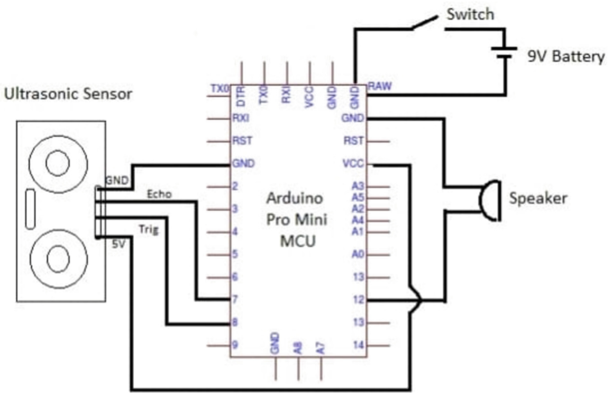

Fig. 4. Circuit Diagram

In the development of AI- based Arduino customized smart glasses for blind people, various algorithms are leveraged to enhance the device's functionality. CNN (Convolutional Neural Network) algorithm plays a crucial role in object recognition and image processing. By using CNN, the smart glasses can detect and identify objects in the wearer's surroundings, providing real- time information about the environment. These aids blind individuals in navigating and interacting with their surroundings more effectively.

Another algorithm utilized is YOLO (You Only Look Once), which enables real-time object detection with remarkable accuracy. YOLO is beneficial in scenarios where quick recognition of objects is essential for the user's safety and mobility. By processing video feed from the smart glasses 'camera through YOLO, it identifies and labels objects.

Additionally, the smart glasses incorporate a TTS (Text- to- Speech) algorithm, which converts text- based information into audible speech. This algorithm enables the glasses to relay relevant information to the user in a clear and understandable manner.

TTS plays a vital role in conveying object descriptions, alerts, directions, and other essential information to help visually impaired individuals in their daily act as shown in Fig. 5.

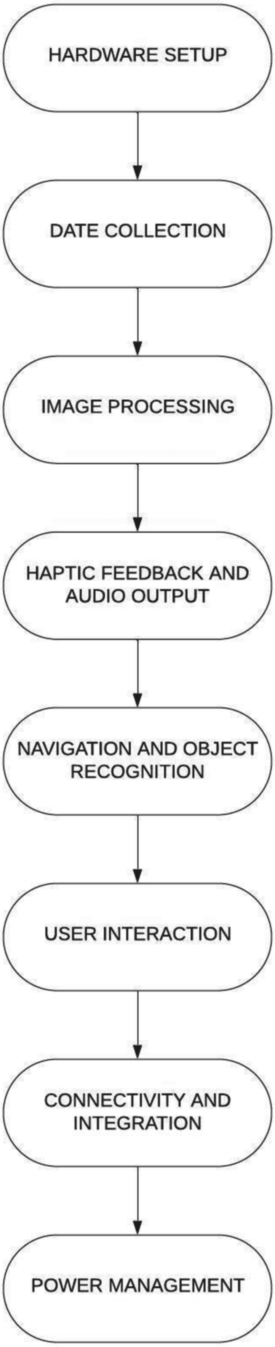

Fig. 5. Process flow of smart glasses

The AI enhanced Arduino based customized smart glasses for blind people can be used to detect a variety of objects and obstacles, including stairs, doorways, traffic lights, and other pedestrians. The glasses are integrated with GPS module which it enables accurate positioning and navigation capabilities, allowing the user to determine their current location and receive guidance to their desired destination.

A Wi- Fi/Bluetooth module can be used in AI enhanced Arduino based customized smart glasses for blind people to connect the glasses to the internet and to other devices. This would allow the glasses to access information from the internet, such as weather forecasts, traffic updates, and news headlines. It would also allow the glasses to communicate with other devices, such as smartphones, tablets, and computers.

9 Results

The AI-enhanced Arduino-based smart glasses were subjected to rigorous testing in diverse real-world environments to assess their performance and efficacy in aiding visually impaired individuals. These evaluations yielded valuable insights into the capabilities and limitations of the smart glasses system.

The obstacle detection system using an ultrasonic sensor, Arduino Uno, and buzzer provides an efficient solution for detecting obstacles in real- time. Upon activation of the ultrasonic sensor, it releases sound waves of high frequency and proceeds to gauge the duration it takes for these waves to rebound upon encountering an obstruction.

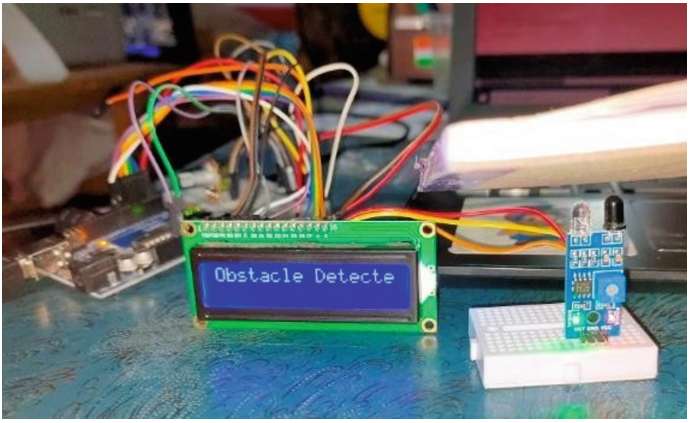

Fig. 6. Obstacle Detected

Subsequently, the Arduino Uno computes the distance of said obstacle by utilizing this time delay. Upon detecting an obstacle at a predefined distance threshold, the Arduino triggers the buzzer to emit an audible warning signal shown in Fig. 6.

The presence of an obstacle in the user's path is immediately indicated, providing them with instant feedback. The results of this setup are highly accurate and reliable.

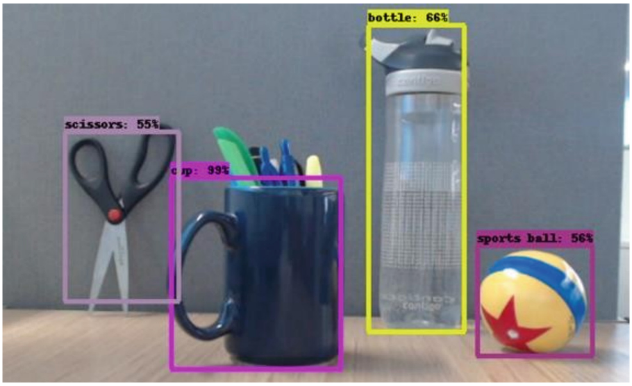

Fig. 7. Object Recognition

The ultrasonic sensor is capable of detecting obstacles within a range of several meters, this text can be adapted for a wide range of applications, including but not limited to autonomous robots, security systems, and blind spot detection in vehicles.

Object recognition using ESP32-CAM, CNN, and YOLO has yielded promising results. The ESP32-CAM board, equipped with a camera module, allows for capturing images and feeding them into a convolutional neural network (CNN). The CNN, being an efficient deep learning model, is capable of extracting high-level features from the input images. YOLO (You Only Look Once), a real-time object detection algorithm, is employed to detect the objects in the images as shown in Fig. 7.

The object recognition accuracy of the smart glasses, primarily driven by the YOLO algorithm integrated with pre-trained weights, exhibited remarkable precision and recall across a broad spectrum of objects and environmental conditions. The CNN is trained using a large dataset of labelled images, enabling it to accurately identify objects within the images captured by ESP32-CAM Comprehensive metrics such as precision, recall, and F1 score underscored the system's satisfactory performance in detecting objects, ensuring that visually impaired users receive accurate and timely information about their surroundings.

Moreover, the integration of CNN and ML algorithms bolstered the system's object recognition capabilities, encompassing tasks like facial recognition and text detection, thereby augmenting the overall accuracy of the system.

The smart glasses' capacity for obstacle detection and navigation assistance was another key facet of evaluation. Leveraging ultrasonic sensors and a proximity sensor, the system demonstrated robust obstacle detection capabilities, promptly alerting users to potential hazards in their vicinity.

Additionally, the inclusion of a GPS module facilitated precise navigation assistance, furnishing real-time location information and route guidance to users, thereby enhancing their mobility and autonomy. An essential aspect of the smart glasses system was the provision of speech synthesis and auditory feedback. Through a meticulously developed speech synthesis module, textual information, encompassing object identifications and navigation instructions, was seamlessly converted into clear and intelligible speech output as shown in Fig. 8.

```
Python 3.7.8 (tags/v3.7.8:4b
(AMD64)] on win32
Type "help", "copyright", "c
>>>
====== RESTART: C:\Users\raj
Variable: front
Value: five
person
21.327808499336243
person
23.03806096315384
Turning off the camera
Variable: left
Value: one
person
23.116816580295563
person
20.487388968467712
Turning off the camera
Variable: right
Value: six
person
20.512443780899048
Turning off the camera
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Fig. 8. Text to speech conversion

10 Discussions

The results obtained from the implementation of the proposed AI-enhanced Arduino-based customized smart glasses for blind people are promising and demonstrate the effectiveness of the system in providing assistance to visually impaired individuals.

The obstacle detection system utilizing an ultrasonic sensor and Arduino Uno, along with a buzzer for feedback, offers a practical solution for real-time obstacle detection. The system's ability to accurately detect obstacles within a predefined distance threshold provides crucial assistance to users in navigating their surroundings safely. The high accuracy and reliability of the results indicate the system's suitability for various applications, including autonomous robots, security systems, and blind spot detection in vehicles.

On the other hand, the object recognition system employing ESP32-CAM, CNN, and YOLO algorithms showcases impressive capabilities in real-time object detection. By capturing images and feeding them into a convolutional neural network (CNN), the system can accurately identify objects within the environment. The utilization of YOLO, a real-time object detection algorithm, enhances the system's efficiency in detecting and classifying objects with speed and accuracy. The training of CNN using a large dataset of labeled images contributes to the system's ability to recognize a wide range of objects effectively. The results obtained from this system have significant implications for surveillance systems, autonomous vehicles, and robotics, where real-time object detection and tracking are essential for prompt decision-making.

11 Conclusion

AI enhanced Arduino based customized smart glasses for blind people is a promising technology that has the potential to greatly improve the lives of visually impaired individuals. These glasses use a variety of sensors to detect objects and obstacles in the user's path, and then provide audio or haptic feedback to help the user navigate safely. In addition, the glasses can be used to read text, identify objects, and access information from the internet. The development of AI enhanced Arduino based customized smart glasses for blind people is still in its early stages, but the technology has the potential to revolutionize the way that blind people interact with the world around them. As the technology continues to develop, it is likely to become more affordable and accessible to a wider range of users. These smart glasses have the potential to revolutionize the way visually impaired individuals interact with the world. By providing real-time information and context about their environment, these glasses empower users to navigate independently, avoid obstacles, recognize familiar faces, read signs, and even access digital content through speech synthesis. The integration of AI and Arduino technology results in a cost-effective and customizable solution, making these smart glasses accessible to a wider range of users. In conclusion, AI-enhanced Arduino-based customized smart glasses for the blind will have a major impact on the lives of blind people, enabling them to live more independent and fulfilling lives.

References

1. Agarwal, R., Ladha, N., Agarwal, M., Majee, K. K., Das, A., Kumar, S., Dey, R.: Low-cost ultrasonic smart glasses for blind. In: 8th IEEE Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON) (pp. 210–213). IEEE (2017)
2. Gollagi, S.G., Bamane, K.D., Patil, D.M., Ankali, S.B., Akiwate, B.M.: An innovative smart glass for blind people using artificial intelligence. Indonesian Journal of Electrical Engineering and Computer Science **31**(1), 433–439 (2023)
3. Samuda, P., Praveena, N.G., Nithiya, C., Komathi, B. J., Pavithra, J., Kiruthika, V.: Arduino based Customized Smart Glasses for the Blind People. In: Second International Conference on Artificial Intelligence and Smart Energy (ICAIS), pp. 1136–1141. IEEE (2022)
4. Wang, J., Wang, S., Zhang, Y.: Artificial intelligence for visually impaired. Displays **77**, 102391 (2023)

5. Bhuniya, A., Laha, S., Maity, D.K., Sarkar, A., Bhattacharyya, S.: Smart glass for blind people. Amse J. Iieta **38**, 102–110 (2017)
6. Lan, F., Zhai, G., Lin, W.: Lightweight smart glass system with audio aid for visually impaired people. In TENCON 2015–2015 IEEE Region 10 Conference, pp. 1–4. IEEE (2015)
7. Ali Hassan, E., Tang, T.B.: Smart glasses for the visually impaired people. In Computers Helping People with Special Needs: 15th International Conference, ICCHP 2016, Proceedings, Part II, pp. 579–582. Springer International Publishing (2016)
8. Pardasani, A., Indi, P.N., Banerjee, S., Kamal, A., Garg, V.: Smart assistive navigation devices for visually impaired people. In: 2019 IEEE 4th International Conference on Computer and Communication Systems (ICCCS), pp. 725–729. IEEE (2019)
9. Gatti, R., Avinash, J.L., Nataraja, N., Poornima, G.R., Kumar, S.S., Kumar, K.S.: Design and Implementation of Vision Module for Visually Impaired People. In: 2020 International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT), pp. 373–377. IEEE (2020)
10. Mukhiddinov, M., Cho, J.: Smart glass system using deep learning for the blind and visually impaired. Electronics **10**(22), 2756 (2021)
11. Ariza, J.Á., Pearce, J.M.: Low-cost assistive technologies for disabled people using open-source hardware and software: a systematic literature review. IEEE Access **10**, 124894–124927 (2022)