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AI Based Assistive Glasses for Visually Impaired Persons

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Abstract

There been a lot of change in tools for assisting visually impaired persons from simple analog tools to digital sensor-based devices. In this paper, we have designed an AI-based smart assistive glass which can detect objects, read text their nature, distance and give feedback through audio output in real time. This system stores visual data and with use of object recognition it analyzes surroundings. Besides, VL53L0X TOF measures accurate distance which helps to identify obstacles easily. Users can communicate with system by text to speech component which gives audio output to user. Low cost, portability and high energy efficiency are main features of our system. Additionally, by constantly tracking changes in the environment and warning users of any dangers nearby, the suggested smart glasses promote improved situational awareness. Artificial intelligence enhances text recognition and object categorization accuracy in a variety of lighting scenarios. Experimental assessments show dependable performance with quick reaction times and good detection accuracy in both indoor and outdoor settings. In outdoor environments, the system assists users by detecting nearby obstacles and providing timely audio alerts during movement. The camera-based analysis and distance measurement work together to monitor the surroundings and support safer navigation. The system is also designed to provide useful information under changing lighting conditions and different environmental situations. For visually challenged people, the suggested solution enhances their quality of life, increases their autonomy, and promotes safer movement. By performing several experiments, it has concluded that it improves mobility and situational awareness of user for visually impaired individuals effectively.

Keywords: Assistive technology, smart glasses, visually impaired navigation, raspberry Pi, computer vision, obstacle detection, ultrasonic sensors, text-to-speech

INTRODUCTION

Assistive technology plays a major role in improving the lifestyle of blind persons so that they can perform their daily tasks easily and independently. For the past several decades, white canes and guide dogs have been majorly used. However, these methods cannot explain the surrounding area in detail. Artificial intelligence and embedded systems have made it possible to design and develop more assistive, fast, and intelligent system [1-4].

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Smart glasses are hands-free, portable, and wearable platforms that include various sensing and processing technologies, allowing users to receive updates of their surroundings in real time, which avoids serious accidents and improves mobility. Wearable technologies have received more attention because of their compact hardware, which is energy efficient.

Computer vision has improved the abilities of assistive technology. The camera module captures visual data, and objects and obstacles are identified after analyzing this data.VL53L0X tof sensor is used to measure the distance of surrounding objects. Raspberry Pi is more useful in context assistive technology because it is reliable, smaller in size, more intelligent, and capable of handling complex environments. It is also easier to integrate various sensors, and text to speech helps to assist users in communicating with audio output, which is more important for visually impaired persons [5–10].

In this paper, we present a smart assistive glass and its design. In the proposed system, we integrated computer vision, infrared sensors, and audio feedback. This system was developed to provide safe navigation and improved user experience. The following sections explain the implementation, reference, related work, and use of deep learning and IoT.

Related Work

Artificial intelligence and embedded systems are prominently used to integrate wearable components for visually impaired individuals. Ai Based smart vision glasses technology was designed, which includes Raspberry Pi, camera used for object detection, and voice feedback [11]. A wearable system using an ultrasonic sensor was designed for obstacle detection and audio output [12]. In addition, an embedded system using ultrasonic sensors was designed, and haptic feedback was provided through a vibration motor [13]. A generative AI-based smart glasses system that can perform object detection and read multiple languages has been developed [14]. A multifunctional Assistive system that includes depth sensing and object detection was proposed [15]. However, these systems have limitations, such as different lighting conditions and battery life, which can minimize their use. A smart assistive system using sensors and auditory feedback was designed and developed to safely guide users [16]. In addition, an IoT-based smart glass system [17]. includes connectivity features so that signals of object detection can be sent to a mobile device in real time. This system can improve the user experience, but continuous use can lead to delays and confidentiality issues.

Deep learning-based technology is also used to improve the accuracy of object recognition and real-time control. In a Yolov5 based system [18]. obstacles are identified using strong object detection and a Raspberry Pi. This method improves the identification process, but requires high computing capacity, and the functioning capacity can be reduced by environmental conditions.

Sensor-based mobility systems are still important in assistive technology, especially because of their simplicity and reliability. An ultrasonic-based mobility assistive system that includes voice alerts for obstacle detection was proposed [19]. A camera and sensor are designed, and text-to-speech facility-based assistive wearable systems are used to obtain information about our surroundings [7]. Even if these systems are capable of functioning, they still have limitations in terms of battery, range, power consumption, and capacity for object recognition.

SYSTEM DESIGN AND ARCHITECTURE

Design Philosophy

This system is designed for wearable multimodal navigation assistance, which includes Edge AI and Cloud AI. This system is capable of scene understanding, object recognition, surrounding awareness, and obstacle detection in real time. Therefore, visually impaired persons can be guided safely indoors and outdoors.

Hardware Layer

1. *Central processing unit:* Raspberry Pi 4 is the heart of the system and is the main processing unit of the system. Asberry processes data from sensors, activates the AI model, and controls the entire functioning of the system. The Raspberry Pi is a low-cost computing feature controller with a compact size.
2. *Spacial sensors:* Two VL53LOX time-of-flight distance sensors are mounted on the right and left corners to measure the distance and direction of the obstacles. Both sensors have the same I2c address; therefore, we need to use XSHUT pins to give them different addresses so that both sensors can measure the distance simultaneously.

3. *Kinematic sensor:* MPU6050 IMU sensor was mounted on the heat sink of the Raspberry Pi. This sensor was used to detect the motion of the user. It gets true values when the user is in motion, and when the user sits down or stands up, it shows false values, which means that this sensor helps in movement tracking.
4. *Vision interface:* Waveshare OV5693 5MP USB camera was used to capture wide-angle video frames. These video frames are continuously processed and analyzed using computer vision and algorithms to obtain information about the object, obstacles, and surroundings.
5. *User interface:* It has a capacitive touch sensor and a 3.5 mm audio jack for voice feedback. Therefore, users can communicate with the system effectively using real-time feedback.

Software Layer

1. *Multithreading:* This system uses an asynchronous multi-threaded architecture, in which different threads are used for camera input, sensor data processing, and audio output to reduce lag and delay and enable real-time processing.
2. *Decision engine:* centralized decision-making module is responsible for analyzing obstacles and object distances and classifying them as safe or warning and directions such as left, center, and right.
3. *System fusion:* This system utilizes data from the ToF sensor, camera, and IMU, which increases the accuracy and reliability of the system. This is also a fusion method that provides navigation assistance even if any of the components fail. Figure 1 shows a flowchart of assistive glasses for visually impaired people.

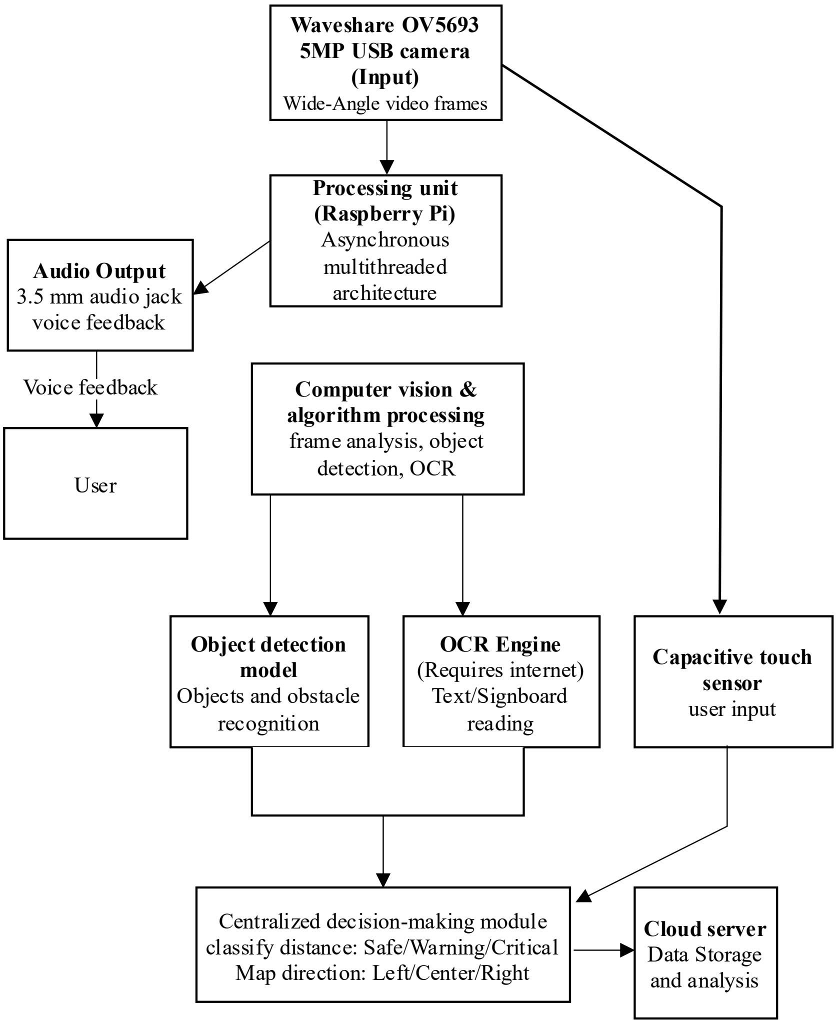

Figure 1. Block diagram of assistive glasses for visually impaired person.

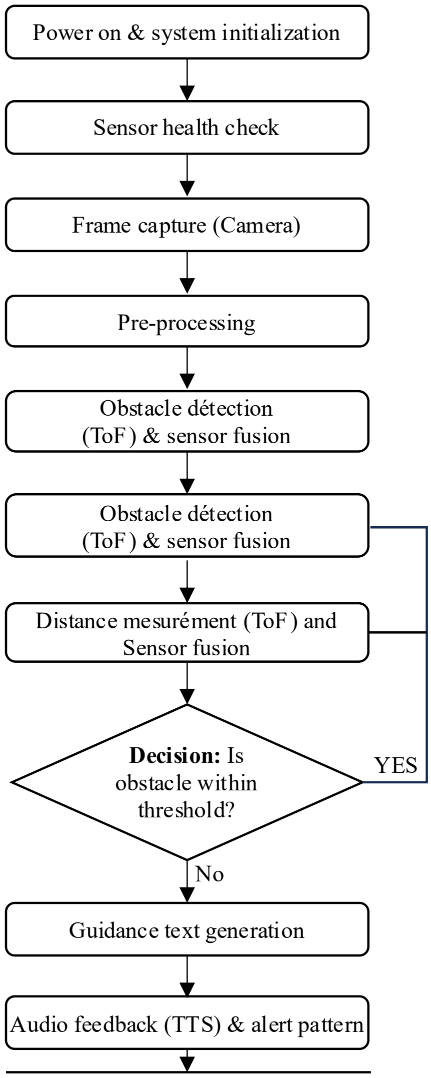

Figure 2. Flow chart diagram of assistive glasses for visually impaired person.

System Architecture Overview

Figure 2 shows smart assistive glasses system helps visually impaired persons and provides them real time navigation of surrounding using different sensors, processing units and feedback technology. VL53L0X time of flight for distance measurement, OV5693 5 MP for object and text recognition, MPU6050 for situation understanding and mobility detection and Touch sensor for communicating with user. The Raspberry Pi processes sensor data, which measures and detects obstacles, movement detection, and text-to-speech conversion. The feedback module provides a real-time audio output of the process data using the TTS method so that the user is aware of the surrounding conditions and safe road. A microSD card was used to store the frames, videos, and system logs. This system is more useful for visually impaired persons, making them independent in performing their own daily tasks.

IMPLEMENTATION

Local Processing

This system uses PyTorch to activate the Yolov8 model locally on the Raspberry Pi. The system can detect objects of daily use in real time without the need for an Internet connection.

Remote Processing

In this system, an AI model is used for scene understanding. The captured frames are encoded serially and sent to the cloud for frame analysis and generation of meaningful information.

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Smart Audio Routing

An audio system was used to ensure functionality and reliable communication. In this system, we used Google TTS to generate audio output, which can provide zero latency and a faster response.

Smart Mute and Gate Tracking

The MPU6050 sensor continuously measures the user's movement. It activates when the user starts moving and gets off when the user sits or stops moving. It also detects major obstacles when they get too close to the user.

Capacitive Touch Controls

Touch sensor is used to enable communication between user and system, touch sensor uses time based logic for communication. A hold time of 5 s enables the camera to capture a frame of the surroundings so that the frame is sent to the controller for analysis and then produces a useful audio output.

RESULTS AND DISCUSSION

Obstacle Detection and Accuracy

The system detects and identifies obstacles using camera-based object detection and ToF-based distance measurement. The camera detects chairs, walls, and daily things like persons very correctly, and the ToF-based distance measurement is also good. The accuracy of the camera decreases in low light or dark light or at night, but the ToF-based sensor keeps measuring the distances of objects because

Real-Time Performance and Response

Table 1 lists the real-time output performance. This system has achieved real-time recognition, which is required for assistive navigation. Distance measurement is easier with the help of a ToF-based sensor, and object detection with the YOLO model added delay because of the load on the system. A delay is also added because of the dependency on the network, which creates a trade-off between speed and processing capabilities.

Directional Awareness and System Reliability

The system detects and identifies obstacles using camera-based object detection and ToF-based distance measurement. The camera detects chairs, walls, and daily things such as persons very correctly, and the ToF-based distance measurement is also good. The accuracy of the camera decreases in low light or dark light or at night, but the ToF-based sensor continues measuring the distances of objects because of infrared light. The results indicate that the system is reliable for use in daily life.

LIMITATIONS AND FUTURE SCOPE

Current Limitations

Limited detection range: This system has a limited range of detection because the ToF-based VL53LOX sensor can detect objects or obstacles only up to a range of 2 m; beyond this range, the sensor cannot detect objects. Therefore, this system can be risky in crowded, busy, and fast environments.

Battery limitations: Power bank runs off fast because of the continuous load of the working camera module and processing unit. Therefore, it becomes necessary to charge the battery frequently, and it is difficult to keep the system on for a full day. This requires a high-capacity battery, a highly energy-efficient system, and proper battery management.

Environmental constraints: Rain, fog, and dust can decrease the reliability of the system to work in different environmental conditions; therefore, components require a highly weather-resistant design so that it does es not affect the reliability.

Dependency on lightning conditions: This system is highly dependent on bright-light environments because cameras cannot capture and analyze the dark frames from the environment; therefore, using infrared lights and systems that work well in low-light conditions can improve performance in low-light conditions.

Table 1. Real-time output performance table.

S.N.	Input scenario	Total input (words/objects)	Detected / processed
1	1 Book reading	100 words	20 words
2	2 Newspaper reading	120 words	30 words
3	3 Handwritten letter	80 words	15 words
4	4 Signboard detection	10 words	6 words
5	5 Object detection	10 objects	8 objects
6	6 Face recognition	5 persons	3 persons
7	7 Obstacle detection	10 obstacles	9 obstacles

User comfort and usability issues: Integration of too many hardware on glasses makes it more complicated for users to wear and use the system. It takes time to get comfortable at starting days for users may need some time to get used to it before using it effectively.

Future Directions

Advanced deep learning methods can be used to increase the accuracy of object detection and recognition systems. Algorithms such as YOLO can be used to run on a Raspberry Pi effectively, and the system can be improved by including features such as face recognition, voice recognition, and scenario understanding.

The system can become faster and more accurate after including IoT and cloud computing devices, making it possible to share real-time data with the authorities and obtain an immediate response in case of an emergency. Tracking users' locations can be installed by using GPS navigation. Enhancing battery life and reducing hardware makes it more portable and long lasting. User experience can be improved by using vibration feedback output with audio output in the system.

CONCLUSION

The proposed system was designed and developed to assist visually impaired persons in becoming more independent in moving and communicating in their environment. This system integrates hardware and software architecture, such as Raspberry Pi, computer vision, text-to-speech component, AI module, and infrared sensors, to update real-time information of the surroundings to the user. The combination of different types of sensors can increase the reliability of the system for different environmental conditions. This system is low-cost, portable, and useful for blind people in real-life tasks.

However, the system has some limitations. A camera requires a bright-light environment to capture frames, and the processing power of the components is limited, with some latency. In the future, it is possible to improve accuracy, fast processing, and latency by using advanced technology. Overall, this system is a useful and effective step towards assisting visually impaired persons.

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