Object Detection and Alert System for Visually Impaired Users

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Abstract

Visually impaired individuals often face significant challenges in accessing textual information, recognizing currency, and identifying people in their surroundings. This project aims to address these challenges by developing an integrated **Object Detection and Alert System** tailored for visually impaired users. The system focuses on three primary functionalities: reading books, detecting and recognizing currency, and identifying known individuals.

The proposed solution leverages cutting-edge technologies in computer vision and natural language processing. **Optical Character Recognition (OCR)** is used for real- time text extraction from books or documents, with the output delivered as audio feedback via Text-to-Speech (TTS) technology. A deep learning-based object detection model is implemented for recognizing currency denominations, ensuring accurate identification under various conditions. For known person detection, a facial recognition module matches detected faces against a pre-stored database, announcing the identified person's name through voice output.

The system is designed to be portable, user-friendly, and cost-effective, utilizing readily available hardware such as cameras and processing units (e.g., Raspberry Pi). Experimental results demonstrate the effectiveness of the system, achieving high accuracy in text reading, currency recognition, and face identification. This project contributes to enhancing the independence and quality of life for visually impaired individuals, offering them a practical and reliable assistive technology.

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Introduction:

According to the World Health Organization (WHO), there are approximately 285 million visually impaired individuals worldwide, including 39 million who are completely blind. These individuals face significant challenges in their daily lives, particularly in accessing printed materials, identifying currency, and recognizing people. Tasks that may seem simple, such as reading a book, verifying the value of money, or identifying acquaintances in a crowd, can be incredibly daunting for visually impaired users, often requiring assistance from others.

Despite advancements in assistive technologies, many existing solutions are either limited in scope, expensive, or not tailored to the specific needs of visually impaired users. There is a need for an affordable, portable, and comprehensive system that integrates multiple functionalities to enhance the independence and confidence of visually impaired individuals.

The development of an object detection and alert system for visually impaired users aims to bridge the gap between existing assistive technologies and the specific needs of the visually impaired community. This project focuses on creating a user-friendly and cost-effective solution that combines three key features:

1. Reading printed text, such as books and documents, and providing audio feedback.
2. Detecting and recognizing currency denominations to ensure financial transactions are handled independently.
3. Identifying known persons in real time to facilitate social interactions.

This multi-functional system has the potential to improve the quality of life for visually impaired individuals by empowering them to perform daily tasks with ease and dignity.

Objectives:

The primary objectives of this project are:

1. To develop a text recognition module using Optical Character Recognition (OCR) technology for real-time text-to-speech conversion.
2. To implement a robust currency detection system using deep learning-based object detection models.
3. To design a facial recognition module capable of identifying known individuals from a pre-stored database.
4. To integrate these functionalities into a portable system with an intuitive interface and real-time audio feedback.

Future Scope:

This project is aimed at visually impaired users who require assistance in everyday tasks such as reading, financial transactions, and social interactions. The system is designed to be:

- **Portable:** Using minimal hardware, such as a camera and a processing unit, to ensure easy mobility.
- **Accessible:** Providing simple voice-based interactions to cater to users with little to no technical knowledge.
- **Efficient:** Delivering accurate and timely outputs in diverse environmental conditions, such as varying lighting and noise levels.

By addressing these needs, the project seeks to contribute to the development of inclusive technologies that promote accessibility and independence for the visually impaired community.

Technology & Material Specification

Raspberry Pi 4:

The Raspberry Pi 4 is a powerful single-board computer with a quad-core ARM Cortex-A72 processor and up to 8GB of RAM, making it ideal for AI, IoT, and multimedia projects. It offers fast connectivity options, including WiFi 5, Bluetooth 5.0, and Gigabit Ethernet, along with dual micro HDMI ports supporting 4K output. The 40-pin GPIO header allows for hardware integration, while USB 3.0 ports provide high-speed data transfer. Compact and versatile, it’s suitable for applications like machine learning and embedded systems, though it requires good power management and cooling for intensive tasks.

Raspberry Pi Spy Camera:

The Smart AI Glasses feature a Raspberry Pi Spy Camera for discreet and efficient image capture. This compact and high-resolution camera ensures accurate text recognition by providing clear images for processing. Its small form factor seamlessly integrates into the 3D-printed frame, making the design lightweight and user-friendly.

Optical Character Recognition (OCR):

OCR is a technology that converts different types of written or printed text—such as scanned documents, photos of text, or sign boards—into machine-readable digital text. This project utilizes the Doctr library, a Python-based OCR framework that employs machine learning models for high-accuracy text recognition. Doctr supports a variety of fonts, languages, and text layouts, making it robust in diverse scenarios. In this project, OCR processes the images captured by the glasses' camera, extracting the text for audio transcription.

Text-to-Speech (TTS):

TTS technology converts text into spoken words, making written content accessible to users who cannot read or prefer listening. In this project, the pyttsx3 library is used for TTS. Pyttsx3 is a Python-based engine that supports multiple voices, languages, and speed adjustments. It generates an audio file from the extracted text, which is then played for the user. This real-time conversion from text to audio forms the core functionality of the Smart AI Glasses.

Doctr Library:

Doctr (Document Text Recognition) is an open-source library for OCR that utilizes deep learning models built with PyTorch or TensorFlow for high-speed and accurate text extraction from images. The library is particularly suited for structured text layouts, such as those in books, signs, or documents. Doctr’s capability to handle various lighting conditions and text orientations enhances the reliability of the Smart AI Glasses.

pyttsx3 Library:

Pyttsx3 is a cross-platform, offline text-to-speech conversion library in Python. Unlike many TTS solutions that rely on online APIs, pyttsx3 operates locally, ensuring that the Smart AI Glasses function without an internet connection.

It supports different voices and languages, allowing customization based on user preferences.

OpenCV (Open-Source Computer Vision Library):

OpenCV is a widely used library for image processing and computer vision tasks. In this project, OpenCV captures images from the camera at regular intervals or when triggered by a manual button press. The library's preprocessing capabilities, such as cropping or enhancing images, improve the accuracy of OCR.

3D Printing:

The glasses' frame is designed using 3D modeling software and printed using PLA filament, a type of thermoplastic known for its strength and ease of printing. The 3D-printed design ensures a lightweight and comfortable fit while securely housing the electronic components.

Lithium-Ion Polymer Battery:

The glasses use a rechargeable 3.7V Lithium-Ion Polymer battery, which provides sufficient power to operate the Raspberry Pi Zero 2 W and connected peripherals. A power booster circuit steps up the voltage as needed, ensuring stable and efficient operation.

GPIO (General Purpose Input/Output) Pins:

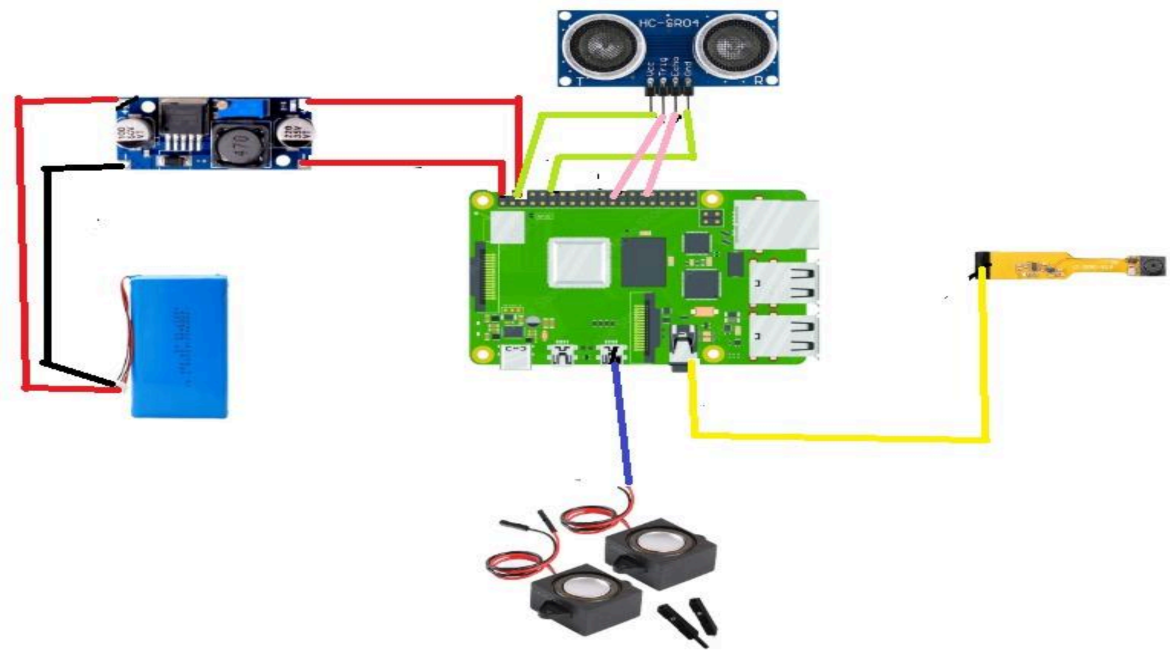
The GPIO pins on the Raspberry Pi are used to connect external components like pushbuttons. In this project, a push button can be configured to trigger the camera for capturing text at specific moments, enhancing user control and accuracy.

Raspberry Pi Speaker:

The Smart AI Glasses utilize a Raspberry Pi-compatible speaker for audio output, providing a direct and reliable sound solution. This ensures clear and immediate audio feedback without the need for external wireless connections.

By combining these technologies and components, the Smart AI Glasses deliver an innovative solution for real-time text-to-audio conversion, significantly enhancing accessibility for visually impaired individuals.

CIRCUIT DETAILS:



(1) CIRCUIT DIAGRAM

Components & Their Roles

1. Raspberry Pi 4 – The main processing unit that controls the peripherals.
2. Ultrasonic Sensor (HC-SR04) – Measures distance using sound waves.
3. Raspberry Pi Spy Camera – Captures images and video.
4. 7.4V Battery – Power source for the Raspberry Pi.
5. Buck Converter (Step-Down Converter) – Converts 7.4V to 5V to safely power the Raspberry Pi.
6. Raspberry Pi Speakers – Outputs audio.

Circuit Connections

1. Power Supply Setup

- The 7.4V battery output is too high for the Raspberry Pi, so we need the buck converter.
- Connect the battery's positive terminal (+) to the buck converter’s input + (VIN).
- Connect the battery's negative terminal (-) to the buck converter’s input - (GND).
- Set the buck converter output to 5V (using a multimeter).
- Connect the buck converter’s output + (VOUT) to the 5V pin of the Raspberry Pi.
- Connect the buck converter’s output - (GND) to the GND pin of the Raspberry Pi.

2. Connecting the Ultrasonic Sensor (HC-SR04)

- VCC → Connect to 5V pin on Raspberry Pi.
- GND → Connect to GND pin on Raspberry Pi.
- TRIG → Connect to GPIO 23 on Raspberry Pi.
- ECHO → Connect to GPIO 24 on Raspberry Pi (via a voltage divider using two resistors to step down 5V to 3.3V).

3. Connecting the Raspberry Pi Spy Camera

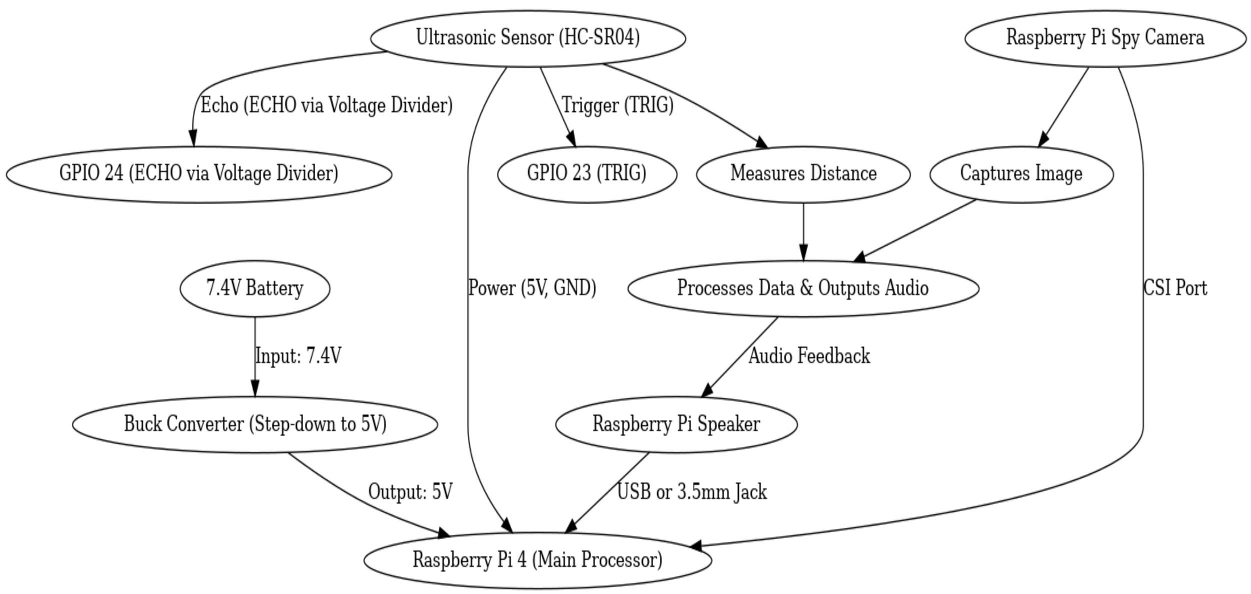
- Attach the camera module to the CSI port of the Raspberry Pi.
- Ensure the ribbon cable is properly aligned (contacts facing the correct side).

4. Connecting Raspberry Pi Speakers

- If using USB speakers, plug them into a USB port.
- If using 3.5mm audio jack speakers, connect them to the headphone jack on the Raspberry Pi.
- Configure audio output using Raspberry Pi settings.

Working Principle

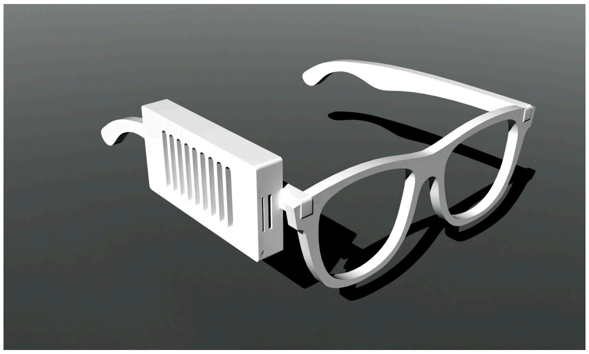
1. The ultrasonic sensor measures distance and sends data to the Raspberry Pi.
2. The Raspberry Pi Camera captures images based on commands.
3. The Raspberry Pi processes the data and can give audio feedback through the connected speakers.
4. The system is powered by a 7.4V battery, which is regulated to 5V using a buck converter.



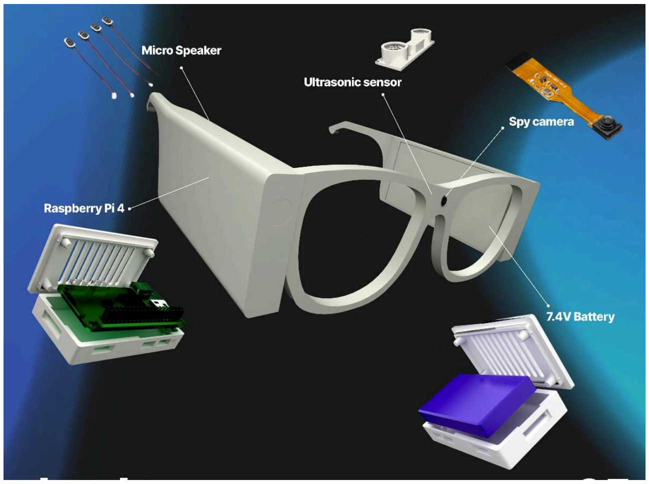
(2) Flowchart of the circuit

System Design and Architecture:

The system is designed to assist visually impaired users by integrating three key functionalities: book reading, currency detection, and known person identification. It uses a camera as the primary input device, processes data using a central processing unit (e.g., a Raspberry Pi, mobile phone, or computer), and provides output through audio feedback.)



(3) CAD Model



(4) Picture Depiction of 3D Glasses

SUMMARY OF FUTURE WORKS:

The current system provides essential functionalities for visually impaired users, including book reading, currency detection, and known person identification. However, there are opportunities to enhance the system further to improve its usability, scalability, and accuracy. Future developments could include:

1. **Integration of Object Detection for Daily Objects:**
   Expanding the system to detect and identify everyday objects such as household items, appliances, and landmarks to assist users in navigation and performing routine tasks.

2. **Multilingual Support:**
   Extending text recognition and audio output to support multiple languages, enabling broader adoption in diverse regions.

3. **Improved Face Recognition with Larger Databases:**
   Enhancing the face recognition module to handle larger databases of known individuals and improving accuracy in challenging conditions, such as low light or partial occlusions.

4. **Edge Computing for Real-Time Processing:**
   Optimizing the system to work on lightweight, portable devices with edge computing capabilities for faster real-time processing and reduced dependency on cloud services.

5. **Voice Command Integration:**
   Adding voice command features to enable hands-free mode switching and interaction with the system, enhancing accessibility.

6. **Wearable Device Implementation:**
   Transforming the system into a wearable device, such as smart glasses, for greater convenience and ease of use.

7. **Enhanced Robustness:**
   Improving system performance under varying environmental conditions, such as extreme lighting, background noise, or cluttered scenes.

8. **Integration with Navigation Systems:**
   Combining the system with GPS-based navigation tools to help visually impaired users move independently in unfamiliar environments.

By incorporating these enhancements, the system can evolve into a more comprehensive and versatile assistive technology, significantly improving the autonomy and quality of life for visually impaired users.

Results:

Findings from Research Study

The research identified key technologies suitable for an object detection and alert system for visually impaired users. Optical Character Recognition (OCR) was found effective for text extraction, while deep learning models like YOLO and FaceNet showed promise in object and face recognition tasks. Portable hardware such as Raspberry Pi is a feasible choice, though its processing limitations may affect real-time performance.

Anticipated Outcomes

The system is expected to accurately:

1. Extract and read printed text.
2. Detect and classify currency denominations.
3. Identify known individuals from a pre-stored database.

Expected Costs:

Proposed Bill of Materials

S.No.	Component Name	Quantity	Specification	Cost (₹)	Source of Procurement
1	Raspberry Pi 4	2	Computer , Model B 4GB RAM	12,896	Amazon.in
2	7.4 Volt Battery	1	7.4 Volt Li-Ion 18650 Rechargeable Battery (Pack of 2)	1,560	Amazon.in
3	Buck Converter	2	Shockley 10 Amp 300W high power buck converter	1,180	Amazon.in
4	Raspberry Pi Spy Camera	2	Fixed focused lens, 8 Megapixel, native resolution sensor capable of 3280X2464 pixel static images	3,940	Robu.in
5	SunLu PLA+ Black Filament	2	1.75mm 1kg/roll	2,550	Robu.in
6	Raspberry Pi Speaker	2	Built in 1W 8 ohm speaker	4,000	Robu.in
7	Ultrasonic Sensor	4	3.3V - 5.5V HC-Sr04+ Ultrasonic Sensor 4 pin	700	Robu.in
8	Miscellaneous		Extra Material Requirements	5,000	

Grand Total ₹ (in figures) : **31,826**

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