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VOICE-GUIDED NAVIGATION SYSTEM WITH SOS AND OBSTACLE DETECTION FOR ENHANCED MOBILITY IN VISUALLY IMPAIRED INDIVIDUALS

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Abstract : The Smart Blind system empowers visually impaired individuals with real-time object recognition and an SOS feature. It uses a Raspberry Pi and Pi Camera to capture the environment, processing images via a COCO-based machine learning model. Detected objects are conveyed through eSpeak text-to-speech audio feedback. An SOS button linked to an Arduino retrieves GPS-based location data, sending it to caretakers via a GSM module for emergencies. This system enhances independence and safety by integrating machine learning, GPS, and GSM for intuitive functionality. Future upgrades may include ultrasonic sensors and voice recognition, further improving its utility for visually impaired users.

IndexTerms - **Object Detection, Raspberry Pi, Arduino UNO, SOS, Visually Impaired, Machine Learning, GSM, GPS, eSpeak, COCO Dataset.**

I. INTRODUCTION

According to the World Health Organization (WHO), over 2.2 billion people worldwide suffer from some form of visual impairment, with many facing significant challenges in navigating their surroundings independently. While mobility aids like canes and guide dogs provide some assistance, they have limitations when it comes to providing detailed information about the environment or addressing emergencies. This gap calls for innovative solutions to enhance the independence, safety, and quality of life for visually impaired individuals.

The Smart Blind system is an advanced assistive technology developed to address these challenges. By leveraging modern technologies such as machine learning, real-time object detection, and location-based alert systems, the project aims to provide a comprehensive tool for visually impaired users. The system integrates a Raspberry Pi microprocessor with a Pi Camera to capture and analyze the environment. A pre-trained machine learning model based on the COCO dataset classifies objects in front of the user, and the eSpeak library converts the results into audio feedback, enabling users to understand their surroundings through sound.

In addition to real-time object recognition, the Smart Blind system includes an SOS feature designed for emergencies. A button connected to an Arduino Uno microcontroller allows users to send their live location to caretakers via a GPS module and GSM module. This ensures timely assistance in critical situations, enhancing user safety and peace of mind.

The Smart Blind system is a step forward in assistive technology, combining cutting-edge machine learning with reliable hardware components to deliver real-time assistance. By reducing dependency on others and improving navigation and safety, this system empowers visually impaired individuals to lead more independent and confident lives.

II. Related Works

Prior research in assistive technologies for the visually impaired has explored various methods involving machine learning, object detection, and emergency communication systems. One study implemented a YOLO-based object detection model using Python and OpenCV to assist blind individuals through real-time object recognition paired with Google's text-to-speech engine for auditory feedback. Although effective in controlled environments, this system lacked integrated mobility or emergency response capabilities.

Another approach utilized ultrasonic sensors mounted on smart walking sticks to detect nearby obstacles and alert users via buzzers or vibrations. While affordable and portable, such devices provided limited contextual awareness and no object-level classification. Further development saw the integration of GPS and GSM modules into mobility aids to enable location tracking and emergency alerts, improving user safety. However, these systems typically operated independently of real-time object recognition.

Some designs employed Raspberry Pi and Arduino platforms to enable multi-functional assistive tools, combining cameras for image capture with embedded computing for object recognition. These models often used pretrained convolutional neural networks (CNNs) like MobileNetV2 or TensorFlow Lite for efficient classification. Despite promising results, many of these systems faced challenges with latency, power consumption, and scalability for outdoor use.

Recent works have focused on improving accessibility by combining OCR (Optical Character Recognition) with text-to-speech conversion to assist in reading printed text. Additionally, systems using PIR and ultrasonic sensors enhanced obstacle detection but lacked integrated emergency alert mechanisms.

The proposed Blind Assist System seeks to address these gaps by combining object detection, OCR, obstacle sensing, and GPS-based SOS alerts into a single, portable unit powered by Raspberry Pi and Arduino. This integrated approach offers a comprehensive solution aimed at enhancing mobility, safety, and independence for visually impaired individuals.

III. System Architecture

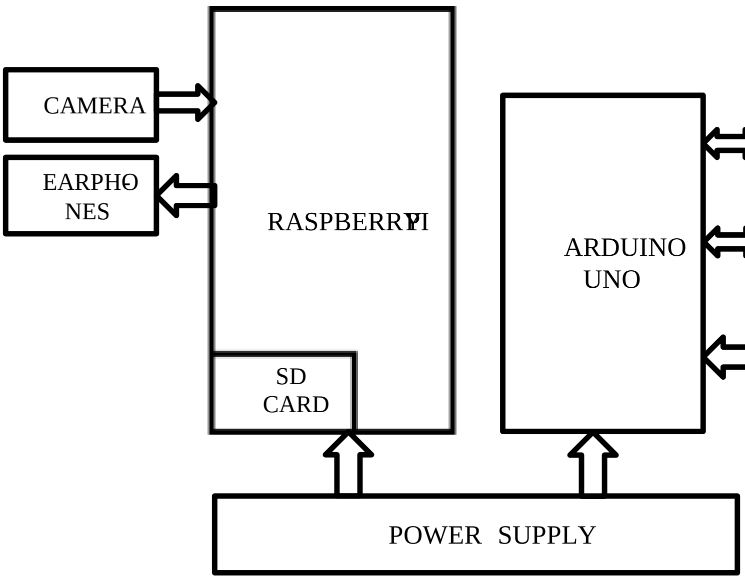

fig 1: block diagram of the system

Using a Raspberry Pi microprocessor, a Pi Camera, SD card, and earphones, a smart blind assist system is developed to aid visually impaired individuals through real-time object recognition and audio feedback. The system integrates an Arduino UNO with an SOS button, GPS module, and GSM module to handle emergency alerts and location tracking functionalities.

The Raspberry Pi processes the captured images using a machine learning model based on the COCO dataset and delivers voice output using the eSpeak text-to-speech engine. An SD card is used to store the operating system and model files. The audio feedback is provided to the user through standard earphones.

The Arduino UNO receives inputs from the SOS button and communicates with the GPS module to fetch the user's location. In case of an emergency, the GSM module is triggered to send an SMS alert containing the real-time location to predefined caretakers.

A common power supply unit is shared between the Raspberry Pi and Arduino UNO, ensuring compactness and portability of the system. Fig. 1 illustrates the block diagram of the proposed system.

Fig. 1 shows the proposed system's block diagram. The upcoming section provides a detailed explanation of the system architecture, including its layers and data flow.

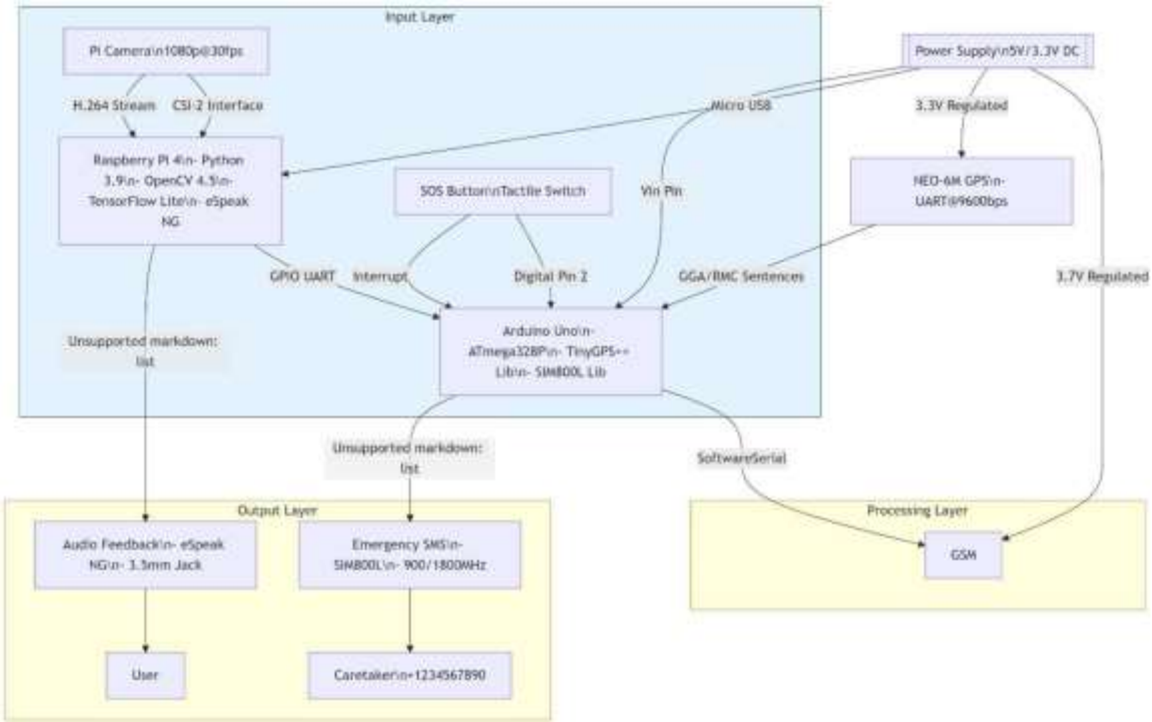

fig2: system architecture

To implement a fully functional and layered assistive device, the Smart Blind System uses a Raspberry Pi for vision processing and an Arduino UNO for emergency management. The architecture, as shown in Fig. 2, is divided into multiple layers: input, processing, and output.

In the input layer, the Pi Camera is connected to the Raspberry Pi via a CSI-2 interface, capturing real-time images in high resolution. These images are processed by TensorFlow Lite models implemented using Python and OpenCV libraries. A tactile SOS button is connected to the Arduino UNO's digital input, which triggers emergency protocols upon activation.

The processing layer consists of both the Raspberry Pi and Arduino UNO. The Raspberry Pi handles real-time image processing and audio feedback, converting identified objects into speech using the eSpeak text-to-speech engine. The Arduino UNO processes the SOS signal, fetches GPS coordinates from the NEO-6M GPS module via UART, and communicates with the GSM module (SIM800L) to send emergency SMS alerts to caretakers.

The output layer consists of two key elements. First, the user receives audio feedback through 3.5 mm jack earphones, allowing them to hear object names and notifications. Second, the emergency signal is transmitted via GSM, alerting the caretaker with the user's exact GPS location.

The entire system is powered through a regulated 3.3V and 5V DC supply, ensuring compatibility with both the Raspberry Pi and Arduino components. Fig. 2 illustrates the layered system architecture, clearly showing the interaction between modules and the data/control flow.

Fig. 2 depicts the detailed architecture of the blind assist system. It highlights the modular integration of hardware and software, with clear demarcation of data processing responsibilities across the input, processing, and output layers.

IV. Hardware and Software Requirements

1. Raspberry Pi 4

- Acts as the central processing unit.
- Handles object detection using a Pi Camera (connected via the CSI port).
- Runs Python, OpenCV, and TensorFlow Lite for image processing.
- Provides voice feedback through audio output.
- MicroSD card holds the operating system and ML models.

fig 3: raspberry pi board 4

2. Pi Camera (connected to Raspberry Pi)

- Used for capturing real-time images.
- Connects to the Raspberry Pi through the flat CSI-2 ribbon cable.
- Feeds image frames to the object detection model.

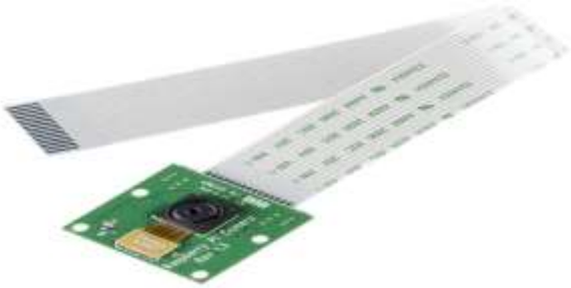

fig3: pi camera 5mp

3. Ultrasonic Sensor (HC-SR04)

- Located near the center above the battery pack.
- Measures distance to nearby objects.
- Used for obstacle detection and to aid in spatial awareness.

fig4: ultrasonic sensor (hc-sr04)

4. Arduino UNO

- Manages emergency response operations.
- Interacts with the GPS and GSM modules.
- Receives input from the SOS button.
- Sends SMS alerts to caretakers with GPS coordinates.

fig5: arduino uno r3

5. GPS Module (NEO-6M)

- Positioned above the Arduino board.
- Receives satellite signals and provides latitude/longitude data.
- Communicates with the Arduino through UART.

fig6: gps module (neo-6m)

6. GSM Module (SIM800L)

- Sends SMS alerts to predefined emergency contacts.
- Triggered when the SOS button is pressed.
- Connected to the Arduino via SoftwareSerial pins.

fig7: gsm module (sim800l)

7. SOS Button

- Located next to the GPS module (small black push button).
- Used by the user to manually trigger an emergency alert.
- Sends a signal to the Arduino when pressed.

fig8: sos buttons.

8. Battery Pack

- Contains two 3000mAh rechargeable lithium batteries.
- Powers both Raspberry Pi and Arduino circuits.
- Ensures portability and uninterrupted field operation.

9. Buck Converter/Voltage Regulator

- Converts higher battery voltage to regulated 3.3V or 5V as needed.
- Powers sensitive modules like GPS and GSM.

fig10: buck convertor

SOFTWARE IMPLEMENTATION

The proposed blind assist system utilizes a combination of software frameworks and libraries to enable real-time object detection, audio feedback, and emergency alert transmission. Each component is carefully selected for compatibility with the Raspberry Pi and Arduino platforms, ensuring lightweight execution and optimal performance.

A. Raspberry Pi Software Environment

The Raspberry Pi serves as the main processing unit and is configured with the following software stack:

- **Operating System**: Raspberry Pi OS (32-bit, Debian-based) installed on a 16GB microSD card.
- **Programming Language**: Python 3.9 is used as the core development language due to its vast library support and simplicity.
- **OpenCV 4.5**: Employed for image acquisition, preprocessing, and visualization. It facilitates real-time video streaming and frame-by-frame analysis from the Pi Camera.
- **TensorFlow Lite**: A lightweight deep learning framework used to load and infer object detection using a MobileNet SSD model trained on the COCO dataset. This framework enables edge-device inference with minimal latency.
- **COCO Dataset**: The system utilizes a pre-trained model that recognizes 80 common object categories, ensuring a wide range of environmental awareness.
- **eSpeak**: An open-source text-to-speech (TTS) engine that converts identified object names into audio feedback. The output is delivered through a 3.5mm audio jack connected to earphones.

B. Arduino UNO Programming

The Arduino UNO is responsible for emergency communication. It is programmed using the Arduino IDE with the following libraries:

- **SoftwareSerial**: Used to establish serial communication with the GSM module (SIM800L) on alternate digital pins.
- **TinyGPS++**: A lightweight library used to parse the GPS data from the NEO-6M module and extract latitude and longitude.
- **SIM800L AT Commands**: Used to send SMS messages containing location data to a predefined mobile number.

The logic includes interrupt-based monitoring of the SOS button. Upon detection, the Arduino reads the GPS coordinates and triggers the GSM module to send an alert SMS with a clickable Google Maps link.

C. Interfacing and Integration

Communication between Raspberry Pi and Arduino is handled independently, ensuring modularity. The object detection and emergency signalling systems operate in parallel, allowing the device to perform multiple tasks simultaneously. Data preprocessing is minimal to maintain speed, and audio feedback is handled on the Raspberry Pi without external cloud dependencies, ensuring real-time performance.

V. METHODOLOGY

The proposed system operates through four integrated modules, designed to assist visually impaired individuals with real-time environmental awareness, reading ability, and emergency response.

A. Real-time Object Detection and Audio Feedback

A Raspberry Pi 4 serves as the core processing unit, connected to a Pi Camera that continuously captures real-time images of the user's surroundings. These images are processed using a pre-trained object detection model (COCO dataset) with OpenCV and TensorFlow. Once objects are detected, their names are converted to speech using the eSpeak text-to-speech engine. The audio is delivered through headphones, enabling visually impaired users to understand and navigate their environment independently.

B. Obstacle Detection Using Ultrasonic Sensors

To further assist in spatial awareness, the system incorporates ultrasonic sensors (HC-SR04) to detect nearby obstacles. These sensors continuously measure the distance to nearby objects. The data is processed by the Raspberry Pi, and corresponding distance alerts are provided as audio feedback to the user, helping them avoid potential hazards.

C. Emergency SOS Alert System

An SOS button is interfaced with an Arduino Uno microcontroller. Upon pressing the button, the Arduino fetches the user's current location using a GPS module (NEO-6M). The location is then transmitted to pre-defined emergency contacts through a GSM module (SIM800L) in the form of an SMS containing a Google Maps link. A buzzer is also activated to alert nearby individuals.

D. OCR-based Text Recognition and Voice Output

The system includes Optical Character Recognition (OCR) capability to aid in reading printed or handwritten text. The Pi Camera captures an image of the text, which is then processed using Pytesseract OCR in Python. The recognized text is converted into speech using the eSpeak engine, allowing users to "read" text from books, signs, or labels through voice output.

VI. Results and Discussion

The authors have conducted a series of evaluations to test the effectiveness and functionality of the developed blind assist system. The testing focused on several key areas: real-time object detection accuracy, responsiveness of the audio feedback system, effectiveness of the emergency alert mechanism, and the overall power efficiency of the integrated hardware.

With the help of a pre-trained machine learning model (based on the COCO dataset) deployed on the Raspberry Pi, the system successfully detected common objects in the environment such as chairs, bottles, people, and vehicles. The captured images were processed in real-time using OpenCV and TensorFlow Lite, and object names were conveyed audibly to the user via the eSpeak text-to-speech engine. The detection speed and audio feedback were observed to be timely and intelligible, enabling visually impaired individuals to interpret their surroundings with improved awareness.

The emergency alert system was triggered through an SOS button connected to the Arduino UNO. Upon activation, the Arduino fetched the user's real-time GPS location using the NEO-6M GPS module and transmitted it via SMS to predefined caretaker numbers through the SIM800L GSM module. The GPS coordinates were accurately received and opened directly in Google Maps, ensuring efficient location tracking. The delay between triggering the SOS and receiving the SMS was measured to be within a few seconds under standard GSM network conditions.

The ultrasonic sensor provided additional support in obstacle detection, effectively alerting users to nearby objects by measuring distance. This feature acted as a supplementary aid alongside the camera-based recognition system.

The power supply, based on a 3000mAh dual-cell battery pack, provided sufficient operational time for both the Raspberry Pi and Arduino-based components. Voltage regulation using a buck converter ensured stable performance for modules requiring 3.3V and 5V inputs. Power consumption was optimized by managing idle times in the Arduino and reducing unnecessary image processing when no object was detected.

The integrated system successfully demonstrated its ability to offer object awareness, environmental interaction, and emergency communication in a compact and portable design. While the current model functions effectively in indoor and moderately lit outdoor environments, future enhancements could address challenges like voice control integration, night vision support, and waterproof casing for outdoor use.

The complete prototype illustrates how Raspberry Pi and Arduino, when used in a collaborative architecture, can form an intelligent assistive tool for the visually impaired. Through a combination of sensors, real-time AI, and wireless communication, the blind assist system enhances both safety and mobility.

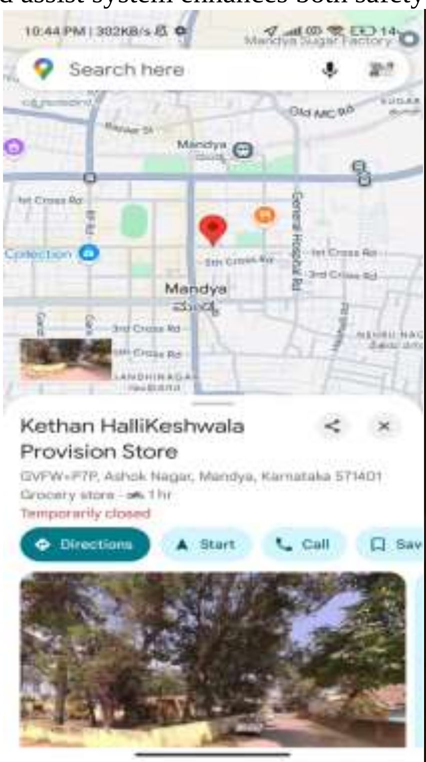

fig11: sos output with live location feed.

fig 12: circuit of the system and output of the object detection

VII. Conclusion

The Smart Blind system is an innovative assistive technology designed to empower visually impaired individuals by enhancing their independence and safety. By leveraging a Raspberry Pi, Pi Camera, and a pre-trained machine learning model, the system provides real-time object detection and audio feedback, allowing users to perceive and navigate their surroundings effectively. The integration of an SOS button, GPS module, and GSM module adds an essential layer of safety by enabling emergency communication and location tracking.

This project highlights the potential of modern technology to address the challenges faced by visually impaired individuals in their daily lives. Its user-friendly design, real-time functionality, and affordability make it a practical solution for individuals and communities. While the system has certain limitations, such as dependency on power and environmental conditions, these can be addressed in future iterations through advancements in hardware, software, and design.

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