Vision-Based Assistive Device for the Visually Impaired using Xiao ESP32-S3 Sense and YOLOv3

Project Overview:

This project focuses on the development of a cost-effective and portable assistive system for blind and visually impaired individuals. The device uses real-time object detection and audio feedback to inform the user about nearby objects, enhancing navigation and situational awareness.

Key Components:

1. Hardware

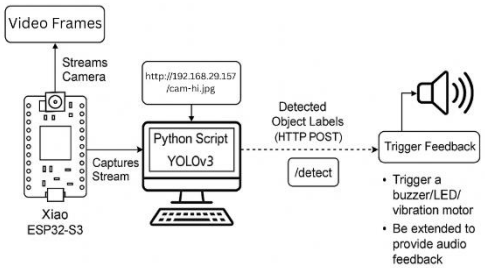
- **Microcontroller:** Xiao ESP32-S3 Sense
- **Camera Module:** Built-in with the ESP32-S3 Sense
- **Other Peripherals:** GPIO-based outputs for buzzer/vibrator or LED
- **Power Supply:** USB-C or LiPo battery (for future portability)

2. Software Stack

- **Microcontroller Environment:** Arduino IDE with ESP32 libraries
- **Object Detection:** YOLOv3 (Darknet model) using Python + OpenCV
- **Communication Protocol:** HTTP (via POST requests from PC to ESP32)
- **Camera Streaming:** Captures live stream from the Xiao ESP32-S3 via `/camera` route

System Architecture:

1. The Xiao ESP32-S3 captures video frames through its onboard camera.
2. The ESP32 streams the video locally (e.g., `http://192.168.x.x/camera`).
3. A **Python script** running on a computer captures this stream and performs object detection using YOLOv3.
4. Detected object labels are extracted from the model output and sent to the ESP32-S3 as HTTP POST requests (`/detect` route).
5. Upon receiving the label, the ESP32 can:
    - Trigger a **buzzer/LED/vibration** motor for feedback.
    - Be extended to provide **audio feedback** using external TTS modules or via PC speakers.



Implementation Details:

ESP32 Arduino Sketch

- Configured camera settings using `esp_camera.h`.
- Launched a simple web server with two endpoints:
  - `/camera`: Streams camera feed.
  - `/detect`: Accepts detected object labels via POST and triggers GPIO pin for feedback.
- Used `Serial.println()` for real-time debugging of received object labels.

Python + YOLOv3 Script

- Loaded the YOLOv3 model and configuration files (`.cfg` and `.weights`).
- Read class labels from `coco.names`.
- Captured image frames from the camera stream using OpenCV.
- Processed each frame to:
  - Detect objects with bounding boxes.
  - Filter results based on confidence and NMS thresholds.
  - Send detected labels to the ESP32 via POST request.
- Provided live feedback on console for detection results.

Feedback Mechanism:

Currently, the system uses a **GPIO trigger** to turn on an output pin upon receiving any label. This is intended to be connected to:

- **LED**: For basic visual cue
- **Buzzer**: For short beeps upon detection
- **Vibration Motor**: For tactile feedback (recommended for visually impaired users)

Planned Upgrade:

- **Audio Feedback using ESP Sense Board and Amplifier:**
  - Using prerecorded audio stored in a SD Card to be played using an amplifier board and speaker.
- **Audio Feedback via Text-to-Speech (TTS):**
  - Using Python's `pyttsx3` or `gTTS` to read out the detected object labels.
  - Can be played through a speaker for direct user feedback.

Sample Output:

```
Detected Objects:
→ PERSON (98%)
→ CHAIR (89%)
→ BOTTLE (90%)
```

Testing Status:

- Camera stream working via ESP32
- Object detection accurate and real-time
- Object label transmission via HTTP POST
- GPIO output control verified
- Audio feedback integration (next step)