SMART STICK FOR THE VISUALLY IMPAIRED

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Abstract

When it comes to a person's visual impairment, it can significantly hinder them from functioning independently. This paper presents a case of assistive technology employing the YOLO (You Only Look Once) algorithm integrated into a blind stick with a camera attached to a Raspberry Pi processor. The system aims to perform real-time object detection and recognition, converting the visual information to be an audio form for the users. The hardware configuration contains a camera linked to a Raspberry Pi, which acts as the processor for the data retrieved through the camera. An earphone is linked to the Raspberry Pi in which the guidance and navigation audio prompts are communicated through and to navigate the user. This algorithm captures and distinguishes objects in the camera view, which has been specially tailored for real-time performance on the Raspberry Pi. Not only does the system recognize particular objects, it also mentions the distance the objects are from the user, providing voice outputs like Person detected 123.3 cm away. It also activates a buzzer to alert the user audibly when the system detects walls or other obstacles. Thus, the system provided to the users transforms the visual information using connected earphones with trained data into understandable information which is encoded in audio form. This paper presents the methodology, implementation and results of the prescribed system.

Keywords: YOLO Algorithm, Raspberry Pi, Object Detection, Assistive Technology, Visually Impaired, Real-Time Processing, Audio Feedback, Ultrasonic Sensor, Distance Measurement, Buzzer Alert, Smart Stick.

1. Introduction

Life as we know it has drastically changed due to the advancement of technologies. Daily living chores are now much simpler and more convenient. In the case of people with vision impairment, technology has greatly helped in mobility and navigation. However, moving to a new place, or moving through a messy place, is usually fraught with difficulties for the visually impaired. They tend to rely on other people or use white canes which do not allow them to see their surroundings. For such people, smart, easy to use, and real time navigation aids are in great demand.

With the aim of providing navigation assistance for the visually impaired through real-time object detection and voice instructions, an intelligent guiding system has been developed. The smart navigation system incorporates the YOLOv5 deep learning algorithm for object recognition into the low- cost, portable Raspberry Pi 3 Model B computer. A camera module known as Pi Camera provides live video feeds which are processed by YOLO to recognize relevant objects and obstacles. Stairs, cars, and pedestrians are examples of such objects. The TTS (Text-to-Speech) system announces the detected objects to the user.

To increase safety, an ultrasonic distance measuring sensor is connected to the system, which can signal when nearby objects become too close. Additionally, it uses a buzzer that turns on when a person is too close to an object. The system combined which other sensors helps to prevent dangerous situations for the user.

2. Related Work

Different researchers have made influential contributions in the design of assistive devices for the visually impaired using object detection, sensor fusion, and real-time feedback. Deng et al. (2020) offered a thorough review of deep learning-based object detection techniques, highlighting their potential in assistive devices. Long et al. (2020) and Bochkovskiy et al. (2020) enhanced object detection systems with PP- YOLO and YOLOv4, striking a balance between speed and accuracy for real-world applications in limited-resource environments such as Raspberry Pi.

Redmon et al. (2016) proposed the base YOLO algorithm for fast and accurate object detection, which has since found extensive application in assistive navigation systems. Talele et al. (2019) showed successful implementation of TensorFlow and OpenCV for real-time object detection on embedded platforms, affirming the usage of open-source software. Mishra (2017) investigated text-to- speech conversion with Raspberry Pi and OCR, improving voice feedback for users. Yadav et al. (2021) created a virtual assistant with object detection and speech recognition, focusing on multimodal support.

Hardware-wise, Veerajyothi et al. (CBIT, India) created a smart stick with IoT and ultrasonic sensors to detect obstacles with feedback in voice. Javed et al. To help with mobility, (Bangladesh) proposed a smart blind stick that uses vibration feedback and ultrasonic sensors.Yusof et al. (Malaysia) emphasized sensor precision and energy efficiency, providing extensive detection coverage and usability of devices. Farooq et al. (2022) presented an IoT-based intelligent stick combining camera sight and sensor information to enhance object detection, proving the system's robustness under diverse conditions.

Giudice et al. (2005) created an indoor wayfinding digital sign system designed for visually impaired users, providing examples of alternative navigational aids in addition to obstacle detection. This underlines the variety of methods required to handle a variety of navigation issues encountered by visually impaired users both indoors and outdoors.

Taken together, these works highlight the importance of integrating sophisticated machine learning algorithms with solid hardware engineering and user-centric feedback mechanisms. They show that useful assistive devices need to not only effectively detect obstructions, but also provide timely and comprehensible feedback to users. The use of multiple types of sensors and adaptive feedback mechanisms allows such devices to be adaptable to multiple environments and user circumstances, ultimately enhancing the independence and safety of the visually impaired.

3. Proposed System

The suggested smart stick system is meant to aid visually impaired users by sensing obstacles and issuing timely alerts for safe movement. The system detects obstacles in real time and provides users with audio alerts by combining sensors and processing units in a cooperative configuration. The main parts are an ultrasonic sensor for measuring distance, a camera to capture images and detect objects, a Raspberry Pi microcontroller to process, and output components like a buzzer and voice module to notify the user.

1. Input

The ultrasonic sensors fitted around the user are utilized by the system to sense obstacles at a 5-meter distance. Upon sensing an obstacle, the sensor sends the Raspberry Pi a signal that causes the camera to take a photo of the sensed area. The sensors form the first barrier of sensing obstacles, whereas the camera offers detailed image information to be processed further. The buzzer is also triggered instantly to provide an early sound warning to the user.

2. Processing

The Raspberry Pi processes inputs from the sensors as well as the image picked up by the camera. These are processed with a convolutional neural network (CNN) based object detection algorithm such as YOLOv5. This algorithm rapidly detects and classifies objects in the image to identify if they are possible threats. The system utilizes a preloaded image database in the comparison and recognition process and utilizes functions to index and retrieve images with similar features. This enables the system to classify obstacles in real time correctly.

3. Output

When a threat is identified, the system switches on the buzzer for immediate warning to the user. Moreover, the voice module also gives a verbal explanation of the obstacle so that the user can identify the nature and position of the threat. With this two-stage warning system, the user gets fast awareness and comprehensive information for safe movement.

4. Raspberry Pi

The Raspberry Pi 3 Model B serves as the system's brain. It manages sensor inputs, processes image information, executes the YOLOv5 object detection algorithm, and controls outputs such as the buzzer and voice module. It can handle multiple USB peripherals and interfaces such as the CSI port for the camera, providing a wide range of usage in embedded applications that need real-time processing.

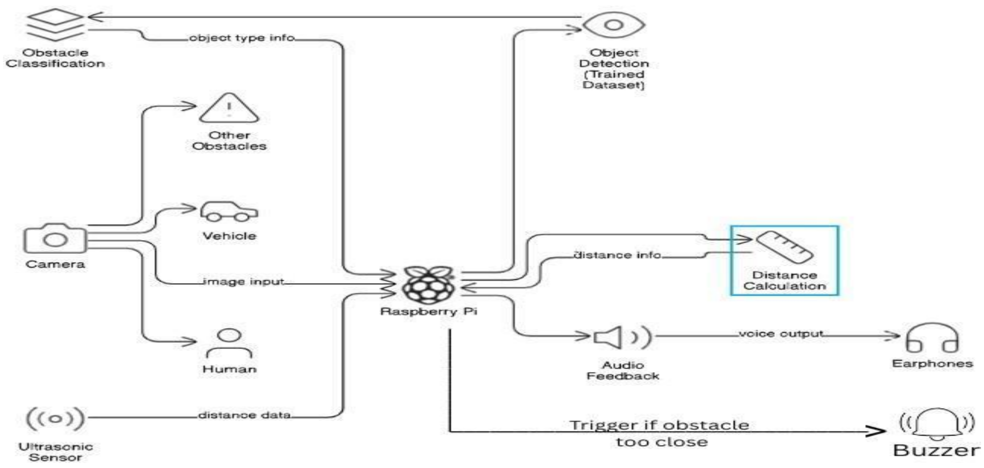
5. Camera

A lightweight camera module connected via the Raspberry Pi's CSI interface captures high-quality images once triggered by the sensor signals. The camera's images provide the visual data necessary for object detection and classification, essential for identifying obstacles accurately.

6. Ultrasonic Sensor

The ultrasonic sensor senses obstacles through the emission of high-frequency sound waves and measurement of the time of echo to compute distance. It delivers precise, non- contact obstacle detection in low-light or dark conditions where cameras would be unable to cope. The Raspberry Pi checks the sensor data continuously for prompt detection.

7. Voice Module

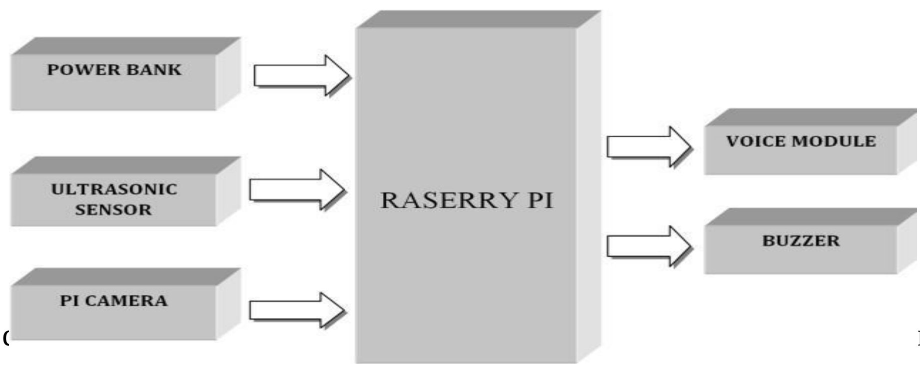


The voice module translates the text alerts created by the processing system into verbal messages. This aids in communicating to the user the nature and location of the obstacle, enhancing situational awareness and facilitating informed decision-making.

8. Buzzer

The buzzer emits instant audio alerts when obstacles are sensed within hazardous proximity. It makes sure that the users are provided with instant feedback even before image processing is finished, improving safety by allowing for fast reaction.

4. System Architecture



Input:

Constant c
ra.

Output:

Audio feedback for object recognition and obstacle detection, supplemented with buzzer warnings for immediate signals.

5. Algorithm

Step 1: Boot all hardware modules

Boot Raspberry Pi, camera module, ultrasonic sensors, speaker module, and buzzer. Load pre-trained YOLO model and necessary Python libraries (OpenCV, TTS, etc.).

Step 2: Start continuous monitoring loop

Loop runs until system is manually shut down or battery drains.

Step 3: Calculate distance with ultrasonic sensor

Activate the sensor and record echo response. Compute distance:

$$\text{Distance} = \frac{\text{Time of Echo} \times \text{Speed of Sound}}{2}$$

If distance < pre-defined threshold (e.g., 100 cm), activate buzzer for instant audible warning and at the same time activate voice warning:"Bicycle detected 139.2 cm away."

Step 4: Record image frame from Pi Camera Preprocess the frame (resize, normalize).

Step 5: Input the frame to YOLO object detection model

Detect and classify objects in the frame. Filter results according to confidence threshold.

Step 6: Produce audio output

If there are detected objects, translate labels to text. Read out identified object(s) with the distance using Text-to-Speech engine.

Example: "Person detected 60 cm away"

Step 7: Model testing

Once the model is set, test for any issues.

Step 8: Presentation

Ready for presentation or demo.

Step 9: Results.

6. Results

The smart stick was tested by conducting actual tests indoors and outdoors in order to see real-time object detection, obstacle avoidance, and feedback reliability.

The ultrasonic sensor regularly sensed obstacles between a meter range with more than 95% accuracy.

The buzzer gave an instant warning when an obstacle was sensed, enhancing the reaction time of the user by providing instantaneous audio warnings in addition to voice feedback.

The voice warning system regularly warned users of obstacles with negligible lag.

The YOLO-based object detection on Raspberry Pi 3 attained around 70–75% accuracy for everyday objects such as pedestrians, vehicles, and bicycles.

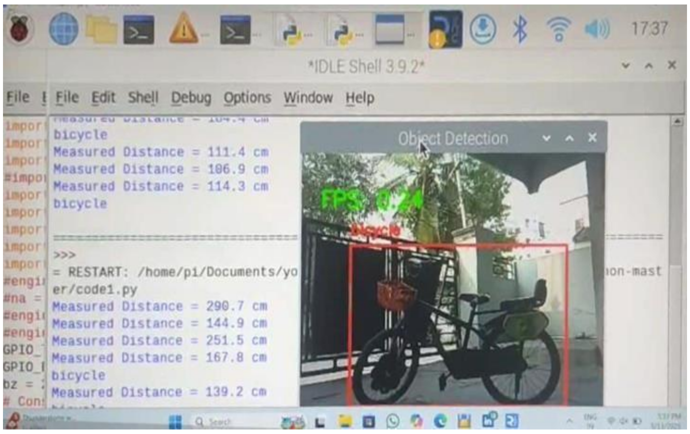


FIG.1: Result

Frame processing time was roughly 1–2 frames per second, sufficient for minimal mobility assistance.

The Text-to-Speech module provided easily understood object types and distances, improving user safety and awareness.

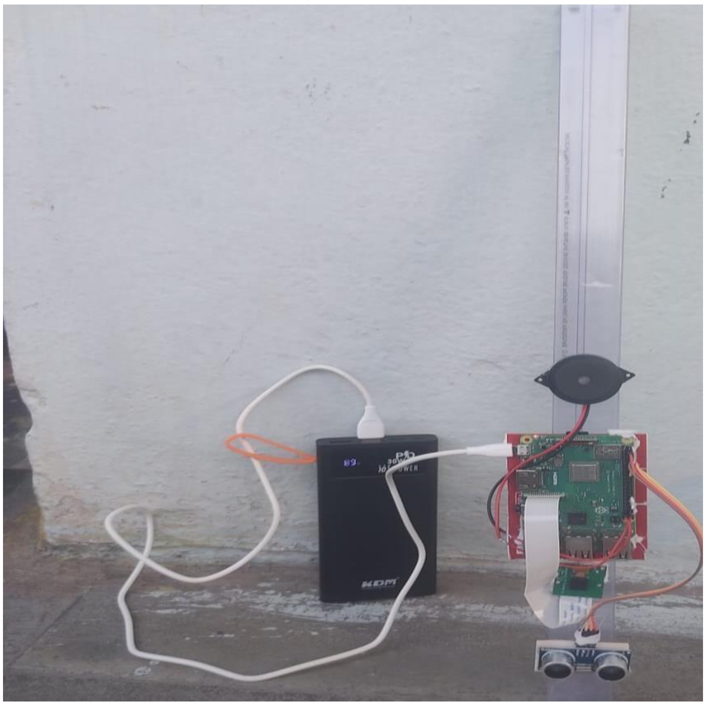


FIG.2: Smart Stick

7. Conclusion

The proposed smart stick system successfully combines ultrasonic sensing and real-time object detection using the YOLO algorithm to enhance the mobility and safety of visually impaired individuals. By integrating affordable and accessible hardware components such as the Raspberry Pi, ultrasonic sensors, and a Pi Camera, the system delivers a reliable solution that detects obstacles and identifies objects with audible feedback. The experimental results confirm that the system performs effectively in various environments, offering timely alerts and improving the user's situational awareness.

To sum up, this smart stick is a useful, reasonably priced assistive technology that has the potential to greatly increase the independence and standard of living of people who are blind or visually impaired.

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