IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.102 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 12, December 2024

DOI: 10.17148/IJARCCE.2024.131202

Real-Time Traffic Sign Detection and Obedience System for Autonomous Vehicle on Indian Roads using Machine Learning

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Abstract: Traffic sign detection plays a pivotal role in enhancing road safety and enabling autonomous vehicles. Indian roads, with their unique multilingual signs and dynamic environments, present significant challenges due to diverse regional languages, fonts, and conditions. Addressing these complexities is essential for developing reliable navigation systems for autonomous bots and vehicles. This objective aims to design and implement a real-time traffic sign detection system for Indian roads using the YOLOv5 model deployed on a Raspberry Pi. The system integrates multilingual detection capabilities and dynamically displays decisions in a terminal interface, enabling autonomous bots to operate efficiently in unpredictable environments. The methods in the dataset comprising multilingual Indian traffic signs were collected and annotated. The YOLOv5 model was trained with augmented data to enhance detection accuracy. The trained model was optimized for edge devices using TensorRT and Pytorch. A Raspberry Pi, integrated with a depth camera, processed real-time video streams for detection. Detected signs were mapped to pre-programmed actions, which were displayed in the terminal and executed via bot navigation. The Results of the system achieved high detection accuracy and low latency, even under challenging lighting and weather conditions. Multilingual OCR integration ensured robust detection of diverse traffic signs. Real-world tests demonstrated reliable navigation and responsive action execution. The project's significant contribution to traffic management, road safety, and autonomous vehicle technologies, addressing the unique challenges of multilingual environments. The scalable solution has implications for smart city initiatives and real-time navigation systems on Indian roads.

Keywords: YOLOv5, Autonomous Vehicles, Traffic Sign Detection, Multilingual OCR.

I. INTRODUCTION

A. Background on Traffic Sign Detection

Traffic sign recognition is a crucial aspect of intelligent transportation systems, combining computer vision, machine learning, and road safety. Traditional methods, such as color and shape-based detection, faced challenges with lighting variations, weather conditions, and sign degradation. Modern deep learning models like YOLOv5 have revolutionized this field, offering real-time, robust detection capabilities adaptable to complex and dynamic road environments.

B. Relevance of Multilingual Support on Indian Roads

India's diverse linguistic landscape adds complexity to traffic sign detection. With 22 official languages and numerous regional dialects, traffic signs often feature region-specific symbols and text. This diversity necessitates a detection system capable of transcending linguistic and design barriers to ensure accurate recognition across different regions. Failure to interpret signs correctly can result in severe safety risks, emphasizing the need for reliable, multilingual recognition systems for autonomous navigation on Indian roads.

C. Objectives and YOLOv5 Integration

This project focuses on designing a real-time traffic sign detection system using YOLOv5 and a Raspberry Pi. The system ensures accurate recognition of traffic signs under varying conditions, translating detections into actionable commands for safe navigation. Optimized for the Raspberry Pi, the setup leverages frameworks like TensorFlow Lite, enabling cost-effective, scalable deployment for autonomous vehicles.

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D. Overview of YOLOv5 and Raspberry Pi Integration

Integrating YOLOv5 with Raspberry Pi creates a lightweight, efficient solution for traffic sign detection. Leveraging frameworks like TensorFlow Lite and hardware accelerators, the Raspberry Pi captures frames, processes detections, and outputs results in real time, enabling reliable autonomous navigation.

II. LITERATURE SURVEY

Triki, N. et al., have identified that Traffic Sign Recognition (TSR) systems face challenges like limited categories, lighting variations, occlusions, and varying angles. An attention-based deep convolutional neural network (CNN) is proposed to improve accuracy and handle these issues, expanding recognition to various sign types. The system combines Haar cascade techniques for quick detection with CNN for precise classification, using preprocessing and data augmentation for enhanced performance. Testing on the GTSRB dataset and Raspberry Pi 4 achieved 99.91% accuracy with fast processing, demonstrating robustness in challenging conditions. Future work will focus on further optimizing the CNN model and exploring additional datasets for improved reliability.[1]

Bichkar et al., have observed that Indian traffic sign detection faces challenges such as obscured, damaged, and poorly lit signs, complicating real-time recognition for human drivers and autonomous systems. To address these issues, deep learning-based approaches using CNN and YOLO v3 have been explored. Transfer Learning enables adaptation to Indian datasets, while HSI colour segmentation improves detection under varying lighting. Experiments with CNN models trained on GTSRB and Indian datasets achieved 98.85% training accuracy, with YOLO v3 attaining 87% detection accuracy using resized RGB images. This combination ensures robust classification and detection. Future work aims to develop real-time systems with feedback for enhanced driver safety.[2]

Md Isa et al., have studied that Malaysia's rising road accidents emphasize the need for advanced driver assistance systems (ADAS) to improve traffic safety. Addressing issues like missed signs due to fatigue or poor visibility, a real-time traffic sign detection and recognition system was developed using TensorFlow Lite on a Raspberry Pi 3 with a NoIR camera. Trained on 500 images across five traffic sign classes, the system achieved over 90% accuracy under normal and challenging conditions, including faded or nighttime signs, with a detection delay of 3.44 seconds. However, this latency limits its effectiveness at higher speeds. Future enhancements involve optimizing processing time, upgrading hardware, and expanding datasets for broader traffic sign coverage and robust performance in diverse driving environments.[3]

Jency S et al., addressed challenges in Traffic Sign Recognition (TSR) systems caused by environmental factors like lighting, occlusion, and weather. They proposed a solution using Convolutional Neural Networks (CNNs) for robust detection and classification, supported by image pre-processing techniques such as resizing, contour detection, and ROI extraction. Vehicle-mounted cameras capture images, which are standardized and denoised before CNN-based classification. Testing on Indian traffic sign datasets demonstrated high accuracy, even under challenging conditions. The study underscores CNN's effectiveness in overcoming environmental variability, with future work focusing on multi-task learning, sensor fusion, and real-time optimization for low-power devices.[4]

III. METHEDOLOGY

The proposed system is designed to process live video input from the environment to detect traffic signs and lights, classify signal colours, and make decisions accordingly. The methodology is as follows:

a. Live Video Input and Frame Capture

The system begins by receiving continuous live video input from a camera mounted on a vehicle or at a fixed location. The video feed is divided into individual frames to facilitate frame-by-frame processing. Each frame is preprocessed to ensure compatibility with the object detection model, including resizing, normalization, and format adjustments.

b. Object detection using YOLO

YOLO (You Only Look Once) is employed as the primary object detection algorithm due to its efficiency and real-time capabilities. Each captured frame is processed through the YOLO model, which segments the image and identifies objects of interest. For this application, the focus is on detecting traffic signs and traffic lights. The YOLO algorithm provides bounding boxes, class labels, and confidence scores for detected objects.

c. Traffic Sign Detection and Classification

Detected objects classified as traffic signs are processed further to identify specific sign types, such as "Stop," "Speed Limit," or "No Entry." This involves matching the detected objects with a pre-trained traffic sign database. The identified signs are used to determine if any specific action is required from the system or driver.

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d. Traffic Light Detection and Signal Classification

For objects identified as traffic lights, additional processing is conducted to classify the light's signal color into red, yellow, or green. This is achieved using colour segmentation techniques, where pixel intensity and hue values within the detected traffic light area are analysed. The classified signal colour determines the next course of action.

e. Decision making based on signal classification

The classified signal triggers one of the following actions:

- Red Signal: The system issues a "Stop" command, ensuring the vehicle halts until the signal changes.
- Yellow Signal: A "Caution" alert is activated, signaling the driver to proceed with care or prepare to stop.
- Green Signal: The system initiates a "Go" command, allowing the vehicle to continue forward.

f. Consolidated Decision-Making

The outcomes from traffic sign and traffic light detection modules are consolidated to make a final decision. For instance, if a red light is detected while a "Speed Limit 40" sign is present, the system prioritizes stopping the vehicle. These decisions ensure adherence to traffic rules while enhancing safety.This integrated methodology combines YOLO's object detection capabilities with advanced classification and decision-making mechanisms, enabling robust real-time traffic sign and light detection systems suitable for autonomous and assisted driving environments.

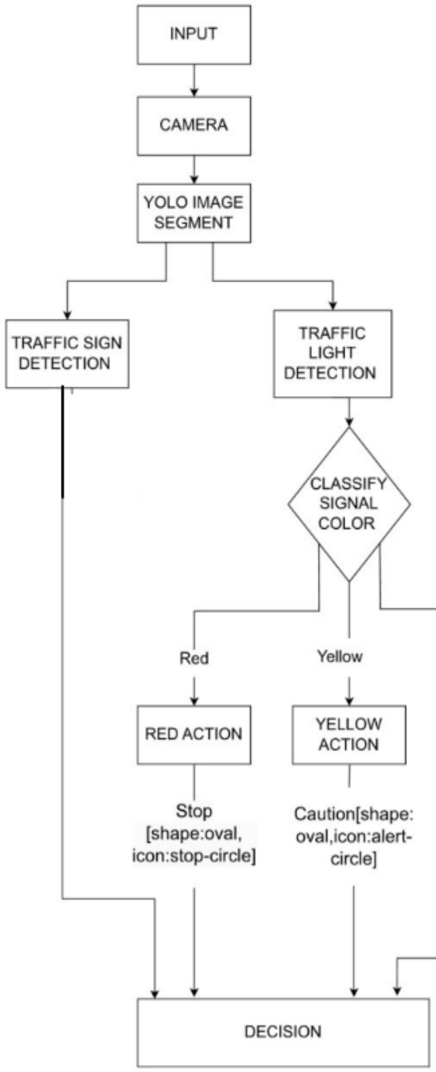

Fig. 1 Software flow diagram

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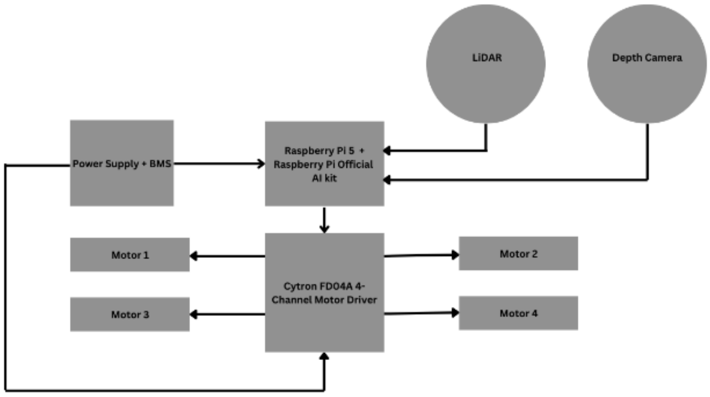

Fig. 2 Hardware block diagram

TABLE I HARDWARE

Sl.no	Hardware components	Function/ role
1.	Raspberry Pi 5 (8GB RAM)	Main processor
2.	Raspberry Pi Official AI Kit	Hardware-accelerated computation for AI tasks
3.	Cytron FD04A 4-Channel Motor Driver	Controls the speed and direction of up to four DC motors
4.	YDLIDAR HP60C RGBD Depth Camera	Combines RGB and depth sensing to provide the car with visual and spatial awareness of its environment.
5.	YDLIDAR X2L Range Finder	Provides 360-degree scanning for obstacle detection and environment mapping.
6.	JGB37-520 Gear Motors	Works with the motor driver for speed and direction control.

IV. CONCLUSION

The integration of an autonomous traffic sign detection system is a transformative step toward enhancing the safety, efficiency, and reliability of autonomous vehicles. By leveraging advanced object detection models such as YOLOv5, the system enables real-time and precise identification of various traffic signs, including speed limits, stop signs, and cautionary symbols. This capability allows autonomous vehicles to make informed decisions, such as adjusting speed, coming to a stop, or altering their path, ensuring compliance with traffic regulations and significantly reducing the risk of accidents.

A key advantage of the system is its multilingual detection capability, which supports languages like English, Hindi, and other regional languages commonly used on traffic signs in India. This feature is crucial for ensuring the system's usability across diverse regions, making it suitable for deployment in a multicultural and multilingual country like India.

Moreover, the system's robust design allows it to perform effectively in dynamic environments, including varying lighting conditions, weather changes, and partial occlusions. It adapts to complex road scenarios, ensuring reliable detection even in crowded or unpredictable traffic conditions. This adaptability is essential for autonomous navigation in real-world settings.

In conclusion, autonomous traffic sign detection systems not only improve road safety and traffic compliance but also address the unique challenges of multilingual and dynamic environments, making them indispensable for the future of autonomous transportation.

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The image depicts a Kannada traffic sign indicating a left turn. The sign is circular, featuring a red border and white background, with the Kannada text "ಎಡಕ್ಕೆ ತಿರುಗಿ" (which translates to "Turn Left") prominently displayed in the center. A bounding box, generated by an object detection model, surrounds the text with the label "kannadleft" and a confidence score of 0.76. A secondary bounding box with a lower confidence score (0.45) also highlights the same region, reflecting the model's attempt to refine its prediction.

Fig. 3 Output of detection

Similar result were obtained for different sign in Kannada and Hindi.

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