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REAL-TIME TRAFFIC SIGN RECOGNITION AND CLASSIFICATION SYSTEM USING OPENCV

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***ABSTRACT*:**

This paper presents a Real-Time Traffic Sign Recognition and Classification System using OpenCV and Raspberry Pi, designed to assist in vehicle automation and faster decision-making for drivers or autonomous systems. The system uses a Raspberry Pi 4 Model B processor and a Pi Camera for live video capture, with OpenCV for image processing. A Convolutional Neural Network (CNN) is trained to classify traffic signs into predefined categories. The system's performance is evaluated based on recognition accuracy, processing speed, and handling multiple traffic signs simultaneously. This real-time system has potential for integration into modern vehicle automation systems and as assistive technology for drivers, contributing to safer roads and more efficient transportation networks.

To enhance the accuracy of the system, a Convolutional Neural Network (CNN) is trained using a dataset of traffic sign images. This CNN model is embedded within the system to classify the detected signs into predefined categories such as stop, yield, speed limit, or no entry. Machine learning techniques are employed to ensure that the model can adapt to different lighting conditions, camera angles, and background noise, thus making the system robust and reliable for real-world usage.

This real-time system offers significant potential for integration into modern vehicle automation systems or as an assistive technology for drivers, contributing to safer roads and more efficient transportation networks. The project demonstrates that low-cost hardware like Raspberry Pi, when combined with powerful image processing libraries like OpenCV, can effectively perform complex tasks such as traffic sign recognition, making it a viable solution for smart city applications and advanced driver assistance systems (ADAS).

***Keywords**: Traffic Sign Recognition, Real-Time Classification, OpenCV, Raspberry Pi, Convolutional Neural Networks (CNN), Autonomous Vehicles, Image Processing, Intelligent Transportation Systems (ITS), Advanced Driver Assistance Systems (ADAS), Edge Detection, Feature Extraction, Vehicle Automation, Smart City Applications.*

1. INTRODUCTION

The development of autonomous vehicles and intelligent transportation systems has led to the need for safer, more efficient, and smarter road networks. Traffic sign recognition and classification are crucial components of these systems, enabling vehicles to understand and respond to road signs in real time. Traditional systems are often dependent on high-end computational resources and complex hardware, making them less suitable for widespread, low-cost implementation. However, with the advent of affordable microprocessors like Raspberry Pi and robust image processing libraries like OpenCV, cost-effective solutions for real-time traffic sign recognition can be developed. This project aims to design and implement a Real-Time Traffic Sign Recognition and Classification System using Raspberry Pi and OpenCV, detecting, identifying, and classifying traffic signs from live video feeds captured using a Pi Camera.

In recent years, the development of autonomous vehicles and intelligent transportation systems has gained significant momentum, driven by the need for safer, more efficient, and smarter road networks. Traffic sign recognition and classification are critical components of these systems, enabling vehicles to understand and respond to road signs in real time. This capability is essential not only for fully autonomous vehicles but also for

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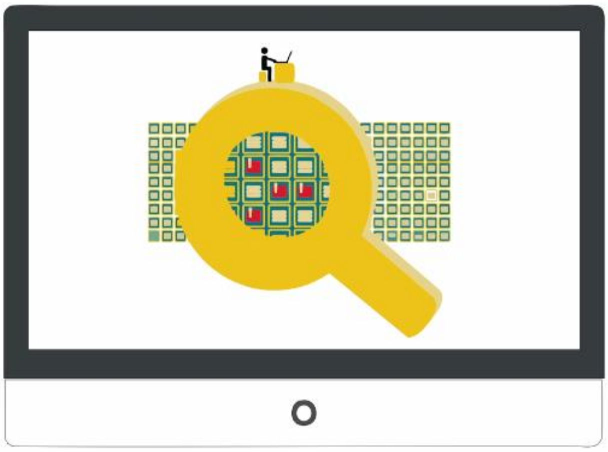
advanced driver assistance systems (ADAS), which help human drivers make informed decisions. Accurate and timely recognition of traffic signs enhances road safety, reduces accidents, and improves overall traffic management.

Traditional traffic sign recognition systems are often dependent on high-end computational resources and complex hardware, making them less suitable for widespread, low-cost implementation. However, with the advent of affordable and powerful microprocessors like the Raspberry Pi, along with robust image processing libraries such as OpenCV, it is now possible to develop cost-effective solutions for real-time traffic sign recognition. The combination of these technologies allows for lightweight, scalable systems that can be integrated into vehicles or used in smart city infrastructure.

This project aims to design and implement a Real-Time Traffic Sign Recognition and Classification System using Raspberry Pi and OpenCV. The system will detect, identify, and classify traffic signs from live video feeds captured using a Pi Camera. A Convolutional Neural Network (CNN), pre-trained on a dataset of traffic signs, will be utilized to classify the signs into specific categories such as speed limits, stop signs, and warning signs.

One of the major challenges in developing such a system is achieving real-time performance while maintaining high accuracy. The Raspberry Pi, being a low-cost, low-power microcontroller, has limited processing capabilities compared to more powerful computers. To address this limitation, the system leverages OpenCV's optimized image processing techniques, ensuring that the traffic sign detection and classification process is fast enough for real-time applications. Additionally, machine learning algorithms are employed to improve the robustness of the system under varying conditions such as different lighting environments, occlusions, and camera angles.

This project is motivated by the potential applications of traffic sign recognition systems in autonomous driving, advanced driver assistance systems (ADAS), and smart city infrastructure. By providing real-time, accurate traffic sign recognition, this system can contribute to safer roads, improved traffic efficiency, and the realization of future smart transportation networks. Moreover, the use of low-cost hardware like the Raspberry Pi makes this solution accessible and scalable, allowing for widespread adoption in vehicles and infrastructure at a fraction of the cost of traditional systems.



In the subsequent sections, we will discuss the system architecture, the methodology for traffic sign detection and classification, the CNN model used for classification, and the performance evaluation of the system in real-world scenarios. Through this research, we aim to demonstrate the feasibility of creating a reliable, cost-effective solution for traffic sign recognition that can be easily deployed in real-time traffic environments.

The project aims to automate real-time traffic sign identification and classification using OpenCV image processing and Raspberry Pi as a cost-effective and energy-efficient platform, enhancing road safety and supporting autonomous vehicles and advanced driver-assistance systems.

Traffic Sign Recognition in Intelligent Transportation Systems

- Enhances road safety and supports autonomous vehicles and ADAS.
- Automates real-time identification and classification of traffic signs.

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- Addresses challenges like lighting, weather, and occlusions.
- Uses OpenCV for image processing and Raspberry Pi for cost-effective, energy-efficient platform.

Figure1.1: Traffic Signal detection

2. LITERATURE SURVEY

Jeya Anusuya S et al., IJIRSET, Vol. 8, Issue 2, 2019. "Traffic Sign Detection to Avoid Accidents by Using Image Processing & Raspberry Pi"
The proposed system uses Raspberry Pi to detect obstacles, edge detection, stopboards, and red traffic signals for autonomous cars. It uses the Raspberry Mera module for signboard detection and ultrasonic sensors for distance measurement. The system uses masking and contour techniques to detect traffic signals and machine learning to determine stop words. The coding is in Python, and the system uses OpenCV for image processing. The ultrasonic sensor is used for obstacle detection instead of a camera, as it provides the distance directly without complex computations.

Muthu Srinivasan et al., IJAREEIE, Volume 10, Issue 4, 2021. "Road Sign Recognition System Using Raspberry Pi"
The project aims to implement road sign detection and control for an autonomous vehicle using the Cascade Classifier algorithm. It uses a Raspberry Pi 3 processor and web camera to capture video data, process it in OpenCV, and control the vehicle.

Sharik Akthar.S et al., IJEAST, Vol. 5, Issue 2, 2020. "Real Time Smart Traffic Managing and Control System"
The model aims to create a real-time traffic management system based on vehicle density, allowing signals to change automatically at each junction lane. This system replaces traditional time-based traffic light control systems, which create more traffic in major cities. The Raspberry Pi microcontroller controls traffic signals based on density, benefiting ambulances in emergency situations.

Quang Nhat Nguyen Le et al., ICAART, Volume 1, 2020. "Real-time Sign Detection and Recognition for Self-driving Mini Rovers based on Template Matching and Hierarchical Decision Structure"
This paper introduces a real-time methodology for classifying traffic signs on affordable single-board computers. The system detects and recognizes signs' color and shape, extracts feature from pre-existing templates, and compares them with potential ROI. Tested on a mini rover, the system showed processing time ranging from 230ms to 800ms.

N Radhakrishnan et al., IJARSE, Vol. 6, Issue 11, 2017. "Real-Time Indian Traffic Sign Detection Using Raspberry Pi and Open CVS"
Traffic problems require proper design and planning for safety and harmony. Governments establish rules through traffic signs, and drivers must interpret and follow them to avoid accidents. An automatic system for detecting, recognizing, and interpreting traffic signs could reduce accidents. This paper proposes an automatic system for detecting and recognizing Indian traffic signs using images captured by a camera, part of Advanced Driver

Assistance Systems (ADAS). Implemented using Raspberry Pi 3 hardware and Raspbian Stretch, the system works on real-time images.

Vishwanath P. Baligar et al., ELSEVIER,2018. "A novel approach in real-time vehicle detection and tracking using Raspberry P"
Researchers propose a video image processing algorithm for real-time vehicle detection, tracking, and counting on roads. The algorithm converts RGB video frames to HSV color domain, removing noise and detecting vehicles based on color features. Vehicle tracking is done using Kalman filters, and the number of vehicles in a video or lane is determined. The algorithm is more effective in terms of accuracy and cost compared to rear-view and morphological operation methods.

Bhavya P et al., IJERECE, Vol 4, Issue 5, 2017. "Smart Road Sign Detection for Driver Assistance System"
The project aims to detect and recognize traffic signs in video sequences from an onboard vehicle camera. Traffic Sign Recognition (TSR) is crucial for regulating traffic signs, warning drivers, and regulating actions. This study uses OpenCV technique to recognize traffic sign patterns on a small computing platform. The system is based on an embedded system, addressing challenges in real-time base implementation and color analysis. The Raspberry Pi is the main target for implementation.

Ganesh Bhagat et al., IRJMETS, Volume:05/Issue:03,2023. "Traffic Sign Detection Using Image Processing"
Traffic sign recognition is crucial for maintaining traffic signs, warning drivers, and preventing accidents. Large companies like Google, Apple, and Volkswagen are increasingly interested in this technology for applications like autonomous driving, driver assistance systems, and mobile mapping. A proposed project uses a Node MCU to automate real-time sign detection and display on a driver dashboard.

Piyush Warule et al., IJCRT, Volume 9, Issue 1, 2021. "Real-time road sign recognition system using machine learning and image processing"
This work aims to develop a method for traffic light detection and road sign board recognition using machine learning and digital image processing. The system accurately detects traffic light colors and signs like speed limit, stop, and turn right. It is also proposed to integrate traffic sign recognition into Driver Assistance Systems.

Aarushi Mittal et al., IJCRT, Volume 9, Issue 6, 2021. "Traffic Sign Detection and Recognition Using Open CV"
This paper discusses traffic sign detection and recognition methods, including the Viola Jones detector and the Histogram of Gradient based SVM classifier. It suggests these systems outperform others and perform accurately under various conditions, including color, lighting, and atmospheric conditions.

Sithmini Gunasekara et al., MECS,2022. "Deep Learning Based Autonomous Real-Time Traffic Sign Recognition System for Advanced Driver Assistance"
This study presents a traffic sign recognition system using novel deep learning architectures. The system identifies and classifies traffic signs from live video feeds, using YOLO and Exception architectures. The model achieved a final accuracy of 96.05% for the local dataset and 92.11% for the standard dataset. The system successfully detects and classifies traffic signs within an average detection time of 4.5fps.

Nikhil S Rajguru et al., INPRESSCO, issue 8,2021. "Deep Learning Approaches for Traffic Sign Detection and Recognition"
Traffic sign recognition is crucial for maintaining traffic signs, warning distracted drivers, and preventing accidents. Large companies like Google, Apple, and Volkswagen are increasingly interested in this technology for applications like autonomous driving, driver assistance systems, and mobile mapping. This paper proposes a cost-efficient system using Raspberry Pi to capture traffic signs and display them on a driver dashboard, thereby reducing accidents at bridges and work areas.

Enis Bilgin et al., Researchgate,2017. "Road Sign Recognition System on Raspberry Pi"
This paper demonstrates the effectiveness of image processing algorithms on a small computing platform, specifically a road sign recognition system based on an embedded system. It discusses the characteristics of speed signs, challenges in implementing a real-time base system, and techniques for classification and recognition. The paper also addresses color analysis issues and the limitations of real-time applications and Raspberry Pi capabilities, focusing on lightweight techniques for better solution.

Ida Syafiza Binti Md Isa et al., IJECE, Vol. 12, No. 1, 2022. "Real-time traffic sign detection and recognition using Raspberry Pi"
Malaysia's road accident rate is increasing rapidly, and advanced driving assistance systems (ADAS) are being developed to reduce these accidents. A traffic sign recognition system has been developed using the TensorFlow algorithm, embedded in a Raspberry Pi 3 processor. The system, tested on twenty different traffic signs, achieved over 90% accuracy and reliability with acceptable delay, demonstrating the potential of ADAS in enhancing road user safety.

Enis Bilgin et al., MSU,2016. "Road Sign Recognition System on Raspberry Pi"
This paper demonstrates the effectiveness of image processing algorithms on a small computing platform, specifically a road sign recognition system based on an embedded system. It discusses the characteristics of speed signs, challenges in implementing a real-time base system, and techniques for classification and recognition. The paper also addresses color analysis issues and the limitations of real-time applications and Raspberry Pi capabilities, focusing on lightweight techniques for better solution.

B. Gnaneswar sai et al., ijetms, Issue: 4 Volume No.6,2022. "Traffic sign description system"
This paper presents a study on traffic sign recognition using Neural Networks technique.
The study uses various image processing techniques to pre-process images, then performs Neural Networks stages to recognize traffic sign patterns. The results show highly accurate classifications of traffic sign patterns with complex background images and low computational cost. Automatic recognition of traffic signs is crucial for driving safety and comfort.

3. AIM

The project aims to create a Real-Time Traffic Sign Recognition and Classification System using OpenCV and Raspberry Pi, enhancing road safety by accurately identifying and classifying traffic signs, thereby contributing to intelligent transportation systems and reducing accidents.

- Real-Time Traffic Sign Recognition System Development
- Utilizes OpenCV and Raspberry Pi for real-time sign identification and classification.
- Uses image processing and machine learning for vehicle video analysis.
- Provides timely alerts about speed limits, stop signs, yield signs.
- Contributes to intelligent transportation systems.

4. OBJECTIVES

- To Develop a real-time traffic sign recognition and classification system using OpenCV for image processing.
- To Implement the system on Raspberry Pi to ensure portability, cost-effectiveness, and real-time processing.
- To Achieve high recognition accuracy and speed suitable for dynamic environments like roads.
- To Ensure the system can operate under various conditions such as changes in lighting, weather, and sign occlusion.
- To Minimize hardware resource consumption while maintaining optimal performance for embedded systems.

5. PROBLEM STATEMENT

The project aims to develop an efficient and cost-effective system using OpenCV and Raspberry Pi to address real-time traffic sign recognition challenges. The system will accurately detect and classify traffic signs under various conditions, enhancing road safety, reducing accident likelihood, and contributing to the development of smart transportation systems, despite the complexity of current systems.

Real-Time Traffic Sign Recognition Project

- Addresses urbanization and vehicle usage impact on traffic accidents.
- Develops efficient, cost-effective system using OpenCV and Raspberry Pi.
- Accurately detects and classifies traffic signs.
- Enhances road safety and contributes to smart transportation systems.

6. RESEARCH METHODOLOGY

System Architecture

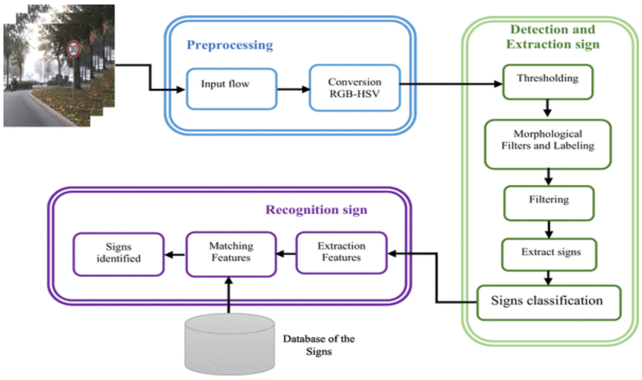

Figure1.2: System Architecture

A visual representation showing the components of the system, including:

- **Camera Module:** Capturing real-time images of traffic signs.
- **Raspberry Pi:** Processing the images and running the OpenCV-based recognition algorithm.
- **Traffic Sign Database:** Storing traffic sign images for classification reference.
- **Display/Alert Module**: Providing feedback on detected signs (e.g., displaying sign type or alerting the driver).

Workflow

Step-by-step process flow

- Image Capture: Camera captures real-time images
- Image Preprocessing: Noise reduction, resizing, and segmentation using OpenCV.
- Feature Extraction: Extract key features like color, shape, and texture.
- Classification: Classify the traffic sign using machine learning algorithms.
- Output: Display the recognized sign on the interface or trigger an alert.
- Modules: Brief description of each system module and its function.

Software Composition

- **Operating System**

Raspberry Pi OS (formerly Raspbian): A Debian-based OS optimized for Raspberry Pi, providing a stable environment for development.

- **OpenCV Library**

Overview: Open-Source Computer Vision Library for real-time computer vision applications.
Key Features: Functions for image processing, machine learning, and video analysis, including image filtering, object detection, and feature extraction.

- **Programming Languages:**

Python: Chosen for its simplicity and the extensive support available for OpenCV.

- **Development Environment:**

IDE: Jupiter lab or Visual Studio Code for writing and debugging code. Version

Classification Algorithm

Traffic Sign Classification Algorithms Overview

- Categorization of traffic signs based on extracted features for real-time recognition.
- Selected algorithms: Support Vector Machine (SVM), K-Nearest Neighbours (KNN), and Convolutional Neural Networks (CNN).
- Training and Validation: Dataset splitting, cross-validation, and performance metrics evaluation.
- Techniques: k-fold cross-validation for model robustness and avoidance of overfitting.

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Testing Methodology for Traffic Sign Recognition System

- Utilizes a separate dataset of diverse traffic signs.
- Conducts tests in various conditions to simulate real-world environments.
- Evaluates accuracy, precision, recall, and F1-Score.
- Presents results through confusion matrices and performance graphs.
- Discusses strengths and weaknesses identified during testing.
- Outlines potential areas for enhancement and future system iterations based on evaluation results.

7. CONCLUSION

Project Summary

- Development of real-time traffic sign recognition and classification system using OpenCV and Raspberry Pi.
- High accuracy rates across various conditions.
- Real-time processing capabilities for effective performance in dynamic driving environments.
- System demonstrated robustness against varying lighting and weather conditions.
- Effective feature extraction and classification techniques contributed to system's reliability.
- Future work includes integrating advanced machine learning techniques, expanding traffic sign database, and improving user interface.

Future Scope

- Enhance Algorithm: Explore advanced deep learning models for improved accuracy and robustness.
- Expand Dataset: Increase training dataset diversity to enhance generalization.
- Real-Time Adaptations: Optimize system for real-time performance using hardware accelerators and efficient coding practices.
- Integration with Navigation Systems: Develop interfaces for enhanced driver assistance.
- Mobile and Cloud-Based Solutions: Explore system deployment for broader accessibility and functionality.
- User Interface Improvements: Enhance user experience with voice alerts, historical data logs, and customizable settings.

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