MINOR PROJECT-2 SYNOPSIS

ROAD SIGNAL RECOGNITION AND AUTONOMOUS MOVEMENT USING RASPBERRY PI

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INTRODUCTION

The rapid advancement of intelligent transportation and automation technologies has brought the need for reliable, real-time road sign recognition and autonomous navigation to the forefront of research and practical deployment. With road accidents remaining a critical concern, especially in densely populated countries like India, there is a pressing demand for systems that can assist or automate driver awareness, thereby enhancing road safety and paving the way for future smart mobility solutions. Traditional driver assistance systems are often expensive and inaccessible for widespread educational or prototyping use. The Raspberry Pi, a cost-effective and flexible embedded platform, offers an ideal foundation for developing such systems, making advanced computer vision and robotics accessible to students, researchers, and hobbyists alike. This project focuses on creating a smart system that can detect and recognise road signs in real-time and respond accordingly with autonomous movement. By using advanced computer vision and machine learning techniques, the system will identify road signs and make decisions to navigate safely. Additionally, it will include a line detection feature, ensuring the system moves along a defined path and stays within lanes.

The ultimate goal is to create a cost-effective and intelligent transportation solution that enhances road safety, reduces human intervention, and improves driving efficiency. This system can be applied in autonomous vehicles, smart traffic management, and driver assistance technologies, contributing to the future of intelligent mobility.

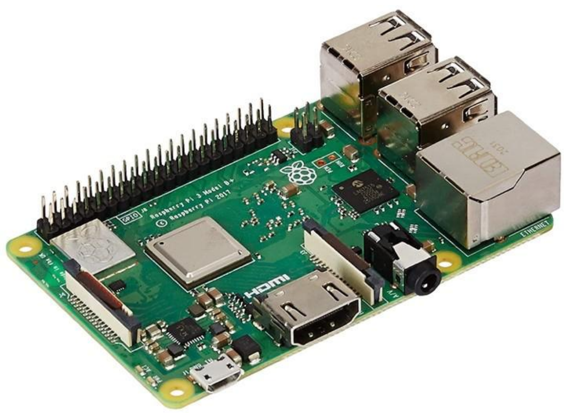

Figure 1: Raspberry Pi 3 B+ [1]

The Raspberry Pi (Refer to figure 1) provides an efficient platform that supports the deployment of lightweight machine learning models. Using the USB Camera, the Raspberry Pi will capture live video feed at an adequate FPS (Frames Per Second) so which will be processed using the OpenCV module. TensorFlow Lite will be used to detect and classify objects.

The design of a sign detection robot based on Raspberry Pi that can perform tasks of object detection (currently limited to signs in the dataset), observing live video feed and movement is proposed. This project starts from an earlier version [minor project 1] in which a USB Camera was used to capture images, and preprocess them before running them through the model to detect the sign.

Figure 2: Test Results of Road Sign Recognition Model

TECHNOLOGIES USED

1. Raspberry Pi OS: It is a lightweight Linux-based OS especially made for Raspberry Pi. Its user-friendly GUI makes it efficient and perfect for programming, especially Python. It also supports a wide range of hardware and software applications, making it versatile. The Raspbian / Debian Bullseye version OS and Distribution System is installed.

2. **TensorFlow Lite:** It is a light version of the TensorFlow library, especially designed for lightweight devices such as the RPI. It lets us run pre-trained machine learning models for multiple applications. Here, for real-time object recognition [3].
3. **OpenCV:** It is a widely used open-source library for computer vision. It is essential for our task of object recognition and also assists in image filtering and real-time image analysis.
4. **Python:** Python is used in this project for road sign detection, lane tracking, and autonomous movement. It integrates TensorFlow Lite and OpenCV for real-time processing and controls the motor driver for movement based on detected signs.

PROBLEM FORMULATION

The rapid evolution of computer vision and embedded systems has enabled real-time object detection and autonomous navigation, but deploying these technologies on resource-constrained hardware remains a significant challenge. Applications such as smart mobility, warehouse automation, and retail logistics demand systems that can accurately interpret environmental cues and execute precise movements in real time. While industrial-grade solutions exist, their high cost and computational demands make them inaccessible for small-scale operations, such as local retailers or compact warehouses.

The project proposes to solve this problem by utilising RPI. To address these issues, this project integrates road sign recognition with real-time decision-making and movement automation. By leveraging a Raspberry Pi, a USB camera, an LCD, and motorised control, the system aims to provide a cost-effective and efficient solution for smart mobility applications. In this scenario, the need has arisen for cost-effectively solving the depalletizing problem to make the technology available, for instance, to retailers of goods such as wood pellet bags or small warehouses, just to mention two use cases.

Many existing systems either struggle with performance when deployed on resource-constrained hardware or are prohibitively expensive for small-scale implementations. A platform like Raspberry Pi is a suitable place to start analysing the performance of the Machine learning models in a limited context [6].

OBJECTIVE

The primary objective of this project is to design and develop an autonomous robotic system based on the Raspberry Pi platform that is capable of real-time road sign recognition and intelligent navigation through line following. The system aims to demonstrate how affordable, compact embedded hardware can be leveraged to perform complex tasks typically associated with advanced driver assistance systems (ADAS) and smart mobility solutions.

At its core, the project seeks to integrate computer vision, machine learning, and embedded control to enable a robot to perceive its environment, interpret critical road signs, and make timely decisions that govern its movement. Using a USB camera, the robot continuously captures live video of its surroundings. These video frames are processed using a lightweight, custom-trained TensorFlow Lite model that detects and classifies road signs such as stop, turn, and speed limit indicators. Upon recognising a sign, the system translates this information into actionable commands-such as stopping, turning, or adjusting speed-by interfacing with an L293D motor driver that controls two DC motors.

In addition to sign recognition, the robot is equipped with photoresistor-based sensors that allow it to follow a black line on the floor, simulating lane-keeping behaviour. If the robot strays from the line, it initiates a search routine to reacquire the path, ensuring continuous autonomous navigation. Real-time feedback is provided to users through a 16x2 LCD, which shows detected signs and system status, enhancing transparency and usability.

WORKING

Phase 1: Sensing and Detection:

- The USB camera mounted on the robot continuously captures live video of the environment ahead. These video frames are sent to the Raspberry Pi, which processes each frame in real time.
- Using image processing and a trained recognition model, the system detects and identifies any road signs (such as stop, turn, or speed limit signs) present in the camera's field of view. Simultaneously, photoresistor sensors on the bottom of the robot monitor the floor to detect and follow a black line, helping the robot stay on its path.

Phase 2: Decision and Control:

- Once a road sign is detected, the Raspberry Pi interprets the sign and determines the appropriate action (for example, stop, turn left or right, or adjust speed). The system also checks the status of the line sensors to decide if the robot is still on track or needs to search for the line.
- Based on these inputs, the Raspberry Pi sends control signals to the L293D motor driver, which operates the DC motors to execute the required movement.

Phase 3: Feedback and Autonomous Movement

- As the robot moves, the system continuously updates the detected sign and status on a 16x2 LCD, providing real-time feedback to the user. The robot autonomously navigates along the black line, adjusting its path as needed and responding to new road signs as they appear.

- If the line is lost, the robot automatically initiates a search routine to reacquire the path and resume normal operation.

Future Enhancements: Future improvements to the system include integrating remote monitoring and control through wireless communication for live video streaming and remote operation. Obstacle detection using ultrasonic or LiDAR sensors will enhance navigation safety by preventing collisions. Expanding the dataset will improve traffic sign recognition, allowing the system to identify more complex road symbols. A text-to-speech module can be added to provide voice alerts for detected signs, improving accessibility. AI-based decision-making will enable smarter navigation by considering multiple traffic factors.

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