Design and Implementation of a Raspberry Pi–Based Autonomous Vehicle
Using Image Processing and Web-Based Interface

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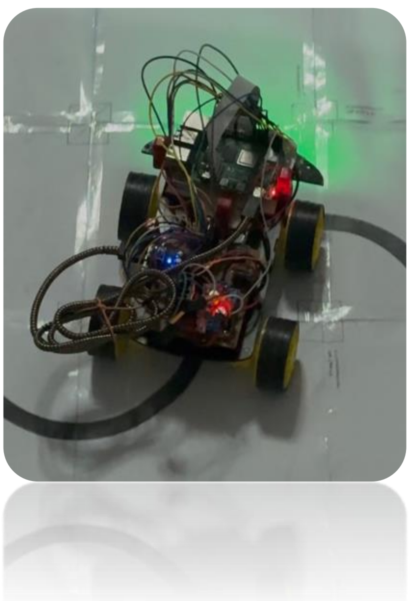


Abstract

This paper presents the design and implementation of a small-scale autonomous vehicle based on the Raspberry Pi platform. The proposed system integrates real-time image processing, embedded motor control, power management, and a web-based monitoring and control interface. Visual data acquired through an onboard camera is processed to support navigation and obstacle awareness, while control commands are generated to drive DC motors via motor driver modules. In addition to autonomous operation, a browser-based interface developed using HTML and CSS enables live monitoring and manual control of the vehicle. Particular attention is given to UX considerations within the web-based human–machine interface, improving usability and operational safety.

Keywords

Autonomous Vehicle; Raspberry Pi; Image Processing; Embedded Systems; Web-Based Control; Robotics

1. Introduction

Autonomous vehicles are an active research area due to their applications in robotics, intelligent transportation systems, and industrial automation. This work focuses on system-level integration and educational applicability.

2. Related Work

Existing studies demonstrate the feasibility of Raspberry Pi–based autonomous platforms using image processing and web-based control.

3. System Overview

The overall system architecture is composed of four tightly integrated subsystems: perception, control, actuation, and user interface. These subsystems operate cohesively to enable both autonomous and manual driving modes.

In autonomous mode, visual data captured by the onboard camera is continuously processed to extract relevant environmental information, which is then used by the control subsystem to generate motion decisions without human intervention. In manual mode, control commands are issued directly by the user through a web-based interface, allowing real-time supervision and intervention. This dual-mode operation enhances system flexibility, safety, and ease of experimentation during development and testing phases

4. Hardware Architecture

The Raspberry Pi functions as the central processing and control unit of the vehicle. It interfaces directly with a camera module for real-time image acquisition and with motor driver modules responsible for controlling the DC motors mounted on the four-wheel chassis.

To ensure reliable operation, the system incorporates regulated power circuitry, including DC–DC converters and voltage regulation modules, which provide stable voltage levels for the Raspberry Pi and peripheral components. Proper electrical isolation and wiring organization are implemented to protect sensitive GPIO pins and to improve overall system robustness. The physical assembly, as shown in the prototype, reflects a compact and modular hardware layout suitable for rapid prototyping and future expansion.

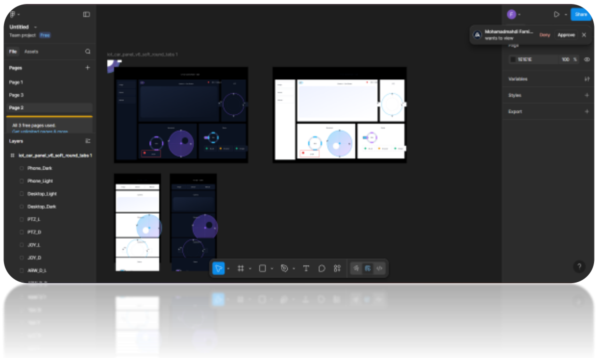
5. Image Processing and Control Method

The image processing pipeline begins with continuous frame acquisition from the camera module. Each frame undergoes preprocessing steps such as resizing and grayscale conversion to reduce computational complexity and improve real-time performance.

Following preprocessing, basic visual analysis techniques are applied to extract meaningful features relevant to navigation and motion planning. Based on the extracted visual information, the control algorithm determines appropriate motion commands, including direction and speed adjustments. These commands are then translated into low-level control signals using GPIO and PWM outputs, which drive the motor driver modules. This closed-loop perception–control structure enables responsive and adaptive vehicle behavior.

6. Web-Based User Interface

A responsive web-based user interface is developed to serve as the system's Human–Machine Interface (HMI). The interface enables real-time monitoring of the vehicle's camera feed and system status, as well as manual control of motion when required.



Special emphasis is placed on UX (User Experience) clarity, ensuring that control elements such as directional commands and emergency stop functions are intuitive and easily accessible. This design approach improves usability, reduces operator error, and enhances safety during experimental operation and demonstrations.

7. Experimental Results

The proposed system was evaluated in an indoor testing environment under controlled conditions. Experimental results demonstrate stable navigation behavior in autonomous mode, with the vehicle responding consistently to visual input. In manual mode, the web-based interface provided smooth and responsive control with acceptable communication latency.

Live video streaming and command execution exhibited performance suitable for real-time operation on the Raspberry Pi platform. These results validate the feasibility of integrating image processing, embedded control, and web-based interaction within a single compact system.

8. Conclusion

This work presented a modular and extensible Raspberry Pi–based autonomous vehicle platform integrating perception, control, actuation, and user interface subsystems. By combining real-time image processing with a web-based control interface, the system offers both autonomous functionality and user supervision capabilities.

The proposed platform serves as a solid foundation for future research and development, including the integration of advanced computer vision algorithms, additional sensors, sensor fusion techniques, and more sophisticated navigation strategies.

The presentation slides for this project are available at the following link:
[Presentation Slides Link]

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