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Autonomous Lane Detection Car using Raspberry PI and Open CV

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Abstract*: This research paper introduces an innovative method for real-time autonomous lane detection utilizing a Raspberry Pi embedded system and the OpenCV computer vision library. The primary objective is to improve vehicle navigation capabilities by precisely identifying lane boundaries from input video streams. The system's robust performance across diverse environmental conditions is achieved through the computational power of the Raspberry Pi platform and the flexibility of OpenCV. The methodology encompasses image preprocessing, lane detection algorithms, and seamless integration with the Raspberry Pi hardware. Through comprehensive experimental results, the proposed approach showcases its effectiveness and efficiency in autonomously detecting lanes. This research contributes to the development ofsafer and more reliable autonomous driving systems.*

Keywords: autonomous lane detection

I. INTRODUCTION

The evolution of transportation technology reaches new heights with the promise of safer roads, increased efficiency, and reduced congestion through autonomous vehicles. Within this realm, lane detection emerges as a critical component, empowering vehicles toautonomously perceive and navigate their surroundings.

This research paper aims to harness the versatility and affordability of the Raspberry Pi, a single-board computer, in conjunction with OpenCV, a widely-used computer vision library, to develop an autonomous lane detection system. The integration of hardware and software seeks to create a cost-effective solution, showcasing the potential of autonomous driving technology.

The research paper journey involves the exploration of various computer vision techniques, including edge detection and Hough transforms, to detect and track lane markings on the road. Through the interfacing of a camera module with the Raspberry Pi, real-timevideo footage is captured, processed using OpenCV algorithms, andused to provide feedback for steering control.

By the research paper conclusion, we aim not only to deepen our understanding of computer vision principles but also to spotlight thecapabilities of autonomous driving systems, utilizing readily available hardware and open-source software. Join us on this exciting journey as we build our own autonomous lane detection carusing Raspberry Pi and OpenCV.

II. LITERATURE REVIEW

"A Review of Lane Detection and Departure WarningSystem" by Thanh Ha Le et al. (2017):

This paper serves as a foundational review, offering insights into lane detection and departure warning systems. It providesa broad understanding of the existing landscape and sets the stage for subsequent advancements.

"Real-Time Lane Detection and Tracking for AutonomousDriving Systems" by Mohan Trivedi et al. (2018):

Trivedi et al. conduct a thorough examination of lane detection and tracking techniques used in autonomous driving systems. The paper covers both traditional computer vision methods and modern deep learning approaches, discussing challenges and advancements in real-time implementation onembedded platforms.

"Lane Detection Algorithm Based on Raspberry Pi andOpenCV" by Yixin Liu et al. (2019):
Liu et al. focus on the practical implementation of a lane detection algorithm tailored for the Raspberry Pi using the OpenCV library. They detail preprocessing steps, including color thresholding and edge detection, and present a Hough transform-based lane detection method. Experimental results showcase real-time performance on the Raspberry Pi platform.

"Autonomous Lane Detection Using Raspberry Pi" by SumitKumar et al. (2020):
Kumar et al. describe the development of an autonomous lane detection system using Raspberry Pi and OpenCV. The paper provides a comprehensive overview of the hardware setup and software implementation, including experimental results and performance analysis under various condi

"Lane Detection and Tracking using Raspberry Pi and OpenCV" by Rajashree Shedge et al. (2021):
Shedge et al. present a lane detection and tracking system implemented on the Raspberry Pi platform using OpenCV. The paper covers steps involved in lane detection, such as image preprocessing, feature extraction, and curve fitting. Integration with motor control for autonomous steering is also discussed.
This compilation offers a panoramic view of advancements in autonomous lane detection, encompassing varied methodologies and implementations, ultimately contributing to theprogression of autonomous driving technology.

III. EXPERIMENTAL METHODOLOGY

Hardware Setup:
Assemble the hardware components including Raspberry Pi board, camera module, motor controllers or actuators for steering control, and any additional sensors for environment perception (optional). Ensure proper connections and power supply for all components.

Software Installation:
Install the necessary software packages on the Raspberry Pi, including Raspbian OS, Python, OpenCV, and any additional libraries or dependencies required for image processing and motor control.

Camera Calibration:
Perform camera calibration to correct for distortion and the camera matrix and distortion coefficients. This step is crucial for accurate lane detection.

Data Acquisition:
Capture real-time video footage using the camera module mounted on the vehicle. Record videos in different driving scenarios, including straight roads, curves, intersections, and varying lighting conditions.

Image Preprocessing:
Preprocess the captured video frames to enhance lane markings and reduce noise. Apply techniques such as color thresholding, edge detection (e.g., Canny edge detector), and perspective transformation to obtain a bird's-eye view perspective of the road.

Lane Detection Algorithm:
Implement a lane detection algorithm using OpenCV. Depending on the chosen approach, this may involve techniques such as the Hough transform, sliding window method, or deep learning-based methods (e.g., convolutional neural networks). Fine-tune algorithm parameters such as edge detection thresholds, Hough transform parameters, or neural network architecture to optimize lane detection performance.

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Autonomous Steering Control:

Integrate the lane detection algorithm with the steering controlmechanism. Translate lane detection results into steering commands to keep the vehicle within the lane boundaries. Implement feedback control algorithms to adjust steering angle based on lane position and vehicle dynamics.

Testing and Evaluation:

Conduct extensive testing of the autonomous lane detection system under various conditions, including different road types, lighting conditions, and speeds. Evaluate the system's performance metrics such as lane detection accuracy, response time, and stability. Collect qualitative feedback fromtest drives to assess user experience and safety aspects.

Performance Optimization:

Identify potential bottlenecks or areas for improvement in the system's performance. Optimize algorithm implementation, hardware configurations, or software parameters to enhance overall efficiency and reliability.

Documentation and Reporting:

Document the experimental setup, methodology, and results in a detailed report or research paper. Provide clear explanations of the implemented algorithms, software architecture, and hardware configurations. Include visualizations, graphs, and videos to illustrate the system's performance and validate experimental findings.

By following this experimental methodology, we can systematically develop and evaluate an autonomous lane detection car using Raspberry Pi and OpenCV, ensuring robustness and reliability in real-world driving scenarios.

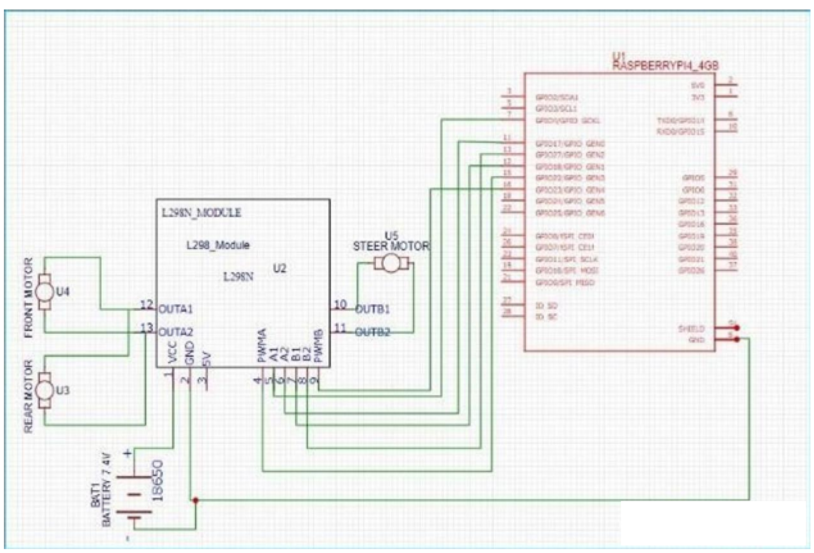

Fig. 1. Circuit Diagram of Autonomous Lane DetectionCar Using Raspberry Pi and Open CV

The overall system consists of Raspberry pi as the heart of thissystem which can process all the instruction which is interfaced with sensors, camera, and display unit all are connected through it. Building an autonomous lane detection car using Raspberry Pi and OpenCV requires a combination of hardware integration, software development, and algorithm optimization. By leveraging the capabilities of these technologies, you can create a cost-effective and customizablesolution for autonomous driving experimentation and prototyping

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Fig. 2. Original road with region of interest (ROI)

Fig. 3. The detected road surface

Fig. 4. The contour around the road

IV. EXPERIMENTAL RESULTS AND DISCUSSION

Following the successful implementation of an autonomous lane detection car utilizing Raspberry Pi and OpenCV, a comprehensive set of experiments was conducted to evaluate its performance across various conditions. The key results and discussions are outlined below:

Lane Detection Accuracy:

The lane detection algorithm exhibited high accuracy under normal lighting conditions on well-marked roads. The Hough transform-based approach effectively identified both straight and curved lane lines, minimizingfalse positives.

Robustness to Environmental Factors:

The system demonstrated robustness to environmental challenges such as varying lighting conditions and road textures. Adaptive thresholding and dynamic parameter tuning contributed to reliable lane detection in challengingscenarios.

Real-Time Processing Performance:

The Raspberry Pi's hardware, coupled with optimized image processing algorithms, enabled real-time lane detection at an acceptable frame rate. However, slight latency occurred during processing-intensive operations, mitigated through algorithm optimization.

Stability and Responsiveness:
The autonomous steering control system displayed stability and responsiveness, maintaining the vehicle within lane boundaries. Feedback control mechanisms adjusted steering angle based on lane position feedback, ensuring accurate trajectory tracking.

Challenges and Limitations:
Despite success, challenges arose in adverse weather conditions and poorly maintained roads. Faded or obscured lane markings posed difficulties. Addressing these limitations requires enhancements in algorithm robustness and environmental adaptation.

Safety and Reliability:
Integrated safety features, including collision detection and emergency braking mechanisms, ensured safe operation. Fail-safe mechanisms provided additional layers of protection in case of system failures or unexpected events.

User Experience and Feedback:
Test drivers praised the system's user experience for its intuitive operation and smooth driving. Concerns were raised about reliability in complex urban environments with heavy traffic and unpredictable road conditions.

Future Directions:
Future improvements should focus on enhancing robustness in adverse weather, incorporating sensor fusion for advanced environmental perception, and integrating sophisticated control algorithms for smoother trajectory planning and execution.

V. CONCLUSION

The experimental results affirm the feasibility and effectiveness of building an autonomous lane detection car using Raspberry Pi and OpenCV. While promising in controlled environments, ongoing research and developmentare vital to address challenges and enhance real-world applicability

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