คณะวิศวกรรมศาสตร์
Faculty of Engineering

PROJECT DAY 2026

INC11

DEVELOPMENT OF A PROTOTYPE AUTONOMOUS VEHICLE FOR LANE KEEPING USING DATA-DRIVEN PID CONTROL

CONTROL SYSTEM AND INSTRUMENTATION ENGINEERING

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1. ABSTRACT

This project focuses on the design and development of a prototype autonomous vehicle system capable of automatic braking when obstacles are detected and maintaining the vehicle within the lane. A PID (Proportional-Integral-Derivative) controller based on a data-driven approach is employed to achieve effective steering control and maintain the stability of the vehicle near the center of the lane. The project also studies and compares controller tuning techniques between the conventional Trial and Error method and the data-driven Fictitious Reference Iterative Tuning (FRIT) method **[1]**, which is used to tune the K_P, K_I, K_D parameters of the controller in order to identify the most suitable approach for the system. The prototype vehicle consists of an Intel RealSense D435 camera and an RPLIDAR S2 sensor for environmental perception. In addition, an NVIDIA Jetson Orin Nano is used as the main processing unit, working together with the YOLOP model to detect objects, lane lines, and drivable areas within a single frame. Furthermore, MATLAB is used for controller design and simulation to demonstrate the controller performance before implementation and testing on the real system.

2. PROJECT OVERVIEW

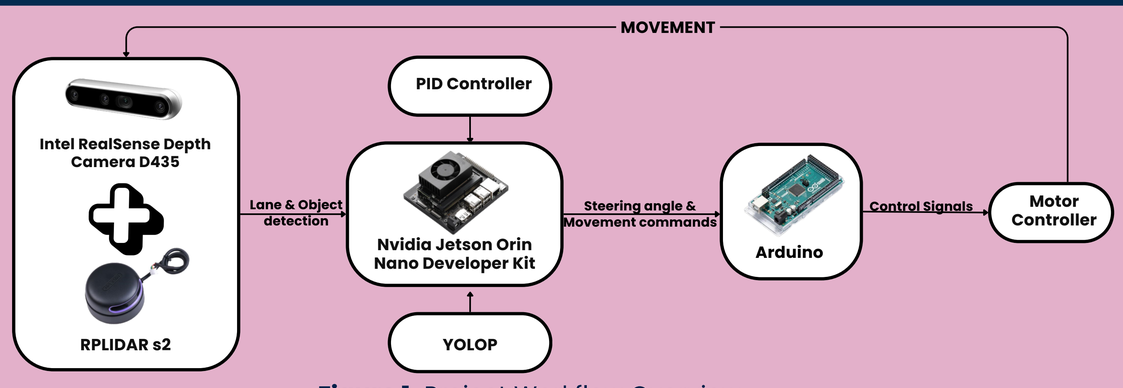

Figure 1. Project Workflow Overview

The system acquires visual data from the camera and distance information from the LiDAR sensor, which are processed by the NVIDIA Jetson Orin Nano. A sensor fusion approach combines data from both sensors to improve environmental perception and enhance detection accuracy**[3]**. Utilizing the YOLOP model, the system performs real-time lane and object detection, followed by the calculation of lateral and heading errors to support steering angle adjustments. Furthermore, movement and automatic braking commands are transmitted to the Arduino, which controls the motor to ensure accurate vehicle response according to real-time driving conditions.

3. METHODOLOGY

HARDWARE CONFIGURATION → PANOPTIC PERCEPTION (YOLOP) → LANE-KEEPING CONTROL SYSTEM

HARDWARE CONFIGURATION

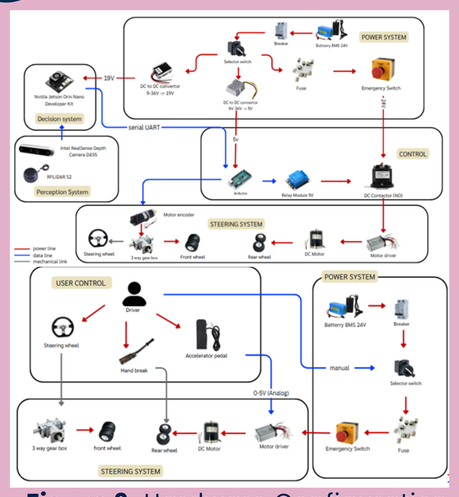

Figure 3. Hardware Configuration

Computing Unit : The NVIDIA Jetson Orin Nano serves as the main processor.
Perception Suite : The Intel RealSense D435 camera and RPLIDAR S2 are used for lane detection, obstacle detection, and distance measurement.
Power System : A 24V battery source regulated by DC-to-DC converters to provide stable 19V for the Jetson and 5V for the Arduino.

PANOPTIC PERCEPTION (YOLOP)

- **Multi-task Inference :** Simultaneously detects traffic objects, lane lines, and drivable areas in a single frame.
- **Error Calculation :** Computes Lateral and Heading Errors in real-time to provide feedback for the control system.

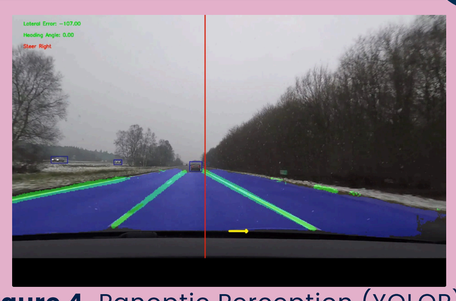

Figure 4. Panoptic Perception (YOLOP)

LANE-KEEPING CONTROL SYSTEM

A lane-keeping control system is developed to maintain the vehicle within its lane using a PID controller. The controller takes lateral position and heading error, obtained from sensor fusion, as inputs. These errors are weighted and combined, then used to generate a steering angle command, which is sent to the vehicle actuator to correct and maintain the desired trajectory, as illustrated in the figure.

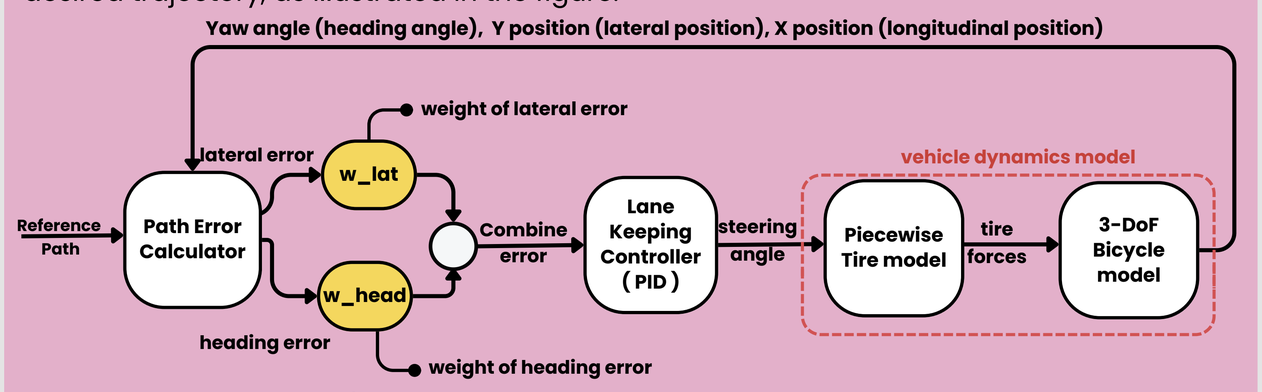

Figure 2. Lane-Keeping Control System Diagram

To evaluate the performance of the designed PID controller, it is compared with the conventional Stanley Controller **[2]**, a widely used method for lane-keeping applications. Furthermore, FRIT (Fictitious Reference Iterative Tuning) is applied to determine the optimal controller gains (Kc,Ti,Td). This approach follows a data-driven methodology, where controller parameters are tuned based on actual system response (experimental data), eliminating the need for complex mathematical modeling.

4. RESULT

➤ Path Tracking Simulation Results

Note: ● PID (Trial & Error) ● PID (FRIT) ● Stanley Controller --- Reference

Case 1

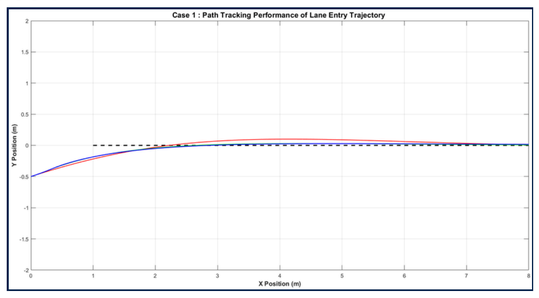

Figure 5. Case 1 Lane Entry Performance

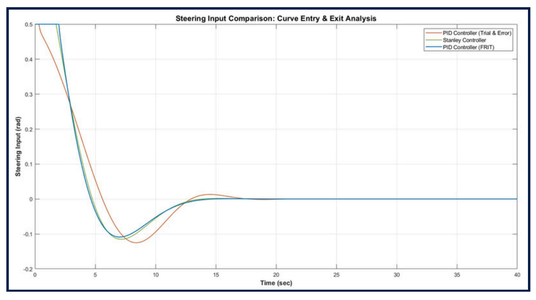

Figure 6. Case 1 Steering Command

Case 2

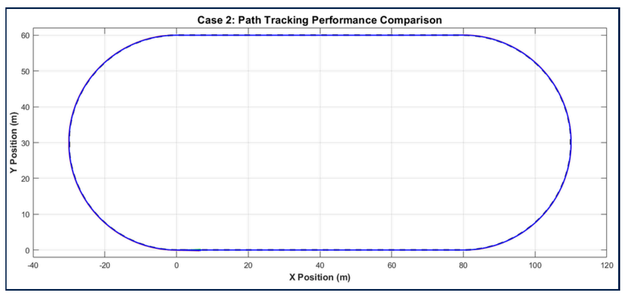

Figure 7. Case 2 Full Track Reliability

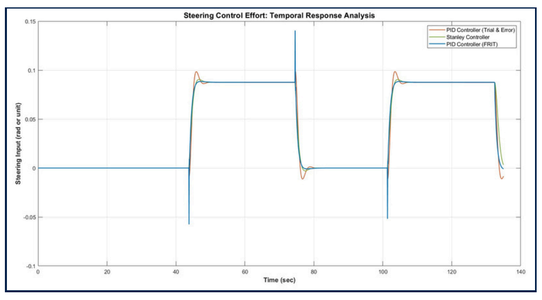

Figure 8. Case 2 Steering Command

Case	Stanley Controller	PID Controller	
		Trial & Error	FRIT
1	0.12036	0.12846	0.12028
2	0.47553	0.55127	0.46017

Table 1. Comparison of RMSE Values for Path Tracking Performance

- **PID Controller (FRIT)** achieves the lowest RMSE across all test cases, demonstrating consistently higher tracking accuracy than both trial-and-error tuning and the Stanley controller.
- **The steering response** analysis demonstrates that the PID (FRIT) achieves the superior performance with reduced oscillation and smoother convergence, indicating better transient behavior and control stability.
- The results confirm that **FRIT** approach effectively identifies optimal control gains (Kc,Ti,Td) directly from experimental data, without relying on complex system modeling.

➤ RPLidar S2 Sensor Performance Analysis

Ground Truth	Measured Distance (White Target)	Absolute Error	Measured Distance (Black Target)	Absolute Error
1 m	1.040 m	4.0 cm	1.047 m	4.7 cm
4 m	4.045 m	4.5 cm	4.059 m	5.9 cm
7 m	7.060 m	6.0 cm	7.064 m	6.4 cm
10 m	10.075 m	7.5 cm	10.078 m	7.8 cm
15 m	15.054 m	5.4 cm	15.094 m	9.4 cm
30 m	30.063 m	6.3 cm	29.071 m	92.9 cm

Table 2. Range Accuracy Test

Range Accuracy : The RPLIDAR S2 provides high accuracy within a range of 1–15 meters, with an error margin of approximately 4–7 cm. However, for black objects, the measurement error tends to increase at distances greater than 10 meters.

Angle	Distance	Measured Angle (White Target)	Absolute Error	Measured Angle (Black Target)	Absolute Error
30°	1 m	30°	0°	30°	0°
	4 m	30.1°	0.1°	30.2°	0.2°
	7 m	29.6°	0.4°	29.7°	0.3°
	10 m	29.5°	0.5°	29.5°	0.5°
45°	1 m	45.2°	0.2°	45.3°	0.3°
	4 m	44.7°	0.3°	44.7°	0.3°
	7 m	45.0°	0°	45.3°	0.3°
	10 m	44.4°	0.6°	44.3°	0.7°
60°	1 m	59.7	0.3°	59.7	0.3°
	4 m	59.5	0.5°	59.5	0.5°
	7 m	59.0	1°	59.0	1°
	10 m	56.7	3.3°	56.7	3.3°

Table 3. Angle Accuracy Test

Angular Precision : The RPLidar S2 is highly accurate at 30°–45° (error<0.6°), but accuracy decreases as angle and distance increase, reaching a 3.3° error at 60° (10m).

5. CONCLUSION

This work presents a data-driven PID-based lane-keeping control system using FRIT tuning. The proposed method achieves higher accuracy and improved stability compared to conventional approaches. The results confirm that optimal controller performance can be obtained directly from experimental data without relying on complex mathematical models, helping to improve accuracy and reduce costs before real hardware implementation. In the near future, the system will integrate camera and LiDAR data to estimate the vehicle's position and heading.

REFERENCE

[1] Arthit Julkananusart, and Itthisek Nilkhamhang, 2015,"Quadrotor Tuning for Attitude Control Based on Double-Loop PID Controller Using Fictitious Reference Iterative Tuning (FRIT)", Available: https://ieeexplore.ieee.org/document/7392862 [7 May 2025].
[2] G. M. Hoffmann, C. J. Tomlin, M. Montemerlo, and S. Thrun, "Autonomous Automobile Trajectory Tracking for Off-Road Driving: Controller Design, Experimental Validation and Racing," in Proceedings of the 2007 American Control Conference, New York City, NY, USA, 2007, pp. 2296-2301. [20 January 2026].
[3] Walid Benayed, Imen Mabrouk, Mohamed Slim Masmoudi, and Wafa Ben Abdelaziz, 2025, "LiDAR 2D and Camera Fusion for ADAS: A Practical Approach With YOLOv9 and ROS2 Framework", Available:https://ieeexplore.ieee.org/document/11145440, [17 September 2025].