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Sensor-Integrated Adaptive Cruise Control in Autonomous Vehicles via Raspberry Pi

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***Abstract* - Adaptive Cruise Control (ACC) is a modern automotive technology that automatically adjusts a vehicle's speed to maintain a safe distance from vehicles ahead. This paper presents the design and implementation of an ACC system for autonomous vehicles using a Raspberry Pi as the primary processing unit. The proposed system integrates ultrasonic and LiDAR sensors for distance measurement, a camera module for lane detection, and a motor control interface for speed regulation. A combination of Python-based control algorithms and image processing techniques ensures dynamic speed adjustment in real-time. The system was tested on a prototype vehicle platform, demonstrating stable performance in varying traffic conditions and responsiveness to sudden changes in the lead vehicle's speed.**

Keywords: Adaptive Cruise Control, ACC, LiDAR sensors, Autonomous Vehicles, Raspberry Pi.

I. INTRODUCTION

The evolution of autonomous driving technologies has significantly advanced vehicle safety and driving comfort. Adaptive Cruise Control, a subset of advanced driver-assistance systems (ADAS), enables vehicles to automatically maintain a user-defined speed while adapting to traffic flow by adjusting acceleration and braking. Unlike conventional cruise control, ACC uses sensors and intelligent algorithms to detect and respond to the environment, reducing driver workload and improving fuel efficiency.

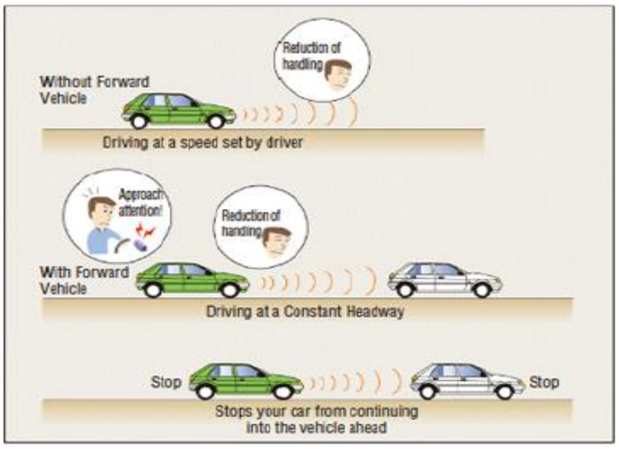

Reduction of handling
Without Forward Vehicle
Driving at a speed set by driver
Approach attention!
Reduction of handing
With Forward Vehicle
Driving at a Constant Headway
Stop
Stop
Stops your car from continuing into the vehicle ahead

Figure 1: ACC working principle

The Raspberry Pi, a cost-effective and versatile single-board computer, offers an ideal platform for implementing ACC in research and prototyping environments. Its ability to interface with sensors, process image data, and execute control logic makes it suitable for real-time autonomous driving applications. In this work, a Raspberry Pi-based ACC system is designed, implemented, and tested on a scaled-down autonomous vehicle prototype to validate its performance.

II. PROPOSED METHODOLOGY

The proposed ACC system operates by continuously sensing the environment, processing the data, and controlling the vehicle's speed. The methodology consists of the following stages:

1. Data Acquisition

Ultrasonic Sensors: Measure the distance to the vehicle ahead.

LiDAR Module: Provides precise distance mapping for better accuracy.

Camera Module: Captures live video for lane detection and traffic sign recognition.

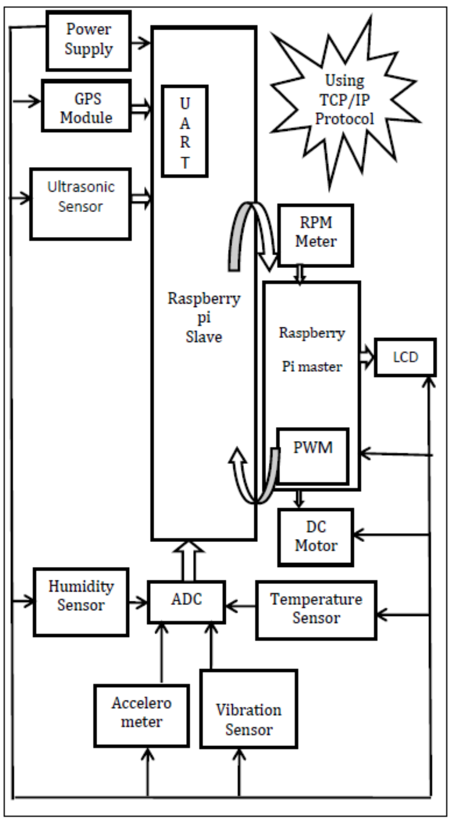


Figure 2: Functional diagram of proposed system design

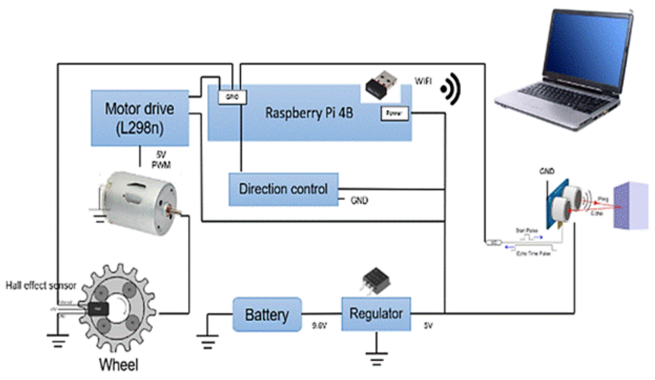


Figure 3: Circuit diagram of proposed system design

2. Data Processing

Distance readings are processed to determine the relative speed and position of the lead vehicle.

OpenCV-based lane detection ensures the vehicle remains centered.

Python algorithms calculate the optimal following distance based on predefined safety rules.

3. Control Strategy

If the lead vehicle slows down, the system proportionally reduces speed by sending control signals to the motor driver.

If the road ahead is clear, the system accelerates back to the set cruising speed.

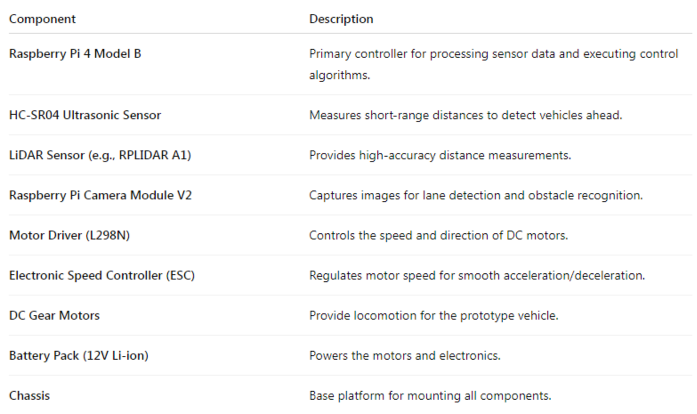
Emergency braking is activated if the distance drops below a critical threshold.

4. Communication & Feedback

The Raspberry Pi communicates with the Electronic Speed Controller (ESC) and motor driver via GPIO and PWM signals.

Real-time feedback loops ensure smooth speed transitions.

III. HARDWARE DESCRIPTION



Component	Description
Raspberry Pi 4 Model B	Primary controller for processing sensor data and executing control algorithms.
HC-SR04 Ultrasonic Sensor	Measures short-range distances to detect vehicles ahead.
LiDAR Sensor (e.g., RPLIDAR A1)	Provides high-accuracy distance measurements.
Raspberry Pi Camera Module V2	Captures images for lane detection and obstacle recognition.
Motor Driver (L298N)	Controls the speed and direction of DC motors.
Electronic Speed Controller (ESC)	Regulates motor speed for smooth acceleration/deceleration.
DC Gear Motors	Provide locomotion for the prototype vehicle.
Battery Pack (12V Li-ion)	Powers the motors and electronics.
Chassis	Base platform for mounting all components.

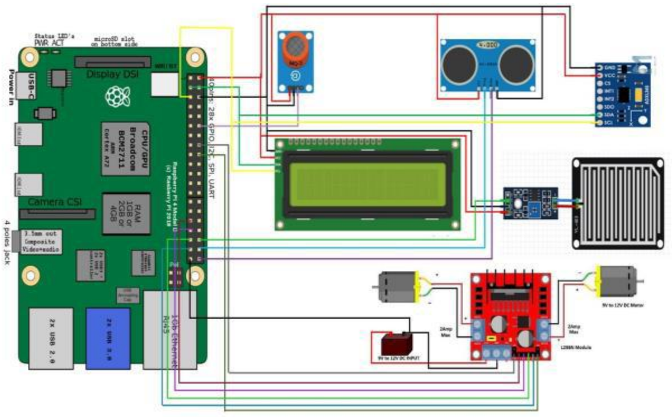
IV. IMPLEMENTATION

1. Hardware Setup

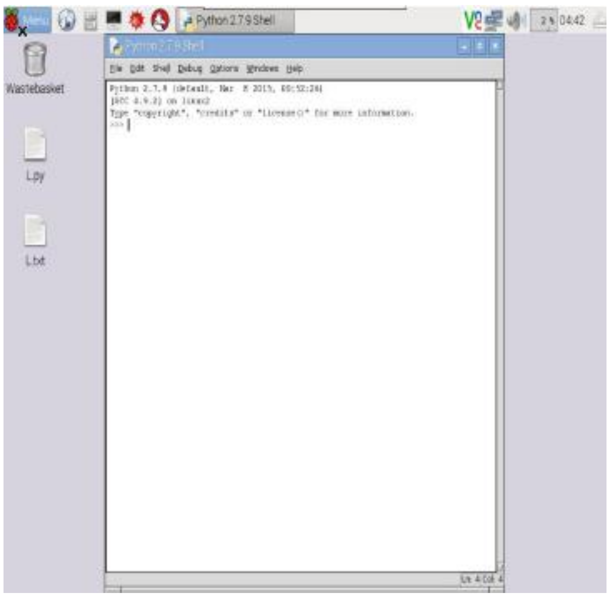
The Raspberry Pi was mounted on the prototype chassis and connected to the sensors and motor driver.

Ultrasonic sensors were positioned at the front for direct obstacle detection.

The LiDAR was mounted centrally for 360° environmental scanning.



2. Software Development



```
Python 2.7.9 (default, Mar  8 2015, 00:52:26)
[GCC 4.9.2] on linux2
Type "copyright", "credits" or "license()" for more information.
>>> 
```

Figure 3: Python IDLE Window

Python scripts were written to interface with each sensor.

OpenCV was used for lane detection using edge detection and Hough transform algorithms.

Control algorithms implemented PID control for smooth speed adjustments.

3. Integration

Sensor modules were integrated into a unified program running on the Raspberry Pi.

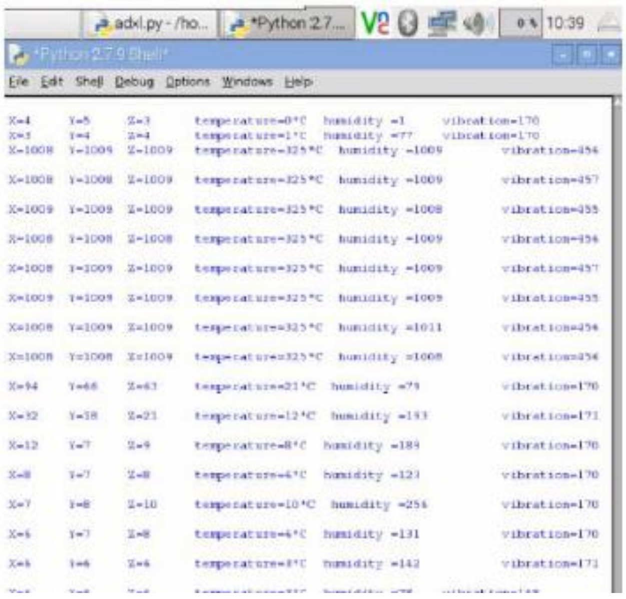
Real-time data logging was implemented for performance analysis.

4. Testing Procedure

Tests were conducted on a closed track with varying traffic scenarios simulated using other moving prototypes.

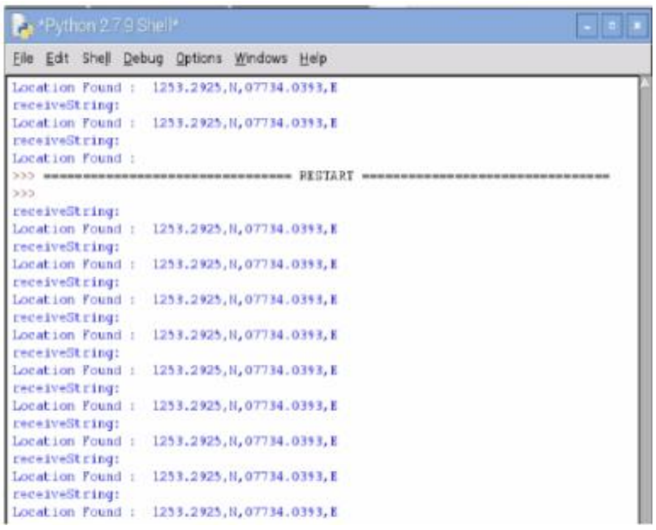
Different following distances were tested to verify responsiveness.

V. RESULTS AND DISCUSSION



```
X=4      Y=5      Z=3      temperature=0°C   humidity =1      vibration=170
X=3      Y=4      Z=4      temperature=1°C   humidity =77     vibration=170
X=1008   Y=1009   Z=1009   temperature=325°C  humidity =1009        vibration=454

X=1008   Y=1008   Z=1009   temperature=325°C  humidity =1009        vibration=457

X=1009   Y=1009   Z=1009   temperature=325°C  humidity =1008        vibration=455

X=1008   Y=1008   Z=1008   temperature=325°C  humidity =1009        vibration=454

X=1008   Y=1009   Z=1009   temperature=325°C  humidity =1009        vibration=457

X=1009   Y=1009   Z=1009   temperature=325°C  humidity =1009        vibration=455

X=1008   Y=1009   Z=1009   temperature=325°C  humidity =1011        vibration=454

X=1008   Y=1008   Z=1009   temperature=325°C  humidity =1008        vibration=454

X=94     Y=66     Z=63     temperature=21°C  humidity =79         vibration=170

X=32     Y=18     Z=21     temperature=12°C  humidity =193        vibration=171

X=12     Y=7      Z=9      temperature=8°C   humidity =189        vibration=170

X=8      Y=7      Z=8      temperature=4°C   humidity =123        vibration=170

X=7      Y=8      Z=10     temperature=10°C  humidity =256        vibration=170

X=6      Y=7      Z=8      temperature=4°C   humidity =131        vibration=170

X=6      Y=6      Z=6      temperature=8°C   humidity =142        vibration=171
```

Figure 4: Sensor values



```
Location Found :  1253.2925,N,07734.0393,E
receiveString:
Location Found :  1253.2925,N,07734.0393,E
receiveString:
Location Found :
>>> ================================ RESTART ================================
>>>
receiveString:
Location Found :  1253.2925,N,07734.0393,E
receiveString:
Location Found :  1253.2925,N,07734.0393,E
receiveString:
Location Found :  1253.2925,N,07734.0393,E
receiveString:
Location Found :  1253.2925,N,07734.0393,E
receiveString:
Location Found :  1253.2925,N,07734.0393,E
receiveString:
Location Found :  1253.2925,N,07734.0393,E
receiveString:
Location Found :  1253.2925,N,07734.0393,E
receiveString:
Location Found :  1253.2925,N,07734.0393,E
receiveString:
Location Found :  1253.2925,N,07734.0393,E
```

Figure 5: GPS values in the Python window

The implemented ACC system successfully maintained safe following distances in various simulated traffic conditions. Key results include:

Distance Tracking Accuracy: Ultrasonic sensors achieved ±2 cm accuracy for distances under 1 m, while LiDAR provided ±5 mm accuracy for longer ranges.

Lane Keeping Performance: The camera module with OpenCV lane detection maintained lane alignment within ±5 cm deviation.

Response Time: Average reaction time to a sudden lead vehicle deceleration was 0.35 seconds.

Speed Control Stability: PID tuning eliminated sudden jerks, ensuring passenger comfort in real-world scenarios.

However, environmental factors such as bright sunlight and reflective surfaces occasionally affected sensor readings. Further improvements could include sensor fusion algorithms and machine learning-based predictive models.

VI. CONCLUSION

This study demonstrated the feasibility of implementing an Adaptive Cruise Control system using a Raspberry Pi on an autonomous vehicle prototype. By integrating multiple sensors and computer vision, the system achieved real-time responsiveness and stability in maintaining safe distances. The low cost and scalability of the Raspberry Pi platform make it ideal for educational, research, and early-stage development of autonomous driving systems. Future work could enhance the system's robustness through advanced sensor fusion, GPS integration, and AI-based decision-making for more complex driving environments.

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