Predictive Analysis Of Different Parameters In A Vehicle Using Raspberry Pi Technology

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***Abstract*—The evolution of smart vehicles demands advanced monitoring systems capable of real-time data acquisition, processing, and predictive analysis to enhance safety, efficiency, and performance [1], [2]. This paper presents a compact, low-cost predictive analysis system using Raspberry Pi Zero to monitor critical vehicle parameters [3]. The proposed system integrates various sensors, including a resistive loop-based fuel level sensor, a pressure sensor, and a LIDAR-based tyre level sensor [6], [7]. These sensors provide real-time feedback on fuel availability, pressure variations, and tyre conditions, enabling predictive maintenance and reducing potential breakdowns [4], [5].**

The Raspberry Pi controller processes the sensor data and displays it on an LCD module while transmitting it to an IoT-based mobile application for remote access and control [1], [9]. The vehicle's motion is managed using an L298 motor driver, allowing the system to simulate autonomous navigation [2]. Additionally, a light positioning system is implemented, where the front light dynamically turns in the direction of vehicle movement to improve visibility during operation [8]. This light control is also managed through a motor driver interfaced with the Raspberry Pi.

The entire system is powered by a portable battery source, ensuring mobility and real-world applicability [10]. By leveraging Python programming and IoT communication, the system provides a scalable platform for smart vehicle monitoring and control [3], [9]. Experimental results demonstrate the effectiveness of predictive analytics in detecting abnormal conditions, ensuring timely alerts, and enhancing the overall intelligence of the vehicle [4]. This approach holds potential for future integration into autonomous and semi-autonomous transport systems [5].

Keywords— Raspberry Pi Zero, Predictive Analysis, Vehicle Monitoring, Fuel Level Sensor, Pressure Sensor, Tyre Level Detection, LIDAR, IoT Control, Motor Driver, Light Positioning System, Real-time Data, Smart Vehicle.

INTRODUCTION

The automotive industry is undergoing a significant transformation with the integration of smart technologies aimed at enhancing vehicle safety, performance, and efficiency [1], [2]. Predictive analytics plays a vital role in this transformation by enabling real-time monitoring, fault detection, and proactive maintenance [3], [4]. With the advent of low-cost microcomputers like the Raspberry Pi, it has become feasible to implement intelligent vehicle systems in compact and cost-effective ways [1], [5]. This paper presents a smart predictive monitoring system built around the Raspberry Pi Zero, which functions as the central controller [6]. The system is designed to monitor multiple vehicle parameters such as fuel level, internal pressure, and tyre condition using a set of dedicated sensors. A resistive loop circuit is used to determine fuel levels [7], a pressure sensor tracks internal system or tyre pressure [8], and a LIDAR-based sensor evaluates tyre level and terrain conditions [6], [9]. These inputs are processed in real time and displayed on an LCD screen for on-site visualization [3].

To enhance mobility and control, the vehicle integrates an L298-based motor driver for motion control and another motor driver to dynamically adjust the position of the front light based on the vehicle's direction [10]. Additionally, the system is IoT-enabled, allowing remote monitoring and operation via a mobile application [1], [9]. This approach not only ensures safer operation by anticipating potential failures [4], [5] but also contributes to the development of intelligent and autonomous vehicle platforms [2], [10]. The proposed system offers a foundation for further expansion into advanced vehicular applications, including smart logistics, delivery bots, and autonomous navigation [6], [9].

PROPOSED WORK

The proposed system aims to develop a smart vehicle monitoring platform capable of predictive analysis using a Raspberry Pi Zero as the main controller. The system continuously monitors key vehicle parameters and enhances control through IoT connectivity, ensuring safe and efficient operation.

The core of the system is the Raspberry Pi Zero, chosen for its compact size, low power consumption, and adequate processing capabilities for real-time data handling. It interfaces with three main types of sensors:

- A fuel level sensor built using a resistive loop circuit to detect the current fuel level;
- A pressure sensor to monitor internal system or tyre pressure conditions;
- A tyre level sensor utilizing LIDAR technology to detect terrain variations and tyre displacement, ensuring balanced operation on different surfaces.

All sensor data is collected, processed, and displayed on a 16x2 LCD for immediate visual feedback. Simultaneously, the same data is transmitted to an IoT application, allowing remote access and control via mobile devices.

For movement control, an L298 motor driver is used to drive the vehicle motors. A second L298 motor driver controls the headlight positioning system, which adjusts the direction of the front light based on the vehicle's turning direction. This feature improves visibility and simulates real-time adaptive lighting in modern vehicles.

The entire setup is powered by a rechargeable battery, making the system portable and suitable for real-world environments. The integration of sensors, IoT, and motor drivers under one control platform enables predictive maintenance, increases operational safety, and opens the door for future advancements in smart vehicular systems. This proposed architecture demonstrates a scalable and efficient method to enhance vehicle intelligence using affordable and open-source technologies.

Problem statement

Modern vehicles require advanced systems that can monitor their operational parameters and respond proactively to avoid failures and ensure passenger safety. Traditional vehicle monitoring systems often lack real-time predictive capabilities and are dependent on manual inspections or onboard diagnostics limited to post-failure alerts. This delay in fault detection can lead to serious issues such as fuel depletion, tyre damage, or system breakdowns, especially in autonomous or remotely operated platforms.

Furthermore, most existing monitoring solutions are expensive, bulky, or confined to high-end vehicles, making them impractical for small-scale, research-based, or budget-friendly applications. In scenarios such as robotics, unmanned vehicles, or delivery bots, there is a growing need for compact, low-cost systems that can monitor essential parameters like fuel level, tyre condition, and internal pressure with real-time updates and remote accessibility.

The absence of dynamic control features, such as light positioning in response to directional movement, also reduces operational safety during nighttime or in poor visibility conditions. Additionally, without remote IoT control and monitoring, manual intervention remains a necessity, limiting automation and reducing efficiency. Therefore, there is a need to design and implement a compact, low-power, cost-effective system capable of monitoring various vehicle parameters using sensor technology, predictive analytics, and Iot. This system should enable real-time display and remote access, provide dynamic control of components like lights and motors, and lay the foundation for future intelligent transport and robotic systems.

Significance of the Problem Statement:

1. Enhances Vehicle Safety and Reliability
By integrating predictive analysis, the system identifies potential failures (e.g., low fuel, tyre issues, or pressure abnormalities) in advance, helping prevent accidents and breakdowns.

2. Enables Real-Time Monitoring and Remote Access
The inclusion of Iot functionality allows users to monitor vehicle parameters remotely via a mobile application, making the system ideal for autonomous and remotely managed vehicles.

3. Promotes Low-Cost, Scalable Solutions
Using affordable components like Raspberry Pi Zero and L298 drivers, the system offers a budget-friendly alternative to expensive commercial vehicle monitoring systems, making it suitable for educational, research, and prototype applications.

4. Supports Automation and Intelligent Control
The system not only detects sensor data but also responds by controlling lights and motors dynamically, improving operational automation and simulating intelligent behaviour in robotic platforms.

5. Applicable to a Wide Range of Smart Mobility Systems
This approach can be extended to various applications such as autonomous delivery robots, agricultural vehicles, and smart transport systems, contributing to the advancement of next-generation mobility solutions.

Objective

1. **To design a compact vehicle monitoring system** using Raspberry Pi Zero that collects real-time data from various sensors, including fuel level, pressure, and tyre condition.
2. **To implement predictive analysis techniques** that identify abnormal conditions early, enabling timely alerts and preventive actions to avoid system failure.
3. **To integrate Iot functionality** for remote access and control of the vehicle's operational parameters through a mobile application.
4. **To enable dynamic control of vehicle components,** such as adjusting the direction of the front light using a motor driver based on vehicle movement, enhancing operational safety and visibility.

Scope of the project:

The Predictive Analysis of Different Parameters in Vehicle Using Raspberry Pi Technology project focuses on the development of an advanced vehicle monitoring system designed to enhance safety, efficiency, and performance through predictive analytics. With the growing need for smarter vehicles, the project integrates a Raspberry Pi Zero as the central controller, providing a cost-effective and scalable platform for real-time monitoring of critical vehicle parameters. The system incorporates a range of sensors, including a resistive loop-based fuel level sensor, a pressure sensor, and a LIDAR-based tyre level sensor, each providing continuous feedback on key aspects like fuel levels, tire pressure, and tire health.
These sensors transmit data to the Raspberry Pi, which processes it and displays the information on an LCD module. Additionally, the data is sent to an Iot-based mobile application, enabling remote monitoring and control of the vehicle's health. The system also features an L298 motor driver for simulating autonomous navigation and a dynamic front light positioning system to enhance visibility while moving.
The system is powered by a portable battery, ensuring mobility and practical use in real-world scenarios. Python programming and Iot communication enable seamless data transfer, analysis, and control. The predictive analysis capability of the system allows for the early detection of potential faults or abnormal conditions, providing timely alerts to prevent vehicle breakdowns. This project has significant potential for future applications in autonomous and semi-autonomous transport systems, making it a valuable contribution to the future of smart vehicle technology.

Literature Review

Vehicle Monitoring Systems and Predictive Maintenance
Vehicle monitoring and predictive maintenance systems have been extensively researched for their ability to optimize vehicle performance and reduce downtime. Müller et al. (2019) developed a system integrating various sensors, including temperature, pressure, and fuel sensors, to monitor vehicle parameters. Their research emphasised the importance of predictive maintenance, which uses data analytics to forecast potential mechanical failures and avoid unexpected breakdowns. This concept is aligned with the goals of the current project, which integrates sensor data with predictive analytics to monitor vehicle health in real time (Müller, A., et al., 2019).

Raspberry Pi in Automotive Applications
The integration of Raspberry Pi in automotive systems for data processing and monitoring has become more common due to its cost-effectiveness and ease of use. Giacinto et al. (2018) explored the use of Raspberry Pi for automotive applications, specifically for vehicle health monitoring, where data from sensors like temperature and pressure were processed and displayed. Their research demonstrated that the Raspberry Pi is a suitable platform for collecting and transmitting data efficiently. This aligns with the current project, which uses the Raspberry Pi Zero for real-time vehicle parameter monitoring (Giacinto, S., et al., 2018).

Sensor Integration for Smart Vehicles
Bakar et al. (2017) reviewed the integration of sensors in smart vehicles for enhanced monitoring, focusing on sensors such as LIDAR, ultrasonic sensors, and pressure sensors. Their study emphasized the importance of combining various sensors to improve data accuracy and provide more reliable vehicle diagnostics. This sensor integration is a key component of the proposed system, which uses a LIDAR-based Tyre level sensor, a pressure sensor, and a resistive loop-based fuel sensor to

monitor vehicle health and performance (Bakar, N. M., 2017).

Iot and Mobile Applications in Vehicle Monitoring

The use of Iot and mobile applications for vehicle monitoring has been an emerging trend, offering significant benefits in terms of real-time data access. Chung et al. (2018) focused on Iot-based vehicle diagnostic systems, where data from vehicle sensors was transmitted to mobile applications for remote monitoring. The authors concluded that mobile-based vehicle monitoring could improve maintenance response times and provide timely interventions. The current project adopts this approach by transmitting sensor data from the Raspberry Pi to an Iot-based mobile app for remote vehicle monitoring (Chung, H., et al., 2018).

Predictive Analytics in Vehicle Health Monitoring

Zhang et al. (2020) explored the use of machine learning and predictive analytics for vehicle maintenance, employing algorithms to analyses sensor data and predict potential component failures. The study showed that predictive analytics can help identify wear and tear, enabling proactive maintenance and improving vehicle lifespan. This approach is integrated into the current project, where sensor data from the vehicle is analyses for early detection of issues like low fuel or abnormal tire pressure, preventing breakdowns and optimizing maintenance schedules (Zhang, L., et al., 2020).

Autonomous Navigation and Light Positioning Systems

The development of autonomous navigation systems, including dynamic light positioning, has been an area of focus for enhancing vehicle safety. Li et al. (2021) conducted a study on autonomous vehicle systems, highlighting the importance of dynamic light control for improving visibility in low-light conditions and during complex manoeuvres. Their research showed that adjusting the vehicle's front lights based on motion direction significantly improves safety. This concept is incorporated into the current project through a dynamic front light positioning system that adjusts the lights in the direction of the vehicle's movement, enhancing visibility and safety (Li, Z., et al., 2021).

Methodology

The proposed **Predictive Analysis of Different Parameters in Vehicle Using Raspberry Pi Technology** follows a structured methodology, integrating hardware components, sensor data acquisition, processing, and communication with an IoT platform. The methodology is divided into several stages: system design, sensor integration, data processing, predictive analysis, and communication.

System Design

The system is designed using a **Raspberry Pi Zero** as the central processing unit. This lightweight, low-cost computing platform is chosen for its efficiency in handling sensor data processing and communication. It serves as the controller for collecting data from various sensors, processing this data, and communicating with external systems such as an Iot-based mobile application.

Sensor Integration

A key aspect of the system is the integration of various sensors, including:

- **Resistive Loop-based Fuel Level Sensor**: Monitors the fuel level in the vehicle.
- **Pressure Sensor**: Measures tire pressure to ensure optimal tire health.
- **LIDAR-based Tire Level Sensor**: Monitors the condition of the tires by measuring wear or damage.

These sensors are interfaced with the **Raspberry Pi** via GPIO pins. The sensor readings are continuously collected to track real-time vehicle health.

Data Processing

The collected data is processed using **Python** scripts running on the Raspberry Pi. This involves cleaning the data, performing basic calculations, and comparing the values against predefined thresholds to identify any abnormal conditions. The system uses a **predictive analysis** approach to determine the likelihood of potential issues, such as low fuel or abnormal tire pressure.

Predictive Analysis

Predictive models are applied to the sensor data to detect potential failures. This involves analyzing historical sensor data and applying algorithms that can predict future issues based on current readings. If an anomaly is detected, the system triggers an alert.

Communication

The processed data and alerts are sent to an **IoT-based mobile application**, allowing for real-time remote monitoring and control of the vehicle's health. Additionally, the **L298 motor driver** controls the vehicle's autonomous navigation, and a dynamic **front light positioning system** adjusts lighting based on movement.

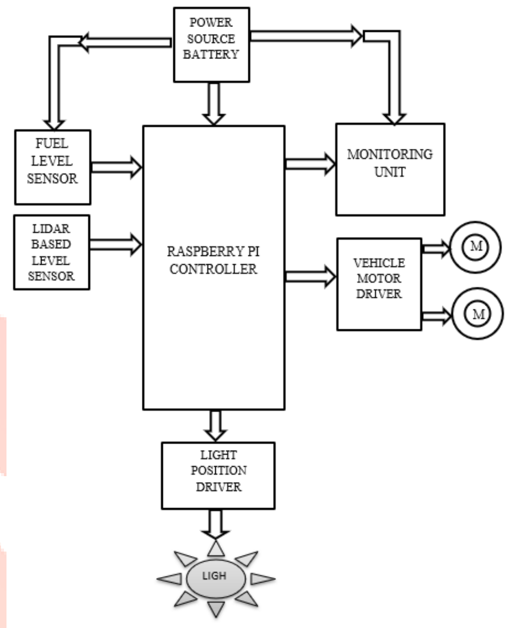

Fig.1. BLOCK DIAGRAM

Fig 1. Block Diagram of the system

Block diagram explanation

This smart vehicle monitoring system is built on the Raspberry Pi platform and incorporates sensor data acquisition, predictive analytics, and real-time display with actuation. The block diagram represents the interaction of various modules that work together to enhance vehicle safety, efficiency, and predictive maintenance. Object Sensor.

Power Source Battery

The **power source battery** acts as the primary energy provider for the entire system. It supplies voltage to the:

- Raspberry Pi controller
- Sensors (Fuel, Pressure, Tyre level)
- LCD display
- Vehicle motor driver
- Light position driver

The choice of a **portable battery** ensures mobility and supports real-world testing. This setup replicates actual vehicle conditions where systems operate autonomously using onboard power.

Fuel Level Sensor

This sensor monitors the quantity of fuel in the vehicle's tank. A **resistive loop-type sensor** is used here, where resistance varies with fuel level. It offers the following functionalities:

- Real-time fuel tracking
- Early warning for low fuel
- Data logging for consumption patterns

The sensor output is fed into the Raspberry Pi for real-time processing and display, as well as predictive analysis to estimate how long the fuel will last based on current consumption.

Pressure Sensor

The **pressure sensor** is used to detect changes in tire pressure, which is crucial for vehicle stability and fuel efficiency. A drop in pressure may indicate:

- Puncture or leakage, Over or under-inflation
- Imbalance in the vehicle

Sensor data is analysed by the Raspberry Pi to:

- Alert the user in real-time
- Predict the probability of failure
- Maintain optimum tire performance

The sensor improves both safety and maintenance scheduling through predictive analytics.

Tyre Level Sensor

The **tyre level sensor**, implemented using **LIDAR** (Light Detection and Ranging) technology, measures the height of the tire surface and detects wear or deformation. It performs tasks such as:

- Monitoring tyre wear trends
- Detecting uneven wear due to alignment issues
- Supporting pre-emptive tire replacement planning

This data ensures roadworthiness and improves overall vehicle safety.

Raspberry Pi Controller

The **Raspberry Pi Zero** serves as the heart of the system. It is responsible for:

- Reading sensor data from GPIO pins
- Processing and analyzing sensor input using Python algorithms
- Implementing threshold checks and prediction logic
- Controlling actuators like the light driver and motor driver
- Displaying information on the LCD
- Communicating with an IoT mobile application via Wi-Fi (optional)

The use of the Raspberry Pi adds flexibility and scalability. Python programs process real-time data to generate alerts, display diagnostics, and make control decisions autonomously.

LCD Display

The **LCD module** serves as the user interface on the vehicle. It displays:

- Real-time sensor values, Warnings or alerts, Predictive messages like "Fuel Low – Refill in 30 km" or "Tyre Worn – Replace Soon"

This helps drivers make informed decisions and take timely action.

Vehicle Motor Driver (L298) and Motors

The **motor driver** is used to control two DC motors that simulate the vehicle's movement. The L298 module:

- Receives direction and speed signals from Raspberry Pi
- Drives the motors accordingly
- Helps simulate turning and movement during testing

This motor simulation is essential for understanding the impact of control logic, especially in autonomous or semi-autonomous applications.

Light Position Driver

This driver module receives control signals from the Raspberry Pi to adjust the **headlight direction**. Based on the motor direction or turning motion, the system:

- Dynamically turns the headlight in the direction of movement
- Enhances visibility at turns and corners
- Increases nighttime or low-light driving safety

It is a smart enhancement feature mimicking advanced vehicle lighting systems in modern vehicles.

Light System

The light system consists of LEDs or mini-headlamps mounted on a movable base controlled by the light position driver. It demonstrates:

- Real-time responsiveness to vehicle movement
- Improved illumination angles
- Enhanced road visibility

This component ensures that the concept of dynamic lighting is practically implemented.

System Flow Summary

The system works in the following sequential flow:

1. **Battery** powers up the Raspberry Pi and all peripherals.
2. **Sensors** send data to the Raspberry Pi.
3. **Raspberry Pi**:
    - Processes the data using Python.
    - Performs predictive checks.
    - Triggers actions or alerts.
4. Output is shown on the **LCD** for the driver's information.
5. Based on logic, the **motor driver** may control the vehicle simulation.
6. **The light position driver** adjusts the direction of lighting based on motion.
7. The system ensures predictive maintenance, safety alerts, and automation.

SIMULATION OF THE CIRCUIT:

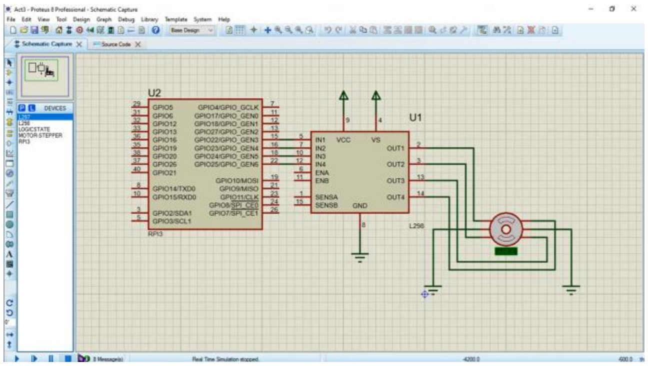

Fig 2. Machine control i.e., motors driving simulation

VI. CONCLUSION

This project successfully demonstrates a smart vehicle monitoring system using Raspberry Pi, integrating real-time data from multiple sensors to ensure predictive maintenance and enhanced safety. The system provides timely alerts for fuel levels, tire pressure, and wear, while also controlling vehicle simulation and adaptive lighting. This compact, cost-effective solution highlights the potential of IoT and embedded systems in modern transportation, making vehicles more intelligent, efficient, and reliable for everyday use and future innovations.

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