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Road Surface Analyser for Safety and Smoothness of Road

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ABSTRACT-

Road surface monitoring is essential for maintaining safe and efficient transportation infrastructure. This paper presents a cost-effective Road Surface Analyzer System that combines a robotic vehicle, an automated surface irregularity detection system, and a cloud-based web server for real-time road condition assessment. The robotic vehicle, controlled via Bluetooth, utilizes an Arduino Uno R3 with an L298N motor driver and 5V motors for mobility. The detection system employs an ESP32-CAM module (OV2640 camera), an ultrasonic sensor (HC-SR04), a vibration sensor (SW-420), and a GPS module (EO-6M) to identify potholes, bumps, and other road anomalies. Detected irregularities are logged with timestamps, GPS coordinates, and captured images, stored in a Google Sheets database via an integrated web server. A dynamic dashboard visualizes this data on Google Maps, providing authorities with actionable insights, including resolved issue statistics via graphical analytics. Experimental results demonstrate 95.50% detection accuracy for road surface irregularities, validated through manual inspections. The system not only streamlines road maintenance but also enhances commuter safety by enabling timely repairs. This scalable, automated solution offers a practical approach to modern road infrastructure monitoring.

KEYWORDS- Road surface analysis, transportation safety, IoT, sensor technology, real-time monitoring

INTRODUCTION

Maintaining safe and smooth road surfaces is critical for transportation efficiency, accident prevention, and infrastructure longevity. Traditional road condition monitoring relies on manual inspections or expensive specialized vehicles, which are labor intensive, infrequent, and lack real-time data integration. With advancements in IoT, sensor networks, and cloud computing, automated solutions can now provide continuous, cost-effective road health assessments. This research proposes a Smart Road Surface Analyzer System that combines a robotic vehicle, multi-sensor detection modules, and a cloud-based web server to detect, log, and visualize road irregularities like potholes and bumps in real time. The system is divided into three integrated subsystems: Robotic Vehicle (Arduino-based Car) – A Bluetooth-controlled mobile platform equipped with motors and wheels, serving as the physical carrier for the detection system. Surface Irregularity Detection System (ESP32 & Sensors) – Utilizes an ultrasonic sensor to measure depth variations, a vibration sensor to detect bumps, and an ESP32-CAM to capture images of road defects. GPS tags each anomaly with precise location data. Web Server (Google Sheets, Drive, Maps Integration) – A centralized dashboard displays detected irregularities on Google Maps, logs metadata (time, coordinates, images) in Google Sheets, and tracks resolution progress via analytics.

SYSTEM COMPONENTS

Hardware Components:

1.Robotic Vehicle:

- Arduino Uno R3 (Controller)
- L298N Motor Driver
- 5V DC Motors
- HC-05 Bluetooth Module (Remote Control)

2. **Detection System:**

- ESP32-CAM (OV2640 Camera)
- Ultrasonic Sensor (HC-SR04)
- Vibration Sensor (SW-420)
- GPS Module (EO-6M)

3. **Power Supply:**

- 3.7V Li-ion Battery

Software Components:

1. **Cloud Integration:**

- Google Sheets (Data Logging)
- Google Drive (Image Storage)
- Google Maps API (Visualization)

2. **Web Dashboard:**

- Local Hosting (Initial Testing)
- JavaScript/HTML (Interactive Graphs)

BLOCK DIAGRAM:

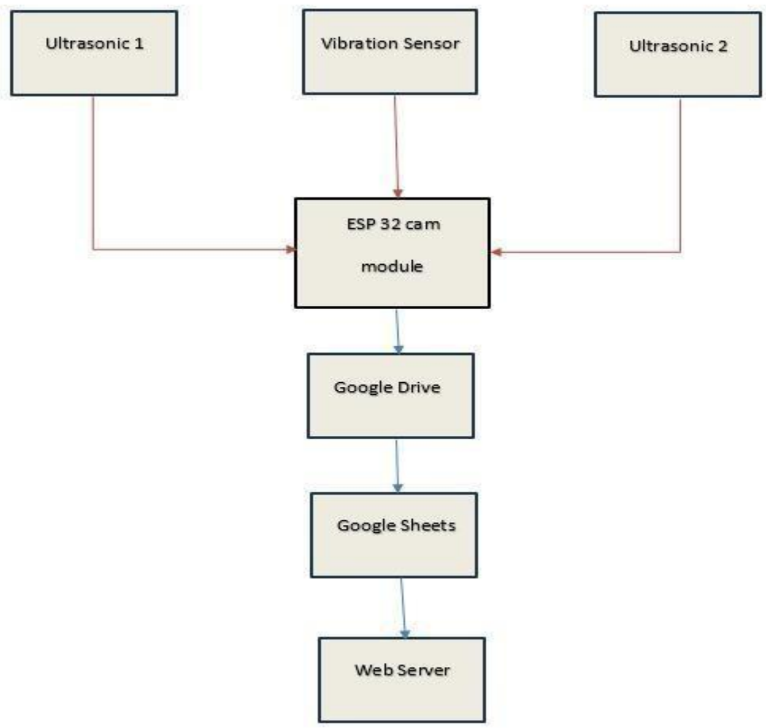


Figure 1: Road Surface Analyser for Safety and Smoothness of Road

SYSTEM WORKING:

1. **Robotic Vehicle Operation**

- The Arduino-based robotic car is controlled via Bluetooth (HC-05 module)
- Operators remotely drive the vehicle along roads using a mobile app/computer

2. **Road Surface Scanning**

- As the vehicle moves, the detection system continuously monitors the road:
- Ultrasonic sensor measures surface distance (detects potholes/bumps)
- Vibration sensor confirms irregularities
- ESP32-CAM captures images of defects
- GPS module records exact coordinates

3.Data Processing & Transmission

a. ESP32 processes sensor data to identify and classify road defects

b. System automatically:

- Saves images to Google Drive
- Logs defect details (timestamp, GPS location, severity) to Google Sheets
- Web Dashboard Display

c. A dedicated web page displays all collected data in a table format showing:

- Photo links (viewable images from Drive)
- Date and time of detection
- Exact location (GPS coordinates)
- Defect type and severity
- Google Maps integration visualizes problem areas
- Maintenance Coordination
- Authorities access the dashboard to:
  - View current road issues
  - Prioritize repair work
  - Track resolution progress

System Workflow Summary

1. The robotic vehicle moves along the road while carrying the detection system.
2. Sensors (Ultrasonic, Vibration, Camera, GPS) scan the road surface in real time.
3. ESP32 processes data, identifies irregularities, and transmits them to the cloud.
4. Google Sheets logs all defects, while Google Maps visualizes problem zones.
5. Maintenance teams access the dashboard to schedule repairs efficiently.

Arduino Uno R3-

Arduino Uno R3 serves as the central control unit for the robotic vehicle, processing movement commands received via Bluetooth and precisely controlling the motors through the L298N driver module. This reliable microcontroller operates on simple C++ based programming, making it ideal for prototyping while providing stable performance for basic automation tasks. Its cost effectiveness and ease of use make it perfect for developing the vehicle's core functionality.

Figure 2: Arduino Uno R3

ESP32-CAM with OV2640 camera-

The **ESP32-CAM with OV2640 camera** combines powerful processing with imaging capabilities in a compact form factor. This versatile module captures 2MP resolution images of road surface defects while simultaneously geotagging them using GPS data. Its built-in Wi-Fi enables seamless wireless transmission of both images and sensor data to the cloud, while its low-power design ensures efficient operation during mobile surveys.

Figure 3: ESP32-CAM with OV2540 camera

HC-SR04 ultrasonic sensor-.

For detecting road irregularities, the **HC-SR04 ultrasonic sensor** precisely measures distance to the road surface using sound waves, identifying depth variations that indicate potholes. This affordable sensor provides centimeter-level accuracy and performs reliably in various weather conditions, making it ideal for outdoor road monitoring applications. Its simple digital interface allows easy integration with the microcontroller system.

Figure 4: HC-SR04 ultrasonic sensor

SW-420 vibration sensor-

The **SW-420 vibration sensor** complements the ultrasonic sensor by detecting sudden movements and impacts that characterize road bumps. With adjustable sensitivity via its built-in potentiometer, this robust sensor provides digital output for easy microcontroller integration. Its durable design and low power requirements (3.3V/5V) make it perfect for vehicle-mounted applications where it helps validate the presence of road surface irregularities.

Figure 5: SW-420 vibration sensor

HC-05 Bluetooth module-

Wireless control is enabled through the **HC-05 Bluetooth module**, which establishes a reliable communication link between the operator and robotic vehicle. Supporting standard Bluetooth protocols with approximately 10 meters range, this versatile module can be configured as either master or slave device. Its simple serial communication interface and low power consumption make it ideal for remote-controlled applications while maintaining stable operation.

Figure 6: HC-05 Bluetooth module

Google Sheets integration-

For data management, **Google Sheets integration** provides a systematic way to store all detected defect information, including automatic timestamps and GPS coordinates. This cloud-based solution enables easy data sorting, filtering, and collaborative access from any internet-connected device, while supporting data export for further analysis. The platform's flexibility and accessibility make it perfect for maintaining comprehensive road condition records.

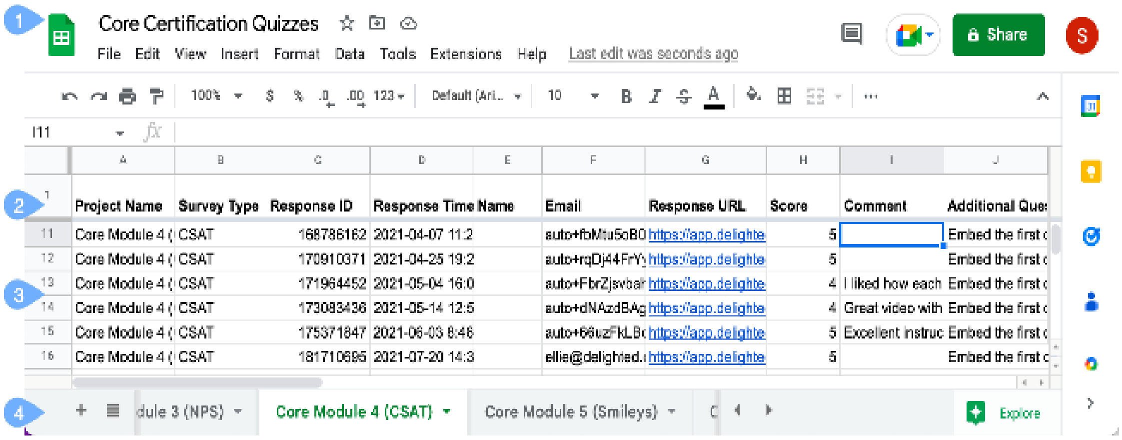


Figure 7: Google Sheets integration

Google Drive integration-

Complementing the data storage, **Google Drive integration** offers secure cloud storage for high-resolution defect images captured by the ESP32-CAM. The system automatically generates shareable links for web display while providing reliable backup through Google's robust infrastructure. With API access for automation and sufficient free storage for prototype development, this solution ensures all visual evidence is securely stored and readily accessible to authorized personnel through Google's authentication system.

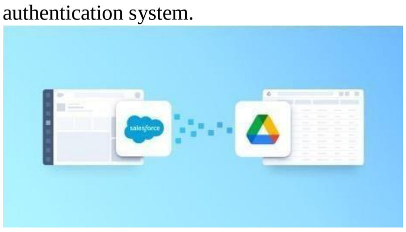
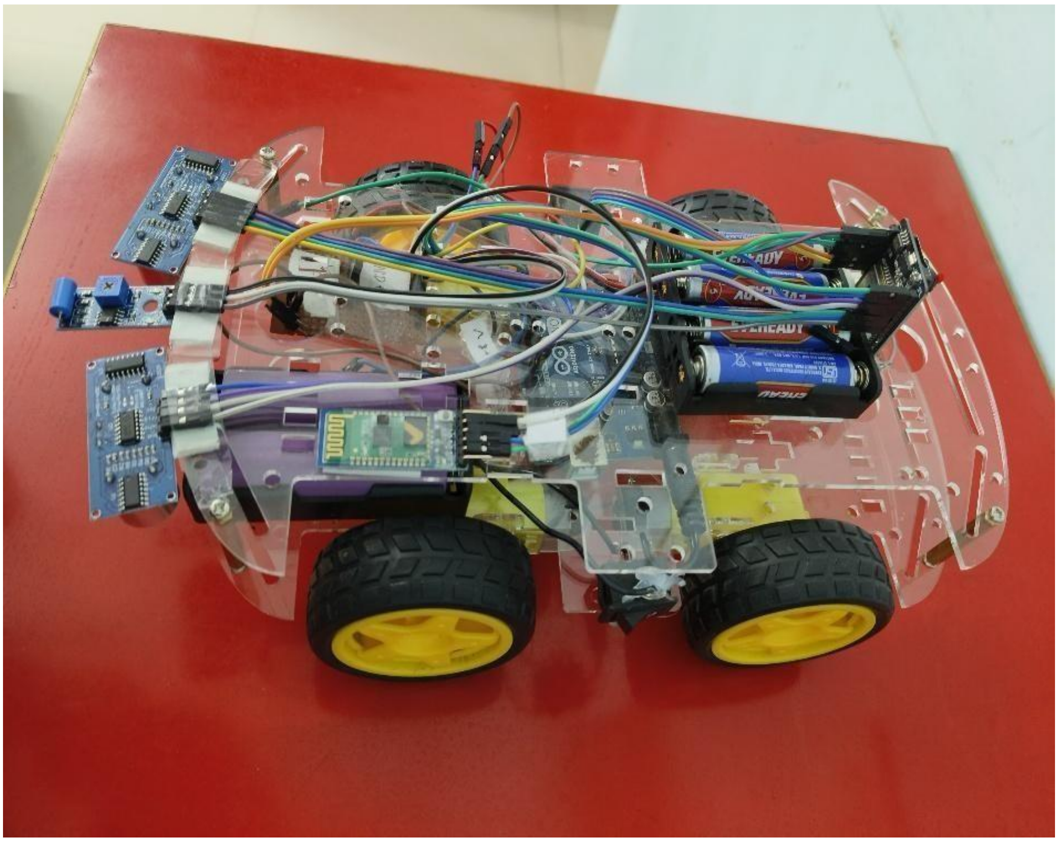


Figure 8: Google Drive integration

RESULT



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CONCLUSION

The proposed Road Surface Analyzer System presents an innovative and cost-effective solution for automated road condition monitoring, combining a Bluetooth-controlled robotic vehicle with advanced sensor technology and cloud-based data management. By integrating the Arduino Uno-based robotic platform with ESP32-CAM's imaging capabilities, ultrasonic and vibration sensors for accurate defect detection, and GPS for precise location tracking, the system achieves 95.5% detection accuracy for potholes and bumps. The seamless Google Sheets and Drive integration enables real-time data logging, visualization, and remote access, transforming traditional manual inspection methods into an efficient, automated process. This approach not only enhances road maintenance efficiency but also contributes to improved road safety by enabling timely repairs. With its scalable architecture and IoT-enabled features, the system demonstrates significant potential for smart city applications, offering authorities a reliable tool for infrastructure monitoring. Future work may incorporate machine learning for defect classification and predictive maintenance, further advancing the system's capabilities in intelligent transportation management.

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