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# Road Quality Analysis using Smartphone Sensors

Pradnya V. Sawant<sup>1</sup>

Department of Physics, Sant Rawool Mahavidyalaya Kudal, Sindhudurg, Maharashtra, India<sup>1</sup>

**ABSTRACT:** Smartphone-based sensing offers a low-cost, scalable approach to road condition monitoring. This study presents an experimental system that uses a standard smartphone's accelerometer, gyroscope, and GPS sensors to detect road anomalies (such as potholes) during normal driving. We collected synchronized motion (3-axis acceleration and angular velocity) and location data using the Phyphox app and a GPS logging app while driving a vehicle over urban roads. Data were exported to CSV files and analyzed in Python (using NumPy/Pandas) to identify peaks in the vertical (Z-axis) acceleration and sudden orientation changes, which indicate anomalies. Detected events were matched to GPS coordinates to locate the faults. For example, abrupt acceleration spikes (well above the baseline road vibration) were found at latitudes 16.331778, 73.688124 and 16.337623, 73.674230, among others. These findings demonstrate that common smartphone sensors can effectively flag pothole events and map them geospatially.

**KEYWORDS:** Road quality, Smartphone sensors, Accelerometer, Gyroscope, GPS, Pothole detection

## I. INTRODUCTION

Road surface degradation, such as potholes and cracks, increases accident risk, vehicle damage, and maintenance costs while reducing traffic efficiency. Continuous and accurate road condition monitoring is therefore essential for improving safety and enabling effective infrastructure management [1]. Traditional road monitoring relies on manual inspections or specialized vehicles with laser and sensor systems. Although accurate, these methods are costly, labor-intensive, and infrequent, limiting large-scale and real-time assessment. Hence, there is a need for low-cost and scalable monitoring solutions [2]. Smartphones equipped with accelerometers, gyroscopes, and GPS can act as vehicle-mounted sensors to detect road roughness. Their widespread use enables crowdsourced road condition monitoring during normal driving. [1,3]. Smartphone-based road anomaly detection uses acceleration spikes and gyroscope variations to identify potholes. While simple threshold methods are effective, machine learning models such as Random Forest have achieved high detection accuracy, with Wu *et al.* reporting 88.5% precision and 75% recall[4]. Smartphone-based road monitoring systems use embedded accelerometers and GPS modules to detect pavement irregularities and geotag anomaly locations. Basavaraju *et al.* demonstrated that vibration data from smartphone sensors can effectively differentiate between normal and damaged road segments[5]. Chelvaratnam *et al.* further emphasized the importance of GPS integration for accurate spatial mapping[6]. Some methodologies include traditional in situ measurements, which are often costly and time-consuming, and newer approaches utilizing smartphone sensors for real-time data collection to enhance efficiency and reduce costs [7].

Unexpected potholes and poorly constructed road surfaces significantly increase accident risks and vehicle damage. Sudden road irregularities can cause loss of control, especially at higher speeds, compromising passenger safety and ride comfort. The absence of a systematic and continuous road quality monitoring method further worsens the problem. Without reliable real-time assessment, authorities often fail to identify deteriorating sections at an early stage. This delays preventive maintenance measures, leading to severe pavement degradation, higher repair costs, and increased safety hazards. This project uses vehicle-mounted smartphone sensors—accelerometer, gyroscope, and GPS for real-time road condition detection. Vibration and motion data collected during travel help identify and locate potholes and surface irregularities efficiently. Smartphone-based sensing provides a low-cost and scalable alternative to traditional road inspection methods. Real-time sensor data combined with GPS enables accurate detection and mapping of road anomalies. The collected geotagged information helps authorities prioritize maintenance, optimize resource allocation, and support smart city infrastructure monitoring.

## II. EXPERIMENTAL METHODOLOGY

The experimental methodology was designed to evaluate the effectiveness of vehicle-mounted smartphone sensors for real-time road anomaly detection and geospatial mapping. The system integrates accelerometer, gyroscope, and GPS modules embedded within a standard smartphone to capture vehicle dynamics induced by road surface irregularities.

### 2.1 Smartphone Mounting Configuration

The surveyed road segment exhibited visible potholes and surface irregularities, as shown in Figure 1a, which were used to validate the detected anomaly locations during field experimentation. The smartphone was securely mounted on the vehicle dashboard using a stable holder to minimize unwanted motion and maintain consistent orientation as shown in Figure 1 b. The accelerometer was aligned such that its Z-axis corresponded to the vehicle's vertical axis, ensuring accurate measurement of vertical acceleration caused by potholes and surface irregularities.



Figure 1: (a) Potholes observed on the surveyed road segment (b) Smartphone mounted on the vehicle dashboard

### 2.2 Sensor Data Acquisition

The experimental data were collected through controlled field surveys conducted on selected road segments exhibiting varying surface conditions. During the experiments, the vehicle was driven at a steady speed range of 30–40 km/h to ensure consistent and reliable measurements. The triaxial accelerometer recorded linear acceleration along the X, Y, and Z axes, with primary emphasis on the Z-axis to detect vertical vibration spikes caused by potholes and uneven road surfaces. The gyroscope measured angular velocity to distinguish road-induced disturbances from driver-induced motions such as braking or steering. The GPS module continuously captured latitude, longitude, and timestamp data to enable precise geotagging of detected anomalies. Sensor data acquisition was performed using the Phypox mobile application, which allows real-time monitoring and export of high-resolution sensor measurements. All recorded data were logged continuously and exported in CSV format for subsequent pre-processing, signal filtering, and analytical evaluation.

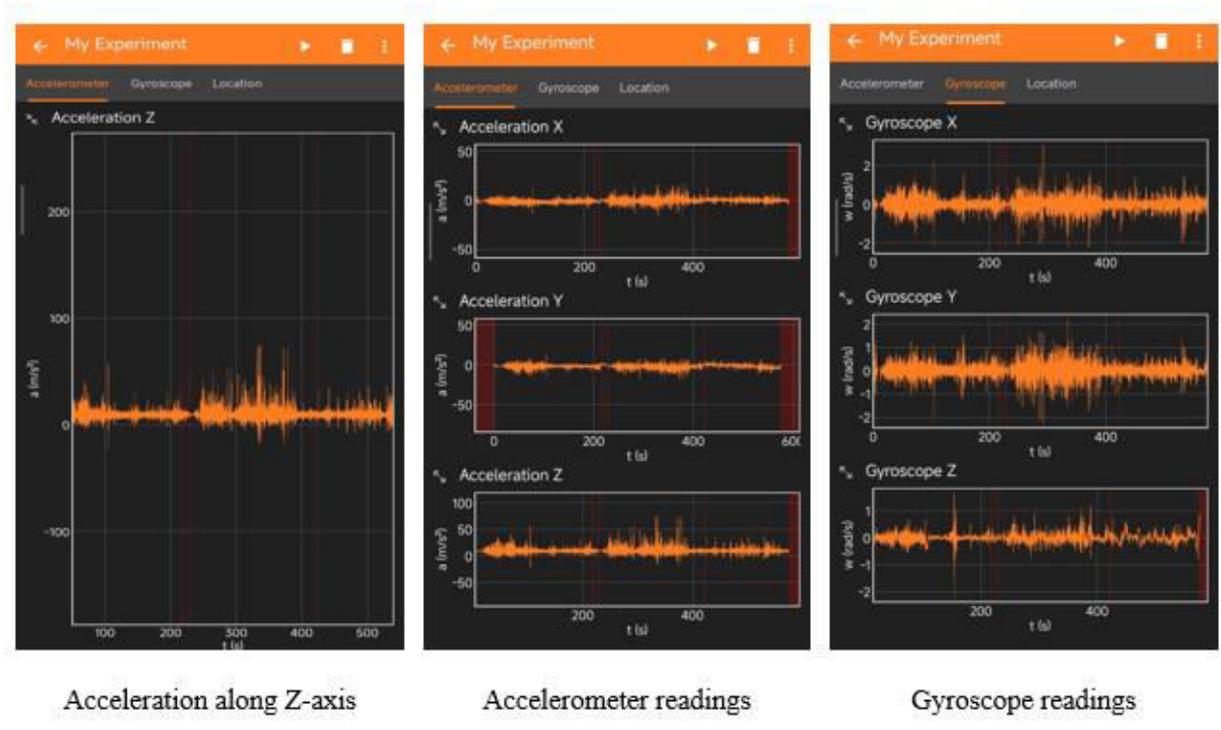


Figure 2: Phyfox application interface showing real-time accelerometer data.

### 2.3 Signal Pre-processing and Anomaly Detection

Raw sensor signals were preprocessed using a moving average filter to reduce noise from engine vibrations and environmental disturbances. For each detected acceleration spike, the corresponding GPS coordinate was extracted. These geotagged anomaly points were plotted on a digital map to identify specific road locations exhibiting surface defects. Spatial clustering analysis was performed to determine high-density damage zones requiring maintenance prioritization. Timestamp synchronization between acceleration and GPS data ensured accurate mapping. Anomalies were detected when the absolute Z-axis acceleration exceeded  $\pm 2 \text{ m/s}^2$ , with gyroscope data used to reduce false detections from steering or braking. The identified anomaly locations were geotagged at (16.331778, 73.688124), (16.330787, 73.707523), (16.331782, 73.688901), and (16.337623, 73.674230), corresponding to visibly damaged road segments as shown in Figure 3.

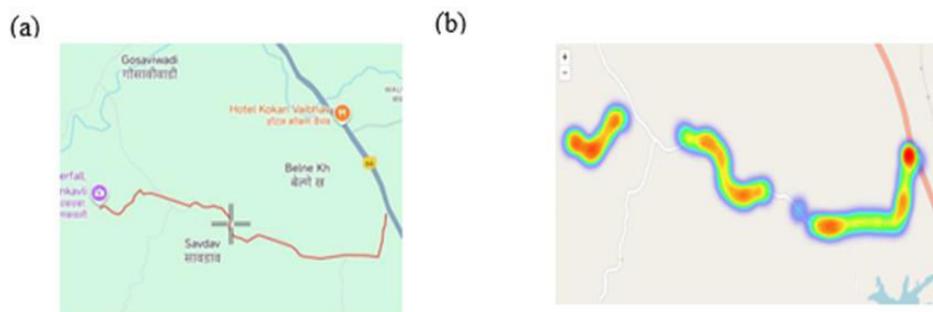


Figure 3: (a) Path of Survey (b) Anomaly density map created by collected data

### III. DISCUSSION

The proposed system offers several significant advantages. It is low-cost and highly accessible, as it utilizes existing smartphones instead of expensive and specialized road inspection equipment. The approach is portable and easy to deploy, requiring no additional hardware beyond a securely mounted mobile device inside a vehicle. By enabling real-time and crowdsourced data collection, the system provides immediate feedback on road conditions with wide user participation, improving coverage and reliability. The integration of multiple sensors—accelerometer, gyroscope, and GPS—ensures accurate detection and precise geolocation of anomalies. Furthermore, the system is flexible and adaptable, functioning effectively across different vehicles and varying road environments. Its scalability and data-driven framework make it well-suited for smart city applications, supporting intelligent and efficient infrastructure monitoring.

### IV. FUTURE SCOPE

The future scope of this work lies in integrating Artificial Intelligence (AI) for predictive maintenance and full system automation. By applying machine learning algorithms to large-scale vibration datasets, it becomes possible to predict pavement deterioration trends and identify high-risk zones before severe damage occurs. The incorporation of real-time data processing will enable instant anomaly detection and live reporting, enhancing responsiveness. Crowdsourcing road condition data from multiple users can significantly improve spatial coverage and detection reliability, forming a distributed sensing network. Developing a dedicated mobile application can connect users, vehicles, and cloud servers into an intelligent monitoring ecosystem. Furthermore, collaboration with government road management systems would allow seamless data sharing, automated maintenance scheduling, and data-driven infrastructure planning, supporting smart city initiatives and efficient public resource utilization.

### V. CONCLUSION

This comprehensive experimental study demonstrates that vehicle-mounted smartphone sensors provide a reliable and economical solution for road quality analysis. Accelerometer-based vibration detection combined with GPS mapping enables accurate identification of potholes and surface irregularities. The system reduces inspection costs, minimizes manpower requirements, and supports intelligent infrastructure management. With integration into smart city platforms and AI-based predictive maintenance systems, smartphone sensing can revolutionize road condition monitoring.

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