IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940



International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 11, November 2026

DOI: 10.17148/IJARCCE.2026.1511175

Multi-Model Edge-AI System for Real-Time Road Health Diagnostics using Vision-Acoustic Sensor Fusion

Supriya V[1], Rishika S[2], Niharika K[2], Rishi H[2], Thanuja K B[2]

Assistant Professor, Department of Electronics and Communication Engineering, K S School of Engineering and Management, Bengaluru, India[1]

Students, Department of Electronics and Communication Engineering, K S School of Engineering and Management, Bengaluru, India[2]

Abstract: Road damage, particularly potholes, poses significant challenges to transportation safety and road maintenance. Conventional road inspection methods rely heavily on manual surveys, which are time-consuming and may not provide continuous monitoring. This paper presents a multi-modal Edge AI system for real-time pothole detection and road health monitoring using computer vision, accelerometer sensing, and GPS-based location tracking. The proposed system uses a Raspberry Pi 4 Model B as the central processing unit, integrated with a USB camera, MPU6050 accelerometer, and NEO-6M GPS module. OpenCV is employed for image acquisition and frame processing, while a trained YOLOv8 model identifies potholes from captured road images. Accelerometer readings provide supporting information about vehicle motion, and GPS coordinates are associated with detected pothole events. The collected images and detection records are stored locally and displayed through a web-based dashboard containing a map, photo log, and data table. The system performs processing at the edge, reducing reliance on continuous cloud communication. The proposed implementation provides a compact and practical approach to automated road damage identification, location-based reporting, and road condition monitoring.

Keywords: Edge AI, YOLOv8, OpenCV, Raspberry Pi 4, Pothole Detection, MPU6050, GPS, Sensor Fusion, Road Health Monitoring.

I. INTRODUCTION

Road infrastructure plays an important role in transportation, economic development, and public safety. However, road surfaces gradually deteriorate due to traffic loads, environmental conditions, water infiltration, and inadequate maintenance. Potholes are among the common forms of road damage and can lead to vehicle instability, accidents, increased maintenance costs, and discomfort for road users. Identifying these defects at an early stage is important for improving road safety and supporting timely maintenance activities.

Conventional road inspection generally involves manual observation and periodic surveys. Although these methods can identify damaged road sections, they require considerable time and labour and may not provide continuous updates about changing road conditions. Recent developments in computer vision, machine learning, embedded computing, and sensor technology have enabled automated road damage monitoring using cameras and vehicle-mounted sensing systems.

The proposed work develops a compact road health monitoring system that combines YOLOv8-based pothole detection, OpenCV image processing, accelerometer sensing, GPS location tracking, and Raspberry Pi-based edge processing. The system captures road images during vehicle movement, identifies potholes, associates detections with available location and sensor information, and presents the collected records through a web dashboard.

II. LITERATURE SURVEY

[1]Edge-Cloud Collaborative Pothole Detection via Federated Temporal Segmentation (2026)

This study explores a collaborative approach to pothole detection using edge computing and cloud-based processing. The method focuses on processing road-related data across distributed computing environments to improve detection and monitoring efficiency. Temporal segmentation is used to analyse road information across different time intervals. The

 This work is licensed under a Creative Commons Attribution 4.0 International License

DOI: 10.17148/IJARCCE.2026.1511175

federated approach supports collaborative learning while reducing the need to centralize raw data. This research highlights the potential of combining edge intelligence and cloud resources for scalable road monitoring.

[2]**Multi-Sensor Pothole Detection and Monitoring System (2025)**

This research presents a pothole monitoring approach based on the integration of multiple sensing technologies. The use of different sensors helps collect complementary information about road surface irregularities during vehicle movement. Sensor-based monitoring provides an alternative to conventional manual road inspection and enables continuous data collection. The study emphasizes the importance of combining sensor observations to improve road condition assessment. It provides a foundation for developing integrated road monitoring systems.

[3]**Deep Road Guard: Enhanced Pothole Detection Using Bayesian Fusion and Night-Vision Data (2025)**

The proposed Deep Road Guard system focuses on improving pothole detection under challenging environmental and lighting conditions. It incorporates Bayesian fusion techniques to combine relevant detection information and support more reliable identification of road defects. The use of night-vision data addresses difficulties associated with low-light road monitoring. This approach highlights the importance of improving detection reliability beyond normal daylight conditions. The study is relevant to developing road monitoring systems that operate under varying environmental conditions.

[4]**YOLOv8 and Point Cloud Fusion for Enhanced Road Pothole Detection and Quantification (2025)**

This study combines YOLOv8-based object detection with point cloud information to improve pothole identification and assessment. The visual detection model identifies pothole regions, while point cloud data provide additional information about the road surface geometry. Integrating these two modalities helps overcome some limitations of image-only detection, particularly when estimating pothole characteristics. The research demonstrates the potential of combining deep learning and spatial sensing for road damage analysis. It highlights the benefits of multimodal perception in intelligent transportation applications.

[5]**Edge Intelligence-Based Road Damage Detection Using Lightweight Deep Learning Models (2024)**

This study investigates lightweight deep learning models for road damage detection on edge computing platforms. The primary focus is on reducing computational complexity while maintaining useful detection performance. Lightweight architectures are suitable for embedded devices with limited processing power and memory resources. Edge-based inference also helps reduce dependence on continuous cloud connectivity. This approach is relevant to implementing real-time road damage detection on compact computing platforms such as the Raspberry Pi.

[6]**IoT and Cloud-Based Automated Pothole Detection Model Using Extreme Gradient Boosting (2023)**

The research presents an automated pothole detection system that combines IoT technologies with cloud-based processing. Extreme Gradient Boosting is employed as a machine learning technique for analysing collected data and identifying road abnormalities. IoT integration enables sensor information to be collected and communicated for further processing and monitoring. The cloud platform supports centralized data storage and analysis. This study demonstrates the role of connected systems in automating road condition monitoring.

[7]**Sustainable Road Pothole Detection: A Crowdsourcing-Based Multi-Sensors Fusion Approach (2023)**

This work proposes a crowdsourcing-based framework for identifying potholes using information collected from multiple sensors and road users. Crowdsourcing enables road condition data to be gathered from different vehicles travelling across various locations. Multi-sensor fusion helps combine observations to improve the understanding of road surface conditions. The approach supports wider road coverage without depending entirely on dedicated inspection vehicles. It presents an efficient direction for scalable and community-supported road monitoring.

[8]**Real-Time Pothole Detection Using Machine Learning and Edge Computing (2023)**

This research focuses on identifying potholes using machine learning techniques combined with edge computing. The system processes collected road information locally to support faster detection and reduce communication overhead. Edge computing is particularly useful in applications where immediate processing is required and network connectivity may be limited. The study highlights the practical advantages of performing computation close to the sensing device. It supports the development of low-cost, real-time road monitoring solutions.

[9]**Road Surface 3D Reconstruction Based on Dense Subpixel Disparity Map Estimation (2022)**

This study investigates road surface reconstruction using dense disparity maps obtained through image-based depth estimation techniques. Subpixel disparity estimation improves the precision of depth information by estimating differences at finer levels than whole-pixel measurements. The reconstructed road surface can provide information about

 This work is licensed under a Creative Commons Attribution 4.0 International License

DOI: 10.17148/IJARCCE.2026.1511175

surface geometry and irregularities. Such techniques are useful for analysing road damage beyond its appearance in two-dimensional images. The study demonstrates the potential of depth-based vision techniques for road surface assessment.

[10] **Enhanced Pothole Detection System Using YOLOX Algorithm (2022)**

This research employs the YOLOX object detection framework for automated pothole identification from road images. The model is designed to detect pothole regions efficiently while supporting object localization in image frames. Deep learning-based detection reduces the dependence on manually defined image-processing features. The use of an advanced object detection architecture supports faster analysis of road conditions. This work demonstrates the applicability of modern YOLO-based models to automated road damage detection.

[11] **Multi-Modal Sensor Fusion for Auto Driving Perception: A Survey (2022)**

This survey examines different multimodal sensor fusion techniques used in autonomous driving and vehicle perception systems. It discusses the integration of sensing technologies such as cameras, LiDAR, radar, and other sensors to improve environmental understanding. The study explains how individual sensor limitations can be addressed through complementary information. Different fusion strategies and their applications in perception are also explored. This survey provides a theoretical foundation for developing vision and sensor-based road monitoring systems.

[12] **Computer Vision for Road Imaging and Pothole Detection: A State-of-the-Art Review of Systems and Algorithms (2022)**

This review provides an overview of computer vision methods used for road imaging, pavement inspection, and pothole detection. It discusses image acquisition techniques, image-processing methods, machine learning approaches, and deep learning-based detection systems. The study highlights the evolution of road damage identification from conventional image analysis to advanced neural network models. It also discusses challenges associated with environmental conditions and image quality. The review serves as a useful reference for selecting suitable techniques for automated road inspection.

[13] **Real-Time Pothole Detection Using YOLOv5 (2022)**

This research uses the YOLOv5 object detection model to identify potholes from road images in real time. The model detects pothole regions and provides their locations using bounding boxes. YOLO-based detection enables image analysis within a single inference pipeline, making it suitable for time-sensitive applications. The study demonstrates the use of deep learning for automated road defect identification. It also provides a basis for further improvements using newer YOLO architectures.

[14] **Multi-Scale Feature Fusion for Road Pothole Detection (2021)**

This study focuses on improving pothole detection by combining visual features obtained at multiple scales. Multi-scale feature fusion helps the detection model identify potholes with varying sizes, shapes, and appearances. Small potholes and irregular road defects can be difficult to identify when features are extracted at a single scale. Combining different feature representations can improve the model's ability to recognize road damage. The research highlights the importance of feature extraction and fusion in vision-based detection systems.

[15] **Smart Pothole Detection Using Deep Learning Based on Dilated Convolution (2021)**

This work introduces deep learning-based pothole detection using dilated convolution operations. Dilated convolution expands the receptive field of a neural network without significantly increasing the number of parameters. This enables the model to capture wider spatial information and contextual details from road images. The technique can improve the representation of pothole regions with varying shapes and sizes. The study explores the potential of advanced convolution techniques for enhancing road damage detection.

[16] **Pothole Detection Using Computer Vision and Learning (2020)**

This research examines the use of computer vision and machine learning techniques for identifying potholes in road images. It discusses the process of extracting visual information and applying learning-based methods to distinguish damaged road surfaces from normal pavement. The study highlights the challenges involved in detecting potholes with different shapes, textures, and appearances. Learning-based approaches offer improved adaptability compared with fixed image-processing rules. This work contributes to the development of automated road inspection systems using visual data.

[17] **Asphalt Pavement Pothole Detection Using Deep Learning Method Based on YOLO Neural Network (2019)**

This study applies the YOLO neural network to detect potholes on asphalt pavement surfaces. The model performs object detection on road images and identifies damaged regions within the captured frames. Deep learning enables the system to learn pothole characteristics directly from training images rather than relying entirely on manually designed features.

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 11, November 2026

DOI: 10.17148/IJARCCE.2026.1511175

The research demonstrates the use of neural network-based object detection for pavement inspection. It supports the development of faster and more automated road damage identification methods.

[18] **Evaluation of Detection Approaches for Road Anomalies Based on Accelerometer Readings (2018)**

This study investigates the detection of road anomalies using accelerometer data collected during vehicle movement. The acceleration measurements are analysed to identify variations associated with irregular road surfaces. Sensor-based detection provides information about the physical response of the vehicle when it encounters road disturbances. However, readings may also be affected by vehicle speed, suspension characteristics, and sensor placement. The study highlights the usefulness of inertial sensors for road condition monitoring.

[19] **Road Damage Detection and Classification Using Deep Neural Networks with Smartphone Images (2018)**

This research explores the use of smartphone-captured road images and deep neural networks for identifying and classifying road damage. Images collected using mobile devices provide an accessible source of data for road inspection applications. Deep learning models are used to recognize different damage patterns and automate the classification process. The approach reduces dependence on specialized image acquisition equipment. This study demonstrates the potential of mobile vision-based technologies for large-scale road damage monitoring.

[20] **Intelligent Pothole Detection and Road Condition Assessment (2017)**

This research investigates intelligent methods for pothole identification and road condition assessment using automated data analysis techniques. It focuses on reducing the limitations of traditional manual inspection by introducing computational methods for analysing road conditions. Automated assessment can help identify damaged road sections and support maintenance planning. The study represents an early direction toward intelligent road infrastructure monitoring. Its approach provides background for the development of more advanced deep learning and sensor-integrated road inspection systems.

III. PROPOSED SYSTEM

The proposed system presents a multi-modal Edge AI approach for real-time road health monitoring and pothole detection. It combines computer vision, deep learning, accelerometer sensing, and GPS-based location tracking to identify and record damaged road surfaces. The system is designed to be installed on a two-wheeler, allowing road conditions to be monitored during regular vehicle movement.

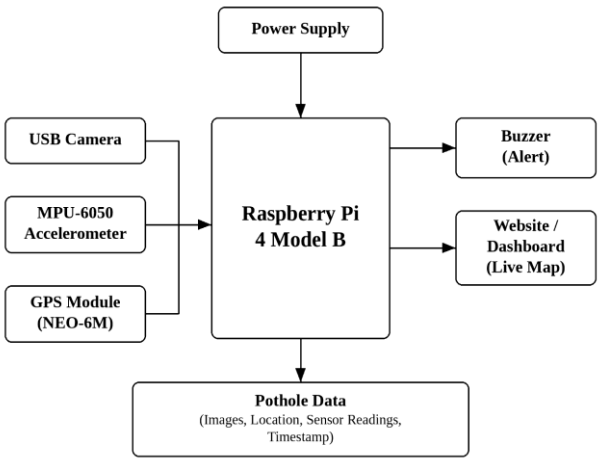


Fig. 1 Block Diagram

The USB camera, accelerometer, and GPS module act as the input devices for the system. The camera supplies road images, while the MPU6050 and NEO-6M provide motion and geographical information. The Raspberry Pi performs the central processing operations and runs the image processing and detection modules.

OpenCV handles camera frame acquisition and preparation, and YOLOv8 performs pothole detection. The detection output is combined with available sensor and location information to form an event record. The storage module saves the detection images and associated data, while the dashboard provides access to the collected records. The buzzer is activated according to the implemented detection condition.

 This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 11, November 2026

DOI: 10.17148/IJARCCE.2026.1511175

IV.METHODOLOGY

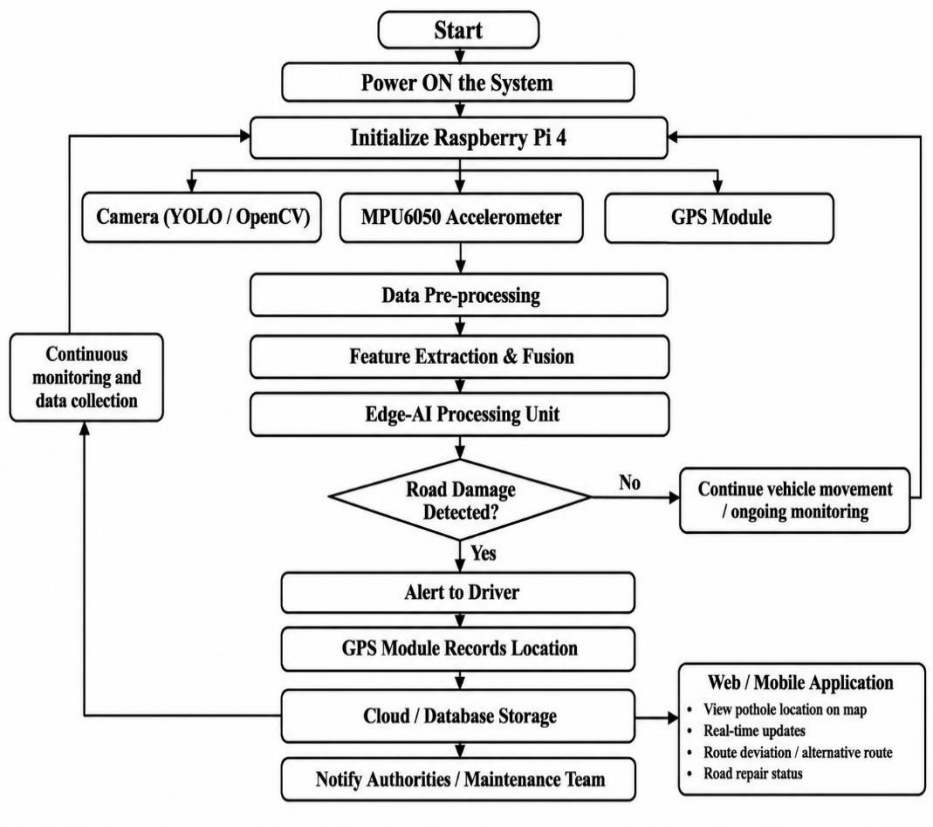


Fig.2 Flow Chart

The system follows a multi-modal approach to road health monitoring by integrating image-based pothole detection, accelerometer sensing, GPS location tracking, and edge processing. A Raspberry Pi 4 Model B acts as the central processing unit, coordinating image acquisition, sensor data collection, detection, and data storage.

1. Image Acquisition and Processing: A USB camera mounted at the front of the vehicle captures road images during movement. OpenCV is used to access the camera stream, extract video frames, and prepare the images for pothole detection. The captured frames are continuously supplied to the detection model for road surface analysis.

2. Pothole Detection Using YOLOv8: The trained YOLOv8 model analyses the captured frames to identify potholes. It generates bounding boxes around detected regions along with class labels and confidence scores. The detection output is used to identify possible road damage and initiate the recording of relevant information. The model performs inference locally on the Raspberry Pi, supporting edge-based detection without requiring continuous cloud processing.

3. Accelerometer-Based Monitoring: The MPU6050 accelerometer measures vehicle acceleration along the X, Y, and Z axes. Variations in these readings provide supporting information about vehicle movement and disturbances caused by uneven road surfaces. The sensor readings are collected during operation and can be associated with the detection timestamp to provide additional context for the identified potholes.

4. GPS-Based Location Association: The NEO-6M GPS module provides the geographical coordinates of the vehicle in terms of latitude and longitude. The Raspberry Pi reads the GPS data and associates the most recent valid coordinates with each pothole detection event. The validity of the location information is considered before recording it, preventing unavailable or outdated coordinates from being incorrectly assigned to new detections.

5. Data Logging and Web-Based Monitoring: When a pothole is detected, the system records the detection label, confidence score, timestamp, available GPS coordinates, sensor readings, and corresponding image path. The captured

 This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 11, November 2026

DOI: 10.17148/IJARCCE.2026.1511175

images and associated records are stored locally. A web-based dashboard presents the collected information through a map, photo log, and data table, allowing users to review detection images and geographical locations.

6. Alert Mechanism: A buzzer is interfaced with the Raspberry Pi to provide an audible indication when the programmed pothole detection condition is satisfied. The alert is triggered by the implemented detection logic, notifying the user of a registered event without requiring continuous visual monitoring of the dashboard.

V. IMPLEMENTATION



Fig. 3 Hardware Implementation

The proposed road health monitoring system was implemented using a Raspberry Pi 4 Model B, USB camera, MPU6050 accelerometer, NEO-6M GPS module, and buzzer. The hardware components were integrated with Python-based software to perform pothole detection, sensor data collection, location tracking, and data recording.



Fig. 4 Camera Placement

The USB camera was mounted on the front panel of the two-wheeler, facing forward towards the road surface. The camera was positioned at a suitable height and viewing angle to capture the road area in front of the vehicle, allowing it to record potholes and other visible surface irregularities during movement. Care was taken to ensure that the camera had a clear field of view without obstruction from the vehicle body or other components. The camera was securely fixed to maintain a stable position and reduce unwanted movement caused by vehicle vibrations. Proper positioning is important because excessive vibration, poor lighting, and an unsuitable camera angle can affect image quality and detection performance. The front-facing arrangement also allows the camera to continuously acquire road images without requiring manual operation by the rider. The captured video stream is accessed by the Raspberry Pi 4 Model B through OpenCV. The video is processed frame by frame, and the selected frames are passed to the trained YOLOv8 model to identify potholes. When a pothole is detected, the corresponding image is stored along with the available timestamp and GPS information. This arrangement enables continuous road image monitoring and provides visual records that can be reviewed later through the developed web dashboard.

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 11, November 2026

DOI: 10.17148/IJARCCE.2026.1511175



Fig. 5 Other Components

The Raspberry Pi 4 Model B, which acts as the central processing unit, was placed near the dashboard along with the associated electronic components. The MPU6050 accelerometer was interfaced with the Raspberry Pi to measure acceleration variations along the X, Y, and Z axes while the vehicle was in motion. The NEO-6M GPS module was installed to receive satellite signals and provide the vehicle's geographical coordinates. A buzzer was also connected to provide an audible alert when a pothole detection event was registered.

VI. RESULTS AND DISCUSSIONS

The developed system was tested to examine its ability to identify potholes from road images, collect supporting sensor information, associate geographical coordinates, and display the recorded information through a web-based dashboard. The Raspberry Pi 4 Model B processes the camera frames using the trained YOLOv8 model, while OpenCV handles image acquisition and visualization of the detection results.



Fig. 6 Camera Detected Photo

The USB camera captures images of the road surface while the vehicle is in motion. The captured frames are processed using OpenCV and analysed by the trained YOLOv8 model. When a possible pothole is identified, the model highlights the detected region using a red bounding box and displays its class label along with a confidence score.

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 11, November 2026

DOI: 10.17148/IJARCCE.2026.1511175

In one of the recorded outputs, the model identifies a damaged road patch with the label "pothole 0.33". The confidence score of 0.33 indicates relatively low confidence in this particular prediction. The detected image is saved with its corresponding timestamp, allowing the result to be reviewed later.



Fig. 7 Accelerometer Readings

The NEO-6M GPS module provides the geographical coordinates of the vehicle during operation. When a pothole detection event is registered, the latest available GPS coordinates, including latitude and longitude, are associated with the corresponding image and timestamp. These coordinates represent the approximate vehicle location at the time of detection. The recorded GPS information is used to identify the geographical position of the detected pothole on the website. This converts the camera-based detection output into a location-based record, making it easier to identify road sections where damage has been observed.

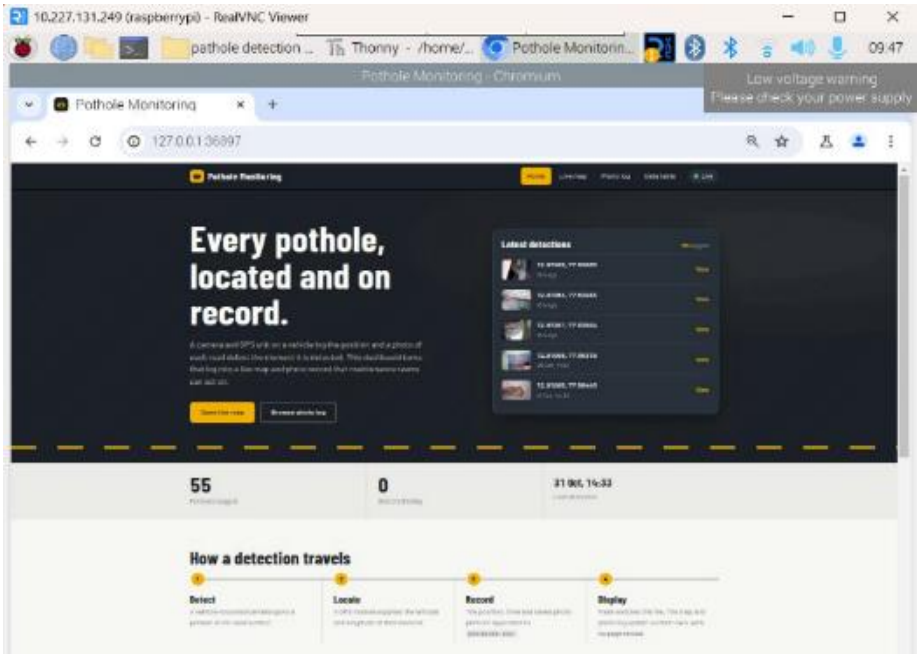


Fig. 8 Home Page

The above figure shows the home page of the developed road health monitoring website. It provides an overview of the pothole detection records collected by the system. The page displays the project heading, latest detection details, and summary information, including the total number of recorded potholes and recent detection activity. Navigation options are provided to access the live map, photo log, and data table, allowing users to move easily between different sections of the application.

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 11, November 2026

DOI: 10.17148/IJARCCE.2026.1511175

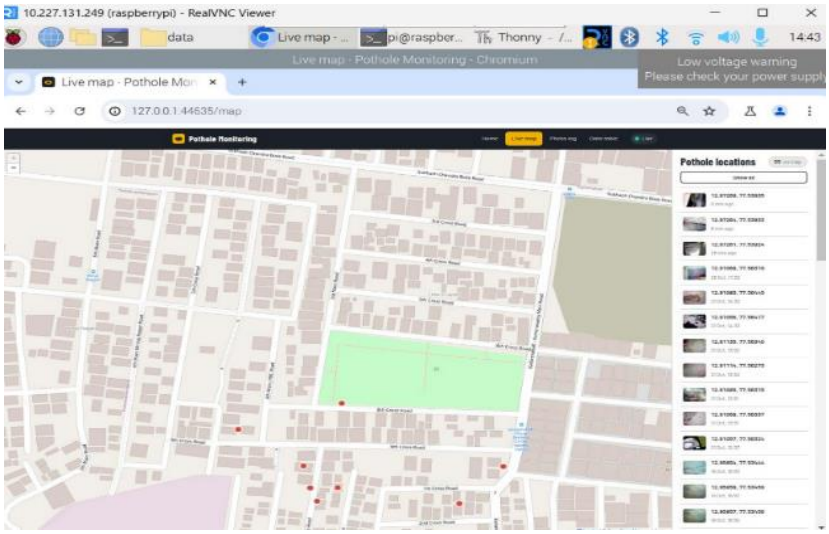


Fig. 9 Live Map

The figure 9 illustrates the live map interface, which displays the geographical locations of detected potholes using red circular markers on an OpenStreetMap background. The latitude and longitude obtained from the GPS module are used to position these markers on the map. A separate location panel provides details of individual detection records, including the corresponding image, coordinates, and detection time. This helps users identify the approximate road locations where potholes have been recorded.

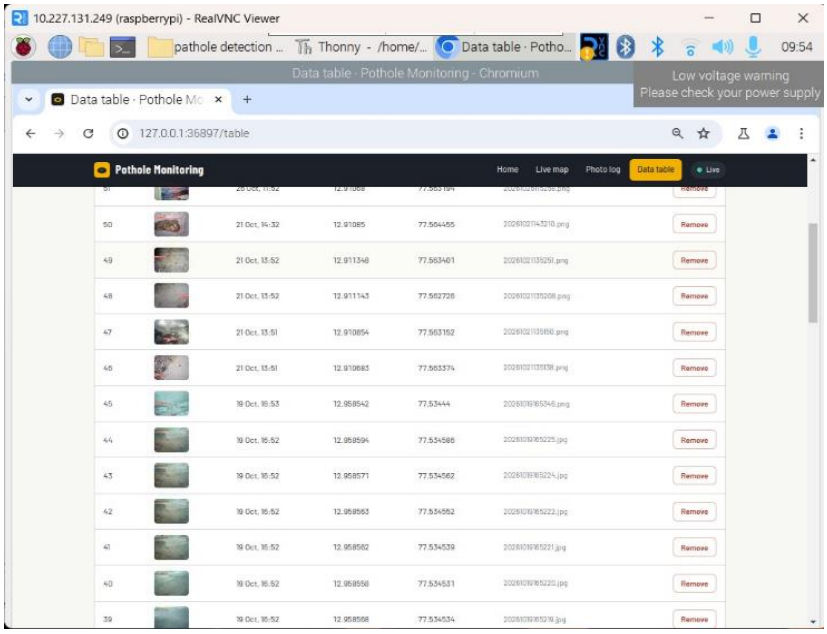


Fig. 10 Photo Log

The above fig 10 represents the photo log section of the website, where images captured during pothole detection are displayed in a gallery format. Each image is arranged as an individual card containing the visual output generated by the YOLOv8 model. The bounding boxes and class labels help users identify the detected road damage. The gallery is updated when new detection images are saved, providing a convenient way to review both recent and previously recorded pothole observations.

 This work is licensed under a Creative Commons Attribution 4.0 International License

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 11, November 2026

DOI: 10.17148/IJARCCE.2026.1511175

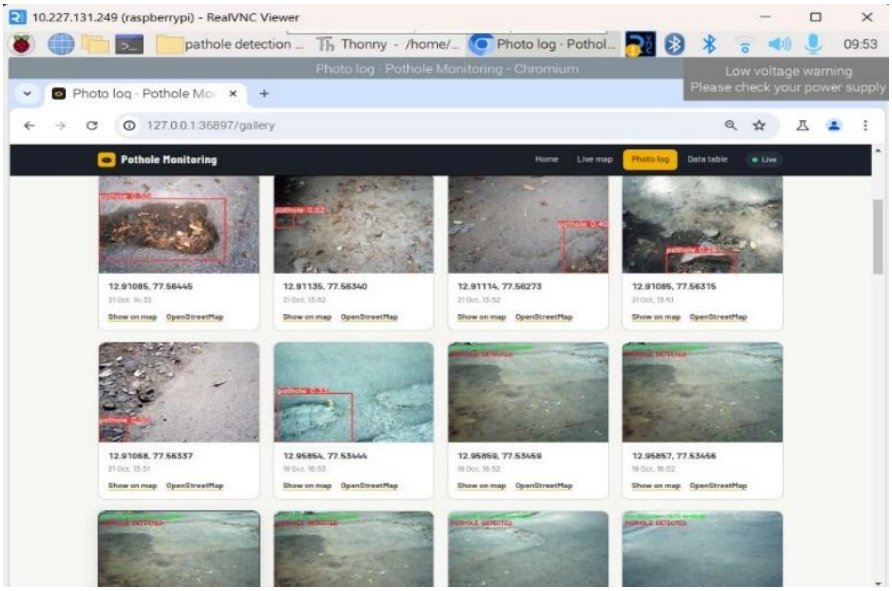


Fig. 11 Data Table

The above Fig 11 shows the data table section, which presents the collected pothole detection records in a structured format. Each row contains details such as the record number, image thumbnail, detection date and time, latitude, longitude, and image filename. The latest records are displayed first, making recent detections easier to access. The table is connected to the CSV data file and also provides an option to remove unwanted duplicate entries, helping maintain an organized record of pothole detections.

VII. CONCLUSION

This paper presents a multi-modal edge-based system for real-time road health monitoring using computer vision, accelerometer sensing, and GPS technology. The proposed system integrates a Raspberry Pi 4 Model B with a USB camera, MPU6050 accelerometer, and NEO-6M GPS module to identify potholes and record their associated information. OpenCV is used for image acquisition and processing, while the trained YOLOv8 model performs pothole detection on the captured road images. The system also maintains detection images and related records, which are presented through a web-based dashboard containing a live map, photo log, and data table. The integration of visual detection with supporting sensor and geographical information provides a practical approach to automated road condition monitoring. By recording pothole locations and images, the system can assist in identifying damaged road sections and support road maintenance activities. Overall, the implementation demonstrates the potential of edge computing and multi-modal sensing in developing accessible and automated road monitoring solutions.

VIII. FUTURE SCOPE

The proposed system can be further improved through the following developments:

1. Improved Detection Accuracy: The YOLOv8 model can be trained with a larger dataset containing potholes of different sizes, shapes, road conditions, and lighting environments to improve detection reliability.
2. Advanced Sensor Fusion: Accelerometer readings can be combined more effectively with visual detection results using suitable sensor fusion algorithms to improve the identification and assessment of road irregularities.
3. Road Damage Classification: The system can be extended to identify different types of road damage, such as cracks, surface deterioration, and damaged patches, in addition to potholes.
4. Cloud-Based Data Management: A cloud platform can be incorporated to maintain a centralized database of detected road defects, allowing information from multiple vehicles to be collected and analysed.
5. Automated Maintenance Reporting: The recorded pothole locations and images can be used to generate road condition reports and assist concerned authorities in prioritizing inspection and maintenance activities.
6. Enhanced Hardware Design: Future versions can use a compact embedded platform, improved camera positioning, and a more reliable vehicle power supply to support long-term deployment under different road conditions.

 This work is licensed under a Creative Commons Attribution 4.0 International License



International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 11, November 2026
DOI: 10.17148/IJARCCE.2026.1511175

REFERENCES

[1]. Y. Wu, K. Chen, and T. Liang, "Edge-cloud collaborative pothole detection via federated temporal segmentation," *arXiv preprint arXiv:2605.10055*, 2026, doi: 10.48550/arXiv.2605.10055.
[2]. I. Romero, H. Mantz, T. Walter, and M. Schneider, "Multi-sensor pothole detection and monitoring system," in *Proc. SMSI*, 2025, doi: 10.5162/SMSI2025/P12.
[3]. A. G. Nair, J. Baskar, V. Kumar, and A. Krishnan, "Deep Road Guard: Enhanced pothole detection using Bayesian fusion and night-vision data," in *Proc. IEEE 2nd International Conference on Computing and Data Science (ICCDS)*, Chennai, India, 2025.
[4]. J. Zhong, D. Kong, Y. Wei, B. Pan, *et al*., "YOLOv8 and point cloud fusion for enhanced road pothole detection and quantification," *Scientific Reports*, vol. 15, Art. no. 11260, 2025, doi: 10.1038/s41598-025-94993-0.
[5]. S. Sharma, P. Verma, R. Gupta, and A. Kumar, "Edge intelligence-based road damage detection using lightweight deep learning models," 2024.
[6]. K. Ghafoor, M. A. M. Sadeeq, and S. R. M. Zeebaree, "IoT and cloud based automated pothole detection model using extreme gradient boosting," *Scalable Computing: Practice and Experience*, vol. 24, no. 4, 2023, doi: 10.12694/scpe. v24i4.2176.
[7]. M. Ghogho *et al*., "Sustainable Road pothole detection: A crowdsourcing based multi-sensors fusion approach," *Sustainability*, vol. 15, no. 8, Art. no. 6610, 2023, doi: 10.3390/su15086610.
[8]. R. G. Gowda and G. P. Revathi, "Real time pothole detection using machine learning and edge computing," 2023, doi: 10.1109/ICAECC59324.2023.10560282.
[9]. R. Fan *et al*., "Road surface 3D reconstruction based on dense subpixel disparity map estimation," *Remote Sensing*, vol. 14, no. 3, Art. no. 613, 2022, doi: 10.3390/rs14030613.
[10]. M. Prakash B. and K. C. Sriharipriya, "Enhanced pothole detection system using YOLOX algorithm," *Autonomous Intelligent Systems*, vol. 2, Art. no. 22, 2022, doi: 10.1007/s43684-022-00037-z.
[11]. K. Huang, B. Shi, X. Li, and X. Li, "Multi-modal sensor fusion for auto driving perception: A survey," *arXiv preprint arXiv:2202.02703*, 2022, doi: 10.48550/arXiv.2202.02703.
[12]. N. Ma, H. Wang, J. Zhao, and Q. Yang, "Computer vision for road imaging and pothole detection: A state-of-the-art review of systems and algorithms," *Transportation Safety and Environment*, vol. 4, no. 4, Art. no. tdac026, 2022, doi: 10.1093/tse/tdac026.
[13]. S. Ajmera, C. A. Kumar, P. Yakaiah, and B. Kumar, "Real-time pothole detection using YOLOv5," 2022, doi: 10.1109/ASSIC55218.2022.10088290.
[14]. J. Fan, Y. Wang, M. Liu, and X. Shen, "Multi-Scale Feature Fusion for Road Pothole Detection", in *Proc. IEEE International Conference on Autonomous Systems (ICAS)*, Montreal, Canada, 2021.
[15]. K. R. Ahmed, M. T. Hossain, and S. Rahman, "Smart pothole detection using deep learning based on dilated convolution," *Sensors*, vol. 21, no. 24, Art. no. 8406, 2021, doi: 10.3390/s21248406.
[16]. A. Dhiman and R. Klette, "Pothole detection using computer vision and learning," *IEEE Transactions on Intelligent Transportation Systems*, vol. 21, no. 8, pp. 3536–3550, Aug. 2020, doi: 10.1109/TITS.2019.2931297.
[17]. E. N. Ukhwah, Y. K. Suprapto, and E. M. Yuniarno, "Asphalt pavement pothole detection using deep learning method based on YOLO neural network," in *Proc. Int. Seminar Intell. Technol. Its Appl. (ISITIA)*, 2019, pp. 35–40, doi: 10.1109/ISITIA.2019.8937176.
[18]. R. Carlos, E. Meneguette, and L. Villas, "Evaluation of Detection Approaches for Road Anomalies Based on Accelerometer Readings", *IEEE Transactions on Intelligent Transportation Systems*, vol. 19, no. 3, pp. 1–10, 2018.
[19]. H. Maeda, Y. Sekimoto, T. Seto, T. Kashiyama, and H. Omata, "Road damage detection and classification using deep neural networks with smartphone images," *Computer-Aided Civil and Infrastructure Engineering*, vol. 33, no. 12, pp. 1127–1141, 2018, doi: 10.1111/mice.12387.
[20]. U. Bhatt, S. Mani, E. Xi, and J. Z. Kolter, "Intelligent pothole detection and road condition assessment," *arXiv preprint arXiv:1710.02595*, 2017.

 This work is licensed under a Creative Commons Attribution 4.0 International License