AI Powered Real Time Road Anomaly Detection Using Yolov11 and IOT Integration for Indian Smart Cities

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***Abstract*—Road infrastructure plays a vital role in Indian transportation safety, efficiency and economics growth of India. However, issues such as potholes, cracks, and road encroachments pose significant risks to commuters and increase maintenance costs. Traditional road inspection methods are often slow, labour-intensive, and prone to human error. This project presents an AI-powered road safety system that provides real-time automated detection of road anomalies using advanced computer vision techniques. The system employs a YOLOv11-based model integrated with vehicle-mounted cameras to detect potholes, cracks, and encroachments in live road images. Each detected anomaly is GPS-tagged and transmitted to a central dashboard, enabling timely maintenance actions and improved road safety. The AI-powered solution aims to enhance road safety, reduce maintenance delays, and provide a scalable method for continuous monitoring of road infrastructure in the Indian cities.**

***Index Terms*—AI; Computer Vision; Road Safety; YOLOv11; Real-Time Detection, Smart Cities India.**

I. INTRODUCTION

Road infrastructure is critical for safe and efficient transportation and a standard economic growth. Despite its importance, many roads suffer from potholes, cracks, and encroachments, which compromise commuter safety and increase vehicle maintenance costs. Traditional inspection methods rely heavily on manual surveys, which are slow, labour-intensive, and susceptible to human error. These limitations make it challenging for authorities to maintain roads efficiently and respond promptly to hazardous conditions (Birari, H et al., 2023; Rajan, P, 2023). In recent years, artificial intelligence (AI) and computer vision technologies have shown great potential in automating inspection processes. By leveraging deep learning-based object detection models, road anomalies can be detected in real time, enabling faster decision-making and reducing risks to commuters. The AI Powered Road Safety System integrates YOLOv11, a state-of-the-art real-time object detection model, with vehicle-mounted cameras and GPS modules to provide accurate detection and location information for each anomaly. This system addresses the critical need for automated, real-time monitoring of road conditions. By capturing live images of road surfaces, analyzing them using AI, and reporting anomalies to a centralized dashboard, it ensures that maintenance teams can respond quickly and effectively. While prior studies have explored AI-based road anomaly detection, this work presents a context-specific, system level architectural design and feasibility analysis tailored to Indian road conditions and economics.

II. LITERATURE REVIEW

The rapid growth of intelligent transportation systems has intensified research into automated road condition monitoring using computer vision and artificial intelligence techniques. Traditional road inspection methods predominantly relied on manual surveys and visual assessments, which are time-consuming, labour-intensive, costly, and susceptible to human error. Such approaches are inadequate for large-scale and continuous monitoring of road infrastructure, especially in regions with extensive and diverse road networks [8], [9].

Early automated road anomaly detection systems primarily employed conventional image processing techniques such as edge detection, thresholding, and morphological operations. These methods demonstrated limited effectiveness in real-world environments due to their sensitivity to illumination variations, shadows, surface textures, and environmental noise [10], [11]. As a result, their applicability was restricted to controlled conditions, limiting scalability and robustness.

The introduction of deep learning, particularly Convolutional Neural Networks (CNNs), significantly enhanced feature extraction and detection accuracy for road defect identification. Object detection frameworks such as Faster R-CNN and SSD achieved improved precision in identifying cracks and potholes but suffered from high computational complexity and latency, making real-time deployment on mobile or vehicle-mounted platforms challenging [12], [13]. Subsequent studies further demonstrated the effectiveness of CNN-based approaches for crack and damage detection, while also highlighting the trade-off between accuracy and inference speed [14].

To address real-time performance constraints, recent research has increasingly focused on YOLO (You Only Look Once)–based object detection models due to their lightweight architecture and fast inference capabilities. Multiple studies have successfully applied YOLO variants for detecting potholes, cracks, and road surface anomalies across large-scale datasets, establishing YOLO as a suitable model for real-time and mobile road monitoring applications [3], [15], [16]. Enhanced versions such as YOLOv8 and its optimized variants have further demonstrated improvements in detection accuracy while reducing computational overhead, enabling scalable deployment without proportional increases in hardware requirements [7], [17], [23].

In addition to detection accuracy, integrating geolocation technologies has been emphasized to support actionable road maintenance workflows. Several studies have incorporated GPS and GNSS data with vision-based detection systems to precisely map the spatial distribution of road anomalies, facilitating efficient maintenance planning and infrastructure management [5], [19]. These integrations are particularly relevant for large road networks where timely identification and prioritization of defects are critical.

Recent surveys and review studies have highlighted the growing trend toward end-to-end smart road monitoring solutions that combine AI-based vision models, IoT devices, geolocation tracking, and cloud-based dashboards. Such systems enable continuous monitoring, centralized reporting, and data-driven decision-making for transportation authorities [1], [2], [4], [18], [20], [21]. The literature consistently supports the feasibility and effectiveness of AI-powered real-time road inspection systems for improving road safety and maintenance efficiency.

Building upon these advancements, the proposed work focuses on a conceptual AI-powered road safety system utilizing an enhanced YOLO-based detection framework integrated with vehicle-mounted cameras and GPS tagging. By addressing real-time detection, scalability, and geolocation mapping, the proposed system aligns with current research directions and aims to contribute toward intelligent, automated road infrastructure monitoring.

III. PROBLEM STATEMENT

Road infrastructure plays a vital role in transportation safety, efficiency and economic growth in India. However, issues such as potholes, cracks, and road encroachments pose significant risks to commuters, lead to vehicle damages and increase maintenance costs. Traditional road inspection methods are often slow, labour-intensive, and prone to human errors and the lack of geolocation information make it difficult for the officers or corresponding authorities to prioritize maintenance activities effectively. Therefore, there is a crucial need in Indian cities for the automated, intelligent and real-time anomaly detection systems to detect the anomalies in the roads and to report their locations to ensure the timely and efficient maintenance.

IV. OBJECTIVES OF THE STUDY

4.1 Primary Objective

The aim of this project is to design an AI powered automated system which is capable to detect the anomalies like potholes, cracks etc., in roads and to report using computer vision techniques and IoT integration.

4.2. Secondary objectives

- To design a YOLOv11 based object detection model for Indian road anomaly detection.
- To integrate GPS based geolocator to Locate or Mapp the anomaly.
- To develop a dashboard for monitoring the detected reports and maintenance works.
- To ensure road safety and to minimize inspection time through automation.
- To support Indian municipal authorities and smart city initiatives through automated road condition monitoring.

V. SCOPE OF THE WORK

This work focuses on the conceptual design and architectural development of the AI-powered automated system for real-time road anomaly detection. The scope incorporates system architectural design, workflow modelling and feasibility analysis for vehicle mounted deployment. Even this paper doesn't provide a full-scale implementation or large-scale deployment, it provides a strong foundation and idea for the development and applications in smart city infrastructures especially for Indian cities.

VI. PROPOSED SYSTEM OVERVIEW

6.1 System Design Philosophy

The proposed system is designed in such a way it is scalable, cost-effective and suitable for real-time operation. It focuses automation, accuracy and smooth integration with existing transportation infrastructure.

6.2 Overall System Architecture

The system consists of four modules. The first module is a vehicle mounted cameras for image capturing, a YOLOv11 based detection module for anomaly detection, a GPS module for location mapping and a dashboard for visualization and reporting.

6.3 Data Flow Description

The road images are captured along with the GPS coordinates are pre-processed and passed to the detection module. Images detected with the anomalies are the sent to the central server with their tagged GPS coordinates, where they displayed on the monitoring dashboard.

VII. METHODOLOGY

7.1 Image Capturing

High resolution cameras mounted on vehicles continuously capture road surfaces during the normal vehicle operation without interrupting.

7.2 GPS Tagging and Geolocation Mapping

Each captured image is associated with the latitude and longitude coordinates obtained from the GPS module, enables the precise location mapping.

7.3 Image Preprocessing

Various images preprocessing techniques like resizing, normalization, noise reduction etc., are employed to enhance detection accuracy under varying lighting and environmental conditions.

7.4 Anomaly Detection using YOLOv11

The YOLOv11 model is used to detect the anomaly road images. The model is conceptually trained to identify potholes, cracks and encroachments from the road images.

7.5 Dashboard and Reporting Module

A centralized dashboard visualizes detected anomalies on a map interface, allowing authorities to monitor the road condition and plan the maintenance activities effectively.

VIII. ALGORITHMIC WORKFLOW

1. Capturing live road images using vehicle-mounted cameras along with GPS coordinates.

2. Preprocessing the Images.
3. Applying YOLOv11 to detect anomalies.
4. Transmitting anomaly data to the central server.
5. Displaying the results on a real-time monitoring dashboard.

IX. EXPECTED OUTCOMES

- Accurate real-time detection of road anomalies.
- Reduction in manual inspection time and costs.
- Improved road maintenance planning.
- Enhanced commuter safety and infrastructure management.
- Improved road safety and safe transportation.

X. FEASIBILITY AND VIABILITY ANALYSIS

10.1 Technical Feasibility

Various studies confirm the feasibility of using AI and Computer Vision for automated road anomaly detection. DL methods, especially object detection models (ODM) have standard approach for identifying road anomalies such as potholes and cracks due to their remarkable performance over the traditional image processing techniques. Reviews indicates that CNNs and YOLO based models outperform classic 2D and 3D methods in both accuracy and adaptability for real time detection [1].

Recent research applying YOLO variants for road hazard detection demonstrated robust performance and real-time capability across various environments [3].

Moreover, hybrid approaches that combine annotated datasets with DL pipelines have proven the technical viability on real-world road images [6].

10.2 Economic Feasibility

Researches indicated that vision-based approaches can significantly reduce inspection costs compared to the manual inspections, which require sustained manpower and other field operations. Review article highlights that automated systems not only reduce labour expenses but also enable more frequent monitoring without proportional increases in cost [1].

Moreover, studies implementation DL based potholes detection using affordable hardware and open-source software demonstrates feasibility on lower-cost platforms. For instance, work integrating YOLO models with common processing units highlights reduce computational overhead while maintaining high detection performance, proving economic viability [1].

10.3 Operational Feasibility

The operational feasibility of automated rod monitoring systems can be supported by the Government vehicles like Government buses. Studies using vehicle mounted cameras and GNSS receivers paired with object detection pipelines achieved stable performance in real traffic scenarios, demonstrating practical operation under real driving conditions [5].

In addition to that, literature emphasizes that vision-based systems can be incorporated into existing municipal workflows, allowing inspection vehicles to capture continuous data without interrupting routine transport operations. This supports seamless integration into daily usage by civic agencies [6].

10.4 Scalability

Scalability of computer vision-based detection systems is discussed well in the literatures along with the modern architectures designed to handle increased data volumes and multi-location deployments. Reviews and case studies shows that scalability is achievable through cloud-based processing or edge-augmented approaches which enables expansion from pilot region to extension road networks [1].

Enhanced models are also shown to reduce computational complexity while increasing the performance, which supports scaling across many vehicles and infrastructure projects without proportionally increasing hardware demands [7].

XI. LIMITATIONS

The proposed system may have the following limitations,

- Performance variation in extreme weather or low-light conditions.
- Requires large annotated dataset for initial training.
- Real-world deployment requires hardware optimization.

XII. FUTURE WORKS

The future enhancement of this work includes,

- Full-scale or Large-scale implementation.
- Training on large datasets.
- Integrating with edge AI devices.
- Incorporating drone-based inspection for wider coverage.

XIII. CONCLUSION

In Indian context, the proposed system offers a practical and scalable solution to address the road infrastructure challenges. By integrating the computer vision, geolocation and IoT technologies, the system supports for the effective road maintenance and enhance the public safety which supports the sustainable urban development in India.

XIV. AUTHOR CONTRIBUTION

All authors contributed equally to system design, literature review, conceptual methodology and manuscript preparation.

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