

AI- Based Road Pothole's Detection System

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Email: thakurnitish112@gmail.com¹, gm.mspatil@gmail.com², kadamsahil642@gmail.com³, priyabhor2404@gmail.com⁴,
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<p>Peer Review Information</p> <p><i>Type: Article</i> <i>Received: 23 February 2026</i> <i>Revised: 24 March 2026</i> <i>Accepted: 22 April 2026</i> <i>Published: 20 May 2026</i></p>	<p style="text-align: center;">Abstract</p> <p>Road safety and maintenance have become critical concerns due to the growing number of accidents and vehicle damages caused by potholes. Manual inspection of roads is inefficient, time-consuming, and often inaccurate, especially under varying environmental conditions. To address these challenges, this project presents an AI-Based Road Pothole Detection System using the advanced YOLOv8 object detection algorithm for accurate, real-time identification of potholes from road videos. The system allows users to upload a video of a road segment, which is processed frame by frame to detect and localize potholes in both daytime and nighttime conditions, including rainy weather scenarios. Once a pothole is detected, the system calculates its approximate depth, captures the image, retrieves the GPS location, and automatically sends an email notification with these details to the concerned authority. Additionally, it provides an estimated cost for pothole repair, supporting smart decision-making in road maintenance management. By integrating computer vision, deep learning (YOLOv8), and automated alert systems, this model ensures faster, more reliable, and cost-effective pothole detection compared to traditional manual surveys. The proposed system contributes toward building smart city infrastructure, enhancing road safety, and optimizing maintenance efficiency under diverse environmental conditions.</p> <p>Keywords: YOLOv8; Vision Transformers (ViT); EfficientDet; MobileNetV3; Transfer Learning; Edge AI Deployment; Real-Time Image Detection; Precision Agriculture</p>
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Introduction

Road transportation is one of the most important components of modern infrastructure, playing a vital role in economic development, public safety, and daily mobility. However, the increasing occurrence of potholes and road surface defects has become a major concern in both urban and rural areas. Potholes are primarily caused by environmental conditions, heavy traffic loads, poor drainage systems, and inadequate road maintenance. These road defects not only damage vehicles and increase maintenance costs but also contribute significantly to road accidents, traffic congestion, and reduced driving comfort. Therefore, timely detection and repair of potholes are essential for ensuring safe and efficient transportation systems.

Traditional road inspection methods mainly rely on manual surveys conducted by maintenance teams. Although these approaches are commonly used, they are labor-intensive, time-consuming, costly, and often inaccurate when applied to large-scale road networks. In many cases, potholes remain undetected for long periods due to delayed inspections and limited monitoring resources. Furthermore, manual inspection becomes highly challenging under adverse environmental conditions such as nighttime, rain, shadows, and poor visibility. These limitations highlight the need for an intelligent and automated pothole detection system capable of operating efficiently in real-world scenarios.

Recent advancements in Artificial Intelligence (AI), Deep Learning, and Computer Vision technologies have provided powerful solutions for automated road monitoring and infrastructure management. Deep learning-based object detection algorithms have demonstrated remarkable performance in identifying road defects from images and videos with high speed and accuracy. Among these algorithms, the YOLOv8 model has emerged as one of the most advanced real-time object detection frameworks due to its improved feature extraction capabilities, anchor-free detection mechanism, and efficient processing speed. YOLOv8 enables accurate detection of objects under complex environmental conditions while maintaining real-time performance, making it highly suitable for intelligent transportation applications.

This project presents an AI-Based Road Pothole Detection System that utilizes the YOLOv8 deep learning algorithm to detect potholes from road videos automatically. The proposed system processes video frames in real time and identifies potholes under different environmental conditions, including daytime, nighttime, and rainy weather scenarios. In addition to pothole detection, the system estimates pothole depth, captures pothole images, retrieves GPS coordinates, and automatically sends email notifications to the concerned authorities with detailed information about the detected road damage. Furthermore, the system estimates the repair cost of potholes based on their size and depth, assisting authorities in maintenance planning and resource allocation.

The integration of AI-driven detection, geolocation tracking, automated alert systems, and cost estimation creates a complete and intelligent road monitoring framework. The proposed system aims to minimize manual inspection efforts, improve detection accuracy, reduce response time for road maintenance, and enhance public safety. By leveraging deep learning and automation technologies, the system contributes toward the development of smart city infrastructure and intelligent transportation systems capable of ensuring efficient and reliable road surface monitoring.

Literature review

Road pothole detection has become an important research area in intelligent transportation systems and smart city infrastructure due to the increasing number of accidents and vehicle damages caused by poor road conditions. Researchers have proposed several traditional and modern approaches to identify potholes efficiently and improve road maintenance processes.

Initially, pothole detection was mainly performed through manual inspection methods, where road maintenance teams physically surveyed damaged road segments. Although these approaches were straightforward, they were highly time-consuming, labor-intensive, and inefficient for monitoring large road networks. To overcome these limitations, sensor-based detection techniques were introduced using accelerometers, vibration sensors, and ultrasonic sensors mounted on vehicles. These systems collected road surface irregularity data during vehicle movement. However, sensor-based approaches often produced inaccurate results due to variations in vehicle speed, suspension systems, traffic conditions, and environmental noise.

With the advancement of image processing and computer vision technologies, researchers began utilizing digital image analysis techniques for automated pothole detection. Traditional computer vision methods such as edge detection, threshold segmentation, contour analysis, and texture-based feature extraction were applied to identify potholes from road images. Koch and Brilakis (2011) proposed one of the early image-processing approaches for pothole detection in asphalt pavement images. Although these techniques reduced human effort, they lacked robustness under varying lighting conditions, shadows, occlusions, and complex road backgrounds, which limited their real-world applicability.

The emergence of machine learning and deep learning significantly improved the performance of automated road defect detection systems.

Convolutional Neural Networks (CNNs) became widely adopted due to their ability to automatically extract high-level features from images and achieve higher classification accuracy. Zhang et al. (2016) demonstrated the effectiveness of deep convolutional neural networks in detecting road cracks and pavement defects with improved precision compared to traditional image processing techniques. Similarly, Eisenbach et al. (2017) introduced a systematic deep learning-based framework for pavement distress detection and emphasized the importance of large annotated datasets for improving model accuracy and generalization.

Recent research has focused on real-time object detection models such as the YOLOv8 architecture due to its high speed and detection accuracy. YOLO-based models process images in a single stage, making them highly suitable for intelligent transportation applications requiring real-time performance. Dhiman and Klette (2020) showed that deep learning and computer vision techniques provide more reliable pothole detection compared to traditional methods. Furthermore, Maeda et al. (2018) developed a smartphone-based road damage detection system using deep neural networks, demonstrating the feasibility of practical and low-cost road monitoring systems.

More advanced studies have explored multi-scale feature extraction and robust environmental adaptability. Arya et al. (2021) proposed a deep learning-based road damage classification framework capable of handling multiple road conditions across different countries. Fan et al. (2024) presented a comprehensive survey on deep learning techniques for pavement defect detection and highlighted the effectiveness of modern object detection frameworks in identifying potholes under challenging environmental conditions such as rain, low illumination, and varying road textures.

Several researchers have also integrated geolocation and communication technologies into pothole monitoring systems. GPS-based mapping enables accurate localization of potholes for maintenance planning, while cloud-based and email notification systems improve communication between detection systems and road authorities. These intelligent reporting mechanisms reduce response time and support efficient road maintenance operations.

Despite significant advancements, existing pothole detection systems still face several challenges, including accurate depth estimation, performance degradation under extreme weather conditions, real-time deployment on low-power devices, and efficient maintenance cost prediction. Many existing approaches also lack complete integration of detection, localization, alert generation, and repair planning within a single framework.

The proposed AI-Based Road Pothole Detection System addresses these limitations by integrating YOLOv8-based real-time detection, pothole depth estimation, GPS location tracking, automated email notification, and repair cost estimation into a unified intelligent framework. By combining deep learning, computer vision, geolocation services, and automation technologies, the proposed system aims to provide an accurate, efficient, and scalable solution for modern smart transportation and road infrastructure management systems.

System architecture

The AI-Based Road Pothole Detection System is designed to provide end-to-end automation — from video input to pothole detection, depth estimation, location mapping, cost calculation, and email notification.

The architecture consists of the following main components:

- User Interface Module – Allows the user to upload a road surveillance video through a web or desktop application.
- Video Processing Module – Splits the uploaded video into frames for real-time pothole detection.
- YOLOv8 Detection Module – Uses a pretrained YOLOv8 deep learning model to detect potholes from each frame with high accuracy.
- Depth Estimation Module – Calculates the depth of detected potholes using pixel and contour analysis.
- GPS & Location Module – Retrieves the geographical coordinates (latitude, longitude) of the detected pothole using GPS or embedded video metadata.
- Cost Estimation Module – Predicts the repair cost of each pothole based on its size and depth.
- Email Notification Module – Sends an automated email to road maintenance authorities containing the pothole image, location, depth, and estimated cost.

This architecture integrates AI (YOLOv8), computer vision, geolocation, and cloud/email services into one efficient pothole detection and reporting system.

Yolov8 Architecture Components

Table 1. YOLO-Based Detection Architecture Components and Functions

Component	Function	Details
Backbone (CSPDarknet)	Extracts image features	Uses convolutional and residual blocks
Neck (PANet + FPN)	Merges features from multiple scales	Helps detect potholes of all sizes
Head	Predicts bounding boxes and classes	Uses anchor-free approach
NMS (Non-Max Suppression)	Filters overlapping detections	Keeps the most confident bounding box
Loss Function	Guides model training	Combines classification, box, and objectness loss

Key Features

Table 2. Benefits of the Proposed Pothole Detection System

Feature	Benefit in Pothole Detection
Real-Time Detection	Detects potholes instantly during driving
High Accuracy	Detects even small and cracked potholes
Lightweight	Operates efficiently on embedded systems
Custom Dataset Training	Learns road-specific conditions
Robust Performance	Handles various lighting and weather conditions

Software Requirements

Table 3. Software and Tools Used for Pothole Detection System Implementation

Software / Tool	Specification / Description	Purpose
Operating System	Windows 10/11, Ubuntu 20.04+, or Raspberry Pi OS	Project execution environment
Programming Language	Python 3.8 or higher	Core development language
YOLOv8 Framework	Ultralytics YOLOv8	Object detection and model training
Deep Learning Library	PyTorch / TensorFlow	Training deep neural networks
OpenCV	Version 4.8+	Image and video processing
NumPy / Matplotlib	Latest version	Data handling and visualization
LabelImg / Roboflow	Annotation tool	Labeling pothole dataset
SMTP / smtplib	Python email library	Sending automated email alerts
Tkinter GUI	Graphical user interface	Video upload and display
Email Client / SMTP Server	Gmail or SMTP configuration	Sending pothole alerts with image and location
Jupyter Notebook / VS Code / PyCharm	IDE	Coding, model training, and debugging

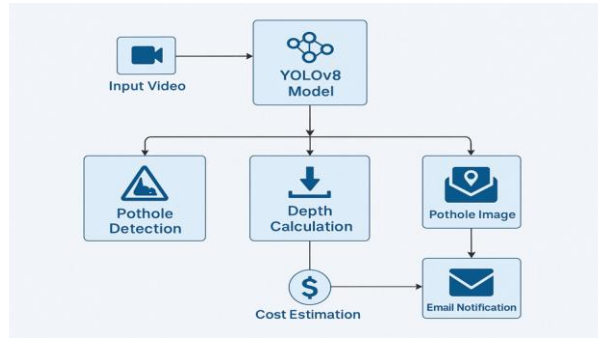


Fig. 1. Architecture Diagram/Flow Chart

Expected outcomes

The AI-Based Road Pothole Detection System is expected to accurately detect potholes from road videos in real-time using the YOLOv8 model. The system will identify potholes under different conditions such as daytime, nighttime, and rainy environments. It will provide additional information including pothole depth, GPS location, and captured images. The system will automatically send email alerts to concerned authorities with complete details, enabling faster response and repair actions. It will also estimate the repair cost based on pothole size and depth, helping in better maintenance planning. Overall, the system aims to reduce manual effort, improve road safety, and support smart city infrastructure through efficient and automated road monitoring.

Login test case					
Test Case ID	Test Case	Test Case I/P	Actual Result	Expected Result	Test case criteria(P/F)
001	Enter The Wrong username or password click on submit button	Username or password	Error comes	Error Should come	P
002	Enter the correct username and password click on submit button	Username and password	Accept	Accept	P

Figure 9.2: login test Cases

GUI Testing:

Test case	Login Screen- Sign up
Objective	Click on sign up button then check all required/ mandatory fields with leaving all fields blank
Expected Result	All required/ mandatory fields should display with symbol "**". Instruction line "** field(s) are mandatory" should be displayed
Test case	Create a Password >>Text Box Confirm Password >>Text Box
Objective	Check the validation message for Password and Confirm Password field
Expected Result	Correct validation message should be displayed accordingly or "Password and confirm password should be same" in place of "Password mismatch".

Result of Test Cases

GUI Testing:

Test case	Login Screen- Sign up
Objective	Click on sign up button then check all required/ mandatory fields with leaving all fields blank
Expected Result	All required/ mandatory fields should display with symbol "**". Instruction line "** field(s) are mandatory" should be displayed
Test case	Create a Password >>Text Box Confirm Password >>Text Box
Objective	Check the validation message for Password and Confirm Password field
Expected Result	Correct validation message should be displayed accordingly or "Password and confirm password should be same" in place of "Password mismatch".

Registration test case					
Test Case ID	Test Case	Test Case I/P	Actual Result	Expected Result	Test case criteria(P/F)
001	Enter the number in username, middle name, last name field	Number	Error Comes	Error Should Comes	P
001	Enter the character in username, middle name, last name field	Character	Accept	Accept	P
002	Enter the invalid email id format in email id field	kk@gmail.com	Error comes	Error Should Comes	P
002	Enter the valid email id format in email id field	kk@gmail.com	Accept	Accept	P
003	Enter the invalid digit no in phone no field	99999	Error comes	Error Should Comes	P
003	Enter the 10 digit no in phone no field	9999999999	Accept	Accept	P

Figure 9.3: Registration Test cases

Login test case					
Test Case ID	Test Case	Test Case I/P	Actual Result	Expected Result	Test case criteria(P/F)
001	Enter The Wrong username or password click on submit button	Username or password	Error comes	Error Should come	P
002	Enter the correct username and password click on submit button	Username and password	Accept	Accept	P

Figure 9.2: login test Cases

Test plan

To test this application we are going with proper sequencing of testing like unit, integration, validation, GUI, Low level and High level test cases, major scenarios likewise. We will go with the GUI testing first and then integration testing. After integration testing performs the high level test cases and major scenarios which can affect the working on the application. We will perform the testing on the data transmitted using the various inputs and outputs and validate the results. It also intends to cover any deviations that the project might take from the initially agreed Test Strategy in terms of scope, testing methodology, tools, etc.. This test plan covers details of testing activities for this project and scope.

Outputs



Figure 10.1: Output 1



Figure 10.2: Output 2

Fig.2. Home Screen



Figure 10.3: Output 3

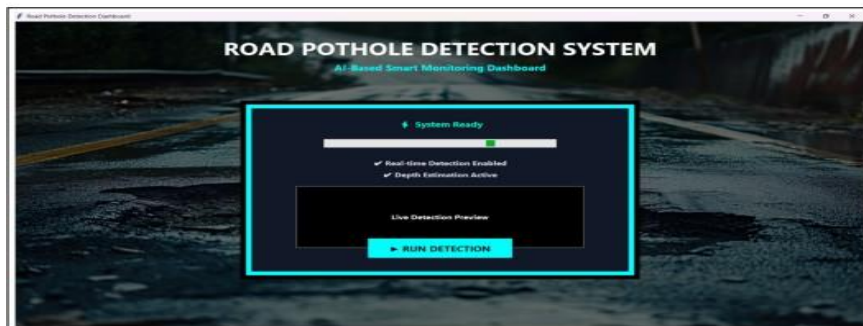


Figure 10.4: Output 4

Fig. 3. Login Screen

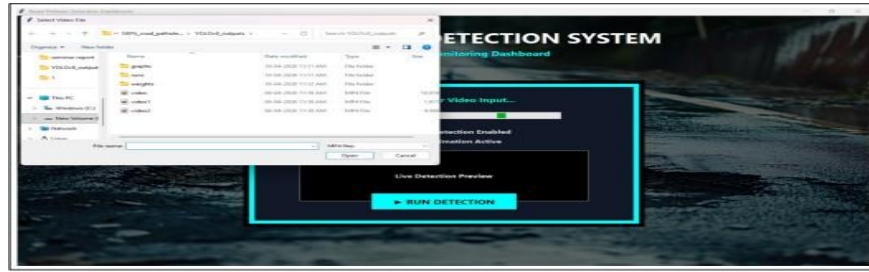


Figure 10.5: Output 5



Figure 10.6: Output 6

Fig. 4. Video Upload Screen

Conclusion

The AI-Based Road Pothole Detection System provides an efficient and modern solution for identifying road damages using deep learning and computer vision. By using the YOLOv8 model, the system can detect potholes accurately in different lighting and weather conditions, making it suitable for real-world applications. Features such as depth estimation, GPS location tracking, image capture, and automatic email alerts help authorities take timely action and plan repairs more effectively. This reduces manual effort, speeds up maintenance processes, and improves road safety for the public. Overall, the system supports smart city development and offers a reliable, automated approach to road surface monitoring.

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