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REGIONAL POTHOLE DETECTION USING DEEP LEARNING

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Abstract — **Potholes on road surfaces pose significant risks to vehicular safety and contribute to the deterioration of transportation infrastructure. Traditional manual inspection methods are inefficient, time-consuming, and fail to provide timely interventions. This research presents an automated pothole detection and mapping system utilizing the YOLOv4-tiny deep learning model for real-time object detection. The system processes images and video streams to accurately identify potholes and stores detection results in an SQLite database for structured data management. A web-based interface facilitates user interaction for location selection and visualization of detected potholes. The proposed solution emphasizes modularity, enabling easy updates, retraining, and deployment on resource-constrained devices. Experimental evaluations demonstrate the model's high accuracy and real-time performance, indicating the system's potential for large-scale deployment in urban infrastructure maintenance programs.**

Keywords — **Pothole Detection, YOLOv4-tiny, Real-Time Object Detection, Road Surface Monitoring, Deep Learning, Smart City Applications.**

I. INTRODUCTION

The quality of road infrastructure is a critical determinant of transportation safety, economic efficiency, and public satisfaction. Among the many challenges faced by road maintenance authorities, potholes represent a persistent and significant issue. They not only degrade the driving experience but also contribute to accidents, vehicle damage, and increased maintenance costs. Traditional pothole detection methods, which often involve manual surveys or citizen reports, are labor-intensive, time- consuming, and lack scalability for widespread monitoring. With advancements in computer vision and deep learning, automated solutions have emerged as promising alternatives to traditional inspection methods. Object detection models, particularly those in the YOLO (You Only Look Once) family, have demonstrated remarkable performance in real-time applications with constrained computational resources. This project presents an automated pothole detection and mapping system that utilizes the lightweight YOLOv4-tiny model for real-time detection of potholes from road images and video streams. Captured media is processed frame-by- frame and detected pothole information is systematically stored in an SQLite database. A minimalistic web interface allows users to interact with the detection results, facilitating visualization.

II. METHODOLOGY

Methodology refers to the step-by-step approach used to carry out the project. It includes identifying requirements, selecting tools and techniques, and following a structured process to develop, test, and validate the system. The methodology includes:

A. System Architecture

The system begins with a Road images or video footage are captured using high-resolution cameras. The input sources can be either live video feeds or pre- recorded videos/images. Video streams are processed to extract frames at regular time intervals using OpenCV. Extracted frames are formatted and passed to the pothole detection engine.

Each frame is analysed using the YOLOv4-tiny deep learning model. The model outputs bounding boxes around detected potholes along with their confidence scores. Post-processing is applied to filter detections based on confidence thresholds. Detection results are stored in a SQLite database. A web-based HTML interface allows users to interact with the database.

Fig. 1. Sample Pothole image

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B: Dataset

The training set must contain realistic pothole images, a recent publicly accessible dataset from Kaggle was employed. Simulate real-world pothole scenarios by using effects of shadow, different lighting levels, photographs of dry and water-filled potholes, and moving automobiles.

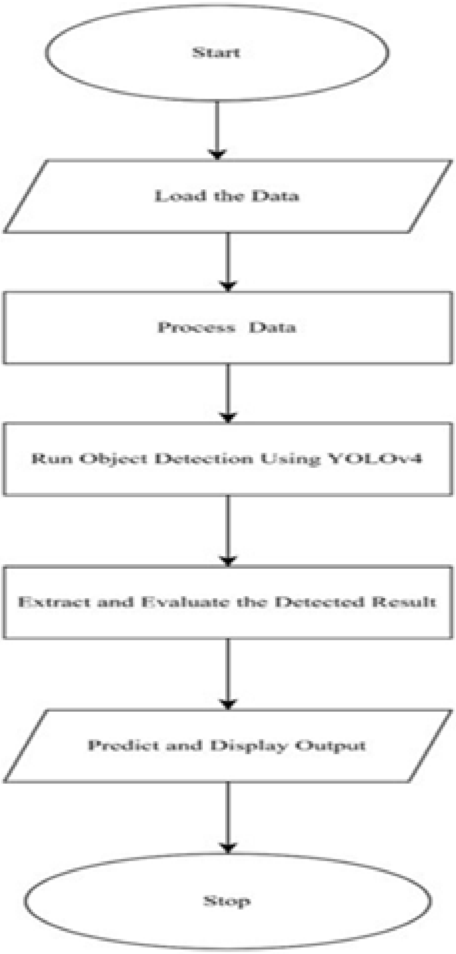

Fig. 2. System Architecture

C: Alert Mechanism

Upon detection of a pothole, the result is updated in the SQLite database. A web application, integrated with database, listens to these updates in real-time. When pothole is detected it sends message to the user through Telegram Bot. The web app also provides a map view and alternative route suggestions

III. IMPLEMENTATION AND RESULT

Implementation and Results cover the actual development and deployment of the system based on the design. It also includes testing the system and presenting the outcomes, showing how well the project meets its objectives

A. **Data Collection and Preprocessing**

A dataset comprising images and video frames of road conditions was collected from open datasets and real-world footage. Each image was manually annotated using the Labeling tool to mark potholes. The YOLO format was adopted for bounding box representation. Preprocessing like Resizing images to 640×640 pixels, Normalizing pixel values, Augmentation: rotation, brightness shifts, and flipping

B. Model Architecture

The pothole detection system uses the YOLOv5s architecture due to its lightweight design and high inference speed suitable for real-time processing. YOLOv5 is a one-stage object detection model that performs localization and classification in a single forward pass. Training Specifications like Epochs: 150, Batch size: 16, Optimizer: SGD, Learning Rate: 0.001, Dataset split: 70% train, 20% validation, 10% test.

C. System testing

The system underwent rigorous unit, integration, functional, and system testing. Tests confirmed reliable real-time detection, robust database updates, and successful detection.
Stress testing was conducted by simulating multiple detection events simultaneously, which confirmed the system's scalability. Functional testing with different environmental conditions, such as height and width simulations, verified the robustness of the object detection model in varied real-world scenarios.

IV. CONCLUSION

In this work, we have developed a comprehensive pothole detection and localization system using deep learning techniques and lightweight computational models. Leveraging the YOLOv4-tiny architecture, the system efficiently detects potholes in real-time from both static images and video streams. Detection outputs are systematically managed and stored in a local database, enabling persistent tracking and future analysis. Furthermore, the integration of a web interface allows for the visualization of pothole locations, supporting potential extensions into mapping and geographic information systems (GIS).
The project emphasizes not only the accuracy of pothole detection but also the scalability and retraining capability of the model. By providing annotated datasets and training scripts, the system remains adaptable to different environments and changing road conditions. Overall, the proposed solution demonstrates a practical, efficient, and extensible framework for urban infrastructure monitoring, paving the way for smarter and more proactive road maintenance strategies
Scope for Future Work
The current system can be significantly enhanced by training a more robust model using a larger, diverse dataset and enabling real-time pothole detection through integration with dashcams

or mobile devices. A mobile application could involve citizens in data collection, while severity analysis would help prioritize repairs based on risk. Predictive maintenance using historical data, crowdsourced validation for increased reliability, and a multilingual interface would broaden system accessibility. Integration with GIS for heatmap visualization and an automated reporting system for authorities would further strengthen the platform. These advancements would transform the solution into a scalable smart- city infrastructure tool, greatly contributing to road safety and urban planning.

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