"Real-Time Pothole Detection Using YOLOv8 for Smart Road Monitoring Systems"

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***Abstract*:**Potholes are a common form of road surface damage and can contribute to accidents, traffic delays, increased vehicle maintenance costs. Detecting them early is essential, but manual examination is slow and often unreliable. The new deep-learning model YOLOv8 was adopted in this study, an automatic detection of potholes from images and videos. The model has been trained on real road data, so is able to spot potholes in different light conditions and weather. The high processing speed of the YOLOv8model makes it can process in real time and so this technology is suitable for mobile phone cameras, surveillance, drone monitoring etc.the results indicates that the system effectively detects potholes and can help authorities to better maintain the smoothness and safety of roads.
Keywords: YOLOv8, pothole identification, deep neural network, visual computing, real-time monitoring, object detection, road safety.

INTRODUCTION

The road network as an essential transport infrastructure component the road infrastructure is of such a great value that transportation would not be possible without it. There are many road defects and among them potholes can be classified as the most common and harmful type of road defect which caused traffic jams, damage to vehicle and accidents on roads. Pavement potholes commonly develop due to continuous heavy traffic loads, accumulation of water on road surface, repeated weather changes, and the need for quick temporary repairs to allow emergency vehicle access after accidents. These factor gradually weaken the pavement structure and lead to surface damage. Conventional pothole detection methods mostly depends on manual inspections or periodic road surveys.

Despite their widespread use, these methods require significant manpower, increase operational costs, and are prone to human error. Moreover, they are inadequate for monitoring large road networks, as data collection is irregular and updates take a long time with latest [progress in artificial intelligence, especially in the domain of computer vision, automated road surface damage detection has emerged as an efficient and reliable alternative. Deep learning based object detection models have shown high effectiveness in processing visual data and identifying complex patterns in real world environments.

Among these model, YOLOv8 stands as a results of its balance accuracy in terms of accuracy and speed. It is capable of processing both image and video frames efficiently, even on systems without high-end GPU support. Additionally, YOLOv8 offers fast training and inference, making it suitable for real-time applications.

The proposed work present an AI-based potholes detection system that employs YOLOv8 to accuracy locate potholes on road surface, aiming to support timely maintenance and improve overall road safety. In this research presents a pothole detection system modeled on YOLOv8 framework so as to detection and predict potholes in static image along with video stream. Therefore, it contains a requirement for system which can automate the process to minimize human efforts and make road monitoring more effective. Through the identification of potholes and visual recording, in real-time systems are available to assist decision makers to timely make maintenance decision saving the road transportation.

LITERATURE REVIEW

Pothole detection has received significant attention using various computer vision and sensor-based approaches. Explored deep learning models to improve accuracy, speed , and scalability in real-world road conditions.

Bhavana et al.(2024) proposed POT-YOLO, a YOLOv8-based pothole detection framework that integrates edge-segmentation prepossessing to enhance accuracy. Their study demonstrated that YOLOv8 outperforms earlier YOLO versions in both precision and real-time efficiency. The work strongly influenced our project by validating YOLOv8 as the most suitable architecture for pothole detection. Although we did not implement their edge-segmentation module, their findings supported our decision to adopt

YOLOv8 as the primary detection model.

Sent et al.(2023) focused on dash-cam-based pothole detection, using frame by frame analysis for real time detection and tracking. Their study highlighted the importance of processing live video streams for practical road safety applications. From their approach, our project adopted the idea of using live webcam input to test the YOLOv8 model in real time conditions and to store detection results for documentation.

Gajjar et al.(2022) compared YOLO, SSD, and faster R-CNN architectures for pothole detection and concluded that YO LObased models are well suited for real time applications due to their speed and efficiency.Based on this analysis, we selected the lightweight YOLOv88n variant, which is optimized for faster inference and can operate effectively on CPU-based systems. Additionally,their observations regarding challenges such as varying lighting conditions and shadow effects guided our data prepossessing and enhancement strategies.

Arjapure and Kalbande (2021) explored pothole detection using mask R-CNN for segmentation tasks. While their approach achieved commendable that segmentation-based models are less piratical for real time road monitoring, as they typically required powerful GPU hardware to function efficiently. These findings further supported our decision to adopt a detection based approach using YOLOv8n, which offers a better balance between performance and computational efficiency, making it more suitable for real time pothole detection applications.

Bansal et al. (2020) developed an IOT based pothole detection system using vibration and motion sensors. Previous studies identified several drawbacks in sensor based pothole detection systems, including noise interference, calibration difficulties, and unreliable performance under different road condition

METHODOLOGY

This study focuses on pothole detection through the collection, processing and ,modeling of real world road data. Images and video footage were captured from various locations to include variations in road surface, lighting, weather conditions and traffic patterns. Incorporating this diversity allows the detection model to perform consistently across different real-world environments. The collected data were further processed to enhance quality and improve model reliability. All images were standardized to a uniform resolution and normalized. Data augmentation techniques including image rotation and brightness adjustments, were apply to expand the data set and introduce variability. This measures help reduce over fitting and improve the model's performance was measured using common metrics such as precision, recall and mean average precision. To increase detection accuracy, post-processing methods like confidence threshold and non-maximum suppression were used to streams. Potholes were detected with minimal delay, demonstrating that the proposed approach can function effectively under real world conditions these results indicates that the system is suitable for continuous, real time road monitoring. The proposed vision based pothole detection system aims to support automated and intelligent road maintenance. By reducing the need for manual inspections, it lowers labor cost and operational expenses. Additionally, automated monitoring enhances road safety and allows maintenance authorities to prioritize repairs, contributing to safer and more efficient transportation infrastructure.

BLOCK DIAGRAM

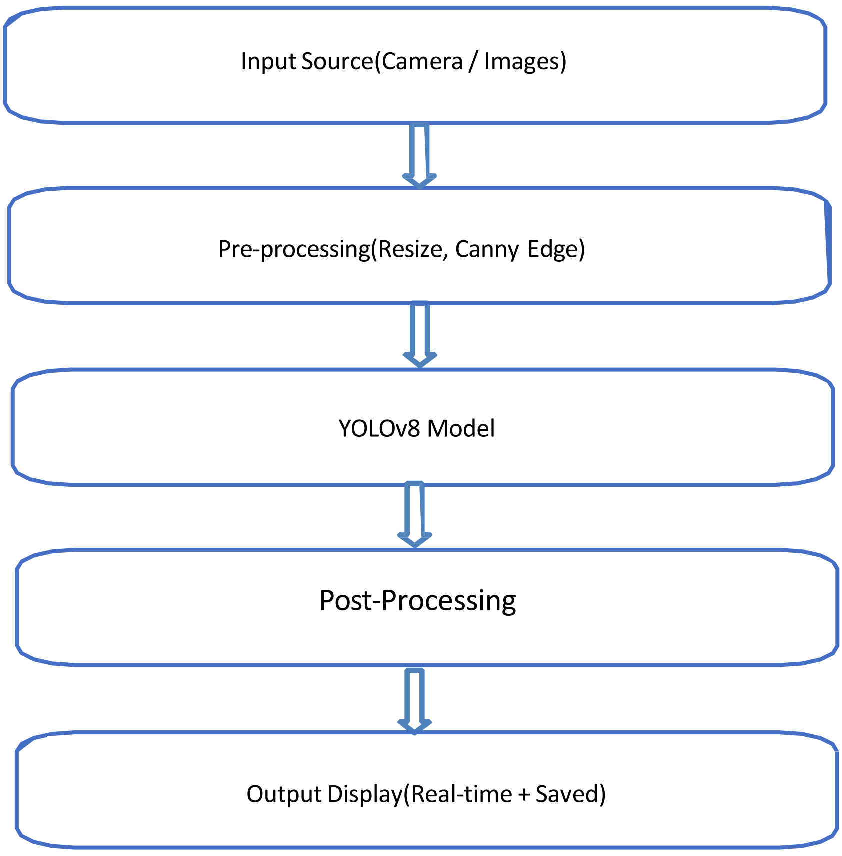

Fig.1: ***flowchat***

EXPERIMENTAL SETUP

All experiments were conducted on a standard laptop with an Intel core i5 processor, 8GB of RAM, and an integrated webcam, running windows 10/11. No external GPU was required, showing that the system can be implemented on low-cost hardware. The model was built using the ultralytics YOLOv8 framework with python 3.10.PyTorch was used for model inference, and open- CV managed real-time video input for training and evaluation, a publicly available pothole data-set from roboflow, containing annotated images in YOLO format, was utilized. The YOLOv8n model was trained for 50 epochs with input images resided to 640*640 pixels, using default optimization settings. The framework generated accuracy metrics, loss curves, and performance plots during training. The trained model was tested on both static images and real time webcam video streams. During live testing, video frames were captured from the webcam, and the YOLO model detection's. All generated outputs including training graphs, confusion matrices, and detected images were stored in the runs/detect/directory and analyzed to assess the system's performance.

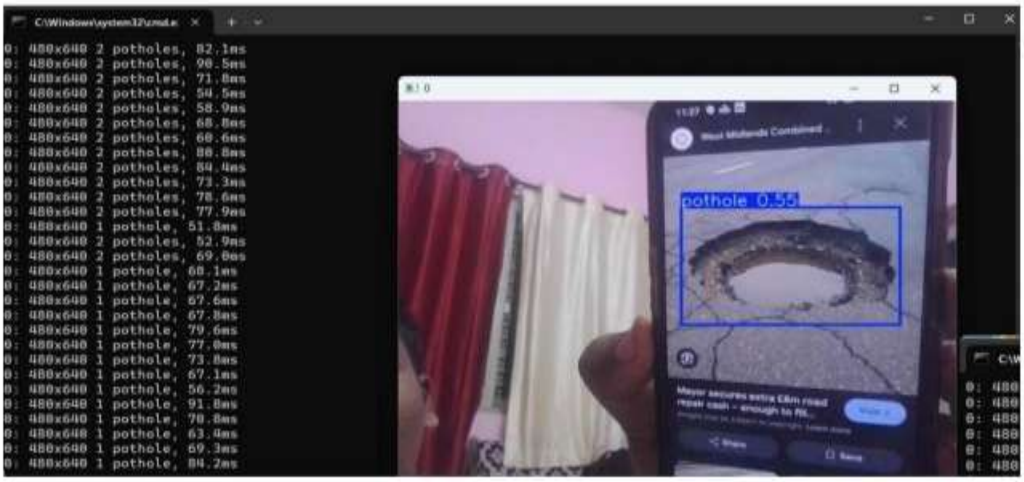

*Fig.2: **Real-time pothole detection output generated by the YOLOv8n model***

RESULT AND DISCUSSION

The pothole detection system was evaluated in three stages: model training, sample images and real-time monitoring by capturing the feed through a webcam. The results prove that the YOLOv8n model is capable of detecting potholes with high performance considering it runs well on general CUP and commodity hardware.

Training results

The YOLOv8n model system was trained for 50 epochs using the annotated pothole data-set. The training curves produced by the system display monotonically decrease in both train and validation loss, demonstrating robust convergence of the model. Both the precision, recall and map increased gradually per epoch, it indicated the pothole feature was learned effectively. The results. Png':fileName that is output from YOLO framework the metrics are captured on the visualized. Png file and testify to this perfect model comparison of accuracy generalization. This demonstrate that even our relatively light-weight YOLOv8n is able to learn interaction road textures and non-smooth pothole boundaries.

Detection on static test images

After training,the model was tested on unseen road images to assess its robustness. The system successfully detected potholes varying shapes, sizes and surface textures. Bounding boxes were generated with high confidence scores, usually above 0.80, indicating strong reliability in detection. Sample test images show that the model can distinguish potholes from cracks, shadows, and road patches, although extreme lighting conditions occasionally affected performance. The detection outputs were saved automatically into the runs/detect/predict directory, providing a visual record of results. These findings confirm that the model generalizes well to new data beyond the training set.

*Fig(3)&(4): **Pothole detection on test image showing bounding boxes and confidence scores***

Real-time detection results

To evaluate practical applicability, the model was connected to a live webcam stream. The system processed each incoming frame and displayed detection live with very low delay, despite operating on a CPU-based laptop. Whenever a pothole was detected, the corresponding frame was automatically saved. This demonstrates that the system can be deployed in real scenarios such as vehicle mounted cameras or roadside monitoring units. Real-time tests show that YOLOv8n maintains stable performance across continuous video input, making it suitable for real time road inspection tasks.

DISCUSSION

The study demonstrates that the proposed system is capable of accurately detecting pothole in both images and video footage. The YOLOv8-based model used in this research is computationally efficient and does not require specialized hardware, making it lightweight and cost-effective for practical deployment. Detected potholes are automatically recorded with timestamps providing valuable information for maintenance teams and enabling further offline analysis. However, the system's effectiveness decreases in low light conditions or when dealing with very narrow or subtle potholes. Further improvements could involve enlarging the data-set, employing more advanced prepossessing methods, or incorporating additional techniques such as depth estimation to enhance detection accuracy and reliability. Overall, the experimental results suggest that the system is practical and effective for automated monitoring of road conditions and can contribute to smart city infrastructure projects.

CONCLUSION

the results of this study demonstrate that combining YOLOv8 with suitable image processing techniques leads to an efficient and reliable pothole detection system. The model successfully identifies potholes from both static images and real-time video streams with consistent accuracy. The proposed approach reduces manual inspection time, supports maintenance teams in making informed decisions, and contributes to the development of intelligent road monitoring solutions for smart city applications.

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