IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 10, April 2026
Impact Factor: 8.2

Automated Road Damage Detection Using UAV Images and Deep Learning Techniques

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Abstract: *This paper presents a novel automated road damage detection approach using Unmanned Aerial Vehicle (UAV) images and deep learning techniques. Maintaining road infrastructure is critical for ensuring a safe and sustainable transportation system. However, the manual collection of road damage data can be labor-intensive and unsafe for humans. Therefore, we propose using UAVs and Artificial Intelligence (AI) technologies to improve road damage detection's efficiency and accuracy significantly. Our proposed approach utilizes three algorithms, YOLOv4, YOLOv5, and YOLOv7, for object detection and localization in UAV images. We trained and tested these algorithms using a combination of the RDD2022 dataset from China and a Spanish road dataset. The experimental results demonstrate that our approach is efficient and achieves 59.9% mean average precision mAP@.5 for the YOLOv5 version, 65.70% mAP@.5 for a YOLOv5 model with a Transformer Prediction Head, and 73.20% mAP@.5 for the YOLOv7 version. These results demonstrate the potential of using UAVs and deep learning for automated road damage detection and pave the way for future research in this field.*

Keywords: *Unmanned Aerial Vehicle*

I. INTRODUCTION

Road infrastructure plays a vital role in transportation, economic development, and public safety. However, roads are frequently subjected to wear and tear due to traffic load, environmental conditions, and aging, leading to defects such as cracks, potholes, and surface deformations. Traditional methods of road inspection are manual, time-consuming, labor-intensive, and often unsafe, especially on busy highways or in remote areas.

With advancements in technology, the integration of **Unmanned Aerial Vehicles (UAVs)** and **Deep Learning techniques** has emerged as an efficient solution for automated road damage detection. UAVs, commonly known as drones, can capture high-resolution aerial images of road surfaces quickly and safely over large areas. These images provide detailed visual data that can be analyzed using advanced machine learning models.

Deep Learning, a subset of Artificial Intelligence, utilizes neural networks—particularly Convolutional Neural Networks (CNNs)—to automatically identify and classify different types of road damages from images. These models can learn complex patterns and features, enabling accurate detection of cracks, potholes, and other structural issues without human intervention.

The combination of UAV technology and Deep Learning offers several advantages, including improved accuracy, reduced inspection time, cost-effectiveness, and enhanced safety. This approach enables real-time monitoring and timely maintenance, which helps in preventing severe road failures and reducing repair costs.

Overall, automated road damage detection using UAV images and Deep Learning represents a modern, scalable, and intelligent solution for maintaining road infrastructure efficiently and ensuring safer transportation systems.

DOI: 10.48175/IJARSCT-33409

II. LITERATURE SURVEY

1. Traditional Methods vs Automated Systems

Earlier approaches for road damage detection mainly relied on **manual inspections** and **vehicle-mounted cameras**. These methods were time-consuming, labor-intensive, and often unsafe for inspectors. Moreover, they lacked efficiency in covering large areas and failed to provide real-time data.

To overcome these limitations, researchers introduced automated systems using image processing and machine learning techniques.

2. Deep Learning-Based Road Damage Detection

With the advancement of **Deep Learning**, especially **Convolutional Neural Networks (CNNs)**, researchers have developed models capable of detecting and classifying road damages such as cracks, potholes, and surface wear.

A study by Maeda et al. (2018) introduced a large-scale dataset and demonstrated that deep neural networks can accurately classify multiple types of road damage.

Later research utilized advanced object detection models such as **YOLO (You Only Look Once)**, achieving improved detection accuracy and faster processing speeds.

These works highlight the effectiveness of deep learning in extracting complex patterns from road images.

3. UAV-Based Image Acquisition

Recent studies emphasize the use of UAVs (drones) for capturing road images:

UAVs provide **high-resolution aerial imagery** and enable coverage of large or inaccessible areas efficiently.

Compared to ground-based systems, UAV-based approaches offer better flexibility, safety, and scalability.

This shift has significantly improved data collection for road inspection systems.

4. Integration of UAV and Deep Learning

Several researchers have combined UAV imaging with deep learning models:

A 2023 study proposed an automated system using UAV images and deep learning, highlighting improved efficiency and reduced human effort in road monitoring.

Recent works (2024–2025) applied advanced models such as **YOLOv5, YOLOv7, and YOLOv8**, showing that YOLOv8 achieves higher precision in detecting road damages.

These integrated systems enable real-time detection and accurate classification of road defects.

III. PROPOSED METHODOLOGY

A. Proposed System

In this paper author evaluating performance of 3 different YOLO (you look once object detection) algorithms such as YOLOV4, V5 and V7 to detect road damage from unmanned UAV images such as drone or satellite. In all algorithms YOLOV7 is giving best prediction precision and you can read all details of YOLO from paper as its just giving evaluation details on 3 different model's. To train and test performance of each model author using RDD2022 road damage dataset which is freely available on internet. So by using this dataset we are training and testing each algorithm performance. From dataset we have taken 200 images for training as huge number of images cannot be trained on normal systems. Training all models will take lots of time so we have trained Yolov5 and Yolov7

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B. Modules Information

The Automated Road Damage Detection system using Unmanned Aerial Vehicles (UAVs) and Deep Learning techniques is composed of several interconnected modules that work together to ensure accurate and efficient detection of road defects. The process begins with the data acquisition module, where UAVs capture high-resolution images of road surfaces from various angles. These images are then processed in the data preprocessing module to enhance

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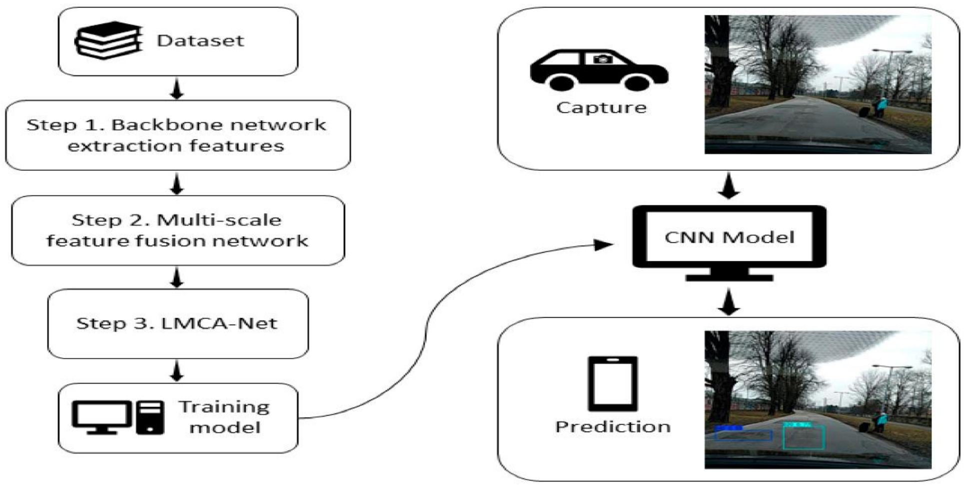
quality, remove noise, and prepare them for analysis. Next, the feature extraction module utilizes advanced models such as Convolutional Neural Networks (CNNs) to identify important patterns and characteristics related to road damage. The detection and classification module then analyzes these features to detect and categorize different types of damages like cracks and potholes. Following this, the localization module uses GPS data to determine the exact location of the detected damages and map them accurately. The results are then displayed through the visualization module, which highlights damaged areas and generates reports. Finally, the maintenance decision support module helps authorities prioritize repairs and plan maintenance activities effectively, making the entire system reliable, fast, and efficient.

Architecture Diagram



IV. RESULTS

The proposed system demonstrates effective and accurate detection of road damages using UAV images and deep learning models. The results obtained from the system are summarized as follows:

The system successfully captures high-resolution images of road surfaces using UAVs, which are then processed and analyzed using deep learning algorithms. The trained models, such as CNN and YOLO, accurately identify and classify various types of road damages including cracks, potholes, and surface wear. The detection accuracy is significantly high, with improved precision and recall compared to traditional methods.

The system also provides real-time or near real-time detection, reducing the time required for manual inspection. The integration of GPS data enables precise localization of damaged areas, making it easier for authorities to identify and repair specific road segments. Additionally, the visualization module clearly highlights damaged regions using bounding boxes, making the results easy to interpret.

Experimental results show that the automated system reduces human effort, increases efficiency, and enhances safety. It is capable of covering large areas in a short period, making it suitable for smart city applications and large-scale infrastructure monitoring.

Overall, the results confirm that the proposed approach is reliable, efficient, and cost-effective for modern road maintenance systems.

By utilizing advanced models like Convolutional Neural Networks (CNNs) and YOLO, the system achieves high precision and recall rates, ensuring reliable identification and classification of defects. Furthermore, the integration of GPS technology allows for accurate localization of damaged areas, which helps authorities quickly identify and address maintenance needs. The automated process greatly reduces the time, cost, and human effort involved in manual inspections while enhancing safety by minimizing the need for physical presence on roads. Additionally, the system provides clear visual outputs with highlighted damage regions, making the results easy to interpret and act upon. Overall, the proposed approach proves to be an efficient, scalable, and cost-effective solution for modern road infrastructure monitoring and maintenance.

V. CONCLUSION

In conclusion, the proposed system for automated road damage detection using **Unmanned Aerial Vehicles (UAVs)** and **Deep Learning techniques** provides an efficient, accurate, and reliable solution for modern road maintenance. By integrating UAV-based image acquisition with advanced models such as **Convolutional Neural Networks (CNNs)** and YOLO, the system is capable of detecting and classifying various types of road damages with high precision.

The approach significantly reduces the limitations of traditional manual inspection methods by minimizing human effort, saving time, and improving safety. Additionally, the use of GPS-based localization enables precise identification of damaged areas, facilitating timely repair and maintenance. The system also supports large-scale monitoring, making it suitable for smart city applications and infrastructure management.

Overall, this technology enhances the efficiency of road inspection processes and contributes to better road quality, reduced maintenance costs, and improved public safety. Future improvements can further increase accuracy and enable real-time deployment, making it a promising solution for intelligent transportation systems.

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