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Department of Built Environment Studies and Technology, College of Built Environment, UiTM Perak Branch

Co-organiser :

INSPIRED 2024. Office of Research, Industrial Linkages, Community & Alumni (PJIMA), UiTM Perak Branch

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POTHOLE DETECTION USING UAV WITH DEEP LEARNING ALGORITHM FOR ROAD INSPECTION

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Abstract
Pothole detection is a crucial component of road maintenance, essential for ensuring safety and minimizing vehicle damage. Traditional road inspection methods are often limited by their coverage, labor-intensive nature, and time-consuming processes. This paper presents an innovative approach to pothole detection by utilizing Unmanned Aerial Vehicles (UAVs) in combination with a Convolutional Neural Network (CNN) algorithm. The primary aim of this study is to evaluate the effectiveness of the CNN algorithm in detecting road potholes. The results indicate a high level of detection confidence, demonstrating that UAVs operating at low altitudes can accurately capture orthophotos for pothole identification. The pothole detection model achieved a precision of 0.437, a recall of 0.800, and a mean average precision (mAP) of 0.740, highlighting its accuracy and reliability. The study concludes that while UAVs integrated with artificial intelligence show promise for effective pothole detection, low-altitude flights present practical challenges due to environmental factors. Despite these limitations, the combination of UAVs and CNNs offers a viable solution for enhancing road inspection efficiency and accuracy.

Keywords: *Pothole detection, Convolutional Neural Networks, AI-based methods, Real-time detection.*

1. INTRODUCTION

Pothole detection is essential for road safety and infrastructure maintenance. Traditional methods of road inspection have limitations in coverage and efficiency. To overcome these challenges, integrating Unmanned Aerial Vehicles (UAVs) with deep learning algorithms, specifically Convolutional Neural Networks (CNNs), has emerged as a promising approach for accurate and efficient pothole detection. By utilizing UAVs equipped with high-resolution cameras and deep learning algorithms, road authorities can enhance their ability to detect and assess road anomalies such as potholes in a timely and cost-effective manner. Traditional road inspection methods include manual notifications through mobile apps, computer vision-based techniques, and sensor systems. A basic approach involves using smartphone apps to photograph potholes and send images and locations to authorities, but automated detection is more efficient, reducing reliance on manual reporting (Aparna et al., 2022). Timely maintenance is essential to prevent severe and costly road damage, as deterioration can worsen under traffic and weather conditions. Predictive maintenance strategies, highlighted by Hassan et al. (2023), focus on early interventions to reduce costs and extend road life. Ground data collection often uses motorcycles with GoPro cameras and GPS to capture and georeferenced road conditions, aiding in effective repair prioritization (THB Maintenance Sdn. Bhd., 2024).

Recent studies have demonstrated the effectiveness of combining UAVs with deep learning algorithms, particularly CNNs, for pothole detection. For instance, a study by Ozoglu (2023) successfully detected road potholes with an accuracy ranging from 80% to 87% using a CNN

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method based on road vibration data. Additionally, Sharif (2023) proposed a pothole crack detection model based on CNNs optimized with K-fold cross-validation, achieving high precision and recall rates in identifying potholes. The potential of using Unmanned Aerial Vehicles (UAVs) for leveraging their ability to cover large areas and capture high-resolution images. Nomqupu (2024) enhanced detection accuracy by combining sigmoid calibration and entropy thresholding on multispectral imagery, finding that adjusting UAV radiometric properties improves results, particularly using the red channel.

2. RESULTS AND DISCUSSION

2.1 Pothole Detection on Orthophoto

The study highlighted significant in pothole detection accuracy using UAV- orthophoto images. From recent study, ground-level camera images achieved a higher detection confidence of 90%, attributed to their optimal angles and high resolution, providing detailed and clear views of road surfaces. This clarity enhanced the model's ability to accurately identify potholes. Conversely, UAV orthophoto images exhibited a slightly lower detection confidence of 82%. This decrease in accuracy was primarily due to the reduced resolution and increased noise inherent in images captured from higher altitudes, as well as perspective distortions that complicated the detection process. Environmental conditions, such as variable lighting and shadows, further impacted the clarity of UAV images.

Additionally, the model's training primarily on ground-level images may have limited its effectiveness when applied to aerial imagery. Despite these challenges, the 82% detection confidence of orthophotos is still within an acceptable range for many applications. This finding underscores that the choice of the most suitable accuracy for pothole detection depends on specific application requirements, with some systems achieving high accuracies above 95% and others providing acceptable results in the range of 86-94% (Fan et al., 2020). The comparative results are detailed in Figure 2 and Table 4 below.

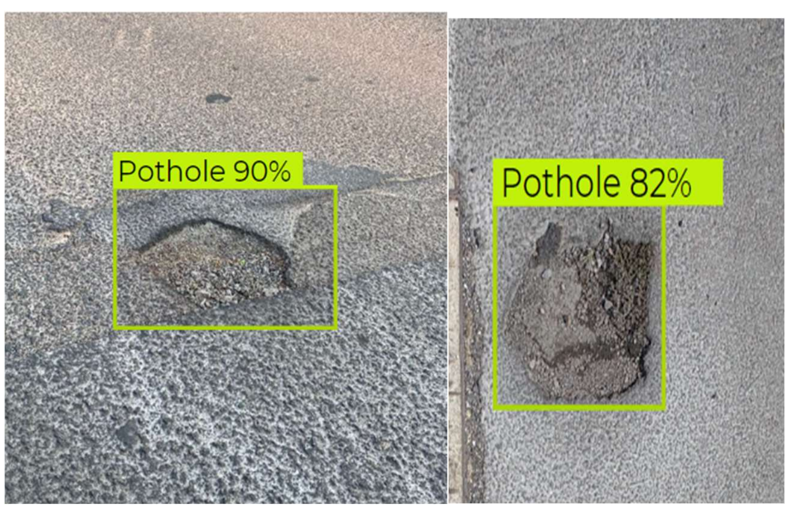

Figure 4: Result 1 pothole detection on camera image and orthophoto

Table 4. Result 1 of confidence detection between camera image and orthophoto

Method	Confidence (%)
Camera image	0.900
Orthophoto	0.820

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Based on Figure 5 and Table 5, when analysed another image of potholes, the results showed a clear distinction in detection confidence between the camera images and the orthophoto images. The camera images achieved a confidence level of 72%, indicating a relatively high level of certainty in identifying the pothole present in the image. This suggests that the camera images, with their focused and detailed perspective, provided clearer and more reliable information for the model to process, enabling it to detect the pothole with greater confidence. On the other hand, the orthophoto images obtained significantly lower confidence levels of 47% and 26%. Despite these lower confidence percentages, the orthophoto images were able to identify two potholes within the broader area they covered. This capability highlights the strength of orthophotos in providing comprehensive coverage, which allows for the detection of multiple road surface anomalies that may be spread across a larger area. However, the lower confidence levels suggest that the orthophotos, while useful for broader surveys, may not provide the same level of detail and clarity as the camera images for pinpointing individual potholes.

Figure 5: Result 2 pothole detection on camera image and orthophoto

Table 5: Result 2 of confidence detection between camera image and orthophoto

Method	Confidence (%)
Camera image	0.720
Orthophoto	0.470, 0.260

2.2 Accuracy of Detection on Orthophoto from Different Height

The study evaluated the accuracy of pothole detection using UAV orthophotos captured at various altitudes, uncovering significant variations in performance across different heights. At a low altitude of 5 meters, the detection accuracy was notably high, achieving an 85% success rate. This can be attributed to the optimal image resolution and detail that low-altitude images provide, allowing for precise identification of potholes. However, as the altitude increased, detection accuracy decreased sharply: falling to 51% at 10 meters, 42% at 15 meters, and dropping dramatically to just 9% at 20 meters. An improvement was observed at 25 meters with accuracy slightly rising to 46%, but at 30 meters, the process encountered significant errors, highlighting the challenges in detecting potholes accurately at higher altitudes.

These results underscore the importance of capturing images at lower altitudes (5-15 meters) to maintain high image quality and detail, which are crucial for accurate pothole detection.

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However, for practical reasons, operating UAVs at such low altitudes may not always be feasible. Low-altitude flights can pose risks such as collisions with obstacles like trees, buildings, and utility poles, and they can also disrupt traffic or pedestrians if flown over roads. Additionally, maintaining consistent low-altitude flight paths over long distances can be challenging due to varying terrain and environmental conditions. Therefore, while lower altitudes provide the best conditions for image clarity and detection accuracy, UAVs may need to balance altitude with safety and logistical considerations. This implies that UAV deployment strategies should be carefully planned, possibly integrating data from various altitudes and employing advanced image processing techniques to compensate for the reduced detail at higher altitudes. This balanced approach aims to leverage UAV technology effectively for pothole detection, ensuring both accuracy and practicality in road maintenance operations

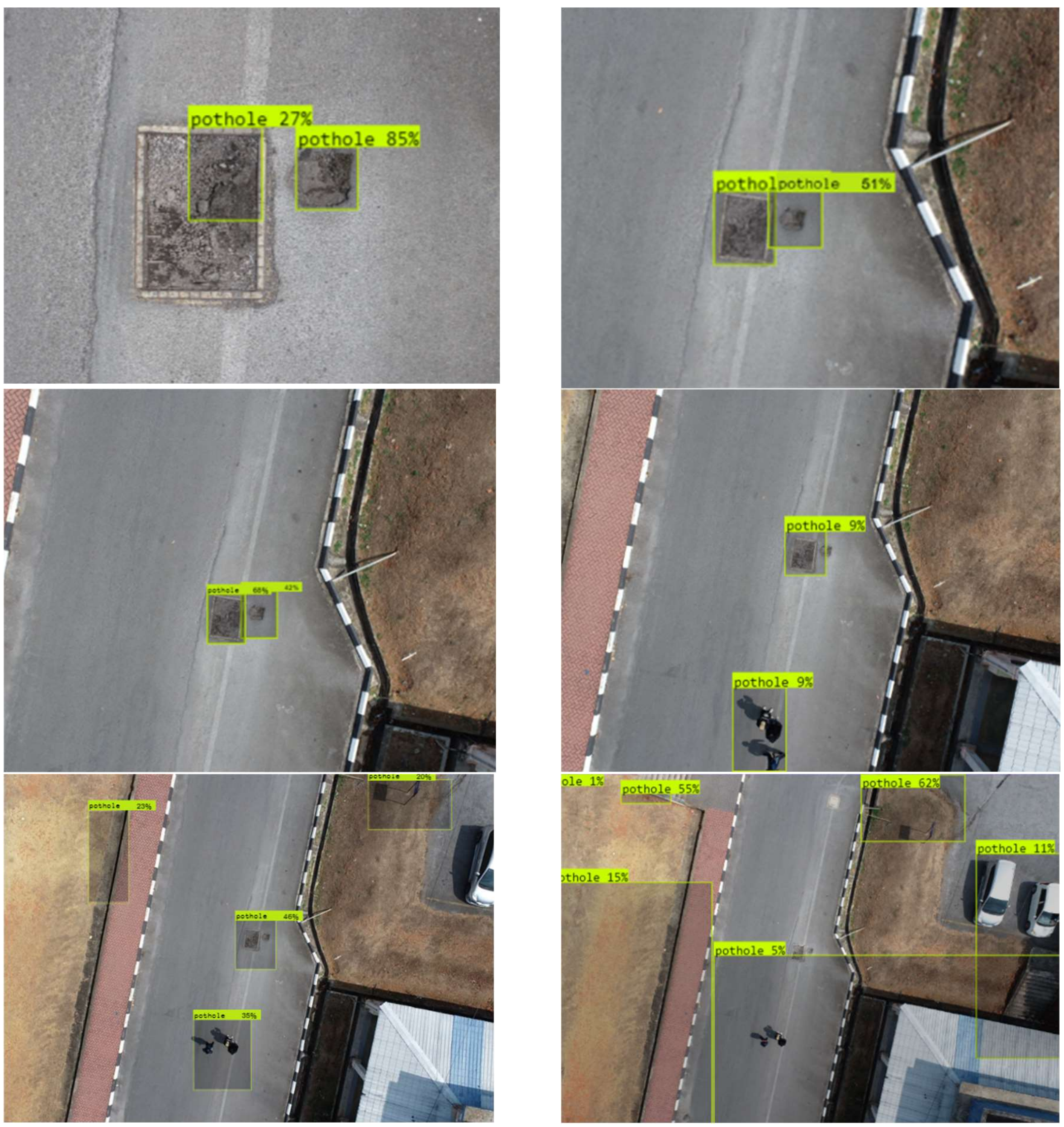

Figure 6: Pothole detection on orthophoto from different altitude

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Table 6: Result of confidence detection on orthophoto with different altitude

Height (m)	Confidence (%)
5	0.850
10	0.510
15	0.420
20	0.090
25	0.460 and Error
30	Error

2.3 Accuracy of Model Training

The pothole detection model demonstrated a high recall rate of 80%, indicating its effectiveness in identifying most of the potholes present in the images. This high recall suggests that the model was highly sensitive and capable of detecting a significant portion of road surface defects, which is crucial for ensuring comprehensive road safety and maintenance. However, the model's precision was 43.7%, which reveals a tendency to generate a considerable number of false positives by incorrectly classifying non-pothole features as potholes. This issue could stem from the model's sensitivity; while it is beneficial for capturing most potholes, it can also lead to over-detection and misclassification of other road surface irregularities as potholes.

The mean average precision (mAP) of 74% reflects a strong overall performance, balancing the trade-offs between precision and recall. The mAP score suggests that the model is generally effective in its detection tasks, capturing a wide range of potholes while maintaining a decent level of accuracy. However, there is room for improvement, particularly in increasing precision to reduce the number of false positives and thereby improving the reliability of the detection system.

Table 7: The confusion matrix of pothole detection model

Model	Precision	Recall	mAP
Pothole Detection	0.437	0.800	0.740

3 CONCLUSION

In conclusion, this research demonstrates that camera images achieve higher accuracy in pothole detection than orthophoto images captured by Unmanned Aerial Vehicles (UAVs), due to the ability to adjust camera height and angle for optimal perspective. While UAVs offer extensive area coverage, their effectiveness is limited by the challenges of capturing high-resolution images at low altitudes, where environmental conditions and regulatory constraints pose significant operational barriers. Convolutional Neural Network (CNN) algorithms prove effective for both camera and UAV images, though the study highlights a critical limitation in the dataset, which lacks sufficient pothole images to ensure robust model performance across diverse scenarios. Expanding this dataset is essential to improve detection accuracy and model reliability.

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The findings emphasize a trade-off between the precision of camera images and the broader coverage of UAVs, suggesting that camera images are preferable for accuracy, whereas UAVs are better suited for large-area surveys. Future advancements in UAV technology and image processing, coupled with a more comprehensive training dataset, could enhance the role of UAVs in pothole detection. Thus, optimizing detection strategies requires balancing these strengths and limitations to meet road maintenance needs effectively in real-world conditions.

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5 REFERENCES

Ali, Dana Mohammed, and Haval A.Sadeq. "Road Pothole Detection Using Unmanned Aerial Vehicle Imagery and Deep Learning Technique." Zanco Journal of Pure and Applied Sciences, vol. 34, no. 6, 20 Dec. 2022,pp.107–115, zancojournal.su.edu.krd/index.php/JPAS (2022).

Aparna, et al. "Convolutional Neural Networks Based Potholes Detection Using Thermal Imaging." Journal of King Saud University Computer and Information Sciences, vol. 34, no. 3, 2022, pp. 578–588, www.sciencedirect.com/science/article/pii/S1319157818312837, https://doi.org/10.1016/j.jksuci.2019.02.004 (2022).

Farhad Samadzadegan, et al. "Automatic Road Crack Recognition Based on Deep Learning Networks from UAV Imagery." ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. X-4/W1-2022, no. IV, 14 Jan. 2023, pp. 685–690, https://doi.org/10.5194/isprs-annals-x-4-w1-2022-685-2023 (2023).

Maeda, Hiroya, et al. "Road Damage Detection and Classification Using Deep Neural Networks with Smartphone Images." ComputerAided Civil and Infrastructure Engineering, vol. 33(12), no. 1127-1141, 2018, https://doi.org/10.1111/mice.12387 (2018)

Nomqupu, Sandisiwe, et al. "Integrating Sigmoid Calibration Function into Entropy Thresholding Segmentation for Enhanced Recognition of Potholes Imaged Using a UAV Multispectral Sensor." Applied Sciences, vol. 14, no. 7, 22 Mar. 2024, p. 2670, mdpi-res.com/applsci/applsci-14-02670/article_deploy/applsci-14-02670.pdf?version=1711080388, https://doi.org/10.3390/app14072670 (2024).

Ozoglu, F. and Gökgöz, T. Detection of road potholes by applying convolutional neural network method based on road vibration data. Sensors, 23(22), 9023. https://doi.org/10.3390/s23229023 (2023).

Sharif, M. S., Emiola, D. I., Zorto, A., & Apeagyei, A. Utilising convolutional neural networks for pavement distress classification and detection. 2023 International Conference on Innovation and Intelligence for Informatics, Computing, and Technologies (3ICT). https://doi.org/10.1109/3ict60104.2023.10391401 (2023).

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