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Improving detection of asphalt distresses with deep learning-based diffusion model for intelligent road maintenance

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ABSTRACT

Research on road infrastructure structural health monitoring is critical due to the increasing problem of deteriorated conditions. The traditional approach to pavement distress detection relies on human-based visual recognition, a time-consuming and labor-intensive method. While Deep Learning-based computer vision systems are the most promising approach, they face the challenges of reduced performance due to the scarcity of labeled data due, high annotation costs misaligned with engineering applications, and limited instances of minority defects. This paper introduces a novel generative diffusion model for data augmentation, creating synthetic images of rare defects. It also investigates methods to enhance image quality and reduce production time. Compared to Generative Adversarial Networks, the optimal configuration excels in reliability, quality and diversity. After incorporating synthetic images into the training of our pavement distress detector, YOLOv5, its mean average precision has been enhanced. This computer-aided system enhances recognition and labelling efficiency, promoting intelligent maintenance and repairs.

1. Introduction

Monitoring and evaluating pavement health status based on road surface distresses is vital for civil engineers to establish necessary maintenance, thereby guaranteeing public transportation safety (Hou et al., 2021), (Lee et al., 2022a). Also, road infrastructure is crucial for economic growth, enabling investment, supply chains, and efficient, accessible, and reliable nationwide mobility, contributing to poverty reduction (Sarmiento, 2021). The deterioration of road surfaces can rapidly intensify due to the effects of heavy traffic, material aging, and severe changes in the environment (Ai et al., 2023). Traditional inspection, which involves expert engineers manually recording and assessing pavement conditions for safety and functionality, is becoming less prevalent due to its time-consuming, labor-intensive, and expensive nature (Chu et al., 2022). Another more modern approach involves the use of sophisticated data collection vehicles with automatic algorithms, but their acquisition and operation costs are extremely expensive, often exceeding the limited budgets of road maintenance administrations (Majidifard et al., 2020). Additionally, the acceleration of road infrastructure development underscores a pressing need of research.

Given these points, the widespread adoption of deep learning-based non-intrusive computer vision techniques for automatic pavement distress recognition has led to a significant surge due to the beneficial impact on road agencies, road users (Sun et al., 2020) and the environment (Xu et al., 2021a). Computer Vision systems based on Deep Learning can provide enriched information to achieve a high-level understanding of objects and events present in a scene, including automated post-construction quality assessment for defects in road inspection using visual data (Luo et al., 2022). These vision-based systems are incorporated as a recognition engine in GIS-like tools. Geotagged road images are uploaded, passed through the model to obtain detections and distress types, and represented, even with other pavement condition indices, maintenance budgets, etc. These innovative tools enable the design of strategic roads maintenance plan, offering enhanced pavement serviceability with lower fuel consumption, reduced traffic congestion, greater safety and a lower carbon footprint due to prompt conservation actions, respectively. The establishment of automated testing tools will not only ensure efficient maintenance management, timely fault detection, and optimal facility utilization, but will also lead to a reduced requirement for human resources. Automated computer-aided approaches for Structural Health Monitoring are also used in other fields, such as the recognition of defects in bridges from

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