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Entitled

AUTOMATION OF CRACK DETECTION AND QUANTIFICATION IN CIVIL INFRASTRUCTURE FACILITIES USING DEEP LEARNING TECHNIQUES

by

Luqman Ali

Faculty Advisor

Dr. Fady Alnajjar

College of Information Technology

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Abstract

Cracks are the earliest signs of structural deterioration that reduce the lifespan and reliability of structures and can lead to severe damage. Assessment and monitoring of the facilities are required for lifetime maintenance and failure prediction. Structure condition information can be obtained manually, i.e., through subjective visual inspection and evaluation by human experts. Manual inspection techniques are labor-intensive, time-consuming, and inspector-dependent, i.e., vulnerable to the inspector's perceptiveness. Automatic crack detection is crucial at the earliest stage to avoid further structure degradation and allow fast intervention. Deep Learning algorithms have become more popular in crack detection systems in recent years. However, many challenges are associated with the development of Deep Learning based crack detection and segmentation systems. Some of the limitations and challenges include the deployment of DL models on devices with limited computational resources, availability of public datasets, selection of optimum dataset size, the impact of parameters such as variance within data samples, network depth, and the required number of training epochs on the performance of the model. Additionally, improving the performance of DL-based crack detection and segmentation approaches presents an added complexity, particularly when integrating them with various modules. Moreover, achieving efficient segmentation of cracks and evaluating their severity based on their quantity poses an additional challenge. Therefore, to address these challenges, we developed various lightweight and optimized novel DL models for crack classification, localization, and segmentation tasks. Furthermore, we investigated how data and model parameters affect the performance of the models. The crack classification and localization performance of the DL was enhanced by exploring ensemble modeling and its integration with traditional classifiers. Additionally, we introduced two novel architectures for crack segmentation tasks, one utilizing ViT (Vision Transformer) blended with a Sliding Window and Tubularity Flow Field (TuFF) algorithm and the other built upon U-Net, which we have named RS-Net. The proposed RS-Net architecture was also integrated with various morphological operations to assess the severity of cracks and categorize them into hairline, medium, and severe labels based on their respective width. The proposed models were trained by utilizing both publicly available datasets and custom datasets collected from concrete and pavement structures. Extensive Experimental results demonstrated that the proposed models have promising performance, outperforming earlier models on testing data for crack classification, localization, and segmentation with a promising accuracy (>0.97). Overall, the proposed research has significant potential to automate traditional inspection techniques and help the authorities to make well-informed decisions about the maintenance of the structures.

Keywords: Crack Detection, Structural Health Monitoring, Deep Learning, Computer Vision, Machine Learning, Crack Quantification, Severity Assessment.