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트랜스포머 기반 딥러닝 기법을 통한 건물 구성요소의 건강상태에 따른 자동화된 구조품질 분류

Automated Structural Quality Classification Based On Health Condition Of Building Components Via Transformer-Based Deep Learning Approach

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Abstract

Currently, the practice of computer vision in structural maintenance of buildings still mainly focuses on damage detection, which is not directly available for inspection process reports. Therefore, in this work, we propose an automated framework for the structural health status of building components. There are two models. First, a multi-damage detection module and a status classification based on the detected features are followed. Transformer architecture is also adopted to investigate the performance on new CNNs. The results are expected to show the outstanding performance of the proposed model over existing CNN-based models and provide an efficient procedure for structural quality evaluation.

키워드 : 딥러닝, 스마트 유지보수, 구조적 상태 모니터링, 트랜스포머
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1. Introduction

Regular inspection of structural elements is crucial to maintain serviceability and durability from deterioration. The current practices of manual inspection are performed by quality assurance workers, which is labor-intensive, time-consuming, and prone to error [1]. Furthermore, unobvious, or tiny defects are easily neglected by conventional inspection, which can pose severe destruction later on. Not to mention for large-scale projects, a long-term inspection can lead to inspector fatigue and lower the process accuracy. In an attemptto address these drawbacks of conventional inspection, the trend of computer vision-based methodology in automated structural inspection has been arising in the last decades. Several studies have shown great success of the deep learning approach and outperformed all of the traditional models of morphological or machine learning tasks.

However, the current automatic defect inspection tasks deploy common convolution-based models for local surface defects, typically generating predefined simple semantic labels of single words or phrases of the damage types [2], [5]. These outcomes can not be directly used for decision-making on the overall performance of infrastructure since it is difficult to accurately evaluate based on simple damage classification labels or segmentation. Instead, the critical condition assessment of structural components to evaluate the deterioration level remains an insufficient research field.

To resolve these problems, a transformer-based architecture for detecting damages and classifying the health condition of the structure is proposed in this study. The feasibility of the proposed method consists of two sequential modules and shows efficient detection of multi-damages and assessment of structural serviceability to leverage the implementation of advanced deep learning techniques in structural health monitoring practices.

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2. Methodology

2.1 Transformer-based structural quality model

In this study, we propose a sophisticated two-stage architecture employing Transformer networks for the purpose of damage detection and condition classification in apartment buildings. The Transformer architecture represents a stack of self-attention networks, departing from traditional models such as Convolutional Neural Networks (CNNs) or recurrent neural networks. It exclusively incorporates the self-attention mechanism, reducing computational complexity without compromising experimental outcomes. Illustrated in Figure 1, the Transformer consists of both an encoder and a decoder.

In the initial stage, leveraging a Transformer-based damage detection model, detection stage exploits the attention mechanisms of Transformer networks to capture intricate patterns associated with various types of damages. Following the damage detection phase, the identified damages are then subjected to a Transformer-based condition classification network. This network is specifically designed to categorize the detected damages into different structural conditions, providing valuable insights into the severity and nature of the identified issues. The attention mechanisms in the Transformer facilitate a nuanced understanding of the contextual information surroundingeach damage, aiding in accurate condition classification. By employing a two-stage approach, our Transformer-based architecture is comprehensively investigated in both detecting damages within apartment buildings and the task of condition classification.

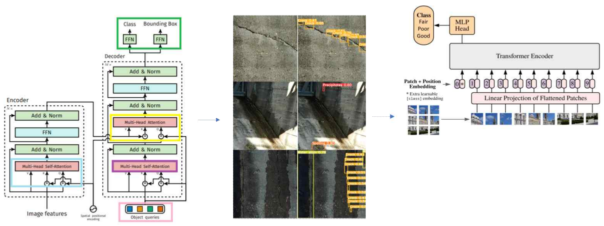

Figure 1. The architecture of the transformer-based quality assessment of component buildings.

2.2 Model implementation

In this study, CODEBRIM (COncrete DEfect BRidge IMage Dataset) for multi-target multi-class concrete defect classification was used to train our model [3]. In addition, the model was pre-trained on the Microsoft Common Objects in Context (COCO) dataset was used to initialize the Transformer-based detection network [4]. In our study, we utilized Python language for proposed models and TensorFlow framework as the backend library. In this study, both stages were trained using the Adam W optimizer, a batch size of 8. Evaluation indexes such as accuracy, precision, F1 score and recall are still used to compare the proposed algorithm with CNN-based methods. The loss function of consists of two parts: localization and classification losses.

3. Conclusion

The significance of this proposal lies in its potential to revolutionize the practices of inspection and assessment in apartment building maintenance. Leveraging the capabilities of deep learning, Transformer architecture is expected to facilitates automated and accurate detection of structural components, overcoming the limitations of CNN-based defect detection methods, especially in small perception fields, despite their high accuracy. Additionally, the Transformer-classifier enhances decision-making by providing precise information about the level of deterioration, thereby facilitating targeted maintenance strategies. This approach optimizes resource allocation and mitigates the risks associated with overlooked defects or inadequate maintenance.

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