Automatic Detection of Tunnel Linings Crack and Structural Evaluation with YOLOv11 Deep Learning Framework

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Abstract

This study demonstrates a better method of assessing structural integrity of linings of tunnels by using the YOLOv11deep learning model. There are cracks in underground structures, which form hazards because of their slight morphology [8] and other shallow discontinuities concealed by moisture, stains, low-light or other surface degradation. Early edge detectors such as the Canny or Kirsch usually confuse noise and shallow edges as edges registered, resulting in the spurious output. Conversely, YOLOv11 introduces multi scale feature fusion and better label assignment policy that enables one of the two bodies to be specifically identification of true crack and background in case they are almost similar to each other. The backbone network implies hierarchical visual messages across resolutions of finer edge details to coarser contextual messages, and the neck synthesizes the various representation at the varying degree of hierarchy. This is followed by the introduction of dual prediction heads to set roles on categorical classification and geometric localization on accurate recognition and bounding respectively. The generalization of the model trained in an annotated tunnel image will help minimize false alarms and ensure more confidence in automated monitoring. Being able to do batch-level inference enables the efficient offline inspection pipelines wherein defect maps may be created based on repositories of the raw images to be inspected by engineers. By the concomitant enhancement of accuracy, robustness, and throughput, YOLOv11 offered a strong foundation towards making orders about prioritization of maintenance activities, adaptive rehabilitation measures and management of the infrastructure in the tunnel in a sustainable manner as exhibited in the research paper.

Keywords

Multi-Scale Feature Fusion, YOLOv11 Object Detection Framework, Tunnel Structural Health Monitoring, Tunnel system monitoring, Crack Localization Accuracy, Automated Maintenance priorities, Deep Learning-Based Infrastructure Assessment, Deep Learning-Based Defocusing, and Defect Quantification Algorithms.