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Autonomous Bolt Loosening Monitoring in Steel Structures using CAD-Assisted PointNet Deep Learning

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ABSTRACT

This study presents a novel method for autonomous bolt-loosening monitoring in steel structures using CAD-assisted PointNet deep learning and 3D point cloud processing. A computer-aided design (CAD)-based procedure is developed to generate diverse and well-labelled databanks of steel girder bolt connection for training PointNet segmentation and classification models. The PointNet segmentation model is used for identifying bolts from 3D point cloud, and the PointNet classification models are used for identifying bolt head angles and loosening lengths. The CAD-assisted PointNet models are validated on real-world 3D point clouds of a bolt connection under different loosening conditions. The 3D point clouds are reconstructed using Structure-from-motion (SfM) technique. To enhance the performance of PointNet deep learning, advanced 3D point cloud processing techniques such as plane's normal vector detection, bolt isolation using K-means clustering, and best-fitting rectangle for bolt group identification are introduced. Experimental results demonstrated that the proposed method effectively identify bolt-loosening angles with high accuracy.

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