TIDC Transportation Infrastructure Durability Center AT THE UNIVERSITY OF MAINE

Deep Learning-based Joint Loosening Detection for Infrastructure Components

Yang Zhang, Ting Wang, Jiong Tang
Department of Mechanical Engineering, University of Connecticut

Abstract

The integrity of infrastructure is crucial for ensuring transportation safety and operational efficiency. A critical aspect of this integrity is the reliance on bolt joints as fasteners within components such as railway tracks and bridge segments. These bolt joints are prone to loosening due to harsh working conditions, leading to abnormal structural performance. Thus, bolt loosening can be considered as one damage type. However, it is challenging to relate bolt joint loosening to dynamic responses through first-principle-based models due to the complexity of the interactions involved. To address this issue, this research employs a hybrid methodology that integrates deep learning with active sensing using piezoelectric transducer to monitor the health of bolt joints within the railway track structures. This approach leverages the advanced pattern recognition capabilities of deep learning algorithms, specifically trained to analyze sensor data, to accurately detect and localize bolt joint loosening. Besides, the chirp signal is utilized to facilitate the data acquisition due to its variable frequency and information-rich characteristics that can provide distinct features about detected objects or anomalies. The results on testing datasets show that the proposed framework not only identifies the presence of loosened bolts but also pinpoints their location, facilitating targeted maintenance and repairs. The proposed approach shows promise from engineering perspective for a digital-twin-enabled system that provides for real-time monitoring of the condition of bolt joints in railway tracks, showing ability to perform predictive maintenance, which contributes to increased safety and reliability in railway systems.

Acknowledgements: Funding for this research is provided by the Transportation Infrastructure Durability Center at the University of Maine under grant 69A3551847101 from the U.S. Department of Transportation's University Transportation Centers Program.