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AI-DRIVEN METHOD FOR DETECTION OF TRANSVERSELY IMBALANCED LOADS IN FREIGHT WAGONS USING ON-BOARD SENSORS

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Summary: Abstract: Load distribution on railway freight wagons is a significant challenge. Imbalanced loads across the train's wagons generate uneven stresses on them and, ultimately, increase the risk of derailment during operation. Therefore, efforts to guarantee load balance and detect potential situations of load imbalance in freight wagons are essential to maintain operations and avoid serious incidents. This research study focuses on an unsupervised AI method for detecting transverse load imbalances in railway freight wagons using displacement sensors. To fulfil this, different loading schemes are considered: Scenarios with even load distribution or with transversal imbalances within the values defined by the UIC loading guidelines, which are baseline cases; Scenarios with lateral load shifts exceeding the aforementioned UIC limits, which are the risk cases. Moreover, different rail irregularities and train speeds are taken into account to enhance the representativeness of the scenarios. By simulating time integration analysis in a multibody freight wagon, the vertical distance between each axlebox and bogie frame, on both the left and right sides of the vehicle, is determined using virtual displacement sensors. For feature extraction, Auto Regressive (AR) models are used to transform time series data into alternative information, where the correlation with load imbalances is more easily visible. Afterwards, a Principal Components Analysis (PCA) normalises the features, along with the application of a Mahalanobis distance to perform data fusion. Finally, an outlier analysis allows the features to be disposed above or below the baseline cases, in order to detect lateral imbalanced loads. The preliminary results show effective detection of the transverse imbalanced load scenarios exceeding the normative values.

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