Master of Science in Engineering MSE – Business engineering and Production

Detection of Propagated Mechanical Failures in a Gearbox Using a Classification Model

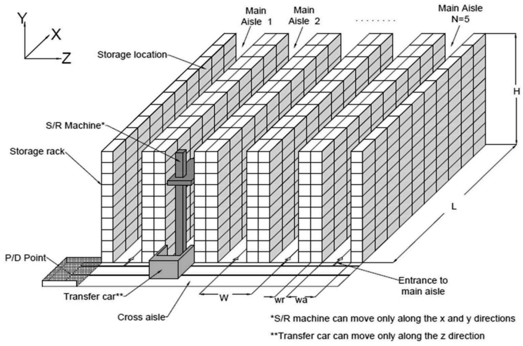

Figure 1: Automated Storage and Retrieval system

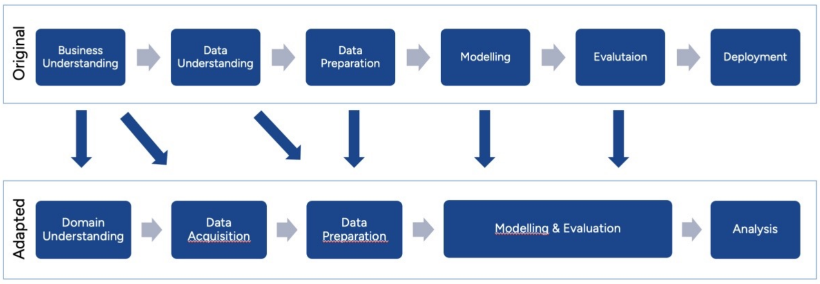

Figure 2: Methodology

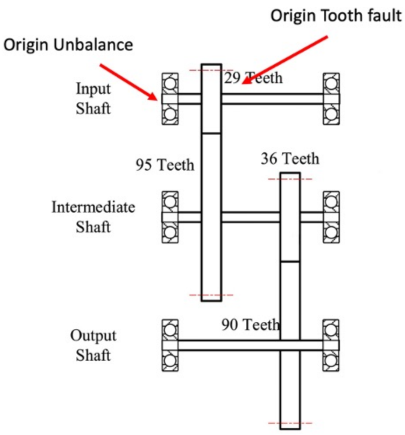

Figure 3: Modelled System

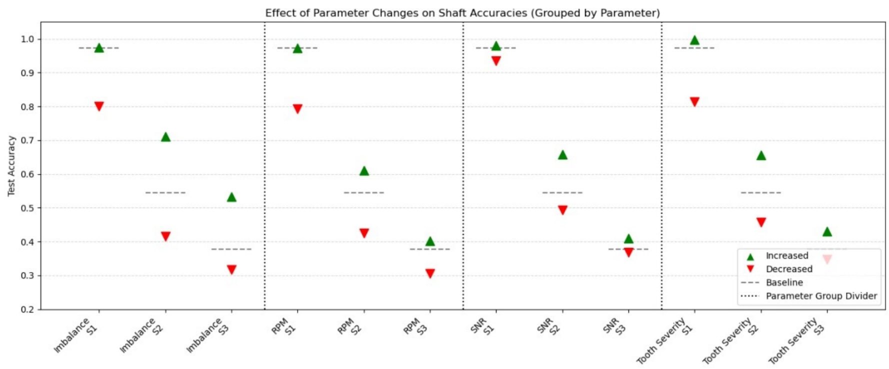

Figure 4: Shaft-wise Accuracy under Varying Operating Conditions

Problem description

The manufacturing of vehicles is increasingly shifting toward electrification, necessitating the development of specialized facilities for the assembly of battery packs for electric vehicles. Within these new assembly sites, automated storage and retrieval systems (Figure 1) constitute critical components for efficient and reliable operations. Failures in critical mechanical structures often occur at locations where sensors cannot be mounted, making detection from remote measurements challenging due to subtle failure signatures. This work addresses this issue using machine learning to capture and interpret weak failure signals. The case study focuses on a gearbox, where vibration analysis was selected as the most effective method for identifying remote failures.

Solution concept

The entire process, from data generation to model evaluation, was structured using an adapted CRISP-DM methodology (Figure 2), ensuring a systematic and reproducible approach.

To evaluate the model's ability to detect remote mechanical failures, a simulated dataset was generated, as real failure cases are rare. The study considered a two-stage gearbox (Figure 3) consisting of three shafts and gears with different tooth counts.

Two fault types were introduced: a tooth defect on the first shaft and an unbalance at the first shaft. Vibrations were then simulated on all three shafts to analyze how the fault effects propagated through the system.

Results

Evaluation of the classification accuracy based on vibration data from the different shafts indicated that the model is generally capable of detecting propagated failures. To explore this capability in greater detail, key operating parameters—such as input shaft speed, failure severity, and noise level—were systematically varied (Figure 4). The analysis showed that the accuracy of detecting remote failures is strongly influenced by these operating conditions as well as by the degree to which failure effects propagate through the mechanical structure. In conclusion, this work has demonstrated a methodology for developing and preparing a classification model suitable for real-world application.

As a next step, the proposed approach should be validated on a physical test setup to ensure that the modeled vibration propagation accurately reflects real-world behavior.

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