Development of Deep Learning Methods for Reducing Computational Cost

A Case Study on Load Capacity Calculations of Crawler Cranes

Graduate

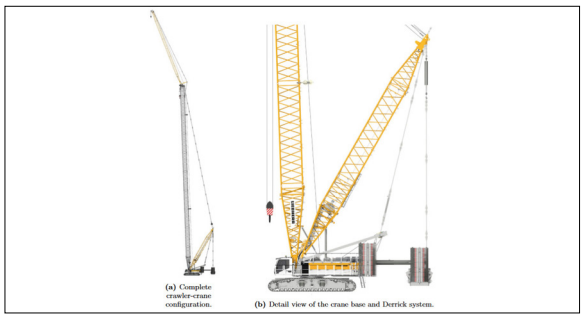
Abraham Nachbaur

Introduction: High-fidelity finite-element simulations are essential for assessing the structural utilization and load-bearing capacity of crawler cranes, but their computational cost limits their application across large load-case spaces. This thesis investigates deep-learning-based multi-fidelity surrogate models for predicting high-fidelity utilization quantities from computationally cheaper low-fidelity simulations. The available data consist of paired low- and high-fidelity simulation results, scalar configuration, load-case descriptors, and graph representations of the reduced crane structure.

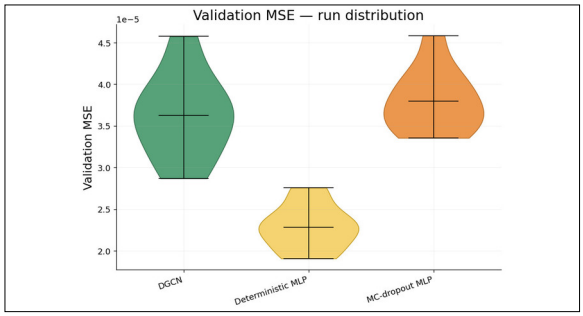
Approach: A tabular multilayer perceptron is established as the main deterministic baseline and compared with uncertainty-aware models based on Monte Carlo Dropout and a Deep Gaussian Covariance Network. Graph Attention Networks are evaluated to determine whether structural connectivity provides additional predictive information, and prediction-level combinations of tabular and graph-based models are investigated. The study further examines the influence of high-fidelity training-set size, uncertainty calibration and rejection, uncertainty-guided sample acquisition, and transfer to a related crane geometry. In addition to standard regression metrics, the evaluation considers tail-oriented and directional errors to account for the safety relevance of underprediction.

Result: The results show that low-fidelity simulation outputs and scalar configuration features contain substantial information about the corresponding high-fidelity response. The tabular model achieves strong average predictive performance, although relevant target-specific and worst-case errors remain. Graph-based models do not consistently outperform the tabular baseline, but exhibit complementary behavior that can be exploited through model combinations. Calibrated uncertainty estimates, particularly those produced by the covariance-based model, are useful for identifying unreliable predictions and reducing several error measures through selective rejection.

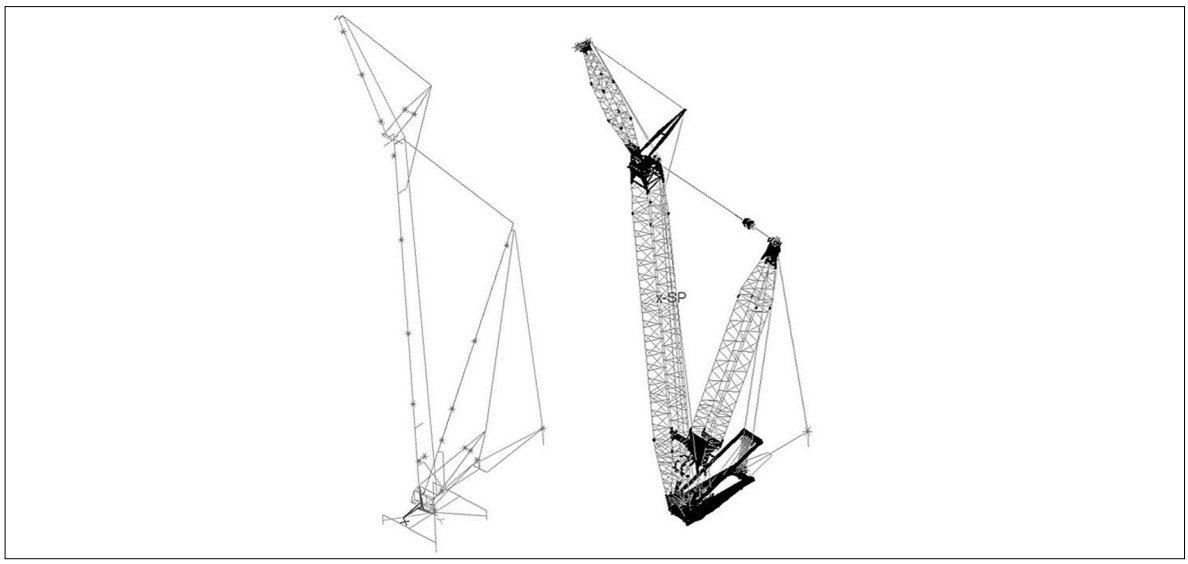
Representative views of the crawler-crane systems considered in this thesis.
Own presentment



Cross-validation distributions of aggregated MSE for the tabular models.
Own presentment



Comparison of the low-fidelity structural and high-fidelity representations.
Own presentment



Advisor
Prof. Dr. Christoph Würsch

Co-Examiner
Dr.-Ing. Robin Pfefferkorn

Subject Area
Data Science, Mechanical Engineering

Project Partner
Liebherr-Werk Nenzing GmbH, Nenzing, Vorarlberg