UNIVERSITÄT PADERBORN

FAKULTÄT FÜR ELEKTROTECHNIK, INFORMATIK UND MATHEMATIK

Abstract of the Dissertation:

Online optimized system excitation and thermal model identification of electric machines for automotive application

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Temperature estimation is crucial for the safe operation of modern electric drives, but direct measurement is impractical due to high costs, maintenance challenges, and technical complexities in data transmission from moving parts. Model-based estimation methods address these issues by analyzing variables like current, voltage, and speed, aiming for real-time accuracy. Traditional analytical models, however, struggle with balancing computational efficiency and precision due to the nonlinear thermal behavior of machines. Data-driven models overcome these limitations using system identification and empirical datasets. A key challenge lies in designing efficient experiments to generate diverse datasets, as existing offline approaches are heuristic, often resulting biased data and limiting model robustness.

This thesis investigates a closed-loop online excitation technique that optimizes dataset distribution by considering the machine's temperature. A model predictive control (MPC) algorithm is used to select excitation signals that optimize data distribution while meeting safety and dynamic constraints. The cost function for the optimization problem is formulated using the Jensen–Shannon divergence (JSD) method, which quantifies the divergence between the reference data distribution and the collected data distribution. Since MPC requires a system model for predictions, a state-space neural network (SSNN)--based thermal model with online training is proposed. Early in the experiment, when data is limited and predictions are less accurate, a safety and exploration layer is added to the MPC to address the SSNN's limitations.

Simulation results reveal that the proposed online excitation outperforms the offline designed pseudorandom binary signal (APRBS) excitation in terms of exploring a more diversified dataset. The optimized excitation method achieved a mean JSD score of 0.0815, far outperforming the APRBS method's score of 0.5058. Practical implementation confirms that the simulation results are achievable by the end of the experiment, demonstrating the method's real-world viability. Practical trials exposed challenges absent in the simulations, such as the requirement for remote edge computing to manage computationally intensive data and optimization processes, and the impact of initial state inaccuracies, resulting in marginally lower accuracy than simulated outcomes.