Accelerating Computation of Physical Simulations using Surrogate Modelling

Graduate

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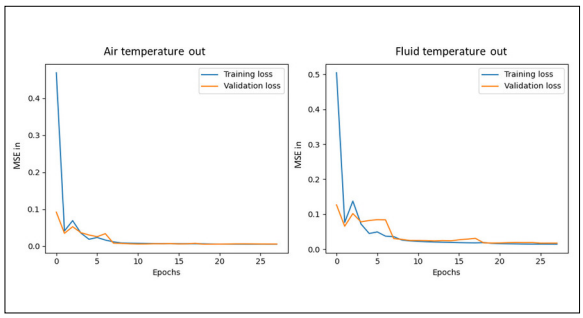
Introduction: Heat exchangers are crucial in HVAC systems but often require complex simulations. This thesis explores machine learning-based surrogate models to simulate heat exchanger behavior more time efficient. Data preprocessing involved normalization, truncation, windowing, and batching. The data includes five time-series as input features and two time-series as output features.

Approach: Data preprocessing involved normalization, truncation, windowing, and batching. Several machine learning models, including Multi-Layer Perceptrons (MLP), Spectral State Space Models (SSSM) and Recurrent Neural Networks (RNN) such as Long Short-Term Memory networks (LSTM) and Gated Recurrent Units (GRU) were examined. These models were optimized to capture temporal dynamics and predict the corresponding output. LSTMs and GRUs addressed the issue of sequence memory through gated mechanisms, while SSSMs leveraged spectral analysis for state modelling and the MLP was used as simple baseline. The Mean Squared Error (MSE) was used to evaluate predictive accuracy and Loss in the training process. In the testing phase, multiple metrics such as the MSE, RMSE, MAE, R2-score and relative MAE were employed to assess the performance of the models.

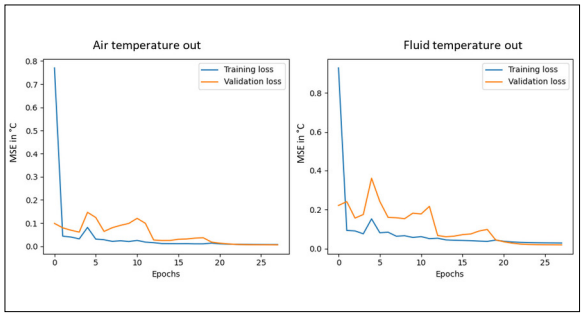
Result: The GRU model was identified as the most effective model in terms of capturing the patterns exhibited by the time series, with LSTMs exhibiting a marginally lower level of accuracy. The models demonstrated proficiency in sinusoidal and linear patterns, while struggeling with abrupt changes. Long-term predictions indicated the robustness of RNN, demonstrating no error propagation over extended sequences and effective generalization to new and complex data.

The findings emphasize the potential of machine learning-based surrogate models in reducing computational demands for physical simulations. Future work will explore integrating these models into closed-loop systems to test also the time saving and efficiency aspect. Additionally, there is scope to expand their application to encompass more noisy and complex patterns.

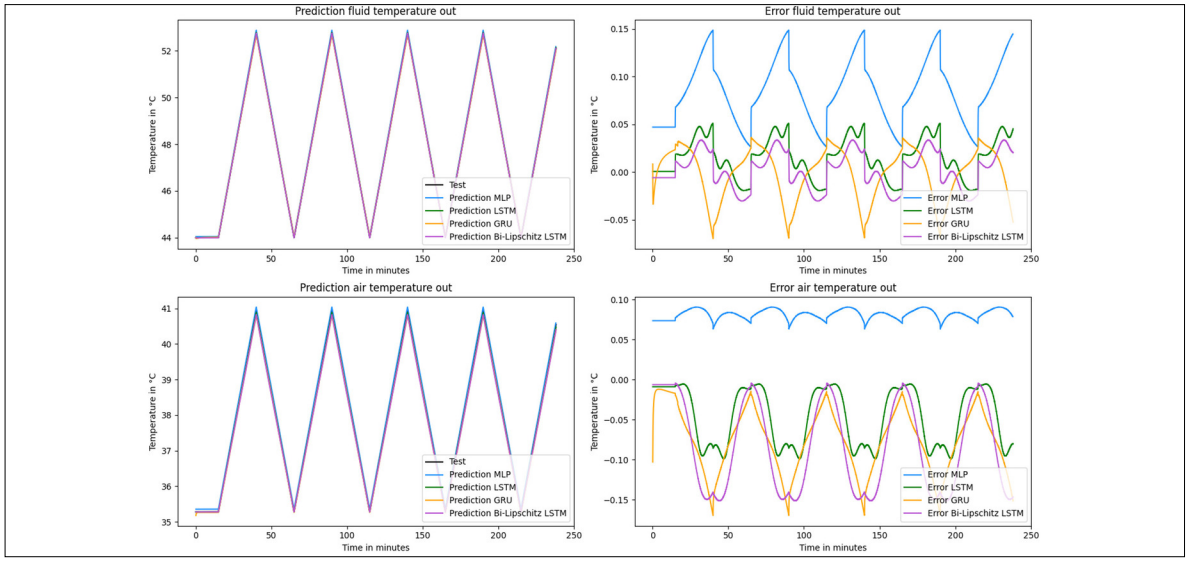
Training and validation curves of the GRU model in the original scale over the epochs.
Own presentment



Training and validation curves of the LSTM model in the original scale over the epochs.
Own presentment



Predictions and errors of all models, as well as the actual data in black.
Own presentment



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Subject Area
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