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Multi-fidelity Modeling for Process Optimization in Refinery Operations

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Ensuring precise process monitoring in industrial refineries presents inherent challenges due to discrepancies between the continuous, high-frequency low-fidelity data streams from online sensors and the low-frequency high-fidelity laboratory measurements. In collaboration with Slovnaft, a.s., we construct a multi-fidelity soft sensor to address these inconsistencies, refining the accuracy of an online analyzer reading located on a downstream recycle of an alkylation unit. By leveraging multi-fidelity modeling techniques, we enhance real-time process control and improve decision-making in the operation room.

Both static and dynamic modeling formulations are integrated to evaluate their efficacy in process monitoring. Feature selection methodologies, encompassing Principal Component Regression, Partial Least Squares, LASSO, and Stepwise Regression, undergo assessment, with Stepwise Regression emerging as the most effective in balancing predictive accuracy and model interpretability. Our dynamic models explicitly incorporate time-lagged variables, capturing the intricate temporal dependencies introduced by recycle streams re-entering upstream processes. We employ a Gaussian Process, choosing multiple different covariance functions [1] to correct deviations between online analyzer data and laboratory measurements. A composite kernel effectively combines both stationary and non-stationary components, accounting for the different temporal behaviors and trends in the data.

The multi-fidelity models are able to capture the deviations between the low-fidelity and high-fidelity data. The dynamic multi-fidelity model is the best-performing, surpassing the static multi-fidelity model and the high-fidelity model. Compared to the currently deployed online analyzer, our multi-fidelity soft sensor achieves a noticeable, over 50 % enhancement in accuracy. These findings underscore the potential of multi-fidelity modeling in improving sensor reliability, minimizing dependence on laboratory sampling, reducing associated costs, and advancing decision-making strategies in industrial operations.

Key words: Data-driven modeling, Feature selection, Predictive accuracy, Data analysis

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