Comparing Linear and Nonlinear Soft Sensor Approaches for Industrial Distillation Columns

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With increasing computational power and the rise of artificial intelligence, there is a growing demand for smart industry solutions. Inferential or soft sensors play a crucial role in industrial monitoring and control by providing estimates of key process variables, such as product quality, based on measurements of other process variables. In this study, we compare linear and nonlinear approaches to soft sensor design using datasets from two industrial distillation columns: the depropanizer column in the Fluid Catalytic Cracking unit and the main fractionator in the Vacuum Gasoil Hydrogenation unit at the oil refinery Slovnaft, a.s. in Bratislava, Slovakia.

The soft sensor design procedure involves four steps: (1) input domain analysis, (2) data preprocessing, (3) training of model parameters, and (4) model validation and testing. In the input domain analysis step, we explore the potential of various nonlinear transformations of the original input variables with respect to the specific case study. The resulting dataset undergoes data treatment and feature selection analysis in the data preprocessing step and is then divided into training and testing sets. In the third step, various linear and nonlinear approaches are used to calculate the model parameters on the training dataset with respect to specific objectives. Finally, the obtained models are validated.

The results suggest that nonlinear transformations have a generally positive impact on the performance of inferential sensors, but it appears that the performance improvement is more significant for linear sensors compared to nonlinear ones. This is supported by the comparable performance of both approaches on the depropanizer column dataset, while the accuracy of the nonlinear soft sensors only slightly improves (by approximately 2%) on the main fractionator dataset. Furthermore, it appears that more complex (nonlinear) soft sensors are more prone to overfitting, which is a significant issue for applications with high levels of noise.

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