

58a Data-Driven Soft Sensor Design - Application to Cement Kiln

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This paper addresses challenges for development of soft sensors from operating data and describes a systematic procedure. Soft sensors based on a first principles model (FPM) can be derived if the model describes the process sufficiently accurately. However, FPMs are normally difficult to develop and validate due to the complex kinetics and limited operational measurements. Modern measurement techniques enable a large amount of operating data to be collected, stored and analyzed, thereby rendering data-driven soft sensor development a viable alternative.

A data-driven soft sensor is an inferential model, which utilizes readily available process measurements to estimate plant variables that can neither be measured reliably nor directly in real-time. The key issue for development of a data-driven soft sensor is to effectively extract useful information from available process data. Since operating data are commonly contaminated with outlying measurements, abnormal observations and missing data, the first essential step is data preprocessing. Although, multivariate statistical approaches, such as principal component analysis (PCA) and partial least squares (PLS), address the collinearity in process data sets, their performance suffers from outlying observations. The second challenge is to robustify the standard multivariate statistical techniques such that process information can be efficiently extracted in the presence of abnormal observations. Given cleaned process data and a robust PLS approach, a regression model is developed in the third step. Performance enhancements will be implemented based on the analysis of the initial results, such as augmenting with time lagged data and introducing nonlinear functionalities. The fourth step is to validate the soft sensor on independent data sets to ensure that the essential process dynamics is modelled.

The systematic procedure to develop a data-driven soft sensor is described with case studies of cement kilns, which features low signal-to-noise ratio, unreliable online analyzers, but offline quality measurements – the free lime that denotes the quality of the product. Soft sensors are developed to estimate the free lime and the NO_x emission. Both dynamic and nonlinear PLS approaches are investigated and compared with a soft sensor derived with a recurrent neural network (RNN). The initial results reveal that soft sensors are able to provide reasonable prediction for the free lime and NO_x, showing the potential to be used for effective quality control.