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Adaptive soft sensor for product quality estimation in clinker production

The real-time estimation of key quality variables remains a critical challenge in industrial environments due to the limited availability of direct measurements and the presence of complex, dynamic process behavior. This work proposes an adaptive soft-sensing framework for the estimation of cement quality in clinker production, where quality indicators are traditionally measured through costly and infrequent laboratory analyses. The proposed framework builds upon Partial Least Squares (PLS) regression, extending it to address nonlinearity, process dynamics, and non-stationarity through a combination of recursive updating, lagged-variable modelling, and local learning strategies.

In particular, two complementary adaptive modelling strategies are investigated. The first is based on a Quasi-Ensemble PLS approach, in which multiple models with different hyperparameter configurations are combined to enhance estimation accuracy against model uncertainty. The second strategy proposes an autonomous soft sensor capable of self-adapting to time-varying plant conditions by integrating recursive PLS modelling with Bayesian optimization for the real-time tuning of hyperparameters, enabling continuous adaptation while preserving model interpretability and computational tractability.

The methodologies are validated on industrial data from cement production plants, demonstrating accurate predictive ability and robustness compared to state-of-the-art soft sensors. Furthermore, the proposed framework offers a general and scalable solution for adaptive soft-sensing in complex industrial systems, with potential applications beyond the cement industry.

Special/ Invited session

Classification

Both methodology and application

Keywords

soft sensor, virtual sensor, PLS, cement

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