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ROBUST DATA-DRIVEN MODELING OF BLAST FURNACE THERMAL BEHAVIOUR

A FRAMEWORK FOR INCREASING TRANSPARENCY AND ROBUSTNESS OF DATA-DRIVEN MODELS IN PREDICTIVE MODELING OF BLAST FURNACE OPERATION

Modeling and controlling a blast furnace are incredibly challenging due to the intricate mass and heat transfer processes, the diverse range of gas-solid, solid-solid, and solid-liquid reactions occurring within it, and the limited ability to directly measure its internal state. Due to the inherent complexity of the process characterized by non-linear and time-varying dynamics, the reduction process inside the blast furnace has yet to be accurately characterized by first-principles model.

Therefore, this mission-critical nature of the process leads to skepticism in relying on black-box ML models without additional transparency information with process operators relying more on instrumentation such as thermal imaging, temperature, flow and pressure measurements, their experience and support from expert systems.

These challenges hindered the adoption of effective black-box models in process control and served as motivation for research of methods for robust and transparent predictive models. These set of methods were unified in a transparency framework developed within the project with the goal of increasing the adoption of data-driven models in blast furnace operation.

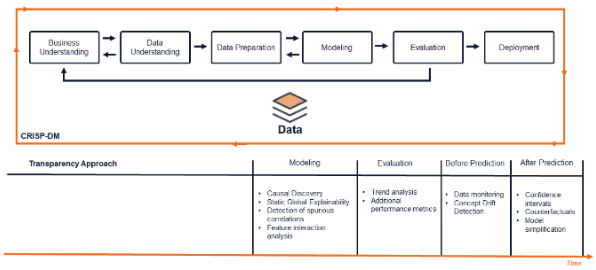

Fig.1 Outline of the transparency framework

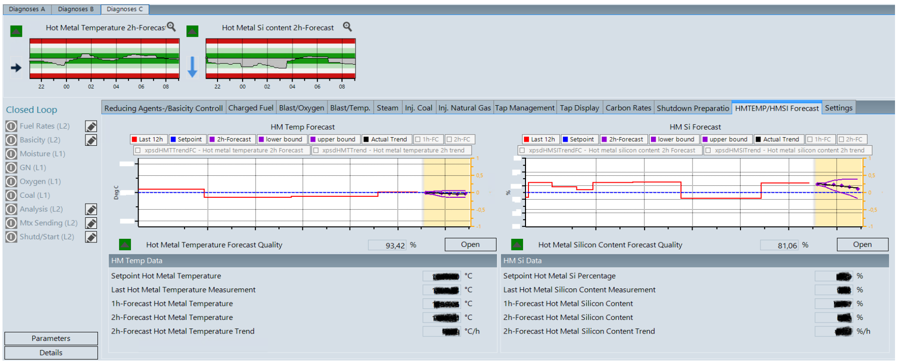

Fig.2 Integration of research methods into process control system

The transparency framework is comprised of methods in different stages of predictive model lifecycle. During the modeling phase causal discovery algorithms, such as FCI and ANM, were utilized to understand the causal relationship between variables to define a robust set of features accurately representing the underlying process mechanisms. In the evaluation phase, the focus was put on adapting predictive models to, in addition to standard performance metrics, accurately predict the overall trends in thermal behavior. Finally, a set of methods, such as confidence intervals, counterfactuals and anchors, for pre- and post-inference analysis was developed to identify unseen samples and model confidence in the accuracy of the predictions.

Impact and effects

The findings of the project have a direct effect in the production improvement of running blast furnace plants and show promising results in the prediction of the thermal behavior of the blast furnace. The RMSE of the hot metal temperature prediction was around 13° Celsius with a mean 90% prediction interval around 40° Celsius.

As seen in figure 2, methods developed in this project have been integrated into the process control system and are currently deployed in blast furnace plants. Due to great collaboration between domain experts, researchers and scientific partners, this project demonstrated the successful transfer of scientific methods to the industrial setting making a real-world impact.

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