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Adaptive cusum control using prediction intervals for condition monitoring

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Shell operates large and complex assets, such as oil refineries, chemical plants and offshore platforms, as one of the key parts of its business. A typical refinery will include thousands of individual pieces of equipment ranging from simple valves to highly complex systems, such as distillation columns.

These systems are monitored for early signs of failure. Successful early detection might result in increased availability and reduced maintenance costs. Furthermore, the insights from monitoring equipment can be used to improve equipment care strategies and performance of assets.

One of the large-scale monitoring approaches in Shell is based on comparing a measured output of a simple component to its virtual counterpart. Both the measured output and inputs to the model to construct the virtual counterpart are process variables, such as valve opening position, flow rate, temperature, and pressure. The idea is that under normal operation, the measured output and its virtual counterpart are approximately the same. Deviations could be an early sign of failure.

To implement this approach, a prediction target is selected for each monitored component. Other model features are used to predict that target at each point in time as a nowcast. The model predictions are compared to the actual target measurements. The prediction error feeds into a cusum statistic, which in turn is used to raise alerts if a certain threshold is reached.

In addition to the point estimates produced by the model, we also quantify the uncertainty of the point estimate in terms of a prediction interval. We propose to use these prediction intervals to adaptively change the hyperparameters of the cusum control [1]. More specifically, we can penalize prediction errors when the prediction interval is small and be more tolerant of prediction errors when the prediction interval is large.

We describe the virtual sensor approach in the context of condition monitoring. Furthermore, we detail adaptive cusum control using prediction intervals and additional challenges to implementing and validating this at scale in an industrial setting.

[1] Montgomery, D. C. (2009). Statistical quality control (Vol. 7)

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