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Recurrent Neural Networks for Control Performance Assessment

Elizabeth Vieira Melo[a], Argimiro Resende Secchi[a], Maurício B. de Souza Jr.[a,b*]

[a]*Programa de Engenharia Química, Universidade Federal do Rio de Janeiro, RJ, Brasil*
[b]*Escola de Química, Universidade Federal do Rio de Janeiro, RJ, Brasil*
**mbsj@eq.ufrj.br*

ABSTRACT

Performance monitoring of Model Predictive Controllers (MPCs) has been a focus of the industry over the decades. It is an important aspect to ensure industrial profitability and to explore the full benefits of the implementation of MPCs. Methods have been developed to detect the degradation of MPCs performance and diagnose their source, mostly focusing on data-driven methods. However, there is still a lack of methodologies available to give a prompt and quick diagnosis, since many sources cause similar behavior in the closed-loop data. To isolate fault sources and give a precise diagnosis, machine learning (ML) models stand out due to their capability of capturing complex patterns from data. Since process data is a time-series type of data, recurrent neural networks (RNNs) might be a good candidate for both the detection and the diagnosis of the MPC loss of performance. However, to be implemented for online monitoring, a balance between accuracy in the prediction and computational speed is required. For this purpose, this study aims to evaluate three different types of RNNs: the Simple RNN, the Long-Short Term Memory (LSTM), and the Gated Recurrent Unit (GRU). The computational cost of each model is related to the number of parameters. Simple RNN are expected to have the lowest computational cost. However, it is more likely to suffer from the vanishing gradient problem, which leads to a lack of performance in some cases. LSTM models can deal with long-term data, but have more trainable parameters, which increases their computational cost. GRU, on the other hand, was designed to decrease the computational requirements for the predictions while maintaining the accuracy of the predictions. The most appropriate type of diagnosis for each model type was also investigated to keep the online evaluation as simple as possible. The case study used was the van de Vusse reactor controlled by an NMPC. The models were evaluated in cascade, with each ML being responsible for a binary classification. The first model is responsible for the detection, deciding whether the closed-loop data is under normal conditions or under a fault scenario. The second model is responsible for evaluating whether the fault has a valve stiction as a source or is an internal controller configuration problem. The third model receives the data classified as "control problem" to analyze whether the source is a tuning issue or a plant-model mismatch. Finally, once the control internal model has been pointed out as the primary source of failure, the last model identifies which parameter of the model should be recalibrated. It is important to highlight that this arrangement was made considering that those were the primary sources of faults for the case studied. The cascade arrangement can be adapted to every process based on different kinds of possible anomalies. The results show that, for the detection procedure and for diagnosing the source of plant model mismatch, the simple RNN is already capable of classifying the data samples correctly, without noticeable improvements when using other models. For the tuning diagnosis, both LSTM and GRU have similar performances. Since the GRU requires less computational cost, it is preferable to be implemented in industry. The valve stiction diagnosis, on the other hand, was better classified when the LSTM was used. Both GRU and Simple RNN have similar performances, which indicates that the GRU algorithm did not improve the diagnosis quality. The results show that it is not possible to state, based only on the ML theory, which RNN algorithm is better for diagnosing the NMPC source of degradation. In this simulation study, the relative performance depends on the specific scenario considered, indicating that the choice of the algorithm should rely on case-specific evaluation.

Keywords: Control Performance Assessment, NMPC, RNN, van de Vusse reactor.

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