Contribution ID: **22** Type: **not specified**

Data-Efficient Upscaling and Optimal Control of Fed-Batch Bioprocesses via Hybrid Modelling and Transfer Learning

Optimisation and control of industrial fed-batch bioprocesses remains a complex and resource intensive task. Process development from laboratory to manufacturing scale requires extensive experimental trials to characterise system behaviour and identify optimal conditions, incurring significant costs. While advanced process control (APC) technologies have been widely applied to industry, their application is limited by the lack of data and predictive models at manufacturing scale. Within the last decade, hybrid modelling, combining mechanistic knowledge with data-driven techniques, has emerged as a promising approach to accelerate scale-up of complex processes. Furthermore, transfer learning has shown to significantly reduce data requirements for reliable predictions across scale. Therefore, to overcome the challenges of bioprocess development and optimisation at scale, this work proposes a unique predictive optimal control strategy that integrates two powerful modelling techniques: hybrid modelling and transfer learning. A hybrid model was trained on 2 datasets at laboratory scale and applied within a model predictive control framework to achieve a desired end-point product concentration by manipulating substrate feed flow within a fed-batch bioreactor at production scale. Two strategies were compared in this work: updating optimal control actions with and without transfer learning-based hybrid model update. Through comparison, the model update strategy demonstrated superior predictive performance however both strategies were successful at satisfying the end-point criteria. Overall, this work demonstrated feasibility to combine hybrid modelling with transfer learning to achieve accurate prediction and optimal control at scale and accelerate bioprocess development.

Special/ Invited session

Classification

Both methodology and application

Keywords

Machine Learning, Hybrid Modelling, Bioprocessing

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Track Classification: AI: Machine Learning and Predictive Analytics