Fast Stochastic Model Predictive Control under Parametric Uncertainties

by

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Abstract

Model predictive control (MPC) is widely applied in industry due to its ability to handle constraints explicitly. Many processes in chemical engineering have a high number of states, but a relatively low number of inputs and outputs. Input-output formulations of MPC employ process models, predicting outputs directly from input data and thus avoiding the higher computational complexity of state space models, resulting in fast MPC. Model uncertainties are ubiquitous and there are two popular approaches to incorporate them in the MPC framework. In robust MPC, the worst case of the uncertainty is optimized, which can result in sluggish performance, because this case often has a very low probability of occurrence. Stochastic MPC on the other hand incorporates information of the probability distribution of the uncertainty, which allows the optimization based on the probability of occurrence.

The main focus of this thesis is on fast stochastic input-output formulations of MPC. Polynomial Chaos Theory is used to incorporate probability distributions of uncertainties into process models. This approach avoids the need for sampling and makes on-line model evaluations possible. Fast stochastic MPC algorithms are presented that address probablistics uncertainties while having no steady-state offset. One method of applying Polynomial Chaos Theory to process models is Galerkin projection, which requires the manipulation of model equations. A fully automated implementation based on symbolic arithmetic is presented to perform these manipulations. By introducing output feedback control, it is shown that the fast stochastic MPC can be used to control unstable systems.

The thesis also shows the applicability of linear input-output formulations of MPC to control a highly integrated nonlinear continuous crystallization process.

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