A Complete NMPC Solution of the Tennessee Eastman Benchmark Problem for Plantwide Control

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Abstract: The Tennessee Eastman (TE) process is regarded as one of the challenging benchmark problems for advanced process control. The medium-sized process is a highly nonlinear and open-loop unstable system. Its complex multi-input multi-output system structure makes it ideally suited for nonlinear model predictive control (NMPC) strategies.

However, past publications on NMPC for the TE process generally concerned themselves with quite unrealistic scenarios - as either only simplified models are considered or measurements and model and, therefore, states and parameters are all assumed error-free. Under realistic conditions it is inevitable to insert a powerful state and parameter estimator. The moving horizon estimator (MHE) is particularly suited if constraints are present and if uncertain model parameters are to be estimated simultaneously. So far, no work combining NMPC and MHE has been published for the TE process. The aim of this study has been to close this gap and to demonstrate the potential of a fully nonlinear model-based real-time optimization scheme for both control (NMPC) and state and parameter estimation (MHE).

The chosen process scenarios can be considered as realistic. We consider the structure of the full nonlinear, open-loop unstable process model, additional varying uncertain model parameters and additional process noise on all differential states of the "real" process, thus introducing plant-model mismatch. The control scheme is demonstrated for several test cases, including feed disturbances, setpoint changes, and drift in reaction kinetics. The combined NMPC and MHE algorithm results in stabilizing control with very good control performance. The arising least-squares optimization problems are solved numerically by the direct multiple shooting technique. Due to the intelligent real-time iteration approach, CPU times for one complete estimation and control cycle typically lie in the range of 5 seconds with a maximum of about 25 seconds on a standard PC. With calculation times clearly below the sampling time of 100 seconds, the combined NMPC-MHE scheme proves real-time feasible.

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