469a Output-Feedback Nonlinear Model Predictive Control for Chemical Processes without the Need of Fast Observers

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Nonlinear model predictive control is inherently a state feedback control scheme. In chemical engineering applications, however, typically not all states can be directly measured. In practice, following the so called certainty equivalence principle, the necessary state information is typically recovered using a suitable state estimator or observer. However, since for nonlinear systems no general valid separation principle exists, the stability of the closed-loop does not automatically follow from the stability of the observer and the state feedback alone.

By now various researchers have addressed the question of stabilizing output-feedback control based on state-feedback NMPC, for a detailed discussion see e.g. [1]. Most of the existing results are based on the certainty equivalence principle and can yield stability if the estimation error is sufficiently small. The main problem of most of the existing results is that the uncertainty introduced by the state estimation is only indirectly taken into account. The state estimation error is considered as a sufficiently small disturbance/perturbations, which NMPC is able to reject assuming that certain conditions on the value function hold [2, 3]. Since only small state estimation errors can be rejected, it is necessary to require that the rate of convergence of the observer-error can be made as high as required to achieve stability. Furthermore, predictive controller o not always possess inherent robustness properties [4].

After a brief review of the existing output-feedback approaches we propose in this presentation to explicitly account for the observer error in the NMPC controller. For this purpose we propose the use of a min-max based NMPC controller in conjunction with a set-valued state observer. In the min-max based optimal control problem of the NMPC controller the "uncertainty" in the state estimate is considered as a "maximizing player", while the input applied to the system is considered as the "minimizing player".

To counteract the conservatism of an open-loop feedback resulting from a min-max optimal control problem, the approach proposed does employ a hierarchical feedback strategy. The min-max NMPC controller does actually not provide an open-loop input which is directly applied to the system. Rather it provides an open-loop reference/parameter signal for a lower level feedback controller. This can be, for example, a PID controller as typically used in process industry. As shown, the proposed setup guarantees under certain conditions closed-loop stability.

The application of the outlined approach is exemplified and compared to existing approaches considering the control of a biochemical reactor.

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