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Application of an extended IHMPC to an unstable reactor system: Study of feasibility and performance

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ABSTRACT

Almost all the theoretical aspects of model predictive control (MPC), such as stability, recursive feasibility and even the optimality are now well established for both, the nominal and the robust case. The stability and recursive feasibility are usually guaranteed by means of additional terminal constraints, while the optimality is achieved considering closed-loop predictions. However, these significant improvements are not always applicable to real processes. An interesting case is the control of open-loop unstable reactor systems. There, the traditional infinite horizon MPC (IHMPC), which constitutes the simplest strategy ensuring stability, needs to include an additional terminal constraint to cancel the unstable modes, producing in this way feasibility problems. The terminal constraint could be an equality or an inclusion constraint, depending on the local controller assumed for predictions. In both cases, however, a prohibitive length of the control horizon is necessary to produce a reasonable domain of attraction for real applications. In this work, we study the application of an IHMPC formulation that has maximal domain of attraction (i.e., the domain of attraction is determined by the system and the constraints, and not by the controller) to an unstable reactor system. It is shown that the method is suitable for real applications in the sense that it accounts for the case of output tracking and it is offset free if the output target is reachable, and minimizes the offset if some of the constraints become active at steady-state.

1. Introduction

When a constrained open-loop unstable system, as an unstable reactor system, is attempted to be controlled the guarantee of recursive feasibility and constrained stability is a highly desirable controller property. First, the maximal controllable sets associated to the system equilibrium should be carefully determined since, opposite to what happens with stable systems, input constraints could make impossible the rejection of large disturbances, independently of the controller. Then, a controller with guaranteed stability that explicitly takes into account these limitations should be designed. In this context, MPC appears to be the most suitable option. In fact, the stability, feasibility and even optimality of MPC is now well established in the theoretical aspects [1,2]. Standard approaches use the dual-mode prediction paradigm [3] in conjunction with an infinite horizon. Within this paradigm it is assumed that a fixed unconstrained feedback K (local controller) proceeds for predictions beyond the control horizon, stabilizing in this way the unstable modes. In this context, a major obstacle is to establish a trade-off between the desirable volume of the domain of attraction (the set of states for which the controller can generate a feasible input), the overall complexity (computational cost), and the achievable performance for a given control horizon (degree of optimality). Assuming that the control horizon is chosen small for computational reasons, the domain of attraction is dominated by the aggressiveness of the fixed unconstrained feedback, since additional (terminal) constraints are needed to assure the feasibility of the local control law. Recent MPC formulations are based on the existence of a control Lyapunov function (CLF), which is independent of the control cost function. These formulations also allow the explicit characterization of the stability region subject to constraints and they do not need an infinite output horizon or terminal stability constraints. Although the construction of the CFL may not be a trivial task, the CLF based MPC is applied to the control of switched systems by incorporating constraints in the control problem that ensures that the transition between modes will result in a stable closed-loop system [4]. A more general approach was applied to the control of a styrene polymerization reactor [5]. In

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