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Decentralized model predictive control of dynamically coupled linear systems ☆

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ABSTRACT

This paper proposes a decentralized model predictive control (DMPC) scheme for large-scale dynamical processes subject to input constraints. The global model of the process is approximated as the decomposition of several (possibly overlapping) smaller models used for local predictions. The degree of decoupling among submodels represents a tuning knob of the approach: the less coupled are the submodels, the lighter the computational burden and the load for transmission of shared information; but the smaller is the degree of cooperativeness of the decentralized controllers and the overall performance of the control system. Sufficient criteria for analyzing asymptotic closed-loop stability are provided for input constrained open-loop asymptotically stable systems and for unconstrained open-loop unstable systems, under possible intermittent lack of communication of measurement data between controllers. The DMPC approach is also extended to asymptotic tracking of output set-points and rejection of constant measured disturbances. The effectiveness of the approach is shown on a relatively large-scale simulation example on decentralized temperature control based on wireless sensor feedback.

1. Introduction

Large-scale systems such as power distribution grids, water networks, urban traffic networks, supply chains, formations of cooperating vehicles, mechanical and civil engineering structures, and many others, are often hard to control in a *centralized* way. The spatial distribution of the process impedes collecting all the measurements at a single location, where complex calculations based on all such information are executed, and redistributing the control decision to all actuators; moreover constructing and maintaining a full dynamical model of the system for control design is a time consuming task. Hence the current trend for *decentralized* decision making, distributed computations, and hierarchical control.

In a decentralized control scheme several local control stations only acquire local output measurements and decide local control inputs, possibly under the supervision of an upper hierarchical control layer improving their coordination. Consequently, the main advantages in controller implementation are the reduced and parallel computations, and reduced communications. However, all the controllers are involved in controlling the same large-scale process, and is therefore of paramount importance to determine conditions under which there exists a set of appropriate local feedback control laws stabilizing the entire system.

Ideas for decentralizing and hierarchically organizing the control actions in industrial automation systems date back to the 70's [1], but were mainly limited to the analysis of stability of decentralized linear control of interconnected subsystems. The interest in decentralized control raised again since the late 90's because of the advances in computation techniques like convex optimization [2]. Decentralized control and estimation schemes based on distributed convex optimization ideas have been proposed recently in [3,4] based on Lagrangean relaxations. Here global solutions can be achieved after iterating a series of local computations and inter-agent communications.

Large-scale multi-variable control problems, such as those arising in the process industries, are often dealt with model predictive control (MPC) techniques. In MPC the control problem is formulated as an optimization one, where many different (and possibly conflicting) goals are easily formalized and constraints on state and control variables can be included [5,6]. However, centralized MPC is often unsuitable for control of large-scale and networked systems, mainly due to lack of scalability and to maintenance issues of global models.

In view of the above considerations, it is then natural to look for *decentralized* or for *distributed* MPC (DMPC) algorithms, in which the original large-size optimization problem is replaced by a number of smaller and easily tractable ones that work iteratively and cooperatively towards achieving a common, system-wide control objective. In a typical DMPC framework at each sample

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