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Multirate Lyapunov-based distributed model predictive control of nonlinear uncertain systems

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ABSTRACT

In this work, we consider the design of a network-based distributed model predictive control system using multirate sampling for large-scale nonlinear uncertain systems composed of several coupled subsystems. Specifically, we assume that the states of each local subsystem can be divided into fast sampled states (which are available every sampling time) and slowly sampled states (which are available every several sampling times). The distributed model predictive controllers are connected through a shared communication network and cooperate in an iterative fashion at time instants in which full system state measurements (both fast and slow) are available, to guarantee closed-loop stability. When local subsystem fast sampled state information is only available, the distributed controllers operate in a decentralized fashion to improve closed-loop performance. In the proposed control architecture, the controllers are designed via Lyapunov-based model predictive control techniques taking into account bounded measurement noise, process disturbances and communication noise. Sufficient conditions under which the state of the closed-loop system is ultimately bounded in an invariant region containing the origin are derived. The theoretical results are demonstrated through a nonlinear chemical process example.

1. Introduction

With the rapid growth in the area of network technology, augmentation of local process control systems with additional networked sensors and actuators has become a subject of increasing importance. Such an augmentation can significantly improve the efficiency, flexibility, robustness and fault tolerance of an industrial control system (e.g., Refs. [1–3]) at the cost of coordination and design/redesign of the various control systems employed in the new control architecture. Motivated by this trend towards network-based control systems in a variety of engineering applications, significant efforts over the last ten years have led to results on analysis and design of networked control systems using centralized control architectures (e.g., Refs. [4,5]).

Model predictive control (MPC) is an appropriate framework to deal with the design and coordination of networked control systems because of its ability to account for process/controller interactions in the calculation of the control actions while handling input/state constraints. Typically, MPC is studied within a centralized control architecture in which all the manipulated inputs are calculated in a single MPC [6]. In the evaluation of MPC control actions, the evaluation time of the MPC strongly depends on the number of manipulated inputs because online optimization problems need to be solved. As the number of manipulated inputs increases as it is the case in the context of networked control systems, the evaluation time of a centralized MPC increases significantly. This may impede the ability of networked centralized MPC to carry out real-time calculations within the limits imposed by process dynamics and operating conditions. Moreover, a centralized control system for large-scale systems may be difficult to organize and maintain and is vulnerable to potential process faults. To overcome these issues, decentralized and/or distributed MPC can be utilized. While in a decentralized control architecture [7], individual controllers make their decisions based on local information, in a distributed framework, controllers communicate with each other to coordinate their actions.

Distributed MPC (DMPC) has attracted a lot of attention in the design of cooperative networked control systems. In a DMPC architecture, the manipulated inputs are computed by solving more than one control (optimization) problems in separate processors in a coordinated fashion. In the literature, several DMPC methods have been proposed; please see Refs. [8–14] for results in this

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