Handling communication disruptions in distributed model predictive control

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ABSTRACT

In this work, we study distributed model predictive control (DMPC) of nonlinear systems subject to communication disruptions – communication channel noise and data losses – between distributed controllers. Specifically, we focus on a DMPC architecture in which one of the distributed controllers is responsible for ensuring closed-loop stability while the rest of the distributed controllers communicate and cooperate with the stabilizing controller to further improve the closed-loop performance. To handle communication disruptions, feasibility problems are incorporated in the DMPC architecture to determine if the data transmitted through the communication channel is reliable or not. Based on the results of the feasibility problems, the transmitted information is accepted or rejected by the stabilizing MPC. In order to ensure the stability of the closed-loop system under communication disruptions, each model predictive controller utilizes a stability constraint which is based on a suitable Lyapunov-based controller. The theoretical results are demonstrated through a nonlinear chemical process example.

1. Introduction

The chemical process industry is a major sector of the US and global economy. Hence, the development of optimal process control and operation methodologies for chemical processes is a research subject of considerable importance. Advanced process control stands to benefit from the emergence of networked process control and operations, with the purpose of augmentation of traditional point-to-point local control systems with additional cheap, safe and easy-to-install networked sensors and actuators. Networked control systems (NCS) can substantially improve the efficiency, flexibility, robustness and fault tolerance of an industrial control system while reducing the installation, reconfiguration and maintenance expenses at the cost of coordination and design/redesign of different control systems in the new architecture [1–3]. Recent research efforts have led to important results on the design of networked control systems (e.g., [4–7]), employing a centralized control paradigm where all manipulated inputs are evaluated by a single control system.

Model predictive control (MPC) is a natural framework for dealing with the design and coordination of distributed control systems because it can account for the influence of other control systems on the computation of the control action for a certain set of actuators. MPC takes advantage of a process model to predict the future evolution of the process at each sampling time according to the current state along a given prediction horizon. These predictions are incorporated in an optimization problem to obtain an optimal input trajectory by minimizing a meaningful performance index. To reduce the computational complexity of the optimization problem, MPC obtains the optimal input solution over the family of piecewise constant trajectories with fixed sampling time and finite prediction horizon. Once the optimization problem is solved, only the first manipulated input value is implemented, discarding the rest of the trajectory and repeating the optimization in the next sampling step (e.g., [8]). In a centralized MPC paradigm, all the manipulated inputs of a given control system are coupled in a single optimization problem to obtain the optimal input trajectory. In the case of large number of state variables and manipulated inputs for a given control system, the computational complexity of the centralized MPC may increase significantly and consequently degrade closed-loop system performance, especially in the case of employing a nonlinear model in MPC. A computationally effective approach to overcome the above mentioned drawbacks of centralized MPC is to employ distributed MPC (DMPC) in which the optimal trajectory is obtained through solving a number of distributed optimization problems with lower dimensionality compared to the centralized design.

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