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Distributed model predictive control based on agent negotiation

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ABSTRACT

In this paper we consider the control of several subsystems coupled through the inputs by a set of independent agents that are able to communicate. We assume that each agent has access only to the model and the state of one of the subsystems. This implies that in order to take a cooperative decision, the agents must negotiate. At each sampling time agents make proposals to improve an initial feasible solution on behalf of their local cost function, state and model. These proposals are accepted if the global cost improves the cost corresponding to the current solution. In addition, we provide conditions that guarantee that the closed-loop system is asymptotically stable along with an optimization based design procedure that is based on the full model of the system. Finally, the proposed scheme is put to test through simulation.

1. Introduction

Traditionally, control theory has coped with information and timing constraints in a centralized fashion, that is, under the assumption that all the information is available at a single point at the right time. Unfortunately, there are different factors that hinder the application of centralized schemes. In first place, real systems may not have a model that capture correctly their dynamics. Moreover, even if a model can be obtained, it may be too complex to be useful to design a controller. Likewise, there are other important limitations. For example, the system may be geographically disperse, just as happens in transportation networks [1]. Other times it is a matter of privacy: the subsystems that compose the overall system may be independent and have incentives to keep some information secret. This could be, for example, the case of a supply chain. It is at this point where decentralized and distributed controllers come into play. The idea behind these schemes is simple: the centralized problem is divided in several different parts whose control is assigned to a certain number of local controllers or *agents*. These agents share information with the rest in order to improve closed-loop performance, robustness and fault-tolerance.

Decentralized and distributed systems have been a subject of study for a long time, but it has not been until the last decade when they have been at their very peak. The renewed interest in distributed and decentralized schemes has been mainly motivated by the proliferation of low cost wireless transceivers and their wide range of applications [2,3]. Wireless autonomous networks provide a mean to measure or actuate much cheaper than the traditional wired solutions.

There are several important issues that characterize distributed control problems. Aspects such as the way agents share information are crucial. The complexity of a distributed control problem roots in the fact that the performance of the closed-loop system depends on the decisions that all the agents take. Crossed interactions and side effects are key ideas to understand why cooperation and communication policies become very important issues. This problem is not new and has been studied by disciplines such as economics and game theory. Game theory is a theoretical framework that allows one to study the problem of cooperation of different agents with, maybe, conflicting control goals, from a mathematical point of view [4,5]. In an economic context the role played by undesired interactions between subsystems is studied under the idea of externalities [6].

In this work we focus on distributed model predictive control (MPC) schemes. MPC is a popular control strategy for the design of high performance model-based process control systems because of its ability to handle multi-variable interactions, constraints on control (manipulated) inputs and system states, and optimization requirements in a systematic manner. MPC takes advantage of a system model to predict its future evolution starting from the current system state along a given prediction horizon. The success of MPC in industrial applications [7] has motivated an important amount of research on the stability, robustness and optimality of model predictive controllers. Nevertheless, MPC has strong computational requirements which hinder its application to large-scale systems. Hence, it is natural to use a distributed approach for this class of systems. Several distributed MPC schemes have been proposed in the literature in the last years. Next, we provide a review of the most important contributions that can be found in the liter-

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