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A comparative analysis of distributed MPC techniques applied to the HD-MPC four-tank benchmark☆

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ABSTRACT

Recently, there has been a renewed interest in the development of distributed model predictive control (MPC) techniques capable of inheriting the properties of centralized predictive controllers, such as constraint satisfaction, optimal control, closed-loop stability, etc. The objective of this paper is to design and implement in a four-tank process several distributed control algorithms that are under investigation in the research groups of the authors within the European project HD-MPC. The tested controllers are centralized and decentralized model predictive controllers schemes for tracking and several distributed MPC schemes based on (i) cooperative game theory, (ii) sensivity-based coordination mechanisms, (iii) bargaining game theory, and (iv) serial decomposition of the centralized problem. In order to analyze the controllers, a control test is proposed and a number of performance indices are defined. The experimental results of the benchmark provide an overview of the performance and the properties of several state-of-the-art distributed predictive controllers.

1. Introduction

Distributed model predictive control (DMPC) is an important control methodology in current control engineering for large-scale or networked systems, mainly to overcome computational (and possibly communication) limitations of centralized approaches. These distributed algorithms are based on a wide range of techniques. Systematic studies of these techniques require the analysis of benchmark problems to assess the performance of the different algorithms and to characterize their properties.

The use of benchmarks is useful for evaluating the capabilities of different approaches to control systems for real problems. Benchmarks allow one to test, evaluate, and compare different control solutions on real or simulated plants. The research and the industry community benefit from these activities since the design of a good simulation test-bed is often time and resource consuming. However, many simulation test-beds are often subject to harsh criticism as they either cover only a narrow part of the problem or they are purposely designed to get biased rather than objective performance results. Suitable benchmark problems would effectively overcome these problems by (a) allowing an objective evaluation of alternative control technologies, by (b) reducing resources and time spent on developing validation models, by (c) giving researchers the possibility to evaluate their proposals on a variety of cases, and by (d) opening up a forum to compare the performance of various solutions and to discuss the quality of the results.

The objective of this paper is to design and implement several distributed control algorithms, to analyze the algorithms, and to compare them on a common real benchmark process, namely a four-tank plant located in the Department of Ingeniería de Sistemas y Automática of the University of Seville. This plant is based on the quadruple-tank process [8]. This process has proven to be a very interesting system for control education and research despite its simplicity, since the system is a highly coupled system that can exhibit transmission zero dynamics, the dynamics are nonlinear and the states and inputs are subject to hard constraints. Furthermore, the four-tank plant is implemented using industrial instrumentation and is safe to use. The quadruple-tank process has been used to illustrate various control strategies including internal model control [6], dynamic matrix control [5], multivariable robust control [24] and distributed MPC [12]. In addition, it has also been utilized as an educational tool to teach advanced multivariable control techniques.

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