2012 American Control Conference
Fairmont Queen Elizabeth, Montréal, Canada
June 27-June 29, 2012

Control of a water delivery canal with cooperative distributed MPC

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Abstract— **This article addresses the problem of controlling pool levels in a water delivery canal using a novel cooperative distributed MPC control algorithm that incorporates stability constraints. According to a distributed control strategy, a local control agent is associated to all canal gates (actuators). In order to achieve cooperative action, each control agent computes the corresponding gate position (manipulated variable) by performing the minimization of a cost function that considers not only its local control objectives, but also the ones of their immediate neighbors. For this purpose, a MPC algorithm with stability constraints is used (SIORHC). At the beginning of each sampling interval, local control agents exchange information with their neighbors and adjust their decisions in an iterative way. The resulting distributed MPC is denoted D-SIORHC and yields a stable closed-loop. Experimental results are provided to show the influence of the controller configuration parameters on the resulting performance.**

I. INTRODUCTION

A. Motivation

Water delivery canals [1], [2] provide an interesting and meaningful example of an application requiring distributed control. These are large, spatially distributed structures that transport water from the sources (*e. g.* reservoirs or dams) to the user points (*e. g.* land irrigation or hydro-power plants). The control of such systems attracts an increasing interest both due to the environmental and social impact associated with an efficiency increase in the use of water, and to the scientific challenges it raises. Indeed, due to their infinite dimensional and nonlinear dynamics, the design of robust, high performance controllers is a nontrivial task. Furthermore, it is natural to investigate distributed solutions, in which the controllers that drive the different gates (actuators) share information in order to act in a coordinated way [3].

Although several other control strategies may be considered for water system applications, model based predictive control [4] has a number of advantages. Besides being intuitive to the practitioners, MPC allows to design the controller such as to incorporate constraints, either related to process operation or to ensure stability [5]. There is thus a strong motivation to extended MPC algorithms to the distributed control framework. In particular, in this work we consider a distributed version of SIHORC, an MPC algorithm for linear systems that embodies a constraint to ensure stability (in the centralized version) with a finite receding horizon.

This work was supported by FCT, Portugal, under project *AQUANET: Decentralized and reconfigurable control for water delivery multipurpose canal systems*, contract PTDC/EEA-CRO/102102/2008, and INESC-ID multi-annual funding through the PIDDAC Program funds.

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B. Literature review

Distributed MPC have been approached in a number of works. In [6] a number of situations in which the distributed controllers exchange information to achieve some degree of coordination is considered. An extension of a class of stability constraint MPC algorithms to the distributed case is presented (SC-DMPC). Other examples include [7], [8], [9], and [10] that addresses an application to power generation. In [11] distributed MPC is addressed using sensitivity based coordination. In [12] the same problem is solved based on agent negotiation when the plant is decomposed in several subsystems coupled through the inputs.

The reference [13] proposes an iterative algorithm for networked MPC applied to serially connected processes, in which local control agents interact with their neighbors in a game-like framework. A similar procedure is followed in this work, but with a different basic MPC algorithm, the SIORHC controller [14], [15] being considered and modified in order to get a distributed version.

Several approaches to distributed control, including distributed MPC, have been applied to water delivery canals, of which [16], [17], [18] are examples.

C. Paper structure and contributions

In this work the application of a new distributed MPC algorithm to a water delivery canal is presented. The new controller is applicable to systems that can be decomposed in subsystems connected sequentially, *i. e.* in which each subsystem is affected only by a precedent and a subsequent neighbor subsystem. At each sampling interval, adjacent local controllers negotiate between themselves in an iterative way in order to reach a consensus on the value of the manipulated variables that corresponds to a suboptimal solution.

We emphasize the novelty of the algorithm proposed with respect to the ones currently available in the literature. Opposite to [10] that relies on algorithmic methods of optimization, in this paper we present a closed form solution for the local controllers. This is possible because we ruled out the inclusion of operational inequality constraints. Furthermore, although [13] also relies on closed form expressions for the local MPC agents, the control law considered in this paper is different because it considers stability constraints. As a consequence, we can prove stability of the resulting distributed MPC, opposite to [13] where nothing can be said about stability for a finite prediction horizon.

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