HD-MPC

Hierarchical and Distributed Model Predictive Control for

Irrigation Canals

Water is a limited resource. In addition, nowadays several regions in Europe and all over the world are confronted with long seasons of drought. As a consequence, the development of innovative control techniques that optimize water management is a relevant issue.

The main objective of irrigation canals is to supply water to farmers according to a specific schedule. To this aim irrigation canals management involves operating gates, pumps, and valves in order to satisfy user demands and to minimize costs. A set of constraints imposed by the physical system and management policies has to be considered.

An irrigation canal is composed of several reaches, connected by gates, and usually following a tree structure. In a typical irrigation canals there are tens of gates and hundreds of off-take points, used by farmers to take water from the canal. Typical lengths are hundreds of kilometers.

Main Challenges

Irrigation canals can be considered as large-scale systems, where coordination and communication between subsystems (reaches) is needed. Model Predictive Control (MPC) approaches have been widely and successfully applied in water systems in order to predict the process output at future time instants. However, MPC is a technique with strong computational requirements that hinder its application to large-scale systems such as water networks in a centralized way.

Moreover, the communication difficulties in a system extended in a geographical area of hundreds of kilometers make it not sensible to use a centralized real-time control system based on long-distance communications.

As a consequence, most large-scale and networked water control systems are based on a decentralized control architecture where the system is divided into several subsystems, each one controlled by a different control agent. However, the main drawback of decentralized control is that the usually important coupling effects among the different subsystems are not taken into account, producing an important loss in the control performance.

Another issue to deal with is the fact that sometimes different sections of the canal can be managed by different control centers and even by different organizations.

FP7 STREP project

HD-MPC - Hierarchical and distributed model predictive control of large-scale systems

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Project website

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Sept. 1, 2008-Dec. 31, 2011

How to ...?

Control in an optimal way a tree-structured irrigation canal, with constraints and a variable water demand.

HD-MPC Solutions for Irrigation Canals

One of the objectives of the HD-MPC project has been to develop distributed MPC techniques to optimize the management of water in irrigation canals.

The distributed solutions developed in the HD-MPC project can be applied to any tree-structured irrigation canal and different control structures:

- downstream or upstream control,
- gate opening or flows as manipulated variables,
- water levels or flows as controlled variables.

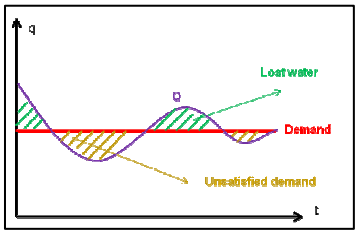
One of the most promising distributed MPC methods is based on game theory for multiple agents. This algorithm provides a reasonable trade-off between performance and low communication requirements needed to reach a cooperative solution.

A flexible platform has been developed by connecting a hydraulic model of an irrigation canal system with distributed MPC controllers.

This solution has been tested in simulation on a section of the Postrasvase Tajo-Segura, a canal for irrigation and drinking water at the South-East of Spain. This section consists of two branches with a total length of 24 kilometers, 5 gates, and 5 off-takes distributed along the canal. A complete description of the applied algorithm can be found in the special issue of the *Journal of Process Control* on HD-MPC (vol. 21, no 5, June 2011).

Impact and Benefits

At present, most of the canals are manually operated or controlled using local PI or sometimes decentralized MPC controllers. The proposed distributed MPC approach has been compared with these conventional approaches, obtaining notable improvements regarding set-point changes, perturbation rejection, and water losses.



Different scenarios have been tested on the 24 kilometers canal benchmark (changes in the level references, variation in off-takes demand and heavy rain), showing a cost reduction of up to 25%, considering both lost water and unsatisfied demand.

Main achievements

Distributed MPC controllers have been developed and tested in order to control large-scale water canal systems, and their efficiency has been demonstrated on a benchmark. An application on water canal systems illustrates the anticipation and coordination of gate openings and inflow to control water levels and flows in the canals and to guarantee demand requirements.