# An Iterative Approach for Distributed Model Predictive Control of Irrigation Canals

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## 1 Introduction

Optimization techniques have played a fundamental role in designing automatic control systems for the most part of the past half century. This dependence is ever more obvious in today's wide-spread use of online optimization-based control methods, such as Model Predictive Control (MPC) [1]. The ability to capture process constraints and characterize comprehensive economic objective functions has made MPC the industry standard for controlling complex systems.

However, the growing size and geographical spread of these systems is reaching unprecedented levels, which makes the traditional centralized control paradigm inefficient and sometimes even infeasible. Cost-effective and reliable operation of such systems requires a more pragmatic control approach relying on distributed control techniques. These methods strive for a division of the optimization task into problems of smaller size, which involve only a subset of the global variables in order to tackle the computational complexity and respect operational constraints in a large-scale optimal control problem. This is achieved by a trade-off between information exchange among local controllers and the complexity of their local computations.

## 2 Distributed version of Han's method

In order to address the challenges raised by distributed control using online optimization-based approaches, we have recently developed a distributed version of Han's parallel method for convex optimization [2]. This method aims to define local controllers for dynamically coupled subsystems that share coupling constraints and minimize a separable objective function. Relying on the decomposition of the dual optimization problem such that local problems have analytical solutions, the algorithm uses an iterative update procedure that converges asymptotically to the global optimizer of the primal problem. The solution approach allows each controller to work in parallel and exchange information only with a small number of other controllers. The control solution obtained in a distributed way converges to a globally optimal control sequence. Repeating the iterative solution procedure based on new measurements leads to a Distributed Model Predictive Control (DMPC) approach.

## 3 DMPC of irrigation canals

In this paper we illustrate the application of the novel DMPC approach on the control of a system of irrigation canals. Irrigation channels are large systems, consisting of many interacting components, and spanning vast geographical areas. For the most safe and efficient operation of these channels, maintaining the levels of the water flows close to prespecified reference values is crucial, both under normal operating conditions as well as in extreme situations. Manipulation of the water flows in irrigation channels is done using devices such as pumps and gates.

The distributed optimization-based control approach is demonstrated on the West-M irrigation system [3] composed of 8 canal reaches and on an artificial irrigation network involving 34 reaches to illustrate the scalability of the method. In both simulations, the control objective is to regulate water levels at downstream ends of all reaches, with respect to operational constraints including control input limitations, upper and lower bounds and rates of change of the water levels. The results confirm that the DMPC scheme obtains asymptotic global optimality in a distributed way.

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### References

[1] J. Maciejowski, *Predictive Control with Constraints*, Prentice Hall, 2000.

[2] D. Doan, T. Keviczky, I. Necoara, M. Diehl, and B. De Schutter, "A Distributed Version of Han's Method for DMPC of Dynamically Coupled Systems with Coupled Constraints," submitted to *NecSys'09 conference*, 2009.

[3] A.J. Clemmens, T.F. Kacerek, B. Grawitz, and W. Schuurmans, "Test cases for canal control algorithms," *Journal of Irrigation and Drainage Engineering*, vol. 124, no. 1, pp. 23–30, January 1998.