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# A hierarchical distributed model predictive control approach to irrigation canals: A risk mitigation perspective

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ABSTRACT

This paper presents a hierarchical distributed model predictive control approach applied to irrigation canal planning from the point of view of risk mitigation. Two levels in optimization are presented. At the lower level, a distributed model predictive controller optimizes the operation by manipulating flows and gate openings in order to follow the water level set-points. The higher level implements a risk management strategy based on the execution of mitigation actions if risk occurrences are expected. Risk factors such as unexpected changes in demand, failures in operation or maintenance costs are considered in the optimization. Decision variables are mitigation actions which reduce risk impacts that may affect the system. This work shows how model predictive control can be used as a decision tool which takes into account different types of risks affecting the operation of irrigation canals.



## 1. Introduction

Water canal system management involves operating pumps, valves and gates to satisfy user demands and minimize costs. The main objective of irrigation canals (IC) is to supply water to farmers according to a specific schedule. A set of constraints imposed by the physical system and by management policy has to be considered.

IC operation may be affected by many important factors. Operations can be interrupted for several reason such as scheduled maintenance, response to warnings, subsystem failure or accidents. Furthermore, variability in demand, changing weather and raw water conditions are parameters that should be considered for the optimal operation and maintenance of the plant. Several studies have been carried out to take into consideration the influence of uncertain factors in the performance of water systems such as [21], [26] or [30] where climate change, drought or demand fluctuations have been analysed.

Uncertain factors not previously considered in the planning may affect IC operation. These uncertainties originate from various causes: political (changes in politics can change water strategy), operational (water level reference varies from that forecast, adjacent land becomes water logged, etc.), financial, maintenance tasks (failure in reach or devices due to wear and tear, seepage loss, sensor theft) or ecological. Most of the factors mentioned are sources of risks that can affect IC performance and should, therefore, be taken into account. Quantifying these risks and incorporating them into mathematical planning and operation models may result in improved water system policies.

Risk management (RM) in plant operation is a discipline that is giving rise to great interest amongst researchers and industrial sectors [4,27]. The objective of RM in engineering systems is to establish risk-based policies to obtain better trade offs in safety and productivity. This technique begins at the conceptual design phase and continues through out the execution and commissioning of the system. In recent years, risk has been intensively studied in water resource engineering, and many significant achievements have been made. In Ref. [31] a risk analysis is developed where parameters such as reliability, resilience and vulnerability are evaluated. In Ref. [2] an identification of different risks in water systems is provided and in Ref. [3] a guideline is presented for mitigating risks. An optimization of the operation of a desalination plant is carried out by risk mitigation in Ref. [28]. It can be concluded that risk in water systems may decrease if risk mitigation actions are adopted beforehand.

From the point of view of IC control, many contributions can be found in the literature. The introduction of automatic control has been increasingly promoted when technical and socio-economic circumstances make it possible [6,19]. There are applications ranging from classical approaches such as PI controllers [17] to model

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