Fault Tolerant Reconfigurable Control of a Water Delivery Canal – Actuator Faults ⋆

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Abstract: This work addresses the problem of designing fault tolerant controllers for a water delivery canal that tackle actuator faults. The type of faults considered consist of blocking of one of the gates. The detection of the fault is made by comparing the gate position command with the actual (measured) gate position. Both centralized and distributed controllers are used for local upstream water level control. Centralized controllers are multivariable LQG-LTR controllers that use a model of the system with all the available manipulated inputs (gate positions) and all the available outputs (pool levels). Initially, three gates and three pools are controlled. After the fault detection, the controller is reconfigured to use the only two still operating gates and the corresponding two pool water levels. Distributed control uses local (SISO) LQG-LTR controllers that negotiate with their neighbors in order to be coordinated. When a fault occurs, this negotiation takes place only among the controllers connected to the actuators that are not in a faulty state. Experimental results obtained in a pilot canal are presented.

Keywords: Fault tolerant control, multivariable control, distributed control, water delivery network.

1. INTRODUCTION

1.1 Motivation

The complexity of large scale water delivery canal systems (Cantoni *et al.* [2009]), together with requirements on reliability and quality of service specifications provide a strong motivation to consider fault tolerant control methods for this type of systems. The idea consists in exploring the redundancy in their sensors and actuators to reconfigure the control system such as to allow the plant operation to continue, perhaps with some graceful degradation, when a sensor or actuator fails.

1.2 Literature review

The concept of fault tolerant control (FTC) has been the subject of intense research in the last twenty years (Zhang and Jiang [2003], Åstrom *et al.* [2009], Blanke *et al.* [2001]). This activity yielded a rich bibliography that, of course, cannot be covered here and that comprises aspects such as fault detection and isolation and fault tolerant control design. In what concerns distributed control an important concept is "integrity", namely the capacity of the system to continue in operation when some part of it fails (Campo and Morari [1994]). Other type of approach model the failures as disturbances that are estimated and compensated by the controller (Zhao and Jiang [1998]).

Concerning water delivery canal systems a topic that receives attention due to their immediate economic impact related to water saving is leak detection (Weyer and Bastin [2008]). Other aspects found in the literature are control loop monitoring (Zhang and Weyer [2005]), and reconfiguration to mitigate fault effects (Choy and Weyer [2005]), which is the issue considered in this work. Reconfiguring the controller in face of a plant fault falls in the realm of hybrid systems and raises issues related to stability that must be taken into account (Koutsoukos *et al.* [2000]).

1.3 Contributions and paper structure

The contribution of the paper consists in the experimental demonstration of reconfigurable controllers that are tolerant to actuator faults in a water delivery canal.

The paper is organized as follows: After the introduction in which the work is motivated, a short literature review is made and the main contributions are presented, the problem addressed is formulated in section 2. Section 3 describes the FTC proposed and section 4 presents the experimental results obtained. Finally, section 5 draws conclusions.

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