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SYSTEM IDENTIFICATION OF ARAGON'S IMPERIAL IRRIGATION MAIN CANAL

Rivas Perez R.*, Feliu Batlle V., Sanchez Rodriguez L.***, Pedregal Tercero D.**, Linarez Saez A.****, Aguilar Mariñoso J.V.****, Langarita García P.******

** Department of Automatica and Computer Science, Havana Polytechnic University, Calle 114 No 11901, CUJAE, Marianao, Ciudad de la Habana, C.P. 19390, Cuba, e-mail: rivas@electrica.cujae.edu.cu*

*** Escuela Técnica Superior de Ingenieros Industriales, Universidad de Castilla-La Mancha, Campus Universitario s/n, Ciudad Real, C.P. 13071, Spain, e-mail: Vicente.Feliu@uclm.es*

**** Escuela Universitaria de Ingenieros Técnicos Industriales, Universidad de Castilla-La Mancha,* Campus *Tecnológico de la Antigua Fábrica de Armas s/n, Toledo, C.P. 45071, Spain, e-mail: Luis.Sanchez@uclm.es*

***** Environment ministry, Hydrographical Confederation of Ebro, P^o de Sagasta No 24-28, Zaragoza, C.P. 50071, Spain, e-mail: alinares@chebro.org*

Abstract: In this paper a mathematical model of the water level variation in the first pool of the Aragon's Imperial irrigation main canal belonging to the Ebro Hydrographical Confederation (Spain) is derived from system identification experiments. The complete identification procedure from experiment design to model validation taking into account prior physical information is presented. It is shown that a linear second order model with an ARMAX structure and a time delay describes adequately the main dynamical behavior of this canal pool. The obtained model will be used for prediction and control purposes.

Keywords: Systems Identification; Mathematical Model; Open Irrigation Canal Control; Irrigation Systems; Parameter Estimation; Environmental Systems, Water Efficient Use.

1. INTRODUCTION

Water has now become a very scarce resource in many parts of the world because of the increasing population and the competition from nonagricultural demands. A lot of water is used in agriculture and its demand keeps growing. There is an urgent need for efficient management of irrigation resources.

At present a lot of water is wasted in most irrigation canals because of a lack of efficient control. In this context, automatic control is considered as a powerful tool for improving efficiency in water distribution irrigation systems (Litrico and Fromion, 2004). Automatic control of irrigation canals is considered as an active research area (Feliu et al., 2005; Malaterre et al., 1998).

In order to design an effective control system of irrigation canals, a model which gives an accurate description of their relevant dynamics is needed.

The physical dynamics of an irrigation canal pool has traditionally been modelled by the Saint-Venant equations (Saint-Venant 1891; Chaudhry, 1993), which are nonlinear hyperbolic partial differential equations (distributed model). These equations are derived from mass and momentum balances and are given by:

$$\begin{aligned} &\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q; \\ &\frac{\partial Q}{\partial t} + \frac{\partial Q^2 / A}{\partial x} + gA\frac{\partial z}{\partial x} = -gAS_f, \end{aligned} \tag{1}$$

where: A - canal cross section area; t - time; Q - flow (discharge); x - longitudinal abscissa in the direction acceleration; z - water surface absolute elevation; of the flow; q - lateral inflow or outflow; g – gravity S_f - friction slope.

The Saint-Venant equations are computationally expensive for simulation purposes and they are not easy to use for control design, although it is quite possible to use them as a starting point for control design (Weyer, 2001).

Irrigation main canals are systems distributed over long distances, with significant time delays and dynamics that change with the operating conditions. Also different structures, like gates, intakes/offtakes, are placed along the canal at particular positions, interacting with the natural dynamics of the canal. Thus, the whole canal has to be regarded as a complex dynamic system with a high number of state variables, outputs and inputs (Malaterre et. al., 1998).

Recently system identification methods are being successfully applied to obtain simple models of the main irrigations canals (Euren and Weyer, 2005; Weyer, 2001). System identification is a specific part of any control design methodology and deals with the problem of building mathematical models of dynamical processes based on observed input-output data (Ljung, 1999). Using system identification, one is able to obtain models which are in agreement with the physical reality and useful for prediction and control. The system identification results determine substantially the achieved control quality.

Irrigation main canals are ideally suited for system identification because their operational data are widely available. In this paper the complete system identification procedure of a pool of one of these canals is presented, from experiment design to model validation, and using prior physical information.

The major difference in the results that are presented in this paper from those that were presented in (Euren and Weyer, 2005; Weyer, 2001) are as follows:

- ✓ The irrigation canal pools in this paper are equipped with undershot gates;
- ✓ The number of upstream gates of the canal pool is bigger than the one in (Weyer, 2001).
- ✓ The current main canal pool is much larger than the one in (Euren and Weyer, 2005).
- ✓ The model obtained in this paper differs of the one that was obtained in (Weyer, 2001).

The paper is organized as follows. In Section 2 a brief presentation of Aragon's Imperial main irrigation canal is offered. The results of the experiment design and nonparametric identification are presented in Section 3. Section 4 is devoted to the model structure selection and parameters estimation. The model validation procedure is developed in Section 5. A discussion and conclusions are presented in the last section. This paper is part of an on-going research project between the University of Castilla-La Mancha and the Ebro Hydrographical Confederation (Spain) on modeling and control of irrigation canals.

2. PRESENTATION OF THE ARAGON'S IMPERIAL IRRIGATION MAIN CANAL

The Aragon's Imperial irrigation main canal belongs to the Ebro Hydrographical Confederation and it is considered as an excellent hydraulic work. This canal flows along its way more or less parallel to the Ebro river, to its right bank and supplies drinkable water to the Zaragoza city, guaranteeing the 60 % of its needs.

This canal gets its water diverted from the Ebro river thanks to the elevation produced by the Pignatelli dam. Water passes through the known as Casa de Compuertas (House of Gates) that controls the 30 m^3/s of discharge in the origin. It has a length of 108 km., a variable depth between 4 and 3 m., a trapezoidal cross section and 10 pools of different lengths separated by undershoot flow gates. The canal stretch between two serial gates is referred to as a pool.

All its pools are electrified and equipped with: downstream end water level and gate position sensors, motors for the gates positioning, and data acquisition, processing and storage systems. The canal also has a remote manual supervisory control system with communication by radio and field buses.

The canal control is carried out fundamentally in a manual way from the Management Center of the Ebro Hydrographical Confederation. For this reason the problem of water losses is significant in this irrigation main canal.

In order to minimize water losses and improve the management and exploitation of the whole canal, the implementation of a water distribution integral control system is being studied. Therefore a first step in this study is the obtaining of simplified mathematical models of the canal pools that must describe accurately their dominant dynamic behaviors, and facilitate the ulterior control system design. This paper deals with the identification of the dynamics of the first canal pool only.

3. EXPERIMENT DESIGN AND NONPARAMETRIC IDENTIFICATION

Data and results from the first pool of the Aragon's Imperial main canal (AIMC), which is known as the Bocal, are reported in this paper. It is a cross structure canal pool of 8 km. long, a variable depth between 3.5 and 4 m., a width of 10 m. and design discharge of 30 m^3/s, in all it extension. Fig. 1 shows an upper view of the Bocal, where the House of Gates can be observed.

Fig. 1. An upper view of the Bocal.