



WISCHE: A DSS for water irrigation scheduling[☆]

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ABSTRACT

In this paper we present the models and the algorithms which are being used in a decision support system (DSS) to determine water irrigation scheduling. The DSS provides dynamic scheduling of the daily irrigation for a given land area by taking into account the irrigation network topology, the water volume technical conditions and the logistical operations. The system has been validated by the Agriculture Community of Elche (Spain) and annexed to their Supervisory Control and Data Acquisition system (SCADA). We present two heuristic approaches to solve the mixed 0–1 separable nonlinear program for irrigation scheduling implemented with free software.

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1. Introduction

In 1968 the Council of Europe published the European Water Charter (<http://assembly.coe.int/>), which states fundamental principles for the conservation of water resources and establishes criteria for their rational use. Besides outlining the fundamental principles for the protection of this indispensable and vital asset, the European Water Charter points out the need for the inventory, control and management of water resources.

The need for rational water management has become greater in many Mediterranean regions as a result of changes in the availability of water, changes in general climatic conditions and the adverse effect of the actions of human beings on the environment. See [6] and the references therein for more details of water-related problems in Mediterranean regions.

Over the last years the traditional irrigation scheduling systems have been changed for other new systems in the southeast of Spain because of the scarcity of water resources in this arid region. The traditional inundating irrigation systems have been progressively substituted by drop (sprinkler) irrigation systems, in which the water is channeled to the irrigation points where it is necessary and the required quantity is completely regulated and controlled. This kind of irrigation systems is more common day by day in the above-mentioned region.

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The ability to help the decision maker in the planning and scheduling of the distribution of water resources depends on the level of sophistication of the tools and techniques available. A comprehensive approach may remedy the inadequacies of the tools currently available, by developing a hydrologic modeling framework and a highly numeric intensive computation decision support system. See [14–17,20] and the references therein.

We should differentiate between water resource planning over a time horizon which is usually long and water distribution scheduling which is usually on a daily basis. For the case of planning see [3] for the deterministic environment, and [13,18] for the stochastic case by considering the uncertainty in the main parameters (water inflow and needs).

The Agriculture Community of Elche (ACE), Elche being a city in the southeast of Spain, is constantly looking for new irrigation systems in order to conserve the natural environment and to save as much water as possible, because they realize the future of the region depends in some way on the management of the scarce and important resource which water is. At this moment, ACE is in a first phase of modernization of the channeling systems and the distribution of irrigation water among its members. The first phase in this work was the substitution of the water canalization for a new system consisting of underground pipes and pumps. The pumps send the water from the dam to each irrigation area. The system is controlled by means of a SCADA (Supervisory Control and Data Acquisition) which controls and regulates the available flow in each irrigation area. The advantages of this improvement to the installations are obvious. On the one hand, the water lost by evaporation and filtering is reduced and, on the other hand, each member of ACE has the guarantee of a fixed quantity of irrigation water with a specific pressure on his land.

This improvement in the infrastructures of the irrigation system is very important in order to save irrigation water but

there are two technical problems to be resolved: (i) the design of the pipe network does not guarantee the irrigation service to all members of ACE simultaneously, therefore some priority criteria are needed in the management of the system; (ii) the overall pressure of the pipe network has to be controlled to avoid possible breakage of the pipes or water losses. To determine the irrigation scheduling we have considered a set of time periods. The scheduling interval is five periods per day of 4 h each, the number of daily periods can be changed by system requirements. In each period the members of ACE are divided into two groups: active and non-active. Each member of the active group has a certain water volume and a minimum pressure in each period of time guaranteed, and each member of the non-active group has the service of the irrigation water blocked. The SCADA controls the opening and closing of the valves.

The DSS WISCHE (Water Irrigation for SCheduling) provides a solution to the problem of assigning each member of ACE to a set of consecutive time periods in the daily irrigation scheduling, such that the water volume and the minimum service pressure are guaranteed. In addition, the solution provided guarantees that the water speed in the network does not exceed a previously fixed maximum value.

As the preferences of the members of ACE over all daily periods could be the same or coincide in some periods and, very likely, it is impossible to satisfy all preferences simultaneously, a special module has been incorporated into the system which records the past consumption of water and records the scheduling for previous time periods for each hydrant. Thus, we are able to determine indices of inefficient use and the time period assigned for each hydrant in previous days. These indices allow us to determine an irrigation earliness–tardiness unit cost for each member of ACE. The optimization model implemented in the software minimizes the daily irrigation earliness–tardiness cost of the users. It is a mixed 0–1 separable nonlinear model presented in [1], that for completeness we include below.

For a good exposition of mixed 0–1 linear programming, see e.g. [22], and see [4] for a mixed-integer linear programming model in a irrigation scheduling problem in another context. A linear integer programming for scheduling decision at a distributor of industrial gasses is presented in [9].

The decision support system presented in this work has been tested by solving a real-life problem presented by “La Comunidad de Regantes, Riegos de Levante, Canal 2nd”, which belong to ACE. Its irrigation area comprises 2188 Ha and is distributed in 20 pipe sectors (i.e., 20 head nodes) with a total number of 2831 nodes (2025 of them are hydrants with their own water demand needs). The irrigation is needed on a daily basis for a set of time periods. The water flows from a reservoir with a capacity of 13 Hm³, and the full system has an arborescent structure.

The remainder of the paper is organized as follows. In Section 2 we describe the structure of the decision support system WISCHE. Section 3 presents the irrigation earliness–tardiness unit cost system for the hydrants. Section 4 introduces the mixed 0–1 separable nonlinear model. In Section 5 we present the optimization algorithms implemented in the software WISCHE, as well as the results of the computational experiment that has been carried out for validating the system. Finally, Section 6 concludes.

2. WISCHE structure

WISCHE is a decision support system annexed to a SCADA. It sends to the control system the daily scheduling of the irrigation system, providing information about which hydrants will be served in each time period, and receives information from the control system on the water consumption of each hydrant. A

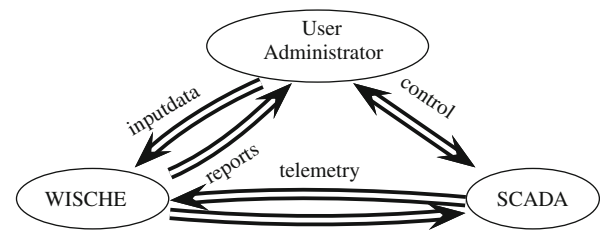


Fig. 1. Components of the decision support system and flow of data.

scheme illustrating the implemented systems and the relation between them is shown in Fig. 1. WISCHE consists of four modules. The first module processes historical data of telemetry, debugs reading errors and provides tools to create graphs of water consumption, pressure, etc. The second module allows to introduce the irrigation target starting time period for each hydrant user. Additionally it allows to modify the priority criteria. The third module is responsible for processing all the information in the file telemetry, together with the history of the members preferences and their new preferences for the following day or week. Taking into account all this information, the module generates a set of irrigation earliness–tardiness unit costs for each hydrant and time period. This set of priorities is used by the optimization module that provides the assignment of irrigation periods to each member of ACE. The diagram shown in Fig. 2 presents the structure of the files that the WISCHE and SCADA modules share.

3. Earliness–tardiness cost for irrigation scheduling

It is probably impossible to satisfy the preferences of all the members of ACE because of the design and dimension of the irrigation network and the constraints on the pressure and the speed of the water. So, it is absolutely necessary to have a mechanism which penalizes the assignment of a particular hydrant to an irrigation time period when there are several hydrants with the same or coincident preferences.

The WISCHE system receives the irrigation target time periods of the members of the ACE in a table-form. These preferences are then combined with the past history of use of the hydrant. We have taken into account two significant factors to determine the assignment of a hydrant to a particular irrigation period:

- Factor 1 (F_{ht}^1): Inefficiency in the use of the assigned time periods starting at time period t in a number of previous daily schedules. It is measured as the fraction of the number of previous days that hydrant h has been assigned to a set of consecutive time periods starting at time period t and not using these time periods.
- Factor 2 (F_{ht}^2): Fraction of the number of irrigation target periods starting at time period t that in fact have been assigned to hydrant h in previous daily schedules.

Both factors provide two indices (in (0,1)) which measure, for each hydrant, the inefficiency in the use of the target irrigation period (Factor 1) and the fraction of times that their target periods have been assigned (Factor 2). These factors are used by the system to calculate the hydrants' weights in the assignment of the irrigation scheduling, i.e., the weight w_{ht} is evaluated as a weighted average of both factors, such that $w_{ht} = \alpha F_{ht}^1 + (1-\alpha)F_{ht}^2$ with $0 \leq \alpha \leq 1$. It is worthy to note that the weights w_{ht} can be different for each hydrant h along the time horizon since the preferences of a hydrant are not homogeneous along the time

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