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SOFT COMPUTING FOR SMARTER OPERATION MANAGEMENT IN WATER DISTRIBUTION SYSTEMS

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Abstract *This document is intended to be a presentation of session ST36 of CMN2017, placing this session in the appropriate context to understand its motivation and guide its content. The circumstances that occurred in 2016 have led the session to become a posthumous tribute to Rafael Pérez García who died on October 7, 2016. This document also presents concisely the 17 contributions submitted to the session, by shortly describing how they fit into the session scope, seeking for soft computing techniques that ease smarter management of water distribution systems, including planning, operation and maintenance of those increasingly complex systems, especially when online actions are the target.*

1. INTRODUCTION

During the last 25-30 years, Urban Hydraulics has had an exceptional reference for Spain and Latin America at the Universitat Politècnica de València (UPV). Trying to stick to the more recent history, we will refer here approximately to the last 10-15 years. After several vicissitudes (certainly, history has not been easy), given the scientific production related to Urban Hydraulics and, more specifically, to water distribution systems (WDS)[i] , a bunch of people gathered in the research group called FluIng, within the Institute for Multidisciplinary Mathematics (IMM) of the UPV, has excelled. As can be read on its website (fluing.upv.es), FluIng has been steered by professors Rafael Pérez García and Joaquín Izquierdo Sebastián. Unfortunately, Rafa passed away on October 7, 2016. However, Rafa's influence continues to feel tangible. Currently, FluIng is an immaterial, nonconventional, scientifically transverse and geographically global research group. FluIng currently consists of almost 30 people with varied original training, and geographically dispersed in 12 countries in Europe and Latin America. All of us are deeply affected by Rafa's departure, recognize his magisterium and good work, and participate in this session, *ST36: Soft computing for smarter operation management in water distribution systems*, of CMN2017 to give him our deepest gratitude. This technical session, therefore, has the vocation of giving a posthumous tribute to Rafa, without whose activity and guidance, FluIng would not have had the development of which we are currently so proud.

Originally, Rafa and I (JIS) practiced classical science in Urban Hydraulics. Our first achievements made it clear. Just as an example, we both were authors of respective software programs of design and simulation[ii] in Urban Hydraulics based on classical mathematical models, algebraic and differential equations, and classical optimization methods, in sum, in theory-driven techniques. We soon noticed that data-driven science was beginning to anchor in the scientific community [1]. Thus, with the invaluable participation of exceptional people in the realization of their Doctoral Theses and other collaborators (see next references), FluIng started to produce works in Urban Hydraulics using neural networks [2], fuzzy logic [3,4], evolutionary algorithms [5-7], clustering techniques [8], artificial intelligence [9], intelligent data analysis techniques [10,11], multi-agent based systems [12,13], etc. We also observed the importance of the human factor in the management and operation of systems and in decision-making, and began to study aspects including human interaction [14], multi-criteria decision-making techniques for the consideration of intangible elements [15-17], and techniques for automatic learning and interpretation of results [18,19].

We all have collectively built the work niche (see the web of FluIng, fluing.upv.es, for a wider vision) in which FluIng is currently focused and that has led to the organization of this technical session.

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[i] 10 doctoral dissertations plus another 10 on-going PhD projects; more than 70 journal papers, most in high impact journals; more than 250 contributions to international congresses and meetings; organization of international events such as SEREA, with 14 completed editions, and specialized sessions in international congresses such as SELASI and iEMSs.

[ii] DIOPRAM (Spanish acronym of optimal design of branched networks) and DYAGATS (Spanish acronym of analysis and design of water hammer in simple pipes)

2. ABOUT THE SESSION

The complexity of water distribution systems (WDSs) derives from the nature of the classical hydraulic models describing WDS phenomena [20], and from the increased need to suitably handle the huge amount of data generated in the various processes associated with water distribution (see, for example, [21-25]). WDSs must be: firstly, suitably designed (in the case of new systems) and refurbished (enlarged and rehabilitated at later stages) so that they can provide the intended service; secondly, suitably monitored to have enough quality judgement elements for (preferably real-time) control; thirdly, optimally operated to provide seamless quality service; and finally, properly managed to integrate the maximum number of benefits, including such conflicting objectives as economic revenue and social satisfaction.

2.1. Session contributions in context

Given the complexity of the problems associated to WDSs [26], efficient numerical techniques are needed [27]. While [26] may be considered a position paper presenting the kinds of problems we are concerned about, [27] presents the position of the session organizers from the point of view of the numerical techniques, the soft computational tools we are interested in.

How these issues are addressed in the various contributions presented to the session are specifically described in the following paragraphs.

Robust and efficient optimization algorithms (able to deal with non-linearities, mixed variables, and discrete processes – including those with an evolutionary vocation and, naturally, multi-objective optimization) are paramount in the various tasks associated to water supply. Optimization, including some of the abovementioned characteristics, is dealt with in [28-31]. In [28], the performance of eight penalty functions for Genetic Algorithms and Particle Swarm Optimization, in classical water distribution design problems, is evaluated and the benefits obtained with respect to other results found previously are presented. In [31] the search space is bound by analysing two opposite extreme flow distribution scenarios and then applying velocity restrictions to the pipes; the proposal reduces considerably the search space and provides a much faster and more accurate convergence than the classical genetic algorithm formulation. In [29], a multi-objective optimization process with preferences to deal with a water pollution management constrained problem with 6 design objectives is applied. [30] addresses a real-world problem, and try to adjust the demand pattern of different areas of a WDS through a combination of a clustering technique and a heuristic bio-inspired optimization algorithm.

Monitoring of service quality, an aspect addressed in [32, 33], especially real-time, as emphasized in [32, 26], will benefit from efficient techniques of time series data treatment [27]. In [32] the influence over the final water balance result of not collecting measurements from all the water meters simultaneously is estimated. [33] proposes a numerical method to approximate the concentrations of pollutants in pipe joints, which helps improve water quality in WDSs. As emphasized in [32] and [26], substantial improvements in WDS operation and management can only be achieved through smart techniques that include real-time measurements.

Operation may be defined in terms of a number of Boolean operators optimally defined and integrated into appropriate data structures (relying, in turn, on other types of optimization techniques, such as evolutionary optimization). Finally, management includes a wide spectrum of issues: preventive maintenance, for example, as considered in [34],which addresses suitable maintenance strategies with the focus on third world countries; control of network resilience or other indicators, considered in [35, 36], which tackle the resilience of a WDS, a crucial indicator in operation; demand forecast addressed from different points of view in [37, 30], the former proposing alternative resources to satisfy the demand, and the latter pointing towards suitable demand calibration to guarantee quality service; network sectorization, as in [38], where a hybrid approach using neural networks and clustering techniques is used; leakage detection, considered from different points of view in [39, 40], the former comparing several machine learning techniques to detect and isolate leaks, and the later using image analysis from GPR surveys; cadastre maintenance, using GPR image processing, as in [40]; and consumer satisfaction assessment, among others.

The soft computing techniques used to approach these processes (such as neural networks, support vector machines, clustering, agent-based systems, and social network theory) are expected to be robust and efficient [27]. In addition, despite some of the elements integrated in these issues are quantifiable, others may be classified as intangible. As a consequence, suitable techniques to treat information that is plagued with uncertainty and subjectivity are also needed, as in [41], which uses AHP, a multi-criteria decision-making technique, to prioritize among various maintenance strategies.

Further research is essential to develop algorithms that apply in real-world situations [26] and on datasets with many elements [27]. In particular, in the water distribution industry, improvements in big data computing [27] for exploiting data as fully as possible in Advanced Metering Infrastructures (AMI) [26] will greatly help reduce non-revenue water in the near-term. Moreover, such improvements will contribute, through more efficient operation, as in [42], which tries to ascertain how anomalies affect the nodes they are connected to in case of threat or hazard, to maintain a level of long-term excellence in the urban water cycle [26] and, eventually, contribute to the smart city concept [27].

3. CONCLUSION

In addition to the complexity inherent to water distribution systems, derived from the nature of the classical hydraulic models describing their phenomena, and from the increased need to handle the huge amount of data generated in the various processes associated with water distribution, the need for online actions to manage those systems in real time, makes it evident the necessity of powerful techniques able to cope with such associated complexity. In this session, computational techniques to address these kinds of problems have been presented based on soft computing techniques including such paradigms as evolutionary algorithms, intelligent data analysis, computation in uncertain environments, and multi-agent systems, just to name a few.

Acknowledgments

Due to the recent death of Professor Rafael Pérez García, this session, originally thought of as a milestone in the recent evolution of FluIng, has finally been dedicated to honoring his memory. The FluIng family and their friends express their deepest feelings towards both the magisterium and bonhomie of Rafael Pérez García.

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