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Optimal management of pressure in water supply networks through district metered areas with creation based on machine learning

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Abstract
Integrated management of water supply systems with efficient use of resources requires optimization of operational performances. Clustering the water supply networks into small units, so-called district metered areas (DMAs), is a strategy that allows the development of specific operational rules, responsible for improving the network performance. In this context, clustering methods congregate neighboring nodes in groups according to similar features, such as elevation or distance to the water source. Taking into account hydraulic, operational and mathematical criteria to determine the configuration of DMAs, this work presents k-means model and a hybrid model, that combines a self-organizing map (SOM) with k-means algorithm, as clustering methods, comparing four clustering mathematical criteria, namely Silhouette, GAP, Calinski-Harabasz and Davies-Bouldin; and analyzing the influence of varying three clustering topological criteria, the water demand, node elevation and pipe length, in order to determine the optimal number of clusters. Furthermore, to identify the best DMA configuration, the particle swarm optimization (PSO) method is applied to determine the number and location of DMA entrances.

Key words:
Water distribution system analysis, DMA creation, k-means.

Introduction

Water supply systems play a key role in urban design, not only to ensure that citizens have access to essential goods, but also for public safety reasons (Di Nardo et al., 2011, Grayman et al., 2009). The management of water supply systems has become increasingly complex in the face of the reduction of available natural resources, with the need to reduce energy consumption and water loss.

This study aims to develop and analyze models of DMA creation for water supply networks using mathematical criteria to define the optimal number of clusters. The two models to be studied are the k-means and hybrid models, with the purpose of determining the optimal cluster number of nodes with similar characteristics.

At a second stage, the challenge to find optimal entrances of each DMA is solved by Particle Swarm Optimization (PSO). The minimization of costs, reaching the minimal pressure at the network is conducted, resulting in the best scenario considering the best DMA creation model, mathematical criteria and minimal costs.

Results and Discussion

The water supply system in study is the D-Town network (Marchi et al., 2014). It is composed of 398 nodes, 458 pipes, 7 water sources, 1 reservoir, 13 water pumps and 4 valves.

Considering both mathematical and topological criteria for the study, the DMA creation based on the k-means model generated well distributed, geographic and compact aspect sectors. By using the hybrid model the DMAs presented the same pattern of clustering in diagonal bands, losing the essence of compact clusters and possibly representing difficulties in the strategic management of the sectors, since they have an elongated format.

The variation of the topological criteria resulted in changes in the arrangements and number of sectors, in which the increase of the criteria values tended to reduce the number of sectors. The mathematical criteria did not show drastic differences among them, with the Calinski-Harabasz criterion presenting the largest number of sectors and the GAP criterion the lowest number of sectors in the case of the model using only k-means.

The PSO optimization method was successful in identifying the best DMA configuration, minimizing pressures in the water supply system's grid in a fix operation and 24 hour operation situation.

Conclusions

The consideration of topological and mathematical criteria and the PSO is essential for the effective accomplishment of the DMA creation for the network. The topological criteria presented greater customization possibilities, valuable for the management of networks that have certain values and limits to be considered. It can be concluded that depending on the criterion, the size and configuration of the sectors will be unique, and it is up to the manager to choose the criteria that will be considered.

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[1] Di Nardo, A.; Di Natale, M. *A heuristic design support methodology based on graph theory for district metering of water supply networks*. Engineering Optimization, v. 43, n. 2, p. 193-211, 2011.
[2] Grayman, W.M.; Murray, R., Savic, D. *Effects of redesign of water systems for security and water quality factors.* Proceedings of the World Environmental and Water Resources Congress, S. Starrett, (Eds.), May 17–21, Kansas City, Missouri, United States, 10.1061/41036(342)49, 2009.
[3] Marchi, A. et al. *Battle of the water networks II*. Journal of water resources planning and management, 140(7), 04014009, 2014.