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Combining multiple perspectives on clustering. Node-pipe case in hydraulic sectorization

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Abstract. This work addresses the problem of water network division into district metered areas by the use of clustering respect to multiple views. In our application will use two data perspectives: one of these will be associated with consumption nodes of the water supply network, meanwhile the other one will be related to pipes. It also will be needed to combine the information from these multiple points of view. Thus, we communicate both solutions negotiating the respective cluster memberships by the interaction of their configurations based on schemes of intelligent agents that can merge the respective information layers of each structure. The result of this proposal is a very useful approach because it combines pipe properties, nodes, and graph information associated with the supply network as strong criterion to achieve system division. A real water supply system will serves as a case-study to check the performance of the division proposed.

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1. Introduction

Rational distribution of water in supply networks (WSNs) is a complex problem. This complexity increases if the system is large and the goal is to offer regular supply of clean water at the pressure required by consumers. Sectorization, understood as network partition into sub-networks with controlled inputs and outputs, is a strategic option which homogenizes the elements, measurements, and design parameters of each sub-network. In this way, we gain accuracy and avoid bias in decision-making about supply management [1]. Sectorization facilitates the detection, identification, and monitoring of possible abnormalities in the water supply due to inspection area reduction.

This paper proposes to apply spectral clustering and partitioning clustering to the individual views (nodes and pipes) and a posterior ensemble of these results. This communication between both solutions will be based on negotiating the respective cluster memberships by the interaction of both configurations based on schemes of intelligent agents [2] that can merge the respective information layers of each structure.

2. Combining two clustering views by multi-agent systems in water supply networks

First of all, a WSN must be considered as a particular graph including geographical and connectivity information. Then, we start by building the affinity matrix associated with a WSN. The next correspondences must be considered.

First, graph nodes are the consumption points of the WSN and their weights are their variables associated with nodes (demand, pressure, or elevation, among others). Then a cluster analysis based on the spectrum of a matrix is the more suitable technique to cluster this kind of information which also can take into account the structure of the graph. Spectral methods are based on the eigenvalues and eigenvectors of a block-diagonal matrix conveniently associated with the graph [3].

The next step of the proposal of this paper is to extend the single view of the problem of partition of the supply network, until now approached as a set of interconnected nodes, to a more complex view. This analysis involves adding potential groups arising to a clustering of the arcs of the graph of the problem. In the case of the application to water supply networks, the arcs represent pipes supply network. This fact makes that we focus on these analysis of this results of pipes, at least to the same level as the clustering of nodes (and their interconnection structure inherited) addressed so far. Thus, the study adds to variables such as demand or pressure elevation of each point, other important features of the pipelines (such as diameter, length, material or age

of the pipes). To take into account the different nature in the data associated with the pipes, it is proposed to use the algorithms CLARA/PAM [5]. Their memberships will be propagated to their corresponding nodes (starting and ending of each pipe), in order to merge this solution with the before found node solution.

A multi-agent system (MAS) [2] will communicate both solutions negotiating the respective cluster memberships by the interaction of their configurations based on schemes of intelligent agents that can merge the respective information layers of each structure (see Figure 1).

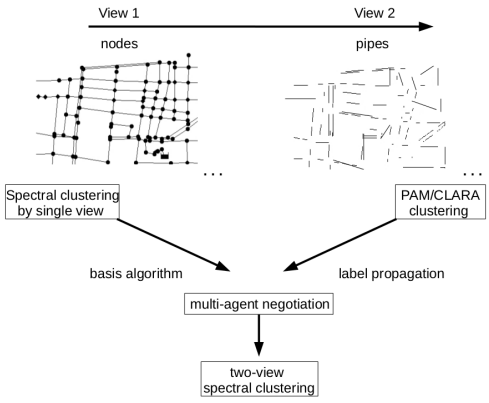

Figure 1: Overall proposed process of two-view clustering

3. Experimental study: water supply network sectorization

In order to show the performance of the presented process we consider here a real case, the WSN of the Central area of Celaya (Guanajuato, Mexico), fed by one reservoir and five tanks with five pump stations. This network is made out of 479 lines and 333 consumption nodes.

The sectors are composed as follow: By nodes, the results suggest a division into three sectors of 101, 96 and 136 nodes respectively. Its average elevation is similar. On the demand associated, it is higher in the Sector 3 than in the other two. The description of the sectors is completed from the viewpoint of the pipes. Thus, while the pipe material Sector 1 is iron (cast and galvanized), the Sector 2 is composed of asbestos cement pipes. Sector 3 is composed of both cast iron pipes and asbestos cement. Another notable difference is the average age of pipes: about 42 years in the Sector 3, while it is around 37 in sectors 1 and 2. The number of pipes per division is 121, 149,

and 209, respectively.

4. Conclusions

The result of this proposal is a very useful approach because it combines pipe properties, nodes, and graph information associated with the supply network as strong criterion to achieve system division, and also taking a complete vision of the clustering process. In order to combine both solutions in a single final model, it is proposed a new voting process based on multi-agent systems to negotiate the final classification, combining the solution for nodes and pipe-node propagation, avoiding usual bias in ensemble methods.

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