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META-HEURISTIC VERSUS GRADIENT-TYPE METHODS FOR REAL TIME DEMAND CALIBRATION IN WATER DISTIRBUTION SYSTEMS

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Water distribution system modeling in real time involves many challenges for water utilities. Calibration of models to match measurements coming from a water network with calculation resulting from models is a necessary step to make models reliable [1]. There are many variables involved in the analysis of a water distribution system and each of them contains a determined level of uncertainties. Nevertheless, in a real time scenario it is significant the impact that water demands at nodes could have compared with other variables. Demands, in contrast to pipe roughness for example, are much more sensitive to changes in time. A better estimation of how much water is being consumed at each point can help a lot to assess properly the current state of the network [2], [3], [4]. This information is crucial for supporting decision making processes based on models working online and can be used as a starting point for decisions involving a short term forecasting of the network behavior. Among the challenges of the presented research it should be mentioned the reduced available time for providing calibration results in a "real time" context. The methods used in this paper are not only trying to achieve good results but to achieve results in a relative short period of time. This idea has been accomplished by combining different heuristics, data mining and optimization techniques. Results presented in an online context are calculated based on the analysis of historical data and the analysis of the current information coming from water networks.

INTRODUCTION

Real time demand calibration in water distribution systems can be understood as an optimization problem. The use of a deterministic method to solve the problem can produce good solutions in a relative short period of time; nevertheless, these methods would be hard to apply without some compromises in the problem statement. Using stochastic methods based on heuristics can give much more flexibility but the computational efforts are higher and the guarantees of obtaining always good solutions are arguable. This research, enclosed in the development of the project *SMaRT-Online*^{WDN} [5], has the objective to compare both a heuristic solution of the problem and a classic deterministic solution in order to find the best approach to address the online calibration of water demands.

Selecting which is the most appropriate heuristic for solving a specific problem is not an easy task. That´s why a combination of different heuristics, evolutionary algorithms and data mining techniques was tested to identify what works better for real time demand calibration. The platform of Agent Swarm Optimization was used to support the combination of different heuristics, evolutionary algorithms and data mining techniques, aimed to reduce the search space of the problem [6], [7].
For the deterministic approach the experiences from other researches were crucial to deal with the mathematical complexity [8], [9]. In this research it was formulated a least squares problem with bound constraints for adjusting demand class coefficient in order to fit observed values at a given time. It was used a gradient-based method to solve the problem; the limitations of this method were explored considering different levels of complexity in the water models.

Evaluation platform

For testing purposes, this research also includes the development of a software component for emulating the data transmission from the water network to an OPC server and from there to the algorithms in charge of demand estimation. This platform makes possible the analysis of different scenarios in a controlled environment. Additionally, for a known water distribution system model, measurements can be artificially generated by using the results of hydraulic simulations after introducing some desired level of uncertainties in the model. Sensors could be placed potentially anywhere in the network in order to get the values resulting from simulations. Those values are saved in a database and are later "replayed", it means, they are sent to an OPC Server in an attempt to emulate what could be happening in a real system. The use of this evaluation platform for testing other online calculation algorithms is perfectly possible without any significant change in its code.

Application

Two real world network sections, one from Germany (Berlin) and the other one from France (Paris), were used for evaluating the algorithms implemented during this research. Two other additional synthetic networks were used for evaluating the algorithms in a controlled environment. From the software perspective a combination of different technologies were used for bringing ideas into live. One of the priorities was to maintain the compatibility with OPC technologies for receiving measurement values directly from sensors located in the network. This compatibility makes easier the application of the resulting algorithms directly in the industry. More than just an academic approach, the intention of this research is a practical application of a software component that could be reused by any water utility interested in online calibration of their models.

Conclusion

Neither a deterministic approach nor a heuristic approach can be said to be better in all cases or under any circumstances. Each approach has its own advantages and disadvantages and depending on the situation one of them could be more desirable than the other. The results of this research showed us a way to combine both approaches as the best alternative to solve the problem. Several improvements could be still be done to the way both approaches are combined, this research is just a starting point of how to accomplish that combination based on the advantages each approach can offer.

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