Congress on Numerical Methods in Engineering CMN2017
Valencia, 3-5 July, 2017

A new efficient bounding strategy applied to the heuristic optimization of the water distribution networks design

Juan Reca*, Juan Martínez* and Rafael López-Luque†

*Department of Engineering
Universidad de Almería
Ctra. Sacramento S.N., La Cañada de S. Urbano. 04120 Almería, Spain
e-mails: jreca@ual.es, jumartin@ual.es

*Department of Applied Physics
Universidad de Córdoba
Campus Universitario de Rabanales. 14071 Córdoba, Spain
e-mail: rafael.lopez@uco.es

ABSTRACT

The optimal design of looped water distribution networks can be regarded as a class of complex combinatorial problems known as NP-hard as it is a non-linear, constrained, non-smooth, non-convex, and hence multi-modal problem. Although mathematical programming methods such as linear and non-linear programming techniques [1,2] has been applied to solve this problem, metaheuristics methods have been preferred due to their ability to cope with global optimization problems. Genetic and evolutionary algorithms [3], Simulated Annealing (SA) [4], Shuffle Frog leaping algorithm [5] and particle swarm optimization [6] are among the most extended meta-heuristic approaches applied to water distribution networks design.

Although heuristics approaches can handle global optimization problems, they do not guarantee finding the optimal solution [7]. In addition to the accuracy of the provided solution, another shortcoming of these procedures is the relatively long time that these methods take to converge. Much research work has been carried out to improve their performance in recent times. However, for very large water distribution networks, these methods are still inefficient and time-consuming due to the wide search space of the problem. These algorithms waste a long time evaluating unfeasible solutions and the probability of finding the optimal solution in a short time decreases as the size of the search space increases.

This work presents a new approach to increase the efficiency of the heuristics methods applied to the optimal design of water distribution methods. The proposed approach is based on bounding the search space by analysing two opposite extreme flow distribution scenarios and then applying velocity restrictions to the pipes. The first scenario is the one that provides the most uniform flow distribution in the network. This scenario represents the network with the maximum entropy and resilience. The opposite scenario is the network with the maximum flow accumulation in a spanning tree of the network. Both extreme flow distributions are calculated by solving a quadratic programming problem, which is a very robust and efficient procedure. The approach proposed in this work has been coupled to a genetic programming approach. The genetic algorithm used in this work has an integer coding scheme and variable number of alleles. The number of alleles depends on the number of possible diameters comprised within the velocity restrictions of each pipe. The proposed methodology has been applied to several benchmark networks and its performance has been compared to a classical genetic algorithm formulation with a non-bounded search space. The proposed algorithm reduced considerably the search space and provided a much faster and more accurate convergence than the classical genetic algorithm formulation. The approach developed in this work can also be coupled to other type of metaheuristics.

REFERENCES

[1] E. Alperovits and U. Shamir, "Design of optimal water distribution systems", *Water Resources Research,* **13**(6), 885–900, (1977)
[2] K. Varma, S. Narasimhan and S.M. Bhallamudi, "Optimal design of water distribution systems using NLP method", *Journal of Environmental Engineering*, ASCE **123**(4), 381–388, (1997)
[3] J. Reca and J. Martínez, "Genetic algorithms for the design of looped irrigation water distribution networks", *Water Resources Research* **42,** W05416, (2006)
[4] M.D. Cunha and J. Sousa, "Water distribution network design optimization: simulated annealing approach", *J. Water Resources Planning and Management*, **125**(4), 215–221, (1999)
[5] K.E. Lansey and M.M. Eusuff. "Optimization of Water Distribution Network Design Using the Shuffled Frog Leaping Algorithm". *J. of Water Resources Planning and Management*, **129**(3), 10-25, (2003)
[6] I. Montalvo, J. Izquierdo, R. Pérez and M.M. Tung, "Particle Swarm Optimization applied to the design of water supply systems". *Computers & Mathematics with Applications* **56**, 769–776, (2008). doi:10.1016/j.camwa.2008.02.006
[7] F. Glover, M. Laguna and K.A. Dowsland, "Modern Heuristic Techniques for Combinatorial Problems", Blackwell, London, 1993.