A Cross Entropy Approach to the Optimization of the Water Distribution Networks: Optimization of the Hanoi Benchmark Problem

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Abstract
Cross-Entropy (CE) method is a new generic approach for combinatorial optimization and rare event simulation. CE has been applied successfully to optimization problems such as traveling salesman, quadratic assignment problem, the maximal cuts, and partitioning of graphs. The Hanoi problem is one of the problems that are extensively studied by many researchers, using a variety of optimization methods including genetic algorithms, ant colony, simulated annealing and other heuristic methods. In this study, the cross entropy method is applied to the optimization of the Hanoi water distributing benchmark problem. The problem independent nature of CE approach enables ease of use for the optimization of various engineering design problems. The EPANET2 hydraulic solver is linked to the CE Method for optimization of Hanoi benchmark problem. Results show that Hanoi water distributing network benchmark problem could be successfully optimized by CE method with a very limited objective evaluations. It is concluded that CE is not only a robust and easy to use method in dealing with the optimization of the water distribution networks, but also has the capability of rapid convergence to the optimum solutions.

Keywords: Cross Entropy, optimization, Hanoi water distribution network, combinatorial optimization

1. INTRODUCTION

Water distribution systems constitute a vital part of civil infrastructure of every society. The purpose of a water distribution system is to ensure the supply of water to different users with various usages [1]. Water is usually transferred to the consumption points, or nodes, from the sources through mains and are stored in the temporary storage locations, then distributed to the users. The distribution system usually consists of looped or branched networks. In order to design a network properly, the velocity and pressure limitations should be met. The distribution of the velocity and pressure in the network is analyzed utilizing the conservation of mass and energy principals. The current widely used simulation method is the demand driven simulation which is shown to be the same as the pressure driven simulation [2].

Water usage or consumption varies daily and seasonally. The large variations on the demand patterns in a typical day require the network to be very redundant and the designer must provide enough flexibility and capability in the network to meet the peak demands that are stochastic inherently. The provided capacity to meet the peak demands causes extreme pressures to be exerted to the pipes at times when demands are lower, especially at nights which in turn exert limitations on the layout and size of pipes to be used in the network. These problems call for the extended period simulations of the WDN’s.

However for systematic study of the performance of the different methods utilized by researchers, some benchmark problems are adopted by the experts of the fields in WDN optimization that does not involve all the real world complexities involved in the design process. Simple models proposed to have basic components of a water distribution networks, retaining the basic components and characteristics of the water distribution networks and at the same time, general enough to be useful in comparing performance of the optimization method for the real world applications. One of the models proposed is the Hanoi water distribution network [3]. The Hanoi WDN is introduced at the next sections of the paper is chosen to illustrate the efficiency of the Cross Entropy method.