SEWER NETWORK OPTIMAL DESIGN BASED ON CELLULAR AUTOMATA PRINCIPLES

YUFENG GUO

Research Student, Centre for Water Systems, School of Engineering, Computer Science and Mathematics, University of Exeter, Exeter, EX4 4QF, UK
(Tel: +44-1392-263600, Fax: +44-1392-217965, e-mail: Yufeng.Guo@exeter.ac.uk)

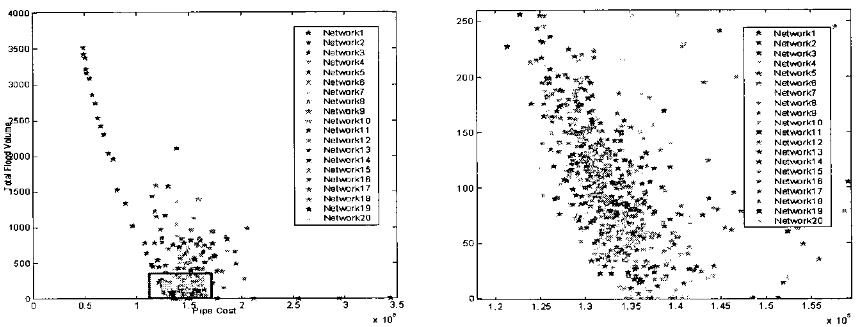
Designing a cost-effective sewer system may involve many factors: sewer line layout, pipe size, pipe gradient, control facility characteristics, storage size and location, etc. However, it is very common to pose this problem only as an optimal pipe-sizing problem. Therefore the decision variables are usually the diameters of sewer pipes. The prevailing approach is to knit certain sewer simulator and optimization tools together. The hydraulic sewer simulator is employed to model the performance of the proposed design and identify problems, such as unwanted flooding and surcharges in the system. The optimization tool is utilized to tune design scenarios according to information gained from the hydraulic simulations and the predefined objectives.

Currently, the use of evolutionary computation, or more specifically, genetic algorithm (GA) is employed as the optimizer for sewer system design. However, a GA needs a big population of solutions for a large number of generations to achieve a sound level of good design solutions. Therefore, GAs always suffer from high computational cost, especially for large networks. This paper introduces a novel alternative approach to cost-efficient sewer network design based on cellular automata (CA) principles, and is referred to here as the CASiNO method (Cellular Automata for Sewers in Network Optimisation). This study was initially inspired by some similar work on water distribution system design problems (Keedwell & Khu, 2005). The proposed approach is heuristic and driven by local searching towards a global optimum. It has the following key features inherited from CA: (1) close relationship with surrounding neighbors for local design improvements; (2) heuristic transition rules imitating human decisions; (3) parallel update in the whole spatial domain for high efficiency; (4) the solution at each time step corresponding to one sewer network pipe-sizing scenario.

The paper summarizes the development of a modelling experiment that links CA with the hydraulic simulation software EPA-SWMM (Rossman, 2004) and its library functions. The test problem is an artificial sewer network with 29 manholes, 29 pipes and 1 outfall. Two optimization objectives are formulated as minimization of capital cost of the network pipes and minimization of total flooding volume in the system. Some results of modelling experiments are illustrated in Fig. 1. Each point in the graph represents the solution found by CASiNO at each step, and each colour indicates a run from a different initial condition.

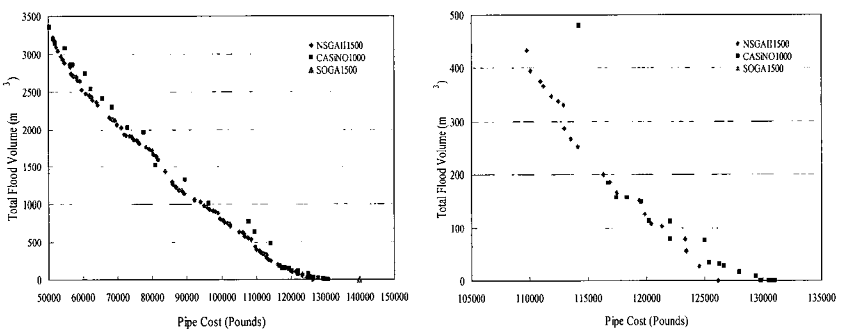
In order to determine the performance of this approach, the solutions obtained by CASiNO were compared to those found by Genetic Algorithms (See Fig. 2). From the practical view of sewer engineers, the solution having least capital cost with no flooding is favoured. Hence these types of solutions are selected and utilized as one performance indicator. It is found when the GA solver (NSGAII) takes a large number of function evaluations (150000 in this study), it achieves a good solution. Correspondingly, taking only 37.4% of the computation cost of NSGAII, CASiNO reported a solution slightly more expensive (2.85%) than that of NSGAII. However from the view for two objectives optimization, CASiNO does have some solutions very similar or even slightly better in performance when comparing the optimal fronts found by the different approaches. It is fair to say that CASiNO and NSGAII have quite similar levels of performance, but CASiNO has proved to be more efficient.

Although this study is still at its early stage, it demonstrates promising advantages on modelling efficiency compared to GAs, whilst achieving near optimal solutions. Therefore, it is considered that CASiNO can be usefully developed for the optimal design of large sewer networks.



(a) Full view of the optimization procedure (b) Enlarged view for the area of interest

Fig. 1 The optimization results on the sewer network



a. Full view of optimal front obtained b. Enlarged view on the area of interest

Fig. 2 Comparison of the solutions obtained by CASiNO (for 1000 runs) and GAs (for 1500 generations with populations of 100)

REFERENCES

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