Application of genetic algorithms - Determination of the optimal pipe diameters

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Abstract

The past decade has marked the development of computational capacity that far exceeds the capacity of the "instructor" to define options to be evaluated when optimisation has to be achieved. In the context of water supply, there are numerous variables that can influence the selection and, hence, the final cost of system implementation, improvement and operation. This article reflects some of the findings of a research project, funded by the Water Research Commission of South Africa to establish the potential use of GAs in the water industry in South Africa. A utility program (GAPOP) was developed to demonstrate the application of GAs in the determination of the optimal pipe diameter.

Introduction

The past decade has marked the development of computational capacity that far exceeds the capacity of the "instructor" to define options to be evaluated when optimisation has to be achieved.

The Government's objective to provide "water for all" made it essential for the limited capital to be employed to provide the maximum benefit. The optimal investment decision for water infrastructure implementation, expansion, addition or rehabilitation has to be reviewed against the background of the conflicting demand for capital and the backlog of water service provision. This complicates the decision to select the cost-effective and efficient solution.

The determination of the optimal selection of system components requires techniques that can be employed to assist the decision-maker in finding the appropriate solution within the environment of all the possible solutions (solution space).

Genetic algorithms (GAs) have been developed (Holland, 1992) to assist in searching through complex solution spaces for the optimum solution. GAs have been applied as search techniques for various engineering problems such as structural design optimisation, water distribution network evaluation, pump scheduling, hydrological runoff predictions and resource utilisation. This technique has not been generally used in South Africa.

Within the context of water supply, there are numerous variables that can influence the selection and the final cost of system improvements. The high variance in rainfall and runoff, availability of alternative water supply with different reliabilities, demand pattern variability, operational complexity of the system, maintenance requirements, running cost (especially power cost), affordability and willingness to pay for services, will influence the decision on whether the water supply scheme should be implemented, refurbished, replaced, discarded or expanded.

Identification and analyses of the system components, which are required to optimise the solution, will have to employ techniques that can assist in finding the optimal solution. GAs have been developed as an optimisation search technique.

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Based on the functioning of DNA in nature to produce a gene population with specified characteristics, a mathematical cloning of this process has been defined to produce outcomes with specific characteristics. If the objective outcome can be defined, be it the minimum cost solution or any other objective, the genetic algorithm process will "calculate" which gene pool will best approach the objective function (Goldberg, 1989).

The technique of GAs has been applied on a number of different real problems and has resulted in exciting, but not always straightforward solutions.

In complex water distribution systems, for instance, the alternative options when evaluating the extensions to water supply systems become numerous. GAs provide procedures for the evaluation of the optimal solutions in the solution space.

The need for optimisation in the water sector

It has been indicated that the challenges in the water industry in South Africa and the world at large, together with the capital constraints and operational cost escalation, necessitate the evaluation of technical, economical and environmental parameters to reach an optimal solution.

In the water sector it has been indicated that large savings can be accomplished if optimal solutions are implemented (Walters et al., 1999), when new systems are designed or when existing systems are refurbished or extended.

The need for the application of optimisation techniques stems from the fact that:

- the selection of system components to be evaluated in a water system is dependent on a number of inter-dependent variables. For example, if an optimal diameter has to be determined it is known that by reducing the diameter the capital cost is reduced but the operating cost (pumping) will escalate and the possibility of pipe burst due to surge pressures associated with high-flow velocities will increase.

- a number of uncertainties exist when the optimisation of water infrastructure is considered, such as:
  - what would the influence of escalation be on operational and capital replacement cost;