Alexandria Engineering Journal (2013) 52, 99–111

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

Parametric analysis for genetic algorithms handling parameters

A.R. Ayad *, H.A. Awad, A.A. Yassin

AWCO, Technical Support Dept., 61 Horeiya Street, Alexandria 21511, Egypt

Received 25 January 2012; revised 6 October 2012; accepted 8 October 2012
Available online 1 December 2012

KEYWORDS

Evolutionary algorithms;
Optimization;
Water distribution networks

Abstract In the present paper, Evolutionary Algorithms (EAs) computing techniques have been used for economical studies that concern water distribution networks, such as, economical design of pipe network, parallel expansion, and pipe rehabilitation and maintenance. EAs are used because of capability of searching vast and complex search space and locating near global optimal solutions rapidly. A model created under the name "EAnet" combines GA models with ELGTnet as hydraulic analysis models to obtain optimal design of water pipe networks. Finally, summary of key findings and recommended parameters to be used is presented.

1. Introduction

Different researchers have produced many variations of (GAs), and all of them are very different from each other. They all, however, display the same characteristics of the GAs. GA is a member of a class of search algorithms with a method based on artificial evolution Holland [1] in which attempt to simulate the optimal process of the evolution of living things. GAs imitates mechanisms of population genetics and natural rules of survival in search of concepts of adaptation. GAs searches for the Global optimum in a solution space of a given shape, within the span of evolution, living things subjected to a particular environment develop through process of adaptation. GAs search, sometimes with modification to the traditional GAs formulation, has performed efficiently in a number of applications that indicates the robustness of the search method and the flexibility of the formulation. In the present paper, GAs has been used for pipe network optimization as follows according to Simpson et al. [2].

Step 1. Generation of initial population.

The GAs randomly generates an initial population of coded strings representing pipe network solutions of population size N. Each of the N strings of the random starting population represents a possible combination of pipe sizes.

* Corresponding author. Tel.: +20 1277887979, mobile: +20 1023365530.
E-mail address: a.dreamer82@gmail.com (A.R. Ayad).
Peer review under responsibility of Faculty of Engineering, Alexandria University.

Production and hosting by Elsevier

1110-0168 © 2013 Faculty of Engineering, Alexandria University. Production and hosting by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.aej.2012.10.007

Step 2. Computation of network cost.

The GAs considers each of the N strings in the population in turn. It decodes each substring into the corresponding pipe size and computes the total cost.

Step 3. Hydraulic analysis of each network.

A steady state hydraulic network solver computes the heads and discharges for each of the network designs in the population.

Step 4. Computation of penalty cost.

The GA assigns a penalty cost for each demand pattern if a pipe network design does not satisfy the minimum pressure constraints.

Step 5. Computation of total network cost.

The total cost of each network in the current population is taken as the sum of the network cost (Step 2) plus the penalty cost (Step 4).

Step 6. Computation of the fitness.

The fitness of the coded string is taken as some function of the total network cost. The GAs computes the fitness for each proposed pipe network in the current population as the inverse of the total network cost from Step 5. The use of the inverse was found to be the most effective in the GAs search.

Step 7. Generation of a new population using the selection operator.

GAs generates new members of the next generation by a selection scheme. The probabilities of selection for string i, (p_i) to go into the next generation of N members using a proportionate selection method given by (Eq. (1)).

$$p_i = \frac{f_i}{\sum_{J=1}^{N} f_i} \tag{1}$$

where f_i is the fitness of string i (determined in Step 6), N = Population number (number of available solution per generation).

Step 8. The crossover operator.

Crossover is the partial exchange of bits between two parent strings to form two offspring strings. Crossover occurs with some specified probability of crossover P_c for each pair of parent strings selected in Step 7.

Step 9. The mutation operator.

Mutation children are generated by applying random changes to a single individual in the current generation to create a child.

Step 10. Production of successive generations.

The use of the three operators described above produces a new generation of pipe network designs using Steps 2–9. The GA repeats the process to generate successive generations. A number of best cost strings are stored and updated as cheaper cost alternatives. Fig. 1 shows a flow chart of GAs procedures

1.1. Newly introduced self adaptive penalty function

A new penalty function is presented in this study, taking into consideration the effect of violating points, which are the junction points in the network violating the pressure constraints set for the network, and taking into consideration its count, the Max violation for pressure deficit, and average of pressure violations deficits *mean* $(H_{jmin} - H_j)^2$. Constraint violation values are normalized since large differences in the magnitude of the constraint values can lead to local minimum trapping.

$$C_p = \frac{C_T}{N_p ipes} \cdot \frac{Vio}{N_{nodes}} \sum_{j=1}^{N_{nodes}} (H_{jmin} - H_j)^2 * max(H_{jmin} - H_j)^2 / (mean(H_{jmin} - H_j)^2 \tag{2}$$

where C_T is the total cost of the network, N_{pipes} the number of pipes in network, N_{nodes} the number of nodes in network, N_{pipes} the number of pipes in network, H_{jmin} the minimum allowed pressure in the network junctions, H_j is the junction pressure, Vio the total number of Violatng network junctions $\sum_{j=1}^{M} count(H_{jmin} - H_j) > 0$, *max* $(H_{jmin} - H_j)^2$ the max violation for pressure deficit, *mean* $(H_{jmin} - H_j)^2$ is the average of pressure violations deficits.

1.2. EAnet architecture

The architecture EAnet tool is lightweight and open. It integrates two software components, as shown in the data flow diagram in Fig. 2.

2. ELGTnet

The developed hydraulic simulation model for water pipeline networks is given in the present chapter. The developed model is based on the Extended Linear Graph Theory (ELGT) technique given by [3]. This technique is modified to include: (i) new network components such as flow control valves, tanks, and for extended period simulation (EPS), and (ii) improve the convergence rate by introducing a modified method for the calculation of updated flows [4].

3. EAnet

EAs computing techniques have been used for economical studies that concern water distribution networks; such as, economical design of pipe network, parallel expansion, and pipe rehabilitation and maintenance. EAs are used because of capability of searching vast and complex search space and locating near global optimal solutions rapidly the model created under the name "EAnet" combines GA with ELGTnet as hydraulic analysis models to obtain optimal design of water pipe network. Introducing a new adaptive penalty function. The presented model has been coded in Matlab® language (Release14) and applied on PC computer (Ayman et al. [4]).

3.1. Implemented networks

The EAnet developed model have been implemented to two benchmarks networks