On Convergence of Multi-objective Pareto Front: Perturbation Method

Raziyeh Farmani, Dragan A. Savic, and Godfrey A. Walters

Centre for Water Systems, School of Engineering, Computer Science and Mathematics, University of Exeter, Exeter, EX4 4QF, UK
{r.farmani, d.savic, g.a.walters}@exeter.ac.uk
http://www.ex.ac.uk/cws

Abstract. A perturbation method is proposed to detect convergence of the Pareto front for multi-objective algorithms and to investigate its effect on the rate of convergence of the optimization. Conventionally, evolutionary algorithms are allowed to run for a fixed number of trial solutions which can result in a premature convergence or in an unnecessary number of calls to a computationally intensive real world problem. Combination of evolutionary multi-objective algorithms with perturbation method will improve the rate of convergence of the optimization. This is a very important characteristic in reducing number of generations and therefore reducing the computational time which is important in real world problems where cost and time constraint prohibit repeated runs of the algorithm and the simulation. The performance of the method will be examined by its application to two water distribution networks from literature. The results will be compared with previously published results from literature and those generated by evolutionary multi-objective algorithm. It will be shown that the method is able to find the Pareto optimal front with less computational effort.

Keywords: Multiple objective, Pareto front, convergence, water distribution.

1 Introduction

Water Distribution network design involves conflicting objectives that each needs to be optimized. Optimal performance according to one objective often implies low performance in one or more of the other objectives. Evolutionary algorithms (EAs) have demonstrated unique ways of handling multi-objective optimization problems. Farmani et al. [1] investigated the application of different evolutionary multi-objective optimization methods in the search for the non-dominated (Pareto) set of solutions to the water distribution network problem. Two non-elitist methods, Multi-Objective Genetic Algorithms (MOGA) [2] and Niched Pareto Genetic Algorithms (NPGAs) [3] and three elitist methods, Non-Dominated Sorting Genetic Algorithm (NSGAII) [4], Pareto-Archived Evolution Strategy (PAES) [5] and Strength Pareto Evolutionary Algorithm (SPEA2) [6] were investigated through application to two test cases for the comparative study.

S. Obayashi et al. (Eds.): EMO 2007, LNCS 4403, pp. 443–456, 2007.

SPEA2 performed better than the other methods. NSGAII method performed slightly worse than SPEA2 but outperformed other three methods. In this work the NSGAII constrained optimization method will be considered as an evolutionary multi-objective optimization technique for the developed hybrid method. Farmani et al. [1] also showed that although most of the methods have managed to converge to the region of optimal solution but Pareto front was sub optimal. Evolutionary algorithms have good initial convergence characteristics, but slow down considerably once the region of the optimal solution has been identified. Combining local search with evolutionary algorithm, hybrid methods, have been very successful in the context of single objective optimization [7]. Talbi et al. [8] proposed a hybrid two-phase approach for multicriteria optimization problems as follows: run an MOEA for a fixed number of generations; then for each Pareto optimal solution, compute the neighborhood and store any non-dominated solutions found; update the list of Pareto front solutions and again recompute all the neighborhoods; iterate the procedure until no improvement occurs. Goel and Deb [4] presented two local search strategies to enhance the probability of NSGAII's true convergence. In the first method, the posteriori approach, the obtained non-dominated solutions of a multi-objective evolutionary algorithm run were modified using a local search method (The local search strategy was suggested from each obtained solution of NSGAII to find a better solution. A weighted objective function was used to convert multiple objectives into a single objective for local search). In the second method, the online approach, a local search method was applied to each solution obtained by genetic operation in a MOEA run. Goel and Deb [4] concluded that the posteriori approach is better than the online approach, the main reason being that in the online approach more emphasis is allocated to the local search method.

To achieve optimal non-dominated front in less computational time, the posteriori approach was applied to two benchmark water systems. Two issues might be raised by doing so, first the order of variables might affect the final result and secondly the weighted method might result in solutions that are dominated by original Pareto front and also it might cluster solutions, which is contrary to second goal of multi-objective optimization (diversity among the solutions). Preliminary research, by Farmani et al. [9], into effect of order of variables in local search method made it clear that final solution is not effected considerably by the order of design variables. The main reason for this is that the local search is done on individuals on Pareto front at final generation of NSGAII, and usually there are only few small changes possible. However, study into the choice of weighting method for decision making in accepting or rejecting of changes by local search showed that solutions are usually clustered in a small region and sometimes they are dominated by the original Pareto set.

In this paper, perturbation of variables of the individuals on the Pareto front is presented to assess the sensitivity of the solutions. The perturbation method is implemented in two ways, random and deterministic, and judgement on efficiency of newly generated solution is done based on Pareto non-domination rather than weighting method. Two different runs are carried out. The first run