Efficient Multi-Objective Ant Colony Optimization

MOHAMMAD MORTAZAVI[1], GEORGE KUCZERA[1], LIJIE CUI[1]

1- School of Engineering, The University of Newcastle, Newcastle, NSW 2308, Australia

Seyedmohammad.mortazavinaeini@uon.edu.au

Abstract

Most optimization problems in water resources management require tradeoffs between conflicting objectives. Multi-objective optimization is a growing research area with the aim of finding the Pareto optimal set of solutions which defines the optimal trade-offs. In past studies, the focus has been on developing methods to find Pareto fronts with better diversity and coverage- the issue of objective function evaluation was of secondary importance. However, in water resource applications, objective function evaluations can be computationally very expensive. This leads to our motivation of developing a multi-objective optimization method which not only converges to the optimal Pareto front with improved diversity but also with fewer function evaluations. An efficient multi-objective ant colony optimization method (EMOACO) is proposed and compared against benchmark methods such as NSGA-II, eMOEA and SMPSO. The results demonstrated the capability of EMOACO to converge to the approximate Pareto-optimal with significantly fewer evaluations.

Keywords: Multi-objective optimization, Ant colony optimization, fast convergence

1. Introduction

A large research literature exists on the development of models to simulate complex water resource systems and to optimize decisions – see recent review by [1]. A recent development has been the application of multi-objective optimization (MOO) techniques to help decision makers deal with conflicting objectives – applications include reservoir operation [2-7] and water supply [8-10]. In a multi-objective problem, there exists a set of alternative solutions, referred to as the Pareto optimal solution set, for which there are no other solutions that are superior when all objectives are simultaneously considered. Hence the goal of multi-objective optimization is to find the Pareto optimal set.

The development of multi-objective optimization algorithms has seen considerable advanced particularly since the advent of probabilistic optimization methods – see [11]. A variety of heuristic algorithms, including evolutionary, particle swarm and ant colony optimization methods, have been developed for solving multi-objective problems [11-15]. The performance of these algorithms, typically, has been investigated using well-known benchmark problems and their results have been compared using different indicators that measure the convergence and diversity of the solutions after performing a pre-defined number of function evaluations.

Unlike the benchmark problems, water resources applications typically use computationally expensive methods for computing their objective functions [16]. For example, in the case study presented in this paper involving the Canberra headworks system, a 140-year simulation at monthly time steps takes approximately 2 cpu seconds, which is several orders of magnitude more than the standard benchmark problems.

In recent years a number of studies have sought to address this issue. Knowles [17] proposed a hybrid algorithm called ParEGO to obtain the Pareto optimal front with very small number of evaluations, i.e. 100 or 250 evaluations. Pierro et al. [16] applied two hybrid algorithms, ParEGO and LEMMO, to optimize cost and pressure deficit of water distribution network systems and compared their performance against a benchmark evolutionary algorithm, PESA-II method. They found LEMMO generated solutions compatible with benchmark results on a medium-size network with a considerable reduction in number of hydraulic simulations. However, LEMMO did not perform well on a larger network. Runarsson et al. [18] developed a new particle swarm optimization requiring only 4000 evaluations to converge to the optimal Pareto front; this was shown to be competitive with the well-established benchmark NSGA-II algorithm [13]. In a similar study, Obayashi et al. [19] presented an efficient multi-objective particle swarm optimization method EMOPOS, which, for 2000 evaluations, produced a solution closer to the optimal Pareto front than did NSGA-II.

A recent development in probabilistic optimization, namely ant colony optimization (ACO), was proposed by Dorigo et al. [20] who emulated the foraging behaviour exhibited by ant colonies in their search for food. ACO algorithms have been successfully applied to a number of benchmark combinatorial optimization problems, such as the travelling salesman and quadratic assignment problems[21]. This finding led researchers to apply ACO to multi-objective problems. Although there have been many ACO algorithms