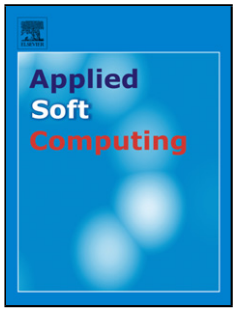

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Formulation and parameter selection of multi-objective deterministic particle swarm for simulation-based optimization

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Abstract

Global derivative-free deterministic algorithms are particularly suitable for simulation-based optimization, where often the existence of multiple local optima cannot be excluded a priori, the derivatives of the objective functions are not available, and the evaluation of the objectives is computationally expensive, thus a statistical analysis of the optimization outcomes is not practicable. Among these algorithms, particle swarm optimization (PSO) is advantageous for the ease of implementation and the capability of providing good approximate solutions to the optimization problem at a reasonable computational cost. PSO has been introduced for single-objective problems and several extension to multi-objective optimization are available in the literature. The objective of the present work is the systematic assessment and selection of the most promising formulation and setup parameters of multi-objective deterministic particle swarm optimization (MODPSO) for simulation-based problems. A comparative study of six formulations (varying the definition of cognitive and social attractors) and three setting parameters (number of particles, initialization method, and coefficient set) is performed using 66 analytical test problems. The number of objective functions range from two to three and the number of variables from two to eight, as often encountered in simulation-based engineering problems. The desired Pareto fronts are convex, concave, continuous, and discontinuous. A full-factorial combination of formulations and parameters is investigated, leading to more than 60,000 optimization runs, and assessed by two performance metrics. The most promising MODPSO formulation/parameter is identified and applied to the hull-form optimization of a high-speed catamaran in realistic ocean conditions. Its performance is finally compared with four stochastic algorithms, namely three versions of multi-objective PSO and the genetic algorithm NSGA-II.

Keywords: Multi-objective optimization; derivative-free optimization; global optimization; deterministic particle swarm optimization; simulation-based optimization

1. Introduction

Simulation-based optimization has a peculiar set of features that brings unique challenges to the practicability of the optimization process and the identification of the optimization solutions. The objectives usually derive from complex simulations, which solve partial differential equations, and are computationally very expensive. Therefore, the optimization process needs to rely on a relatively small number of objective evaluations. In most applications, black box tools are used for the simulations and the objective derivatives are not available. Their evaluation through finite differences is often very critical due to the residuals associated to the simulation solutions, which introduce noise in the simulation output. Additionally, the existence of local minima cannot be excluded a priori. For these reasons, global derivative-free algorithms represent an advantageous option for the solution of simulation-based optimization problems.

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