

Chapter 8

Pareto Artificial Life Algorithm for Multi- Objective Optimization

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ABSTRACT

Most engineering optimization uses multiple objective functions rather than single objective function. To realize an artificial life algorithm based multi-objective optimization, this paper proposes a Pareto artificial life algorithm that is capable of searching Pareto set for multi-objective function solutions. The Pareto set of optimum solutions is found by applying two objective functions for the optimum design of the defined journal bearing. By comparing with the optimum solutions of a single objective function, it is confirmed that the single function optimization result is one of the specific cases of Pareto set of optimum solutions.

INTRODUCTION

Most engineering optimization deals with multiple objective functions rather than a single objective function. Basically, there are two kinds of approaches to solve a multi-objective optimization problem (MOP). The first approach is the transformation of a given MOP into a single objective optimization problem (SOP). The motivation of this approach is to establish a single basis of comparing each candidate solution in

the course of optimization and finally to derive a single optimum solution (or approximate to the optimum solution). One method which could be used for this approach is to aggregate multiple objective functions into a single overall objective function. Optimization of the objective function is then conducted with one optimal design as a result. This result is greatly dependent on how the objectives are aggregated (Anderson, 2000). The form which is either linear combination or multiplication is usually employed as an aggregated

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single objective function. Another method is to select only the most interesting object function as a final objective function and to set the other objective functions as constraints.

The second approach is to consider simultaneously the multiple objective functions, which is called Pareto optimization. In order to provide possible solutions for the final decision maker, the downside which is not able to find other possibilities besides a single solution obtained through conversion into a single objective function is supplemented. To avoid this difficulty and to explore various possibilities, the concept of Pareto optimality is employed.

Recently, many researches on Pareto optimization problems have been carried out to enable the application of heuristic global optimization algorithms such as evolutionary algorithm (Schaffer, 1985; David, 1985; Goldberg, 1989; Horn et al., 1994; Srinivas & Deb, 1995) and tabu search method (Shiyong & Ni, 1998; Ho et al., 2002). In the case of function optimization, heuristic optimization methods have the advantages of not being subjected to special restrictions on problem formulations. They are also evaluated as an outstanding search capability in finding a global optimum solution of optimization. As a heuristic global optimization technique, artificial life algorithm (AL) (Yang & Lee, 2000; Yang et al., 2001; Yang & Song, 2002) has been applied to determine optimum design problems of journal bearing (Song et al., 2005) and engine mount (Ahn et al., 2003, 2005). However, the expansion onto Pareto optimization has merely been attempted in real applications.

In order to apply AL to MOP in engineering problems, it is necessary to solve the Pareto optimization problem. Therefore, in this study, AL has been enlarged on enabling the application of Pareto optimization to solve the MOPs.

MULTI-OBJECTIVE OPTIMIZATION PROBLEMS

A MOP is defined as a problem which has two or more objective functions. A general MOP is defined as

$$\text{Minimize } \mathbf{F}(\mathbf{x}) = (f_1(\mathbf{x}), f_2(\mathbf{x}), \dots, f_k(\mathbf{x}))^T \quad (1)$$

$$\text{subject to } \mathbf{c}(\mathbf{x}) = (c_1(\mathbf{x}), c_2(\mathbf{x}), \dots, c_m(\mathbf{x}))^T \geq 0 \quad (2)$$

$$\mathbf{x} = (x_1, x_2, \dots, x_n)^T, \mathbf{x} \in S \quad (3)$$

where $f_i(\mathbf{x})$ is the set of k objective functions, $c_i(\mathbf{x})$ is the set of m constraints, x_j is the n optimization parameters, and $S \in R^n$ is the solution or parameter space. Obtainable objective vectors $\{F(\mathbf{x}) | \mathbf{x} \in S\}$ are denoted as Y , where $Y \in R^k$ is usually referred to the attribute space.

In MOP, it is important to emphasize that there might be constraints imposed on the objectives. It is normal for the objectives of MOP to be in conflict with each other (Coello & Zaccatenco, 2006). However, most MOPs do not lend themselves to a single solution but have a set of solutions. Such solutions are trade-offs or good compromises among the objectives. In order to generate these trade-off solutions, an old notion of optimality is normally adopted. This notion of optimality was generalized by Pareto (1896) and is called Pareto optimum. The solution for a MOP is Pareto optimal if no other feasible solutions exist that would decrease some objective function values without causing a simultaneous increased in at least one other objective function value.

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