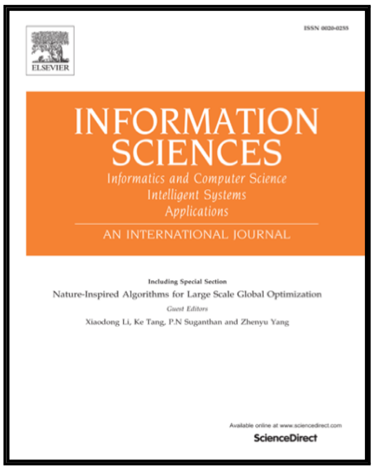
Accepted Manuscript



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PII: S0020-0255(16)32069-2
DOI: 10.1016/j.ins.2017.05.012
Reference: INS 12882

To appear in: *Information Sciences*

Received date: 15 December 2016
Revised date: 29 March 2017
Accepted date: 9 May 2017

Please cite this article as: Mengjun Ming, Rui Wang, Yabing Zha, Tao Zhang, Pareto Adaptive Penalty-based Boundary Intersection Method for Multi-objective Optimization, *Information Sciences* (2017), doi: 10.1016/j.ins.2017.05.012

Pareto Adaptive Penalty-based Boundary Intersection Method for Multi-objective Optimization

Mengjun Ming, Rui Wang, Yabing Zha, Tao Zhang

College of Information Systems and Management, National University of Defense Technology, Changsha, 410073, P.R. China

Abstract

Penalty-based boundary intersection (PBI) method is a frequently used scalarizing method in decomposition based multi-objective evolutionary algorithms (MOEAs). It works well when a proper penalty value is provided, however, the determination of a suitable penalty value depends on the problem itself, more precisely, the Pareto optimal front (PF) shape. As the penalty value increases, the PBI method becomes less effective in terms of convergence, but is more capable of handling various PF shapes. In this study, a simple yet effective method called Pareto adaptive PBI (PaP) is proposed by which a suitable penalty value can be adaptively identified, which therefore can maintain fast convergence speed, meanwhile, leading to a good approximation of the PF. The PaP strategy integrated into the state-of-the-art decomposition algorithm, MOEA/D, denoted as MOEA/D-PaP, is examined on a set of multi-objective benchmarks with different PF shapes. Experimental results show that the PaP strategy is more effective than the weighted sum, the weighted Tchebycheff and the PBI method with (representative) fixed penalty values in general. In addition, the MOEA/D-PaP is examined on a real-world problem – multi-objective optimization of a hybrid renewable energy system whose PF is unknown. The outcome of the experiment further confirms its feasibility and superiority.

Keywords: multi-objective evolutionary algorithms, scalarizing method, Pareto adaptive PBI method, hybrid renewable energy system

1. Introduction

Many engineering problems encountered in practice include multiple contradictory objectives which are required to be optimized simultaneously. Usually these problems are referred to as multi-objective optimization problems (MOPs), and can be mathematically defined as follows:

$$\min \mathbf{F}(\mathbf{x}) = (f_1(\mathbf{x}), f_2(\mathbf{x}), \ldots, f_m(\mathbf{x})) \qquad \text{subject to} \ \ \mathbf{x} \in \mathbf{\Omega} \tag{1}$$

where $\mathbf{x}$ is a decision vector in $\mathbf{\Omega}$ (which refers to a feasible search space), $f_i(\mathbf{x})$ is the i-th objective in $\mathbb{R}^m$ ($\mathbb{R}^m$ refers to the objective space). $\mathbf{F} : \mathbf{\Omega} \rightarrow \mathbb{R}^m$ consists of m real-valued objective functions. As objectives in an MOP are often in conflict with each other, the optimal solution of an MOP is usually not a single one but rather a set of trade-off solutions, called Pareto optimal solutions [38]. The image of those Pareto optimal solutions in the objective space is called Pareto optimal front (PF).

Multi-objective evolutionary algorithms (MOEAs), which are well suited for solving MOPs since their population based nature can generate a set of trade-off solutions in a single run [6]. Till now a number of well performed MOEAs have been proposed, for example, [4, 35, 23, 12, 27]. Loosely speaking, existing MOEAs can be categorized into three classes according to their selection strategies [26], i.e., Pareto-dominance based

Email addresses: mmengjun@gmail.com (Mengjun Ming), ruiwangnudt@gmail.com, corresponding author (Rui Wang)