Chapter 14
Multi-Objective Simulated Annealing Algorithms for General Problems

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ABSTRACT

Simulated Annealing is an analogy with the annealing of solids, which foundations come from a physical area known as statistical mechanics. This chapter presents a review of the literature on multi-objective simulated annealing (MOSA). There are several multi-objective approaches to solve optimization problems with simulated annealing such as hybridizations, implementation of strategies from different metaheuristics. Modern MOSA research includes populations and adaptive rules, and are briefly described in this chapter. We discuss different approaches in multi-objective and we revise the modern MOSA framework.

1. INTRODUCTION

Optimization has many applications in almost any area of the human activity and has two kind of research areas: single optimization and multi-objective optimization. These areas study single-objective problems or SOP (with only one objective function) and multi-objective problems or MOP (with more than one objective functions) respectively (Coello Coello, Lamont, & Van Veldhuizen, 2007). Even though single optimization is far to be a closed research area, many deterministic and stochastic strategies have been studied since the second world war. In addition, several reviews are available for the problems of this area. In the case of problems belonging to multi-objective optimization area, nature and physical principles are applied to develop algorithm for solve them. Multi-objective Evolutionary Algorithms (MOEAs) and multi-objective Simulated Annealing (MOSA) are among the most common of these algorithms (Deb, 2001). We will use the next model for distinguish single to multi-objective optimization problems:

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$$\min/\max f_m(x_i); m = 1,\ldots,M; i = 1,\ldots,N$$

subject to

$$g_j(x) \geq 0; j = 1,\ldots,J$$

$$h_k = 0; k = 1,\ldots,K$$

$$x_i^{Lower} \leq x_i \leq x_i^{Upper}; i = 1,\ldots,N$$

In single optimization problems, M is always equal to one, while M is always greater than one for multi-objective optimization problems. The rest of this model is the same for SOP and MOP with the next features: There are $N \geq 1$ decision variables x_i. There are two set of algebraic expressions g_j and h_k known as inequality and equality constraints respectively. The number of these constraints are $J \geq 0$ and $K \geq 0$. Finally, x_i^{Lower} and x_i^{Upper} are respectively the lower and upper bound of each decision variable x_i.

Most of the practical problems belongs to the second category and the NP-Hard problems. For the last kind of problems, many multi-objective evolutionary algorithms (MOEAs) have been published since their review (Deb, 2001); the most popular MOEAs are using Pareto Archived Evolution Strategy (PAES), this use a file where dominated solutions, which are employed for new solutions (Knowles & Corne, 2000), are updated.

Current applications of MOSA can be found in the development of proportional integral derivate (PID) controller design (Hung, Shu, Ho, Hwang, & Ho, 2008) which are used in industrial process control. Other application of MOSA is in the management inventory problem and it will be applied to a large-scale supply chain at a major steel producer (Alrefaei, Diabat, Alawneh, Al-Aomar, & Faisal, 2013). MOSA is used in telecommunications networks to optimize the multicast routing problem (MRP) (Xu & Qu, 2011; Xu, Qu, & Li, 2013). Other application of MOSA is in the mobile telecommunications network's air interface with the optimization of a Code Division Multiple Access (CDMA) (Smith, Everson, Fieldsend, Murphy, & Misra, 2008). MOSA is used to solve the redundancy allocation problem (RAP) in the reliability design of parallel sub-system which have applications on networks designs (Zaretalab, Hajipour, Sharifi, & Shahriari, 2015). In (Safaei, Jardine, & Banjevic, 2008) the MOSA is used to solve a real maintenance workforce scheduling problem (MWSP) in a steel company. In this case MOSA minimizes the workforce cost and the flow time of the work request. The MOSA is used for solving an unrelated parallel machine scheduling problem in (Lin & Ying, 2015). Other scheduling application of MOSA can be found in (Frutos & Tohmé, 2015; Frutos, Olivera, & Tohmé, 2010; Loukil, Teghem, & Tuyttens, 2005).

This chapter is organized as follows. In Section 2 the multi-objective optimization is presented. In Section 3 the fundaments of Simulated Annealing algorithm and multi-objective optimization theory is presented. In Section 4, the multi-objective Simulated Annealing framework. In Section 5, the current