Chapter 14
Extreme Value Metaheuristics and Coupled Mapped Lattice Approaches for Gas Turbine-Absorption Chiller Optimization

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ABSTRACT

The increasing complexity of engineering systems has spurred the development of highly efficient optimization techniques. This chapter focuses on two novel optimization methodologies: extreme value stochastic engines (random number generators) and the coupled map lattice (CML). This chapter proposes the incorporation of extreme value distributions into stochastic engines of conventional metaheuristics and the implementation of CMLs to improve the overall optimization. The central idea is to propose approaches for dealing with highly complex, large-scale multi-objective (MO) problems. In this work the differential evolution (DE) approach was employed (incorporated with the extreme value stochastic engine) while the CML was employed independently (as an analogue to evolutionary algorithms). The techniques were then applied to optimize a real-world MO Gas Turbine-Absorption Chiller system. Comparative analyses among the conventional DE approach (Gauss-DE), extreme value DE strategies, and the CML were carried out.

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INTRODUCTION

As engineering systems become exceedingly complex, there is a growing need for advanced and innovative techniques for optimizing these systems. Metaheuristics have been widely used to tackle such engineering problems – especially in industries related to power generation (Marmolejo *et al*., 2017). Multiobjective (MO) settings are also becoming commonplace in engineering; where the engineer has to consider multiple target objectives when making critical decisions. MO optimization problems could be broadly divided into two classes. The first is bi-objective problems which have lower complexity as compared to its many-objective counterpart. These problems are endowed with only two objectives and there are well established methods for solving them such as: Non-Dominated Sorting Genetic Algorithm (NSGA-II) (Sadeghi *et al*., 2014) and Strength Pareto Evolutionary Algorithm (SPEA-2) (Maheta and Dabhi, 2014). As for problems with many objectives, scalarization approaches are among the most effective strategies. Examples of scalarization approaches are the weighted sum (Yang *et al*., 2013) and the Normal-Boundary Intersection (NBI) (Charwand *et al*., 2015; Brito *et al*., 2014) methods. Using scalarization approaches, the multiple objectives are aggregated and the problem is transformed to a single-objective problem. This reduction in complexity then makes the problem easier to solve.

In engineering and other real-world applications, the penalty factor approach is also employed for dealing with situations with multiple objectives. Similar to the weighted sum approach, this method involves the weighted aggregation of the objectives. The distinction with the weighted sum approach is that the penalty factor method converts all the objectives into financial terms forming a single cost function. For instance, in Sheng *et al*., (2013), an optimization of a distributed generation (DG) power system was carried out using evolutionary algorithms. The penalty factor method was used as a basis to solve the problem; where the DG utilization was maximized while minimizing the system's losses and environmental pollution. Another application using this method could be seen in the works of Daryani and Zare, (2016). In that work, the authors used the Modified Group Search Algorithm (MGSA) in tandem with the penalty factor approach to solve a MO problem in power and emission dispatch.

The Pareto distribution is among the first non-Gaussian distributions encountered in statistics. In economics this distribution shows large amounts of wealth are owned by a smaller percentage of individuals in any society. The idea is often expressed as the 80-20 Rule – 20 percent of the population owns 80 percent of the wealth (Sanders, 1987). Ever since its appearance, the Pareto distribution has found diverse applications – stretching out to other applications besides economics. In quantum statistics the variant of Pareto distributions has been employed to study particle distributions (Biró *et al*., 2015). These distributions have also seen application in stochastic physical processes; particularly in sub-recoil laser cooling (Bardou, 1995). It has also been used to design and assess software reliability models using failure data (Faqih, 2013; Karagrigoriou and Vonta, 2014). In Fernández *et al*., (2016), Pareto distributions were used to improve the signal quality of radar systems. In that work the Pareto distribution coupled with a neural network was employed to estimate and eliminate background echoes in radar signals known as 'sea clutter'. Similarly in Lenz (2016), a variant of the Pareto distribution called the Generalized Pareto Distribution in field of microscopy. In that application, the distribution became critical for the construction of an efficient autofocus system.

As with the GPD, the Generalized Extreme Value (GEV) distribution has been utilized in a wide range of applications (Marmolejo and Rodriguez, 2015). For instance in electromagnetic systems, Orjubin (2007) successfully modeled the field in a reverberation chamber. The author used the GEV distribution GEV to determine the maximum field in the chamber. GEC has also been applied to communications

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