Chapter V
Multi-Objective Optimization Using Artificial Immune Systems

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ABSTRACT

The human immune system (HIS) is a highly evolved, parallel and distributed adaptive system. The information processing abilities of HIS provide important aspects in the field of computation. This emerging field is referring to as the Artificial Immune Systems (AIS). In recent years, AIS have received significant amount of interest from researchers and industrial sponsors. Applications of AIS include such areas as machine learning, fault diagnosis, computer security and optimization. In this chapter, after surveying the AIS for multi-objective optimization, we will describe two multi-objective optimization algorithms using AIS, the Immune Dominance Clonal Multi-objective Algorithm (IDCMA), and the Nondominated Neighbor Immune Algorithm (NNIA). IDCMA is unique in that its fitness values of current dominated individuals are assigned as the values of a custom distance measure, termed as Ab-Ab affinity, between the dominated individuals and one of the nondominated individuals found so far. According to the values of Ab-Ab affinity, all dominated individuals (antibodies) are divided into two kinds, subdominant antibodies and cryptic antibodies. And local search only applies to the subdominant antibodies while the cryptic antibodies are redundant and have no function during local search, but they can become

subdominant (active) antibodies during the subsequent evolution. Furthermore, a new immune operation, Clonal Proliferation is provided to enhance local search. Using the Clonal Proliferation operation, IDCMA reproduces individuals and selects their improved maturated progenies after local search, so single individuals can exploit their surrounding space effectively and the newcomers yield a broader exploration of the search space. The performance comparison of IDCMA with MISA, NSGA-II, SPEA, PAES, NSGA, VEGA, NPGA and HLGA in solving six well-known multi-objective function optimization problems and nine multi-objective 0/1 knapsack problems shows that IDCMA has a good performance in converging to approximate Pareto-optimal fronts with a good distribution. NNIA solves multi-objective optimization problems by using a nondominated neighbor-based selection technique, an immune inspired operator, two heuristic search operators and elitism. The unique selection technique of NNIA only selects minority isolated nondominated individuals in population. The selected individuals are then cloned proportionally to their crowding-distance values before heuristic search. By using the nondominated neighbor-based selection and proportional cloning, NNIA pays more attention to the less-crowded regions of the current trade-off front. We compare NNIA with NSGA-II, SPEA2, PESA-II, and MISA in solving five DTLZ problems, five ZDT problems and three low-dimensional problems. The statistical analysis based on three performance metrics including the Coverage of two sets, the Convergence metric, and the Spacing, show that the unique selection method is effective, and NNIA is an effective algorithm for solving multi-objective optimization problems.

INTRODUCTION

The human immune system (HIS) is a highly evolved, parallel and distributed adaptive system. The information processing abilities of HIS provide important aspects in the field of computation. This emerging field is referring to as the Immunological Computation, Immunocomputing or Artificial Immune Systems (AIS) (Tarakanov & Dasgupta, 2000) which can be defined as computational systems inspired by theoretical immunology and observed immune functions, principles and models, which are applied to problem solving (de Castro & Timmis, 2002a). In recent years, AIS have received a significant amount of interest from researchers and industrial sponsors. Some of the first work in applying HIS metaphors was undertaken in the area of fault diagnosis (Ishida, 1990). Later work applied HIS metaphors to the field of computer security (Forrest, Perelson, Allen, & Cherukuri, 1994), which seemed to act as a catalyst for further investigation of HIS as a metaphor in such areas as Anomaly Detection (Gonzalez, Dasgupta, & Kozma, 2002), Pattern Recognition (Carter, 2000; Timmis, Neal, & Hunt, 2000; White, & Garrett, 2003), Job Shop Scheduling (Hart & Ross, 1999; Coello Coello, Rivera, & Cortes, 2003), Optimization (de Castro & Von Zuben, 2002; Jiao &Wang, 2000) and Engineering Design Optimization (Gong, Jiao, Du, & Wang, 2005; Hajela, Yoo, & Lee, 1997).

In this chapter, after surveying the AIS for optimization, we will describe two multi-objective optimization algorithms using AIS, the Immune Dominance Clonal Multi-objective Algorithm (IDCMA) and the Nondominated Neighbor Immune Algorithm (NNIA). IDCMA is unique in that its fitness values of current dominated individuals are assigned as the values of a custom distance measure, termed as Ab-Ab affinity, between the dominated individuals and one of the nondominated individuals found so far. According to the values of Ab-Ab affinity, all dominated individuals (antibodies) are divided into two kinds, subdominant antibodies and cryptic antibodies. And local search only applies to the subdomi-