Clonal Selection with Immune Dominance and Anergy Based Multiobjective Optimization

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Abstract. Based on the concept of Immunodominance and Antibody Clonal Selection Theory, we propose a new artificial immune system algorithm, Immune Dominance Clonal Multiobjective Algorithm (IDCMA). The influences of main parameters are analyzed empirically. The simulation comparisons among IDCMA, the Random-Weight Genetic Algorithm and the Strength Pareto Evolutionary Algorithm show that when low-dimensional multiobjective problems are concerned, IDCMA has the best performance in metrics such as Spacing and Coverage of Two Sets.

1 Introduction

In 1984, Schaffer put forward a vector evaluated genetic algorithm (VEGA) by modifying the fitness assignment and the individual selection strategy[1]. His work is regarded as the beginning of solving multiobjective optimization problems by genetic algorithm. Until the middle 1990s, the number of literatures on multiobjective evolutionary algorithms (MOEAs) increased greatly. Among them, Fonseca et al's Multiobjective Genetic Algorithm, Horn et al's Niched Pareto Genetic Algorithms and Srinivas et al's Nondominated Sorting in Genetic Algorithm attracted more attention[2]. These evolutionary algorithms show better performance in solving multiobjective problems than traditional algorithms. However, they didn't adopt elitism preserving strategy definitely, which was recognized and supported by experiments in the following years. In recent years, a lot of newly improved algorithms were proposed, such as Deb et al's A Fast Elitist Non-dominated Sorting Genetic Algorithm, Corne et al's Pareto Envelope based Selection Algorithm and Zitzler's the strength Pareto evolutionary algorithm (SPEA and SPEA2). In particular, Zitzler et al's SPEA and SPEA2 have shown many good performances[3,4]. At the same time, Coello Coello et al presented their own multiobjective evolutionary algorithms and proposed an multiobjective algorithm named by the Multiobjective Immune System Algorithm (MISA)[5] using the clonal selection principle. They set out that MISA was very promising based on a few simulations.

C. A. Coello Coello et al. (Eds.): EMO 2005, LNCS 3410, pp. 474 – 489, 2005.

Artificial immune system (AIS) makes use of the mechanism of vertebrate immune system, and constructs new intelligent algorithms with immunology terms and fundamental. Artificial immune system provides the evolutionary learning mechanism like noise enduring, non-teacher learning, self-organization, and memory, thus it has the potential for providing novel method for solving problems, and its research production refers to many fields like control, data processing, optimization learning and trouble diagnosing, and it has been a research hot spot after the neural network, fuzzy logic and evolutionary computation.[6]

After defining several basic concepts of artificial immune system in Section 2, a novel multiobjective optimization algorithm, Immune Dominance Clonal Multiobjective Algorithm (IDCMA), is put forward in Section 3. The influences of main parameters are analyzed empirically, then five representative low-dimensional multiobjective problems and three famous multiobjective algorithms, the Random-Weight Approach proposed by Ishibuchi[7], and the Strength Pareto Evolutionary Algorithm proposed by Zitzler[3], and Multiobjective Immune System Algorithm proposed by Coello Coello [5] are selected for simulation tests in Section 4.

2 Basic Definitions

Although an antigen has many epitopes (antigenic determinants), only one works to induce a special immune response for the host cells. The phenomenon is called immunodominance, the epitope is called a dominant epitope, immunodominance is produced by the action of antibody and antigen[8]. The clonal selection theory (F. M. Burnet, 1959) is used in the immune system to describe the basic features of an immune response. Its main idea lies in that the antigens can selectively react to the antibodies, which are the native production and spread on the cell surface in the form of peptides. The reaction leads to cell proliferating clonally and the colony has the same antibodies. Some clonal cells divide into antibodies that produce cells, and others become immune memory cells to boost the second immune response. The clonal selection is a dynamic process of the immune system self-adapting antigen stimulation. From the viewpoint of the Artificial Intelligence, some biologic characters such as learning, memory and antibody diversity can be used in artificial immune system.

In order to describe the algorithm for multiobjective optimization problems well, we just define the glossary as follows.

Definition 1. Antigen
In AIS, antigen usually means the problem and its constraints. Especially, for multiobjective optimization problems, we have

$$(P)\begin{cases}\min\ F(\boldsymbol{x}) = (f_1(\boldsymbol{x}), f_2(\boldsymbol{x}), \ldots f_p(\boldsymbol{x}))^T \\ S.T.\quad g_i(\boldsymbol{x}) \le 0 \quad i = 1, 2, \cdots m\end{cases} \tag{1}$$