Chapter 6
Artificial Clonal Selection Model and Its Application

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ABSTRACT

Artificial Immune System as a new branch in computational intelligence is the distributed computational technique inspired by immunological principles. In particular, the Clonal Selection Algorithm (CS), which tries to imitate the mechanisms in the clonal selection principle proposed by Burent to better understand its natural processes and simulate its dynamical behavior in the presence of antigens, has received a rapid increasing interest. However, the description about the mechanisms in the algorithm is rarely seen in the literature and the related operators in the algorithm are still inefficient. In addition, the comparison with other algorithms (especially the genetic algorithms) lacks of analysis. In this chapter, several new clonal selection principles and operators are introduced, aiming not only at a better understanding of the immune system, but also at solving engineering problems more efficiently. The efficiency of the proposed algorithm is verified by applying it to the famous traveling salesman problems (TSP).

INTRODUCTION

Most living organisms exhibit extremely sophisticated learning and processing abilities that allow them to survive and proliferate generation after generation in their dynamic and competitive environments. For this reason, nature has always served as inspiration for several scientific and technological developments.

This area of research is often referred to as Biologically Inspired Computing. The motivation of this field is primarily to extract useful metaphors from natural biological systems, in order to create effective computational solutions to complex problems in a wide range of domain areas. The more notable developments have been the neural networks inspired by the working of the brain, and the evolutionary algorithms inspired by neo-Darwinian theory of evolution.

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More recently however, there has been a growing interest in the use of the biological immune system as a source of inspiration to the development of these computational systems. The immune system contains many useful information-processing abilities, including pattern recognition, learning, memory and inherent distributed parallel processing. For these and other reasons, the immune system has received a significant amount of interest to use as a metaphor within computing. This emerging field of research is known as Artificial Immune Systems (AIS).

Essentially, AIS are the use of immune system components and process as inspiration to construct computational systems. The system is an emerging area of biologically inspired computation and has received a significant amount of interest from researchers and industrial sponsors in recent years. Applications of AIS include such areas as learning (Hunt & Cooke, 1996; Ichimura et.al, 2005; Nanni, 2006), fault diagnosis and fault tolerant (Canham, 2003; Branco, Dente, & Mendes, 2003), computer security and intrusion detection (Aickelin et.al., 2003; Dasgupta, 1999), and optimization (Engin & Doyen, 2004; Khilwani et.al, 2008). The field of AIS is showing great promise of being a powerful computing paradigm.

In this chapter, we further study the constructs and immune mechanism of natural immune system and present artificial immune systems based on the clonal selection principle. The mechanisms used in the algorithm are interpreted and several improvements of the algorithm are also introduced.

First and foremost, we study the receptor editing which is one of the most important mechanisms in the immune cell tolerance. Both hypermutation (HM) and receptor editing (RE) operators are used to maintain the diversity of the repertoire of B cells. And hypermutation is good for exploring local optimum, whereas receptor editing may help immune system to escape from local optima. Therefore the hypermutation and receptor editing might play complementary roles in affinity maturation process. Besides, by using the characteristics of ergodicity and dynamic of chaos variables, the chaotic initialization mechanism is introduced into the clonal selection model to improve its global search capabilities. In order to overcome the inefficient local search ability of the algorithm, a distance-based hypermutation (DHM) operator which makes use of the information during gene positions is proposed. In this improved operator, the gene which is nearer to the preselected gene has higher probability to be selected. As a result, the improved hypermutation operator has a remarkable ability to generate higher affinity antibodies. Moreover, for the purpose of realizing the cooperation and communication among different antibodies, we also introduce a greedy crossover operator to the polyclonal selection algorithm and combined it to the traditional simulated annealing (SA) strategy. By using SA the probability of local minimum can be reduced because of the introduction of jump probability which can be adjusted by controlling the temperature. Furthermore, in order to solve the inherent disadvantages such as the information exchange during different antibodies, a literal interactive receptor editing (LIRE) is also presented. Inspired by the Idiotypic Network Theory, LIRE enables the system to realize the communication during different antibodies and therefore the performance is improved. Last but not least, we also proposed a pheromone-linker to combine the clonal selection algorithm with another nature phenomena inspired algorithm (Ant Colony Optimization) to construct a hybridization model. The pheromone-linker is utilized not only to realize the cooperation and communication between different elite pools in the clonal selection algorithm, but also to give the ant colony optimization some initial pheromones to accelerate its convergence speed. Simulations based on several traveling salesman problems demonstrated the efficiency and robustness of the proposed clonal selection models mentioned above.

Finally, some suggestions for future research are proposed, and the general remarks of this chapter are given to conclude this chapter.