Chapter 6

Artificial Immune Optimization Algorithm

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ABSTRACT

Artificial immune system (AIS) is a paradigm inspired by processes and metaphors of natural immune system (NIS). There is a rapidly growing interest in AIS approaches to machine learning and especially in the domain of optimization. Of particular interest is the way human body responds to diseases and pathogens as well as adapts to remain immune for long periods after a disease has been combated. In this chapter, we are presenting a novel multilayered natural immune system (NIS) inspired algorithms in the domain of optimization. The proposed algorithm uses natural immune system components such as B-cells, Memory cells and Antibodies; and processes such as negative clonal selection and affinity maturation to find multiple local optimum points. Another benefit this algorithm presents is the presence of immunological memory that is in the form of specific memory cells which keep track of previously explored solutions. The algorithm is evaluated on two well-known numeric functions to demonstrate the applicability.

INTRODUCTION

Nature, through millions of years of learning has found efficient, robust and innovative methods for dealing daily challenges. The primary mechanism for these methods is ‘neo-Darwinism’, which is evolution by natural selection underpinned by modern genetics. This has led to the emergence of a relatively recent area of computing called ‘evolutionary computing’, which refers to a collection of nature-inspired techniques for solving hard problems in computer science. The computing algorithms inspired by such natural process are genetic algorithms (Goldberg, 1989; Jones, Willett, & Glen, 1995), simulated annealing (Goodsell & Olson, 1990; Kirkpatrick, Gelatt, & Jr., 1983), particle swarm optimization (PSO) (Kennedy & Eberhart, 1995) and ant colony optimization (ACO) (Shelokar, Jayaraman, & Kulkarni, 2004; Zhang, Yen, & Zhongshi, 2014). The contribution of these algorithms their contributions in various subfields of machine learning is well established and recognized in the literature. All of these algorithms
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take their inspirations at the level of an individual organism or in populations of organisms. In recent few decades, our understanding of genetics has increased significantly. However, there is relatively less focus by computational researchers to develop novel computing algorithms inspired by genetic mechanisms. Natural immune system is an example of an area that is less explored by computational researchers. In this chapter, the primary focus is to look into various processes and functions of natural immune system and propose a novel optimization algorithm.

In 1782 Jenner discovered that a smallpox viral attack can be prevented if people are injected with a small amount of the cowpox virus – a weaker form of the smallpox virus found in cattle. This is a form of vaccination, where a weaker form of pathogen is introduced in living organisms to immunize the body from stronger pathogens of the same kind. This finding formulated the basis for a new field of science called natural immune system. Natural Immune System (NIS) are known to possess learning and adaptive capabilities for dealing with pathogens not previously encountered and for finding preventative solutions for disinfection once infection is identified. Moreover, such disinfection can take place in a timely manner so that, in some cases, the organism does not even notice that it has been infected. Since there appears to be no supervision of the NIS (i.e. there appears to be no equivalent to a central executive in the organism for dealing with NIS), an AIS approach will need to be adaptive and cooperative. Also, once a pathogen is dealt with, the NIS has a ‘memory’ of that pathogen should it be encountered again. Because of these adaptive and learning aspects, previous AIS research has been located in the machine learning literature. However, our knowledge of the molecular biology underlying NIS is growing constantly and new discoveries being made that indicate that the NIS for multi-cellular organisms are much more complex than originally thought.

The early researchers of AIS considered that an immune system-inspired algorithm can only work in the pattern recognition domain due to its alignment with the human immune system and its pathogen recognition and elimination capabilities. The researchers have been using AIS algorithms on a number of different application domains such as computer security (Harmer, Williams, Gunsch, & Lamont, 2002; Kim, Greensmith, Twycross, & Aickelin, 2005), clustering/classification (Ayara, Timmis, Lemos, & Forrest, 2005; L. N. d. Castro & Timmis, 2002c; L. N. d. Castro & J. Zuben, 2000; Timmis, Neal, & Hunt, 2000; Watkins, Timmis, & Boggess, 2004), optimization (L. N. d. Castro & J. Zuben, 2000; Khaled, Abdul-Kader, & Ismail, 2010) and robotics (Lau, Bate, & Timmis, 2009; Whitbrook, Aickelin, & Garibaldi, 2007, 2008, 2009). Hart and Timmis (Hart & Timmis, 2008) presented a general review of application areas where AIS has been applied. The authors, based on a natural grouping of published work, classified AIS application areas into 12 distinct groups (Table 1) (Hart & Timmis, 2008). A reflection of these groupings can also be found in (L. N. d. Castro & F. J. V. Zuben, 2000).

These 12 groups can be re-classified into three more generalized and distinct groups; Anomaly Detection, Optimization and Learning (Hart & Timmis, 2008). It can be seen from Table 1 that groups such as anomaly detection, virus detection and computer security can be classified as Anomaly Detection. Numeric function optimization and combinatorial optimization can be considered as ‘Optimization’ group. Learning group can be formed to contain image processing, web mining, clustering/classification and bio-informatics.

AISs are local search algorithms where hypermutation is used to explore neighboring search space. The random population of solutions are inserted during the course of the algorithm to encourage global search. One of the drawbacks of introducing a randomly generated population of B-cells is that the algorithm can tend to repeat local searches due to the presence of a basis of attraction. Basis of attraction can be defined as follows: ‘Given any local optima, consider the set of all points in the search space