Chapter 1
Conceptual and Practical Aspects of the aiNet Family of Algorithms

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ABSTRACT

In this paper, a review of the conceptual and practical aspects of the aiNet (Artificial Immune Network) family of algorithms will be provided. This family of algorithms started with the aiNet algorithm, proposed in 2002 for data clustering and, since then, several variations have been developed for data clustering, biclustering and optimization in general. Although the algorithms will be positioned with respect to other pertinent approaches from the literature, the emphasis of this paper will be on the formalization and critical analysis of the set of contributions produced along almost one decade of research in this specific theme, together with the provision of insights for further extensions.

1. INTRODUCTION

The study of Artificial Immune Systems on Computer Science (CS) is aimed at mimicking some processes of the vertebrate immune systems on a computational context, trying to solve problems from the most diverse areas, not only from CS but also engineering, medical sciences, and many more (de Castro & Timmis, 2002a).

The first work to apply the known concepts of AIS on CS was the machine learning algorithm of Farmer et al. (1986), in which a dynamic model for the immune system based on Jerne's network hypothesis (Jerne, 1974) was proposed and, as a

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result, the model presented high similarity with Holland's Classifier Systems (Holland, 1984).

Four years later, Bersini and Varela (1990) published a paper about immune networks, trying to exploit even further the relation of immune systems on machine learning and classifier systems.

But only in the mid 90s the AIS paradigm gained the status of an active research area, particularly with the publishing of the application of Self-Nonself Discrimination principles to the computer protection problem (Forrest et al., 1994), and also of the Negative Selection algorithm (Dasgupta, 1998).

In late 90s, the work of de Castro and Von Zuben (1999) introduced the concepts and applications of the Clonal Selection principle (Burnet, 1978) to artificial immune systems, not only dealing with machine learning problems but also adapting the immune-inspired mechanisms to perform discrete and continuous optimization. In the trace of this achievement, the popular CLONALG algorithm (de Castro & Von Zuben, 2002a) – *Clonal Selection Algorithm* – was proposed, and followed by several applications and extensions.

The addition of network-based aspects inspired from Jerne's Immune Network Theory (Jerne, 1974) to the CLONALG algorithm led to the *Artificial Immune Network* algorithm, or simply *aiNet* (de Castro & Von Zuben, 2002b), that not only extended the capabilities of CLONALG but also introduced very interesting aspects such as the network interaction among solutions and the dynamic adaptation of the size of the set of candidate solutions. The aiNet algorithm was originally developed for clustering problems, and it is capable of automatically identifying a proper number of arbitrarily shaped clusters.

Following the successful results obtained by the original aiNet algorithm, many extensions appeared in the literature, not only for clustering problems but also for continuous optimization (de Castro & Timmis, 2002b), combinatorial problems (de Sousa et al., 2004; Gomes et al., 2004), bioinformatics (Bezerra & de Castro, 2003; de Sousa et al., 2004; Gomes et al., 2004), prediction systems (Li et al., 2010), biclustering (Castro et al., 2007a,b,c; Coelho et al., 2008; de França et al., 2006b), multi-objective optimization (Coelho & Von Zuben, 2006a; Coelho et al., 2008), dynamic optimization problems (de França et al., 2005a; de França et al., 2006a; Junqueira et al., 2005; Junqueira et al., 2006), and many others.

With almost ten years of existence and supporting a very active line of immune-inspired algorithms, it has become hard to keep track of all existent variations of the aiNet algorithm and their potential applications. Therefore, the goal of this paper is to critically review the original aiNet algorithm, describing the conceptual aspects associated with it, and to present and discuss its main extensions together with the results obtained so far.

The paper is organized as follows: Section 2 presents the theoretical aspects of natural and artificial immune systems that were applied on the aiNet context; Section 3 is dedicated to draw a parallel between the clustering problem and the immune concepts presented in Section 2, and to explain and discuss the original aiNet algorithm; in Section 4 an overview of the aiNet family of algorithms is presented, together with a discussion of general aspects of the different algorithms and the problems that they are meant to solve; Section 5 is dedicated to optimization algorithms, where the variations of aiNet developed for optimization of continuous, discrete, multimodal, multi-objective and dynamic–environment problems will be detailed; Section 6 discusses and details the extensions of aiNet for biclustering; and, finally, Section 7 concludes this survey summarizing the most relevant issues, presenting the final remarks and discussing some prospects concerning the future of the aiNet family of algorithms.