# Chapter IV
# An Immune Inspired Algorithm for Learning Strategies in a Pursuit-Evasion Game

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## ABSTRACT

*Multi-agent systems (MAS), consist of a number of autonomous agents, which interact with one-another. To make such interactions successful, they will require the ability to cooperate, coordinate, and negotiate with each other. From a theoretical point of view such systems require a hybrid approach involving game theory, artificial intelligence, and distributed programming. On the other hand, biology offers a number of inspirations showing how these interactions are effectively realized in real world situations. Swarm organizations, like ant colonies or bird flocks, provide a spectrum of metaphors offering interesting models of collective problem solving. Immune system, involving complex relationships among antigens and antibodies, is another example of a multi-agent and swarm system. In this chapter an application of so-called clonal selection algorithm, inspired by the real mechanism of immune response, is proposed to solve the problem of learning strategies in the pursuit-evasion problem.*

## INTRODUCTION

Multi-agent system problems involve several agents attempting, through their interaction, to jointly solve given tasks. The central issue in such systems is an agent conjecture about the other agents and their ability to adapt to their teammates' behavior. Due to the interactions among the agents, the problem complexity can rise rapidly with the number of agents or their behavioral sophistication. Moreover, as all the agents are trying to find simultaneously the optimal strategy, the environment is no longer stationary. Also in real-world systems it is necessary to address agents' limitations, which make them not always being capable of acting rationally. To sum up, scalability, adaptive dynamics and incomplete information are the most challenging topics, which have to be coped with by any techniques applied to multi-agent encounters.

Game theory is already an established and profound theoretical framework for studying interactions between agents (Rosenschein, 1985). Although originally designed for modeling economical systems, game theory has developed into an independent field with solid mathematical foundations and many applications. It tries to understand the behavior of interacting agents by looking at the relationships between them and predicting their optimal decisions. Game theory offers powerful tool, however the issues of incomplete information and large state spaces are still hard to overcome.

Artificial immune systems (AIS) are computational systems inspired by theoretical immunology, observed immune functions, principles and mechanisms in order to solve problems (de Castro & Timmis, 2002). The fundamental features of the natural immune system, like distribution, adaptability, learning from experience, complexity, communication, and coordination have decided that immune algorithms have been applied to a wide variety of tasks, including optimization, computer security, pattern recognition, mortgage fraud detection, aircraft control etc. – consult (de Castro & Timmis, 2002) for details.

The above mentioned features indicate a natural parallel between the immune and multi-agent systems, which suggests that immune metaphor constitutes a compelling model for agents' behavior arbitration. Examples of successful utilization of immune metaphor to multi-agent systems include works of Lee, Jun, & Sim (1999), Sathyanath & Sahin (2002), and Singh & Thayer (2002), to name but a few. In the chapter an original algorithm MISA (Multi-Agent Immune System Algorithm) is proposed for a multi-agent contest (Lucińska & Wierzchoń, 2007). Solutions presented in the above mentioned papers as well as the MISA algorithm perform better than traditional techniques (i.e. dynamic programming, reinforcement learning, etc.) for given problem domains. Despite promising results in a wide range of different applications there remain however many open issues in the field of AIS. Being a relatively new perspective, they are deficient in theoretical work to study their dynamic behavior in order to explain the results obtained by computational models.

In this chapter, an attempt is made to compare game theory and artificial immune systems by using multi-agent system as intersection platform. We try to extract commonalities between the two methods, in order to indicate possible directions of their future development. The chapter is organized as follows. In section 2 the pursuit-evasion problem is introduced and different attempts to cope with it are discussed. Section 3 presents an immune-based algorithm proposed to solve such a problem. Both algorithmic details and numerical results are given in this section. In section 4 a short discussion of possible extension of this work is given and section 5 concludes the paper.

## BACKGROUND

In order to concentrate on the immune and game theoretic techniques, the rest of the chapter will focus on one class of the multi-agent encounters, i.e. pursuit-evasion problems. They are among the most widespread, challenging, and important multi-agent scenarios and represent some of the most significant potential applications for robots and other artificial autonomous agents. In a typical contest of this sort, one or more pursuers chase one or more evaders around until all preys are captured. Models in which pursuit-evasion problems are examined differ in: environment, number of players, agents' limitations, definition of capture, optimality criterion, space structure etc. (Isler, Kannan, & Khanna, 2004). Various aspects of pursuit-evasion as well as extensive bibliography on this subject can be found in (Sheppard, 1996).

### Two-Player Pursuit-Evasion Games

In the literature, most studies on pursuit-evasion games have concentrated on two-player games, with a single pursuer and a single evader. Under the game theoretic framework a number of formal solutions regarding optimal strategies have been achieved (Isaacs, 1965, Basar & Olsder, 1998). Some of the most representative solutions will be introduced below.

For the sake of simplicity, both the space and time are discrete: the field of action is assumed to be a two-dimensional grid and at every time-step the players can move to new positions as shown in Fig. 1.

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