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INTELLIGENT IMMUNE-BASED SYSTEM FOR AUTONOMOUS SOCCER ROBOTS

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Abstract

In this paper, we propose a new intelligent and control approach for an autonomous soccer robot based on the immune network. The immune system is characterized by self-regulation and self-adaption in dynamically changing environment as emergent properties of the interaction of its components.

Keywords : Soccer Robot, Multi-agent Systems, Immune System.

1. Introduction

Problem solving in complex domains often involves dynamic environments and the need of adaptation. It is easy to imagine several situations where an adaptive behavior is needed in order to achieve a global objective. Robot Soccer is an example where Real-time Adaptive behavior is needed. The dynamic environment presented in a match requires immediate response from the developed system, when at the same time the agents must learn to adapt to the changing environment.

Micro-Robot World Soccer Tournament (MiroSot) [19] initiative gives a good arena for multi-agent research. Robot soccer makes heavy demands in all the key areas of robot technology, mechanics, sensors and intelligence. The robots used in MiroSot are small in size (7.5cm x 7.5cm x 7.5cm) and autonomous. MiroSot involves multiple robots that need to collaborate in an adversarial environment to achieve specific objectives. An alternative way to manage this form of agent-based system is to utilize emergent properties to obtain self-regulation, self-organization and self-adaption observed in many biological systems.

Biological principles have been exploited in a variety of computationally based learning systems such as artificial neural networks and genetic algorithms [18]. Also, the emergence of complex collective behavior from the local interactions of simple agents is illustrated by many natural social systems, like ant colony [8]. Immunological principles and functionalities from computational viewpoint have been applied to computer security problems, parallel processing, optimization, etc [11,22,7,13]. The immune system present all the required capabilities, such as autonomy, adaptation, etc. In this paper, we propose an immune-inspired approach for intelligent and arbitration of autonomous soccer robot.

The rest of the paper is organized as follows. In section 2, we present the related works. Section 3 presents an overview of the natural immune system and the soccer robot architecture. Conclusion and future work are given in section 4.

2. Related work

The fundamental issue for researchers who wish to build a team for soccer robot is to design a multi-agent system that behaves in real-time, performing reasonable goal-directed behaviors [15]. Goals and situations change dynamically and in real-time. It is essential that agents learn to play the game strategically. There are three challenges for the robot soccer games: learning challenge, teamwork and opponent modelling challenge [15,23].

The objectives of robot soccer learning is to solicit comprehensive learning schemes applicable to the learning of multi-agent systems which need to adapt to the situation. The robot soccer teamwork addresses issues of real-time planning, re-planning, and execution of multi-agent teamwork in a dynamic environment. The robot soccer opponent modelling calls for research on modelling a team of opponents in a dynamic multi-agent domain. In robot soccer teamwork, the individual player has to perform several behaviours, one of which is selected depending on the current situation. Each player agent has a limited view that giving him a partial view of the world. It is therefore a big challenge to create a complete and accurate world state representation for the agent. Each agent keeps a world model that contains information about all the objects on the soccer field [4]. In order to react to the situation in real-time, the soccer robot quickly needs information to select role for the current situation. Since programming the Robot behaviors for all situations is unfeasible, robot learning methods seem promising [14,1]. In this case, collective behaviors should be acquired. The immune-inspired approach is one of the promising approaches to the robot soccer intelligent arbitration and control problems. Our immune-based model is based on the work of Ranjan [20] on modelling adaptive mobile agent, the work of Pattie Maes to modelling adaptive autonomous agent [17] and the work of Watanabe [25] for decentralized behavior arbitration mechanism for autonomous Mobile Robot Using Immune System. Our work is based on our previous experience on the Robot Soccer Field [21,9] and the use of immune system as a model in the distributed system [2,3].

3. Approach overview

3.1. Immune system

The immune system defends the body against harmful diseases and infections. It is capable of recognizing most pathogens and eliminating them from the body [6,10]. To this end, it performs pattern recognition tasks to distinguish molecules and cells of the body(self) from foreign ones(non self). The basic entities of the immune system are B-cells and T-cells. Jerne [12] has proposed the concept of the idiotypic network that we use as a basics of our approach. It states that B-cells are not just isolated, but they are communicating between them through stimulation/suppression chains that form a large-scaled network, and work as a self and non-self recognizer [25]. The key portion of the antigen recognized by the antibody is called an epitope (i.e. antigen determinant). The key portion of the corresponding antibody that recognizes the antigen determinant is called a paratope such as shown in figure 1.

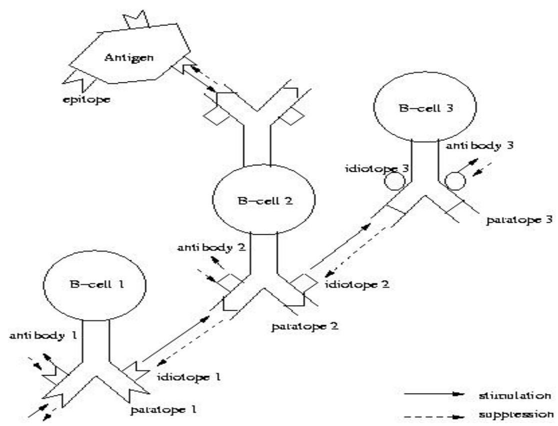

Figure1: The Jerne's idiotypic network

Each type of antibody has its own antigenic determinant, called idiotope. In fact, an antibody is recognized as an antigen by other antibodies. This relationship between antibodies is called the second generation idiotypic network [24,6]. According to this model, the participation of T-cells is typically negliged or ignored.

In this way, the elimination of foreign antigens by immune system is provided by the entire system in a collective manner. This phenomenon is called emergent as it results from the interaction of its entities. In fact, the immune system is self-regulatory to keep the quantitative balance of antibody. Through the stimulation/suppression chains, the populations of specific antibodies increases rapidly, and after eliminating the antigen, decreases again. In other hand, the immune system is self-organizing as its structure of immune system is not fixed, but varies continuously according to the dynamic changes of the environment. This function, called the metadynamics function, is mainly realized by incorporating newly generated cells by the bone marrow or activated cells that proliferates and removing useless one such as depicted in figure 2. This function maintains an appropriate repertoire of cells that cope with the environment change in the piecemeal way.

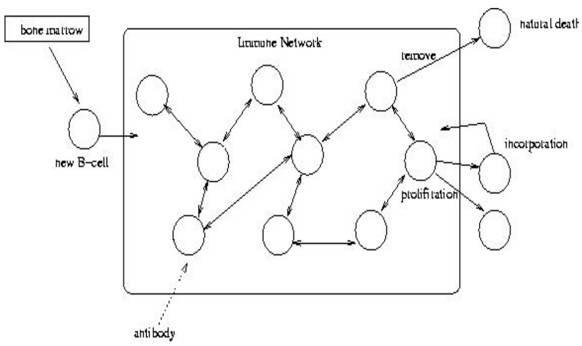

Figure 2: The metadynamic function

3.2. Robot soccer architecture

We define soccer robot as an autonomous agent, composed of distinct bodies and having own resources. An agent is located in its environment and its behavior tends towards the achievement conscious or emergent of goals [5]. It can feel its environment through its receivers and act there by using its effector [20,17]. The agent is called autonomous if it operates completely autonomously, i.e. if it decides itself how to relate (i.e. coupling) its sensors data to motor commands (i.e. effectors) in such a way that its goals are attended to successfully. Adaptation can be viewed as changing the goal set. The effect of the change can be new set of actions to achieve the same overall objectives.

In our model, the agent consists of two modules, The *Interface* of the agent to the environment and the *Controller*. The Interface contains *Sensors* that sense the environment and *Effectors* that can take actions to change the environment. The Controller is the module that decides whether adaptation is necessary and how best to adapt to the current situation. The Interface senses the environment through the Sensors, analyzes them, and creates a view of the environment called percept. The percept is passed into the Controller. If adaptation is needed, a new policy is passed to the Interface, which then transforms it to a set of actions to be carried out. The effectors are used to make any environment change specified in an action. The figure 3 shows the basic structure of the soccer robot and their interaction.

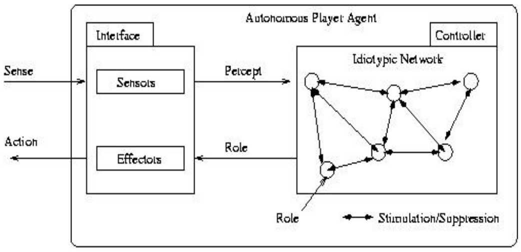

Figure 3: Architecture of player agent

The environment is a soccer field (i.e. other robots and ball). The soccer robot (i.e. player agent) receives regularly the visual information. From the figure 3, we should notice that the current situation of environment (i.e. percept) detected by the Interface (i.e. sensor) work as antigen, and prepared role is regarded as an B-cell or antibody, while the interaction between roles is considered as stimulation/suppression chains between B-cells. The idea of this model is that the Controller equipped with the immune network selects a role suitable for the current situation. Once the role is selected, it is passed on to the Interface, which then transforms the role into a set of actions to be carried out. In fact, the player agent has the possibility of handling the world by the means of several effectors such as move to certain point in the soccer field, strike the ball, etc.

In order to describe the intelligent arbitration for Controller module, we define an attribute as a perceivable feature of the environment (i.e. current situation). A percept (i.e. Pattern) is a set of attributes that describe a view of the dynamically changing environment. The Controller selects the policy that is suitable to the current situation. As described above, the identity of each B-cell is generally determined by its antibody, the paratope and the idiotope. As shown in figure 4, we assign a pair of precondition and policy to the paratope, and the ID-number of the stimulating B-cell and the degree of stimuli to the idiotope.

Precondition under which this Role is selected	Role ID and reference to a corresponding object implementing it	references to stimulating Roles and the degrees of the stimuli (Affinity)
Paratope	Role spesification	Idiotope

Figure 4: Role description

Figure 5 shows the generalized view of an antibody within the idiotypic network. The antibody *i* is stimulated by *N* antibodies and suppresses *M* antibodies. m_{ji} and m_{ik} denotes affinities between antibody *j* and *i*, and between antibody *i* and *k*, respectively. The affinity means the degree of stimulation or suppression. m_{li} denotes the affinity between an antigen *l* and an antibody *i*.

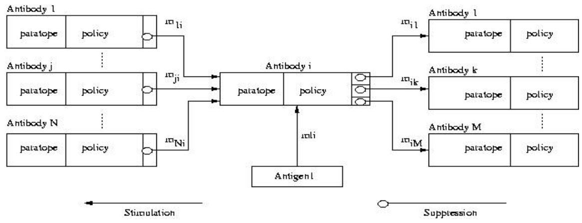

Figure 5: A generalized idiotypic network

The antibody population is represented by the concept of concentration [25]. In order to select the antibody suitable for the antigen, we assign one variable called concentration to each antibody. The concentration of *i-th* antibody denoted by a_i is calculated with the following equations:

$$A_i(t) = A_i(t-1) + \left[k_1 \left(\frac{\sum_{j=1}^{N} m_{ji} a_j(t-1)}{N} \right) - k_2 \left(\frac{\sum_{k=1}^{M} m_{ki} a_k(t-1)}{M} \right) + k_3 m_{li} - d \right] * a_i(t-1) \quad (1)$$

$$a_i(t) = \frac{1}{1 + \exp(0.5 - A_i(t))} \quad (2)$$

In the first equation, the first and second terms denote the stimulation and suppression from other B-cells. The affinity m_{ji} and m_{ik} (i.e. degree) are positive values between 0 and 1. m_{li} is the affinity between the *l-th* antigen and the antibody *i*. d_i denotes the natural death factor of *ith* antibody. K_1 denote the stimulation rate, K_2 the suppression rate and K_3 the antigen stimulation rate. The second equation is the function that squash the parameter $A_i(t)$ calculated by the first equation, between 0 and 1.

Every antibody's concentration is calculated repeatedly during a time defined a priori [25]. The antibody of the highest concentration is selected and passed on to the Interface, which then transforms the role into a set of actins to be carried out.

4. Conclusion and future work

Developing systems of autonomous robots to address complex tasks in dynamically changing environment is particularly challenging. An autonomous soccer robot needs to perceive its environment, make decisions about selection of its roles. This paper describes an immune-inspired approach to design an autonomous and adaptive soccer robot. The agent supports autonomous roles arbitration and can select a suitable role through decentralized interactions among them.

Our simulator was implemented with the Madkit platform [16]. The primary results of simulation shows that the immune-based model improves performance of autonomous soccer robot. Also, the introduction of adaptation mechanisms is highly indispensable. In fact, to evolve the player agent effectively in a dynamically changing environment, the Controller can re-arrange the immune network at run-time by changing affinity values or incorporate an innovation mechanism inspired by the metadynamics function. This mechanism allows a player agent to learn from results. Future research address adaptation and
learning issues.

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