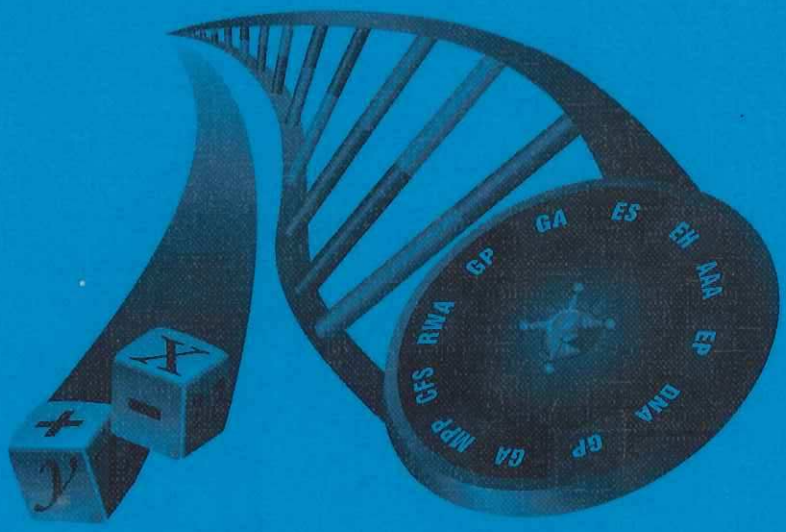

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Immune Mechanisms to Regulate Multi-Agents Systems

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Abstract

We present in this paper the use of immune mechanisms for the regulation of reactive multi-agents systems (MAS). More precisely, the aim of our work is to determine how computer scientists can take benefit from immune phenomenon to auto-regulate agent populations.
This regulation can be made while integrating cell and molecule behaviors into agent's behaviors. Let us quote for example the mitosis, apoptosis or differenciation that are essential mechanisms during an immune response. The work to do or the problem to be solved are seen as foreign substances, that is antigenic bodies.
The agents represent immuno-qualified cells having for goal the antigen inhibition. This process must be efficient, that means it must finish the work (≠ hypo-immune response) and just the work to do (≠ allergy). Each agent inherit from one or several cell behaviors. Those behaviors are extracted from immune cells which have well defined roles.
The first consists in detecting the antigen (the work to do), the second in giving alarm on a large scale, the third in increasing the capacity and the precision of the response and the fourth in eliminating the antigen.
Our agents use these roles to mime an immune response.
Hereafter we explain, in three criteria, the reasons of the immune response choice for MAS.

1. The immune system is compound with autonomous entities, able to cooperate, having behaviors, receptors and means of action. Therefore, a cell is very close to the agent concept.
2. The immune system is able to divide "self" and "non-self". Like this, it can detect the work to do among 10^{20} different patterns. Thus, this system is flexible and adaptative, what gets an unquestionable advantage in environments with strong variability (like for aerial images [McCoy97]). This number of possible shapes is very important, but it can be reduce for the need of simulation [SMI97]
3. The human immune system is quasi-optimal in the power of the answer to eliminate the antigen, which would allow us a quasi-optimal use of the computer resources during multi-agents processes.

The regulation of multi-agents system thanks to immunological principles is few used today [ROD98] [DAS98]. We will begin with the study of the immune concepts we use as metaphors for the regulation of the agent populations. Then, we show two examples illustrating the implementation of the immune concepts. They are dedicated to the image processing coded in levels of gray. Finally, we conclude on the interests of this immune approach for the design of MAS.

Immune Mechanisms for MAS Regulation

We approach in this section the use of a certain number of immune mechanisms for the development of self-regulated MAS.
Thus, we describe several types of immune phenomena implied into self-regulation. We see the negative and positive selections allowing to avoid the presence of cells (or agents) useless or disturbing the system. Then we see the phenomena of activation, differentiation, proliferation and programmed cellular death (apoptosis). The latter are the basis of the mechanisms for automatic regulation during an immune response. The cooperation between the T cells and the B cells within the immune system also allows a limitation of the risks of drift (under-processing of the antigen or edge effects unexpected) while allowing an adaptation located in time and space. But we do not develop this mechanism in this paper. Finally, we propose an architecture of MAS based on the immune principles quoted above.

General structure of our immune-oriented MAS

We can group the different mechanisms describe above into a system that reproduces a part of the immune system (Figure 1).

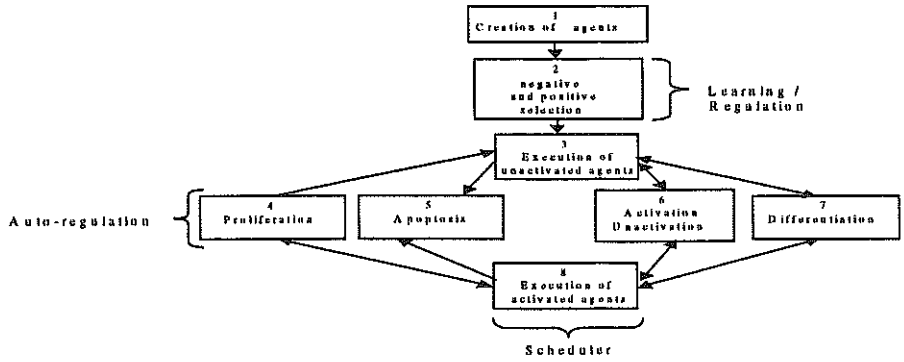

Figure 1: *general structure of our immune oriented MAS*

We apply these immune oriented MAS to image processing and more precisely to low-level image segmentation. We then observe the evolution of agent populations (Figure 2), the success rate (Figure 3-left) and the process duration (Figure 3-right).

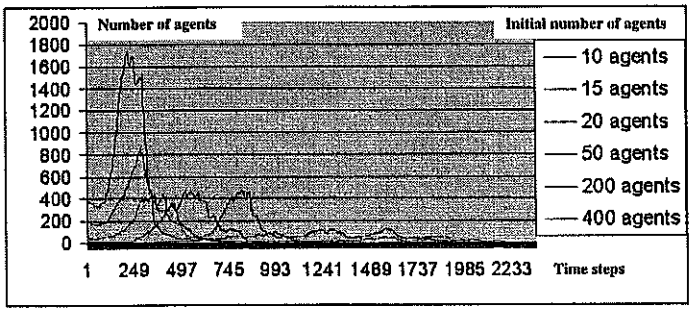

Figure 2: *evolution of the agent populations according to the initial number of entities*

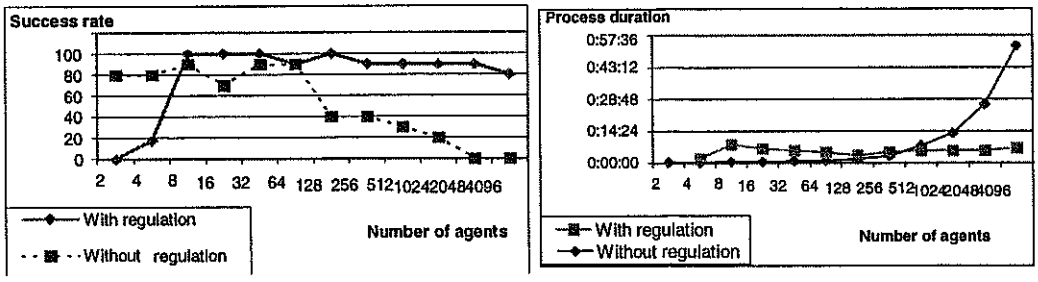

Figure 3: *left: success rate according to the maximum number of agents, right: process duration according to the maximum number of agents*

Conclusion

We have seen that the use of immune regulation into MAS is interesting when the number of agents is relatively importante ($>10^2$). Then, we obtain some good results for the success rate (quality of the result) and the duration of the process (time is quasi-constant). These results are very constant even for an important disparity of the agent numbers. We have compared it with the non-regulated system which is unstable and where the results are difficult to predict.

The immune-oriented MAS allows us to attenuate the number of agent influence: if this number is too little the system increases it, if not, agents use the apoptosis behavior. Like this, the system adapts itself according to its environment.

We have also shown that immune-oriented MAS permits to create image segmentation systems without any global controller nor central decisional system. The immune responses offer to computer scientists many regulation principles that can be included into MAS with few abstraction for the optimization of agent populations.

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