Challenges for Artificial Immune Systems

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1 Introduction

The driving ethos behind Grand Challenge 7 (GC-7) is that biology can serve as both an excellent source of inspiration to creating a new breed of computational systems, and can itself be exploited as a computational system (for example DNA computing). When one examines biology, it is clear that the natural world is full of a vast array of complex systems, which interact in simple (and sometimes complicated) ways. These systems display desirable properties such as homeostasis, self-organisation, development, autonomy and so on. For the purposes of our discussions, we focus on one biological system in particular, the immune system, and outline a number of challenges to the area of Artificial Immune Systems (AIS). The reader is directed to [10] for further information on AIS and the relationship to GC-7.

2 Natural and Artificial Immune Systems

One aspect of applying biological metaphors to computation is the area of Artificial Immune Systems (AIS) [4]. Here, work is concerned with modelling the immune system and extracting metaphors that can be applied to computational problems. Within AIS progress has been made in exploiting the immune metaphor. Effective computer security systems have been developed [5, 8], optimisation, data mining and fault tolerant systems have been created that are performing as well, as the current state of the art in those areas [3, 7, 2]. However, despite the relevant success of the area, we are now entering a phase where we need to begin to address some of the current limitations and issues surrounding AIS.

AIS are poorly understood on a theoretical (mathematical) level and a deeper theoretical understanding is required. Investigations into the dynamics of AIS algorithms would prove insightful, as would a firm understanding of the role of selection, mutation and other operators. Such theoretical developments are well overdue, and would help the discipline mature . Metaphors employed have typically been simple, but somewhat effective. However, as proposed in [11], through greater interaction between computer scientists, engineers, biologists and mathematicians, better insights into the workings of the immune system, and the applicability (or otherwise) of the AIS paradigm will be gained. These interactions should be rooted in a sound methodology in order to fully exploit the synergy. In addition, a greater understanding as to the type of applications that this paradigm should be applied to is required. A curse of some of these types of technologies, is that they are blindly applied to any problem, without first carefully considering the appropriateness of the technique [6]. Within AIS, we should cease to *regurgitate* other disciplines achievements, and look for new and challenging applications that fit the paradigm.

3 Interacting Biological Systems

Homeostasis is the ability of an organism to achieve a steady state of internal body function in a varying environment [1]. This is achieved via complex interactions between a number of processes and systems within the organism, in particular the immune, neural and endocrine systems. We propose that by examining these systems, and their interactions, it should be possible to gain insight into how organisms achieve homeostasis, and therefore exploit these interactions in the realm of computer science and engineering.

Whilst the immune system is clearly an interesting system to investigate, if viewed in isolation, many key emergent properties arising from interactions with other systems will be missed. Such systems do not operate in isolation in biology, therefore, consideration should to be given to the interactions of the immune, neural and endocrine systems,

and how, together, they allow for emergent properties to arise.
Immune, neural and endocrine cells can express receptors for each other. This allows interaction and communication between cells and molecules and it appears that products from immune and neural systems can exist in lymphoid, endocrine and neural tissue at the same time. This indicates that there is a bi-directional link between the nervous system and immune system. It would seem that both endocrine and neural systems could affect the immune system. There is evidence to suggest that by stimulating areas of the brain it is possible to affect certain immune responses, and also that stress (which is regulated by the endocrine system) can suppress immune responses: this is also reciprocated in that immune cells can affect endocrine and neural systems. The action of various endocrine products on the neural system is accepted to be an important stimulus for a wide variety of behaviors such as fight and flight, sexual activity, sleeping and eating [9].

4 Challanges for Artificial Immune Systems

Based on the above observations, we believe there are a number of challenges that are not easy to solve in a day, but rather, can help to shape future research direction.

- **Novel and Accurate Metaphors**. Typically naive approaches to extracting metaphors from the immune system have been taken. This has occurred as an accident of history and AIS has slowly drifted away from its immunological roots. Time is now ripe for greater interaction with immunologists, to undertake specific experimentation and create useful models, all of which can be used as a basis for abstraction into powerful algorithms;

- **Theoretical basis for AIS**. Much work on AIS has concentrated on simple extraction of metaphors and direct application. Despite the creation of a framework for developing AIS [4], it still lacks significant formal and theoretical underpinning. AIS have been applied to a wide variety of problem domains, but a significant effort is still required to understand the nature of AIS and where they are best applied. For this, a more theoretical understanding is required;

- **Application of AIS**. Work to date in the realm of AIS has mainly concentrated on the simple self/non-self paradigm of the immune system as inspiration. This has limited the scope of applications and what can be achieved in applications. By adopting more recent immunological theories away from the self/non-self paradigm, more testing applications can be sought out to break new ground;

- **Integration of Immune and Other Systems**. The immune system does not work in isolation. Therefore, attention should not only be paid to the potential of the immune system as inspiration, but also other systems with which the immune system interacts, in particular the immune, neural and endocrine systems. This will pave the way for a greater understanding of the role and function of the immune system and develop a new breed of immune inspired algorithms.

- **Dissemination of Work**. Raising awareness of the creation and successes of such technologies is of paramount importance: internal to the scientific world, so that results can be verified and techniques adopted for use and external to the scientific world and to industry. The general public should be made aware of progress in technology to broaden the general understanding of science. However, the issue of the general public is not solely the responsibility of AIS community, but of the wider non-classical computation community.

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