IMMUNIZED ARTIFICIAL SYSTEMS--CONCEPTS AND EXAMPLES

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1.1 INTRODUCTION

Immunized Artificial Systems combine *a priori* knowledge with the adapting capabilities of immune systems to provide a powerful alternative to currently available techniques for pattern recognition, modeling, system identification, and control. Immunology is the science of built-in defense mechanisms that are present in all living beings to protect against external attacks. A biological immune system can be thought of as a robust, adaptive system that is capable of dealing with an enormous variety of disturbances and uncertainties. Biological immune systems use a finite number of discrete "building blocks" to achieve this adaptiveness. These building blocks can be thought of as pieces of a puzzle, which must be put together in a specific way to neutralize, remove, or destroy each unique disturbance the system encounters. This paper outlines a technique that reproduces the adaptiveness of a biological immune system in computational systems by identifying and processing information building blocks. Techniques for implementing immunized artificial systems for neural system modeling and for an image recognition problem are presented.

A substantial amount of research in intelligent systems has concentrated on models of intelligence and learning as they occur in human beings. This anthropomorphism overlooks intelligent systems that are not *explicitly* related to the processes of human brains and minds. A good example from nature that is not anthropomorphic, but still exhibits high levels of intelligence, is the biological immune system. The immune system actively exploits memory (both long term and short term), executes strategies, divides tasks hierarchically, recognizes patterns, deals with unforeseen conditions, adapts to changing conditions, etc. However, its operation is markedly different from that of a neural or symbolic processing system.

The immune system is effective due to four reasons: (1) the vast amount of information available in the DNA molecule that has evolved over a period of time; (2) the implicit evolution of information using the building block molecules for on-line, real-time adaptation; (3) the implicit parallelism, non-linear dynamics, flexibility, and uncertainty management capabilities possessed by the system; and (4) the ability to learn and retain important sequence of building blocks for faster adaptation.

How does the immune system metaphor fit into immunized artificial systems? Basically, one can define and learn computational (or information) building blocks, off-line and on-line, to design complex solutions for problems at hand. The building blocks are processed on-line for system adaptation. Specifically, one can define artificial neural networks (ANN), fuzzy systems (FS), and other types of computational building blocks, analogous to the DNA building blocks available for the immune systems. These building blocks can be identified, off-line and on-line, using either learning or by incorporating *a priori* knowledge. Evolutionary algorithms (EA) can be used to process (search through) these building blocks. EA are seen here as a technique for *optimization*, and the other computational paradigms (ANN, FS, and others) are seen as techniques for *information gathering* and *utilization*. Together, these paradigms provide the basis for an immunized computational system that can emulate many features of the immune system.

1.2 THE IMMUNE SYSTEM

The immune system is made up of two major divisions, the innate immune system, and the adaptive immune system [4,21]. The innate immune system is composed of static defenses such as skin and mucus that serve to separate the individual from potential threats. These are supplemented by pre-formed defensive elements that are widely distributed and have the ability to signal the appearance of a threat and call in more of these pre-formed elements. All of these elements are broadly reactive to general categories of problems and have a limited and predetermined set of responses. If the defenses of the innate immune system are breached, the adaptive immune system is called upon to produce a specific reaction to the infectious agent. The adaptive response is driven by the presence of the threat and those cells that nullify the threat the most effectively receive the strongest signal to replicate. As part of the initiation sequence of the adaptive response, signals are sent back to the alerting components of the innate system. These components will modify their programming to make them better able to communicate to the adaptive system and more responsive to subsequent signals. This helps in coping with subsequent attacks.

When an infectious agent attacks a biological system, the job of the immune system is to neutralize or to destroy the hostile agent. The way the immune system carries out this task is by producing molecules called antibodies. Antibodies are a class of molecules produced by B lymphocytes (B cells) of the adaptive immune system. These antibodies bind with the foreign agent to subsequently neutralize them and remove the threat. Antibodies do not bind to the whole infectious agent, but rather to one of the many molecules on the agent's surface. The molecules to which the antibodies adhere are called antigens. Antigens each have a set of antigenic determinants called epitopes. Epitopes are molecular shapes recognized by the antibodies of the immune system. Antibodies are effectively bifunctional molecules. One part is relatively static, this part binds to receptors of B cells, while the other part is highly variable, and is responsible for binding to many different infectious agents. It is the second (variable) part that provides the immune system with most of its robustness and adaptive capabilities. Antibodies are produced by randomly recombining specific segments of a DNA molecule. Once a match is found on the epitope level, a signal is given to the specific B lymphocyte that produced the antibody, and more of it is produced. Thus the antibodies overwhelm the foreign agent, and the threat is nullified.

There is a distinct difference in time-scales and motives between biological evolution and immune system evolution. In biological evolution, one tries to improve the performance of a population of species over very long periods of time. In immune system evolution, the goal is to find the most suitable member of a population in a period which can be as short as few days. The evolution of the immune system could be broken down into two distinct time scales. These include the *slow-learning* mode, which is the evolution of the DNA molecule (global