Basics of Artificial Immune System and Its Applications

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ABSTRACT
Biological systems and processes such as the brain, its evolution and the immune system, have resulted in computational models or example of many such as evolutionary algorithms, neural networks, artificial immune systems etc. Of the existing, Artificial Immune System is the youngest and perhaps the most challenging in that the underlying biology of the immune systems. The immune system has been attracting and become useful to computer engineers, like other biological systems and act as a source of inspiration for development of solutions that are based on observed natural processes to problems related to computational and engineered systems. From a computational point of view, the immune system is considered to exhibit remarkable qualities which make the immune metaphor an interesting approach to adopt within biologically inspired computing. This work is related to the basic fundamentals of Artificial Immune Systems with some of its scopes and applications in various fields.

Keywords- Biological Immune System, Artificial Immune System, Clonal selection, Negative selection.

INTRODUCTION
The main function of a biological immune system is to protect the body from foreign molecules that are known as antigens. This system has great pattern recognition capability that may be used to distinguish between foreign cells that may enter the body thus known as non-self or antigen and the body cells which are known as self cells. Uniqueness, autonomous, recognition of foreigners, distributed detection, and noise tolerance are some of the characteristics of Immune systems which make the system useful for a variety of application domains [1]. Artificial Immune Systems (AIS) are computational paradigms and belong to the computational intelligence family. AIS are inspired by the biological immune system in vertebrates. During the past decade, they have attracted a lot of interest from researchers aiming to develop immune-based...
models and techniques to solve complex computational or engineering problems. Immune system has many appealing features such as recognition, anomaly detection, noise tolerance, robustness, feature extraction, diversity, reinforcement learning, memory, dynamically changing coverage, distributed, multi-layered, adaptive.[7]

BIOLOGICAL IMMUNE SYSTEMS

In biology, immunity is the ability of an organism to resist attacks or any foreign substances that may harm the self cells. The main function of the immune systems is to protect human bodies from infectious agents like viruses, bacteria and other parasites that may be harmful and are commonly known as pathogens [1]. The natural immune system has many useful features such as self-organized and monitored, error-tolerant, distributed and adaptive which are applied in many fields and also has powerful information processing abilities like feature extraction, learning memory, pattern recognition and many more [2].

There are two kinds of immunity: non-specific or innate immunity and specific or acquired immunity.

Innate immunity:  
The innate immunity comprises of an individual's skin, part of the respiratory and gastrointestinal tracts as well as some other factors. These immune mechanisms kill a wide variety of microbes, irrespective of whether these have challenged the body before or not. It is non-specific in that its mechanisms can act against microbes that are not necessarily similar to one another [3]. Basically, vertebrates are born with this immunity which plays a vital role in the initiation and regulation of immune responses. Specialized cells recognize and bind to common molecular patterns of micro-organisms. It doesn't provide complete protection, as it is primarily static in nature (Castro and Zuben , 1999).[1] It is the first line of defense against the aggressive agents. It comprises of some physical and cellular barriers including mechanisms that provide immediate defense to the infectious agents [8].

Adaptive immunity:  
is directed towards specific invaders; either seen before or not previously encountered and gets modified by exposure to invaders. It mainly consists of lymphocytes (white blood cells, more specifically B and T type) that aid the process of recognizing and destroying specific substances, and are antigen-specific (Castro and Zuben , 1999). [1] After an individual has contracted a disease and recovered, it generally does not catch that illness again. This phenomenon is called acquired immunity. It is specific in that its responses are tailored to act against a particular microbe or its products. Such immunity is acquired in which the tailor-made responses are enormously increased as a result of being stimulated by the prior presence of a given microbe or its products.[3]

LYMPHOCYTES

To be able to resist attacks by antigens, the immune system must be able to distinguish between the materials of the body and that of the foreign substance. As all living creatures are basically made up of
similar building blocks, the ability of an organism to distinguish the molecules of itself from which it is composed i.e. self, and from all others i.e., non-self is remarkable. This ability is present in all living creatures to some degree but among vertebrates it is especially a feature of the white blood cells called lymphocytes.

Lymphocytes are the cells responsible for the body's ability to distinguish and react to an almost infinite number of different antigens. There are two main kinds of lymphocytes, i.e., B- and T-lymphocytes (also known as B- and T-cells). The stem cells for both B- and T-lymphocytes originate in bone marrow of bones. Recognition of foreign antigens in the immune system is carried out by receptors on the surface of both the B- and T-lymphocytes [3].

**B-LYMPHOCYTES**

The B-lymphocytes are also called immunoglobulin and are differentiated in the bone marrow (hence the B). Each B-lymphocyte is programmed to make antibody of a single specificity and place it on its outer surface to act as a receptor. When an antigen enters the body it is opposed by a vast array of lymphocytes which are all bearing different antibodies each with its individual recognition site. The antigen will only bind to those receptors with which it makes a good fit and when the receptors of a lymphocyte have bound the antigen, it receives a triggering signal and develop into Antibody-forming plasma cells. Since the lymphocytes are programmed to produce one, and only one, kind of Antibodies, these antibodies generated by the plasma cells will behave just like the Antibodies originally acting as a receptor; thus, it will bind well to the Antigen (Roitt and Delves 2001, pp. 24, 25).[3]

**T-LYMPHOCYTES**

Many microorganisms take advantage of the fact that if they live inside cells of their host, humoral Antibody as presented on the surface of B-lymphocytes is unable to reach them. Thus, a lymphocyte subpopulation, comprising the T-lymphocytes, which is specialized to operate against intracellular organisms exists. Unlike the B-lymphocytes, the T-lymphocytes differentiate within the thymus gland, the thymus is a pyramid-shaped lymphoid organ. In humans it resides immediately beneath the breastbone at the level of the heart. The organ is called thymus as its shape resembles that of a thyme leaf [3].

**ARTIFICIAL IMMUNE SYSTEMS**

Artificial Immune Systems (AISs) are inspired from Biological Immune System (BIS) in vertebrates which were discussed earlier. BIS protects the body of an organism from foreign antigens. BIS has the ability to distinguish non-self from self. AIS can map this feature of BIS to distinguish an anomalous behavior from a normal behavior. AIS learn the normal behavior of a system by tuning an appropriate group of detectors. These detectors are used to describe and differentiate the non-self antigens from the self antigens [4].
Artificial Immune System (AIS) exhibits a high level of complexity as different algorithms used in AIS actually imitate the behavior of the different types of cells of the immune system.

**Clonal Selection**

The Clonal Selection principle is basically a whole process of antigen recognition, cell proliferation and differentiation into memory cell (Burnet, 1959). Many artificial immune algorithms have been developed imitating the clonal selection theory. Castro and Zuben (2002) proposed a clonal selection algorithm named CLONALG for learning and optimization, CLONALG generates a population of N antibodies, each specifying a random solution for the optimization process and during each iteration, some of the best existing antibodies are selected, cloned and mutated in order to construct a new candidate population. The new antibodies are then evaluated and certain percentage of the best antibodies is added to the original population and finally a percentage of worst antibodies of previous generation are replaced with new randomly create ones [1].

B-cells are selected to be fit for the purpose during a “training period”. Those B-cells that exhibit cell-surface receptors (antibodies) that match the corresponding antigen are selected to form the initial B-cell population while the rest that cannot bind to the antigen are removed. The selected B-cells are then released to the periphery and when they encounter the antigen, multiple versions of the B-cell receptors (antibodies) are produced that can bind to the matching antigen.

When clonal selection operates on B-cells these can differentiate into long-lived memory cells[5] so as to encounter the repeated attacks by the same antigen during the entire lifetime of the individual. The initial exposure to an antigen induces an adaptive immune response that is initially handled by a small number of B-cells that produce antibodies of varying affinities. If we can store some high affinity antibody producing cells from the first infection so as to form a large initial specific B-cell sub-population (clone), then the effectiveness and speed of protection would be much more during later attacks[5]. Application of the clonal selection theory leads to algorithms that evolve through a cloning, mutation and selection phase and give candidate solutions in terms of optimization, or pattern detectors in terms of learning. In these algorithms the populations of B-cells (candidate solutions) that match against antigens. These B-cells then undergo cloning mainly in proportion to the strength of the match and mutation that is inversely proportional to the strength of the match. High affinity B-cells then remain in the population and some low affinity cells are removed and new random cells are generated.

The main features of the clonal selection theory are that:

- The new cells are copies of their parents which are known as clones that are subjected to a mutation mechanism with high rates (known as somatic hyper mutation)
- Elimination of newly differentiated lymphocytes is done that carry self-reactive receptors.
- Proliferation and differentiation on contact with antigens of mature cells.
- Elimination of self antigens.
• Restriction of one pattern to one differentiated cell and retention of that pattern by clonal descendants
• Generation of new random genetic changes, subsequently expressed as diverse antibody patterns by a form of accelerated somatic mutation.

![Fig 1. The clonal selection mechanism](image1)

![Fig 2. Clonal selection algorithm](image2)

**Negative Selection**
This theory was proposed by Joshua Lederberg in 1959. He suggested that when T-cells (another class of lymphocytes) are produced, they undergo a period of immaturity during which antigen recognition leads to their death means the T-cells further need activation in the tissues to develop the ability to remove pathogens like bacterial agents and virus affected cells. The negative selection basically provides tolerance to the self cells which means it is the ability of our body to detect only the unknown antigens without reacting against the self cells. During the stage of embryonic development the T-cells migrate to a immune system organ called thymus till puberty. During this time the T-cells are exposed to a comprehensive version of self-antigens and undergo a pseudo-random gene rearrangement procedure followed by a censoring process in the thymus. All T-cells having receptors matching to the self-antigens are removed by a filtering process. After puberty the thymus shrinks to a negligible size and hence all the self-reactive T-cells are
eliminated. The matured T-cells are circulated in the lymphatic system for protection purposes. This can be explained as in the T-cell maturation process of the immune system, if a T-cell in thymus recognizes any self cell, it is eliminated before deploying for immune functionality. Similarly, the negative selection algorithm generates detector set by eliminating any detector candidate that match elements from a group of self samples. Anomaly detection is done using Negative selection based algorithms.[1] T-cells are covered by receptors that are able to bind antigens. The creation of T-cells (detectors) in thymus is a result of a pseudo-random process. After a T-cell is created, it undergoes a censoring process called negative selection. During negative selection T-cells that bind self are destroyed and remaining T-cells are introduced into the body. The recognition of non-self is done by simply comparing T-cells that survived negative selection with a suspected non-self. It is possible that the self set is incomplete, while a T-cell matures (tolerization period) in the thymus. This leads to producing T-cells that can cause an autoimmune reaction [6].

**SCOPE OF ARTIFICIAL IMMUNE SYSTEM**

- Pattern recognition;
- Fault and anomaly detection;
- Data analysis;
- Data mining (classification/clustering)
- Agent-based systems;
- Scheduling;
- Machine-learning;
- Autonomous navigation and control;
- Search and optimization methods;
- Artificial life;
- Security of information systems;
- Optimization etc. [11]

**APPLICATIONS**

Artificial immune systems (AIS) are intelligent and adaptive systems inspired by the immune system toward real-world problem solving. The following features of the immune system are applied in information security systems: learning to detect new viruses; detecting viruses locally; identifying viruses; classifying and eliminating viruses autonomously; multiple layered protection system; different cells being able to detect different viruses and few ‘self’ cells being able to detect multiple viruses; and remembering discovered viruses.[9] AIS is applied to construct a financial early warning system for Taiwanese banking industry.[10]

Some more typical Applications of Artificial Immune System are:
CONCLUSION
Basics of Artificial Immune system have been studied in this article with some of its applications in various fields. Security in computer networks is one of the most interesting aspects of computer systems. It is typically represented by the initials confidentiality, integrity, and authentication or availability. Although, many access levels for data protection have been identified in computer networks, the intruders would still find lots of ways to harm sites and systems. The accommodation proceedings and the security supervision in the network systems, especially wireless sensor networks have been changed into a challenging point. One of the newest security algorithms for wireless sensor networks is Artificial Immune System (AIS) algorithm. Human lymphocytes play the main role in recognizing and destroying the unknown elements. There is a need to revisit existing methodologies with an intension to improve them by applying the concept of immune system to achieve comprehensive security for information systems. So the future work is to apply Artificial Immune System in wireless sensor networks to improve the Network Security.

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