Control Inteligente

Fundamentos de Algoritmos Evolutivos
L12

Luis Moreno, Santiago Garrido, Dorin Copaci

Dpto. Ing. de Sistemas y Automática
Universidad Carlos III
Madrid

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Introducción

- Además de los algoritmos vistos existen otros que veremos en este tema.

Memetic Algorithms

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Memetic Algorithms

Memetic Algorithm

$t \leftarrow 1$;
$P_1 \leftarrow$ Inicializar con μ individuos;
while (criterio de terminacion no alcanzado) {
  $P'_t \leftarrow 0$;
  $i \leftarrow 1$;
  while ($i \leqslant \lambda$) {
    elegir $x \in P_t$ aleatoriamente con distr. uniforme
    $x' \leftarrow mutacion(x)$
    if x' cumple criterio de busqueda local {
      $x'' \leftarrow busquedalocal(x')$ }
    else {
      $x'' \leftarrow x'$ }
    $P'_t \leftarrow P'_t \bigcup x''$;
    $i \leftarrow i + 1$;
  }
  $P'_t \leftarrow$ mejores μ individuos en $P'_t \bigcup P_t$
  $t \leftarrow t + 1$;
}

Artificial Inmune Systems

- The biological immune system is an elaborate defense system which has evolved over millions of years. Many details of the immune mechanisms (innate and adaptive) and processes (humoral and cellular) are yet unknown (even to immunologists).
- It is well known that the immune system uses multilevel (and overlapping) defense both in parallel and sequential fashion.
- Depending on the type of the pathogen, and the way it gets into the body, the immune system uses different response mechanisms (differential pathways) either to neutralize the pathogenic effect or to destroy the infected cells.

Artificial Inmune Systems

The immune features that are particularly relevant are matching, diversity and distributed control.

- Matching refers to the binding between antibodies and antigens.
- Diversity refers to the fact that, in order to achieve optimal antigen space coverage, antibody diversity must be encouraged (see Hightower et al., 1995).
- Distributed control means that there is no central controller; rather, the immune system is governed by local interactions between immune cells and antigens.

- Two of the most important cells in this process are white blood cells, called T-cells and B-cells. Both of these originate in the bone marrow, but T-cells pass on to the thymus to mature, before circulating in the blood and lymphatic vessels.
- The T-cells are of three types: helper T-cells which are essential to the activation of B-cells, killer T-cells which bind to foreign invaders and inject poisonous chemicals into them causing their destruction, and suppressor T-cells which inhibit the action of other immune cells thus preventing allergic reactions and autoimmune diseases.
- B-cells are responsible for the production and secretion of antibodies, which are specific proteins that bind to the antigen. Each B-cell can only produce one particular antibody. The antigen is found on the surface of the invading organism and the binding of an antibody to the antigen is a signal to destroy the invading cell as shown in next Fig.

Artificial Inmune Systems

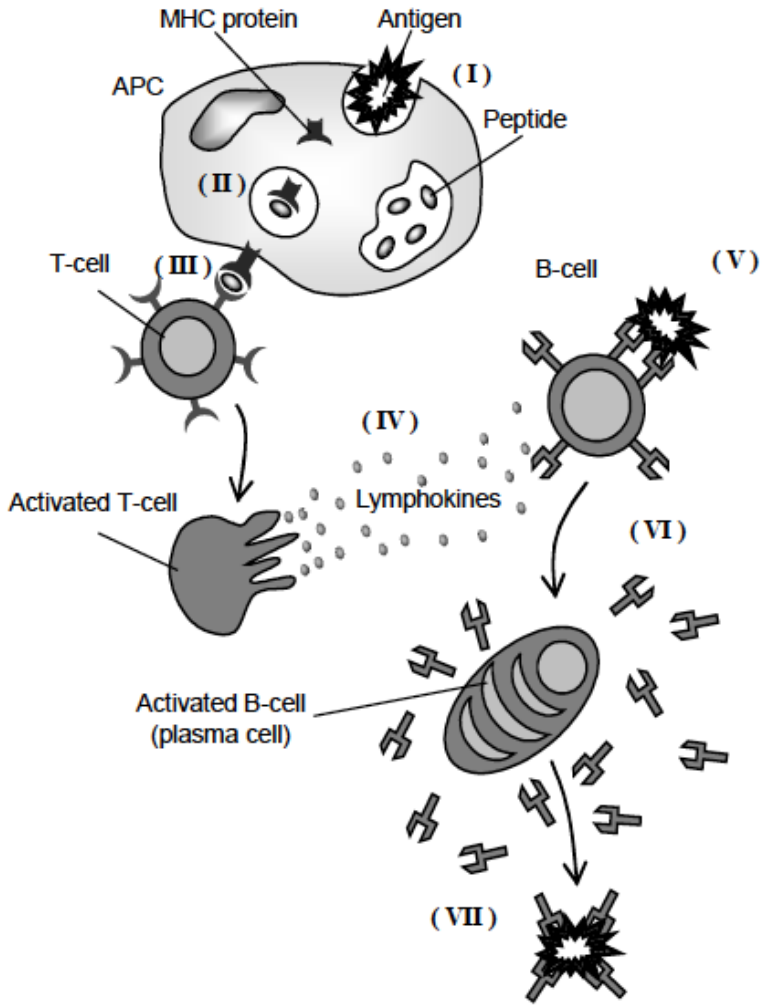

Figura: Pictorial representation of the essence of the acquired immune system mechanism (taken from de Castro and van Zuben (1999)): the invade enters the body and activates T-cells, which then in IV activate the B-cells; V is the

Artificial Inmune Systems

- The human body is protected against foreign invaders by a multi-layered system.
- The immune system is composed of:
  - Physical barriers such as the skin and respiratory system;
  - Physiological barriers such as destructive enzymes and stomach acids; and
  - The immune system, which can be broadly viewed as of two types: innate (non-specific) immunity and adaptive (specific) immunity, which are inter-linked and influence each other.
  - Adaptive immunity can again be subdivided into two types: humoral immunity and cell-mediated immunity.

Artificial Inmune Systems

Learning, adaptability, and memory are important characteristics of adaptive immunity. It is subdivided under two heads: humoral immunity and cell mediated immunity:

1. Humoral immunity is mediated by antibodies contained in body fluids (known as humors).
2. Cellular immunity is cell-mediated; effector T-cells generated in response to antigen are responsible for cell-mediated immunity.

Artificial Inmune Systems

Humoral immunity

- The humoral branch of the immune system involves interaction of B-cells with antigen and their subsequent proliferation and differentiation into antibody-secreting plasma cells.
- Antibody functions as the effectors of the humoral response by binding to antigen and facilitating its elimination.
- When an antigen is coated with antibody, it can be eliminated in several ways. For example, antibody can cross-link the antigen, forming clusters that are more readily ingested by phagocytic cells.
- Binding of antibody to antigen on a micro-organism also can activate the complement system, resulting in lysis of the foreign organism.

Artificial Inmune Systems

Cellular immunity

- Cytotoxic T-lymphocytes (CTLs) participate in cell-mediated immune reactions by killing altered self-cells; they play an important role in the killing of virus-infected and tumor cells. Cytokines secreted by TDH can mediate the cellular immunity, and activate various phagocytic cells, enabling them to phagocytose and kill micro-organisms more effectively. This type of cell-mediated immune response is especially important in host defense against intracellular bacteria and protozoa.

Artificial Inmune Systems

- There is more than one mechanism at work (additional info Farmer et al., 1986; Kubi, 2002; Jerne, 1973), the essential process is the matching of antigen and antibody, which leads to increased concentrations (proliferation) of more closely matched antibodies.
- In particular in Artificial Immune System models the following theories are used:
  - Idiotypic network theory,
  - Negative selection mechanism, and
  - The *clonal selection* and *somatic hypermutation* theories.

Immune Network Theory

The immune network theory was proposed by Jerne (1973).

- The hypothesis was that the immune system maintains an idiotypic network of interconnected B-cells for antigen recognition.
- These cells both stimulate and suppress each other in certain ways that lead to the stabilization of the network.
- Two B-cells are connected if the affinities they share exceed a certain threshold, and the strength of the connection is directly proportional to the affinity they share.

Negative Selection Mechanism

The purpose of negative selection is to provide tolerance for self-cells. It deals with the immune system's ability to detect unknown antigens while not reacting to the self-cells.

- During the generation of T-cells, receptors are made through a pseudo-random genetic rearrangement process.
- Then, they undergo a censoring process in the thymus, called the negative selection.
- There, T-cells that react against self-proteins are destroyed; thus, only those that do not bind to self-proteins are allowed to leave the thymus.
- These matured T-cells then circulate throughout the body to perform immunological functions and protect the body against foreign antigens.

Clonal Selection Principle

The clonal selection principle describes the basic features of an immune response to an antigenic stimulus. It establishes the idea that only those cells that recognize the antigen proliferate, thus being selected against those that do not.
The main features of the clonal selection theory are that

1. The new cells are copies of their parents (clone) subjected to a mutation mechanism with high rates (somatic hypermutation);
2. Elimination of newly differentiated lymphocytes carrying self-reactive receptors;
3. Proliferation and differentiation on contact of mature cells with antigens.

Clonal Selection Principle

- When an antibody strongly matches an antigen the corresponding B-cell is stimulated to produce clones of itself that then produce more antibodies.
- This (hyper) mutation, is quite rapid, often as much as *one mutation per cell division* (de Castro and Von Zuben, 1999) which allows a very quick response to the antigens.
- In Artificial Immune System literature, often no distinction is made between B-cells and the antibodies they produce. Both are subsumed under the word *antibody* and statements such as mutation of antibodies (rather than mutation of B-cells) are common.

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