Intelligent Control of Multivariable Process Using Immune Network System

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Abstract - This paper suggests that the immune network algorithm based on fuzzy set can effectively be used in tuning of a PID controller for multivariable process or nonlinear process. The artificial immune network always has a new parallel decentralized processing mechanism for various situations, since antibodies communicate to each other among different species of antibodies/B-cells through the stimulation and suppression chains among antibodies that from a large-scaled network. In addition to that, the structure of the network is not fixed, but varies continuously. On the other hand, a number of tuning technologies have been considered for the tuning of a PID controller. As a less common method, the fuzzy and neural network or its combined techniques are applied. However, in the case of the latter, yet, it is not applied in the practical field, in the former, a higher experience and technology is required during tuning procedure.

Along with these, this paper used the fuzzy set in order that the stimulation and suppression relationship between antibody and antigen can be more adaptable controlled against the external condition, including noise or disturbance of plant. The immune network based on fuzzy set suggested here is applied for the PID controller tuning of multivariable process with two inputs and one output and is simulated.

1. INTRODUCTION

In recently years, a combined learning-based artificial intelligence (AI) such as neural network, immune network structure have been interested in studying much attention for their robustness and flexibility against a dynamically changing system or complex system, since conventional artificial intelligent systems based on a functional decomposition, leading to a so-called "sense-model-plan-action" cycle have been criticized on many grounds over the last decade[1-3].

They are used extensively on industry in such diverse applications as fault prediction, fault diagnosis, supervisory control, energy management, production management, software engineering, and among others[1-2]. This technology is highly multi-disciplinary and rooted in systems control, operations research, artificial intelligence, information and signal processing, computer software and production background[2].

Each technique such as fuzzy, neural, and neuro-fuzzy is offering new possibilities and making intelligent system even more versatile and applicable in an ever-increasing range of industrial applications. Over the past decade or so, significant advances have been made in two distinct technological area: fuzzy logic(FL) and neural networks(NNs)[5].

On the other hand, biological information processing systems such as human beings have many interesting functions and are expected to provide various feasible ideas to engineering fields, especially intelligent control or robotics. Biological information in living organisms can be mainly classified into the following four systems: brain nervous, genetic system, endocrine system, and immune system. Among these systems, brain nervous and genetic systems have already been applied to engineering fields by modeling as neural network and genetic algorithms, they have been widely used in various fields. However, only a little attention has been paid to application of the other systems, not to mention their important characteristics and model.

The immune system possesses a self organizing and distributed memory therefore, it is thus adaptive to its external environment and allows a PDP (parallel distributed processing) network to complete patterns against the environmental situation. The correct functioning of the immune system is to be insensitive to the fine details of the network connections, since a significant part of the immune system repertoire is generate by somatic mutation processes.

In particular, immune system have various interesting features such as immunological memory, immunological tolerance, so on viewed from engineering. Brooks, a pioneer of the approaches, has presented subsumption architecture for behavior arbitration of autonomous robots. However, the behavior based AI still has the following open questions: how do we construct an appropriate arbitration mechanism among multiple competence modules, how do we prepare appropriate competence modules. One of the promising approaches to tackle(target) the above mentioned problems is a biologically-inspired approach for AIS.

2. OVERVIEW OF THE ARTIFICIAL IMMUNE SYSTEM

The immune system protects our bodies from attack of foreign matters(antigens) which enter the bloodstream.

One way in which immune system does this is

by using antibodies which are proteins produced by B cells, which are a subpopulation of white blood cells. The basic components of the biological immune system are macrophages, antibodies, and B-cell. B-cell is the cells maturing in bone marrow, which collectively form what is known as the immune network. Roughly 10^7distinct types of B-cell are contained in a human body, each of which has a distinct molecular structure and produces "Y" shaped antibodies from its surfaces[4]. When a B-cell encounters an antigen, an artificial immune response is elicited, which causes the antibody matches the antigen sufficiently well, its B cell becomes stimulated and can produce mutated clones which are incorporated into the immune network.
That is, the antibody recognizes specific antigens which are the foreign substances that invade living creatures, and this reaction is often likened to a key and keyhole relationship.

3. ARTIFICIAL IMMUNE SYSTEM BASED MODEL

3.1 Immune Network Model

Jerne first point out the idea that there are some remarkable similarities between the nervous system and the immune system [10] and he also proposed that the immune response is regulated by a network of autoimmune interactions. That idea has been elaborated by Cohn, Edelman & Mountcastle, and Edelamn & Reeke. John E. Hunt & Denise E. Cooke described an artificial immune system which is based upon models of the natural immune system and Geoffrey W. Hoffman suggested a neural network model based on the analogy with the immune system.
In engineering field, robot, decentralized automation, data mining, memory, automatic control have been studied. To understand for model exactly, we need to figure out how they are constructed among the structures in immune system.

3.2 The response of Immune System

The immune system has two types of response: primary and secondary. The primary response is reaction when the immune system encounters the antigen for the first time.
At this point the immune system learns about the antigen, thus preparing the body for any further invasion from that antigen. This learning mechanism creates the immune system's memory.
The secondary response occurs when the same antigen encountered again. This has response characterized by a more rapid and more abundant productin of antibody resulting from the priming of the B-cells in the primary response.

3.3 Antibodies in Immune System

In the AIS the antibodies blind to infectious agents and then either destroy these antigens themselves attract help from other components of the immune system.

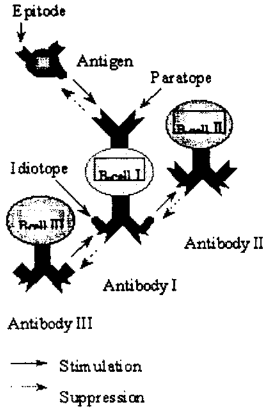

Fig. 1. Structure of idiotypic on Jerne network.

Antibody is actually three-dimensional Y shaped molecules which consist of two types of protein chain: light and heavy. It also possesses two paratopes which represents the pattern it will use to match the antigen. The regions on the molecules that the paratopes can attach are so-called epitopes.

3.4 Interaction Between Antibodies

Describing the interaction among antibodies is important to understand dynamic characteristics of immune system. For the ease of understanding, Consider the two antibodies that respond to the antigens A1 and A2, respectively. These antigens stimulate the antibodies, consequently the concentration of antibody A1 and A2 increases.
However, if there is no interaction between antibody A1 and antibody A2, these antibodies will have the same concentrations. Suppose that the idiotope of antibody A1 and the paratope of antibody A2 are the same. This means that antibody A2 is stimulated by antibody A1, and oppositely antibody A1 is suppressed by antibody A2 as Fig. 1. In this case, unlike the previous case, antibody A2 will have higher concentration than antiobody A1. As a result, antibody A2 is more likely to be selected.
This means that antibody A2 has higher priority over antibody A1 in this situation. As we know from this description, the interaction among the antibodies acts based on the principle of a priority adjustment mechanism.

3.5 Dynamics of Immune System

In the immune system, the level to which a B cell is stimulated relates partly to how well its antibody binds the antigen. We take into account both the strength of the match between the antibody and the antigen and the B cell object's affinity to the other B cells as well as its enmity. Therefore, generally the concentration of i-*th* antibody, which is denoted by δ_i, is calculated as follows[3]:

$$\frac{dS_i(t)}{dt} = \left(\begin{array}{c} \alpha \sum_{j=1}^{N} m_{ji}\, \delta_j(t) \\ -\alpha \sum_{k=1}^{N} m_{ik}\, \delta_k(t) + \beta m_i - \gamma_i \end{array} \right) \delta_i(t) \quad (1a)$$

$$\frac{d\delta_i(t)}{dt} = \frac{1}{1+\exp\left(0.5 - \frac{dS_i(t)}{dt}\right)} \quad (1b)$$

where in equation (1), N is the number of antibodies, and α and β are positive constants. m_{ji} denotes affinities between antibody j and antibody i (i.e. the degree of interaction), m_i represents affinities between the detected antigens and antibody i, respectively.

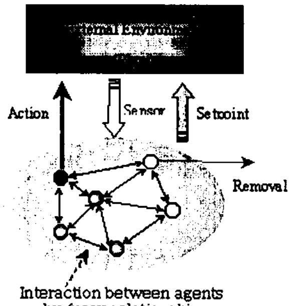

Fig. 2. Proposed mechanism for selection of P, I, D

4. BASIC CONCEPT OF SELECTION MECHANISM

If an antigen is presented to the B cell object, an immune response, that is, the learning is initiated. The level on B cell stimulation depends not only on how well it matches the antigen, but also how it matches other B cell objects in the immune network. The B cell object project produces copies of itself, which turn on a mutation mechanism that generates mutations in the genes that code specially for the antibody molecule.

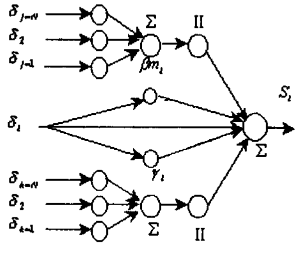

Fig. 3. The structure of network for acton

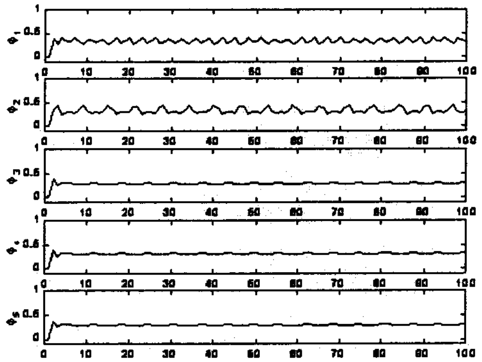

Fig. 4. Variation of parameter, m_{jk}, m_{ki} in equation (1) to time.

That mirrors the mechanism called somatic hypermutation which occurs in the human immune system. Alternatively, if the stimulation level falls below a given threshold, the B-cell object will die off and does not replicate. The stimulation of B cell objects in the immune system. The network is formed by B cell objects recognizing other B cell objects depends on their affinity to the antigen and to the other B cell objects in the network. The new B-cell objects may have an improved match for the antigen and thus proliferate, and then it can survive longer than existing B cell objects.

5. Conclusions and Further Work

Up to the present time, a number of PID controllers have been studied in the context of tuning of PID controllers.
However, a general view is provided that they are the special cases of either the set-point.
This paper demonstrates whither the immune network algorithms can be used effectively for tuning in PID control structures of dynamical changing plant.
More detailed simulation will be revealed to prove whether immune network algorithms are effective use to search for optimal control in control system with disturbance.

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