

Visual computing model for immune system and medical system

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Abstract: Natural immune system is an intelligent self-organizing and adaptive system, which has a variety of immune cells with different types of immune mechanisms. The mutual cooperation between the immune cells shows the intelligence of this immune system, and modeling this immune system has an important significance in medical science and engineering. In order to build a comprehensible model of this immune system for better understanding with the visualization method than the traditional mathematic model, a visual computing model of this immune system was proposed and also used to design a medical system with the immune system, in this paper. Some visual simulations of the immune system were made to test the visual effect. The experimental results of the simulations show that the visual modeling approach can provide a more effective way for analyzing this immune system than only the traditional mathematic equations.

Keywords: Immune system; tri-tier modeling; visual simulation; medical system.

INTRODUCTION

For a long time, there are mainly two methods to model and simulate the immune system (Dibrov, Livshits, & Volkenstein, 1977). One is the mathematic model that is represented with differential equations and algorithms (Kamelreid, Letarte, & Sirard, 1989; Ming, Goodman, & Brown, 1965). The other is called the conceptual model, which is established according to the logic elaborations of the description entities and their interaction rules (Greenberg & Greene, 1976).

With the abstract mathematic models, researchers have successfully simulated an increasing number of immune phenomena. However, most of these models consider only a special part of the immune system with some strict conditions and hypotheses in a particular phenomenon. Moreover, the results of these models are neither visual nor comprehensible enough. To work through this bottleneck of the relative immunological research, from the perspective of artificial intelligence, the traditional models are not applicable enough to understand the immune systems, and new immunological models with visualization techniques should be designed. Only the hypothetical simple immune system is related to a small portion of variables and then can be represented with some differential equations, without fully considering the diversity of the immune systems (Kuehn, Ouyang, & Lo, 2014; Mukhtar, Carvunis, & Dreze, 2011; Alder, Rogozin, & Iyer, 2005).

On the other hand, the conceptual models include the cellular automata, the clustering models and the agent-based models. These models not only simulate a certain

kind of immune mechanism, but also simulate the overall performance of the immune system. However, these conceptual models have some serious drawbacks. For example, the cellular automata only can process some relatively small-scale systems.

Although the above two types of models explained some parts of the immunological phenomena (Li, Wang, & Lu, *et al.*, 2009), the immune systems are difficult to understand and not intuitive (Hart & Timmis, 2008). The multi-tier immune system was investigated (Gong & Xiong, 2013), and the multi-layered artificial immune systems were studied (Gao, Wang, & Tamura, 2009). In this paper, we proposed a novel tri-tier immune computing model of the immune system against some viruses and cancers, and this model is comprised of three computing tiers, i.e. the inherent immune layer, the adaptive immune layer and the immune cell layer. On the other hand, the visualization approach was useful for analyzing the immune system (De Castro & Timmis, 2002). Our visual computing model of the immune system is easier to understand than traditional pure mathematic approaches, and this model is a new tool for simulating both the natural immune system and the artificial immune system. Moreover, the more visual is the simulation of the immune system, the easier is the model of the immune system for the scientists and the doctors to understand and analyze.

Visual computing model of immune system

There are great differences between the model of the human immune system and that of the artificial immune system. These differences lie in the application objects of the models and the modeling methods, so it is difficult to establish an appropriate mapping between the two models (Gong & Cai 2011). The tri-tier visual model is shown in

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fig. 1 and the first one of the three layers in this fig. is the inherent immune layer, based on the innate immune response theory.

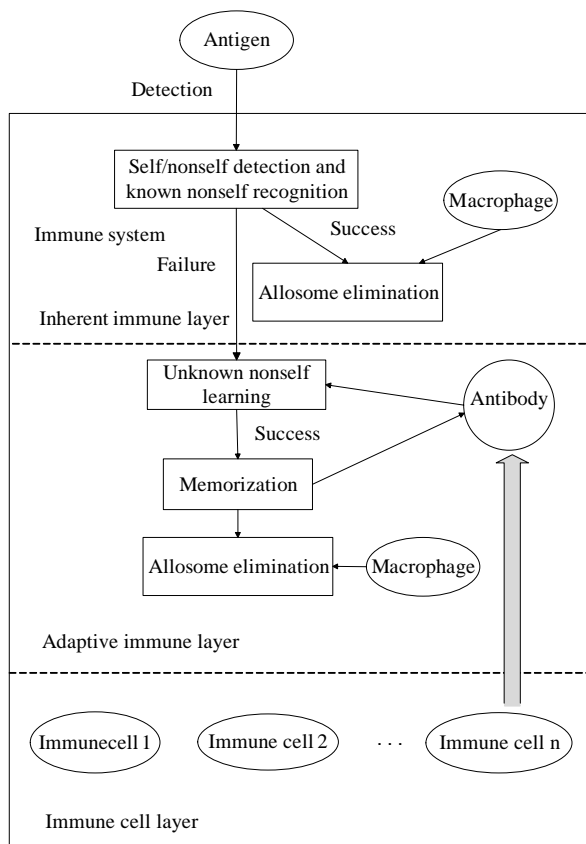


Fig. 1: Visual model of the human immune system.

The second layer is the adaptive immune layer, which recognizes the unknown non-self antigens by the immune learning. Finally, the third layer is the immune cell layer, which generates antibodies to recognize, learn and classify the unknown non-self antigens.

Generally speaking, from nature to computer, the non-self antigen is mapped to the computer virus or malfunction; the self antigen is mapped to the normal component of the computer; the macrophage is mapped to the object eliminator, such as the file-deleting command of some operating system; the antibody is mapped to the immune agent (IA); the memory cell is mapped to the digital storage; the feature matching is mapped to the database querying; the pattern recognition is mapped to the learning and reasoning with some machine learning mechanisms such as the neural network and so on; the immune cell population is mapped to the parallel computer. When the foreign antigen is introduced into the body, the body is being protected by the immune system.

According to the cellular immunological mechanism, a large number of immune cells are circulating in some living organisms (Paul 1999). The lymphocytes are

primary immune cells in the immune response, and they have many characteristics such as specificity, diversity, memory, adaptive learning and so on. The lymphocytes can be divided into two types: T cells and B cells. The B cells produce antibodies to destroy the invading antigens, and the T cells promote or inhibit the immune responses of the B cells, as shown in fig. 2. In this fig. the immune response is made with the T cells and B cells, which can produce antibodies. When the immune system first encounters with a kind of antigen, only a small number of immune cells can recognize the peptides of the antigens. The immune cells, which are able to recognize the antigens, are activated to replicate themselves rapidly, and this procedure is called the clonal expansion.

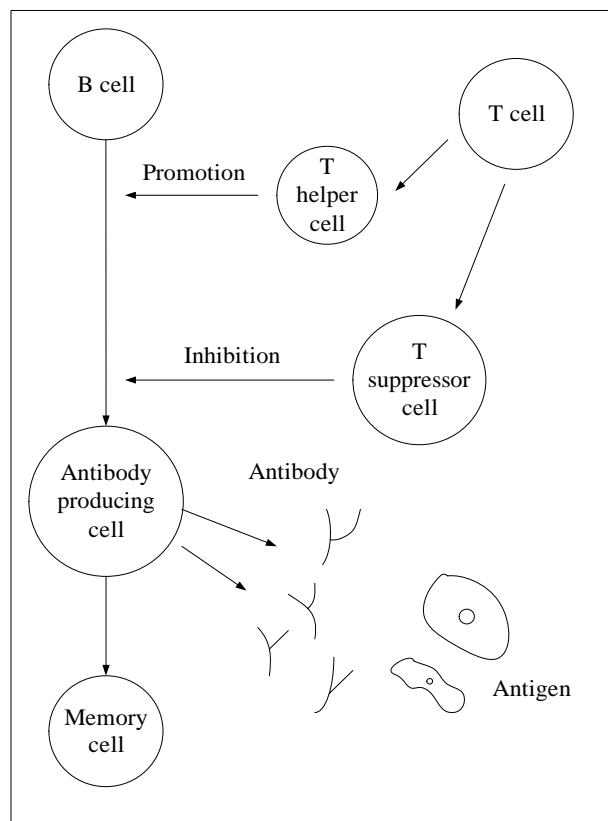


Fig. 2: Mechanism of the immune response.

The clonal expansion is accompanied with the hypermutation, which means, in the process of cell replication, the immune cells can have mutations to some extent. So the clone is able to recognize the antigens with an increasing success rate. Most clones are differentiated from the plasma cells in the action of molecules with interferon and cytokines. The plasma cells can produce the antibodies to eliminate the invading antigens, and this process is known as the primary response.

Design of embedded medical system based on visual immune computing model

The current devices of immune testing mainly include the luminescent immunoassay analyzer, the radio immuno-

assay analyzer, and the time-resolved fluorescent immunoassay analyzer etc. However, all these devices have the problem, i.e. only the current result can be seen and the result is not visual enough.

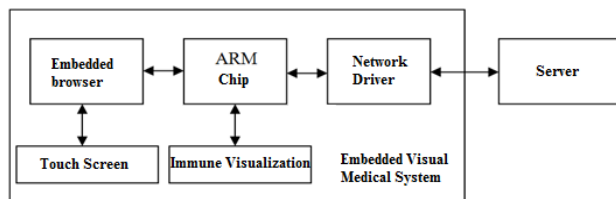


Fig. 3: Relationship between the server and the browsers in the embedded visual medical system.

Thus, a new device is required to show the visual state of the normal immune system, in order to compare the experimental results and verify the correctness of the experimental results. In this paper, the Browser/Server (B/S) is used as the structure of this embedded medical system, as shown in fig. 3. In this fig. the users can input the query command, and get the querying information by the ARM chip from the server. Then the results can be shown in a visual Java Applet at the browser of this embedded medical system. This is an interactive procedure, and this medical system is a dynamic system.

Visual simulation examples of immune system

To improve our understanding of the immune system, it is necessary to simulate some important states of this immune system with the 3D visualization. Before some viruses invade the normal body or the cells become cancers, the normal immune system of the body maintains a great balance with the normal immune response. At this time, though some dying cells are eliminated, some new cells are being generated to keep the functional balance of enough cells, as shown in fig. 4.

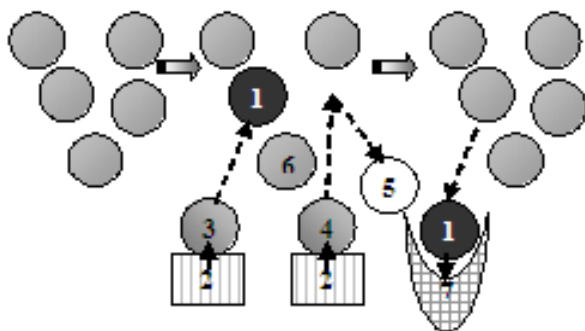


Fig. 4: Normal metabolism of the immune system before the virus infection and/or pathology mutation.

In this figure different immune cells and ordinary cells have different shapes and colors, which may represent different functions and states. This immune system detects the dying cells and the lost cells by checking the normal DNA network (called the normal model) of the

normal cells. The regenerating tissues of cells can recover the damaged body or the lost cells with new cells by adjusting the change of this body. In fig. 4, cell 1 denotes the dying cell; tissue 2 represents the regenerating tissue of cells; cell 3 denotes the new cell to fix the damaged body due to the dying cell (No. 1); cell 4 represents the new cell to make up the lost cell (No. 5) through the generation of regenerating tissue; cell 5 denotes the lost cell due to the physical loss; cell 6 represents the normal cell; cell 7 represents a macrophage.

In this immune system, the macrophage eliminates the trash of the dying cell (No. 1). In the body, the dead cell 1 is fixed with the new cell (No. 3) and the new cell takes the same role as the dying cell. After cell 5 is missing due to some reasons, the body is repaired for the lost cell (No. 5) with the new cell (No. 4), and the new cell is useful for keeping the normal state of this immune system. The regenerating tissues of cells use the nutrition, from the digestive system, blood and marrow, to make new cells to make the metabolism of the body running well.

When the body is infected by the viruses, some cells are actually infected by the viruses. Then the infected cells perhaps cannot make their normal functions and begin to infect more cells with the viruses. The immune system defends the body against the viruses. With the immune responses, the powerful immune system repairs the infected body, as shown in fig. 5.

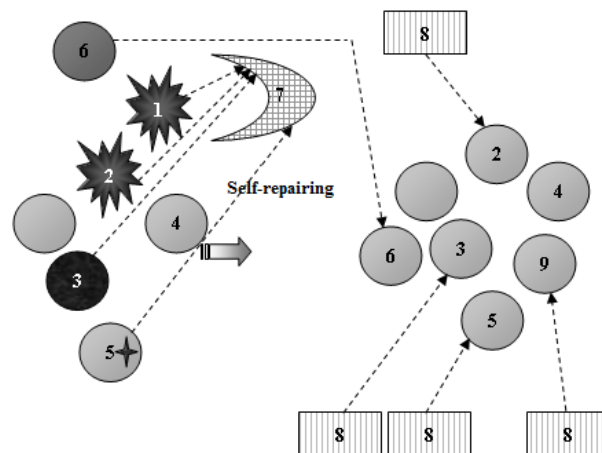


Fig. 5: Self-repairing of the immune system to protect the body.

In this fig. cell 1 denotes the virus; cell 2 denotes the cell that is infected by cell 1; cell 3 denotes the dying cell; cell 4 denotes the normal cell that is not infected by the virus; cell 5 denotes the abnormal cell, which has gene pathology; cell 6 denotes the self antigen that is a new self and becomes a normal cell of the body; cell 7 denotes a macrophage; tissue 8 denotes the regenerating tissue of cells; cell 9 represents the new cell, which is generated by the regenerating tissue (No. 8) to repair the lost cell.



Fig. 6: Visual 3D simulation of this immune system that is attacked by three antigens and protected by two antibodies.

After cell 2 is infected by virus 1, the cell (No. 2) becomes an infective cell and begins to spread the virus to another normal cell. This immune system recognizes the infected cell (No. 2) and repairs the infective cell (No. 2) with new cell from the regenerating tissue.

In order to simulate the tri-tier visual immune model, the examples of this immune system were designed. Suppose there are 100 immune cells in the examples of the immune system part, the Java Applet technology was used to visualize the simplified examples of this immune system, as shown in fig. 6. In this fig. the green balls represent the normal cells, which include immune cells and normal cells. The blue balls represent the antigens, and the red balls represent the antibodies. The antibodies are produced by the immune cells, and used to identify and eliminate the non-self antigens. The visual simulation results show that this tri-tier visual immune system has the properties of recognition, learning and memory (Paul, 1999). With the Java Applet technology, the scientists and the doctors can observe the 3D cells and molecules intuitively and dynamically in this immune system, using the visual simulation of this immune system, rather than the abstract mathematical formulas and limited imagination.

CONCLUSIONS

The visual model of this immune system not only can help the scientist and the doctors understand the human immune system more intuitively and profoundly, but also promote both the computational immunology.

So the visualization of the immune system model is becoming a new tool of investigating new medical systems and artificial immune systems. The visual computing model of the immune system and the medical system can be improved in the future and is important to understand difficult immunological diseases, phenomena and medical approaches more easily for much more people, including excellent immunologists, doctors, patients and normal persons. The visual computing model of this immune system in this paper is still only a logical guess, and need validation and enrichment through some

real immunological experiments. Thus, the immune system modeling is still a very difficult and complex work at present and in the future.

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