A Novel Immune Feedback Control Algorithm and Its Applications

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Abstract. This paper first analyzes the feedback principle of nature immune system and then the immune process is imitated by virtue of nonlinear molecular dynamics. Then the mathematic model of immune system is founded. The model implicates two important processes in immune system. One is that antibodies (Ab) and killer T cells (Tkill) rapidly respond to the change of the number of antigens (Ag). Another is that suppressor T cells (Tsup) inhibit and adjust the number of Ab and Tkill. The model manifests the good performance that immune system can respond to foreign materials rapidly and stabilize itself simultaneously. In this paper, foreign disturbances, input errors and measurement noises are regarded as Ag. The process in which creature presents immune response, produces antibodies and removes antigens is regarded as the control process of disturbances eliminating and differences adjusting. So, we designed a novel control algorithm based on immune feedback principle (IFC). The results of simulation show that the IFC algorithm can make the system respond quickly and get to steady state rapidly, and has good noise-proof feature. Its performance is superior to that of ordinary controllers. It also shows that the IFC algorithm suits for controlling the large time-delay system especially.

Keywords: immune; feedback; nonlinear; control algorithm

1 Natural Immune Feedback Principle

The natural immune feedback process is shown in figure 1. We view the process of antigen defending and removing by immune system as the main feedback process, and the process of balance restoration of the system by suppressor T cells as the inhibition feedback process. By interplay of main feedback and inhibition feedback, immune system can rapidly respond to foreign material and stabilize itself simultaneously.

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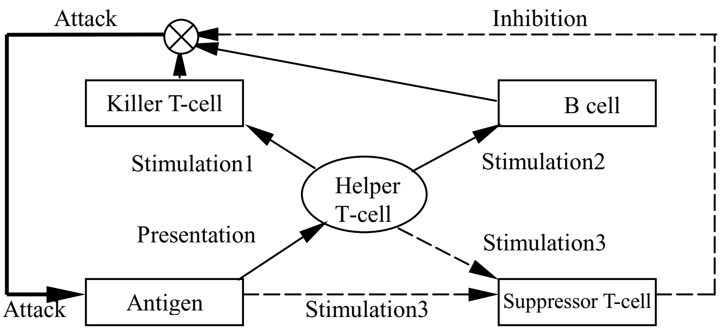

Fig. 1. Scheme of the whole immunity Circle

2 Modeling of Immune Process

Helper T cell :

$$\begin{cases} \dfrac{ds}{dt} = \sigma(Ag - s) \\ \dfrac{dT}{dt} = \alpha + (\dfrac{s}{1+T} - 1)T \end{cases} \tag{1}$$

Killer T cells:

$$T_{kill}(t) = k_c \cdot T(t) \tag{2}$$

B cell :

$$\begin{cases} \dfrac{dB}{dt} = k_1 - k_2 \cdot B \cdot T \cdot H(Ag; \theta_B) - d_1 \cdot B \\ \dfrac{dB_p}{dt} = k_2 \cdot B \cdot T \cdot H(Ag; \theta_B) - d_2 \cdot B_p \\ H(Ag; \theta_B) = \dfrac{Ag^2}{\theta_B{}^2 + Ag^2} \end{cases} \tag{3}$$

Antibody:

$$Ab(t) = k_B \cdot B_p(t) \tag{4}$$

Suppressor T:

$$T_{\sup}(t) = k_2 \begin{Bmatrix} [T_{kill}(t-d) + Ab(t-d)] \\ -[T_{kill}(t-d-1) + Ab(t-d-1)] \end{Bmatrix}^2 \cdot Ag(t) \tag{5}$$

The overall number of immune cells (attacking cells in figure 1) is

$$Attack(t) = T_{kill}(t) + Ab(t) - T_{\sup}(t) \tag{6}$$

Equation (6) describes the immune feedback principle, which is a function about Ag and t. If we regard Ag as input signal, equation (6) describes a nonlinear feedback control algorithm.

3 Conclusions

We apply the IFC algorithm to control a second-order large time delay plant and the outlet temperature of the heat exchange unit in the thermal station of centralized heating system. According to simulation results, we can draw the following conclusions:

1) The nonlinear modeling method from the viewpoint of molecular dynamics is feasible.
2) The feedback principle of nature immune system is able to be led into the domain of the control engineering. The IFC algorithm also ensures the real-time performance of the control system.
3) The immune feedback control algorithm can make the system respond rapidly and stabilize quickly, which is just like the nature immune system. It improves the swiftness and stabilization of the system simultaneously. The all-round property of the immune feedback controller is superior to that of the ordinary PID controller.
4) Moreover, the IFC algorithm possesses good noise-proof feature and robustness.