Chapter XIII
Research of Immune Controllers

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ABSTRACT

In engineering application, the characteristics of the control system are entirely determined by the system controller once the controlled object has been chosen. Improving the traditional controller or constructing the new controller is an unfading study field of control theory and application. The control system is greatly enriched and developed by this way. As a complicated self-adaptable system, the biological immune system can effectively and smoothly stand against antigens and viruses intruded into organism. It is possible to improve the self-learning, adaptive and robustness capability of the control system through embedded an artificial immune controller in control system. Based on the biological immune mechanism and artificial immune model, this chapter attempts to study the immune controller design and application in traditional control system. First, a kind of artificial immune controller is proposed based on the T-B cells immunity. The boundedness and the stability of SISO control systems, which constructed by the artificial immune controller, are proved by the little gain theorem. A general controller structure frame based on the T-B cells immunity is proposed, which includes the same kind of controller proposed previously. The validity of this artificial immune controller is verified by simulation. Second, a new type of artificial immune controllers is constructed according to a simple double-cell immune dynamics model. The non-error characteristic of SISO control systems, which constructed by the artificial immune controller, is proved by the nonlinear theory in this chapter. The I/O stability and no-error characteristic of the system are verified by simulations, which show that the kind of artificial immune system have good anti-lag capability. Third, the Varela immune network model has been improved based on which an artificial immune system is proposed. The odd linearization method of the non-linear system is used to prove the stability and non-error characteristic of the SISO system constructed by the artificial immune control system. Its I/O stability, non-error characteristic and strong anti-lag capability are also verified by simulation. Finally, based on the comparison of the three kinds of immune controllers, a general structure of the artificial immune controller is proposed. The further study on this field is indicated in this chapter lastly.
INTRODUCTION

In engineering application, once the controlled object and the measuring components have been determined, the performance of linear control systems will depend on controllers. For example, (1) One of the most important purpose of studying the theory of fuzzy control is to design fuzzy controller with better adaptability and robustness. (2) The major concern of neural network control is to get neural network controller, which is often composed of two neural networks, one playing the part of the traditional controller, the other dealing with real-time identification of the object model (3) In expert control system, the function of the its expert knowledge and the reasoning is used to adjust the parameters of the controllers, such as PID. Even with the widely used simple PID controller, there are also many people engaged in a wide variety of intelligent study. Thus, the study of the control system is centered on the controller.

Controller is designed to improve the quality of the control system, allowing the system to serve the required control purposes. Once the controlled object is chosen, the design of the controller is the key to guarantee the quality and property of the whole control system, so the design and analysis of the controller is the focus of the entire control field. Traditional controller design methods fall into two categories: one is the design method based on the classical control theory, including linear methods such as root-locus correction, frequency correction, PID regulation as well as non-linear methods such as phase plane and description function; another category is the design methods based on modern control theory, including state-feedback controller, adaptive correction controller, variable structure controller, controller based on H or Lyapunov stability theory and so on. Although the controller design and implementation are based on a series of relatively complete and thorough theoretical approach, there are still shortcomings to overcome, for example, the restrictions on the controlled object are rather rigid and the object model is required to be linear.

Biological immune system can handle the disturbance and uncertainty in human body easily. If an artificial immune controller can be embedded in the control system, the system will undoubtedly possess such intelligence characteristics as self-learning, adaptive, robust and so on. This chapter will study the immune controller design and application in traditional control system based on the biological immune mechanism and artificial immune model.

BACKGROUND

In real applications, once the controlled object and the measuring components have been determined, the performance of linear control systems will depend on controllers. Therefore, designing and constructing new types of controllers or improving traditional controllers have been being a fascinating topic in the theory of control systems. For instance, one of the important applications of fuzzy control theory is to design and construct controllers which have great adaptability and robustness(Jingzhen & Zengji, 1997), so is the neural network (Dongqiang & Yaqing, 2001) and expert system. Even the widely used PID controllers are also studied by many individuals to make it more intelligent. The study and application of intelligent controllers has extraordinarily enriched and developed the theory of control systems.

Intelligent controllers fall into four levels according to the designing complexity: simple robust feedback control, parameter adaptive control based on error criterion, adaptive control based on optimization of objective function and adaptive control based on global optimization of objective function varied with environment conditions. Corresponding with these, biologic immune system fall into four similar levels: firstly, the innate immune system is corresponding to robust feedback control; secondly, T cells stimulate B cells to resist antigens; thirdly, microphages present antigens to T cells and activate B cells; lastly, microphages have some changes against certain antigens. Studies have found that biologic immune system has a series of excellent control characteristics, such as adaptability, distributed control and coordination, dynamic, robust, self-organization, self-learning etc. So a further study of immune system on its mechanism and strategies will provide some ideas for constructing advanced intelligent controllers.

Immune mechanism has been introduced into the research field of control systems for many years. One example is the immune algorithm proposed by Ishida(Watanabe et al., 2004) based on the agent structure to suppress
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