Bio-inspired Event-based Game Theoretical Control for Complex Systems

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***Short Abstract* — This paper proposes a bio-inspired game theoretical control for complex systems. The proposed control is triggered by event-based perception at the global level. In addition, it uses a game theoretical formulation, inspired by the observation that the feedforward control loops used by the immune system are analogous to games wherein the immune system chooses the optimal strategy for defense against an invading pathogen. Multiple inner-loop game theoretical feedbacks are implemented for local stability.**

***Keywords* — Feedback, feedforward, event-based control, bio-inspired control, game theory.**

I. INTRODUCTION

CONTROLING complex systems are extremely challenging. In the past, typical control strategies applied to control engineering systems have been mainly based on feedback control. Frequently, however, measurements for complex systems are insufficient and associated with large delay, which makes feedback control impossible. In addition, for complex systems, feedback control is often difficult to implement on a global level, where local unexpected events can dramatically change the stability of the overall system. Feedforward control presents a possible solution to these difficulties. Feedforward control, however, is usually hampered by issues of robustness. Interestingly, the immune system offers a good example wherein feedforward control is implemented with a high degree of robustness, despite large-scale unexpected events and high levels of noises. In fact, strong performance of the immune system can be maintained not only in the presence of random perturbations, but also, in the context of agents that actively subvert or destabilize immune control. In other words, stabilization of the immune system is designed to be maintained even in a 'worst case scenario'. The proposed control attempts to advance the state of modern control theory through innovation inspired from the immune system.

II. BIOINSPIRED CONTROL

Figure 1 shows a control diagram for the adaptive immune system. Dendritic cells recognize pathogen antigen and stimulate naïve TH cells to differentiate into specific TH cell types. The particular cytokine milieu that results following helper T-cell (TH) cell differentiation and cytokine secretion effectively determines the broad category of pathogen that the immune response will target. The population wide cytokine secretion acts as a global-level distributed decision-making process. Local-level feedback control through cell-pathogen interactions stabilizes the immune response, optimally targeting pathogens while preventing overreaction. **Figure 2** shows the proposed control framework. When disturbances are introduced into the complex system, the disturbances can both directly influence individual sub-systems and generate events for the event-based global game theoretical control. When the disturbances generate events, these events are used by the global feedforward control to direct a change in the 'on/off' status of the different feedback control sub-systems which then operate according to a local subsystem level game theoretical control scheme. The control player wants to optimally distribute the controls to minimize the cost function, while the disturbance player wants to optimally distribute the disturbances to maximize the cost function. To

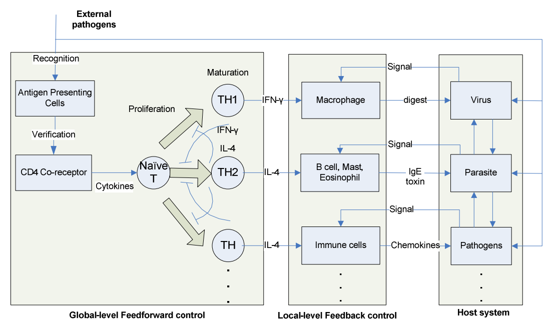

Figure 1 Control diagram for the adaptive immune system

convert the output control from this global game solution into an input at the local level. We formulate this switch as a multi-stable system inspired by the TH cell differentiation mechanism. The net result of this conversion step is that at each instant, the necessary feedback control subsystems will be turned on due to multi-stability. When a particular feedback control subsystem is turned on, this further activates the corresponding local feedback control. In summary, the global-level feedforward control gives a unique sequence of activation periods for the different local feedback controls, which then find optimal solutions within their respective activation periods.

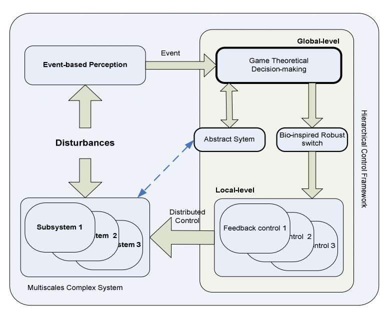

Figure 2 The bio-inspired control

III. CONCLUSION

Potential applications of the proposed control include micro/nano-scale engineered device control, cellular and molecular system regulation.

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