Abstract

This thesis describes an approach to the modeling and analysis of multi-agent populations composed by a large number of agents. The work is motivated by a systems theory approach to the modeling of a biological population of T-Cells. The dynamics of each individual cell is modeled by a deterministic Hybrid Automaton endowed with input events and continuous-valued outputs. The complex interaction among the population cells is modeled by stochastic events. This leads to a Stochastic Hybrid Automaton model, which results from inputting a stochastic event sequence to the individual cell model. The micro dynamics of each individual cell and the observed macro dynamics of the whole population are linked by the application of a statistical physics reasoning to the complete model, through a system of partial differential equations describing the time evolution of a Stochastic Hybrid Automaton state probability density function. The T-Cell receptors triggering dynamics of the T-Cells population interacting with the population of antigen presenting cells is analyzed. The approach provides biologists with analytical tools to pose hypothesis about the individual T-Cell receptors dynamics and gain insight on how to interpret the biological experiments data. The T-Cell receptors distribution predictions based on biologically meaningful hypothesis are compared against the T-Cell receptors distribution data collected in biological experiments with the T-Cell population.

A similar approach can be applied to Robotics, more specifically to the modeling and control of large robotic populations. A scenario concerning the mission control of a robotic population is introduced and the corresponding Stochastic Hybrid Automaton model of the robotic population is presented. Under a stochastic control model, the robotic population can develop different shapes regarding the probability density function of the area occupied by the population robots. The optimal control problem of taking the population to a desired location with maximal probability within a given time instant is introduced. To solve this problem, the application of the Minimum Principle for the optimal control of partial differential equations is discussed.