Chapter IX

Formal Modelling of the Dynamic Behaviour of Biology-Inspired, Agent-Based Systems

Petros Kefalas, CITY College, Thessaloniki, Greece

George Eleftherakis, CITY College, Thessaloniki, Greece

Mike Holcombe, University of Sheffield, United Kingdom

Ioanna Stamatopoulou, South-East European Research Centre, Thessaloniki, Greece

ABSTRACT

Multi-agent systems are highly dynamic since the agents' abilities and the system configuration often changes over time. In some ways, such multi-agent systems seem to behave like biological processes; new agents appear in the system, some others cease to exist, and communication between agents changes. One of the challenges is to attempt to formally model the dynamic configuration of multi-agent systems. Towards this aim, we present a formal method, namely X-machines, that can be used to *formally specify, verify, and test individual agents. In addition, communicating X-machines provide a mechanism for allowing agents to communicate messages to each other. We utilize concepts from biological processes in order to identify and define a set of operations that are able to reconfigure a multi-agent system. In this chapter we present an example in which a biology-inspired system is incrementally built in order to meet our objective.*

INTRODUCTION

An *agent* is an encapsulated computer system that is situated in some environment and is capable of flexible, autonomous action in that environment in order to meet its design objectives (Jennings, 2000). The extreme complexity of agent systems is due to substantial differences in attributes between their components, high computational power required for the processes within these components, huge volume of data manipulated by these processes, and the possibly extensive amount of communication needed to achieve coordination and collaboration. The use of a computational framework that is capable of modelling both the dynamic aspect (i.e., the continuous change of agents' states together with their communication) and the static aspect (i.e., the amount of knowledge and information available) will facilitate modelling and simulation of such complex systems.

The multi-agent paradigm can be further extended to include biology-inspired systems. Many biological processes seem to behave like multi-agent systems, as, for example, a colony of ants or bees, a flock of birds, or tissue cells (Dorigo et al., 1996). The vast majority of computational biological models are based on an assumed, fixed system structure that is not realistic. The concept of growth, division, and differentiation of individual components (agents) and the communication between them should be addressed to create a complete biological system that is based on rules that are linked to the underlying biological mechanisms allowing the dynamic evolution.

For example, consider the case of a tissue, which consists of a number of cells. Each cell has its own evolution rules that allow it to grow, reproduce, and die over time or under other specific circumstances. The cells are arranged in a two- or three-dimensional space, and this layout dictates the way cells interact with others in the local neighbourhood. The rules of communication and exchange of messages are dependent on the particular system. Being a dynamic system, the structure of the tissue — that is, the configuration of cells and