Quantitative Reaction Systems*

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Natural computing is a research area that investigates both human designed computing inspired by nature and computing taking place in nature [4, 3]. The former research strand examines models and computational techniques inspired by nature, the latter examines, in terms of information processing, phenomena taking place in nature [4, 3].

Examples of the first strand of research include evolutionary computation with paradigms inspired by Darwinian evolution of spices, neural computation with paradigms inspired by the functioning of the brain, quantum computation with paradigms inspired by quantum mechanics, and molecular computation with paradigms inspired by molecular biology [4, 3].

Examples of the second strand of research are investigations into the computational nature of self-assembly, the computational nature of developmental processes, the computational nature of brain processes, the systems biology approach to bio-networks where cellular processes are investigated in terms of communication and interaction, and the computational nature of biochemical reactions [4, 3]. The second strand of research highlights the fact that computer science is the central science of information processing as well, and as such a basic science for other scientific disciplines such as biology [4, 3].

This research is focusing on the formal frameworks for the investigation of the functioning of the living cell. It belongs to the second strand of research, as it looks at the functioning of the living cell in terms of formal processes resulting from interactions between biochemical reactions occurring in it. This study considers that these interactions are caused by two mechanisms: facilitation and inhibition – the reactions may facilitate or inhibit each other.

A reaction model is based on principles notably different from those underlying other models of computation in computer science [4, 3, 5, 2]. The fundamental idea of this framework is that the functioning of a living cell is based on interactions between individual reactions [4, 3, 5, 2]. These interactions determine the dynamic processes taking place in living cells, and *reaction systems* are an abstract model of these processes [4, 3, 5, 2].

Typical examples of reaction systems in practice would be analysing user and adversary behaviours in the organizations; analysing data security and privacy in dynamic environments; a hardware system which suffers component breakdowns and reconfiguration; a distributed system whose software is continually updated. Such diverse event-based systems all suffer from a very high dynamic

behaviour due to the intricate dependencies in the representation of the state information, and dynamic system reconfiguration.

There exists some key methods to analyse the reaction systems: In [2], the authors investigated which entities in the system are actually relevant from the point of view of generating dynamic processes through such state transformations. In [5], the authors proposed Petri nets could be used to provide faithful semantics of reaction systems, because Petri nets are a general and well-established model of concurrent and distributed computation and behaviour, including that taking place in biological system. In [1], the probabilistic behaviour of reaction systems is considered. The authors represent sets of reactions by trees, they obtain a useful tool to investigate the state spaces of reaction systems. This study only can be treated as an initial step, and we will consider the extension and application of this studies.

In our study, we consider the number of molecules of reaction systems which allowing for quantitative modelling, and we investigate the interactive processes in the reaction system. Functions and algorithms are introduced to analyse the basic properties of such system.

Our work is inspired by Professor Grzegorz Rozenberg who delivered a workshop on reaction systems when we were post-doctorial research associates in Newcastle University. We would like to thank Professor Maciej Koutny for his vision, insight and detailed explanations about the entities in the system.

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