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Modelling simple biological switching systems using fuzzy logic and extended Petri nets

ABSTRACT

Modelling and simulation have become indispensable in the design of novel and analysis of existing biological systems. Using various approaches, they can significantly reduce the time and cost of planning and executing laboratory experiments. The choice of modelling technique depends on the desired accuracy of simulation results and the available kinetic data of the system. Qualitative approaches can be used to describe basic dynamical properties and topology of the underlying network. On the other hand, quantitative approaches are used for detailed modeling of system's dynamics. However, exact kinetic data that are required to obtain simulation results using state-of-the-art quantitative methods are often missing and are hard or even impossible to obtain. Both qualitative and quantitative approaches can be graphically represented as Petri nets, which serve as a powerful framework for constructing a biological system model. In this dissertation we present a quantitative fuzzy logic modelling approach that is able to cope with unknown kinetic data by using expert knowledge to model process descriptions and can thus produce quantitatively relevant simulation results even when kinetic data are incomplete or only vaguely defined. In addition, we extend the continuous Petri net definition and introduce fuzzy firing rate functions. Moreover, the approach can be used in the combination with the existing quantitative modelling techniques only in certain parts of the system, i.e. where kinetic data are missing. We use the fuzzy logic based approach to construct a model of a hypothetical three-gene repressilator and fuzzy continuous Petri nets for constructing a *Neurospora* circadian rhythm model. Simulation results obtained with fuzzy approach show that using fuzzy logic for describing processes with unknown kinetic does not significantly affect the quantitative aspects of the model.

Key words: modelling biological systems, unknown kinetic rates, fuzzy logic, Petri nets