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Computer structures perspective on switching dynamics of simple biological systems

ABSTRACT

Synthetic biology is a rapidly evolving discipline that copes with the modifications of existent and with the construction of new biological systems with novel functionalities. Its interdisciplinarity arises from combining of engineering and biological sciences. Biological computing is a relatively new research field that is analysing the possibilities in constructing a biological computer. Synthetic biology approaches can also be used in order to build biological computer. Certain levels of abstraction, i.e.with the introduction of models which can be used in order to simulate the dynamics of such biological systems, gives an opportunity to the scientists from different disciplines, such as computer science, to perform in-depth researches on these fields.

Large number of biological systems that are capable of data processing, such as combinatorial logical gates, oscillators and flip-flops, have already been realized with the synthetic biology approaches in the last years. Even more, many models that can be used for simulating the dynamics of such systems already exist. In order to construct more complex biological systems with the data processing capabilities analysis of their *switching dynamics* has to be made. The main weakness in constructing more complex circuits in such manners is in our opinion in the absence of metrics that would estimate the information processing capabilities of basic primitives and possibilities of building more complex systems with their interconnectivity. With the introduction of such metrics the characterization of such systems could be made more straightforwardly and objectively. Construction of more complex biological systems with the data processing capabilities and consequently constructing a biological computer would become a possible task to perform.

We present the basics of construction of biological systems based on gene regulatory networks. We present the basic approaches in modeling of such systems and demonstrate

them with few example models of simple biological systems with data processing capabilities. Based on the results of simulated switching dynamics metrics are establish. Metrics are established regarding the characteristics which are used to describe electronic digital systems and regarding the mathematical field of nonlinear dynamical systems. Evaluation of metrics is demonstrated on simulation results of examples presented before. Metrics are also used in order to evaluate the interconnectivity of presented primitives and to modularly connect these primitives in a more complex biological system with data processing capabilities. Based on the results advantages and disadvantages of processing in such systems are discussed which have to be considered when choosing their target applications.

Synthetic biology is a rapidly evolving area that combines knowledge from different fields and is aimed toward the realization of novel biological systems with predefined functionalities. Synthetic biology methods can also be used in order to construct biological systems with the data processing capabilities.

Biological systems that present basic primitives for data procesing such as *logic gates*, *oscillators* or *flip-flops* have already been constructed. Models that can be used in order to simulate their dynamics have also been realized. The main weakness in constructing more complex circuits in such manners is in our opinion in the absence of metrics that would estimate the data processing capabilities of basic primitives and possibilities of building more complex systems with their interconnectivity. With the introduction of such metrics complex biological systems capable of data processing could be built more straightforwardly which would lead us to the construction of biological computer.

Key words: biological computing, switching dynamics, modeling of biological systems, unconventional computing, synthetic biology, gene regulatory networks, metrics.