Univerzita Komenského v Bratislave

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Introduction

There are a lot of areas in the theoretical computer science that are motivated by other science fields. Computation models motivated by biology forms a large group of them. They include neural networks, computational models based on DNA evolutionary algorithms, which have already found their use in computer science and proved that it is worth to be inspired by biology. L-systems are specialized for describing the growth of plants, but they have also found the applications in computer graphics, especially in fractal geometry.

Other emerging areas are still awaiting for their more significant uses. One of them is the membrane computing. It is relatively young field of natural computing - in comparison: neural networks have been researched since 1943 and membrane systems since 1998. Membrane systems (P systems) are distributed parallel computing devices inspired by the structure and functionality of cells. Recently, many P system variants have been developed in order to simulate the cells more realistically or just to improve the computational power.

P systems

Nature computes not only at the neural or genetic level, but also at the cellular level. In general, any non-trivial biological system has a hierarchical structure where objects and information flows between regions, what can be interpreted as a computation process.

The regions are typically delimited by various types of membranes at different levels from cell membranes, through skin membrane to virtual membranes which delimits different parts of an ecosystem. This hierarchical system can be seen in other field such as distributed computing, where again well delimited computing units coexist and are hierarchically arranged in complex systems from single processors to the internet. Membranes keep together certain chemicals or information and selectively determines which of them may pass through.

From these observations, Păun introduces the notion of a membrane structure as a mathematical representation of hierarchical architectures composed of membranes. It is usually represented as a Venn diagram with all the considered sets being subsets of a unique set and not allowed to be intersected. Every two sets are either one the subset of the other, or disjoint. Outermost membrane (also called skin membrane) delimits the finite “inside” and the infinite “outside”.

Results

We have studied several variants of sequential P systems in order to obtain universality without using maximal parallelism. A variant with rewriting rules that can use inhibitors was shown to be universal in both generating and accepting case. The generating model is able to simulate maximal parallel P system and the accepting model can simulate a register machine. The constructive proof for the generating case is valuable not only for the universality, but also can be seen as a method of conversion between P systems in sequential manner and maximally parallel manner, which may be essential for future works on P systems and other multiset rewriting systems. Sequential variants are promising alternative to traditional maximal parallel variants and will be good subject for the further research. Future plans include research of other more restricted variants such as omitting cooperation in the rules or restricting the power of inhibitors.

In addition, we have defined a new variants of zero-testing, aiming to fit in layers between mere reformulations of the basic sequential P system and universal sequential P systems with inhibitors. These include various forms of detection of empty membranes, which is specific for membrane systems. As for now, the work is currently in progress, and the results obtained so far have been just the computational completeness. However, one variant with objects avoiding empty regions is more promising for our goal because the standard contruction of register machine do not work. We conjecture this variant is not universal, possibly equivalent with Petri nets.

There are many features not yet combined, so we suggest them for the fur ther research (non-cooperative rules, rules with priorities, decaying objects, deterministic steps, ...).

Aside from the research of the computational power, there are many open problems in the area of decision problems of certain properties. Interesting ideas for future work can be taken from Bottoni et. al. as they define an abstract notion of negative application conditions for general rewriting systems, which is for multiset rewriting rendered as usage of inhibitors. Although they considered only nondeleting rules (after application of each rule the resulting multiset is a superset of the current multiset), interesting results was shown that the termination of rewriting was shown to be decidable.

We have investigated the decidability problems of existence of (in)finite computation for a universal class of P systems with active membranes. We have shown and published our results that are on both sides of the decidability barrier. Regarding the open problem stated in about sequential active P systems with hard membranes (without communication between membranes), it could be interesting to find a connection between the universality

and decidability of these termination problems.

We research sequential P systems with active membranes also in combination with notions inspired by reaction systems, i.e. using sets instead of multisets and the assumption of non-permanency of objects. There are no results yet in this area and our proposals could be set as a single topic for the future study.

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