Available online at www.sciencedirect.com
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Electronic Notes in Theoretical Computer Science 156 (2006) 57–78
Electronic Notes in Theoretical Computer Science
www.elsevier.com/locate/entcs

Operational Semantics and Rewriting Logic in Membrane Computing

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Abstract

The existing results in membrane computing refer mainly to the P systems characterization of Turing computability, and to some polynomial solutions to NP-complete problems by using an exponential workspace created in a "biological way". In this paper we define an operational semantics of these P systems, and give a translation of the operational semantics into rewriting logic. We present some results regarding this translation, including an operational correspondence, and discuss why such a translation is relevant in order to take advantage of good features of both structural operational semantics and rewriting logic.

Keywords: P systems, operational semantics, rewriting logic, Maude.

1 Membrane Systems

Membrane systems represent a new abstract model of parallel and distributed computing inspired by cell compartments and molecular membranes [7]. A

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doi:10.1016/j.entcs.2005.10.028

cell is divided in various compartments, each compartment with a different task, and all of them working simultaneously to accomplish a more general task of the whole system. The membranes of a P system determine regions where objects and evolution rules can be placed. The objects evolve according to the rules associated with each region, and the regions cooperate in order to maintain the proper behaviour of the whole system. P systems provide a nice abstraction for parallel systems, and a suitable framework for distributed and parallel algorithms [4]. It is desirable to find more connections with various fields of computer science, including implementations and executable specifications. From the programming point of view, a programming language inspired of the membrane systems does not exist yet. There exist some simulators, both sequential and parallel. A flexible Web-based simulator is available at http://psystems.ieat.ro. It does not require any previous knowledge of P systems, or expertise in computers.

A detailed description of the P systems can be found in [7]. A *P system* consists of several membranes that do not intersect, and a *skin membrane*, surrounding them all. The membranes delimit *regions*, and contain multisets of *objects*, as well as *evolution rules*. Only rules in a region delimited by a membrane act on the objects in that region. Moreover, the rules must contain target indications, specifying the membrane where objects are sent after applying the rule. The objects can pass through membranes, in two directions: they can be sent *out* of the membrane which delimits a region from outside, or can be sent *in* one of the membranes which delimit a region from inside, precisely identified by its label. The membranes can be *dissolved*; this action is important when discussing about adaptive executions. When such an action takes place, all the objects of the dissolved membrane remain free in the membrane placed immediately outside, but the evolution rules of the dissolved membranes are lost. The skin membrane is never dissolved. The application of evolution rules is done in parallel, and it is eventually regulated by *priority* relationships between rules.

A P system has a certain structure represented by a tree (with the skin as its root), or by a string of correctly matching parentheses, placed in a unique pair of matching parentheses; each pair of matching parentheses corresponds to a membrane. Graphically, a membrane structure is represented by a Venn diagram in which two sets can be either disjoint, or one the subset of the other. The membranes are labelled in a one-to-one manner. A membrane without any other membrane inside is said to be *elementary*. The space outside the skin membrane is called the *outer region*.

Formally, a *P system* is a structure $\Pi = (O, \mu, w_1, \ldots, w_m, (R_1, \rho_1), \ldots, (R_m, \rho_m), i_o)$, where: