Simulating a Class of Parallel Architectures: A Broader Perspective

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Summary. The purpose of this paper is twofold. On one hand we introduce the concept of *P system with dynamic communication graphs* in its full generality, independent of applications. On the other hand we illustrate one application of it to the simulation of a *class of parallel architectures.* In this last direction we extend (generalize) previous work concerned with the simulation of particular architectures. The more general framework proposed here is a good starting point also for considerations of costs and complexity aspects.

1 Introduction

Introduced in [7], P systems are powerful computational devices, with a high degree of parallelism, whose functioning is inspired by biological processes at the level of the cells, and of their membranes ([7],[8]). Among these processes, communication plays an important role (see [6]).

Several variants of the initial concept have been very proposed, and studied. (Beyond [8], see [11] for extensive bibliography and new results.) We mention here: (1) *tissue-like P systems*, a notion which allows more generality by replacing the initial *tree*-like dependence structure between membranes by a *graph*-like dependence structure; (2) P systems *with symport/antiport* (see [6]), in which new types of rules, the symport and antiport rules, inspired from biological phenomena, are responsible for communicating data between regions; (3) *dynamic P systems*, (see [1]) P systems which have, besides the "internal" evolution from one configuration to another, an external evolution mechanism which acts on the structure. These are by no means the only variants proposed or used in the literature, but our present proposition extends in a way all these three notions.

The notion of *P system with dynamic communication graphs* has developped gradually in a series of papers [2], [3], [4], devoted to the simulation of certain parallel architectures. The notion is presented here in its full generality. It can be considered a dynamic tissue-like P system, thus combining features (1) and (3) above, to which an extra ingredient is added: the fact that the rules are in this model attached to *edges* between membrane regions, and not to regions themselves. This allows that object evolution or string rewriting rules, generally attached to regions, to be treated in the same way as symport/antiport rules (again traditionally attached to regions) but whose meaning relates to "between regions" relations.

Another direction from which the present research stems from, is that of comparing the biologically inspired computational devices with classical computational models and technologies. The research in [2], [3], [4] belongs to this area too. Simulating one computational device via another brings new insights into comparing the two types. In [2], [3], [4] simulations of two particular parallel models of computation – the shuffle-exchange and the 2D-mesh one – with P systems with dynamic communication graphs are proposed. In particular, simulating the specific algorithms for solving the reduction problem, is a common point of these previous researches.

In the present paper we focus on a *class* of parallel architectures. We refer to SIMD (Single Instruction Multiple Data) models of computation, with fixed number of processors, and communication of data among processors according to fixed network patterns. We propose a coherent manner of simulating any SIMD-X architecture, and furthermore, any particular algorithm Y in a given SIMD-X architecture, with P systems with dynamic communication graphs.

The paper has the following structure. In Section 2 we introduce the notion of P systems with dynamic communication graphs. In Section 3 we present, following closely [9], five major network organizations for processors. The presentation is made for some of them in terms of virtual communication graphs, which will be used in the subsequent formalism. Section 4 presents the SIMD (Single Instruction Multiple Data) model of computation, based on fixed number of processors and given network structure. We also introduce here some useful notation. In Section 4 we give the general guidelines for constructing a simulation of any SIMD-X machine in terms of P systems with dynamic communication graphs. The result is given in terms of a metatheorem. Previous results of [2], [3], and respectively [4], are particular cases of this general result. In Section 5 we make one step further, by considering particular algorithms Y implemented on a SIMD-X machine, and a coherent way of obtaining simulations of them in terms of P systems with dynamic communication graphs is given by a metatheorem. Section 6 is devoted to the discussion of some complexity aspects. In Section 7 we draw some conclusions of our work, and outline some open problems.

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