

Chapter 6

Simulating Spiking Neural P Systems Without Delays Using GPUs

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ABSTRACT

In this paper, the authors discuss the simulation of a P system variant known as Spiking Neural P systems (SNP systems), using Graphics Processing Units (GPUs). GPUs are well suited for highly parallel computations because of their intentional and massively parallel architecture. General purpose GPU computing has seen the use of GPUs for computationally intensive applications, not just in graphics and video processing. P systems, including SNP systems, are maximally parallel computing models taking inspiration from the functioning and dynamics of a living cell. In particular, SNP systems take inspiration from a type of cell known as a neuron. The nature of SNP systems allowed for their representation as matrices, which is an elegant step toward their simulation on GPUs. In this paper, the simulation algorithms, design considerations, and implementation are presented. Finally, simulation results, observations, and analyses using a simple but non-trivial SNP system as an example are discussed, including recommendations for future work.

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1. INTRODUCTION

The trend for massively parallel computation is moving from the more common multi-core CPUs towards GPUs for several significant reasons (Kirk, 2010; NVIDIA Corporation, 2010; Top 500, 2011). One important reason for such a trend includes the fraction of the power consumption of GPUs compared to the set-up and infrastructure in CPU clusters in order to obtain a comparable level of performance (NVIDIA CUDA Developers, 2011). Another important reason is that GPUs are architected for *massively parallel computations* since unlike most general purpose multicore CPUs, a large part of the architecture of GPUs are devoted to parallel execution of arithmetic operations, and not on control and caching like in the CPUs (Kirk, 2010; NVIDIA Corporation, 2010; Garland et al., 2008). GPUs are currently the leading devices in high-throughput and super-computing architectures (Garland & Kirk, 2010). Arithmetic operations are at the heart of many basic operations as well as scientific computations, and these are performed with larger speedups when done in parallel as compared to performing them sequentially. In order to perform these arithmetic operations on the GPU, there is a set of techniques called *GPGPU* (General Purpose computations on the GPU) which allow programmers to do computations on GPUs and not be limited to just graphics and video processing only (Harris, 2005).

P systems, under *Membrane computing*, are Turing complete (for several P system variants) computing models that perform computations non-deterministically, exhausting all possible computations at any given time (Chen et al., 2008). This type of unconventional model of computation was introduced by Gheorghe Păun in 1998 and takes inspiration and abstraction, similar to other members of *Natural computing* (e.g., DNA/molecular computing, neural networks, quantum computing), from nature (Păun, Ciobanu, & Pérez-Jiménez, 2006; P Systems,

2011; Păun, 2000). Specifically, P systems try to mimic the constitution and dynamics of the living cell in information processing: the multitude of elements inside it, and their interactions within themselves and their environment, or outside the cell's *skin* (the cell's outermost membrane). Before proceeding, we clarify what is meant by saying nature *computes*: computation in this case involves reading information from memory from past or present stimuli, then rewrite and retrieve this data as stimuli from the environment, process the gathered data and act accordingly due to this processing (Gross, 1998).

SNP systems differ from other types of P systems precisely because they are *mono-membranar* and the working alphabet contains only *one object type*. These characteristics, among others, are meant to capture the workings of a special type of cell known as the *neuron*. Neurons, such as those in the human brain, communicate or 'compute' by sending indistinct signals more commonly known as action potential or *spikes* (Ionescu, Păun, & Yokomori, 2006)

It has been shown that SNP systems, given their nature can be represented by matrices (Zeng, Adorna, Martínez-del-Amor, & Pan, 2010; Zeng, Adorna, Martínez-del-Amor, Pan, & Pérez-Jiménez, 2011). This representation allowed the design and implementation of an SNP system simulator using parallel devices such as GPUs.

Since the time P systems were presented, many simulators and software applications have been produced (Díaz, Graciani, Gutiérrez-Naranjo, Pérez-Hurtado, & Pérez-Jiménez, 2010). In terms of *High Performance Computing*, many P system simulators have also been designed for clusters of computers (Ciobanu & Wenyan, 2004), for reconfigurable hardware as in Field-programmable Gate Arrays or FPGAs (Nguyen, Kearney, & Gioiosa, 2010b, 2010a), and even for GPUs (Cecilia et al., 2010b, 2010a). All of these efforts have shown that parallel architectures are well-suited in performance to simulate P systems.

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