Chapter 12

Implementation on CUDA of the Smoothing Problem with Tissue-Like P Systems

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ABSTRACT

Smoothing is often used in Digital Imagery for improving the quality of an image by reducing its level of noise. This paper presents a parallel implementation of an algorithm for smoothing 2D images in the framework of Membrane Computing. The chosen formal framework has been tissue-like P systems. The algorithm has been implemented by using a novel device architecture called CUDA (Compute Unified Device Architecture) which allows the parallel NVIDIA Graphics Processors Units (GPUs) to solve many complex computational problems. Some examples are presented and compared; research lines for the future are also discussed.

1. INTRODUCTION

The study of digital images (Shapiro & Stockman, 2001) has seen a large progress over the last decades. The aim of dealing with an image in its digital form is improving its quality, in some sense, or simply achieving some artistic effect. The physical properties of camera technology are inherently linked to different sources of noise, so the application of a smoothing algorithm is necessary for reducing such noise within an image.

In this paper we use Membrane Computing techniques for smoothing 2D images with tissue-like P systems. We refer to Păun (2002) for basic information in this area and to Păun, Rozenberg, and Salomaa (2010) for a comprehensive presentation and the web site http://ppage.psystems.eu for the up-to-date information. The algorithm has been implemented by using a novel device architecture called CUDA (Compute Unified Device Architecture, http://www.nvidia.com/object/cudahomenew.html). CUDA is a general purpose

DOI: 10.4018/978-1-4666-4253-9.ch012

parallel computing architecture that allows the parallel NVIDIA Graphics Processors Units (GPUs) to solve many complex computational problems (for a good overview, the reader can refer to Owens et al., 2008) in a more efficient way than on a CPU. This architecture has been previously used in Membrane Computing (Cecilia et al., 2010a, 2010b) but, to the best of our knowledge, this is the first time that it is used for implementing a smoothing algorithm.

Dealing with Digital Images has several features which make it suitable for techniques inspired by nature. One of them is that it can be parallelized and locally solved. Regardless how large the picture is, the smoothing process can be performed in parallel in different local areas. Another interesting feature is that the basic necessary information can be easily encoded by bio-inspired representations. In the literature, one can find several attempts for bridging problems from Digital Imagery with Natural Computing as the works by Ceterchi et al. (2003) and Ceterchi, Mutyam, Păun, and Subramanian (2003) or the work by Chao and Nakayama where Natural Computing and Algebraic Topology are linked by using Neural Networks (Chao & Nakayama, 1996). Recently, new approaches have been presented in the framework of Membrane Computing (Christinal, Díaz-Pernil, Gutiérrez-Naranjo, & Pérez-Jiménez, 2010; Díaz-Pernil, Gutiérrez-Naranjo, Molina-Abril, & Real, 2010). Christinal, Díaz-Pernil, and Real (2009a, 2009b, 2010) started a new bio-inspired research line where the power and efficiency of tissue-like P systems were applied to topological processes for 2D and 3D digital images.

The paper is organised as follows: Firstly, we recall some basics of tissue-like P systems and the foundations of Digital Imagery. Next we present our P systems family and a simple example showing different results by using different thresholds. In Section 3 we present the implementation in CUDA of the algorithm and show an illustrative example, including a comparison of the times obtained in the different variants. The paper finishes with some final remarks and hints for future work.

2. PRELIMINARIES

In this section we provide some basics on the used P system model, tissue-like P systems, and on the foundation of Digital Imagery.

Tissue-like P systems (Martín-Vide, Păun, Pazos, & Rodríguez-Patón, 2003) have two biological inspirations: intercellular communication and cooperation between neurons. The common mathematical model of these two mechanisms is a network of processors dealing with symbols and communicating these symbols along channels specified in advance.

Formally, a *tissue-like P system* with input of degree $q \geq 1$ is a tuple

$$\prod=(\Gamma, \Sigma, E, w_1,\dots,w_q, R, i_\Pi, o_\Pi)$$

where

1. Γ is a finite *alphabet*, whose symbols will be called *objects*;
2. $\Sigma(\subset\Gamma)$ is the input alphabet;
3. $E \subseteq \Gamma$ is the alphabet of objects in the environment;
4. $w_1,\dots,w_q$ are strings over Γ representing the multisets of objects associated with the cells at the initial configuration;
5. R is a finite set of communication rules of the form $(i,u/v,j)$ for $i,j \in \{0,1,2,\dots,q\}$, $i \neq j$, $u,v \in \Gamma^*$;
6. $i_\Pi \in \{1,2,\dots,q\}$ is the input cell;
7. $o_\Pi \in \{0,1,2,\dots,q\}$ is the output cell.

A tissue-like P system of degree $q \geq 1$ can be seen as a set of q cells (each one consisting of an elementary membrane) labelled by $1,2,\dots,q$. We will use 0 to refer to the label of the environment, i_Π denotes the input cell and o_Π denotes the output cell (which can be the region inside a cell or the environment). The strings $w_1,\dots,w_q$ describe the multisets of objects placed in the cells of the P system. We interpret that $E \subseteq \Gamma$ is the set of objects placed in the environment, each one of them available in an arbitrary large amount of copies.

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