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Advantages of application of unconventional computing to image processing and whence these advances come*

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Abstract

This paper presents the advantages of P system computing based approach to solving image processing problems. Being significantly reduced relative to classic algorithms, P system computing based algorithms nevertheless produce better results and even resolve the problems just unsolvable for classic algorithms. Despite these evident advances, unconventional computing approaches remain less popular in practical image processing because their hardware is mostly virtual that supposes computing on simulator. This obstacle can be in perspective eliminated by direct implementation of P system computing based solutions on today's HPC hardware.

Keywords: Medical imaging, unconventional computing, P system, HPC, image processing.

1 Introduction

This paper intends to demonstrate the advantages of image processing problems solving by application of P system computing [1] that is the branch of unconventional computing.

Unconventional computing, also known as alternative computing, uses new or unusual devices instead of classical silicon ones. The most widely distributed branches of unconventional computing are: quantum

*The results published in this article were presented on November 13, 2015 at the seminar dedicated to the memory of Prof. Iu. Rogojin computing, wetware computing, DNA computing, molecular computing, nanocomputing. The algorithms and programming methods of unconventional computing are conceptually different from the traditional ones. Essentially this difference springs from nature of unconventional computing that supposes computing in parallel on large amount of elementary devices. So, the algorithms and programming methods of unconventional computing suppose to be intrinsically parallel. Practically this aspect means that developers do not need tips-and-tricks to avoid exhaustive search (brute force).

Image processing – in particular medical imaging – is the most perspective user of unconventional computing algorithms. Unconventional computing based solutions are significantly reduced relative to classic based one; nevertheless they not only produce better results, but even resolve just classically unsolvable problems. Despite these evident advances, practical domains like medical imaging still rare use unconventional computing, because “hardware” is mostly virtual that supposes computing on simulator. This obstacle can be surmounted by recently proposed implementation of unconventional computing solutions on today’s hardware – HPC (high performance computing) [2].

Advances of applications of unconventional computing to image processing mostly spring from easy obtaining of pixel neighborhood and possibility to use brute force algorithms without computational overdraft.

In the presented work P system computing – a particular branch of unconventional computing – is applied. This is bio-inspired paradigm, and its models, known as membrane systems or P systems, reproduce the membrane structure of the biological cell. Computing is performed by execution of rules of objects movement or transformation. The rules are applied in parallel. P systems demonstrate challenging applications in images processing and analysis. A variant of P system, called tissue-like P system, shows itself as suitable representation of image: pixel is mapped to cell in tissue [3].

In this work the above formalism and representation are applied to the solution of noisy medical image processing problems. The presented solution is used to illustrate the advantages of application of P system computing.

2 Key features from which advantages come

As it was stated above, programming methods of unconventional computing are conceptually different from the traditional ones. Because of this principal difference the methods of unconventional computing often look tricky and advantages of their application are veiled.

To explane whence the advances come, the application of P system computing to solving practical problems of image processing is presented by illustrative example.

Firstly, P system computing workflow of this example has to be explained. Let us consider the cell as small computer. The substances which are transferred into the cell, could be considered as input. The substances which go out of the cell, could be considered as output. Some substance conversion done inside the cell is data processing. Another name of P system computing is membrane computing because the main aspect of this computing is the cell membrane that divides work area to inner cell and environment. The computation consists in execution of rules which act toward membrane providing:

- objects transition through membrane;
- objects conversion inside membrane or during transition.

The tissue P system is the abstract map of living tissue. The rectangle tissue of cells ordered in rows and columns is the natural representation of image where pixels are the cells and cell content is color value.

Having the brief scheme of P system computing we can show the springs of advantages of this computing application to image processing tasks.

From the very beginning the important aspect has to be stated. The today's application of unconventional computing is effective only for the cases which are hard solvable or even unresolvable by classical methods. Of course this aspect is generated by absence of real hardware and restricted simulators capability.

According to the mentioned aspect, the test use case was selected. This set was selected from medical ultrasound images of gallbladder in SonaRes system database [4]. To prepare the test set of images, regions of interest (ROIs) are subtracted from full image. The resulted images present suitable test because of:

- hard noise make useless application of shape recognition methods;
- small size strikes application of gradient methods.

Moreover, SonaRes is the functioning system with its own retrieval module. For test purposes only those images were selected, the retrieval of which fails.

Formal definition of the problem is: to develop effective algorithms for extracting image-based features from ultrasonic images to be used for image matching and classification in diagnosis supporting process.

The problem solving by P system computing has two steps:

step (1) obtaining of features from test image and

step (2) retrieval the images with similar features from database of already processed images.

For presented use case the contours were chosen as images signatures because they can define the majority of gallbladder pathologies. At the **step (1)**, contours of image artifacts are traced applying P system based grayscale image region-based segmentation algorithm adopted from one proposed by [3]. The details of adoption are presented in our work [5]. The adoption was not a problem because of unconcern of P system based methods to image dimension or grayscale/color content of pixel representation. The proposed algorithm produces the acceptable segmentation result independently on image noisiness. Graphical-related basis of algorithm is the edge-based segmentation using the cross-like 4 points adjacency.

While P system based algorithm of segmentation is efficient and effective, the one currently used for retrieval at **step (2)** is reduced to comparison of contour obtained from pattern image with contours from the database. The problem of contours comparison is mostly finding of shape descriptor suitable to particular retrieval algorithm, in our case – shape descriptor by height function (length of perpendicular to the chosen axis) [6]. The coefficient of similarity is defined as ratio of "common" points obtained by retrieval to the total number of points in contour received from the pattern image.

These outlines of solving steps allow one to demonstrate the specific for P system computing features which make solving noisy image processing problems faster and simpler.

For the both steps, productive P system computing key features are the same:

1. Charge-less using of brute force algorithms makes available the per/pixel processing. Per/pixel processing in this case allows avoiding algorithmic tricks needed for retrieving features indistinguishable by another methods.

2. Tissue structure formalism gives easy access to neighborhood of every shape and complexity. For given problem such easy access provides the separation of grayscale levels that give as result the contour.

The key features application can be demonstrated in detail by presented example. In general, algorithms for the both steps consist in marking of target pixels by specific objects transferred from environment. Marking process is managed by rules. Algorithm executes identical rules for each pixel simultaneously applying massive parallelism feature of P system computing. Rules executing process applies another key feature – accessibility of any neighborhood of every cell of tissue structure.

Focusing on **step (1)** algorithm that is implemented efficiently, the springs of P system based solution advantages can be presented. When implementing segmentation, the rules are executed for each pixel in parallel but computation takes *only 2 steps*.

[I] First set of rules searches for border pixels until all half-border objects will be checked.

[II] Second set of rules repeats the same process converting temporary borders to final ones.

Specifically the native massive parallelism of P system computing makes the proposed algorithm so reduced.

3 Simulation results and perspective of direct HPC implementation

The demonstrated efficiency of P system based algorithm of course provokes the question how appropriate are the obtained results.

As stated above, today the only implementation of P system based solution can be done by simulator.

In this section the sufficiency of P system based image processing can be confirmed by extracts of simulation results. Sample group includes the results of presented use case and results of several tests on use cases taken from works where advanced classical algorithms were applied.

The used simulator is based on P lingua [7] framework. P lingua has full set of patterns for implementation of elements of membrane computing. While segmentation algorithm is the adopted one, its implementation was done in frame of presented work.

The use case for simulation is a set of real medical ultrasound images of gallbladder. Fig.1 shows the test results of cases of gallbladder polyps. In the case of this pathology, contours recognition plays the main role showing the difference between stones and polyps, which have straps with outer wall of gallbladder. P system based algorithm shows the acceptable results, while our attempts to get solutions by classical methods did not give the results at all.

Fig.2 shows the comparative results of test on medical images considered as hard processed in works [8] (left pair) and [9] (right pair).

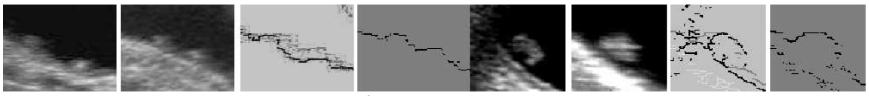

Figure 1. Results of presented use case simulation

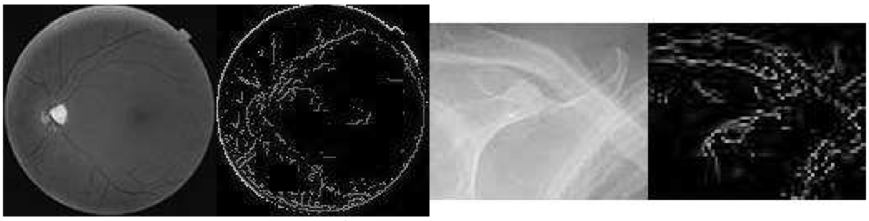

Figure 2. Results of comparative use cases simulation

There is a sufficient number of medical imaging problems solutions by unconventional computing algorithms, which are successfully implemented by simulators. But even working on parallel hardware, simulators cannot implement massive parallel processing of unconventional computing. Moreover, researchers does not trust the results obtained by simulator or just do not intend to spend the time for "ghost" computing. Therefore, despite the described advantages, medical imaging problems solutions based on unconventional computing still meet "non-existent hardware" obstacle. The mentioned "misunderstanding" challenge can be successfully answered by modern research of direct implementation of unconventional computing on today's hardware of high performance computing (HPC). Although this research is very fresh, the problems of such both important and suitable domain as image processing are certainly in list of considered tasks.

We recently have joined this research basing our decision on long experience of Spanish colleagues in CUDA implementation of P systems simulator [10]. Medical imaging use case that is currently the subject of our research shows itself as suitable and perspective application to develop the HPC implementation of presented P system based solution.

4 Conclusions and further work

P system based approach to image processing demonstrates effectiveness and productivity even being implemented on simulator. The solutions of test real-life problems of medical imaging domain promise successful further development of implementation of this approach on today's HPC hardware. The development supposed representing P system computing blocks as universal pattern from which the solution of particular task can be built. To extract suitable blocks more test problems of different domains have to be solved.

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