2D Image Segmentation using Cell like Spiking Neural P System

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Abstract
A new type of computational model that is stimulated by functions and structure of biological cells is called Membrane Computing. Spiking Neural P Systems (SN P Systems) is an unconventional method of computing, where in the rewriting of multisets is implemented by absorbing a multiset present in the membrane region and simultaneously producing new multiset of alphabets. In the present study, edge segmentation of 2D images using Cell-like Spiking Neural P System with various spikes (cSN+P systems) is considered.
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Keywords
Membrane Computing, cSN+P systems, Edge Based Segmentation

1. Introduction

The study of new computational paradigms based on natural phenomena constitutes natural Computing. It abstracts how nature "computes," resulting in new computing models. Neural networks [15], Genetic algorithms [9], and DNA-based molecular computing [1] are some examples of well-established fields in Natural Computing.

A computing model that relies on function of cells and structure to process rules and generate string languages constitutes membrane computing. In general, A P system [16], contains of a membrane structure with compartments in which the predetermined rules that work in non-deterministic parallel manner and are evolved using multisets of objects.

These models can be divided into three groups based on their construction: P systems based on structure of cell, P systems based on tissue, and P systems based on neurons [18]. Membranes are ordered as a tree-like structure in the cell-like P System in the first system. The vesicles that make up acell's interior serves as inspiration for such architecture.

Tissue P systems are computational models motivated by biological systems along with chemical reaction in which multiple individuals live and cooperate in a specific environment where objects can modify when shifting from one region to another. The type of distributed and parallel neural-like computing model that is stimulated by the mode neurons transfer using spikes are the type of SN P systems. This work focuses on the approach: $cSN^{+}P$ System.

SN P system [8], in which neurons communicate with one another via identically shaped electric impulses called spikes. Using spiking and forgetting rules, the neuron processes information in the form of spikes. The following is how spiking rules work: The current spikes are absorbed by the neuron, andnew ones are created. Similarly, the forgetting rule is used to eliminate the count of spikes present in the nerve cell which is predetermined. The rules get triggered, when the regular expression is

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matched with the count of spikes present in a neuron. As the result, the system halts which is the computation in SN P system and the various types of spikes are transmitted to the environment.

In computer vision, partitioning a digital image into multiple segments is a process. known as segmentation. By shortening and/or changing an image's representation, segmentation makes the image simpler to analyse. Substances and borders in images are typically located using image segmentation. In more technical terms, the process of assigning a label to each which have similar visual characteristics and same label is known as image segmentation. Few techniques that are available to segment the image are neural network methods, watershed transformation methods, edge-based method, region-based method and graph partitioning methods.

Medical imaging, Traffic control system, Finger print recognition and Object detection are thefew of the real-world applications of image segmentation. Hepzibah et al., [4,5] used for the first time, P systems based on tissue for segmenting the 2D images which is a variant of P systems.

The work on paper is prepared as follows: We discuss the preliminaries of cell-like spiking neural p system with several types of spikes in section 2. We define a cSN^+P systems for segmentationin 2D image based on edge in section 3.

2. Preliminaries

2.1. Cell-Like SN^+P System

A cSN^+P system [14] of the power $m \geq 1$, is of the form

$$H = (X, Q_1, Q_2 \dots, Q_m, R_1, \dots, R_m, k_0),$$

Where

1.The group of alphabets is denoted by X and its is finite

2.$Q_1, Q_2 \dots, Q_m$ are the neurons of the form

$$Q_i = (W_i, R_i), 1 \leq i \leq m,$$

Where

(i) $W_i \epsilon O^*$ denotes prime multiset of spikes confined in Q_i;

(ii) R_i has two rules of the succeeding form:

(a) The spiking rule Here V is an $\frac{E}{u} \to v$, here V is an arrangement of pairs of the form (V_i, tar) and tar $\{here, out, in_j\}$ and E represents regular language over O.

(b) The forgetting rule $V \to *$, with $V \epsilon O^*$ and $V \epsilon E$

3.The output region of H is indicated by $k_0 \in \{0, 1, \dots, m\}$

The spiking rule of the form $\frac{E}{u} \to v$ works in the following way: The computation begins from the neuron Q_i which has maximum number of spikes and multiset **w** such that $w \epsilon L(E)$ and $u \epsilon sub(E)$. When the rule starts to fire, the production of multiset of spikes $v \epsilon E$ are consumed bythe spikes u and are transmitted to the target indicated. If each of the neuron holds accurately the spikes v, then the firing rule $V \to \lambda$ starts to work. Because the global clock is assumed, the system's operation is synchronized. If n number of rules are present in the neuron at the similar time, any one of rule is used is chosen non-deterministically. The transition of system is formed by application of firing or forgetting rules in a neuron. Any transition sequence begins with the initial configurations. When rule is not applicable, the computation ends and reaches its configuration.

The different types of spikes released from the output neuron in a tentative configuration whichis the output of the cSN+P system. The series of spikes produced from the output neuron forms the edge pixel generated by the cSN+P system.

3. Segmentation of 2D Images using cSN+P System

The two -dimensional digital image 3 with size $n\ x\ m$ ($n.\ m$ ϵ N) is a object in four-sided net(i, j) called pixels with $1 \leq i \leq n$ and $1 \leq j \leq m$ [3]. The ordered set of all colours in 3 be the alphabet of colors of 3 ($c \subseteq N$) [4]. The number of colour of this alphabet is denoted by the size of $c - |C|$. Let us consider that for every pixel of 3 is correlated to a colour of c. The pixel (i, j) is encoded with connected color a ϵ C as the object a_{ij}. The image is coded as the set $\{a_{\text{ij}}: a \in C$ Ʌ $1 \leq i \leq n$ Ʌ $1 \leq j \leq m\}$. Pixels $q_1 = (c, d)$ and $q_2 = (e, f)$ are given and they are said to be adjacent $(q_1. q_2) = \sqrt{(c - e)^2 + (d - f)^2}$ is 1. The 4-adjacency neighborhood concept is used to study the relation between pixels to segment the images.

We can partition an image into regions in this manner, with each area consisting of two-by-two nearby pixels with the same associated colour. The region's boundary is defined as the group of pixels in particular region that have the characteristic of being next to other pixels with a variety of color associated colour. In this section, the edge-segmentation algorithm is used to segment the images. The labels of the pixels in the 2D images are given as input to the system. The successive application of firing rules to the input 2D image identifies the boundary pixels and sends them to the environment. The system applies the rules using 4 adjacency and 2 adjacency neighbourhood on the pixels of the input image. The resultant segmented 2D image is observed in the output neuron of the system.

3.1 Image Segmentation using Cell-like Spiking Neural P System with various types of spikes

Theorem 3.1

The m x n 2D image can be segmented by a Cell -like Spiking Neural P System with various types of spikes having 1 neuron.

Proof:

We define a family of cSN+P System for edge segmentation of 2-D images. For each $n, m \in M$, the system is defined as follows:

$$\pi = (, \mu, \sigma_0, R_0, \sigma_0)$$

Where,

- O = $\{a_{\text{ij}}, b_{kl}\}$ where a_{ij}, b_{kl} are the labels of the input image
- $\mu = []_1$
- $\sigma_0 = \{a_{\text{ij}}, b_{kl}\}$

- $$R_0 = \left\{ \begin{array}{c} {}^{a_{ij}\, b_{kl}}\!\Big/_{b_{kl}} \rightarrow (\, b_{kl}, out), \\ {}^{b_{mn}\, a_{xy}}\!\Big/_{b_{mn}} \rightarrow (b_{mn}, out) \\ \frac{a_{ij}a_{ij+1}\; b_{i+1j}a_{i+1j+1}}{b_{i+1}} \rightarrow (b_{i+1j}, out) \\ \frac{a_{ij}b_{ij+1}\; a_{i+1j}a_{i+1j+1}}{b_{ij+1}} \rightarrow (b_{ij+1}\;, out) \\ \frac{b_{ij}a_{ij+1}\; b_{i+1j}b_{i+1j+1}}{b_{ij}\; b_{i+1j}b_{i+1j+1}} \rightarrow (b_{ij}, out)(b_{i+1j}, out)(b_{i+1j+1}, out) \\ \frac{a_{ij}a_{ij+1}\; b_{i+1j}b_{i+1j+1}}{b_{i+1j}b_{i+1j+1}} \rightarrow (b_{i+1j}, out)(b_{i+1j+1}, out) \\ \frac{a_{ij}a_{ij+1}\; b_{i+1j}a_{i+1j+1}}{b_{i+1j}} \rightarrow (b_{i+1j}, out) \\ \frac{b_{ij}b_{ij+1}\; a_{i+1j}a_{i+1j+1}}{b_{ij}b_{ij+1}} \rightarrow (b_{ij}, out)(b_{ij+1}\;, out) \\ \frac{b_{ij}b_{ij+1}\; a_{i+1j}b_{i+1j+1}}{b_{ij}b_{ij+1}b_{i+1j+1}} \rightarrow (b_{ij}, out)(b_{ij+1}\; out)(b_{i+1j+1}, out) \\ \frac{b_{ij}a_{ij+1}\; b_{i+1j+1}a_{i+1j+1}}{b_{ij}\; b_{i+1j}} \rightarrow (b_{ij}, out)(b_{i+1j}, out) \end{array} \right.$$

- $i_0 = []_0$

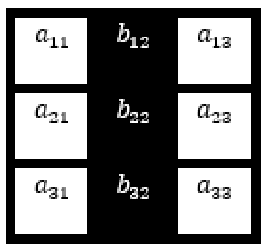

Figure 1: An example of 3x3 Image as input image

4. Overview of the computation

The system has one membrane σ_0 having firing rules defined in the set R_0. The multiset a_{ij}, b_{kl} spikes is present in the membrane σ_0. The rules in R_0 are applied to the initial set of spikes where the region σ_0 gets activated.

The rule R_0 is applied, when an image has different associated colours with two adjacent pixels, the pixel with the less associated colour will remain in the same neuron and other pixels are sent out using spiking rules.

Similarly, the rule R_0 is applied, when an image has four adjacent pixels with different associated colours, the pixel with the less associated colour will remain in the same neuron and other pixels are sent out using spiking rules.

Suppose that the system chooses firing rule ${}^{a_{ij}\, b_{kl}}/_{b_{kl}} \rightarrow (b_{kl}, out)$ non-deterministically. This rule consumes a spike a_{ij} and sends a_{ij} spike to the environment. The edge cells are sent out using the spiking rule and other pixels will remain in the neuron σ_0. The firing rule $b_{mn}\, a_{xy}/b_{mn} \rightarrow (b_{mn}, out)$. This rule consumes a spike a_{xy} and sends a_{xy} spike to the environment. The edge cells are sent out using the spiking rule and other pixels will remain in the neuron σ_0.

If the firing rule $\frac{a_{ij}a_{ij+1}\, b_{i+1j}a_{i+1j+1}}{b_{i+1}} \rightarrow (b_{i+1j}, out)$ is selected by the system non-deterministically then the system will send the spikes b_{i+1j} out, which is four adjacency in image. Similarly, all other rules are applied and the edge cells are sent out using the spiking rule and other pixels will remain in the neuron σ_0. At last, the second set of rules are pertained and send pixels at edge to the output cell.

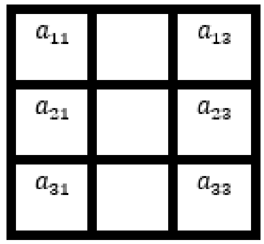

Figure 2: Edge-Segmented 3 x 3 image

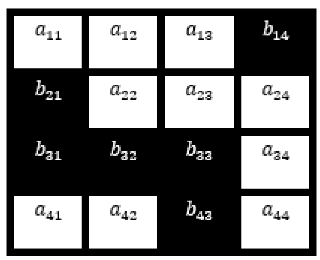

Figure 3: An example of 4x4 Image as input image

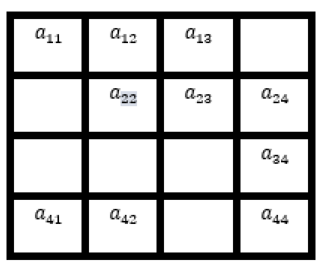

Figure 4: After Edge-Segmentation, The 4x4 Image

5. Conclusion

At present, we studied edge segmentation of the m x n 2D images with the aid of cSN$^+$P systems. Further, need to study segmentation of 3D images. Furthermore, application of the system in medical image processing will be our future work.

6. References

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