

# Realization of Aggregate Applications using Dynamic Behaviour of Cellular Automata

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## Abstract

Cellular automata have proved many of its capabilities and have bestowed a lot in many fields. With the emergence of CA, fabric pattern production has increased in less amount of time. For weaving, cellular automata start with some pattern, then continues with a sequence of steps to produce a new pattern or to change the colour of the cell in a lattice, by using particular transition rules. The main purpose of using cellular automata algorithm as it provides the superlative edge maps and the outstanding quality with one pixel wide edge, with edges having no breaks. We assessed cellular automata capabilities and CA a lot contributions in pattern generation, transformation, and data processing. This research paper reflects the integration of cellular automata across different disciplines. In this paper, we assess the computationally enriched CA rules facilitating spot detection in the study of medical images for cancer diagnosis. The dynamic behaviour of CA increases the scope of transformation and makes it practical for morphing. CA provides prediction of protein structural class and processes dynamic simulation of protein. Flexibility of CA facilitates parallel processing using VLSI, colour graph modelling the linear rules, and its exercise in fabric weaving.

**Keywords:** Cellular Automata, Dynamic Behaviour, Medical Images, Morphing, Parallel Processing, VLSI

## 1. Introduction

Cellular automata constitute of lattice of cells and each cell exhibits discrete states with a particular discrete time, in which the cells states revise synchronously, according to a particular transition rule<sup>2</sup>. The transition rules relies on neighbourhood cell, which are Von Neumann neighbour and Moore neighbour<sup>4</sup>. A cellular automaton represents an intelligent method and cellular automata represent mathematical machine for the production of patterns<sup>3</sup>. Cellular automata have many discrepancies, with respect to cellular space dimensions. Cellular automata categorized into 1-D, 2-D and 3-D cellular automata. Finite cellular automata have cyclic boundaries<sup>2</sup>. In 1-D cellular automata, rules produced by 3-neighbor are used to generate interesting patterns. 256 different images can be created for a same sequence based on CA. Cellular automata consist of number of cells, with the value of 0 or 1<sup>5</sup>.

Cellular automata are self-possessed by rectangular arrays of cells exhibiting unusual states; the most straightforward is binary state, with black representing on state

and white representing off state. The novel state constantly depends on preceding the state. The innovative designs are exceedingly reliant on the preliminary circumstances, such as:

- Existing structure
- Surrounding
- Human needs

The two behaviours, used to describe the cellular automata topology, are used for neighbourhood procedures:

- The cells develop in the entire four directions infinitely.
- The boundary cells represent a static edging.
- The cells enfold just about from edge to edge.

## 2. Background

In the earlier period, fabric weave pattern was generating by manual operation and then by software applications, with

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no prominence on the fundamental fabric composition. Then CAD systems developed, by making an allowance for the designing procedures but with some technical drawbacks due to synchronization of visual pattern with the notational document illustration. However, with the help of CA, fabric weave pattern generation became easy and production as increased. A cellular automaton presents accepted tools, which can be use, in medical image processing due to their straightforward parallel working out execution. In the past, cellular automata were used for basic 2-D image enrichment. Then a 3-D Cellular automaton was use for edge detection for binary and grayscale images. After that, an algorithm for the guidance of cellular automata for image processing came. Then algorithms for follicle image recognition were present<sup>1</sup>.

In the past, the determination of protein 3-D structures was slow. At that time, the protein structure produced by, secondary structure, structural class and domain class prediction methods. Nishikaw discovered that structural classes of proteins have strong relationship with amino acid composition. Then, Chou proposed pseudo amino acid composition, to represent the protein samples. However, CA can predict the hidden, long and complicated amino acid sequence of protein structural classes<sup>5</sup>.

With the knowledge of organization for the pairs of proteins, their communications with nucleic acids can generate electronic cell. In the prior history, it stalled by the lack of appropriate data at a genomic level. At that time, yeast could not draw the consequences for the compositional distribution of the complexes in the cell. Graph representation was not able to offer the spatial and temporal resolution, so providing only the static measurement of the protein interaction network. However, CA can produce a fully dynamic representation of protein within a cell<sup>6</sup>.

Cellular automata are a means for providing efficient speed, power consumption, knowledge storage space, and clarification excellence. Contributions were carrying out for the progress of systematic framework in order to differentiate the cyclic vector subspaces of cellular automaton. In addition, a lot of work was carrying out to present a new algorithm for synchronizing 2-D cellular automata. Due to these contributions, now cellular automata are also use in artificial intelligence<sup>7</sup>.

Morphing is the smooth alteration of a model. In the past, mesh and input mesh-model determined a linear plane having a set of polygons with graph structures

or vertices. Composite topologies with large amount of volume data are complicated to morph and are difficult for the conversion into polygonal mesh, when there is involvement of user control. Thus, leads to correspondence and interpolation problems<sup>9</sup>.

For 2-D CA linear rules, 9-neighbor rectangular rules were use with procedure as Rule matrices, State Transition Diagrams, Boolean functions, Algebraic Normal Form. In this, the current state and 8-cells influence the next state of cell. However, rule 1 presents reliance of the central cell on itself, so on. Therefore, to study linear rules became very difficult and still there is a requisite for having more information for these rules<sup>10</sup>.

In the conventional CA, rule table present the input and output state of the cell for the next step, with respect to present state and its neighbours. Each array of cell can have one of a finite number of states, updated synchronously, according to local interaction rule. The transition in rule-table is implemented in growing-sequential machines, by the interconnection of a rule table. A novel CA model is devise, where the cell handles data and signals, in order to have advancements in growing structures<sup>11</sup>.

In the cryptography, by using the private key crypto system, the sender and the receiver share a common secret key. The sender, send out the cipher text over a public channel. The receiver deciphers text using the shared key. The invader can access the public channel and obtain the cipher text. Therefore, he can recover the text, without having secret key. The most popular secret key encryption is Data Encryption Standards. However, CA based scheme have the lead of providing professional VLSI hardware for realization of enciphering and deciphering functions<sup>12</sup>.

### 3. Methodology

#### 3.1 Cellular Automata Employed for Fabric Weaving Patterns

With the emergence of CA, fabric pattern production has increased in less amount of time. For weaving, cellular automata start with some pattern, then continues with a sequence of steps to produce a new pattern or to change the colour of the cell in a lattice, by using particular transition rules.

Transition Rule 90 is most widely used, as it designs tapestries, demonstrating both trees and abstract triangle patterns. It uses nearest neighbours. It is familiar to biological structure, relates to binomial theorem and

generates long-range patterns, which is suitable for fabric weaving, as shown in Figure 1. The formula for states:

- Position of the cell at  $j$  and initial time is  $t$ .
- State of the cell at time  $t$  is  $a_j(t)$ , its value can be 0 or 1.
- Recursive algorithm:  
 State of the cell at time  $t+1$  is:  
 $a_j(t+1) = \{a_{j-1}(t) + a_{j+1}(t)\} \text{mod} 2$ .

Flat knitting machines, as shown in Figure 2 are wool-len sweater production machines. With CA spatiotemporal behaviour, for designing pattern, this machine has two parts<sup>3</sup>:

- Computer controller
- Computer pattern preparation system

The second part generates data for the entire knitting system. The data includes function control and needle selection, which feeds into controller, to meet great productivity in short time<sup>3</sup>.

### 3.2 Cellular Automata used in Medical Image Processing

CA algorithms are also use in spot recognition in medical images for cancer identification. The algorithm first

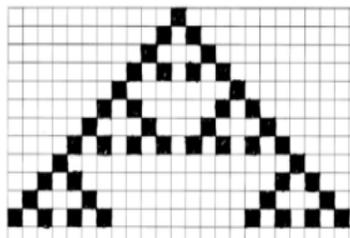


Figure 1. Sierpinski pattern.



Figure 2. Computerized flat knitting systems.

employs for edge detection and then there will be removal of noise, for both binary and grayscale images. At the end of procedure, the spots detection is carry out. CA algorithms used for cancer detection<sup>1</sup>.

The following set operator is use to obtain spot detection<sup>1</sup>:

$$W = X - Y$$

- $X$  represent original image examined
- $Y$  represent edge map by using formula
- $W$  represents the resulting image.

The main purpose of using cellular automata algorithm as it provides the superlative edge maps and the outstanding quality with one pixel wide edge, with edges having no breaks. The results of the used cellular automata algorithms are optimistic and supportive for general practitioner and treatment center in diagnosis of the cancer [1].

### 3.3 Cellular Automata Images for the Prediction of Protein Structural Classes

CA images are employing for the prediction of pseudo amino acid components, reflecting the sequence-order feature of the 3-D structural class protein, with success rates of 89.71%<sup>5</sup>.

In this jackknife test is use, as it is purposeful in prediction, first amino acid hydrophobic index and information theory forms a representation of digital coding for amino acids. Then each protein is test with CA iterative rule 84<sup>th</sup>, as shown in Figure 3. Then visualization techniques transforms 2-D array into CAI of protein sequence. This will reduce the inaccuracy and augment the achievement rate<sup>5</sup>.

With considerable information about features, it then produces high prediction quality in application<sup>5</sup>.

### 3.4 Cellular Automata for Dynamic Simulation of Protein in the Cell Structure

Cellular automata consider each protein molecule then apply interaction rules to the set of discrete particles.

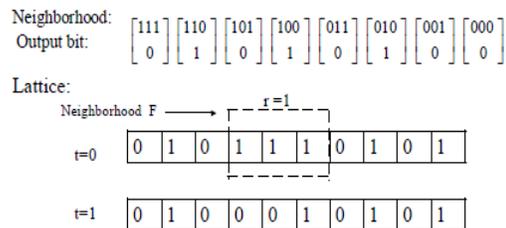


Figure 3. Cellular Automata iterative rule 84.

Therefore, it can simulate the dynamic protein interactions in the cell, as shown in Figure 4, for yeast<sup>6</sup>.

For this model, following are simplifications<sup>6</sup>:

- The domain of the cell is the simulation space having no sections and contains no membrane.
- All the proteins are present on the lattice with same quantity.
- There is no protein synthesis or protein degradation.
- Interrelate proteins have the equivalent probability to form a complex containing a bond, which break at same rate constant.
- Proteins scatter irrespective of size.

This dynamic behaviour can evaluate the equilibrium period, when the rules distorted due to protein modification or change in protein concentrations due to increased deprivation or increased gene appearance<sup>6</sup>.

### 3.5 Cellular Automata in Artificial Intelligence

Due to the progress in cellular automata, CA is also use in artificial intelligence. Radial representation is use to present the advancement in continuous cellular automata called fuzzy cellular automata. It works out for the consequences owing to interaction of bordering cells and exterior interruption on the cells for the augmentation in evolutionary classification. It can also generate the rules automatically, that fabricate spatial prototype in composite systems<sup>7</sup>.

The applications of hierarchical cellular automata are in correcting design problem in civil engineering. In addition, using hybrid techniques of 2-D cellular automata and parallel master-slave genetic algorithms can be used for modelling lava flows on volcano<sup>7</sup>.

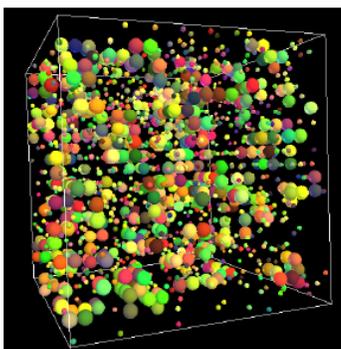


Figure 4. Dynamic structure of protein.

### 3.6 Cellular Automata and its VLSI Applications

In 2-D cellular automata, the cells prearranged in 2-D grid with the neighbourhood cells. The subsequent state of a cell depends on its current state and 8-neighborhood. Insist for parallel-processing architectures are a need for faster computing. For this, 2-D Cellular Automata is implementing in VLSI<sup>8</sup>.

Realization of Finite State Machines (FSM) is use in VLSI. Also CA based cipher system design has presented. A Cellular Automata Machine (CAM) based on parallel architecture of 2-D CA is accessible, used for the analysis of 2-D images. 2-D CA is also use for text compression, VLSI testing and cryptography<sup>8</sup>.

### 3.7 Cellular Automata for 3-D Morphing of Volume Data

Morphing is the smooth transformation of image. CA minimizes the requirement for user input and association between source and the target. CA is a dynamic structure with N-D space, with each cell having a particular value, which changes with respect to some rules for neighbourhood. So, complex global patterns in the morphing consider as the cooperative response of the cells<sup>9</sup>.

Morphing algorithms using the CA are core-increment and the bacterial-growth model, with simple rules for each cell and so straightforward to update or replace, as shown in fig. 5. However, identical 3-D volume sizes are mandatory of the source and destination. No other control points and predefined alteration course are required between the source and target<sup>9</sup>.

### 3.8 Color Graphs: An Efficient Mode for 2-D Cellular Automata Linear Rules

Graph demonstration is simple to imagine as compared to matrix. A novel representation is use by taking into account the colour graphs, with less influence on other objectives, to model all the 512 linear rules for 2-D CA. Therefore,

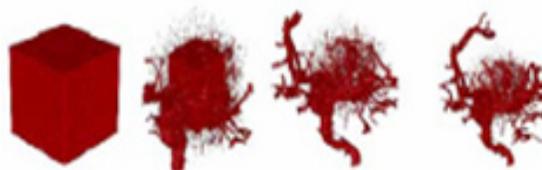


Figure 5. Transformation from source to target.

for this matrices are use, with characteristics of rules. The colour graph property actually makes straightforward the investigation for linear rules. Vertex of the graph refers to each cell of the matrix. For (m x n) binary image, 512 graphs can be form with 512 rules, as shown in fig. 6 [10].

With join-operation, some or all the basic graphs can be combining to form a new. Number of applications is using graphs in computer science and other areas<sup>10</sup>.

### 3.9 Data and Signals Cellular Automaton and its Applications to Growing Structures

In this novel model, the cell is a digital system containing a processing unit and a control unit with 5-neighbor, for the realization of growing structures, introduced the characteristic resources, including self-replicating loops and bio-morphs<sup>11</sup>.

In this, the register is slice into numerous state-variable groups called fields, which makes the rules of the table and can processes data and signals. For this, two goals are required: implementation of digital system, and designing of growing structures. In growing structures, data propagation occurs only when the replication or growth processes are not active.

The hardware accomplishment of the loops is use in the Bio-Wall, as shown in Figure 7, which is electronic wall for bio-inspired applications<sup>11</sup>.

### 3.10 Orthogonal Transformation of 2-D Cellular Automata and its Application in Cryptography

CA based scheme have the advantage of providing efficient VLSI hardware for implementation of enciphering and deciphering, so, border cells are connected with each other, with logic 0-state, then CA is called null boundary CA. Therefore, rule 170 (2-D CA Orthogonal Transformation), is used for null boundary<sup>12</sup>.

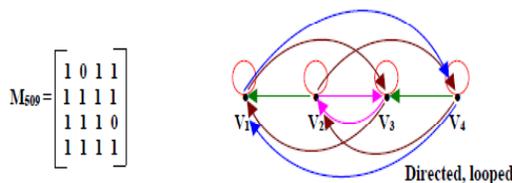


Figure 6. Basic rule graph.

This transformation relies on a cycle length L. By transforming the text x-times, it results in the cipher text. Where x is random integer in the interval 0 & L. Deciphering is obtain by using the same transformation to the cipher text (L-x) times. This system is impenetrable against hacker attacks and is simple to put into practice in VLSI<sup>12</sup>.

CA transition rules generate numerous patterns and models, a few CA rules along with their rule form are in Table 1<sup>13</sup>.

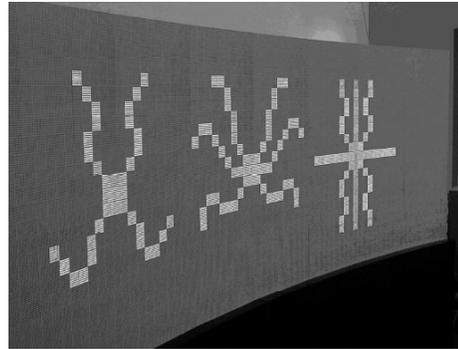


Figure 7. Bio-Wall to implement growing structures.

Table 1. CA rule forms

rule number			boolean expression
dec	binary	hex	
146	10010010	92	$(a_{-1}\bar{a}_0\bar{a}_1) + (\bar{a}_{-1}\bar{a}_0a_1) + (a_{-1}a_0a_1)$
147	10010011	93	$(a_{-1}a_0a_1) + (\bar{a}_0\bar{a}_1) + (\bar{a}_{-1}\bar{a}_0)$
148	10010100	94	$(a_{-1}\bar{a}_0\bar{a}_1) + (\bar{a}_{-1}a_0\bar{a}_1) + (a_{-1}a_0a_1)$
149	10010101	95	$(a_{-1}a_0a_1) + (\bar{a}_0\bar{a}_1) + (\bar{a}_{-1}\bar{a}_1)$
150	10010110	96	$(a_{-1}\bar{a}_0\bar{a}_1) + (\bar{a}_{-1}a_0\bar{a}_1) + (\bar{a}_{-1}\bar{a}_0a_1) + (a_{-1}a_0a_1)$
151	10010111	97	$(a_{-1}a_0a_1) + (\bar{a}_0\bar{a}_1) + (\bar{a}_{-1}\bar{a}_1) + (\bar{a}_{-1}\bar{a}_0)$
152	10011000	98	$(a_{-1}\bar{a}_0\bar{a}_1) + (a_0a_1)$
153	10011001	99	$(\bar{a}_0\bar{a}_1) + (a_0a_1)$
154	10011010	9a	$(a_{-1}\bar{a}_0\bar{a}_1) + (\bar{a}_{-1}a_1) + (a_0a_1)$
155	10011011	9b	$(\bar{a}_{-1}\bar{a}_0) + (\bar{a}_0\bar{a}_1) + (a_0a_1)$
156	10011100	9c	$(a_{-1}\bar{a}_0\bar{a}_1) + (\bar{a}_{-1}a_0) + (a_0a_1)$
157	10011101	9d	$(\bar{a}_{-1}\bar{a}_0) + (\bar{a}_0\bar{a}_1) + (a_0a_1)$
158	10011110	9e	$(a_{-1}\bar{a}_0\bar{a}_1) + (\bar{a}_{-1}a_0) + (\bar{a}_{-1}a_1) + (a_0a_1)$
159	10011111	9f	$(\bar{a}_0\bar{a}_1) + (a_0a_1) + (\bar{a}_{-1})$
160	10100000	a0	$(a_{-1}a_1)$
161	10100001	a1	$(\bar{a}_{-1}\bar{a}_0\bar{a}_1) + (a_{-1}a_1)$
162	10100010	a2	$(\bar{a}_0a_1) + (a_{-1}a_1)$
163	10100011	a3	$(\bar{a}_{-1}\bar{a}_0) + (a_{-1}a_1)$
164	10100100	a4	$(\bar{a}_{-1}a_0\bar{a}_1) + (a_{-1}a_1)$
165	10100101	a5	$(\bar{a}_{-1}\bar{a}_1) + (a_{-1}a_1)$
166	10100110	a6	$(\bar{a}_{-1}a_0\bar{a}_1) + (\bar{a}_0a_1) + (a_{-1}a_1)$
167	10100111	a7	$(\bar{a}_{-1}\bar{a}_0) + (\bar{a}_{-1}\bar{a}_1) + (a_{-1}a_1)$
168	10101000	a8	$(a_{-1}a_1) + (a_0a_1)$
169	10101001	a9	$(\bar{a}_{-1}\bar{a}_0\bar{a}_1) + (a_{-1}a_1) + (a_0a_1)$
170	10101010	aa	$(a_1)$
171	10101011	ab	$(\bar{a}_{-1}\bar{a}_0) + (a_1)$
172	10101100	ac	$(\bar{a}_{-1}a_0) + (a_{-1}a_1)$
173	10101101	ad	$(\bar{a}_{-1}a_0) + (\bar{a}_{-1}\bar{a}_1) + (a_{-1}a_1)$
174	10101110	ae	$(\bar{a}_{-1}a_0) + (a_1)$
175	10101111	af	$(\bar{a}_{-1}) + (a_1)$
176	10110000	b0	$(a_{-1}\bar{a}_0) + (a_{-1}a_1)$
177	10110001	b1	$(\bar{a}_0\bar{a}_1) + (a_{-1}a_1)$
178	10110010	b2	$(a_{-1}\bar{a}_0) + (\bar{a}_0a_1) + (a_{-1}a_1)$
179	10110011	b3	$(a_{-1}a_1) + (\bar{a}_0)$

## 4. Results and Discussion

This paper took into account the interaction of cellular automata with diverse disciplines that follows the CA rules and inferences. Cellular Automata rules that grow in length have uses in fabric pattern generation as compared with pattern replication and the problem of market level production is resolved by efficient CA rules. The focus of null boundaries of CA weighs against simple private key scheme for cryptography. The pioneer dynamic behaviour of CA facilitates protein structure prediction as compared with static behaviour of graph representations and other techniques. CA being a superlative edge mapping technique with no break makes possible the image processing proficiently as compared to 2-D and 3-D CA edge detection techniques. CA images enhanced the prediction of protein structure classes as judged against slow 3-D CA.

Fuzziness of CA is employed for the automated rules formulation furthermore; data and signal CA are more proficient for self-replicating of structure stand out against conventional CA.

## 5. Conclusion

We evaluated cellular automata as it provides self-possessed intelligent methods to provide dynamic representations for complex behaviours. We assessed cellular automata capabilities and CA a lot contributions in pattern generation, transformation, and data processing. Moreover, it assists in structure prediction, dynamic simulation, providing runtime solution, linear rule generation, self-replicating structure growth and encrypting the data. In this paper, we have presented several demonstrations, in which cellular automata have provided many contributions as minimizing the mandatory requirement for user input and control points for 3-D morphing.

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