www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 2 Issue 4 April, 2013 Page No. 980 -985

Survey Paper on Training of Cellular Automata for image

Swati Chauhan
Dept. of Dept. Computer Science & Engg.
Krishna Institute of Engg. And Technology ,Ghaziabad , India
Email- swatichauhan133@gmail.com

Abstract- *A cellular Automata(CA) is a system of finite automata that provide a discrete computational model to under the complex behaviour of images (computational and real).This article provide a survey on how researchers can train the Cellular Automata to learn best rules to achieve optimal solution in a large search space. Many researchers have provided different-different methods (SFFS, with GA, 3-State Representation ....) to train .CA trained with GA(Genetic Algorithm) capable to perform various difficult tasks. This survey also introduces the different fields where CA used with modification techniques (B-Rules CA, 2-Cycle CA).*

Keywords – Cellular Automata, median filter, Gaussian filter ,SFFS, GA, fitness value

I. Introduction

Cellular Automata are called "Systems of Finite Automata," means Deterministic Finite Automata (DFAs) and given in a lattice arrangement [1].Cellular automata primarily announced by Ulam [2] and Von Neumann [3] with the purpose of obtained models of biological self-reproduction. Now a day's Cellular Automata became very popular because of its diverse function and utility as a discrete modal for many processes [4].

Cellular Automata includes an array of cells each of which can be in one of a finite number of possible states, updated synchronously in discrete time steps, according to a local identical interaction state transition function .The state of a cell at the next time step is determined by the current states of a surrounding neighborhood of cells [5].So a CA's simple structure has attracted many researchers .In this survey paper we are defining that how CA could be trained for image processing.
CAs could be applied to perform a range of computer vision tasks, such as-

- Calculating distances to features [1];
- Calculating properties of binary regions such as area, perimeter, and convexity [6];
- Performing medium level processing such as gap filling and template matching [7];
- Performing image enhancement operations such as noise filtering and sharpening [8];
- Performing simple object recognition [9].

Genetic Algorithm is also used to grow CA to perform computation that are require global coordination and used to select a single powerful rule to extract edges from a given black-white images where EvCA (Evolutionary Cellular Automata) is used to determined best rules for CA with the help of GA(genetic algorithm) on a population[3].

II. Cellular Automata

Cellular Automat is discrete system space where time is discrete. A Cellular Automata is a finite number of state and be made of a grid of cells. For example, a simple two state, one dimension CA will consists of a line of cells, each of which can take value 0 and 1. At a particular time cells change their states, each cell looks their neighbour states and congregates information from its neighbour's states then cell decides what its new state should be. All the cells change state at the same time.

CA is both inherently parallel and computationally simple. This means that they can be implemented very efficiently in hardware using just AND/OR gates and are ideally suited to VLSI realization [10].CA is extensible; rules can easily be added, removed or modified([10]).
As the digital image is two dimensions, here two-dimensional cellular automata model same as in one-dimensional CA. Let l be a regular lattice (i.e. cells are the elements of l), S is a finite set of states, $i_0 \in S$ is called the initial state. F is a finite set (of size n = |F|) of neighborhood indices such that $\forall a \in l$, $\forall c \in F$: $a + c \in l$, where a is the finite distance where rules providing the advancement of cells will covers the p-site of CA. left : $S^n \rightarrow S$ be a transition function. Then, we call the quintuplet c= (l, F, S, f, i_0) a cellular automaton. A configuration of time t, Ct: $l \rightarrow S$ is a function that associates a state with each cell of the lattice. The effect of the transition function f is to change the configuration Ct, into the new configuration Ct+1 according to
Where F(a) denotes the set of neighbors of cell a,

$$C_{t+1}(a) = f(\{C_t(i) \mid i \in F(a)\}) \quad (1)$$

$F(a) = \{i \in F \; | a - i \in F\}$ (2)[11]

CA used to simulate a real world problem, we have to decide the lattice geometry, neighborhood size, boundary conditions, initial conditions, state set and transition rule [4].

A CA can update rules that can be stored in a lookup table that has lists for each possible local neighborhood configuration the state which is taken on by the central cell at the next time step.[12]. Cellular automata on multidimensional grids have also been proposed [13], [14].

III. Applications

A great deal has been developed with CA including large variety of phenomena that are originated from physics, chemistry, biology , economics and information system [15,16,17,18].The intention is to convey an idea of all the methodologies that can be applied to image for different purposes and possibly with different objectives. This includes image restorations, enhancement, segmentation, compression, features extraction and pattern recognition. It can similarly be used to achieve all the multiplied data processing tasks [19].

There are some other applications of Cellular Automata-

- The Games of Life [20]
- Cellular automata used in economic systems [21]
- Cellular automata used in biological systems [22]
- Cellular automata used in environmental system and ecological system [23]
- CA used in edge detection [24].
- Cellular automata used in the traffic system. [25]
- CA used in image processing [26].
- Cellular automata used in machine learning and control [27].
- CA used in crystallization process [28]

Besides these there are many other applications of cellular automata which are used in different field's like- in medical diagnosis, Weather forecasting, marine's life study, in forest's fire study etc.

IV. Cellular Automata in Image Processing

Digital image processing acting an vital task in daily life applications such as satellite television, computer tomography and magnetic reverberation imaging also in areas of research and technology like-geographical information systems and astronomy [11].CA has been applied successfully in image processing with various advantages in 1-D as well as 2-D cellular automata. There are various applications which involve image processing. Like- image enhancement is the processing of images to improve its appearance to viewers or to enhance the performance of other image processing system. But in many application of image processing the problems are present of noise which can be reduced using various methods as image processing laboratory (Mat LAB), noise modeling and digital

Where it can define the noise as the process(P) which can affect the obtained image(A).Using the additive noise to starting image signals, we can define the process as-

$A(i, j) = I(i, j) + P(i, j)$ (3)

Where i and j are spatial coordinates.

The attainment of digital image change optical signal in to electric signal and then change in to digital signal in which noise is introduced in the images, each step of this process add a arbitrary value to resulting intensity of given pixels. To remove the noise in images use different- different strategies as median filter, Equally weighted average or Mean filtering ,Gaussian filtering, k-Nearest Neighbor filtering, CA[29].By using median filter can sort all the pixels in the mask according to their pixel values. We then take the value of the middle pixel from this sorted list (which is the median) and assign it to the selected pixel. Where pixels of images in NXN window .Pixel values sorted in ascending order:

$I_1 <= I <= I_2 <= I_3 <= \ldots\ldots\ldots\ldots <= I_{N^2}$ [30]

Where

$\{I_1 <= I <= I_2 <= I_3 <= \ldots\ldots\ldots\ldots <= I_{N^2}\}$ represent the intensity of each pixel in window NXN.

Gaussian Filtering

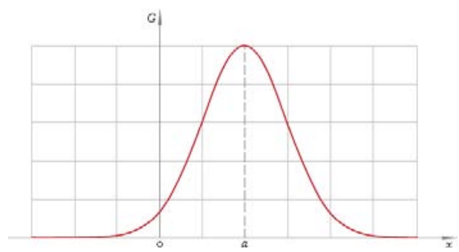
To create the masks, we approximate the two-dimensional Gaussian function given as

$G(a, b) = \exp(-(a^2 + b^2) / (2 * stddev^2))$ [29]

$$G(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-a)^2}{2\sigma^2}}$$

[31]

And its plot is depicted below — **fig. 1**



Where

a —which called *distribution mean* or *statistical expectation* responsible for distribution shifting along x axis to be zero: a=0; and work with simplified form:

$$G(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}}$$

[30]

With the help of CA we can filter the digital images this model is based on a bi-dimensional symmetric non-deterministic CA that can be defined in the form of

$A = (S, N, \delta)$ with set of states $S = \{\#, 0, 1, \ldots\ldots\ldots\ldots k-1\}$. A pixel color's state in $\{0,1\ldots\ldots, k-1\}$ [12]

(k = 2 for a monochromatic image; k = 16 for an image with 16 colors, k = 256 for an image with 256 colors and/or gray levels), # is the quiescent state associated to the cells outside the grid, N the von Neumann neighborhood, while the local transition function δ is based on a comparison criteria of the central cell state with those of the cells from its neighborhood. A cell (not being in the quiescent state) changes its state to the state of the majority of cells in the neighborhood [12].

CA also used in edge detection in digital images that is compared to SUSAN edge detector [12].
Where we see that the border produced by the CA edge detector shows:
1) The edge connectivity at junctions
2) No false edge is reported
3) Qualitative similarity with those produced by the SUSAN method [12].

CA used in various image processing such as:-

A. Image Filtering

To remove noise various strategies are used as median filter, equally weighted average or mean filtering, Gaussian filtering, k-Nearest Neighbor filtering; CA.CA provides a better result in case of salt and pepper noise filtering [29].

B. CA in Border Detection in Digital Images

An edge is a boundary at which some changes could be appeared in some of the physical facet of images.CA has a feature that is used in edge detection that it is independent to the characteristics of the images In border detection, it use very simple transition rules and provide a speedup process of edge detection because rules are triggered by only black pixels [31].

C. Connected Set Morphology

CA can apply the rules to the connected component (more than one image at a time) which take input image and target image produced by the predictable connected set with a suitable value of threshold [32].

D. Image Segmentation

Image segmentation is an integral part of image processing applications like medical images analysis and photo editing. It is an important facet of human visual perception .It came across a cute segmentation idea called “Grow Cut”. This paper by Vladimir Vezhnevets & Vadim Konouchine presents a very simple idea that has very nice results of image segmentation using CA [33].

E. Text Extraction

In images texts are stored which have a rich source of knowledge for content based indexing and retrieval contents. CA using a sequential algorithm can extract the text and enhance the image with the help of various sizes, grayscale values, and complex backgrounds recognition [34].

F. Image Enhancement

CA used in image enhancement because it has dynamic behavior, that provide very fast convergence to fix the points of rule set and it is used with an elementary enhancement algorithm [35].

V. TRAIN THE CELLULAR AUTOMATA

It known that binary image’s cells contains two states: black and white with the eight connected neighbor’s. [23].As Moore neighborhood, Where apply the transition rules to no-boundary cells.

A. set of rules and its uses

Here using a 2D-CA, so there are 256 rules which provide a large search space and which main aim is to choose the best rules to fulfill the need of desired effect. There are a basic algorithm which provide the convergence for central black and white pixel par rally after removing symmetries and reflection that contain 51neighbourhood rules for any central black or white pixel with the help of LUT(look-up table).[36].

B. *Complexity*

Complexity of CA in this process where pixels are P at each iteration and a neighborhood size N ,N=8 the computational complexity will be O(PN) .So the complexity is not depend on the number of rules (based on neighborhood).[36]

C. Density Classification Problem

On the other hand optimal feature selection is tractable and can be performed using branch and bound algorithms, for example [37]. An optimal selection of rules cannot provide a guarantee without any complete details of all combinations [38]. In automatically learning rules most of researchers focus in the density classification problem that is recognized as a standard for exploring cellular automata rules with universal properties [39]. There are two necessary conditions that a CA must satisfy in order to classify density ([40])
1) The density of the initial configuration must be conserved over time.
2) The rule table must exhibit a density of 0.5.

The first gives a link between the density classification problem and the class of density-conserving CA’s. These are used in the physics community, e.g., for modeling of traffic-flow [41] and surface growth [42]. Then a solution is used a standard genetic algorithm (GA) to solve the density classification task with some difficulties [43]which were tackled by Julle and Pollack [44] using GAs with co-evolution .To extend the density classification task for two dimensional grids, Jiménez Morales [31].Applied standard GA for learning rules. There are various feature selection methods that were introduced in [45] also consider GA and SFFS (sequential floating forward search) both have a little difference in effectiveness [45], [46]. The power of training algorithms such that are described in [35] is that all that is required are:
1) Training images set
2) Corresponding target (i.e., ideal) output images set
3) An fitness function for estimating the quality of the real-images formed by the CA.

D. Objective Functions/ fitness function

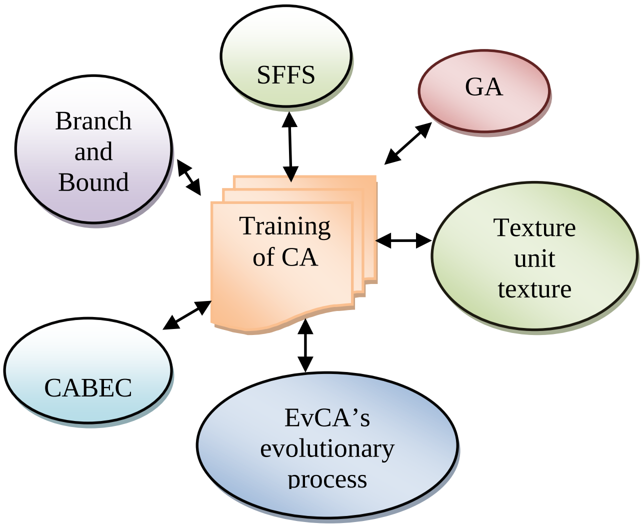


Figure 1 Methods proposed to train the cellular automata

An objective function is required to train the CA in feature selection methods like SFFS and GA, which are hill climbing algorithm, and various error events have been measured [36]. We consider objective function as root mean-square (RMS) error between the input and target image [36]. The distance of each incorrectly colored pixel in the output image to the nearby correctly colored pixel in the target image is calculated then the final error is the summed distances while in the Hausdorff distance rather than summing the distances, only the maximum distance (error) is returned.([36]). A new model called Cellular Automata Based Evolutionary Computation (CABEC) which is used to detect cells for fitness which provides a best value for objective function. [46].

For the enhancement of the design and training the cellular automata two modifications were implemented:
(1) B-Rule CA
(2)Two-Cycle CA
where first is in Yu et al.'s [48] B-rule class of 1-D CA. Adamatzky [15] considered the situation in which the desired rule set must exactly produce the target output (and continually increased the Neighborhood size until this was achieved)([49]).After applying the GAs deposit a leading idea in research into learning CA rules [50,51]. In the search space every rule has its fitness values on the basis of GA that can evolve a best packet of rules [52].

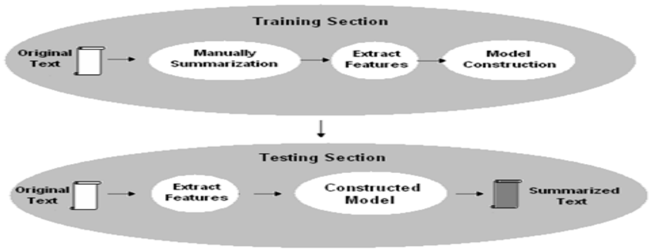


Figure 2 shows the proposed automatic summarization model.

We have two modes of operations:

1 .Training Section

Where features are extracted from 16 manually summarized English documents and used to train Cellular Automata, Fuzzy and Genetic programming models.[53]

2. Testing Section

Where features are extracted from various sentences within one document. The rank of sentences is allotted according to the sets of feature weights evaluated during the training stage [53].

The roll of evaluation based function forms the base for selection and quality improvement. To solve the problem, it provides a task to solve in the evolutionary framework [47].To provides more efficient training we can reduce the number of cell states that is based on the texture unit texture spectrum (TUTS) method of texture analysis [54].

VI.CONCLUSION

As there, it has been seen that GA used to train the CA to detect efficient cells from any problem space and neighborhood detection with a suitable fitness. CA trained with GA has been proved that it is a beneficial approach (simple and easy to implement) in image processing to make it efficient and effective.CA provides better result than standard median filter and training to CA provide flexibility and enhance the performance.

There are evolutionary programs used to train CA which play an important role to provide speed up with perfect objective function/fitness values .But there are also some problems with GA that it require many parameters while SFFS does not require so many parameters and another one is that if we use pixel intensity values directly it provide large complexity so we use decomposition. To speed up the training phase, apply the learnt rules with reduced intensity resolution by using Threshold Decomposition.

VII.ACKNOWLEDGMENT

The author would like to thank Prof. Anand Prakash Shukla for providing the relevant information to the training of cellular automata.

VIII. REFERENCE

[1] J.Avnet, Computation, Dynamics and the Phase Transition Santa Fe Institute. 2000. M. Sipper .The evolution of parallel cellular machines toward evolware.BioSystems, vol. 42, pp. 29–43, 1997.

[2] Ulam, S. Some ideas and prospects in bio mathematics.Anm. Rev.Biophys.Bioengin. 1 :27729 1, 1963.
[3] Von Neumann. J. Theory of Self-Reproducing Automata, University of Illinois Press, IL, 1966
[4] Cuifang Zhao, Caicheng Shi, Peikun He, A Cellular Automaton For Image Compression, icnc, vol. 7, pp.397-401, 2008 Fourth International Conference on Natural Computation, 2008.
[5] Wolfram, Cellular automata as models of complexity, Vol. 311, No. 5985, pp. 419-424, 4 October 1984.
[6] C. Dyer and A. Rosenfeld, Parallel image processing by memory-augmented cellular automata, IEEE Trans. Pattern Anal. Mach. Intell., vol. PAMI-3, no. 1, pp. 29–41, Jan. 1981.
[7] T. de Saint Pierre and M. Milgram, New and efficient Cellular algorithms for image processing, CVGIP: Image Understand. vol. 55, no. 3, pp. 261–274, 1992.
[8] G. Hernandez and H. Herrmann, Cellular automata for elementary image enhancement, Graph. Models Image Process. vol. 58, no. 1, pp. 82–89, 1996.
[9] Paul L. Rosin. Image processing using 3-state cellular automata .Cardiff School of Computer Science, Elsevier Inc. March 2010.
[10] Chun-ling Chang, yun-jif, zhang, yun-yin gdong, cellular automata for edge detection of images, shanghai 26-29 august 2004.
[11] Popovici, A. and Popovici. Cellular automata in image processing, in Proceedings of the 15th International Symposium on the Mathematical Theory of Networks and Systems. vol. 6, in Proceedings of CIAA 2002.
[12] O. Martin, A. M. Odlyzko, and S. Wolfram. Algebraic Properties of Cellular Automata, .Springer-Verlag , Comm. Math. Phys., 93, 219- 258, 1984.
[13] P. Sarkar and R. Barua Multi-dimensional Automata, Polynomial and Generalized Matrices, Theoretical Computer Science, 197(12):111-138, 1998.
[14] Mingfeng He, Jing Lm, Heng Jiang, Xin Liu. The two Population's cellular automata model with predation Based on the Penna model, Physica A.312: 243-250, 2002.
[15] Heinz Muhlembein, Robin Hons. Stochastic Analysis of Cellular Automata with Application of the vater Modder, Advances in Complex Systems, Vol. 5. Number 3.September, 2002
[16] G Diedrich, L Santen, A Schadschneider Effects of On-and off-Ramps in Cellular Automata Models for Traffic Flow, International Journal of Modern Physics. Vol. 11.Number 2, March 2000.
[17] B. Viber, A.Dobnikar, D.Zazula. Cellular automata and Follicle recognition problem and possibilities of using Cellular automata for image recognition purposes, International Journal of Medical Informatics. per file vol. No. 7 • 2 0 1 1 • ISSN 2248-5724 .1998
[18] OluM e. Theory and Applications in Multimedia Compression, Encryption and Modeling, Kluwer Academic Publishers.vol.16. 2000.
[19] N. Ganguly, B. Sikdar, A. Deutsch, G. Canright, and P. Chaudhuri, A Survey on Cellular Automata, Centre for High Performance Computing, Dresden University of Technology, Tech. Rep. 9, 2003.
[20] Hugo de Garis, CAM-Brain. ATR's Bbillion Neuron Artificial Brain Project, International Conference on Evolutionary Computation, Nagoya, Japan, 1996.
[21] Smith, R. The Application of Cellular Automata to the Erosion of Land Forms, Earth Surface Processes and Landforms, 1991.
[22] Aassine, S., El Jaµ1, M.C., And Vegetation Dynamics Modeling: A Method for Coupling Local and Space Dynamics, Ecological Modeling, 154: 237 249, 2002.
[23] Tapas Kumar G, A Novel Method of Edge Detection using Cellular Automata ,Dept. of Information Technology Lingaya's University, International Journal of Computer Applications (0975 –8887) Volume 9– No.4, November 2010
[24] Fukui, M. AndIshibashi, Y. Traffic Flow in a 1D Cellular Automaton Model Including Cars Moving with High Speed,J. Phys. Soc. Jpn.,1996.
[25] Wongthanavasu, S. and Sadananda, R.,In. Pixel-level Edge Detection Using a Cellular Automata-Based Model, Advances in Intelligent Systems: Theory and Applications, vol.59.IOS Press, The Netherlands,343-351, 2000.
[26] Fabio and Marchese, M., A Directional Diffusion Algorithm on Cellular Automata for Robot Path -Planning, Future Generation Computer, Systems. 2002.
[27] S. Nandi, B. K. Kar, and P. Pal Chaudhuri, Theory and Applications of Cellular Automata in Cryptography, IEEE transactions on computers, vol. 43, no. 12, December 1994.
[28] Peters, R.A. A new algorithm for image noise reduction using mathematical morphology, IEEE Transaction on Communication. v. 4, n. 5, 554-568, 1995.
[29] R.C.Gonzales, R.E,Woods, Digital Image Processing, Prentice Hal.vol.4,2002
[30] J.S. Lim, Two Dimensional Signal and Image Processing, Prentice-Hall, International editions, 1990.
[31] P. Douglas Tougaw and Craig S. Lent, Logical devices implemented using quantum cellular automata, Department of Electrical Engineering, J. Appl. Phys., Vol. 75, No. 3, 1 February 1994.
[32] F. J. Morales, J. Crutchfield, and M. Mitchell. Evolving two-dimensional cellular automata to perform density classification, A report on work in progress. Parallel Compute. vol. 27, pp. 571–585, 2001.
[33] Boykkov, Y., and Jolly, M.-P. 2001. Interactive graph cuts for optimal boundary and region segmentation of objects in n-d images, In Proc. Of the International Conference on Computer Vision, vol. 1, 105–112.
[34] G. Sahoo , Tapas Kumar , B. L. Raina , C. M. Bhatia., Text Extraction and Enhancement of Binary Images Using Cellular Automata, Department of Information Technology and Electrical Engineering, international journal of automata and computing vol.6, 2009.
[35] G. Hernandez and H. Herrmann, Cellular automata for elementary image enhancement, Graph. Models Image Process., vol. 58, no. 1, pp. 82–89, 1996
[36] Paul L. Rosin, Training Cellular Automata for Image Processing, IEEE transactions on image processing, vol. 15, no. 7, july 2006
[37] Melanie Mitchell, James P.Crutchfield, and Rajashi Das, Evolving Cellular Automata with Gas, A Review of recent work, in Proc. Of the first inter. Conf. On Ev. Comp. and it Appl.1996
[38] P. Somol, P. Pudil, and J. Kittler, Fast branch and bound algorithms for optimal feature selection, IEEE Trans. Pattern Anal. Mach. Intell., vol. 26, no. 7, pp. 900–912, Jul. 2004.
[39] T. Cover and J. V. Campenhout, on the possible Orderings in the measurement selection problem, IEEE Trans. Systems, Man, Cybern. vol. 7, no. 9, pp.657–661, 1977.
[40] Mathieu S. Capcarre`re* and Moshe Sipper, Necessary conditions for density classfication by cellular automata, Logic Systems Laboratory, Swiss Federal Institute of Technology, 1015 Lausanne, Switzerland-Received 18 April 2001; published 27 August 2001, physical review e, vol. 64, 036113
[41] K. Nagel and H.J. Hermann, Cellular Automata Models for Transportation Applications, Springer publication, Vol. 2493, 2002.
[42] Vladimir Belitsky, Pablo A. Ferrari, Norio Konno, Thomas M. Liggett , A strong correlation inequality for contact processes and oriented percolation Stochastic Processing ,Appl. 67 (1997), no. 2, 213--225 ,1997.
[43] M. Mitchell, P. Hraber, and J. Crutchfield, Evolving cellular automata to perform computation: Mechanisms and impediments, Phys. D, vol. 75, pp. 361–391, 1994.
[44] H. Juillé and J. Pollack, Coevolving the ideal trainer: Application to the discovery of cellular automata rules, in Proc. 3rd Conf. Genetic Programming, 1998, pp.519–527.
[45] A. Jain and D. Zongker, Feature-selection: Evaluation, application, and small sample performance, IEEE Trans. Pattern Anal. Mach. Intell., vol. 19, no. 2, pp. 153–158, Feb. 1997.
[46] H. Hao, C. Liu, and H. Sako, Comparison of genetic Algorithm and sequential search methods for classifier subset selection, in Proc. 7th Int. Conf. Document Analysis and Recognition, 2003, pp. 765–769.
[47] M. Raymer, Ws. Punch, E. Goodman, L. Kuhn, and A. Jain, Dimensionality reduction using genetic algorithms, IEEE Trans. Evol. Compute. vol. 4, no. 2, pp. 164–171, Feb. 2000.
[48] D. Yu, C. Ho, X. Yu, and S. Mori, On the application of cellular automata to image thinning with cellular neural network, in Cell. Neural Netw. Appl., 1992, pp. 210–215.
[49] A. Adamatzky, Automatic programming of cellular Automata, identification approach, Kybernetes 26 (2) (1997) 126–135.

[50] L. Bull, A. Adamatzky, A learning classifier system approach to the identification of Cellular Automata, ,J. Cellular Automata 2 (1) (2007) 21–38.

[51] G. Terrazas, P. Siepmann, G. Kendall, N.O. Krasnogor, An evolutionary methodology for the automated design of cellular automaton-based complex system, J. Cellular Automata 2 (1),2007.pp- 77–102.

[52] S.Slatnia, O.Kazar, Image segmentation based contour using EvCA approach, evolutionary Cellular Automata, University of Biskra, Algeria,vol.9 March 2009, pp.113-118.

[53] Pouya Khosravian Dehkordi and Farshad Kiyoumarsi, Using Cellular Automata to Construct Sentence Ranking, International Journal of Information and Education Technology, Vol. 1, No. 5, December 2011.

[54] Wang, D.C. He, Texture classification using texture spectrum, Pattern Recognition, 23 (1990) 905–910.