Edge Detection Based On Nearest Neighbor Linear Cellular Automata Rulesand Fuzzy Rule Based System

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ABSTRACT

Edge Detection is an important task for sharpening the boundary of images to detect the region of interest. This paper appliesa linear cellular automata rules and a Mamdani Fuzzy inference modelfor edge detection in both monochromatic and the RGB images. In the uniform cellular automataa transition matrix has beendeveloped for edge detection. The Resultshave been compared to the other classic methods for edge detection like Canny, Sobel, Prewitt and Robert. For performance evaluation, and comparison with the other methods the MSE, PSNR(Peak Signal-to-Noise Ratio), SNR(Signal-to-Noise Ratio)criteria have been used. The Comparison results reveals the superiority of the proposed methods in this paper compared to the other standard edge detection methods.

Keywords

Edge detection, Linear cellular automata, Mamdani fuzzy inference model, and Transition matrix, Nearest neighbor

1 Introduction

Edge detection is an important task in image processing. It extracts the contour of an object in an image and provides complete information about region of image [1]. These edges information can be usedsuch as segmentation, object recognition, tracking, face recognition, image retrieval, corner detection. The edge detection is a useful technique for identification of region of interest in many (computer aided detection) CAD applications such astumor identification, breast cancer diagnosis and etc. An important property of the edge detection method is its ability to extract the accurate edges with good orientation in an image, and various papers had been published in the past two decades.

There are many methods for edge detection, and most of them use the computed gradient magnitude of the pixel value as the measure of edge strength [2]. A different edge detection method i.e. Prewitt, Laplacian, Roberts, Canny [3] and Sobel [4] have used different discrete approximation methods based on the derivation function. Surface fitting approach for edge detection has been adopted by several authors [5], [6], [7], and [8].

There are several methods for image edge detection that are divided into two categories: 1) gradient based: this method searches for minimum and maximum in the first derivative of the image. Methods like Robert, Prewitt and Sobel are Gradient class. 2) Laplacian: this methods search zero crossing in second derivative of the image. This method is independent from any direction.

Some optimization based detectors have been presented in [9] and [10]. Statically techniques were represented in [11], [12], and [13]. Other approaches show the usage of Genetic algorithm and other meta-heuristic algorithms like the PSO, BCO, ACO and others [14] and [15] for edge detection. Some of the edge detection methods are based on theNeural

Network such asthe MLP, SOM, MSOM, BP [16]. Also, edge detection methods have been reported that use the Bayesian approach [17], residual analysis-based techniques [18-19]. Some papers have tried to study the effect of noise in images on the performance of image detectors and noise reduction in the image detection level using thresholding and median filter [20-21].

Attanassov's intuitionistic fuzzy set has been applied for edge detection. This method divides image into 3x3 windows without overlapping. Difference between each sample and image's windows is calculated and if all of them processed continue, if not, return to 3x3 dividing, if yes, difference of minimum and maximum of each sample measured, Then used with that dimension in fuzzy difference matrix. A new distance measure called intuitionistic fuzzy divergence has been proposed. This measure has been applied on images for edge. The proposed method detects the dominant edges clearly, while removing the unwanted edges detected [22].

A novel Neuro-fuzzy edge detector by using Canny and Sobelwas presented which is adaptive and can learn to manage digital images corrupted by impulse noise. It is concluded that the proposed edge detector can be used for efficient extraction of edges in digital images corrupted by impulse noise [23].

Another approach proposed an efficient and simple thresholding technique of edge detection based on fuzzy cellular automata transition rules and Sobel optimized by Particle Swarm Optimization method (PSO) [24].

Cellular Automata (CA) were introduced by Ulam and Von Neumann. A cellular automata is a computer algorithm and operates on area of location (e.g. pixels in image processing, peak in signal processing). The CA has been used for various applications because of generating simple rules for complex behavior. The CA has some advantages like fast in time, parallel computation and due to these advantages can be used in image processing.

Another approach is using a fuzzy rule-based system for edge detection based on Mamdaniinference model. Fuzzy image processing is a set of understandable approaches that show and process images which can realized segmented part and features as fuzzy sets. Fuzzy image processing have 3 basic levels: fuzzy representation, modification of membership values and image defuzzification.

This article takes advantages of both CA ad fuzzy rule-based methods for image edge detection. Furthermore, itprovides a comparison analysis of the performance of these two approaches for edge detection.

2 Methodology

This article takes advantages of the CA ad fuzzy rule-based models for the edge detection problem in images. The CA and Fuzzy models are described in the rest of this section.

2.1 Edge detection based on the Cellular Automata

IThe CA is defined over the filed Z2 by using the uniform linear local rules. Then by considering the 2D integer lattice Z2 and the configuration space Ω = {0,1}z2 with elements as shown in formula (1).

$$\{ 0,1\} \rightarrow \sigma: Z2 \quad (1)$$

The value of σ at a point v Z2is denoted by σ, let u1 …, us Z2 be a finite set of distinct vectors and f: {0,1} s→{0,1} be a function.

The CA with local rule f is defined as a pair (Ω,Tf) where the global transition map Tf :Ω→ Ω is given as follows:

$$(Tf\sigma)\ v = f\ (\sigma v+u1\ \dots, + \sigma v+us),\ v \ \square\ Z2 \quad (2)$$

The function f is called local rule. The space Ω is assumed to be equipped with a Tychonoff topology and it is easily seen that the global transmission map Tfintroduced (2) and the shift operator Uy are continuous. The 2D finite CA consists of m×n cells arranged in m rows and n columns, where each cell takes one of the values of 0 or 1. A configuration of the system is an assignment of states to all the cells.

There are nine cells arranged in 3×3 matrix for 2D CA nearest neighbours. Table 1shows the nearest neighbourhood comprises for eight cells with surrounded centre Xij. In that case, the rules are extracted from these matrix as CA rules.

Table 1 - nearest neighbourhood comprises for eight cells with surrounded centre Xij

X{i-1,j+1} (c_64)	X{i,j+1} (c_128)	X{i+1,j+1} (c_256)
X{i-1,j} (c_32)	X{i,j} (c_1)	X{i+1,j} (c_2)
X{i-1,j-1} (c_16)	X(I,j-1} (c_8)	X{i+1,j-1} (c_4)

2.2 Edge detection based on the Mamdani fuzzy inference model

Fuzzy inference model is the main process of mapping from a given input to an output based on fuzzy logic which contains membership function, fuzzy operator and fuzzy rules.

Fuzzy knowledge base system is an expert system that emulates the human expertise in a certain domain based on fuzzy logic instead of Boolean logic. This system uses human knowledge and collected those as dataset to solve problems that ordinary require human expertise. In that case, knowledge of specialist can be transformed into linguistic variables and rules. Facts are represented through linguistic variables and rules that follows fuzzy logic. Fuzzy knowledge base system is a kind of fuzzy expert system that uses fuzzy sets and rules. The rules have this form: IF A is High and B is low; then C is Medium. In that case A and B are inputs variables and C is the output variables and LOW, Medium and High are typical linguistic termsassociated to membership functions defined for input and output variables. The set of rules known as the fuzzy rule base or fuzzy knowledge base. Figure 1 shows the basic architecture of a fuzzy inference system.

For edge detection using a fuzzy inference model, 4 pixelsare selected in a neighbourhood as input that every pixel of them have 2 parts, black and white. Each membership function for black and white is defined using a trapezoidal membership function. These 4 pixelsare linked with neighbour pixels using region growing, as shown in Figure2.

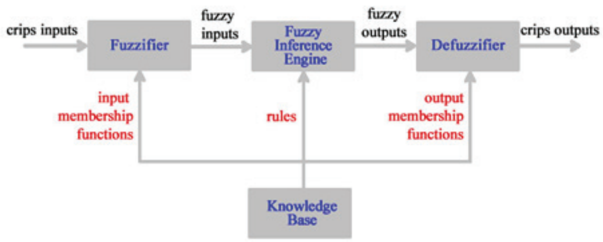

Figure 1: Basic Architecture of a Fuzzy System

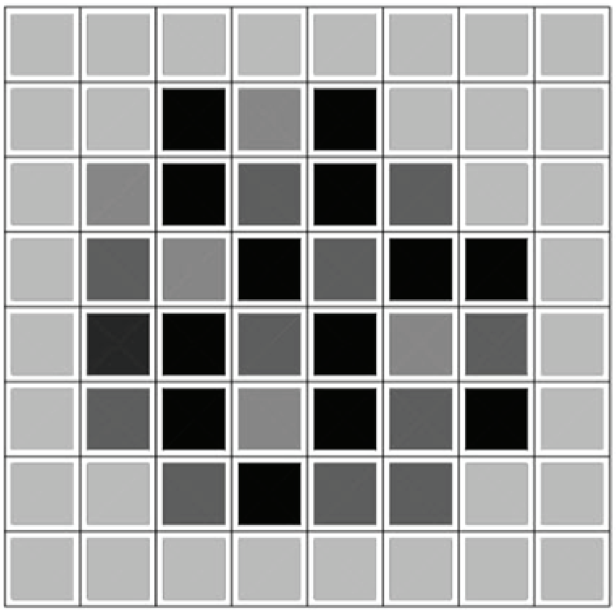

Figure 2:Four pixels and neighbours grow

3 Experimental Results and Performance Evaluation

In this part, the result of the applying the CA and fuzzy rule-based systems for edge detection has been investigated by applying them on images.The rest of this section representsthe implementation details o each model through conducting Study 1 and Study 2.

Study 1)

Edge detection based on the CA methodonBoth RGB and monochromatic images. Classical methods have been applied for edge detection such asCanny, Sobel, Prewitt, and Robert operators on images. At the end to evaluate the proposed technique, best known standard test images are selected and transformed from gray level to the monochromatic structure. This approach for designing rule-changing CA uses two-state CA to deal with monochromatic and RGB images. The proposed method represents a transition rule in a matrix form which can easily be applied to the images by multiplication..In this paper for evaluation purpose, the effectiveness of proposed method for edge detection in images is performedusing the CA rules.

Step 1:

When the program run, the input image with in RGB color mode is converted into gray-scale. This program will be run even choosing gray-scale images as inputAs shown in Figure2.

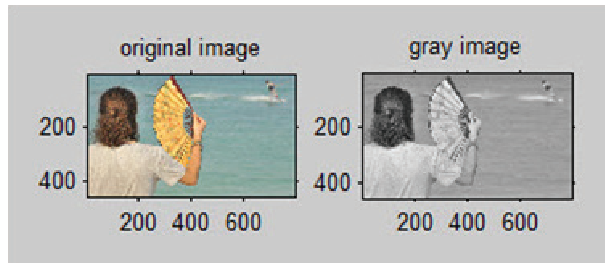

Figure3: input image with grayscale conversion

2. Preprocessing:

After this step, edge detection is started with classical methods like Sobel, Canny, Prewitt and Robert as shown in Figure 3.

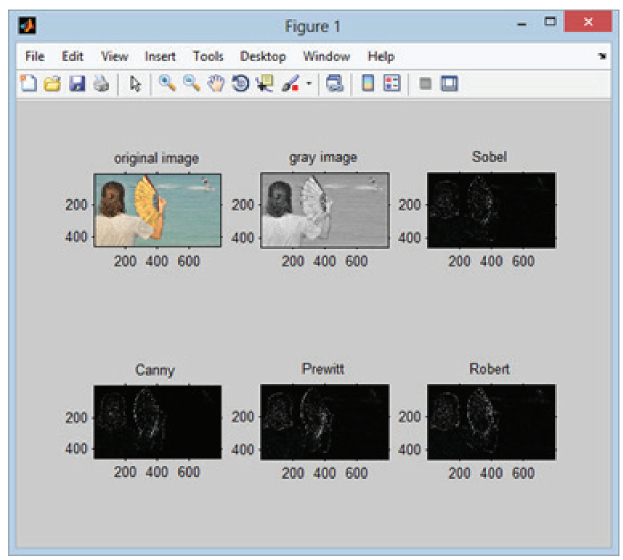

Figure 4: classic methods of edge detection

Apply edge detection based on CA rules: after using the classical methods take effected, the main method , i.e., edge detection by CA rules was appeared in 3 levels as shown in Figures 5 to 7.

TheCAmethod was implemented using command line in MATLAB environment.

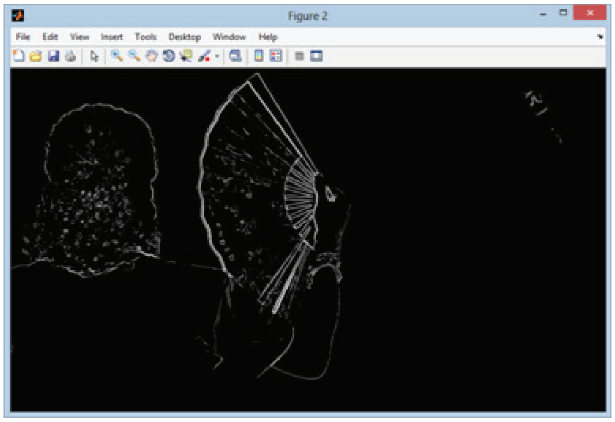

Figure 5: The CA rule, level 1

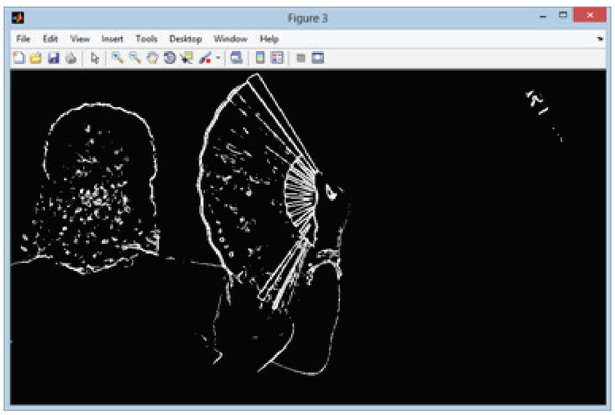

Figure 6: CA rule, level 2

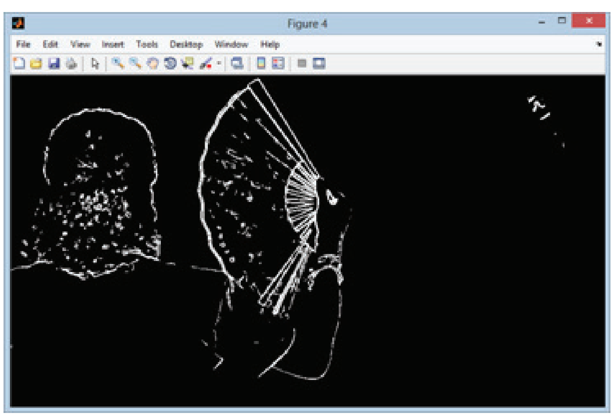

Figure 7: CA rule, final level

Study 2)

Edge detection based on fuzzy inference model: fuzzy 4 pixels selected partis linked with neighbour pixels and using region growing as shown in Figure1. The Implementation of the FIS was conducted using fuzzy logic toolbox in MATLAB.The FIS part have four inputs and one output. The parameters chosen for the FIS are shown in Figure 7.

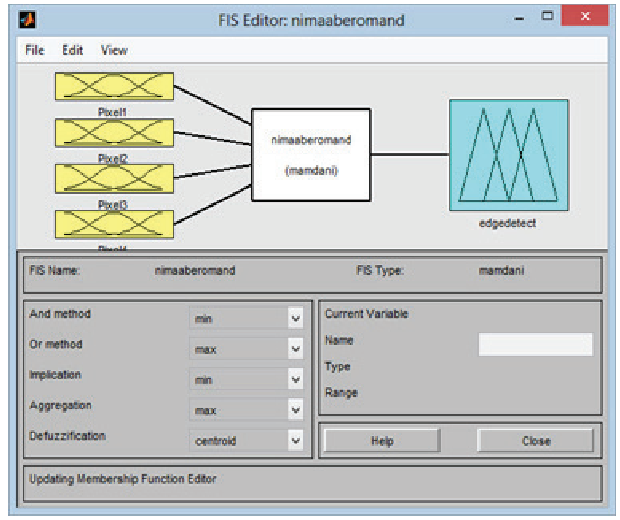

Figure 8:The FIS Parameters in Matlab

Four input variables membership functions are shown in-Figure 8.

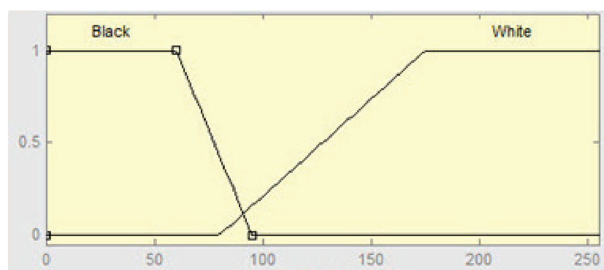

Figure 9: fuzzy membership function of input variable

Output of fuzzy part is shown in Figure 10.

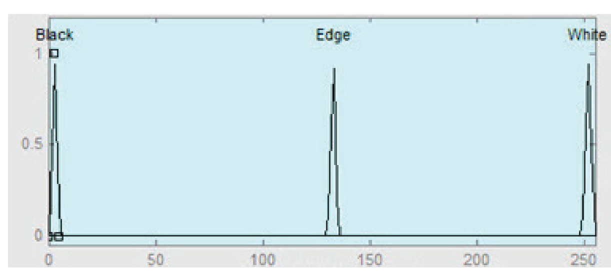

Figure 10: fuzzy output and membership function

After specifyinginput and output fuzzy variables, fuzzy rules are needed.There are 16 rules that they listed in Rule Editor Window in FIS. This method has been applied into 50 matrix images.

4. Comparison of the edge detection methods with the proposed methods

Studies Comparison) this part comparesthe results achieved through conducting two studies for edge detection; i.e. based on the CA and based on the FIS. Notice that the CA results are compared to the classic methods like Sobel, Canny, Robert and Prewitt. Table 2 represents theproposed CA method in comparison with the classical methods. Both methods are tested on the same image and image matrix.

Table 2 – classical methods for edge detection in comparison with the CA

	Sobel	Canny	Robert	Prewitt	CA
MSE	251.20	315.23	391.64	669.64	8.12
PSNR	24.13	23.14	19.87	22.20	14.9
SNR	42.32	41.33	38.06	40.39	33

As show in Table 2, the CA result in terms of MSE, PSNR and SNR is lower than classical methods. The output of the CA was compared with the output of the Fuzzy Mamdaniinference model in Table 3.

Table 3 – CA in comparison with the FIS

	The CA edge Detection	The FIS Edge Detection
MSE	8.12	2.05
PSNR	14.9	5
SNR	33	43

As shown in Table 3 the FIS has better performance fordetecting edges in terms of its MSE and PSNR, but in SNR evaluation, CA is better.

4 Conclusion

This paper presents two approaches for edge detection based on the CA and the FIS. First, edge detection was conducted using nearest neighbor linear cellular automata.Next, a fuzzy inference model was applied for edge detection. Edge detection by transition matrix representation has used as uniform cellular automata for both monochromatic and the RGB images. Rules are based on linear cellular automata for edge detection. Results of the CA are compared to classical methods and evaluation parameters like the MSE, PSNR and SNR, showed that this approach has better performance compared to the other references using a region growing method. The result of CA part was compare with FIS. According to observations of two parts, Fuzzy Mamdani model in terms of the MSE and PSNR criteria has a better performance for detecting edges compared to the CA, but in terms of the SNR evaluation, the CA has a better performance results.

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