Study and Analysis of Edge Detection and Implementation of Fuzzy Set Theory Based Edge Detection Technique in Digital Images

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Abstract – *In this paper, an edge detection method based on fuzzy set theory is proposed. At first the existing edge detection techniques and their disadvantages are studied and then an efficient method is proposed. The method begins with dividing the images into 3x3 windows. The edge pixels are plotted to a range of values separated from each other. The efficiency of the proposed method results for different images are compared to those obtained with the existing methods. It gives a permanent effect in the smoothness and straightness of lines and good roundness for the curved lines. The edges improve incredibly by using cellular learning automata. In the end we compare it with popular edge detection methods such as Sobel and Canny. This edge detection method does not need parameter settings as Canny edge detector does, and it can detect edges more smoothly in a shorter amount of time while other edge detectors cannot.*

Key Words – *Edge Detection, Fuzzy Logic, Heuristic Membership Function, Cellular Automata*.

1. INTRODUCTION

Image processing is an area in artificial intelligence and pattern recognition that has numerous applications in medicine, industry, machine vision, and control. Edge is an image characteristic that is significantly considered as an important feature in image processing and is one of the fundamental subjects in these areas. Many existing edge detection methods make use of the gradient of images and arithmetic operators. For example, methods based on gradient consider edges to be a set of pixels where the gray level has a change in intensity value.

Canny edge detector assumes that edges are step functions corrupted by Additive White Gaussian Noise(AWGN). A disadvantage of these methods is that the neighborhood of an edge is not included in the edge detection process, while in the proposed method, neighborhood plays an important role in edge detection. Ulam and Von Neumann at first proposed Cellular Automata (CA) with the intention of achieving models of biological self-reproduction. After a few years, Amoroso and Fredkin and Cooper described a simple replicator established on parity or modulo-two rules. Lateron, Stephen Wolfram formed the CA theory. Nowadays, CA are widely used in many tasks because of their useful characteristics and various functions. Cellular learning automata are models for systems which consist of simple components and behavior of each component is obtained and reformed upon the behavior of its neighbors and their previous behavior.

The common procedure applied to edge detection problem is the usage of filters. In this case, the edge is considered to be the gray level difference between two neighborhood pixels. It is used to decide in which points in the image the first derivative of the gray level position is of high magnitude. The edges are detected by applying threshold to the new output image. In image analysis, the edges are said to be pixels with a special property. The edge pixels are determined by well-known classical operators such as Sobel, Canny etc. These operators carry out some operations within a window centered on the pixel under investigation.

2. FUZZY SET THEORY

Fuzzy sets have been extensively used in computer vision and machine intelligence. Fuzzy set deals with the imprecision and vagueness embedded in human understanding systems and provides an elegant frame work for describing, analyzing and interpreting the vague and uncertain events. The human vision system is essentially a fuzzy system, since we can understand and interpret the imprecise visual world around us. The conventional set theory is based on a binary valued membership, which implies that a particular element either belongs to a particular set or it does not belong to it. A crisp set is defined as one whose elements fully belong to the set and they possess well-defined common attributes, which can be measured quantitatively. The common attributes are equally shared by all the elements of the set.

In fuzzy sets, the degree of membership of an element to the set is indicated by a membership value which signifies the extent to which the element belongs to the set. The membership value lies between 0 and 1, with membership 0 indicating no membership and 1 indicating full membership of element to the set. In a crisp set, the membership values of its elements are either 0 or 1.The membership assignment is primarily subjective in the sense that the users specify the membership values. In many application the membership is chosen based on an objective criterion. In some situations, probability measures may be used for assigning the membership values.

3. FUZZY IMAGE PROCESSING

Fuzzy image processing is a collection of different fuzzy approaches to image processing. The representation and processing depend on the selected fuzzy technique and on the problem to be solved. Fuzzy image processing has three main stages. Image fuzzification, modification of membership values and image defuzzification.

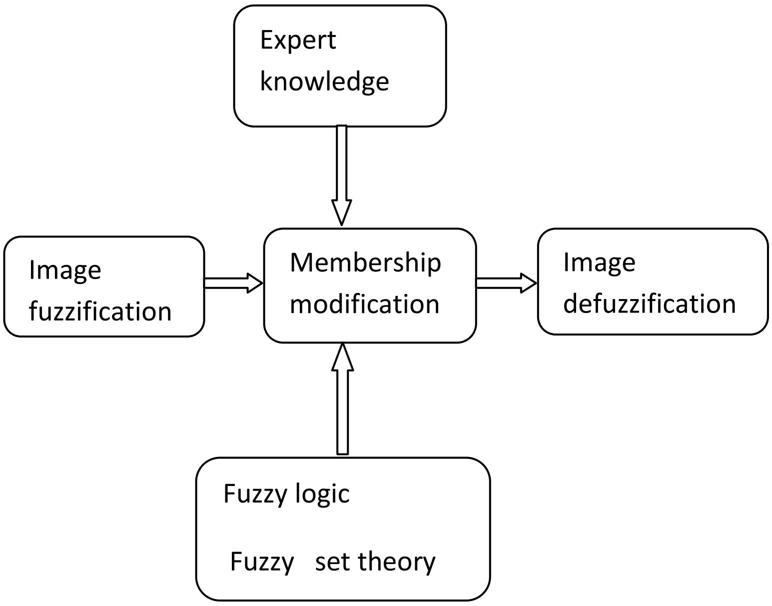


Fig-1: The general structure of fuzzy image processing

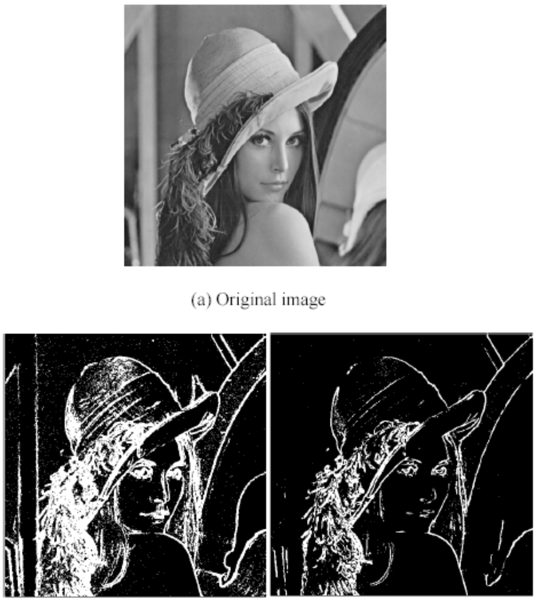
The steps fuzzification and defuzzification are due to the fact that there is no fuzzy hardware. Therefore the coding of image data and the decoding of results make possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step. After the image data are transformed from one gray level plane to membership plane, appropriate fuzzy techniques modify the membership values. This can be a fuzzy clustering, a fuzzy rule based approach, and so on.

4. HEURISTIC MEMBERSHIP FUNCTIONS

The choice of membership function is often determined heuristically and subjectively. In addition to choosing a membership function, we have to construct a set of membership functions for all the fuzzy subsets for each input and each output. A method for determining a proper membership function for each pixel of the image at position *(m,n)* surrounded by a *wxw* window is proposed. Here a formula based on gray level differences in the neighborhood of a pixel surrounded by a 3x3 window is proposed:

$$\mu_{mn} = \frac{\sum_i \sum_j |f_{ij} - f_{mn}|}{\Delta + \sum_i^w \sum_j^w |f_{ij} - f_{mn}|} \qquad (1)$$

where Δ can take any value in *[0,L]*.



(a) Original image

(b) $\Delta = 64$ (b) $\Delta = 128$

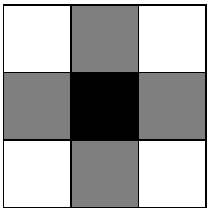
Fig-2: Edge detection with different Δ

5. CELLULAR AUTOMATA

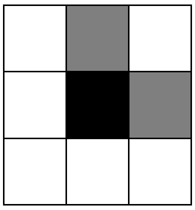
A cellular automaton is a discrete model studied in computability theory, mathematics, physics, complexity science, theoretical biology and microstructure modeling. It consists of a regular grid of cells, each in one of a finite number of states, such as "On" and "Off". The grid can be in any finite number of dimensions. For each cell, a set of cells called its neighborhood is defined relative to the specified cell. For example, the neighborhood of a cell might be defined as the set of cells a distance of 2 or less from the cell. An initial state (time t=0) is selected by assigning a state for each cell. A new generation is created (advancing t by 1), according to some fixed rule that determines the new state of each cell in terms of the current state of the cell and the states of the cells in its neighborhood. For example, the rule might be that the cell is "On" in the next generation if exactly two of the cells in the neighborhood are "On" in the current generation, otherwise the cell is "Off" in the next generation. Typically, the rule for updating the state of cells is the same for each cell and does not change over time, and is applied to the whole grid simultaneously, though exceptions are known.

6. CELLULAR LEARNING AUTOMATA

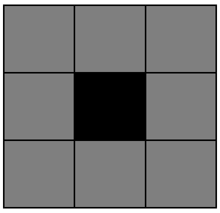
A new system called cellular learning automata is introduced by combining both learning automata and cellular automata. In general, each set of cells can be considered as a neighborhood, but the most common kinds of neighborhoods are Von Neumann, Moore, Smith and Cole, which are known as "nearest neighbors" neighborhoods. These neighborhoods are illustrated in figure 3.



a) Von Neumann



b) Smith



c) Moore

Fig-3: Types of neighborhood

7. PROPOSED METHOD

Fuzzy pre-processing is the group of all methods that known, represent and function the images, their stages and features as fuzzy values. The representation and processing depend on the selected fuzzy equation and on the problem to be solved. Fuzzy image processing has three main stages: image fuzzification, modification of membership values, and image defuzzification. After the image pixels are transferred from gray-level to the membership plane (fuzzification), appropriate fuzzy methods modify the membership values. This can be a fuzzy clustering, a fuzzy rule-based approach, a fuzzy integration The system implementation was carried out considering that the input image and the output image obtained after defuzzification are both 8-bit quantized; this way, their gray levels are always between 0 and 255

In the image that different pixel's value of light is near together or in order hand image is straight, these images have a little edge such as sea's image or sky's image and in image with different pixel's intensity of light; it has a lot of edge. These subject explain the feature extraction that if a image has a little edge its difference of pixels gray level is low and if a image has a lot of edge its variance of pixels gray level is great.

This feature can use for edge determination. For detecting edge with pixel variance is used MOR neighborhood of one pixel as shown in figure 4.

P1	**P2**	**P3**
P4	**P**	**P5**
P6	**P7**	**P8**

Fig- 4: MOR neighborhood for pixel P

In this method, total variance for all pixels of image and mount of variance in MOR neighborhood replaced with centric pixel (P). At the end each pixels variance of MOR neighborhood considered as image edge of original image. Result of this method illustrate in 3 sample image. Edges that detected with this method have high accuracy but fundamental aspect of this method depends on background of something that it isn't edge in edge image. For removing this background can use of optimizes function that this function will amplify edge point and castrate another point that aren't edge.

In this method to determine the length of belonging a pixel to an edge in an image with the dimension of M ×N a fuzzy cellular automata with an M line and N column is used. To demonstrate the enhancement of the performance on the edge detection, with different gray level image of the gear tooth are shown in the figure. The resulting images of our fuzzy technique seem to be much smoother with less noise in the flat areas and sharper in the edgy regions than the conventional Sobel operator.

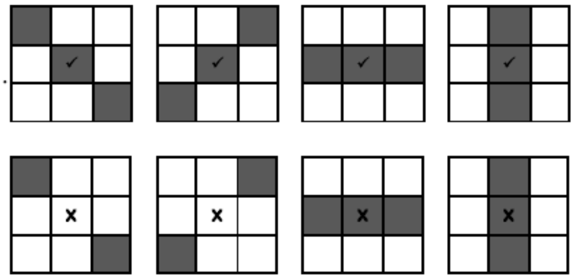
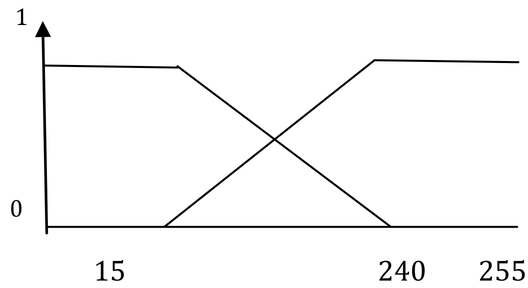


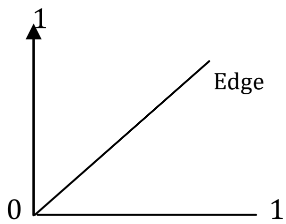
Fig-5: Strengthening and weakening of edges

The last stage of this proposed method depends on the enhancement of the previously measured edging. In this stage it is tried to enhance the edgy image and point out the extra pixels .The unwanted image edges will be also repaired. To reach the mentioned goals, cellular learning automata A with 2 learning automatons will be used in each cell of the image. The following rules is run for each cell:

1. Each cell of cellular learning automata is put on one pixel of image.
2. A probabilistic vector with two values (EDGE, NOT EDGE) is determined to each automaton.
3. The initial value to each vector is done by the pixel gray level and the average value of the image.
4. Each pixel's neighboring MOR is searched to count the number of the pixels which selected the edge order. If the counted number is between 2 and 4 and the pixel itself selects edge order, the EDGE will be rewarded and the NOT EDGE will be fined. Otherwise, the EDGE will be fined and the NOT EDGE will be rewarded.
5. The proposed method is ended when the result of the deducted Entropy of one stage from the former one is less than a defined value.



(a)



(b)

Fig-6: a)Input membership function b)Output membership function

Rule base for α_1 and β_1 is shown in Table 1.

Table-1: Rule base for α_1 and β_1

IF	THEN EDGE
α_1 low and β_1 low	NO
α_1 low and β_1 high	YES
α_1 high and β_1 low	YES
α_1 high and β_1 high	NO

If only two neighbors of the learning automaton consider their pixel as an edge and the central learning automaton does the same, it is rewarded, but if the central learning automaton doesn't consider its pixel as an edge, it is penalized. This is done to improve or weaken separated edges. At each time all cellular learning automaton select a state from their set of states. This selection can be based upon either prior observations or random selection. With respect to neighboring cells and general rules , receives a reward or a penalty. There are three different types of rules in CLA. General, Totalistic and Outer Totalistic. In this type of rules, value of each cell is not taken into account. The image obtained by CLA is more precise than the image obtained in the pre-processing phase. The final image of the pre-processing phase and the image obtained by CLA are shown in Figure 7.

(a) (b)

Fig-7: a) Image obtained after pre-processing b) Final image of CLA

8. EXPERIMENTAL RESULTS

In this section results of the proposed method are discussed. Initially the parameters are defined and then the results are compared to famous edge detection methods like Sobel, Canny etc. Images that are not corrupted by noise are used here. Thefiring order associated with each fuzzy rule were tuned to obtain good results while extracting edges of images. For the segmentation task a thin edge is better because we only want to preserve the edge rather than the details in the neighborhood. The values of the edge map are normalized to the interval of 0 and 1to represent the edginess membership values.

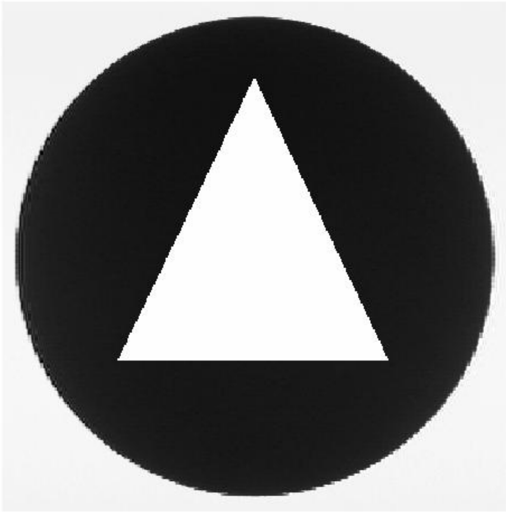


Fig-8: a) Original image

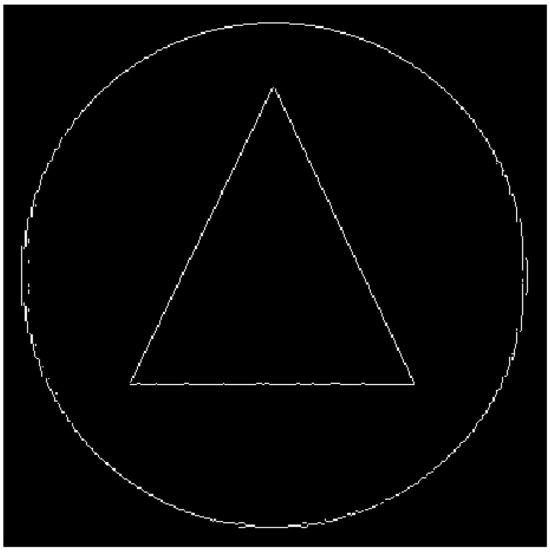


Fig-8: b) Detected edge using Sobel operator

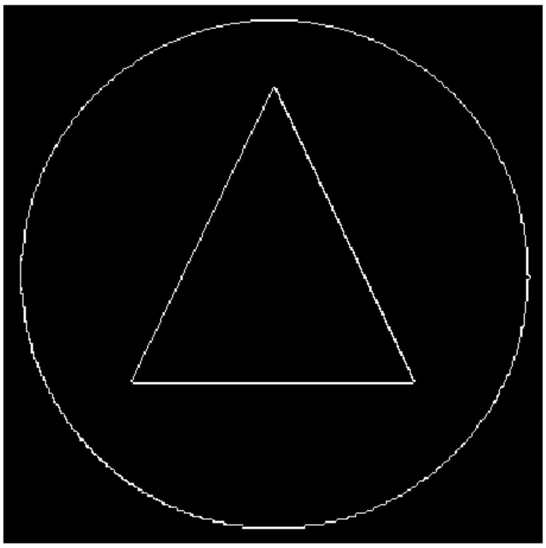


Fig-8: c) Detected edge using proposed method

9. CONCLUSION

In this paper we have proposed a new edge detection method.First the fuzzy membership function is applied and then the edgy image is enhanced by using cellular learning automata.The results exhibit betther performance than conventional methods.By classical methods, the edges of image are not clear but by the proposed method we can improve them.In the future, we will try to apply the method in color images also.

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