Edge Detection Techniques Using Fuzzy Logic

Essa Anas
Digital Signal & Image Processing
University Of Central Lancashire UCLAN
Lancashire, UK
eanas@uclan.a.uk

Abstract—**This article reviews and discusses the fuzzy system implementation as an efficient edges detector for the image. Authors that suggested this method used different ways to feed the fuzzy system and different membership functions that depend on the characteristics of the data input. Some techniques feed the data directly with a 2x2 or 3x3 window others process the data with filters before feeding the fuzzy system. The analysis to the input method revealed that fuzzy system can be coined according to their feeding method to Sliding Window and Preprocessing Kernels fuzzy systems. The article is organized according to this naming and the method of each technique has been discussed. MATLAB codes had been implemented to compare the performance of each method on the same image.**

Keywords—fuzzy logic; edge detection; sliding window;image processing;

I. INTRODUCTION (*HEADING 1*)

During many decades, the topic of edge detection in image processing is gaining a great interest and proved useful in many fields. Application where automated measurements are needed like Robotics, security, computer vision are utilizing edge detection extensively. Edge detection earns more momentum with the increase of the application diversity. Land crop growing images, satellite images and medical images are examples of such applications where edge detection provides an effective way to communicate the information needed in these images [1]. The diversity in the applications motivates researchers to utilize different techniques to reach the performance needed.

In concept, the edge detection process is a way to recognize the edges of an object within the image. This recognition can be achieved by evaluating the gray level deference of the pixels forming the object's boundaries. The problem of the edge detection is that many factors related to the image properties can affect the algorithms performance. Factors like lighting, dynamic background, image geometry and noise level can dramatically reduce the performance of edge detection algorithms [2]. Traditional edge detection kernels like Prewitt and LoG suffer when the image is affected by one or a collection of these mentioned factors. Canny edge detector, however, inherited a filter that can remove the noise[2].

Sponsors: Department of Signal and Image Processing in University of Central Lancashire.

Due to the complexity of the image's information, the algorithms respond differently to the same image grey levels. One algorithm may consider a grey level as a legitimate edge pixel while another may fail to do so. The type of ambiguity in the response led the researches to think about another method where they can find an answer to such uncertainty in the evaluation. Sinha *et al.* first applied the fuzzy logic mathematics into image morphology in the 1990s. Then George *et al.* demonstrate that image processing can utilize fuzzy logic in different aspects of grey pixel processing in 1996. Hu *et al.* applied fuzzy logic in morphology and calculated the edge detection. Adaptive neuro-fuzzy system implemented by Kanchan *et al.* to extract edges from colour images [2]. Barkhoda *et al.* [3] suggested to calculate the image gradient as well as its standard deviation and feed the results as an input to the fuzzy system to evaluate the pixel grey level category [2]. The use of kernels to process the data before feed them to the system fuzzy system started. For instance, Aborisade [4] suggested Low-Pass Filter (LPF) and High-Pass Filter (HPF) as well as and edge detectors as step before feeding the data to the fuzzy system. Similarly, Sun *et al.* [5] used LPF and HPF as well as non-linear (Median) filter as a pretreatment step. Also, Brajpal *et al.* [6] used LPF, HPF and Sobel edge detector at starting and then fed the data to the fuzzy system. Some other researchers applied wavelet transform details, gradient and edge detection entropy before applying the data to the fuzzy system [7]. However, tendency to reduce complexity had been attempted. Agrawal *et al.* [1] used a 3x3 window, and calculate the grey level at each pixel by summing in four directions of that particulate pixel and then feed the (Fig.1). Similarly, [8] suggested a 2x2 window and feed the pixels grey level directly to the a four input fuzzy system.

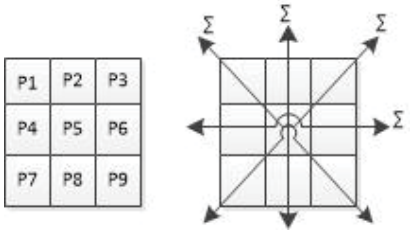


Figure 1: 3x3 window with summation

II. Fuzzy Solution to Edge Detection Problem

The main concept of fuzzy logic started in 1965 by Prof. Lotfi Zadeh. It came to solve decision making problems that uses the approximation that the human brain uses. This function helped many researchers to solve different problems, and the concept had been introduced in many applications. Fuzzy logic is an extended version of the set theory. In fuzzy logic, a member in a group or set has a membership degree which is not always one or zero as the set theory proposes.

Generally, the fuzzy logic techniques used for edge detection in image is based on the concept of dividing the image grey level ranges to three values [9]. These three values represent the entropy maxima that could best describe the image. These values are used to build the membership function of the fuzzy system. Authors used different membership functions to represent the transformation from and to the crisp values. Gaussian is frequently implemented membership function. However, for practical reasons triangle membership function is widely applied [10]. With this concept in mind, researchers build their fuzzy system to target a maximum entropy during their implementation.

In the edge detection problem, the fuzzy system works as thresholding system to increase the discrimination between adjacent pixel points at the edge lines or curves. The resulting grey levels of the image will be in new ranges following the output membership functions. So the gray levels of the pixels are modified to new ranges that are more distinguishable. Such mapping follows IF-THEN set of rules that will control the process. Fig.(2) shows the edge detector block diagram of the fuzzy system. In some cases the authors used different kernels to process the data before presenting them to the system. The fuzzifier stage includes the input membership function where the grey levels of the image are mapped to new set of values. The defuzzifier is the output stage where the values of the grey level are mapped to new crisp values following the rules applied on the mapped input values.

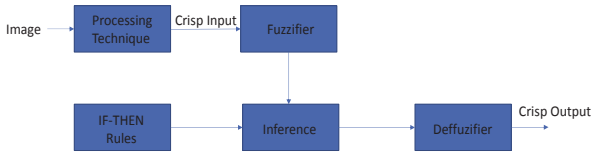


Figure 2: Fuzzy System

A. Fuzzy System Impementation

The implementation of the fuzzy systems as an edge detectors were based on the author's point of view. After reviewing the latest researches, it been noticed that the solutions can be categorized to sliding window solution of kernel based solution. Below is a review of both system and their way of implementation that been used to develop the programs related.

III. Fuzzy System Implementation

The implementation of the fuzzy systems as an edge detectors were based on the author's point of view. After reviewing the latest researches, it been noticed that the solutions can be categorized to sliding window solution of kernel based solution. Below is a review of both system and their way of implementation that been used to develop the programs related.

A. Sliding window

Researchers proposed a sliding window of 2x2 or 3x3 matrix [1],[8] to be fed directly to the fuzzy system. In the case of the 2x2 system, the process starts by feeding four pixels [8] as an input to a four inputs fuzzy system. Authors in [1] suggested to calculate the summation in four directions, and feed the summation values in each direction as an input to the fuzzy system. These input values are with a range from 0 to 1 represent crisp input to the fuzzifier. The membership functions that map these input values are usually identical. In the Inference stage the system applies a set of rules to the mapped values of the grey scale and projects the result according to the output membership function. Fig.(3) represents the input membership functions.

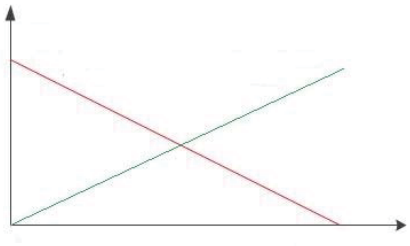


Figure 3: Input Membership function

Fig. (4) represents the output membership functions used in [8]. After this mapping process, the grey level values become more separated which can facilitate the next stage of the first and the second derivative filters to produce the final edge detected image.

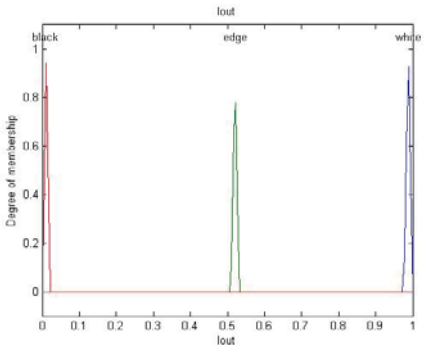


Figure 4: Output Membership function

B. Preprocessing kernel fuzzy system

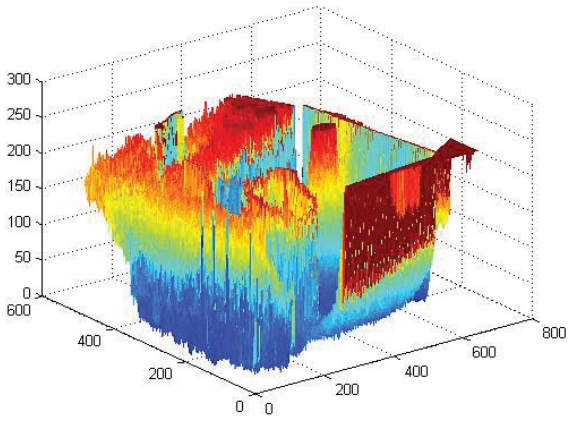
In the aim of improving the edge detection algorithm, other methods and more complicated procedures were introduced. In the articles [4,5,6], the researchers suggesting kernels pre-treatment before applying the data to the fuzzy system and so

the name coined. The kernels used are of 3x3 types, but the fuzzy system has different membership functions and rule sets compared to the ones presented earlier. In this method the more inputs about the same pixel are provided to the fuzzy system. This way allow the system to have more information about the pixel to validate the information. Some researches [4,6] utilized Low Pass Filter (LPF), High Pass Filter (HPF) and Edge Detector kernel to process the image in the input and aggregate the result as crisp input to the fuzzy system for edge detection. The function of the LPF is to remove any unwanted spatial frequencies in the image. Noise represent such type of unwanted frequencies that this filter target. On the other hand, a sudden change in the grey level represents high frequency area. HPF helps to intensify this sudden change which may represent potential edge lines. Choices in [4,6] were Gaussian membership functions for both the fuzzification and the defuzzification stages. However, [5] used four preprocessing kernels; Median, HPF and two Sobel edge detectors (vertical and horizontal) before submitting the data to the fuzzy system. The input membership functions are two Gaussian and one Sigmoid. At the defuzzifier stage, two trapezoidal and one triangle output membership functions are chosen.

IV. Fuzzy system implementation

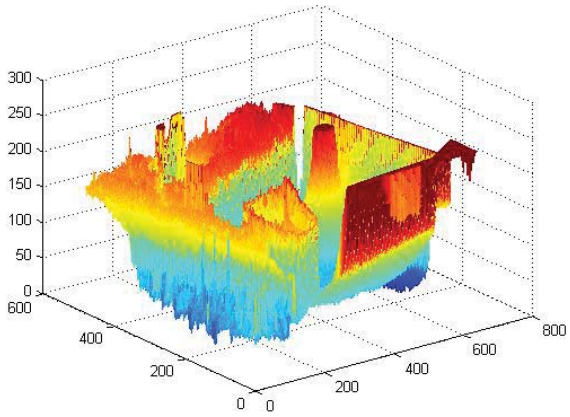
In this section the result obtained from the implementation of the mentioned above techniques has been presented. The setups used in [5] [6] and [8] had been implemented using MatLab. One Sliding Window and two Preprocessing Kernels fuzzy systems are tested against the same image to evaluate their visual performance. In this test we used a 640x480 image (Fig.(5)) to compare results obtained by the mentioned methods and the compare the best results with the well-known zerocrossing edge detector. The original image has different types of backgrounds. Such backgrounds giving different grey level values which allow the fuzzy system weight them differently according to the membership function and the rule sets applied (Fig.(6)). It can be seen the outputs of all the method used have more smooth surfaces and the edges can be recognized easily. After the fuzzy system apply its function, the output had been applied to a zerocrossing edge detector. The results obtained are shown in (Fig.(7)). The first image (Fig.(7.a)) shows the zerocrossing edge detector applied on the fuzzy system output images, and the results of the other method are listed also. It can be seen that all the resulting images shows more the ability to reduce the background in the image. However, system that used Median, HPF and two Sobel kernels provides more robust image, because of continuity and the intensity of the lines produced. It had been noticed also that the Sliding Window is much slower in the execution compared to the Preprocessing Kernels which could be related to the fact that MatLab is optimized for the matrices operations.

(a): Test image

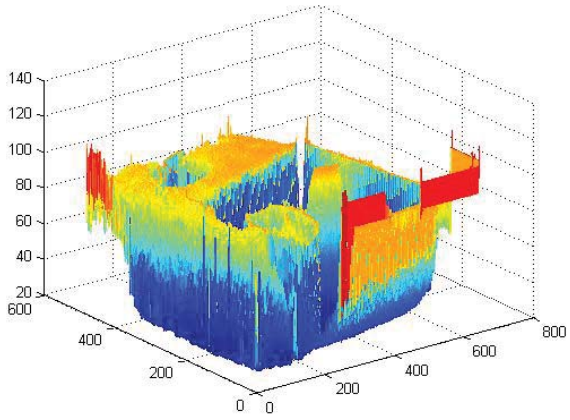


(b): Test image

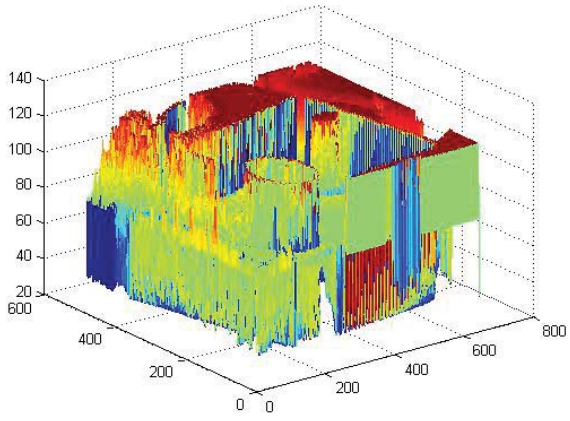
Figure 5 : (a) Test Image and (b) Intensity representation



(a): Sliding window

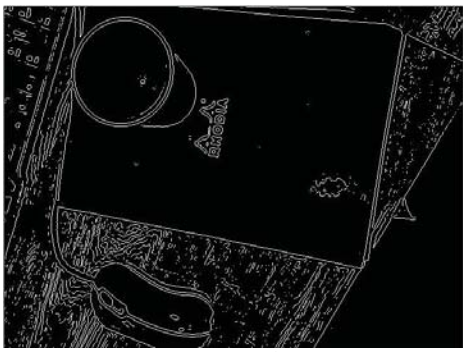


(b): LP-HP-Sobel kernels

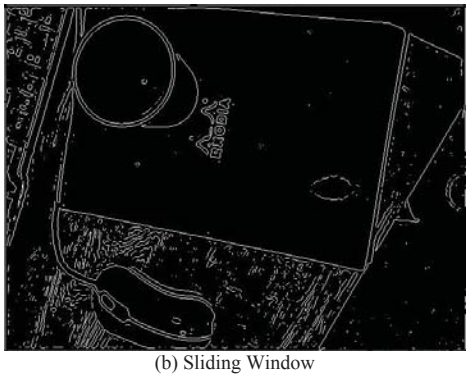


(c): LP-HP-Median Kernels

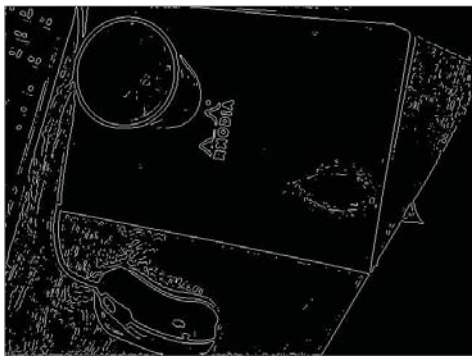
Figure 6: The intensity representation after passing the Fuzzy systems



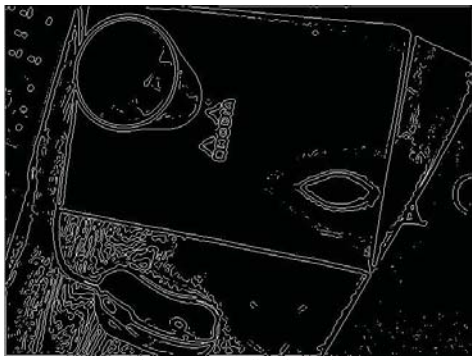
(a) Zerocrossing



(b) Sliding Window



(c) LP-HP-Sobel kernels.



(d) LP-HP-Median kernels.

Figure 7: Edge detection using zerocrossing and Fuzzy methods

V. CONCLUSION

In this work, different implementations of the fuzzy system as an edge detector had been overviewed and compared. The techniques in use are grouped in two approaches according to the feeding method. First, Sliding Window Fuzzy System represent a simplest way of detect an image edges, but the data feeding is slow and hardware may suffer even for small image resolution. Second, Prepossessing Kernels Fuzzy System represents an advance solution and perform better as an edge detector regarding different types of images. The methods presented shows a better capability to recast the image to new grey level and provide a better tool to get better results in the field of the image edge detection.

[a.]

REFERENCES

[1] Neha Agrawal, Rishabh Agrawal, Sushil Kumar: "Fuzzy Edge Filter-Edge Detection and Feature Extraction Technique for Any JPEG Image", *International Journal of Computer Science & Communication*., pp. 387-390, 2010.

[2] S.Lakshmi, V.Sankaranarayanan: "A study of Edge Detection Techniques for Segmentation Computing Approaches", *Computer Aided*

[3] Wafa Barkhoda, Fardin Akhlaqian Tab, Om Kolsoom Shahryari: "Fuzzy edge detection based on pixel's gradient and standard deviation values", *Computer Science and Information Technology, 2009. IMCSIT'09. International Multiconference on*, pp. 7—10, 2009.

[4] D.O Aborisade: "Novel Fuzzy logic Based Edge Detection Technique", *International Journal of Advanced Science and Technology*, pp. 75-82, 2011.

[5] Shuliang Sun, Chenglian Liu, Sisheng Chen: *Fuzzy Inference System – Theory and Applications*. www.intechopen.com, 2012.

[6] Brajpal Singh Jadon, Neelesh Gupta: "Fuzzy Logic Technique in Digital Images using Edge Detection", *International Conference on Cloud, Big Data and Trust*, pp. 192-195, 2013.

[7] Hoda Farag, Said E. El-Khamy: "Rigorous Pack Edge Detection Fuzzy System", *International Journal Of Engineering And Science*, pp. 19-30, 2014

[8] Er Kiranpreet Kaur, Er Vikram Mutenja, Er Inderjeet Singh Gill: "Fuzzy Logic Based Image Edge Detection Algorithm in MATLAB", *International Journal of Computer Applications*, pp. 55-58, 2010.

[9] Mansuo Zhao, Alan Fu, Hong Yan: "A technique of three-level thresholding based on probability partition and fuzzy 3-partition", *Fuzzy Systems, IEEE Transactions on*, pp. 469—479, 2001.

[10] Alavala Chennakesava R.: *Fuzzy Logic and Neural Networks Basic Concepts and Applications*. New Ege International Limited Publications, 2008.

Sponsors: Department of Signal and Image Processing in University of Central Lancashire.