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Fuzzy Inference System for Edge Detection in Flat Electroencephalography Image

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Edge detection is an important step in medical image processing. It aims to mark the point whereby the light intensity changed significantly. The traditional edge detectors such as Prewitt, Robert and Sobel are sensitive towards noise and sometimes inaccurate. Therefore, fuzzy approach is introduced in edge detection in order to overcome the drawbacks. In this paper, fuzzy inference system (FIS) is applied to determine the boundary of the epileptic foci of Flat Electroencephalography (fEEG). The method interprets the values in the input image and according to user defined rules. The input of FIS is obtained from the fEEG input image with three types of filtering such as Sobel operator, high-pass filter and a low pass filter. Furthermore, the performance of the technique is compared with the traditional edge detectors and other fuzzy edge detectors.

Keywords: Edge detection, Flat EEG, fuzzy inference system, fuzzy logic, fuzzy image processing.

I. INTRODUCTION

In image processing, it is important to identify features in an image in order to recognize structure and properties of objects in a scene. Edge is one of the features which has a core role in image processing, image pattern recognition, image analysis, human vision, machine vision analysis and computer vision (Zhai et al. 2008). Edge in an image is the boundaries between two regions and it can help to separate the object and its background clearly. An edge is not a physical entity and it displays just like a shadow. It shows the outline of an object and the difference between the colour and texture. An edge is an essential tool in many areas such as fingerprint recognition, human facial appearance, segmentation lung region, computer-aided diagnosis of medical images and remote sensing image (Rafael et al. 2004). Edge detection is the first stage in image analysis in order to recover information from images. It is an important stage in order to have a complete image understanding system. Edge detection is the study of changes of pixel values which is discontinuous in gray level, colour and texture. In edge detection, there are three main algorithms, gradient measurement, smoothing and localization. Normally, the the gradient

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magnitude in an image is calculated in order to determine edges whereby a grayscale intensity of an image changes the most. Smoothing in edge detection is to remove noise. Localization is a process which intention is to eliminate the number of false edges and edge thinning is usually implemented (Jayaraman 2009).

II. PRELIMINARY CONCEPTS

EEG is a system that measures and records the electrical activity of the brain in graphic form. It reads voltage differences on the head relative to a given point. In order to map the high dimensional signal, namely EEG, into low dimensional space, a method which is known as fEEG was introduced by Zakaria (2008) whereby the EEG coordinate system is defined as

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$$C_{EEG} = \left\{ \left((x,y,z), e_p \right) : x,y,z,e_p \in \Re \text{ and } x^2+y^2+z^2=r^2 \right\} \quad (1)$$

where r is the radius of a patient head and e_p is the electrical potential . The mapping of C_{EEG} to a plane is defined as follows. $S_t : C_{EEG} \to MC$ such that

$$S_t\left((x,y,z), e_p \right) = \left(\frac{rx+iry}{r+z}, e_p \right) = \left(\frac{rx}{r+z}, \frac{ry}{r+z} \right)_{e_p(x,y,z)} \quad (2)$$

whereby the Magnetic Contour $MC = \left\{ \left((x,y)_0, e_p \right) : x,y,e_p \in R \right\}$ is the first component of Fuzzy Topographical Topological Mapping (FTTM). In Zakaria (2008), both C_{EEG} and MC were designed and proven as 2-manifolds. Furthermore, Abdy and Ahmad (2011) transformed the fEEG into image by implementing fuzzy approach as given in Figure 1.

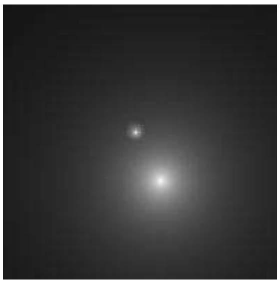


Figure 1. fEEG input image

III. METHODOLOGY

We focus on the edge detection by using techniques of classical first-order edge detector (Sobel operator), fuzzy IF-THEN rules and fuzzy Inference System (FIS). Classical first-order detector filter (Sobel operator), mean filter and high-pass filter are used to obtain the inputs.

A. Image Pre-processing

Sobel operators G_x and G_y are kernels with 3×3 masks which used to estimate the first derivative of image in x and y directions (Cristiano & Adolfo 2001).

$$G_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad , \quad G_y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{3}$$

The high-pass filter *(HP)*, 3×3 is given by

$$HP = \begin{bmatrix} -1 & -2 & -1 \\ -2 & 12 & -2 \\ -1 & -2 & -1 \end{bmatrix} \tag{4}$$

The median filter is defined to ensure that the gray level in each pixel of the output image is the arithmetic mean of the gray levels in 3×3 neighbourhood of the same pixel in the input image.

$$h_M = \text{median} \begin{bmatrix} x_1 & x_2 & x_3 \\ x_4 & x_5 & x_6 \\ x_7 & x_8 & x_9 \end{bmatrix} \tag{5}$$

Then the filtered image will be calculated through a two- dimensional convolution operation:

$$hDH = G_x * I \tag{6}$$

$$hDV = G_y * I \tag{7}$$

$$hHP = HP * I \tag{8}$$

where I is an original image.

Sobel gradient magnitude is calculated by using the kernel *hDH* and *hDV* in (6) and (7) in order to find the absolute magnitude of each point in an image and the formula is given as follows (Sun et al. 2012):

$$Mag = \sqrt{(hDH)^2 + (hDV)^2} \tag{9}$$

B. Fuzzy Inference System (FIS)

The inputs of the FIS is the original image and composed by a high-pass filter, Sobel operator and Sobel magnitude. FIS consists of four functional blocks which are fuzzification, knowledge base, fuzzy inference engine and defuzzification. Fuzzification is the process of conversion from the crisp inputs into degree of match with linguistic values. In knowledge base, there are two bases, rule base and database. A rule base applied the fuzzy if-then rules. A database is the membership function of the fuzzy sets used in the fuzzy rules. Fuzzy Inference Engine is the implementation of the inference operations on the rules. Defuzzification is the conversion of fuzzy domain into crisp domain (Chaira & Ray 2010).

C. Fuzzification

There are three membership function for each selected input which are Z-shaped, Gaussian curve and sigmoid membership functions. The triangular membership function is used for the output variable.

D. Inference Rules Definitions

There are 3 linguistic languages of inputs and outputs, which are low, medium and high. There are 27 fuzzy If-Then rules are designed and shown in Table 1.

E. Defuzzification

Mamdani defuzzifier is used in this process whereby the centroid method is applied since it is known for its accuracy and efficiency [7]. The formula of centroid method is as follows:

$$z = \frac{\sum_{j=1}^{q} z_i u_c\left(z_j\right)}{\sum_{j=1}^{q} u_c\left(z_j\right)} \tag{10}$$

wherebyz is the center of mass and u_c is the membership function in class c at value z_j.

Table 1. If Then Rules for Fuzzy Inference System

hDH	Mag	hHP	hDV	edge
L	L	L	L	L
L	L	M	L	L
L	L	H	L	L
L	M	L	L	L
L	M	M	L	L
L	M	H	L	M
L	H	L	L	L
L	H	M	L	H
L	H	H	L	H
M	L	L	M	L
M	L	M	M	L
M	L	H	M	M
M	M	L	M	M
M	M	M	M	M
M	M	H	M	H
M	H	L	M	M
M	H	M	M	H
M	H	H	H	H
H	L	L	H	L
H	L	M	H	M
H	L	H	H	M

IV. RESULTS AND DISCUSSION

In this section, the output of fEEG images during epileptic seizure are compared based on classical and fuzzy methods for edge detection. Figure 1 is the original fEEG image. The resultant images are shown in Figure 2 to Figure 5. Figure 2 are the output of fEEG images after applying Sobel, Prewitt, and Robert edge detection algorithms. It shows that the two clusters are detected by the bright edged but with many tiny edge lines around the clusters. Figure 3(a) and 3(b) are the results by using Minimum and Maximum operators, respectively. Minimum constructor is able to detect only one cluster clearly. Meanwhile, one cluster is detected clearly in Maximum constructor but with many others unwanted edge lines in the image. The output image by using morphological gradient operation (i.e. dilation-erosian) is given in Figure 4. It shows that both clusters are detected without any other unwanted edge lines around the clusters. However, one of the clusters appears in brighter intensity than the other one. It shows that the morphological operator managed to identify the clusters but in different level of brightness. Meanwhile, Figure 5 shows the output image by applying fuzzy inference system. The results in Figure 5 is better compared to Figure 4 since the clusters can be viewed clearer. Since image processing is problem oriented, the results may be different for different types of images and methods.

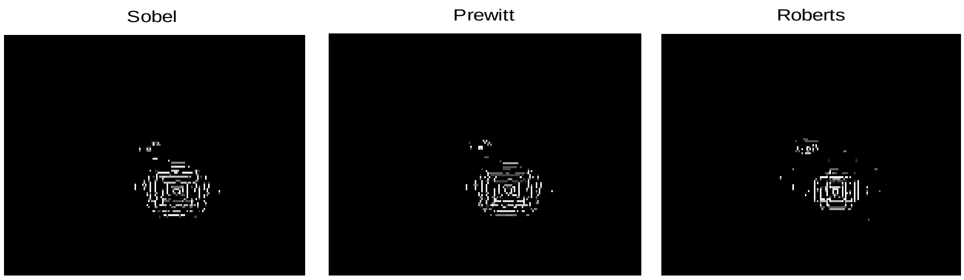
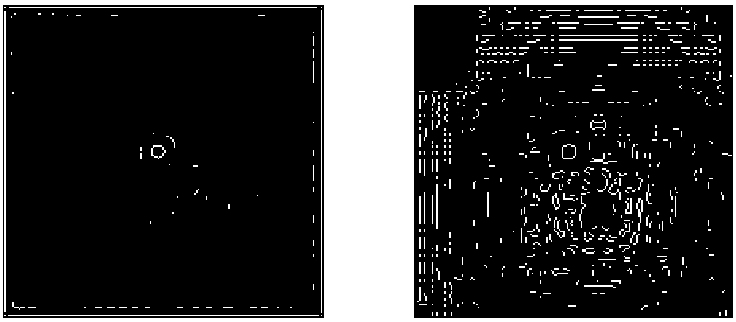


Figure 2. Classical operators



(a) (b)

Figure 3. (a) Minimum constructor (b) Maximum constructor

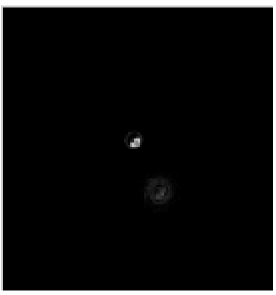


Figure 4. Dilation-erosian operator

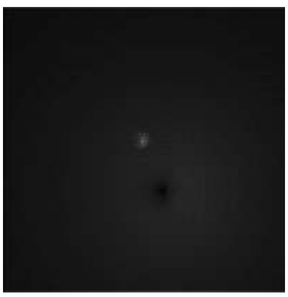


Figure 5. Fuzzy inference system

V. CONCLUSIONS

In this work, the boundary of cluster centres in the original fEEG image can be considered as vague since the sharp boundary was not clearly determined. The vague boundary is represented by different intensity brightness around the clusters. Therefore, the boundary of the cluster centres of fEEG image is detected by using different edge detection algorithms ranging from the classical and fuzzy methods. Each methods gave different edge detection results. Among all the outputs, fuzzy inference system gives better result in detecting the cluster centres with no other false edges around the clusters.

VI. ACKNOWLEDGEMENTS

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