Fuzzy Contrast Enhancement by Intensification Operator in Flat Electroencephalography Image

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ABSTRACT Contrast enhancement plays a major role in image processing. It is applied to improve the visibility or perceptibility of objects by enhancing the brightness difference between objects and their backgrounds. In this paper, the contrast of Flat Electroencephalography (fEEG) image is enhanced by using fuzzy approach. The fEEG image itself is a fuzzy object which is in grayscale. It is originated from a technique known as fEEG which mapped high dimensional signal into low dimensional space. Contrast improvement of fEEG image is done by using Intensification Operator (INT) and New Intensification Operator (NINT). Moreover, the output images are compared for both operators.

KEYWORDS: fEEG image; fuzzy contrast enhancement; Intensification operator.

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INTRODUCTION

An important application of fuzzy image processing is in medical imaging. It is a challenging task since the abnormalities are detected non-invasively. There are various kind of approaches that have been introduced by the researchers from various fields to enhance medical images. Flat Electroencephalography (fEEG) refers to a method that mapped high dimensional Electroencephalography (EEG) signal into low dimensional space (Zakaria, 2008). In the literature, most of the medical images are captured by using medical devices such as X-ray, MRI, CT scan, ultrasound, 3D imaging systems and so forth. However, in Abdy (2014), the EEG signals during epileptic seizures are transformed into image by using fuzzy approach.

Basically, fuzzy image contrast enhancement is a gray level mapping from a gray plane into a fuzzy plane using membership values. The membership values represent the degree of brightness or darkness of the pixels. The membership function is used to find the membership values in an image that lie in the interval [0,1]. New membership values are then generated by using transformation on the membership values. Finally, the new gray values are transformed back to a spatial domain.

In this work, the Intensification Operator (INT) and New Intensification Operator (NINT) are carried out to enhance the contrast of fEEG image and obtain darker background area of the fuzzified images. The INT operator depends only on the membership function. It is applied continuously on an image to obtain the desired enhancement (Zadeh, 1973). This limitation is removed using the NINT which uses a sigmoid function (Hanmandlu *et al.*, 1997). The NINT contains an intensification parameter. The INT and NINT are applied to reduce the fuzziness and increase the image contrast by modifying the membership values.

BACKGROUND THEORY

Electroencephalography (EEG) has been used as a system that measures and records electrical activity of the brain in graphic form (Rudman, 2012). It is a method of visualizing physiology to discover the hidden causes of epilepsy such that it reads voltage differences on the head relative to a given point (Shorvon *et al.*, 2011). Previous study by Zakaria (2008) showed the transformation of the EEG signal into Flat Electroencephalography (fEEG) via flattening method. It is a mathematical technique that involved the mapping from high dimensional signal into low dimensional space whereby it is a method for visualization. Data was collected from epileptic patients by using the EEG. After that, the recorded EEG signal was transformed into fEEG (see Figure 1). In Figure 1, the position of cluster centers are in green colour. Meanwhile, the red colour represents the location of sensors on the surface of the patient's head.

Moreover, previous study by Abdy (2014) showed that the fEEG was transformed into digital fEEG in order to convert it in a form that can be stored in a computer. Next, the digital fEEG was transformed into image by the process of digitization and quantization. The fEEG image itself is a fuzzy object.

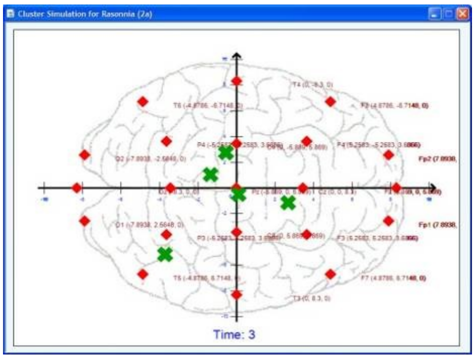


Figure 1. Example of fEEG image

METHODOLOGY

The main aim of this paper is to improve the visibility of the clusters of epileptic foci in terms of contrast enhancement via INT and NINT. Initially, the fEEG input image is fuzzified to convert it from gray plane into a fuzzy plane. In fuzzy plane, the pixel's value is denoted by the membership value which can take values in the closed interval [0, 1]. The membership value $\mu_A(x)$ represents the degree of brightness or darkness of the pixels. After that, the membership value is modified by using the intensifier operators. Finally, the image is transformed into gray plane via defuzzification process. The algorithm is described as follows (Chaira, 2012):

Fuzzy Algorithm

1) fEEG input image is fuzzified by using

$$\mu_A(g_{ij}) = \frac{g_{ij} - g_{\min}}{g_{\max} - g_{\min}}. \tag{1}$$

2) The membership value is modified either by using INT (refer Eq.2) or NINT (refer Eq.3)

$$\mu_A^{enh}(g_{ij}) = \begin{cases} 2\left[\mu_A^{mod}(g_{ij})\right]^2 & if \quad \mu_A^{mod}(g_{ij}) \le 0.5 \\ 1 - 2\left[1 - \mu_A^{mod}(g_{ij})\right]^2 & if \quad 0.5 < \mu_A^{mod}(g_{ij}) \le 1 \end{cases} \tag{2}$$

$$\mu_A^{enh}(g_{ij}) = \frac{1}{1 + e^{-\gamma\left(\mu_{A(g_{ij})} - c\right)}} \tag{3}$$

3) Finally, defuzzification is carried out by using $I = 255 * \mu_A^{enh}(g_{ij})$.

RESULT AND DISCUSSION

The aforementioned algorithm is implemented on fEEG input image for $t = 1$ of size 201x201 (see Figure 2). There are two clusters of electrical current sources that can be observed. The brightness represents the strength of the electrical potential. Figure 3 shows the output images by implementing INT. Whereas the output images for NINT is presented in Figure 4.

Figure 2. fEEG input image

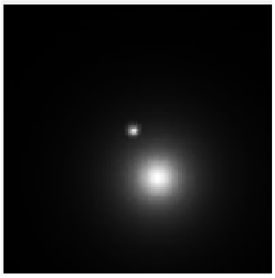
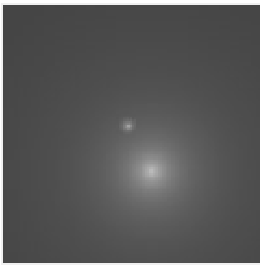
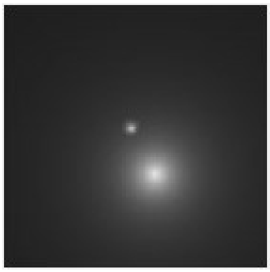


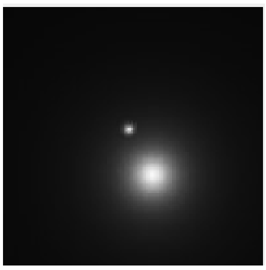
Figure 3. fEEG image processed by INT



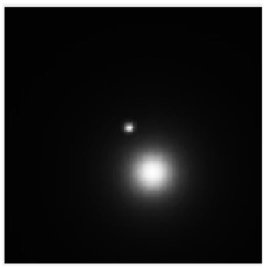
(a) $\gamma = 2$



(b) $\gamma = 4$



(c) $\gamma = 7$



(d) $\gamma = 10$

Figure 4. fEEG image processed by NINT

In Figure 3, the intensifier operator stretches the contrast between the membership values. It transforms the membership values that are above 0.5 to much higher values and the membership values that are lower than 0.5 to much lower values in a nonlinear manner to obtain a good contrast in an image. This INT operator depends only on the membership function. It needs to be applied continuously to obtain a desired, enhanced image. This limitation is removed using NINT operator, which uses a sigmoid function as given in Eq. 3. The output images using NINT operator at various values of γ are depicted in Figure 4. For values $\gamma \geq 5$, the NINT operator has similar response as that of the INT operator. Whereas, for values $\gamma < 5$, the NINT operator has no appreciable influence on the membership function.

Moreover, contrast comparison is carried out for the input and output images based on Wang *et al.* (2004) as follows:

$$c(x,y) = \frac{2\sigma_x\sigma_y}{\sigma_x^2 + \sigma_y^2} \tag{4}$$

whereby σ_x and σ_y are the standard deviations of x and y. The standard deviations measure how similar the contrast between the images. The range value is in the interval $[0,1]$ with the value 1 if and only if the value of the standard deviations are the same. Table 1 shows the contrast comparison between the input and output images of fEEG via INT and NINT. The value of contrast by using INT is 0.4026. For NINT, as the value of parameter γ increases, it shows that the value of contrast tends to deviate from 1. It means that the contrast of output image is different from the input image as the parameter γ increased.

Table 1. Contrast Performance Comparisons.

Method	
INT	NINT
0.4026	$\gamma = 2$; 0.5414
	$\gamma = 4$; 0.4632
	$\gamma = 7$; 0.4159
	$\gamma = 10$; 0.4000

CONCLUSION

In this work, the input image of fEEG is enhanced through contrast enhancement by intensification operator via fuzzy approach. It shows that INT produce fEEG images with darker background but one of the epileptic foci seems bigger in size. The output images by using NINT have similar response as INT operator for values $\gamma \geq 5$.

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