CONTRAST ENHANCEMENT OF FLAT EEG IMAGES VIA INTUITIONISTIC FUZZY APPROACH

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ABSTRACT. *Image enhancement is an initial step in medical imaging before further processing. It is a process to improve the quality of an image which is affected by the presence of noise. Various approaches such as classical and fuzzy methods are used in the area of image processing to obtain the desired output. However, in this paper, an advanced fuzzy approach for contrast enhancement is used. The method is known as intuitionistic fuzzy set (IFS) and it is implemented on flat EEG (fEEG) input images during epileptic seizures. The output images are displayed with different values of parameter lambda,* λ*. Unsmooth output images occurred as* λ *increased.*

KEYWORDS. *Flat EEG, intuitionistic fuzzy set, hesitation degree, contrast enhancements, medical image processing*

INTRODUCTION

Most scholars adopt a classical approach to solving image processing tasks. However, the drawback of this approach is in dealing with uncertainties which arise in reality. Therefore, as an alternative tool, fuzzy set has been used to overcome the problem since it considers the uncertainties. Fuzzy image processing refers to a collection of different fuzzy approaches to image processing that can understand, represent, and process the image. Basically, there are three main steps in fuzzy image processing which are fuzzification, modification of membership function values, and defuzzification. Fuzzy images are characterized by the degree to which each pixel belongs to a particular region (Acharya & Ray, 2005).

Various approaches have been introduced by researchers from different fields to enhance medical images. IFS is one of the approaches used to deal with ambiguity in medical images. The theory introduced by Atanassov in 1983 was an extension of the ordinary fuzzy sets. According to Vlachos and Sergiadis (2007), five main steps have to be considered in the framework of intuitionistic fuzzy image processing, which are fuzzification, intuitionistic fuzzification, modification of intuitionistic fuzzy components, intuitionistic defuzzification, and defuzzification.

In this paper, IFS is used to enhance the image of fEEG. fEEG refers to a method of mapping high dimensional EEG signals into low dimensional space. In (Abdy, 2014) the EEG signals during epileptic seizures are transformed into images using fuzzy approach. In order to minimize the noise and obtain clearer boundaries of the fuzzified images, IFS is carried out to obtain new modified membership values which taking into account the degree of hesitation.

Flat EEG

Flat EEG is a method for mapping high dimensional signals, namely EEG into a low dimensional space. The EEG coordinate system is defined as (Zakaria, 2008)

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

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

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

where $MC=\{((x,y)_0,e_p):x,y,e_p\in R\}$ is the first component of FTTM. Both C_{EEG} and MC were designed and proven as 2-manifolds. Meanwhile S_t is designed to be a one-to-one function as well as being conformal. Details of proofs are contained in (Zakaria, 2008).

Intuitionistic Fuzzy Set

An IFS A in a finite set $X=\{x_1,x_2,\ldots x_n\}$ is defined as $A=\{(x,\mu_A(x),\nu_A(x))|x\in X\}$ whereby $\mu_A(x),\nu_A(x):X\to[0,1]$ represents the membership and non-membership respectively. The necessary conditions that must be fulfilled are as follows (Atanassov, 1986)

$$0\le\mu_A(x)+\nu_A(x)\le 1 \text{ and } \pi_A(x)=1-\mu_A(x)-\nu_A(x) \tag{3}$$

and $0\le\pi_A(x)\le 1$

The occurrence of $\pi_A(x)$ is due to the lack of knowledge about the membership degree or personal error while calculating the distances between two fuzzy sets. The membership value will lie in the interval $[\mu_A(x)-\pi_A(x),\mu_A(x)+\pi_A(x)]$ because of the hesitation that occurs in the membership function (Chaira, 2012).

MATERIALS AND METHODS

In this paper, the enhancement method is based on (Chaira, 2012) wherein a window based enhancement scheme was implemented. The input image is fuzzified using the maximum operator of fuzzy set. The algorithm for the enhancement is described as follows:

Algorithm

1. The image is divided into 4 windows and enhancement is out for each window.
2. The non-membership function is computed by using Sugeno type intuitionistic fuzzy generator as follows:

$$\nu_A(g_{ij})=\frac{1-\mu_A(g_{ij})}{1+\lambda\mu_A(g_{ij})} \tag{4}$$

3. The hesitation degree is given by (from Eq.3):

$$\pi_A(g_{ij})=1-\mu_A(g_{ij})-\frac{1-\mu_A(g_{ij})}{1+\lambda\mu_A(g_{ij})} \tag{5}$$

4. The mean of each window is calculated

5. The modified membership value is given by:

$$\mu_A^{mod}(g_{ij}) = \mu_A(g_{ij}) - mean\ window \times \pi_A(g_{ij}) \quad (6)$$

6. Finally, the contrast enhancement is applied to each window by using the intensifier operator as given by Eq.7:

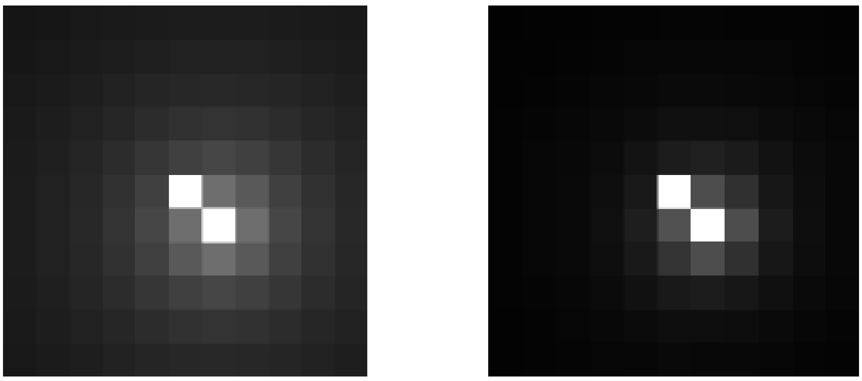
$$\mu_A^{enh}(g_{ij}) = \begin{cases} 2\left[\mu_A^{mod}(g_{ij})\right]^2 & if \quad \mu_A^{mod}(g_{ij}) \le 0.5 \\ 1 - 2\left[1 - \mu_A^{mod}(g_{ij})\right]^2 & if \quad 0.5 < \mu_A^{mod}(g_{ij}) \le 1 \end{cases} \quad (7)$$

In the algorithm, g_{ij} is the $(i, j)^{th}$ gray level of the image.

RESULTS AND DISCUSSION

The enhancement algorithm is implemented on a fEEG image during epileptic seizure at time 1 with size 11x11 (see Figure 1) and 201x201 (see Figure 2). It is observed that the electrical current sources are not clearly detected since Figure 1 has low spatial resolution (11x11 pixels). Meanwhile, higher spatial resolution (201x201 pixels) as in Figure 2, shows that two electrical current sources are visible. In Figure 1 the value of λ is chosen to be 1. Different values of λ are tested for $\lambda = 0.0001$, $\lambda = 0.1$, $\lambda = 1$, $\lambda = 3$, and $\lambda = 10$ (see Figure 2). As λ increases, the non-membership value will decrease and the hesitation degree will increase. The lighter the area means that the value of membership is approaching 1. The value of 1 (white) represents the location of electrical current is exactly there. On the other hand, the darker the area means that the membership value is closed to 0. The black area indicates that there is less or no electrical current evident.

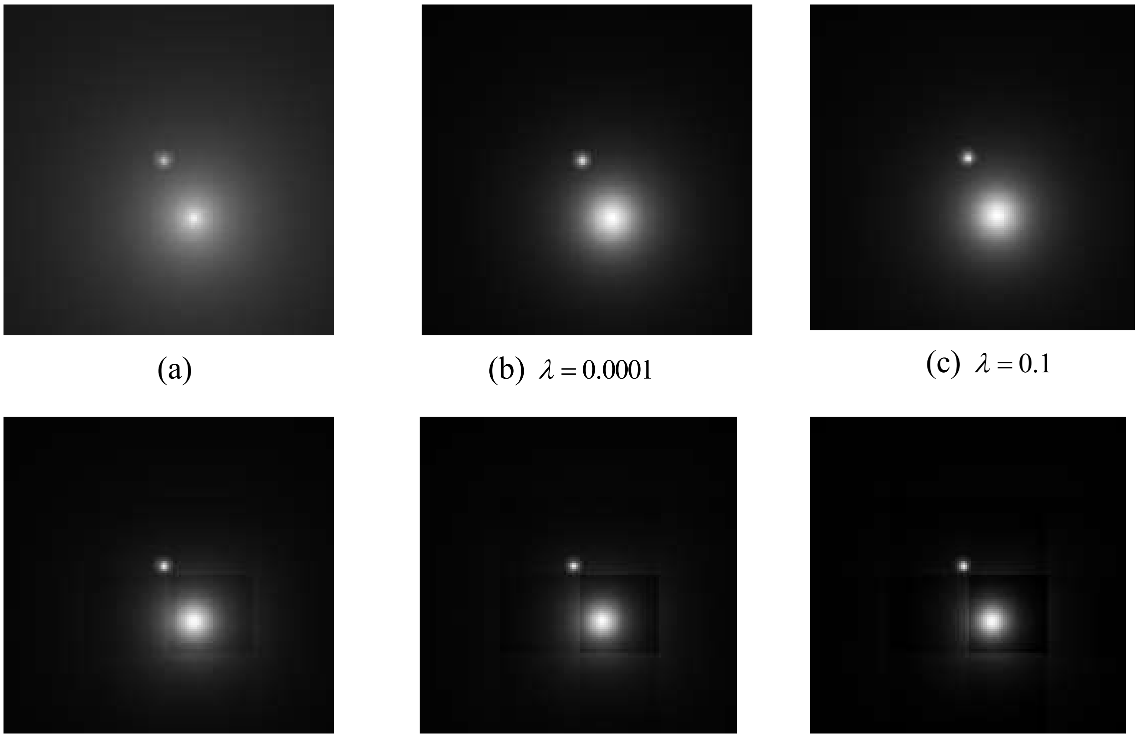
Figure 1(a) shows the input image whereby it is noticed that the region of lighter pixels has a bigger coverage area. Meanwhile, in Figure 1(b), by using the IFS approach, the background become darker narrowing down the domain of electrical sources for that particular area.



(a) (b)

Figure 1: Image of EEG signal during epileptic seizure at time 1 with size of 11x11, (a) input image (b) enhancement by using intuitionistic fuzzy method, $\lambda = 1$

On increasing the spatial resolution, it can be seen clearly that there are two clusters of electrical current sources as given in Figure 2 (a), (b), (c), (d), (e) and (f). Figure 2(a) shows that the lighter area spreads wider and seems closed to the other electrical source point. In Figure 2(b) and 2(c), the two electrical source points seem separated by a darker background area (the darker the intensity or gray level means that few or no electrical sources exist). In Figure 2(b) and 2(c), the spread of the electrical source is reduced compared to Figure 2(a). On increasing the value of λ such as in Figure 2(d), (e) and (f), there exists some noise which lead to unsmooth images.



(a) (b) $\lambda = 0.0001$ (c) $\lambda = 0.1$

(d) $\lambda = 1$ (e) $\lambda = 3$ (f) $\lambda = 10$

Figure 2: Image of EEG signal during epileptic seizure at time 1 with size of 201x201, (a) input image, (b), (c), (d), (e), (f) enhancement by intuitionistic fuzzy method with different values of λ

The histogram of the input image is given in Figure 3. It shows that the pixels are clustered mostly in the range between [30, 50]. Meanwhile, as λ increases, the pixels are closer to the lower gray level values for the output images as given in Figure 4.

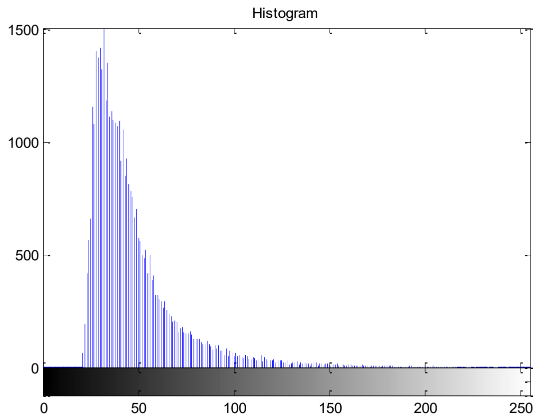
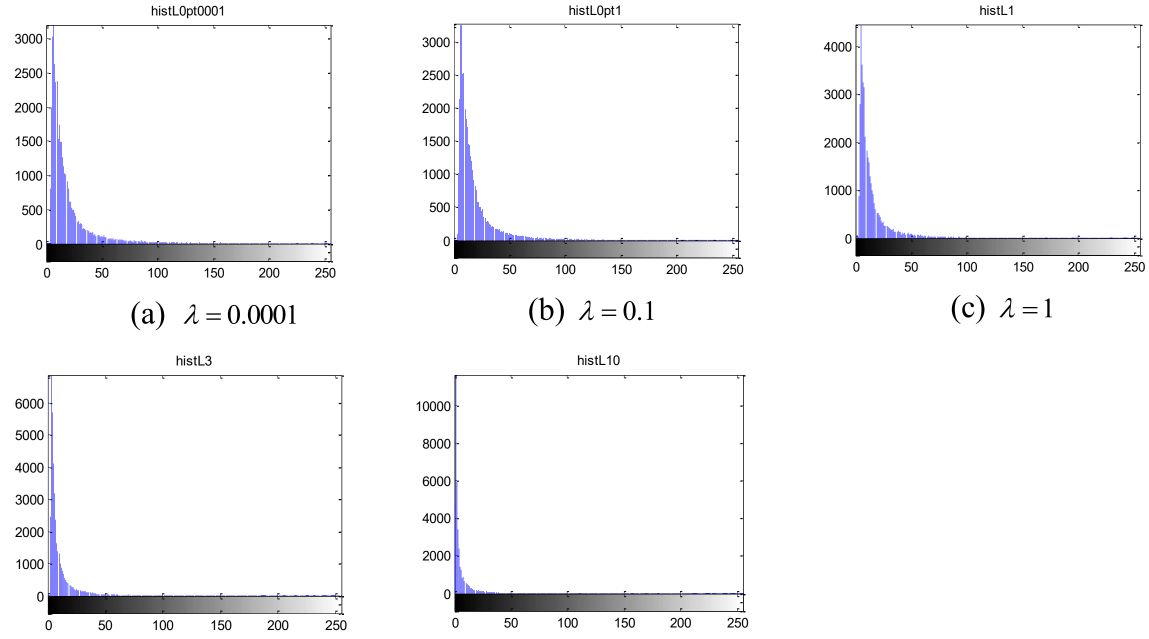


Figure 3: Histogram of the input image



(a) $\lambda = 0.0001$ (b) $\lambda = 0.1$ (c) $\lambda = 1$

(d) $\lambda = 3$ (e) $\lambda = 10$

Figure 4: Histogram of output images

CONCLUSION

In this paper, the image of fEEG is enhanced using IFS approach. This is particularly advantageous especially when visualizing the domains of electrical current sources. Moreover, IFS considers more uncertainties compared to the ordinary fuzzy set, hence better image outputs are obtained.

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