

fEEG Contrast Enhancement: Power Law Transformation vs Intuitionistic Fuzzy Set

Suzelawati Zenian^{1*}, Tahir Ahmad^{2,3} and Amidora Idris³

¹*Department of Mathematics with Computer Graphics, Faculty of Science and Natural Resources, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia.*

²*Centre for Sustainable Nanomaterials, IbnuSina Institute for Scientific and Industrial Research, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Malaysia.*

³*Department of Mathematical Sciences, Faculty of Science, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Malaysia.*

This work focused on contrast enhancement of Flat Electroencephalography (fEEG) image by using Power Law Transformation (PLT) and Intuitionistic Fuzzy Set (IFS). PLT is a classical method whereas the IFS is an advanced fuzzy approach. The values of parameter in both methods are varied to obtain different levels of enhancement. The results show that the IFS is more powerful in preserving the information of the cluster centres as the values of parameter increased.

Keywords: fEEG Image, Intuitionistic Fuzzy Set, Power Law Transformation, Contrast Enhancement.

I. INTRODUCTION

An important application of fuzzy image processing is in medical imaging. It is a challenging task since the abnormalities are detected non-invasively. Various kinds of approaches have been introduced by researchers to enhance medical images. IFS is one of the approaches in dealing with ambiguity in medical images. The theory has been introduced by Atanassov in 1983 which is an extension of the ordinary fuzzy sets (Atanassov, 1986). According to Vlachos and Sergiadis (2007), there are five main steps that 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, there are two methods that are considered to enhance the vague boundaries of the fEEG input image, namely the PLT and IFS. Both methods have different concepts which are non-

fuzzy and advanced fuzzy methods, respectively. In the input image, the brightness that surrounded the foci represents the strength of the electrical potential. The aim of this work is to obtain a clearer boundary or reduce the spread of the electrical potential yet at the same time able to preserve the information of the foci. In 2008, Zakaria introduced the fEEG whereby it mapped high dimensional EEG signal into low dimensional space (Zakaria, 2008). Furthermore, in 2014, the EEG signals during epileptic seizures were transformed into image by using fuzzy approach which was carried out by Abdy (2014). The acquisition of the fEEG image is different from most of the other images since there is no any imaging devices involved. So far, 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. Therefore, in order to minimize the noise and obtain clearer boundaries of the fEEG images, IFS is carried out to obtain new modified membership values which

*Corresponding author's e-mail: suzela@ums.edu.my

considered the hesitation degree. Comparisons are made between both methods which are non-fuzzy and fuzzy.

II. PRELIMINARY CONCEPTS

Electroencephalography (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

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

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 $S_t : C_{EEG} \rightarrow MC$ 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 (2014) transformed the fEEG into image by implementing fuzzy approach.

III. METHODOLOGY

The main aim of this paper is to improve the visibility of the clusters of epileptic foci in terms of contrast enhancement via PLT and IFS. The vague boundaries of the foci which represents the spread of the electrical strength are reduced in both methods. Both methods are briefly described as follows:

A. Power Law Transformation (PLT)

The PLT is a nonlinear function which is useful for

general-purpose contrast manipulation. It can be described as (Marques, 2011)

$$s = c \cdot r^\lambda \quad (3)$$

where r is the input pixel value, s is the output pixel value, c is a scaling constant, and λ is a positive value. Different values of λ give different levels of enhancement whereby a family of possible transformation curves can be obtained.

B. IFS Algorithm

An IFS A in a finite set X may be represented as

$$A = \left\{ \left(x, \mu_A(x), \nu_A(x) \right) \mid x \in X \right\} \quad \text{where}$$

$\mu_A(x), \nu_A(x) : X \rightarrow [0,1]$ are membership and non-membership function, respectively, with the necessary condition

$$0 \leq \mu_A(x) + \nu_A(x) \leq 1 \quad \text{and}$$

$\mu_A(x) + \nu_A(x) + \pi_A(x) = 1$. The enhancement is carried out as follows (Chaira, 2012):

- 1) fEEG input image is fuzzified by using

$$\mu_A(x) = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \quad (4)$$

- 2) The non-membership function $\nu_A(x)$ is computed by using Sugeno type intuitionistic fuzzy generator

$$\nu_A(x) = \frac{1 - \mu_A(x)}{1 + \lambda \mu_A(x)}, \quad \lambda > 0 \quad (5)$$

- 3) The hesitation degree is obtained by using

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x) \quad (6)$$

- 4) The mean of the image is calculated

- 5) The modified membership value is given by

$$\mu_A^{mod}(x) = \mu_A(x) - mean \times \pi_A(x) \quad (7)$$

- 6) The contrast stretching is applied by using the intensifier operator

$$\mu_A^{enh}(x) = \begin{cases} 2[\mu_A^{mod}(x)]^2 & \text{if } \mu_A^{mod}(x) \leq 0.5 \\ 1 - 2[1 - \mu_A^{mod}(x)]^2 & \text{if } 0.5 < \mu_A^{mod}(x) \leq 1 \end{cases} \quad (8)$$

IV. RESULTS AND DISCUSSION

The aforementioned algorithms are implemented on fEEG input image for $t = 2$ of size 201x201 (see Figure 1). There are two clusters of electrical current sources that can be observed in Figure 1. The brightness represents the strength of the electrical potential. Figure 2 shows the output images by implementing PLT whereas the output images for intuitionistic fuzzy approach with different values of parameter λ are presented in Figure 3, respectively. From Figure 2 and Figure 3, it can be observed that both methods are able to produce fEEG images with darker background area. The spread of the electrical potential has been reduced resulting in a smaller area of the vague boundaries. However, in PLT, the cluster centres start to disappear as the value of parameter λ increased. On the other hand, IFS is able to preserve the information of the clusters centres even though the value of λ increased. It shows that the advanced fuzzy method is more powerful in preserving the information of the cluster centres compared to non-fuzzy method as the values of the parameter increased.

Furthermore, the Structural Similarity index (SSIM) is carried out to measure the similarity between input and output images. The formula is given in Eq. (9) as follows (Wang et al., 2004):

$$ssim(x, y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (9)$$

where μ_x and μ_y are local sample means of x and y , respectively. σ_x and σ_y are local sample standard deviations of x and y , respectively. σ_{xy} is local sample correlation coefficient between x and y . c_1 and c_2 are constants. SSIM with zero value indicates that there is no correlation between input and output images. Whereas SSIM with value one represents that the input and output images are the same. Table 1 shows the performance comparisons between PLT and IFS using SSIM. Based on the results, the SSIM value using PLT is higher compared to IFS for $\lambda = 0.5$ till $\lambda = 2$. However, the SSIM value for PLT start to decrease dramatically at $\lambda = 3$. The values continue decreasing and approaching zero starting at $\lambda = 4$ till $\lambda = 20$. The input and output images are the same for PLT at $\lambda = 1$. At $\lambda = 0.5$, the vague boundaries spread widely for PLT compared to IFS. Meanwhile, the SSIM values for IFS continuously decrease slowly as the values of λ increased which shows the difference between the input and output images.

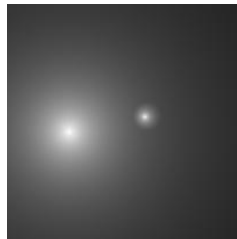
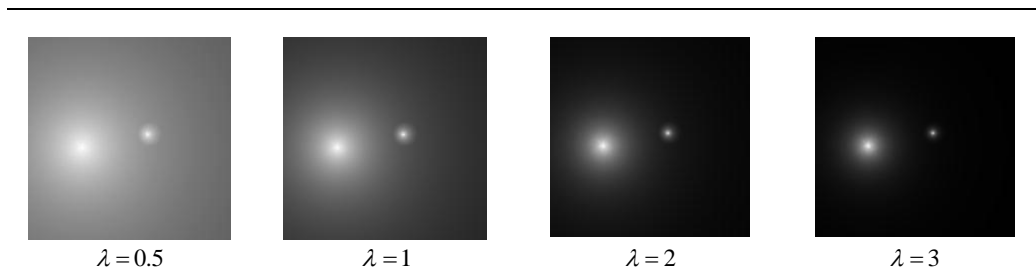


Figure 1. fEEG input image at $t = 2$



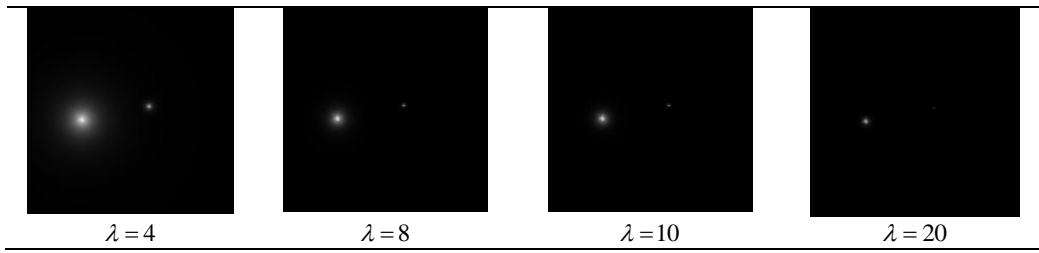


Figure 2. fEEG image processed by PLT with different values of λ

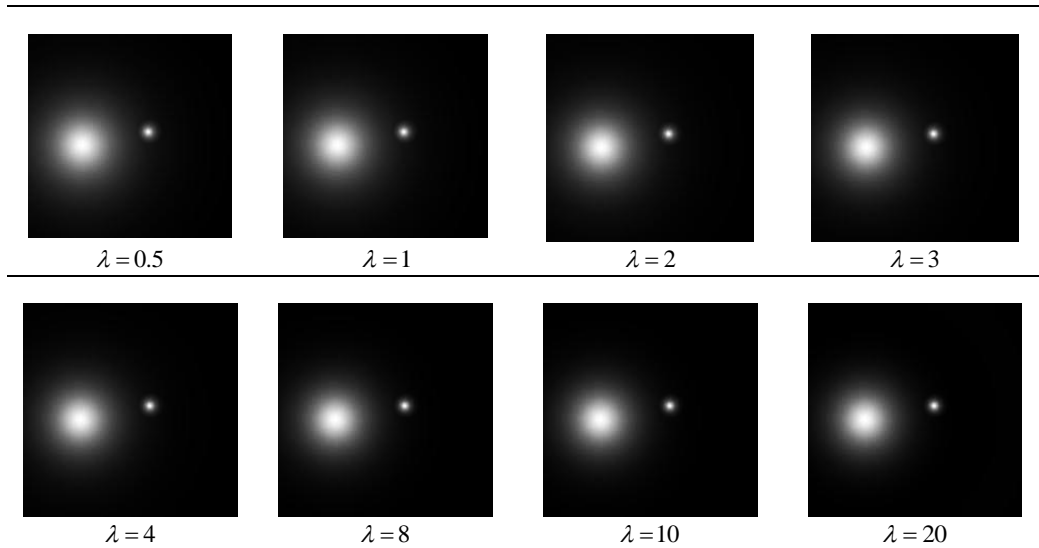


Figure 3. fEEG image processed by IFS with different values of λ

Table 1. SSIM comparisons for PLT and IFS with different values of λ

Values of λ	PLT	IFS
0.5	0.816285	0.343301
1	1.000000	0.317671
2	0.528118	0.277464
3	0.195807	0.247359
4	0.080544	0.226255
8	0.009160	0.181801
10	0.005441	0.171841
20	0.002165	0.157820

V. CONCLUSIONS

In this work, the input image of fEEG is enhanced through contrast enhancement by classical and intuitionistic fuzzy approaches. Both methods are able to decrease the spread of the vague boundaries for particular values of λ . However, the drawback of the PLT is in preserving the cluster centres

as the value of λ increased. On the other hand, the IFS able to maintain the cluster centres for all tested values of λ .

VI. ACKNOWLEDGEMENTS

The authors would like to express heartfelt thanks to Universiti Malaysia Sabah for providing financial support under UMS Research Grant (SLB0154-2017).

VII. REFERENCES

- Abdy, M. 2014. "Fuzzy digital topological space and image of Flat Electroencephalography during seizure". Ph.D thesis. Universiti Teknologi Malaysia.
- Atanassov, K.T. 1986. *Intuitionistic fuzzy sets. J.Fuzzy sets and systems*.**20**, pp. 87-96.
- Chaira, T. 2012. *Medical image enhancement using intuitionistic fuzzy set*. In *1st Int. Conf. on Recent Advances in Information Technology (RAIT-2012)*. pp 54-57.
- Marques, O. 2011. *Practical image and video processing using Matlab*. John Wiley & Sons.
- Vlachos, I.K., Sergiadis, G.D. 2007. Intuitionistic Fuzzy Image Processing. In: Nachtgeael, M., Van der Weken, D., Kerre, E., Philips, W. (eds.) *Soft Computing in Image Processing*. **210**, pp. 383-414. Springer, Heidelberg.
- Wang, Z., Bovik, A.C., Sheikh, H.R., and Simoncelli, E.P. 2004. Image Quality Assessment: From Error Visibility to Structural Similarity . *IEEE Transactions on Image Processing*. **13(4)**, pp. 600-612.
- Zakaria, F. 2008. "Dynamic profiling of EEG data during seizure using fuzzy information space". Ph.D thesis. Universiti Teknologi Malaysia.