Flat Electroencephalography Image: Image Size Dependent Normalization versus Fuzzy Technique

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Abstract. Flat Electroencephalography (fEEG) is a method for mapping high dimensional signal, namely Electroencephalography (EEG) into a low dimensional space. The image of fEEG which is in grayscale form is obtained from digital fEEG by using fuzzy approach. The main aim of this paper is to reduce the spread of the vague boundary and improve the visibility of the clusters of epileptic foci in terms of contrast enhancement via Image Size Dependent Normalization (ISDN) and fuzzy technique. Contrast performance comparison between both methods are carried out for an epileptic patient at varied time, t. It shows that fuzzy method gives better contrast compared to ISDN.

1. Introduction

An image that is represented by a group of pixels is called a digital image. Image processing is a method to perform some operations on an image in order to obtain the desired outputs. It may be divided into two different domains which are classical and fuzzy domains. Classical image processing basically includes three steps such as image acquisition, analysing and manipulating the image, and output image in which result can be an altered image. Meanwhile, fuzzy image processing deals with images in fuzzy domain. There are three main steps involved which are image fuzzification, membership modification, and image defuzzification.

In 2008, Zakaria [1] has formulated fundamental ideas to describe an epileptic seizure as a system that is represented by its motion or a dynamic physical process which is known as fEEG. In the study, data was collected from epileptic patients by using EEG. EEG recorded the electrical activities in the brain. After that, the recorded EEG signal (see Figure 1) was transformed into fEEG whereby fEEG is a method for visualization. The fEEG mapped high dimensional signal, namely EEG into low dimensional space. The main scientific value lies in the ability to preserve information about the surface.

Moreover, the EEG signals can be compressed and analyzed via the fEEG method. Figure 2 shows an example of fEEG of an epileptic patient. Furthermore, in Abdy [2], 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.
2. Methodology

Both ISDN and fuzzy methods have different concepts which are based on classical and fuzzy theory, respectively. The details of the methods are presented as follows:

2.1. Image Size Dependent Normalization

The method is applied directly to the entire image and normalized the image based on its size in the spatial domain. There are two factors that are considered which are speed and efficiency to ensure a fast processing with effective results. In [3], the technique is applied in enhancing the contrast of computed tomography (CT) medical images. In this method, the size of the processed image is determined. The enhancement variable $K$ is used to enhance the brightness of the pixels as follows [3]:

$$K = \frac{\sum_{i=1}^{i} \sum_{j=1}^{j} x(i,j)}{m \times n} \quad (1)$$

Moreover, the enhanced image is obtained by equation (2) as follows

$$E = \left[ x - \min(x) \times e^k \right] \left[ \max(x) - \min(x) \right] \quad (2)$$

whereby the degraded image is denoted by $x$, $K$ is the enhancement variable, $E$ is the contrast improved image, and the minimum and maximum pixel values of the processed image is denoted by $(\min, \max)$.

2.2. Fuzzy Contrast Enhancement

Initially, the fEEG input image is fuzzified to convert it from gray plane into 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 operator. Finally, the image is transformed into gray plane via defuzzification process as follows [4]

1) fEEG input image is fuzzified by using

$$\mu_A(g_y) = \frac{g_y - g_{min}}{g_{max} - g_{min}} \quad (3)$$
2) The membership value is modified by using intensifier operator

\[
\mu_{A^{enh}}(g_y) = \begin{cases} 
2\left[\mu_{A^mod}(g_y)\right]^2 & \text{if } \mu_{A^mod}(g_y) \leq 0.5 \\
1 - 2\left[1 - \mu_{A^mod}(g_y)\right]^2 & \text{if } 0.5 < \mu_{A^mod}(g_y) \leq 1
\end{cases}
\]  

Finally, defuzzification is carried out by using \( I = 255 \cdot \mu_{A^{enh}}(g_y) \).

3. Results

The aforementioned algorithm is implemented on fEEG input image at time \( t = 1 \) to \( t = 4 \) of size 201x201 (see figure 3). The brightness represents the strength of the electrical potential. Figure 4 shows the output images by implementing ISDN technique at time \( t = 1 \) to \( t = 4 \). Meanwhile the output images by using fuzzy technique at time \( t = 1 \) to \( t = 4 \) are presented in figure 5.

![Figure 3. fEEG input image for \( t = 1 \) to \( t = 4 \).](image_url1)

![Figure 4. fEEG image processed by Image Size Dependent Normalization technique.](image_url2)

![Figure 5. fEEG image processed by fuzzy contrast enhancement.](image_url3)

Moreover, contrast comparison is carried out for the input and output images based on Wang and Alan [5] as follows:
whereby \( \sigma_x \) and \( \sigma_y \) 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 best value 1 if and only if the value of the standard deviations is the same. Table 1 shows the contrast comparison between the input and output images of fEEG via classical method namely ISDN and fuzzy approach. The value of contrast by using fuzzy method is closer to 1 compared to ISDN. It means that the contrast of the output images by using fuzzy method is near to the input images.

| Time, \( t \) | ISDN | Fuzzy |
|--------------|------|-------|
| 1            | 0.9506 | 0.9918 |
| 2            | 0.9030 | 0.9607 |
| 3            | 0.7950 | 0.8647 |
| 4            | 0.8670 | 0.9233 |

### 4. Conclusions

In this work, the input image of fEEG is enhanced through contrast enhancement by using classical and fuzzy approaches. It shows that both techniques are able to produce fEEG images with darker background area. However, fuzzy technique shows that the spread of the electrical potential has been reduced resulting in a smaller area of the vague boundaries. Meanwhile ISDN brighten up the area of the cluster centres resulting in a bigger size of clusters compared to the input images.

### 5. References

[1] Zakaria F 2008 Dynamic profiling of EEG data during seizure using fuzzy information space Ph.D thesis (Universiti Teknologi Malaysia)

[2] Abdy M 2014 Fuzzy digital topological space and image of Flat Electroencephalography during seizure Ph.D thesis (Universiti Teknologi Malaysia)

[3] Zohair A, Sulong G and Johar M G M 2012 Enhancing the contrast of CT medical images by employing a novel Image Size Dependent Normalization technique 4 pp 63-8

[4] Chaira T and Ray A K 2010 Fuzzy image processing and application with Matlab CRC Press Inc.

[5] Wang Z and Alan C B 2002 A Universal Image Quality Index IEEE Signal Processing Letters 9 pp 81-4

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