# Advanced Fuzzy Set: An Application to Flat Electroencephalography Image

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**Abstract.** Epileptic seizures refer to temporary disturbance in the electrical activity of the brain. The real time electrical activities of the cortical and subcortical neuronal activity are recorded by using Electroencephalogram (EEG) whereby few specific electrodes are placed on the scalp. EEG measures the differential voltage fluctuations resulting from ionic current flows within the neurons of the brain and can detect the changes over milliseconds. In this study, the image form of the EEG signals known as Flat EEG image is carried out. The advanced fuzzy techniques namely intuitionistic fuzzy set (IFS) and type-2 fuzzy set are explored to enhance the image of Flat EEG. The parameter in intuitionistic fuzzy image is optimized using intuitionistic fuzzy entropy. Whereas Hamacher t-conorm is applied for type-2 fuzzy enhancement. Experimental results on Flat EEG input images at two different time show that type-2 produced better output images compared to intuitionistic fuzzy methods.

**Keywords:** Flat EEG; intuitionistic fuzzy set; type-2 fuzzy set; uncertainty; image enhancement.

## 1 Introduction

The existence of uncertainty in our daily life is an essential and unavoidable. The uncertainty occurs in the precision that we seek. Therefore, there is a strong relationship between precision and uncertainty. In 1965, Zadeh introduced fuzzy set theory which is a fundamental approach in modeling uncertainty and provides a formal way in describing real world phenomena. Zadeh [1] mentioned that in the real world, the membership values for the classes of objects are not always precisely defined. Thus, there exists sets which do not have exact determined boundary. Since then, it has enlivened the notion to explore more on powerful tools in order to deal with uncertainties and imprecision.

The ordinary (type-1) fuzzy set considers only one uncertainty which is the membership function that is user defined. Different results are obtained by different

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R. Alfred et al. (eds.), *Computational Science and Technology*,
Lecture Notes in Electrical Engineering 603,
https://doi.org/10.1007/978-981-15-0058-9_62

membership functions. Thus, there is uncertainty involved in defining the membership function. That is why the extension of ordinary fuzzy set is introduced to represent the uncertainty in a better way. The emergence of advanced fuzzy set is to consider more or different types of uncertainties. In 1975, Zadeh introduced type-2 fuzzy set which considered the uncertainty in the membership function of type-1 fuzzy set. Thus, the membership function is not a single value but rather than an interval [2]. Meanwhile, the intuitionistic fuzzy set considers more uncertainties in terms of membership and non-membership functions. The intuitionistic fuzzy set was introduced by Atanassov in 1983 [3].

One of the applications of fuzzy set is in image processing. Image processing is used to enhance visual appearance of images since the pixel values of an image may not be precise as uncertainty arises within the gray values of an image due to several factors. Prewitt is probably the first person to realize the importance of incorporating fuzzy theory in image processing. Pioneer research on the applications of fuzzy set theory in image processing was carried out by Pal et al. and Rosenfeld in the 1980s [4].

In this study, the uncertainties might occur during the process of imaging and transformation such as Flat EEG since the regions of clusters in Flat EEG are not always defined. The digital Flat EEG itself is a fuzzy object which has been proven in details by Abdy [5]. Hence, the boundary area of the epileptic foci which is represented in the shades of gray is not well-defined. Therefore, the main aim of this work is to handle the uncertainty and improve the visibility of the clusters centres by using two different approaches of advanced fuzzy set. Both approaches have different concepts in determining the uncertainty. Previous work on enhancing the Flat EEG images by using different techniques has been done by Suzelawati et al. [6-7].

## 2 Basic Concepts

Fuzzy Research Group of Universiti Teknologi Malaysia (UTM) developed Flat EEG since 1999 which has been used purely for visualization. The main scientific value lies in the ability of flattening method to preserve information recorded during seizure. The data sources is based only on the data collected from epileptic patients from Hospital Kuala Lumpur (HKL) and Hospital Universiti Sains Malaysia (HUSM) Kubang Kerian, Kelantan.

### 2.1 Flat EEG

Zakaria [8] has formulated fundamental ideas to describe an epileptic seizure as a system that is represented by its motion or a dynamic physical process. The Flat EEG is a method to flatten EEG signals (see Fig. 1) from a high dimensional signal into a low dimensional signal. Thus, the EEG signals can be viewed on the Cartesian plane as depicted in Fig. 2. The 'jewel' of the method is that EEG signals can be compressed and analyzed. The EEG coordinate system (see Fig. 3a) is defined as

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