

Detection of Epilepsy from EEG Signal During Seizure Using Entropy-Based Fuzzy c-Means

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Abstract: One of the major roles of Electroencephalography (EEG) is an aid to diagnose epilepsy. Abnormal patterns such as spikes, sharp wave complexes can be seen. Our main interest is to extract information about the dynamics from a few observations of this record signal. In this study, the entropy-based fuzzy c-Means is used to cluster EEG signal of patients during an epileptic seizure. We obtained signatures of general epilepsy by superimposing results of the method.

Keywords: EEG signal, entropy based method, epileptic patients, fuzzy cluster

INTRODUCTION

Seizures are the result of sudden excessive electrical discharges in a group of brain cells. Epilepsy describes the condition of the patient having been recurring “spontaneous” seizures or brainstorm due to the sudden development of synchronous firing in the cerebral cortex caused by lasting cerebral abnormality. Surgical treatment may be an option in patients having an epileptic seizure refractory to medication (Engel *et al.*, 1993). Seizures are fundamentally divided into two major groups: partial and generalized. Partial (local or focal) seizures are those in which the clinical or electroencephalographic evidence suggests that the attacks have a localized onset in the brain (Gastaut, 1970).

EEG analysis still relies mostly on its visual inspection. Due to the fact that visual inspection is very subjective and hardly allows any statistical analysis or standardization, several methods were proposed in order to quantify the information of the EEG. McSharry *et al.* (2002) studied the detection of epileptic seizure from a scalp EEG recording. They used synthetic signal that was created by merging a linear random process and nonlinear deterministic process. A seizure prediction method was proposed by D’Alessandro *et al.* (2003) for deciding on the EEG features and electrode location within ten minutes of electrographic seizure onset. To obtain EEG signals from multiple intracranial electrode contacts, an intelligent genetic search process was applied. A method was introduced based on chaos theory and global optimization technique by Chaovalitwongse *et al.* (2005). The method has evaluated for identifying pre-seizure state in the dynamic of EEG signals. Zakaria (2008) proposed a new technique for visualization electrical activity in the

brain during an epileptic seizure. They introduced a technique for mapping recorded EEG signal into a flat. Then, fuzzy C-mean was applied to cluster of EEG signals.

In this study, we first briefly introduce entropy based fuzzy c-means algorithms. Then, entropy based fuzzy c-mean algorithm is applied to cluster of EEG signal of patients during epilepsy seizure. Optimal number of cluster is obtained with using two types of cluster validity measure. Finally, the result of the cluster is shown using flattening EEG signal and programing by Matlab software.

Entropy-based fuzzy c-means: Clustering is a general methodology and a remarkably rich conceptual algorithmic framework for data analysis and interpretation (Bezdek, 1981). Entropy-Based fuzzy c-mean algorithm uses concepts in n-dimensional Euclidean space to determine the geometric closeness of data points by assigning them to various cluster or classes and then determining the distance between the clusters. Also the concept of entropy is used in this algorithm. Namely following objection function is used for the Entropy-Based method:

$$J_{efc}(U, V) = \sum_{i=1}^c \sum_{k=1}^N u_{ki} D(x_k, v_i) + v \sum_{i=1}^c \sum_{k=1}^N u_{ki} \log u_{ki} v > 0 \quad (1)$$

where, $U = (u_{ki})$, $k = 1, \dots, N$, $i = 1, \dots, c$ -is membership function that satisfies in following equation:

$$\sum_{i=1}^c u_{ik} = 1, \forall k = 1, \dots, N \quad (2)$$

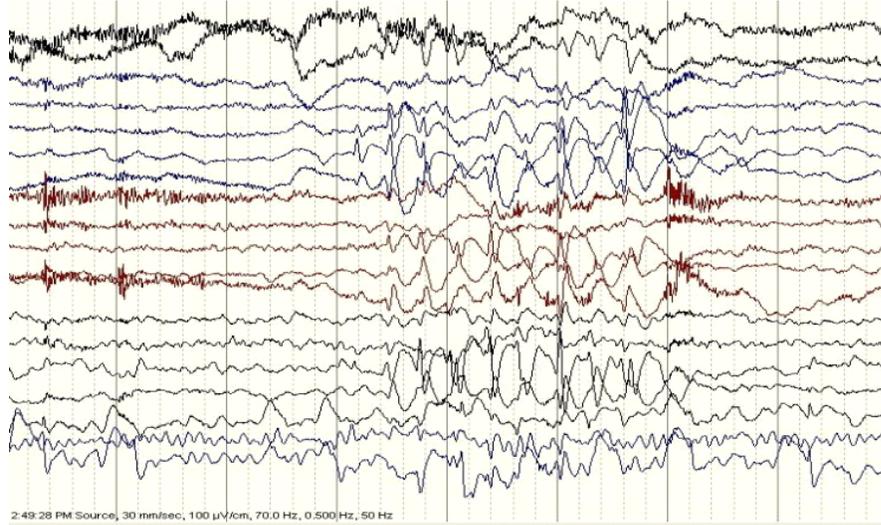


Fig. 1: EEG signal of patient during epilepsy

Also v_i is the centroid of cluster i that $V = (v_i)$, $i = 1, \dots, c$ and $D(x_k, v_i)$ is the Euclidian distance between i th centroid and k th data. The aim of this algorithm is to find cluster center (centroids) that minimize the objective function (1). To reach a minimum of objective function (1) there are two conditions. These are given in Eq. (3) and (4):

$$u_{ik} = \frac{\exp(-\frac{D(x_k, v_i)}{v})}{\sum_{j=1}^c \exp(-\frac{D(x_k, v_j)}{v})} \quad (3)$$

$$v_i = \frac{\sum_{k=1}^N u_{ki} x_k}{\sum_{k=1}^N u_{ki}} \quad (4)$$

Detailed algorithm of Entropy-Based fuzzy c-Mean was proposed by Li and Mukaidono (1995). This algorithm determines the following steps:

- Step1:** Choose a value for the stopping criterion, e and give a constant value $v > 0$.
- Step 2:** Choose a distance measure in the variable-space (eg., Euclidean distance).
- Step 3:** Choose the number of classes or groups, c , with $c = 2, 3, 4, \dots, N-1$.
- Step 4:** Randomly initialize the centroids (v_i).
- Step 5:** Calculate the membership matrix U by using Eq. (3).
- Step 6:** Calculate new centroid by using Eq. (4).
- Step 7:** If $\max_{0 < i < c} \|\bar{v}_i - \hat{v}_i\| < e$, than stop. Otherwise go to stepStep 5.
where, \bar{v} is a new solution and \hat{v} is the optimal solution one step before the last.

Cluster validity: Cluster validity is a difficult problem that is crucial for the practical application of fuzzy clustering techniques. In addition, we note that there are many purposes to employ cluster validity measures (Bezdek *et al.*, 1999). One of the most important applications is to estimate the number of clusters. Partition coefficient is one of the cluster validity measures that it is described as following:

$$F(U; c) = \frac{1}{N} \sum_{i=1}^c \sum_{k=1}^N (u_{ki})^2 \quad (5)$$

Another type of cluster validity measure is Partition entropy:

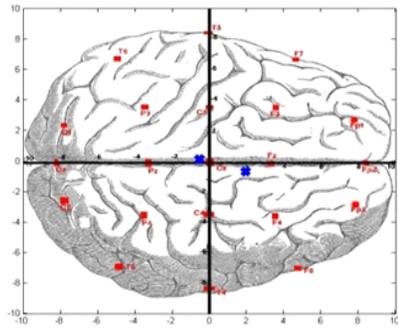
$$E(U; c) = -\frac{1}{N} \sum_{i=1}^c \sum_{k=1}^N u_{ki} \log u_{ki} \quad (6)$$

We should judge better clusters when one of these measures is larger.

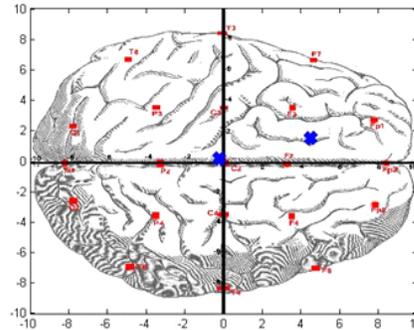
SIMULATION RESULTS

A set of EEG signal recorded from an epileptic patient as shown in Fig. 1 was sampled during seizure. This signal was sampled at 256 discrete data in every second by using Nicolet One EEG software. These signals are transformed by a novel method called Flat EEG that developed by Zakaria (2007). Then, Matlab programing is applied for cluster these signals with entropy-based fuzzy c-Mean. Cluster validity measure is used to find the optimal number of cluster for every second.

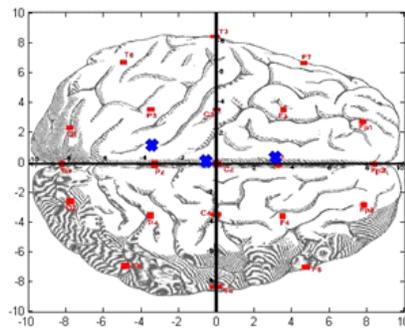
Furthermore, Matlab programing again is used for location of clustered EEG signals and clustered probes during seizure. As a sample of the implementation of the



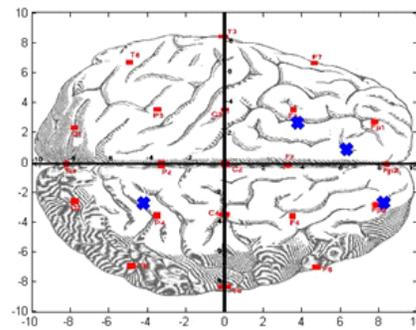
t = 1



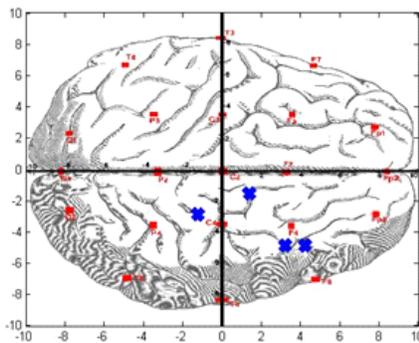
t = 2



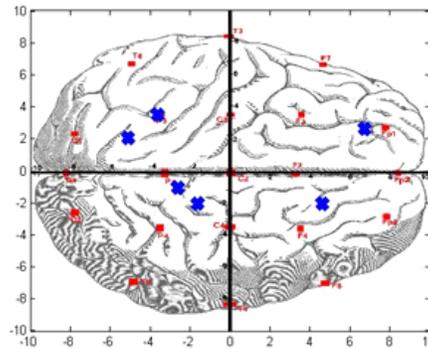
t = 3



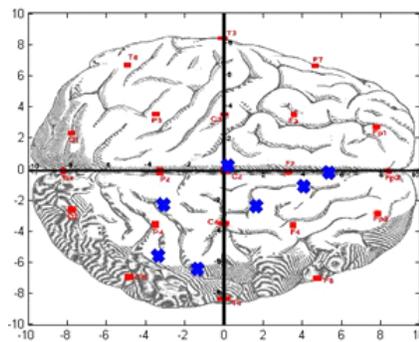
t = 4



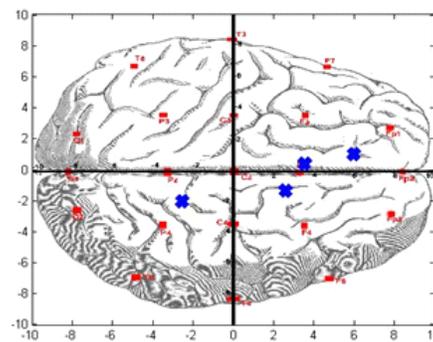
t = 5



t = 6



t = 7



t = 8

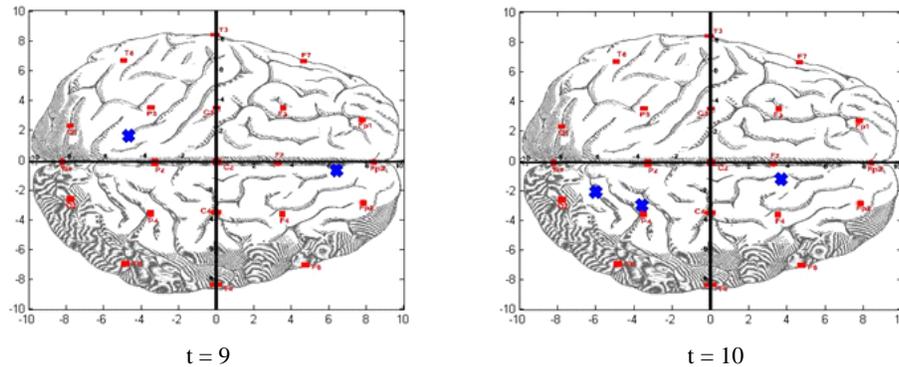


Fig. 2: Clusters centers of EEG signal from $t = 1$ to $t = 10$

software, the result for EEG signal in Fig. 1 is presented in Fig. 2 where locations of sensors on the surface of the patient's head are in red, the cluster's centers for signal are in blue.

CONCLUSION

We present the implementation of entropy based fuzzy c-mean techniques on the real time EEG data and probes obtained from a patient who suffer an epileptic seizure. Result shows most signal activities occur from $t = 4$ until $t = 7$ and start to die out at $t = 8$.

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