Automatic detection of epileptic spike using fuzzy ARTMAP neural network

ALI FARROKHI
Electrical and Electronic Engineering
Islamic Azad University South Tehran Branch
Tehran
IRAN
ali_farrokhi@azad.ac.ir

NEMAT TALEBI
Electrical and Electronic Engineering
Islamic Azad University South Tehran Branch
Tehran
IRAN
nemat-talebi@azad.ac.ir

FATEMEH SAFARI
Electrical and Electronic Engineering
Islamic Azad University South Tehran Branch
Tehran
IRAN
fatemeh_safari84@yahoo.com

Abstract: - The present paper attempts to introduce a new approach for the automatic detection of epileptic spikes in EEG signal which plays a vital role in diagnosing epilepsy. In this approach, we have detected and classified epileptic spikes by using extracted features and Fuzzy ARTMAP neural network. The performance of classifying system is evaluated by three criteria of sensitivity, selectivity and specificity. For the classifying system applied in the current study, the obtained values of these three criteria are 88.24%, 93.75% and 90.9%, respectively, which compared with MLP classifier system, benefits from a higher speed and precision.

Key-Words: - EEG, epilepsy, epileptic spike detection, fourier transform, wavelet analysis, fuzzy ARTMAP

1 Introduction
Electroencephalogram (EEG) includes recording the produced electric potentials in neural cells of the brain which is a valuable clinical tool for diagnosing epilepsy. Epilepsy is often identified with transient and recurrent disturbances in mental activities or in the movement of different parts of the body [1]. During the interictal periods, the patient may experience transient seizures in the form of sharp waves and spikes [2]. An epileptic spike is distinct from the background activity and has a pointed peak and duration of 20-70ms [1,2,3]. Interictal spike has a major role in diagnosing and treating epilepsy [4]. But detecting and categorizing spikes with observing recorded EEG is a difficult and time-consuming process which is also error-prone. Many different ways have been applied to detect and categorize spikes and other transient signals in EEG, most of which are based on artificial neural networks (ANN) [6-10]. In this paper, a new approach has been presented based on Fuzzy ARTMAP neural networks to detect epileptic spikes and the results show that Fuzzy ARTMAP neural networks performance well in detecting epileptic spikes.

2 Methodology

2.1 Data selection
First, the existing events in EEG signal were classified into two groups: 1) epileptic spikes and 2) any other mental task (non-epileptic spikes) which includes background EEG activity and muscular artifacts [1,5]. Then, EEG signal was divided up into...
Hamming time windows with the length of 50 samples and 50% overlap. EEG signal division was done in a way that there was an epileptic spike in each section. In the current study, we have used the EEG data discussed in Gabesan et al. (2007) which is publicly available [11]. These EEG signals are recorded based on 10-20 international standards and through 19 channels. They are also sampled by the frequency of 240 Hz.

2.2 Extracting features
In this paper, the following features were extracted for every section of EEG signal:
1) Zero crossing: The number of sign changes of samples’ amplitude in every section
2) The energy which is calculated from the following equation (1),
\[ E_j = \sum_{n=0}^{N} x_j^2(n) \]  
where \( x_j^2(n) \) is the \( n^{th} \) sample in the \( j^{th} \) section. The value of \( N \) equals to the total number of samples in the \( j^{th} \) section.
3) The energy of 0-20 Hz frequency range: By using Fourier transform, the frequency spectrum of each section is calculated and the absolute value of the real part is computed. Then, the energy of 0-20 Hz frequency range is calculated by using equation (1).
4) Extracted features by using wavelet transform for each section

In this paper, Db3 (Daubechies order 3) wavelet was used for the decomposition of the EEG data into 4 sub-bands. Then the following features were extracted:

4.3) energy of 4th, 5th and 6th frequency band of sub-band 4 (cd4): By dividing frequency spectrum of sub-band 4 into 6 equal parts, 6 frequency bands are obtained and the energy of 4, 5, and 6 frequency band is calculated.
4.4) energy of 5th frequency band of sub-band 3 (cd3): By dividing frequency spectrum of sub-band 3 into 6 equal parts, 6 frequency bands are obtained and the energy of 5th frequency bands is calculated.

This feature is extracted from all epileptic and non-epileptic spikes and is used as the training set for Fuzzy ARTMAP neural network.

2.3 Fuzzy ARTMAP neural network
The network based on Adaptive Resonance Theory (ART) is one of the most popular networks used in classifying and clustering. Fuzzy ARTMAP network has the supervised training algorithm which is obtained through the combination of two Fuzzy ART networks under the names of ARTa and ARTb. These two networks are linked to each other by a series of connections which are located between the F2 layers of these two networks and are called Map Field (F\(_{ab}\)). The input vector to ART\(_a\) and ART\(_b\) in ARTMAP network are exerted utilizing complementary coding of A = (a, a\(^c\)) and B = (b, b\(^c\)) [12,13,14]. In this paper, neural network of Fuzzy ARTMAP was applied because of the high learning speed, lack of amnesia, stability, and high yield in classification of the samples. The structure of this network is presented in Fig.1.

![Fig.1 structure of Fuzzy ARTMAP neural network](image)

2.4 Method implementation
Extracted features for epileptic and non-epileptic spikes are exerted to Fuzzy ARTMAP neural network after being normalized between 0 and 1. The training set is consisted of 247 data and the test set includes 28 data.

3 Results and discussion
The performance of classifying system is evaluated by three criteria of sensitivity, specificity and selectivity. These three criteria are defined through the following equations:

\[ \text{sensitivity} = \frac{TP}{TP + FN} \times 100\% \]  
\[ \text{specificity} = \frac{TN}{TN + FP} \times 100\% \]  
\[ \text{selectivity} = \frac{TN}{TN + FP} \times 100\% \]

in which TP (true positives) is the number of epileptic spikes which is correctly revealed by the system; TN (true negatives) is the number of non-epileptic spikes which is correctly revealed by the system; FP (false positives) is the number of non-epileptic spikes which is incorrectly classified
as the epileptic spike by the system; and FN (false negatives) is the number of epileptic spikes which is incorrectly classified as the non-epileptic spike by the system.

Table 1 shows the obtained results from the our system and MLP classifying system. In our system, the values of sensitivity, selectivity and specificity are 88.24%, 93.75% and 90.9%, respectively, and in MLP classifying system, these values equal to 82.35%, 87.5% and 81.8%, respectively. Therefore, in comparison with MLP classifying system, the classifying system with Fuzzy ARTMAP shows a higher speed and precision in classifying epileptic spikes.

<table>
<thead>
<tr>
<th>Classifier type</th>
<th>Sensitivity (%)</th>
<th>Selectivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuzzy ARTMAP</td>
<td>88.24</td>
<td>93.75</td>
<td>90.9</td>
</tr>
<tr>
<td>MLP</td>
<td>82.35</td>
<td>87.5</td>
<td>81.8</td>
</tr>
</tbody>
</table>

Table 1 system performance

4 Conclusion

This paper attempted to introduce a new method for the automatic detection of epileptic spikes in EEG signal which plays a vital role in diagnosing epilepsy. The suggested approach classifies the epileptic spikes by using Fuzzy ARTMAP neural network and after extracting the features. The best obtained performance with Fuzzy ARTMAP neural network is that of 88.24% sensitivity, 93.75% selectivity and 90.9% specificity which shows a higher speed and precision when compared with that of MLP classifying system with the same extracted features.

References: