Electroencephalogram Lempel-Ziv Complexity analysis in Alzheimer's Disease with different Coarse Graining Techniques

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Abstract -This work explores the possible benefits of adopting k-means as a coarse graining technique (CGT) when measuring electroencephalograms (EEG) complexity using the Lempel-Ziv (LZ) algorithm for the diagnosis of Alzheimer's disease (AD). A significant (p<0.01) complexity decrease between AD patients and control subjects is identified at Occipital, Parietal and Temporal regions of the brain. An accuracy of 86.36% in P3 electrode is achieved; a higher accuracy value than in previous studies.

I. INTRODUCTION

This project explored the use of EEG recordings for improving accuracy in AD diagnosis using the LZ complexity algorithm, a method of symbolic dynamics based on the coarse graining of a signal. The LZ algorithm measures the complexity of one-dimensional signals by determining the number of different substrings and their repetition rate.

II. METHODS

The EEG database used for this study consisted of signals from eleven AD patients and eleven age-matched control subjects; the tested AD patients and control subjects had a mean age of 72.5±8.3 and 72.8±6.1 respectively [1]. The EEGs were recorded using the 10-20 international system and a sampling frequency of 256 Hz. The LZ complexity algorithm was implemented to measure the complexity of EEG signals. This method was tested using the following two and three digits CGTs: k-means, mean and mid-point.

For the central tendency 2 digit CGTs, the mean/mid-point of the signal was directly used as a threshold [2]. In order to transform the EEG data into a 3 digit sequence two thresholds had to be defined [2]. The k-means approach was based on the grouping of data around centroids, which correspond to points around which most of the data is agglomerated [3]. To obtain a 0-1 sequence one set two centroids (k=2) while for a three digit sequence k was set to 3.

The LZ complexity is measured by scanning the coarse-grained sequence from left to right and adding one unit to a complexity counter $c(n)$ every time a new subsequence of consecutive characters is found [1]. Student's t-test was used to quantify the statistical differences between LZ complexity for AD patients and controls. Receiver Operating Characteristic (ROC) curves were used to evaluate the ability of this non-linear analysis method to classify subjects by calculating; sensitivity, specificity and accuracy values. Sensitivity is defined as the proportion of AD patients who test positive, specificity is the percentage of controls correctly identified and accuracy quantifies the total number of patients and controls correctly classified.

III. RESULTS

Table 1: ROC plots for electrodes with p < 0.01.

LZ complexity	Electrode	Sensitivity (%)	Specificity (%)	Accuracy (%)
2 digits conversion				
Mean	O1	90.91	72.73	81.82
	P3	81.82	81.82	81.82
Mid-point	O1	90.91	72.73	81.82
	P3	72.73	81.82	77.27
k-means	O1	90.91	72.73	81.82
	P3	81.82	81.82	81.82
3 digits conversion				
Mean	O1	90.91	72.73	81.82
	P3	81.82	81.82	81.82
	P4	72.73	90.91	81.82
Mid-point	O1	90.91	72.73	81.82
	P3	81.82	81.82	81.82
	P4	72.73	90.91	81.82
k-means	O1	90.91	72.73	81.82
	P3	72.73	100	86.36
	P4	81.82	72.73	77.27

AD patients' EEGs showed a generalised decrease in complexity. Differences between groups were deemed relevant when p-value<0.01. The electrodes where a significant drop in complexity was found are presented in table 1, as well as the results from the ROC analyses. For the two digit CGTs similar accuracy results to the ones published in [1] were obtained. However, for the three digit CGTs, accuracy levels never achieved before were obtained with k-means at electrode P3 (highlighted in yellow).

IV. CONCLUSIONS

AD patients' EEG recordings show a meaningful decrease in complexity. LZ complexity based on k-means CGT presents the highest accuracy in results published so far and, therefore, it can be considered as a potential CGT to be used for the early detection of AD. However, to prove this, further study is required.

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