특징적인 직선요소들의 검색에 기초한 EEG 파형 검출

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EEG WAVEFORM DETECTION BASED ON THE SEARCH OF DISTINCTIVE LINE-SEGMENTS

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ABSTRACT

We present a new EEG waveform detection method, based on the search of distinctive line-segments. The method is based on the assumption that EEG waveform morphology is characterized by a sequence of its distinctive line-segments and their structural features. In this method, the distinctive line segments are first searched for, and the structural feature analysis is performed on the found line-segment sequence. Experiments of detecting epileptic spikes are performed on four different subjects.

INTRODUCTION

In human visual EEG analysis, the most important descriptors are waveforms occurring in the EEG. Thus, a reliable EEG waveform detection is indispensable for an automated EEG analysis that imitates human visual EEG inspection.

Several attempts have been made to automatically detect EEG waveforms. Many investigators used amplitude-duration criteria based on the configuration of extrema either with the use of filters to make specific frequency-range EEG activities more prominent [1, 2, 5]. Relatively few investigators developed waveform recognition systems that use several descriptive features of half waves without using any signal preprocessing [3 4].

In this paper, we present a new waveform detection method, based on the assumption that the morphological characteristics of an EEG waveform can be represented by a sequence of its distinctive line-segments and their structural features. The structural features includes the sequential pattern of distinctive line-segments and their connectivity.

SEARCH-BASED LINE-SEGMENT DETECTION

A variety of segmentation techniques have been developed to represent EEG data for both data reduction and the application of syntactic pattern recognition techniques. In the waveform detection problems, most of these segmentation techniques were applied for the purpose of preliminary signal conditioning, and they usually require no explicit knowledge of waveform morphology. However, the method presented here explicitly uses the morphological knowledge of EEG waveforms to extract the distinctive line-segments that form the EEG waveform being searched for.

The search-based line-segment detection, uses six numerical threshold values to determine two regions: a search-continuation region and a valid line-segment region. During the search process, the search-continuation region acts as a search space limiter, i.e., the existence of a line-segment out of this region will interrupt the current search process. A line-segment within the valid line-segment region will be classified as a valid line-segment, and the search process will continue. Figure 1-a illustrates a successful search process, in which at least one valid line-segment was detected. After the first valid line-segment is successfully searched for, the search-continuation region is shrunk as shown in Figure 1-d.

Since a successful search process finds out at least one valid line-segment, more analysis is necessary in order to select a single line-segment that represents a portion of data. Different selection criteria are available, depending on the morphology of an EEG waveform. In our experiments, we employed the largest amplitude criterion, which select a line-segment with the most largest amplitude.

STRUCTURAL FEATURE ANALYSIS

The structural features of an EEG waveform morphology is represented by the sequential alignment pattern of distinctive line-segments and their connectivity characteristics. The sequential pattern is represented by concatenating the symbols, each of which indicates the type of a line-segment. Numeric parameters that specify how the distinctive line-segments are linked together are used for the representation of the connectivity characteristics.

In a traditional pattern recognition approach, the sequential pattern of primitive elements is used as a main structural discriminator. However, this method used the sequential pattern of distinctive line-segments, called a pattern template, as a preliminary discriminator for discarding an invalid line-segment sequence before a more elaborate analysis is carried out. The sequence of line-segments conforming to a given pattern template will undergo more analysis, but the sequence that does not follow the template will simply be rejected and no more analysis will be performed.

In order for the line-segment sequence that passes the preliminary sequential filtering to be classified as an authentic waveform event, it must pass in the connectivity examination. The connectivity examination consists of two stages: one is to test whether adjacent two line-segments are properly connected and the other is to examine the rhythmic features of line segment sequences.

EXPERIMENTAL RESULTS

In this study, EEG data of six different subjects recorded at the university of Florida, Gainesville, Florida, were used as a database for the evaluation of the waveform detection algorithm. The format of digitization follows the sampling of 250 Hz with a 8-bit resolution. The paper recordings, each of which is 1.5 hour long, contain a variety of epileptic spikes and other abnormalities including background slowing. The subjects talked, ate, moved, and slept, so the recording included eye movements, and muscle, electrode artifacts, and sleep spindles.

The selection of accurate waveform models is a preliminary but an important step for the improvement of the detection performance. Initially, a coarse waveform model is set up by using the waveform characteristics generally admitted. After a cycle of testing and tuning, the parameters are adjusted to give good man/machine agreements. Two EEG records were used as a training data set. After the parameters are finally tuned, four EEG recordings from different subjects were used for the evaluation of the detection performance.

The agreement between the computer and the visual scoring was assessed by a detection ratio and the number of false detections per minute. The detection ratio is defined as the percentage of the number of epileptic spikes that human EEGers and the computer detect, over the total number of epileptic spikes that two EEGers agree. The false detection rate or computer over-recognitions is defined as the number of false detections made by the computer but not marked by either EEGer (i.e., isolated computer detections) per minute.

The results are shown in Table 1. Most of the epileptic spikes found by both EEGers were detedted by the computer. In the subjects R08RO01 and R08DO01, both EEGers found no epileptic spike. Thus, we could not calculate the detection ratio. In most cases, a large amount of false detections were reported.

DISCUSSION

The use of a search technique for detecting distinctive line-segments requires an elaborate connectivity analysis, since the adjacent line segments obtained from the search are not always connected properly. However, the search technique brings in some useful properties. Even when a fast activity is superimposed over a slow activity, it can detect the fast activity without a priori signal conditioning such as band-pass filtering. The unwanted waveform distortions due to the filtering can also be avoided.

Advantages of automated processing of EEG data include inherent consistency of interpretation, rapid and inexpensive data reduction, and on-line EEG monitoring to initiate data storage or analysis. To be effective, the computer must accurately interpret the EEG and operate in real-time or faster.

In the experiments, most of epileptic spikes marked by two EEGers were detected by the detection algorithm, but it also made many false detections. The false detections can be considerably eliminated by analyzing temporal and spatial context information from multiple channels of data, and by using encoded human expertise of visual interpretation [3].

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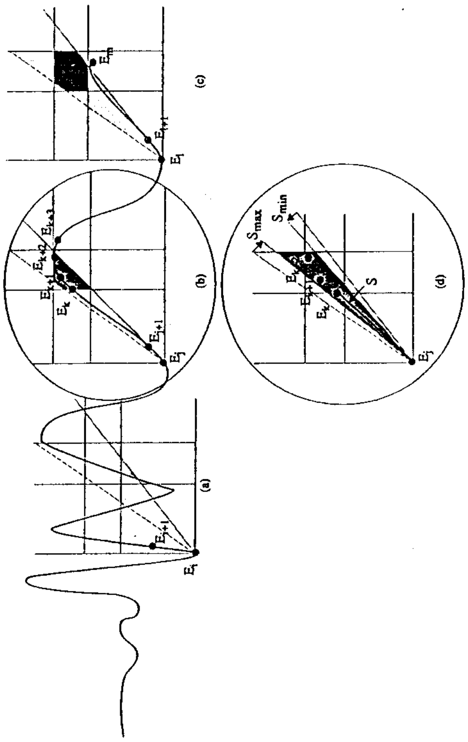

Figure 1. Examples of the search process. (a) Failed search process. (b) Successful search process. (c) Continued, but failed search process. (d) Adjustment of the search-continuation region after detecting the first valid line-segment.

Subject \ Scorer	EEGers agreed	System	Both agreed
R08BU01	25	4858	22
R08PA02	60	980	55
R08RO01	0	547	0
R08DO01	0	16	0

Table 1. Comparison of the visual scoring agreed by two EEGers and the detection system's output (the number of individual epileptic spikes marked during one and half long test period).