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Detection of K-Complex in Sleep EEG Signal using Support Vector Machine

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Abstract — The K-complex is a transient EEG waveform that contributes to the assessment of sleep stages. Due to the non stationary and non linear behaviour of the brain signals, it is very difficult to study the characteristics of these transients manually.The main difficulty of the automated K-complex detection problem has been the lack of specific characterization and the close similar at to other EEG waves. We present a detection approach based on feature extraction and Support Vector machine (SVM) that provides good agreement with visual K-complex recognition. In this case, Independent Component Analysis (ICA) is used for the denoising purpose.The performance of this method is considerably efficient & is a hardware independent solution for the biomedical signal processing field.

Index Term — EEG Signal, ,K-Complex, Sleep Stages , Fast ICA Algorithm , Golay Filter, ,Support Vector machine (SVM)

1 Introduction

The electrical activity of the human brain has been studied extensively since the discovery of the EEG by BERGER in 1924. It is believed that from this early stage and throughout life electrical signals generated by the brain represent not only the brain function but also the status of the whole body. This assumption provides the motivation to apply advanced digital signal processing methods to the electroencephalogram (EEG) signals

In the last three decades, it has become common to classify sleep records according to the set of rules set by the Rechtschafen and Kales committee [1]. In recent years, it has become apparent that these rules are not sufficient and further analysis of the sleep record is essential. In addition to analyzing sleep in a macrostructural manner, i.e. segmenting the night into different stages, a micro structural analysis is performed. Transient events such as micro arousals sleep spindles, K-complexes and many more are analyzed [2]. K-complexes are one of the hallmarks of sleep stage [1], they can be evoked by sensory stimulation and some researches consider this activity an arousal response. It is apparent that the automatic identification of transient events in general, and K-complexes in particular, are of great interest as manual identification are labor intense and cannot be performed on a regular basis.

In this paper, we develop the method for the supervised characterization of EEG signals using Support Vector Machine(SVM) .The aims to partition the feature extracted from the EEG Signals and given to the Support Vector Machine for detection of K-complex from the non-stationary and multidimensional EEG signals

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2 Defination and Past Work.

EEG signal is multivariate (multi-dimensional) statistical data signal which is unique, non-linear, non-stationary and not repeatable signal which is shown in fig.1. K-complexes are relatively large waves with a duration of between 500 and 1500 msec. Typically, they consist of an initial small negative, somewhat sharp wave, followed by a large positive wave, which is shown in fig.2.The initial positive wave is often absent and the peak of the large negative wave could be somewhat rounded, especially due to medication-complexes always occur simultaneously all over the scalp (that they are most pronounced over the front-central areas).The amplitude at channel Four (a right-central electrode location) is often three times background EEG signal and generally larger than 75 micro-Volts. It seems therefore reasonable to conclude that the detection is largely based on contextual information [2]. The K-complex morphology can vary drastically, making the automated detection of K-complexes a difficult task. Few algorithms have been proposed and reported in the literature.

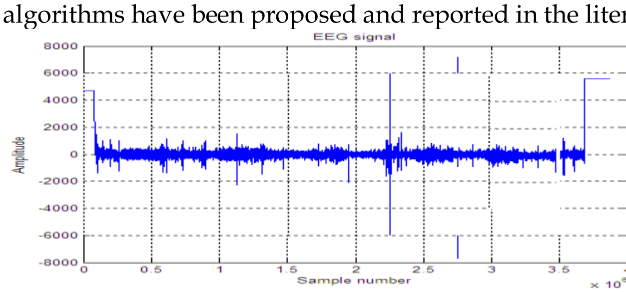

Fig1. EEG Signal

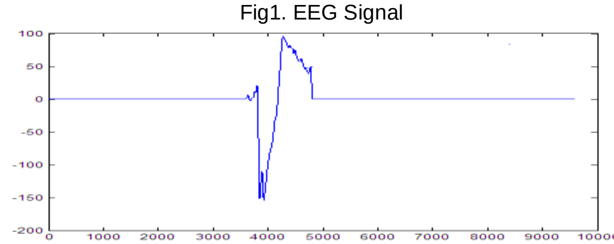

Fig.2.K-Complex

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Some did not test the algorithm on real data [4] and some did not report quantitative results [3]. Bankman used a neural network with 14 features extracted from the EEG as input. The features were based on several amplitude and duration measurements taken on significant points of the K-complex, such as peak-to-peak amplitude, amplitude of the rise, the duration of the whole complex, the duration of the falling slope etc.

The training set included 200 K-complexes and 200 non K-complexes while the test set included 51 K-complexes and 49 non K-complexes [4]. They reported 90% true positive and 8.2% false positive. Tang and Ishii [6] suggested K-complex detection algorithm using the discrete wavelet transforms. The data as tested on records of EEG containing auditory evoked K-complexes. They obtained 13% false reject and 10% false accept rates. Another algorithm that uses joint time and time frequency detection was suggested by Richard and Lenglelle [7].This algorithm does not deal with the detection of K-complex but rather with the classification among K complex and Delta waves. Delta waves are prominent in sleep stages three and four.

3 Suggested Method

We suggest an approach for the detection scheme. As the K-complex is identified by a distinct syntax, i.e. sharp upward wave followed by a downward wave, it is logical to model it by means of Support Vector Machine (SVM) which is supervised learning algorithm. Fig.3. summarized the detection of K-complex method.

3.1 Preprocessing of EEG signal

In the pre-processing part of EEG Signal, The EEG signals first classified into different specific sleep stage which is characterized by the k-complex. Then Independent Component Analysis (ICA) is applied to that signal. Independent Component Analysis can be usefully applied for EEG signals processing in order to get the most important information contained by this signals [8] [9]. This study proves that Independent Component Analysis is used for the denoising the EEG signals [10]. Independent component analysis is a technique that aims to recover the underlying unknown source signals from their observed mixtures without any prior [9] knowledge of the mixing channels. By virtue of the recent increase of interesting in ICA, it has become clear that this principle has a lot of other interesting applications .In this paper Fast ICA algorithm is used for the denoising of EEG signals. Following step involved in the Fast ICA algorithm [12] for the denoising the EEG Signal which is non stationary and non repetitive.

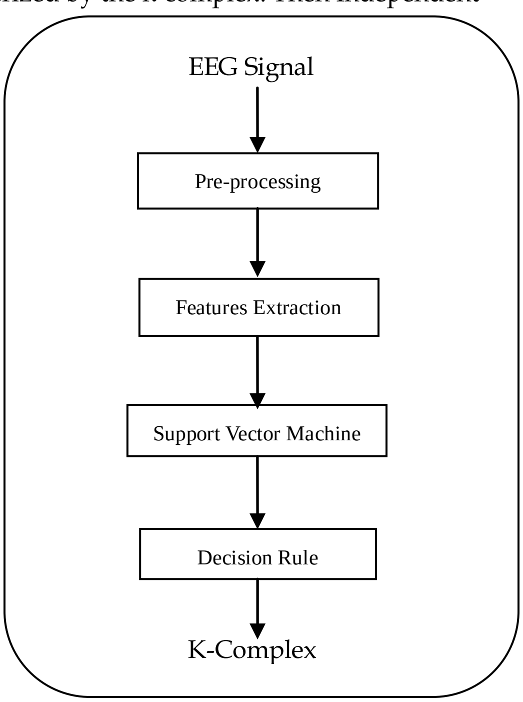

Fig 3.Flow Chart of Suggested Method

Fast ICA Algorithm

1. Centering
2. Whitening
3. Choose m, number of Independent Components to estimate
4. Choose an initial guess of unit norm for weight eg. randomly.
5. Do deflation decorrelation
6. Normalization
7. If weight has not converged, go back to step 5.

After processing of Independent Component Analysis, This signal consist of line interference frequency of 50Hz which is generated by the power supply so that it pass through the bandpass filter of K-complex frequency 0.5Hz - 2Hz.It means output of bandpass filter signal contain the K-complex. In order to smooth that signal we have again used the Golay filter. If the order of the Golay Filter increases, more is smoothness. All the waveform of the EEG signal for ICA, bandpass filter and Golay filter is shown in fig.4.

3.2 Feature Extraction

Due to the large variety of shapes that the K-complex could take, it became evident that automated detection would require several measurements which reflect the visual criteria for acceptance and rejection. In some cases one subjective criterion (e.g., sharpness of positive wave) required more than one measurement. In some other cases it was possible to use more than one measurement to represent the same criterion. The initial feature set of this project contained only a few amplitude and duration measurements. The main concern in the selection of features was to implement visual recognition criteria as closely as possible and therefore some features were not entirely independent. So in this paper we had considered the four features such as maximum amplitude, minimum amplitude and frequency range those represent the contextual features of K-complex were evaluated after the analysis.minimum and maximum time period and phase of the k-complex can also be considered for the same.

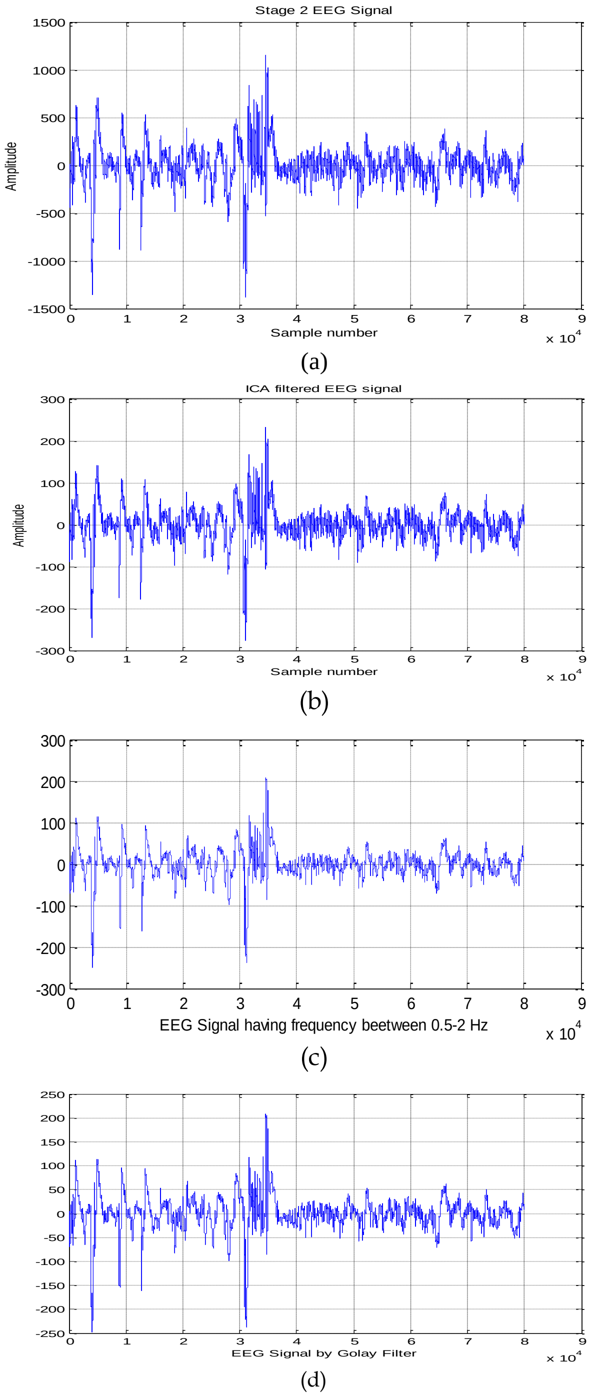

Fig 4. (a) Sleep Stage II (b) ICA Filtered EEG Signal (c) Bandpass Filtered EEG signal (d) Golay Filtered EEG Signal

3.3 K-Complex detection by Support Vector Machine

SVM are widely used for learning classifiers and regression models. Its theoretical support is from statistical learning theory. The SVM empirically works very well, at least for some classes of problems; provide a good generalization performance on pattern classification problems. As an supervised approach, SVM has many important advantages. A supervised approach allows for uniform treatment of K-Complex detection and prediction [11].

The objective of SVM is to find an optimal hyper plane that correctly classifies points as much as possible and separates the points of two classes such as K-Complex and Non K-complex. Given the training sample $\{xi, di\}^N$, where x_i is i^{th} sample and d_i belongs to {−1, 1} is the corresponding desired output. Using a discriminate function

$$g(x) = wT\,x + b \quad (1)$$

and choose a weight vector w and bias b such that

$$g(x_i) = wT\,x_i + b >= 0, \text{ for } d_i = +1$$
$$g(xi) = wT\,x_i + b < 0, \text{ for } d_i = -1 \quad (2)$$

The equation

$$g(x) = wT\,x + b = 0 \quad (3)$$

is called the equation of the hyper plane that separate the two class of response. If ρ is the an arbitrary point in the hyperspace, the distance of the point p from the hyperplane can be expressed to be

$$\rho = \frac{wtp}{|w|} + \frac{b}{|w|} = \frac{g(x)}{|w|} \quad (4)$$

The objective is to find the optimal weight vector w and bias b such that for a given sample $\{xi, di\}^N$ we want the nearest sample is at least some desired distance away from the hyperplane,

$$\rho = \frac{1}{|w|} \quad (5)$$

In this condition, the distance between the margins of the two classes is

$$2\rho = \frac{2}{|w|} \quad (6)$$

The condition can also be written as

$$d_i\, g(x_i) = di(wT\,xi + b) \geq 1, \quad \text{for } i = 1, 2, \ldots, N \quad (7)$$

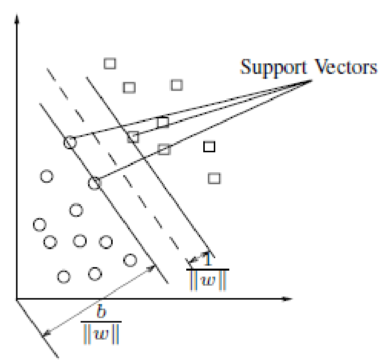

Fig.5.Geometry of SVM in feature space with the hyperplane

Our aim is, for a given sample $T = \{xi, di\}^N$ to find an optimal hyperplane such that the condition in, and the separation margin should be as large as possible. From the define the margin distance in (15), we know that maximizing the separation margin can be achieved by minimizing |w|.

4 Results

As per our detection method in the previous paragraph, when the input signal is passed through the Support Vector Machine classifier as shown in Fig 6. and output is as shown in Fig.7

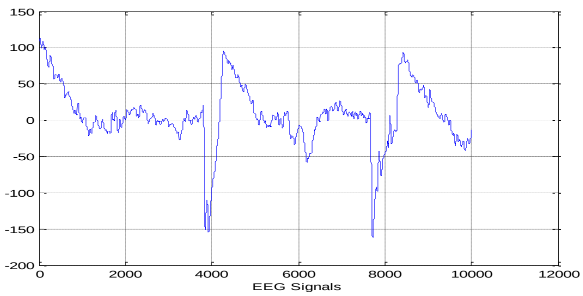

Fig 6. Input Signal to Support Vector Machine (SVM)

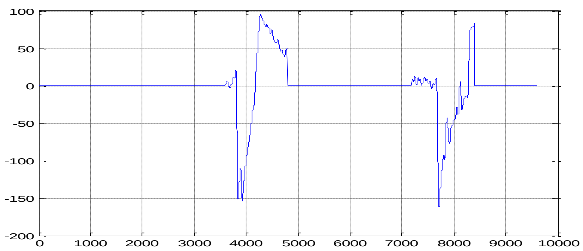

Fig.7 K-Complex Output of Support Vector Machine (SVM)

5 Conclusion

The proposed Support Vector Machine is very efficient for the detection of K-complex EEG signal. In this paper, a new SVM method having better approach than previous neural network approaches are explored in the survey which are inadequate for the detection of K-Complex EEG signal. There are a number of factors that may explain the poor performance of the ANN or 2 hidden layers, with five or ten units per hidden layer, and band pass filtered EEG as the input.SVM is a good model for highly variable time sequence which often noisy and uncertain such as EEG signal so that the performance of SVM is better than the previous approach.

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