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DETECTION OF K-COMPLEX IN SLEEP EEG SIGNAL WITH MATCHED FILTER AND NEURAL NETWORK

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Abstract: ***The k-complex is a transient waveform that contributes in assessment of sleep stages. Main problems in assessments are similarity of k-complex to the other waves in EEG signal, which is buried in noise. To overcome these problems, methods based on reference signal, such as, matched filtering, neural network, etc. are used. Detection of a particular event, i.e. k-complex with a known pattern in a noisy EEG signal is the subject of this paper.***

Keyword: - k-complex, matched filter, Artificial Neural Network (ANN).

I. Introduction:

Electroencephalograph (EEG) is the spontaneous electrical activity along the scalp. German physiologist and psychiatrist Hans Berger recorded the first human EEG in 1924[1]. These brain waves are usually recorded on a multichannel recorder from electrical signal which is amplified and monitored by electrodes placed on several locations on the scalp.

K-complex is a transient wave of sleep stage II in EEG signal, which has sharp positive wave followed by negative wave. In sleep analysis, the k-complex is one of the key features used for determination of different stages of sleep, stage II in sleep is detected by the presence of one or more k-complexes [2]. They are more frequent in the first cycle of sleep. It is having frequency range from 0.5 Hz to 2 Hz and amplitude > 10 0μv. K-complexes are roughly occurring at every 1.0 –1.7 minutes and are often followed by bursts of sleep spindles. They are generated in widespread cortical locations, though they tend to predominate over the frontal parts of the brain. They occur spontaneously but also in response to external stimuli, such as, sounds, touches on the skin, and internal ones. K-complex waveform shapes can vary severely due to the unstable structure of EEG signal. Visual recognition of k-complex in an all night sleep EEG is time consuming and difficult task [2].

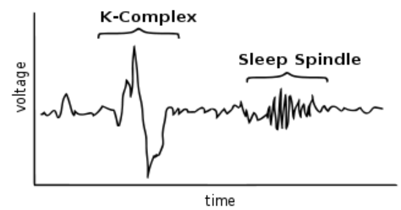


Fig.1:- k-complex followed by spindle.

K-complex detection method has been attempted here with the help of reference signal. This reference signal is compared with input signal and check availability of reference signal in it. In this process, two methods, such as, matched filter and neural network methods have been introduced for detection of k-complex. Then, the results obtained from both these methods are compared based on sensitivity and specificity parameters. Comparisons of these parameters with those of the other existing methods are used for verification.

II.Methodology

A. EEG data acquisition

The implementation process is carried out using the database available in the physonet website. The available database was in EDF format, for compatibility it is converted in to ascii format for the MATLAB 7.9.The raw signal is then segemented according to the Rechtschaen and Kales[1968] sleep stage classification standard[3]. The segmented stage II signal is filtered using 3rd order Savitzky-Golay Filter. Savitzky-Golay filtering can be thought of as a generalized moving average. Savitzky-Golay smoothing filters are typically used to "smooth out" a noisy signal. This filter is also called a digital smoothing polynomial filter or a least-squares smoothing filter. The Savitzky-Golay filtering method is often used with frequency data or with spectroscopic (peak) data.

B. Work flow

The complete flow of the implemantation is give below.

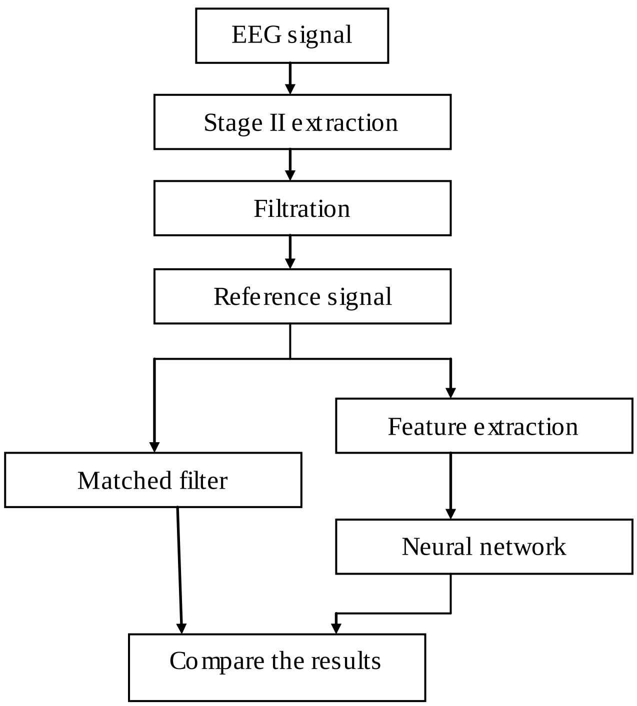


Fig.2:- Algoritham for detection of k-complex

C. Matched Filter

When template of a typical version of a signal event is available, it become possible to design a filter that is matched to the characteristics of the event. Matched filter is obtained by correlating a known signal or template with an unknown signal to detect the presence of the template in the unknown signal[4][5]. This is equivalent to convolving the unknown signal with a conjugated time-reversed version of the template.

$$Y[n] = \sum_{K=-\infty}^{\infty} h[n-k]\, x[k]$$

If a signal that contains repetations of the event with almost the same characteristics is passed through the matched filter, the output should provide peaks at the time instance of occurance of the event. This filter is commonly used for the detection of known charateristic that are buried in noise. It maximizes the signal-to-noise ratio of the filterd signal[5].

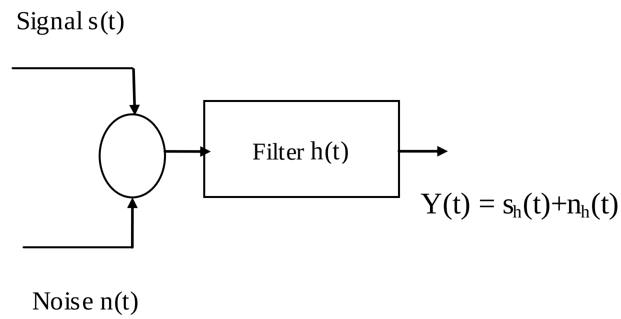
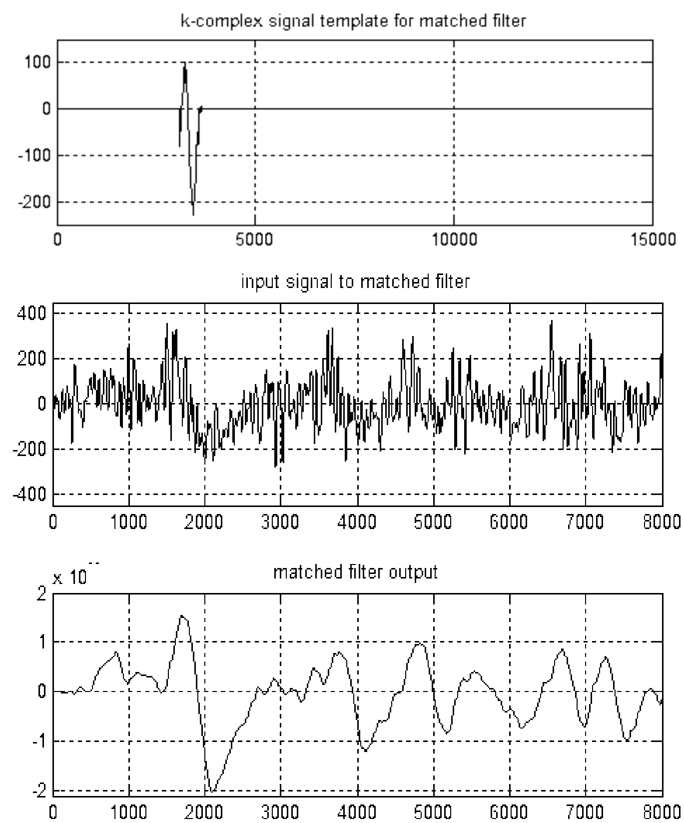


Fig.3:- Basic modle for matched filter.

To use matched filter, it is usually requried that the reference signal is known beforehand. Here template signal is obtained by using amplitude and frequency defination criteriaof the k-complex.

Results for matched filter:

The results obtained by matched filter are shown as follows.



D. Artificial Neural Network:

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Artificial neural networks are nonlinear signal processing devices, built from elementary processing devices called neurons.

A three layered feed-forward backpropagation artificial neural network was used to classify the EEG signals, the results obtained with the network architecture of input-hidden-output nodes, show a high percentage of correct classifications .The back propagation method involves the propagation of error backwards (with no feedback involved), to update weights of the hidden and the input layers so as to minimize the least squared error. Again the outputs are calculated iteratively until the error falls to an accepted minimum level. The network architecture used is as shown in Fig 4. A sigmoid transfer function is used for calculating the results. Input vectors and the corresponding target vectors were used to train the network until the network classifies the input vectors The network was trained initially by the extracted features of the K-complex signal. propagation network was properly trained to classification with a high degree of correct classification. During the training phase, the weights are successively adjusted based on a set of inputs and the corresponding set of desired output targets. The back-propagation algorithm needed weight adjustments in the backward sweep. Excellent results were obtained with a minimum error of 1*e-10, a gradient 1.0 and 3000 epochs, an adaptive momentum constant for speeding up the convergence. The parameters of the ANN such as acceptable minimum error and learning rate, momentum constant were set to get performance of the network over the entire set of EEG data**[6][7].**

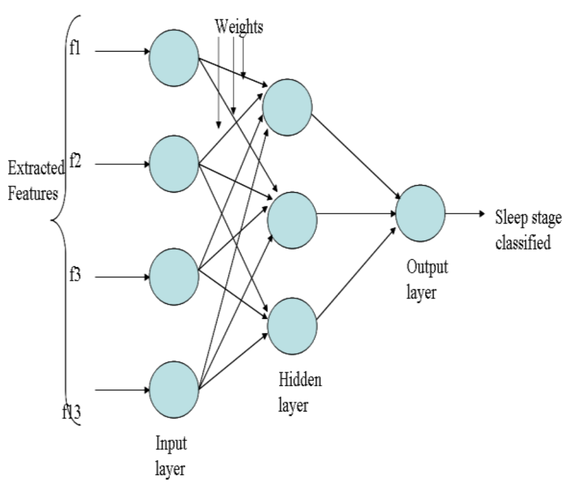

Fig 4:-feed forward ANN

Feature Extraction:

The features are extracted by computing the likelihood thresholds based on amplitude and duration measurement.

The characteristics were selected so as to reflect the visual criteria as well as possible. For the majority of them, they were extracted from significant points other possible K-complex. These significant points are similar to those of Bankman et al. **[8]** and are illustrated in following figure-

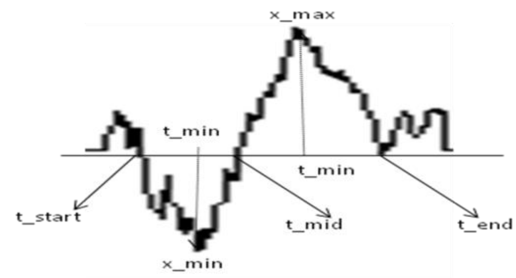

Fig.5:- Features of k-complex waveform

- x_min and t_min correspond to the minimal value of the pseudo K-complex.

- x_max and t_max correspond to the maximal value of the EEG in the interval .

- t_end is the last time interval of the reference signal.which is negative followed by postive.

- t_star corresponds to the first local maximum value.

-x_mid & t_mid are the first value greater than 0uV met by scanning the EEG from left to right starting from t_min.

Following features are obtained based on the above mentioned thresholds are'

The duration of the K-complexe is represented by:

f3=(t_end-t_start)

A minimum peak to peak amplitude is first required although the related threshold is low:

f2=(x_max - x_min)

Concerning the sharpness of the first negative wavecompared to the second positive wave, a relevant criteria is:

f3=(t_end- t_mid)/ (t_mid- t_start)

To ensure that the amplitude of the negative component is at least 50% of the positive amplitude component:

f4=abs(x_min)/ x_max

The sharpness of the negative wave was represented by:

f5=abs(x_min)/((t_mid1- t_start) f sampling*

In order to avoid the possibility of some features dominating the classification process, the values of each feature were normalized so that the range for each feature lies in between 0 to 1. These extracted features where fed as the input for artificial neutral network trained with back propagation algorithm.

III. Results

The Sensitivity and Specificity of both the classifier is as follows,

	Sensitivity	Specificity
Matched Filter	86.47%	67.66%
ANN	96.06%	52.62%

Table 1:- Results for matched filter and ANN.

IV.Conclusion

It has been shown that the k-complex are comprise less than five percent of time in sleep. However, this does not prevent from developing an accurate k-complex detection system for these 5 percent, as the signal is noisy. Therefore, the proposed methods are very efficient for the detection of events buried in noise, even when the SNR (Signal to Noise Ratio) is very small. In the presence of noise, ANN gives more sensitivity and less specificity than Matched filter as shown in table 1.

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