A Review on Sleep Apnea Detection from ECG Signal

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ABSTRACT

Our body constantly communicates information about our health. This information can be capture through physiological instruments that measure heart rate, blood pressure, oxygen saturation and so forth. ECG signal is the most important and powerful tool which contains the diagnosis and treatment of heart diseases. Sleep disorder is characterized by the breaks in respiratory breathing process of uncommon breathing during sleep is called sleep apnea disorder. For an apnea patient the muscles of pharynx relax too much that it obstruct the passage of air flow and this cause the patient to break sleep. From the last few years, various signals have been used for the detection of sleep apnea syndrome or disorder. There are several algorithms for the detection of sleep apnea which include feature extraction followed by feature selection and classification methods. The results of classification can be predicted by accuracy, sensitivity and specificity. These papers focus on the review of various classification methods for detection of sleep apnea from ECG signal.

Keywords: *Sleep apnea, ECG, feature extraction, classifier*.

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1. INTRODUCTION

Sleep apnea is a common disorder where a person will have one or more pauses in breathing. Breathing pauses can last from a few seconds to minutes. They may occur 30 times or more an hour. Sleep apnea usually is a chronic condition that disrupts sleep. When our breathing pauses or becomes shallow, we often move out of deep sleep. As a result, the quality of sleep is poor, which makes fatigue during the day. People who have sleep apnea don't know they have because it only occurs during sleep. The most common type of sleep apnea is obstructive sleep apnea where the airway collapses or becomes blocked during sleep. This causes shallow breathing or breathing pauses. In many cases, an apnea or temporary pause in breathing is caused by the tissue in the back of the throat collapsing.

Fig 1. Normal airway and obstructive sleep apnea

The muscles of the upper airway relax when the person fall asleep as shown in figure 1. Due to sleep apnea disorder, lack of oxygen in our body may receive negative long-term consequences. The most common sleep apnea symptoms are sleepiness during the day irritability, tiredness, impaired concentration, and reduced learning capabilities [1].

Electrocardiography (ECG) is the process of recording the electrical activity of the heart over a period of time using electrodes placed on the skin. These electrodes detect the tiny electrical changes on the skin that arise from the heart muscles during each heartbeat in a PQRST wave form as shown in the below figure 2. It is a very commonly performed cardiology test. Among other instrument, an ECG can be used to measure the rate and rhythm of heartbeats, the size and position of the heart chambers, the presence of any damage to the heart's muscle cells or conduction system, the effects of cardiac drugs, and the function of implanted pacemakers.

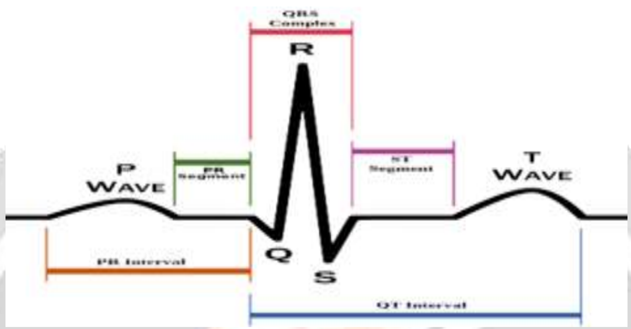

Fig 2. Basic ECG waveform

During each heartbeat, a healthy heart has an orderly progression of depolarization which spreads out through the atrium, passes through the atrioventricular node and to the left throughout the ventricles. This orderly pattern of depolarization gives rise to the characteristic ECG tracing. To a trained clinician, an ECG conveys a large amount of information about the structure of the heart and the function of its electrical conduction system. The ECG signal provides the following information of a human heart:

i. Position of heart and its relative chamber size
ii. Impulse origin and heart rhythm also
iii. Drug effect on heart

2. VARIOUS SLEEP APNEA DETECTION SYSTEMS

Over the last few years, various methods have been developed for diagnosis of sleep apnea disorder. ECG recording is one of the efficient technologies for detecting sleep disorders. Electrical activity of the heart is usually used for the detection of sleep apnea disorder. By extracting different features from the signal and applying classifier we can categorize the patient as apnea or non apnea.

2.1 Sleep Apnea Screening by Autoregressive Models

Martin O. Mendez [2] developed a method which investigates the detection of epochs of sleep apnea from the ECG signal. The aim was to achieve the performance, by selecting smaller number of features for the classification. A bivariate time varying autoregressive (TVAM) model was used to extract features from power spectral density for both RR interval and QRS complex area. The recordings selection for classification where based on satisfying the following criteria:

- No periods with more than eight consecutive misdected QRS complexes,
- No presence of a large quantity of ectopic beats in the recording.

QRS complex area and RR intervals were derived from Pan Tompkins method. A moving average filter is utilizes in order to correct the intervals. At this point, a set of features were extracted from this data through time and frequency domain analysis and then the features were used for classification by KNN. KNN is a nonparametric technique for classification, where it is assumed that it has no a priori parameterized knowledge about the probability structure of the data and data samples are directly used instead. Leave-One-Out Cross-validation (LOOCV) is a loop procedure which is used to compute statistics performance of a classifier. The drawback is isolated apnea is difficult to detect.

2.2 Support Vector Machines for Automated Recognition of Obstructive Sleep Apnea Syndrome

This system was proposed by Ahsan H. Khandoker [3] where a machine learning technique is applied to predict the sleep apnea. Time and amplitude of R peak of QRS complex were determined by using Pan Tompkins algorithm. Since the QRS complex are detected automatically without smoothing filtering, HVR and EDR signal may contain false interval, missed ectopic beats. To overcome this, a moving average filter is applied. Wavelet transform is devoted to the analysis of nonstationary signals. This analysis allows the extraction of the characteristic frequencies contained along a signal.

The obtained HRV and EDR signal where decomposed into 14 levels using Daubechies wavelet. For each record of HRV signals, the detailed coefficients were calculated based on 14 separate levels of decomposition and later the variability power, of coefficients were calculated and named as HRVWv2 up to HRVWv16384. Similarly, for EDR signals, variances of 14 levels of detailed coefficients were named as EDRWv2 up to EDRWv16384. The mean of decomposed HRV and EDR signals where plotted in log scale. In order to provide the relative importance of features, the receiver operating curve (ROC) analysis was used [4], with the areas under the curves for each feature represented by the letter ROC. Here SVM [5] model were considered for automatic recognition of sleep apnea. The margine(dashed line) between the class is maximized in order to predict the obstructive sleep apnea as shown in below figure 3.

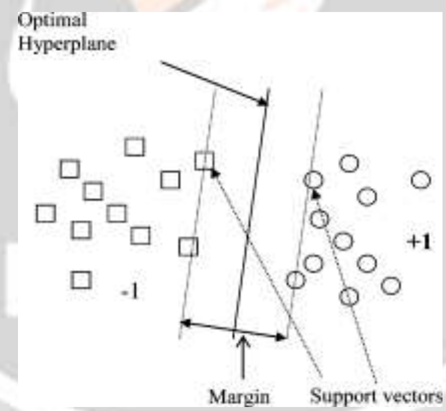

Fig 3. Example of two-class (+1 & −1) problem with optimal separating hyperplane and the maximum margin. The circles and squares represent samples of class +1 and −1, respectively.

SVM first transform the input data into a higher dimensional space by means of kernel function and then construct a liner OSH between the two classes in the transformed space. The data vectors which are nearest to the constructed line in the transformed space are called the support vectors (SVs). SVM approximation method aims to attain low probability of generalization error. Accuracy, sensitivity, specificity, area under ROC curve and kappa values are the measures used to assess the performance of SVM classifier. A main disadvantage of the SVM is its long training time especially with long data set.

2.3Sleep Apnea Detection Method Based on Recurrence Quantification Analysis

This technique was proposed by Shufang Hoa Dinh Nguyen, Brek A. Wilkins, Qi Cheng [6]. HRV reflects the heart's ability to detect, quickly respond, and adapt to changing intrinsic and extrinsic stimuli. The HRV datas are obtain from recurrence plots (RPs) which are believed to be more immune to the effects of the nonstationarity of nonlinear time series, and hence can be used as a good tool for OSA detection. By choosing a different RP thresholding method with different parameters, better attempt is made to capture HR dynamics associated with OSA, thereby improving the classification of apnea versus normal. To exploit the complementary information of different classifiers, two types of binary classifiers, i.e., SVM and NN, are used. A soft decision fusion rule is proposed to combine the outputs of these two classifiers for performance improvement. The classifier combination approach may belong to one of three categories: abstract level, rank level, and measurement level [7].Here the main disadvantage of this method is during feature selection it is difficult to set parameter values especially when size of the feature extracted becomes large.

2.4Sleep Apnea Detection Approach Using a Discriminative Hidden Markov Model

This method was proposed by Changyue Song, Kaibo Liu [8]. The method was implement to overcome the above problems. Here temporal dependency of ECG signal is considered for detection of obstructive sleep apnea. The block diagram of the method is demonstrated in figure 4. RR intervals and EDR signals are obtained from ECG. The data contained critical information about obstructive sleep apnea. The RR interval generally measures the duration of a heartbeat cycle and EDR signals reflect respiratory activities. These data are used to extract features and establish the feature pool for OSA detection. The best feature subset and the observation-to-state classifier are then provided simultaneously by training the discriminative HMM.

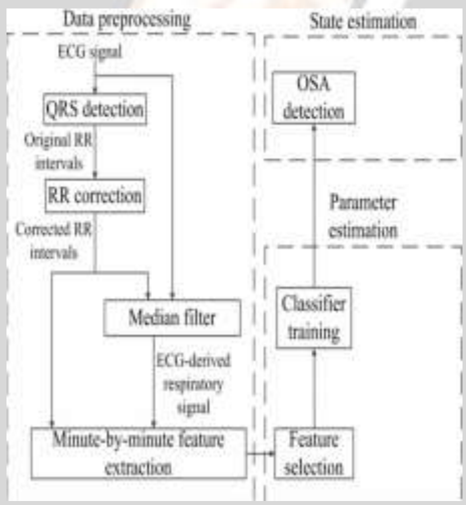

Fig 4. Scheme of the proposed OSA screening approach

In the detection procedure, the Baum– Welch algorithm is used to estimate the state of each segment. The proposed method is evaluated by comparing with the results of existing approaches.

3. PERFORMANCE ANALYSIS

The performance assessment of sleep apnea detection algorithms are performed by sensitivity, accuracy and specificity. Accuracy indicates overall detection accuracy; sensitivity is defined as the ability of the classifier to accurately recognize an OSAS+ whereas specificity would indicate the classifier's ability not to generate a false negative (normal subject, OSAS−).

4. CONCLUSION

In this survey, various automatic algorithm, models and techniques for the deection of obstructive sleep apnea detection using ECG signal recording have been studied. This survey approach, various automated algorithm, models and techniques for the detection of sleep apnea syndrome with the help of ECG signal recordings have been studied. This survey approach helps in selecting the best detection model for algorithm for the diagnosis of sleep apnea disorder events with the higher specificity, sensitivity and accuracy.

5.REFERENCES

[1] D. P.White, "Sleep Apnea," Proc. Amer. Thorac. Soc., vol. 3, pp. 124–128, 2006

[2] M. O. Mendez et al., "Sleep apnea screening by autoregressive models from a single ECG leads," IEEE Trans. Biomed. Eng., vol. 56, no. 12,pp. 2838–2850, Dec. 2009.

[3] H. Khandoker, "Support Vector Machines for Automated Recognition of Obstructive Sleep Apnea Syndrome From ECG Recordings", IEEE TRANSACTIONS ON INFORMATION TECHNOLOGY IN BIOMEDICINE, VOL. 13, NO. 1, JANUARY 2009

[4] J. A. Hanley and B. J. McNeil, "A method of comparing the areas underreceiver operating characteristic curves derived from the same cases," Radiology, vol. 148, pp. 839–843, 1983

[5] V. N. Vapnik, The Nature of Statistical Learning Theory. NewYork: Springer-Verlag, 1995.

[6] Hoa Dinh Nguyen, Brek A. Wilkins AND Qi Cheng , "An Online Sleep Apnea Detection Method Based on Recurrence Quantification Analysis" IEEE JOURNAL OF BIOMEDICAL AND HEALTH INFORMATICS, VOL. 18, NO. 4, JULY 2014

[7] L. Xu, A. Krzyzak, and C. Y. Suen, "Methods for combining multiple classifiers and their applications to handwriting recognition," IEEE Trans. Systems, Man, Cybern., vol. 23, no. 3, pp. 418–435, May/Jun. 1992.

[8] Changyue Song, Kaibo Liu "An Obstructive Sleep Apnea Detection Approach Using a Discriminative Hidden Markov Model From ECG Signals" IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 63, NO. 7, JULY 2016