

Detection of Electrocardiogram Mixed in Electroencephalogram by Stationarization

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Abstract

Signals of Electroencephalogram (EEG) are usually contaminated by signals of Electrocardiogram (ECG) during measurement. Till now, the ECG mixed in EEG is removed as artifacts; however, in this paper we proposed a method to extract the ECG component for medical diagnostics. Stationarization method is applied to extract ECG signals. The ECG signals are extracted by Stationarization, and then averaged as resultant signals. This method requires no more ECG electrodes but only electrodes for EEG detection. A simulation shows the accuracy of our method is over 90 % when the signal-noise ratio (SNR) is sufficiently high.

1. Introduction

It is revealed that feeble ECG may contaminate EEG [1]. Several researches have been conducted to detect and eliminate ECG from EEG.

EEG and ECG are often used in medical diagnostics, but if both signals are measured at the same time, many electrodes are requested. If we can extract ECG components from contaminate EEG signals, we will need no more electrode for ECG, but obtain available information for ECG diagnosis.

To extract ECG component, existing method need to use the periodicity of ECG. In our proposed method in this paper, the ECGs are regarded as aberrations of stationarity of EEG[2].

2. Method: Stationarization

The observed scalp potential $y_{ob}(t)$ can be described as follows,

$$y_{ob}(t) = ECG(t) + EEG(t) \quad (1)$$

Where, $ECG(t)$ is ECG signal on the scalp and $EEG(t)$ is EEG signal. In this study, it is assumed that EEG are applicable to equation (2) which is Ito stochastic differential equations.

$$dEEG(t) = -\beta(t)EEG(t)dt + \alpha(t)dw(t) \quad (2)$$

In equation (2), $\alpha(t)$ and $\beta(t)$ are unknown time varying spectrum parameters, and $w(t)$ is winner process. When patient's eyes are closed, EEG signal measured in O2 or O1 electrode are nearly regarded as winner process, so EEG signal can be described by (2). In addition, according to weak stationarity of EEG, in interval I_t , $\alpha(t)$ and $\beta(t)$ are assumed as constants (3). Thus, when frequencies are described as λ spectral density function $S_t(\lambda)$ in I_t is following (4).

$$\alpha(t) = \alpha_t, \beta(t) = \beta_t \quad \text{for } t \in I_t \quad (3)$$

$$S_t(\lambda) = \frac{\alpha_t^2}{\lambda^2 + \beta_t^2} \quad (4)$$

Based on the method of [5], spectral density functions $S_t(\lambda)$ in each time t are gotten in order to estimate α_t and β_t by equation (4). In consideration of ECG's localization and discretization of (2), we get Equation (5). (5) is divided by $\hat{\alpha}_t \delta t$ in both sides, and left-hand side is treated as one, then equation (6) is leaded. This \hat{y}_t is the signal which is performed by stationarization.

$$\delta y_t + \hat{\beta}_t y_t \delta t = \hat{\alpha}_t \delta w_t \quad (5)$$

$$\hat{y}_t = \frac{\delta y_t + \hat{\beta}_t y_t \delta t}{\hat{\alpha}_t \delta t} \quad (6)$$

When (6) is performed to EEG mixed ECG, stationarities can break up in the time ECGs exist, and ECG signals in EEG signals are emphasized and are eased to be detected.

3. Experiments and Evaluations

3.1 Selection of measurement to detect ECG components

We acquired five minutes data set from three male subjects, respectively. Sampling rate is 500 Hz. ECGs were measured at the same time to EEG signals, simulation data sets were generated by adding ECG signals to EEG signals in given SNR (5-2).

Fig.1 illustrates an example data performed by our proposed method. (a) is an example simulated $y_{ob}(t)$. In (a), ECG signal (d) is added to EEG signal. (b) is the stationarized (a) and this means \hat{y}_t in (6).

Comparing (b) with (a), QRS complex are emphasized obviously. Therefore in (b), threshold is determined, ECG detections are performed. Detected ECG signals are averaged, and it is subtracted from estimated location of ECG. (c) is the EEG signal subtracted averaged ECG signal. Figure (c) shows that ECG artifacts are eliminated.

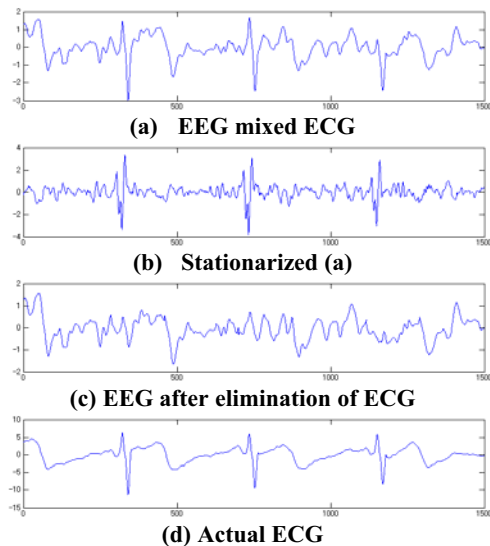


Figure1. Waves before and after performed, kurtosis of performed data and added ECG

3.2 Accuracy:ECG detection by simulated data sets

The result is shown in Table.1. SNR(=power of EEG with ECG / power of original EEG)It shows that difference of R-R interval between actual ECG and detected one, Se(Sensitivity) is true positive / (true positive + FP), Sp(Specification) is true positive / (true positive + FN) and SNR(= power of EEG after elimination of ECG / power of original EEG).

Table1. Performance of this method

SNR Before	Difference of R-R interval (second)	Se (%)	Sp (%)	SNR After
5	0.01939	95	98	1.5
4	0.039141	95	98	1.2
3	0.082817	90	96	1.1
2	0.11509	86	95	1.0

4. Discussion

Table1 shows that differences of R-R interval are a few ms, and both Se and Sp exceed 90 % in high SNR. When SNR is 2, difference of R-R interval became bigger. So current method had have difficulty to be used directly in some diagnosis, but in EEG, result shows that ECG artifacts are almost eliminated from EEG signal, and EEG signal after elimination of ECG are utilizable, when SNR are large. Additionally, manipulation of equation (2) is critical issue, too. And in this research, averaged ECG signals which are detected is subtracted from EEG signals, but ECG shapes are time varying. If these shape variations are considered, performance will be advanced.

5. Conclusion

In this research, ECG signals mixed in EEG signals were detected by Stationarization algorithm using simulation data set. Difference of R-R interval between actual ECG signal and detected one were sufficiently-low and detection accuracies were high in high SNR. When SNR were 1, difference of R-R interval was bigger; therefore, this algorithm must be further developed. EEG signals after elimination of ECG signals are utilizable, because of the similarity of power spectrum between original EEG and one after elimination of ECG.

References

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