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A method to detect heart rate based on electrical bio-impedance

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Abstract. As a basic health indicator, heart rate has been widely used in clinical measurement and daily health care. Electrical bio-impedance (EBI) measurement provides non-invasive method for heart rate detection. Therefore, this paper proposed a method to detect heart rate based on EBI. With the BIOPAC EBI module, the signal can be de-noised in real-time. Finally, the de-noised EBI signal is used to compute heart rate. Four electrodes are located at radial artery of left upper limb in this method. The result proves that this method has high accuracy on heart rate measurement.

1. Introduction

Heart rate detection help in evaluating the state of the subject, especially in study of cardiovascular; heart rate is an independent risk factor of hypertension [1], coronary artery disease [2], and congestiveheart failure [3] and so on. In general, heart rate was measuring through Electrocardiogram(ECG) signal orPhotoplethysmography(PPG)signal[4]. As a novel method,EBI allow us to noninvasively obtain physical information from human body. In general, this measurement is performed on the limb by placing surface electrodes. The blood volume of the blood vessel changes resulting in the change of regional EBI, by measuring the variation of the electrical bio-impedance, the arterial pulse frequency can be collected to represent the heart rate.

EBI measurement with various types of electrodes and measuring systems has long been developed in past years[5 6]. In 2005, Kristiansen et.al using an handheld impedance plethysmograph to measure impedance heart rate, with a Pearson’s of 1.00, the mean difference compare to the gold standard is -x beats/min, show no significance systemic error[7]. In 2008, Rafael et.al present a method from plantar bio-impedance measurement, compare with gold standard ECG derived RR, the mean bias of RR intervals was -0.2ms and the 95% confidence interval was about ±36ms, through the Bland-Altman analysis, there is only one point out of the 95% consistency limit[8]. In 2009, Cho et.al compared different measuring position of arm artery and find an appropriate position with the Pearson’s correlation coefficient of 0.982 to the gold standard, and the RMSE (RootMean Square Error) is 1.817 beats/min[9].

We havedesigneda system to measure the electrical bio-impedance changes to detect the heart rate in motionless condition using multichannel physiologic recorder MP150 (BIOPAC, USA). Due to the low amplitude of the heart-related impedance variations, the collected signal's SNR (Signal- Noise ratio)is not very high, and need to be post process. The rest of this paper is organized as follows. Section II provides details of the methodology, including data acquisition and data process. The result is present in Section III and conclusion is drawn in Section IV.

2. Methodology

The designed system was consisted of hardware module and signal processing method. The ECG and EBI signal could be obtain through the data acquisition system. Figure1 shows the block diagram of the EBI based heart rate measurement system.

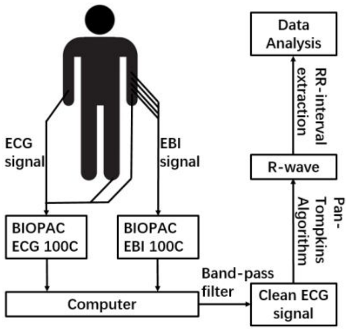

Figure1 the Block Diagram of The Ebi Based Heart Rate Measurement System

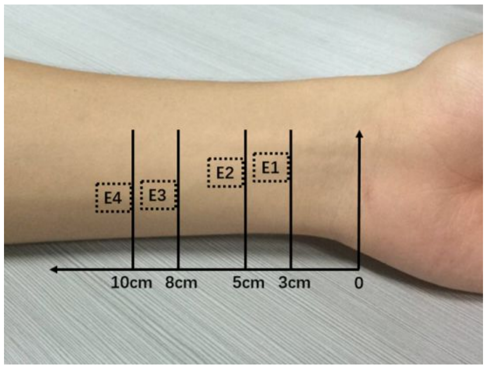

Figure2 The Electrode Position of The Ebi Method

2.1 Data Acquisition

The data of this study consist of 5 minutes simultaneous ECG and EBI signal collected by multichannel physiologic recorder MP150 and its support software acknowledge 4.0, the subjects are 10 healthy people age between 18-25 years old. Here we choose ECG100C and EBI100C module to acquire ECG and EBI signal, respectively. Before paste the electrode, use sandpaper to exfoliating the surface, and then use the medical alcohol to disinfection. Then, paste electrode on lower left limbs, per left limb and right lower limb to composite standard lead of ECG measurement to acquire ECG signal. Paste four electrode E1~E4 on radial artery of arm as figure2, the space is 2cm, 3cm, 2cm. Electrode E1 and E2 is to generate input excitation current with the frequency of 50kHz,E3, E4 is using to receive the output voltage signal. After that, let the subject lie down, while the subject's physiological state is stable, open the MP150, and open the acknowledge 4.0 software on computer, issued a sound command to control subject's breathe regularly, this stage will last for 5 minutes. After that, save the data, close the MP150 and unload the electrode.

2.2 Data Process

Data processing is based on MATLAB R2010b (MATHWORKS, USA). After we obtained the origin signal, we use a band-pass filter with cut-off frequencies is comprised of 0.7and40 Hz, and the filtercould effectively remove the baseline driftand the interference signal such as respiration-related low frequencynoise and50Hz power-line interference[10].R-peaks are found using the Pan–Tompkins algorithm[11] that is properly for this study due to its high accuracy, and the R-peaks location are used to compute the RR interval time series.

3. Results

Figure 3 shows the ECG and the EBI signal from one of the volunteers. It can be observed that the peak of EBI is latter than the ECG signal in the same period. This may due to the closer of the position of the electrode can be faster to obtain the signal. The results of others subjects were similar and the baseline of the two signals were stable as long as the subjects keep quiet.

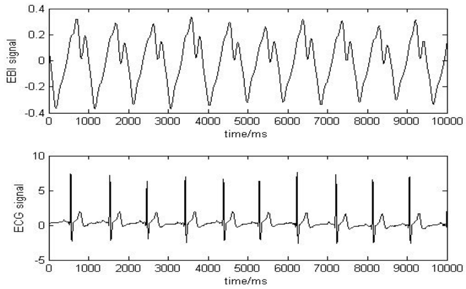

Figure3 ECG Signal and EBI Signal from One Volunteer

Figure 4 shows the EBI and ECG derived RR interval from one of the volunteers, it can be observed that they seemed very similar.

We choose the ECG derived heart rates the gold standard and the ECG derived heart rate is computed using 60/. In order to provide an agreement figure, we used a Bland-Altman plot[12]for each RR interval measured from the ECG and EBI signal in figure 5. The mean bias of RR intervals was -0.0065ms and the 95%

confidence interval was about ±0.04ms. It can be observedthat the RR interval derived from EBI signal essentiallyagrees with the RR intervalmeasuredfromECG.

In figure 6, eachECG derived RR interval is plotted versus the EBI derived RR interval. Pearson correlation coefficient was 0.9965 ($p<0.001$) with an RMSE of 0.0092ms/beat, indicating the EBI derived heart rate has a high accuracy.

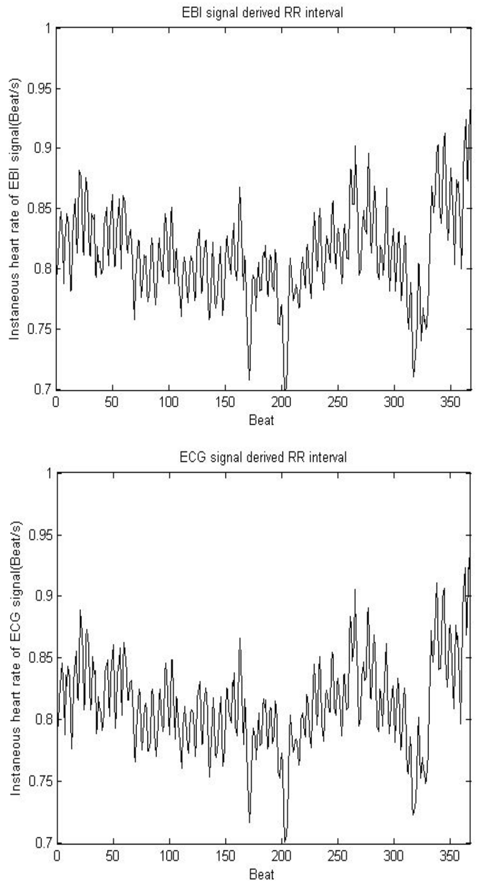

Figure4 EBI and ECG Derived Rr Interval from One of The Volunteers

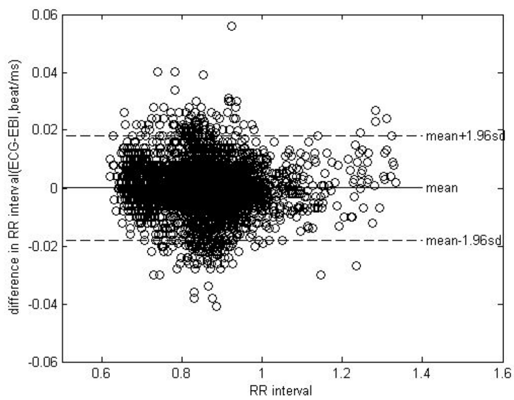

Figure5 Difference Plotted Against Average of Ebi and Ecg Measurements, with Mean and 95% Limits of Agreement.

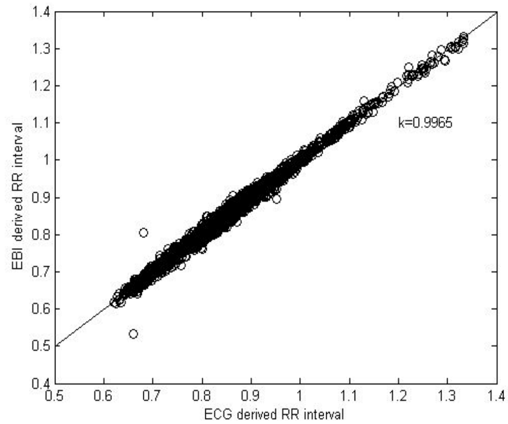

Figure6 The Measured Instantaneous heart Rate Using Ebi Signal Is Plotted Versus by the Reference Signal, the Plot is Fitted by Regression Method.

4. Discussion

A method to detect heart rate based on electrical bio-impedance have been presented ,after calculation and comparison, it is confirmed that the accuracy rate is up to 99.65%, indicate that in the motionless condition, the EBI based heart rate can be accurately reflected the subjects (normal person) heart rate. We also apply the EBI based method to analysis other physiological signal, such as respiratory signal - we designed an EBI based system to research the difference of the respiratory volume between different posture[13].We also concerned on BSN and mobile medical[14],in the future, we may try toapply the electrical bio-impedance on wearable device.

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