Breathing Rate Estimation from the Photoplethysmography using Respiratory Quality Indices

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Context

Breathing Rate (BR) is an important physiological indicator that gives information about a variety of chronic diseases. As direct measurements of respiratory devices are uncomfortable for patients, our objective is to obtain an accurate estimation of BR using only PPG signals.

Methods

To estimate the BR, three respiratory waveforms are derived from the PPG signals based on amplitude modulation (RIIV), frequency modulation (RIFV) and baseline wander (RIAV). Since the derived modulations are highly dependent on patient and activity, it is very difficult to know which one is the most accurate to estimate BR. Therefore, respiratory Quality Indices (RQI) are introduced to assess the quality of derived modulations, before estimation of BR. These RQI are based on a set of features (maximum power in the respiratory physiologically range [0.1-1Hz]) extracted from Fourier Transform (FT), autocorrelation and sinusoidal model (NRMSE) where we suppose that the respiration is a quasi-sinusoidal signal. To estimate BR, the best derived waveform with the highest RQI is selected automatically for each window. The whole process is depicted in Figure 1:

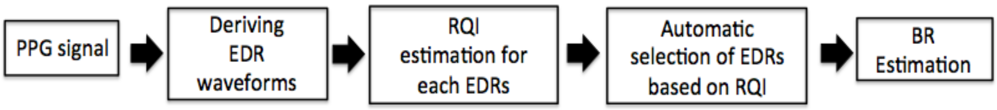

Figure.1 General bloc diagram for the proposed method

Results

This method is compared to four already published methods (pimentel2016, Karlen2013, Flemming2007, Shelly2006). It is evaluated on the 'Capnobase Benchmark', which consists of 42 subjects and data are taking during routine anesthesia. We evaluated the performance of our proposed algorithm for two window sizes W1=32s and W2=64s, as proposed in the literature. An absolute error is calculated between the estimated BR and the capnometric waveform as 'gold standard'. The results are presented as median value error (MVE) and [25-75th percentiles]. The best method reported in the literature gives a MVE 1.2bpm and [0.5-3.4]bpm for W1. Our results, Figure.2, outperform the other published methods and give a MVE of 0.63bpm and [0-3.4]bpm for W1; for W2 the results are 0.4bpm and [0-1.88]bpm for W2.

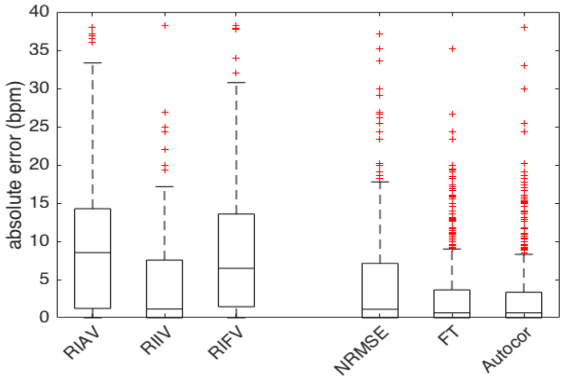

Figure.2 The Boxplots show the distribution of absolute error (bpm) for all 42 patients (8min data*60s*42subjects/W1=630 windows). The first three boxplots are for the derived modulations (RIAV, RIIV and RIFV), then the next three boxplots correspond to the selection of the best window modulations based on RQI. We don't exclude any window from this study; the outliers correspond to 13% from all total number of windows.

Conclusion

Experimental results show that the RQIs coupled with a selection algorithm, when dealing with noisy EDR moduations, is an efficient method in BR estimations. It is a way to estimate accurately BR using only PPG signals. We are currently working on the validation of this method on daily activities.