Heart rate estimates from peripheral sites using instantaneous frequency: a preliminary study

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Delaram Jarchi[1], Alexander J. Casson[2]*
[1] School of Electrical and Electronic Engineering, University of Manchester, Manchester UK, delaram.jarchi@manchester.ac.uk
[2] School of Electrical and Electronic Engineering, University of Manchester, Manchester UK, alex.casson@manchester.ac.uk
* Corresponding author: alex.casson@manchester.ac.uk

Introduction

Continuous monitoring and measuring of Heart Rate Variability (HRV) is crucial for many patient groups to alert carers during critical clinical states. HVR has shown to be very important for healthy subjects during rest, and can be used for remote estimation of cognitive load and subsequent measurement of stress in the work place, and by athletes during physical exercise to increase or decrease their training load. The emergence of wearable sensors has motivated the creation of portable heart rate monitors that can be placed away from the chest, with the wrist being the most popular location. However, this results in a substantial decrease in the amplitude of the recorded heart signal in the case of ECG, and many more motion artifacts in PPG signals. Recent advances in signal processing have allowed heart rate to be measured under these conditions, however, generally at the cost of heavy temporal averaging which obfuscates individual inter-beat (RR) intervals required for HRV analysis. This presentation will present preliminary results using the instantaneous frequency from the Hilbert Transform to attempt to recover this information.

Methods

ECG and PPG signals from the 2015 IEEE signal processing cup are used for this experiment. These are measured as individuals start at rest and go on to perform vigorous exercise, introducing a range of motion interference. Our proposed signal processing method decomposes these ECG and PPG signals through Empirical Mode Decomposition to extract the underlying oscillating components due to heart rate. This is converted to instantaneous heart rate using the instantaneous frequency traces from the Hilbert Transform, which in turn can be used to estimate current HRV. The results are compared to those obtained by applying a Kalman smoothing approach to the estimated RR time-series constructed from detected R-peaks of a chest signal as the ground truth.

Results

Using two subjects, initial extractions of heart rate using the instantaneous frequency show a good agreement with the overall temporal trend compared to the baseline measures throughout the exercise period, ranging from low to high motion. However in high motion cases differences of approximately 20 bpm are seen, with potentially a phase shift between the rates calculated from the instantaneous frequency and baseline. We are in the process of investigating whether this is due to: our signal processing approach breaking down in high motion cases; our instantaneous measure giving different temporal information to the baseline which has to be corrected for in the comparison; or the baseline HR not being a fully accurate gold standard comparison due to motion corruption.

Conclusion

The use of instantaneous frequency via the Hilbert Transform, including an automatic way of selecting the appropriate frequency band to extract heart rate, is a new approach to HRV analysis. It can potentially avoid heavy temporal averaging, important for measurements from peripheral parts of the body. A preliminary analysis has shown some utility to the technique, further work is still needed to validate the approach. This is currently in process, with new data being collected from the wrist and foot to allow future wearable sensors to be placed on any part of the body.