Multi-frequency model fusion for robust breathing rate estimation

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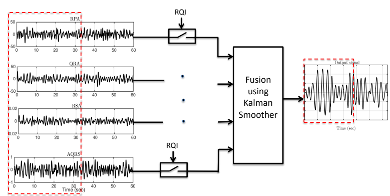
Introduction Breathing rate (BR) is an important physiological indicator monitored for a variety of chronic diseases. Since direct measurement devices are often cumbersome to wear, we aim to obtain an accurate estimation of BR using other monitored signals, such as PPG or ECG. We have previously proposed signal quality based selection of derived modulations and a Kalman smoothing fusion strategy. We further investigate here the pertinence of enhancing model complexity of the smoother by introducing multiple frequency dynamics. Performances are compared to reference methods (Pimentel2016, Karlen2013) on the Capnobase Benchmark dataset (`www.capnobase.org`).

Method The BR estimation by fusion is illustrated through an example of ECG derivation inputs such as R-wave peak amplitude (RPA), Q-R wave amplitude (QRA), R-R temporal series (RSA) and the triangle area of Q,R,S coordinates (AQRS). The application with PPG signals on the otherhand would involve other modulations (RIIV, RIAV and RIFV) as in the previous studies of Pimentel and Karlen. Respiration quality indexes (RQI) are used in order to keep only sinusoid-like modulations for fusion. Metrics such as the energy ratio of dominant frequency components and auto-correlations (see our previous work on the RQI in cinc) are typically used. The originality of this study is to consider multi-frequency model in the Kalman fusion step as opposed to common single frequency models. The strategy is justified from the observation that spectral energies of respiration modulations often include multiple (high-)frequency modes especially for square-formed modulations.



Modulation Fusion using Kalman Smoother

Results and conclusion The multiple-frequency dynamics within the Kalman fusion better fit the respiration modulations and thus yield significant performance gains compared to state of the art reference methods. Notice that Karlen's approach eliminated around 36% temporal segments while we reported estimation results on the whole Capnobase and we also applied the fusion method on available ECG signals, never exploited to our knowledge.

Error in bpm (med and 25-75 percentiles)

Methods	PPG	ECG
Proposed	0.3 (0.1-1.5)	0.1 (0.0-0.6)
Pimentel (optimized)	0.9 (0.5-3.5)	1.4 (0.8-3.6)
Karlen (optimized)	1.1 (0.3-2.6)	1.1 (0.3-2.6)