Selection of reliable RR interval segments using Hidden semi-Markov models

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Context and objective : In ambulatory or intensive care monitoring conditions, noise perturbations present on the electrocardiogram (ECG) can lead to QRS complex detection errors, leading to corrupted RR series. These errors impact Heart Rate Variability (HRV) analysis reliability. To circumvent this problem, classical strategies consist in RR series post-processing (manual or automatic correction) or the detection of clean segments. In this paper, we propose an original approach to retain the most reliable QRS detection periods using Hidden Semi-Markov Models (HSMM).

Methods : Probabilistic features including the amplitude, the slope and the trend of each detected QRS, as well as RR intervals, are extracted from ECG in real-time. These features constitute the observation sequence of two competing HSMM, characterizing unreliable ($HSMM_0$) and reliable QRS detection periods ($HSMM_1$). Being given the two likelihoods L_0 and L_1 obtained, the period is considered reliable if $\log(L_1)$-$\log(L_0)$ is greater than a predefined threshold δ.

Results : The proposed method was evaluated on a simulated noisy ECG database, derived from the first lead of the 48 signals available from the MIT-BIH Arrhythmia Database, where three noise types (baseline wander, muscle artifact and electrode motion artifact), obtained from the MIT noise-stress database, were added with different signal-to-noise ratios. The method was compared to two previously published methods, based on kurtosis and mobility calculation on the ECG. The error criterion EC, which should be minimized, is defined as $EC = \sqrt{\left(1 - \frac{TP}{TP+FP}\right)^2 + \left(1 - \frac{TP}{TP+FN}\right)^2}$ where TP is the true positive of detection, FP the false positive and FN the false negative. Our method outperforms the two others and proposes a reduced EC of 21.37% and 54.57% compared respectively to kurtosis and mobility methods.

Conclusion : The dynamics analysis of information provided by ECG and RR series allows efficient RR series segmentation. The proposed approach offers some promising perspectives for HRV monitoring in noisy context.