OBSS - Analysis of electrocardiographic (ECG) signals

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1 Abstract

In this project we implemented a real-time QRS detection algorithm designed based on a simple moving average filter [1]. Evalutation was done on Long Term ST Database available on Physionet [2]. In addition to algorithm described in the article [1] we added our own improvements and raised sensititvy and positive predictivity by 14% totalling to around 99% for both individually.

2 Introduction

Our task was to implement and evaluate a selected QRS complex detection algorithm. With a simple moving average filter we were able to detect a very high percentage heart beats using ECG signal and pulsatile signals. To get the most accurate results we evaluated the implemented algorithm on the whole available database.

3 Methods

We decided to implement "A Moving Average based Filtering System with its Application to Real-time QRS Detection" [1]. Its algorithm is relatively simple and follows the following diagram:

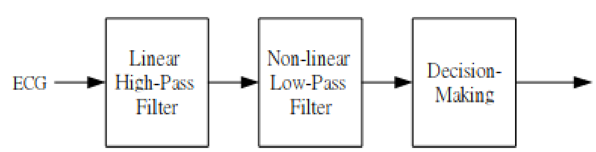

Figure 1: A block diagram of the QRS detection system. [1]

As seen from Figure 1 algorithm goes through 3 main stages. Outputs are indices of detected heart beats.

First, we send ECG signal through a Linear High-Pass Filter. In general, this stage is intended to emphasize the QRS complex while suppressing the lower frequency noise sources of an ECG signal.

Second, gained output is further inputted into a nonlinear Low-Pass Filtering Stage constructed by a cascade of a simple point-by-point squaring operation and a moving window integration or summation system. After this stage, QRS complexes appeared to be significantly enhanced while those corresponding to the undesired noise peaks were relatively attenuated.

Finally we detect assumed heart beats. Here, an adaptive threshold is incorporated into the scheme designed for decision-making and is updated by

$$threshold = \alpha * \gamma * PEAK + (1 - \alpha) * threshold$$

where PEAK is the local maximum newly detected in the feature waveform and α is referred to as the "forgetting factor", γ is a weighting factor for determining the contribution of peak values to threshold adjustment.

4 Results

With recommended parameter values, i.e. M = 5, $\alpha = 0.05$ and $gamma = 0.15$ and our own "best evaluated" settings, we used summation window of size 8 which corresponds to 30 ms. In decision making we used window size of 100, corresponding to 400 ms. With additional improvements such as:

1. Updating threshold every iteration instead of just updating when QRS complex is detected. This allows the algorithm to lower its threshold if an abnormally large peak is detected.

2. We used 2 derivatives of signals and summed them up after 2 stages of algorithm. Second derivative works as a backup, if the first is contaminated by noise.

3. We introduced an additional way to move window when detecting heartbeats. After a heartbeat is detected we additionally move the window by the value of the index of the detected heartbeat in the window. This stops multiple detections of the same heartbeat.

With these improvements we achieved average 99.51 sensitivity and 99.07 positive predictivity on the whole available dataset.

5 Discussion

With obtained results there follow many different improvements. Algorithm still sometimes struggles with noise and large peaks. An additional filter that lowers these abnormalities could achieve even better results.

Literature

[1] H.C. Chen and Szi-Wen Chen. “A Moving Average based Filtering System with its Application to Real-time QRS Detection”. In: vol. 30. Oct. 2003, pp. 585–588. ISBN: 0-7803-8170-X. DOI: `10.1109/CIC.2003.1291223`.

[2] Franc Jager et al. “The Long-Term ST database: a research resource for algorithm development and physiologic studies of transient myocardial ischemia”. In: *Computers in Cardiology 2000. Vol.27 (Cat. 00CH37163)* (2000), pp. 841–844.