Fetal ECG Detection in Abdominal Recordings: a Method for QRS Location

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Abstract

Noninvasive maternal abdominal recordings can help improving fetal monitoring. In this work, in the context of PhysioNet/Computing in Cardiology Challenge 2013, we develop a method to locate fetal QRS in those recordings.

First we eliminate baseline wander and other artifacts through median filter, Notch, and low pass filters. Using the four available channels we locate maternal QRS complexes and remove them from the ECG with an adaptive linear filter. With a peak detector, we locate Fetal QRS occurrences in each channel. The last step consists on selecting one of the four sets of Fetal QRS detections.

1. Introduction

The development of techniques for identifying Fetal ECG (FECG) wave forms in surface abdominal recordings is important to improve fetal monitoring during the second half of pregnancy [1, 2]. Difficulties arise because fetal ECG signal is weaker than mother ECG (MECG) signal and the recordings are subject to multiple sources of noise.

The Physionet/Cinc Challenge 2013 focuses on methodes for locating the Fetal QRS(FQRS) and estimating the QT interval in a one-minute non invasive Fetal ECG recording. Each of these recordings contains four signals, sampled at 1 kHz, obtained from a set of electrodes positioned in the skin of a pregnant woman's abdomen [3].

In this work we describe a method lo locate the Fetal QRS complex (FQRS) in those recordings.

As the energy of MECG component is much bigger than the FECG component, to be able to extract FECG features from abdominal recordings, the common approach is to remove totally or partially MECG from the recordings. The most used techniques are adaptive filters, decomposition in basis functions, e.g. wavelets, and blind and semi blind source separation methods, e.g. ICA, and subspace decomposition methods (see [4] for a brief revision).

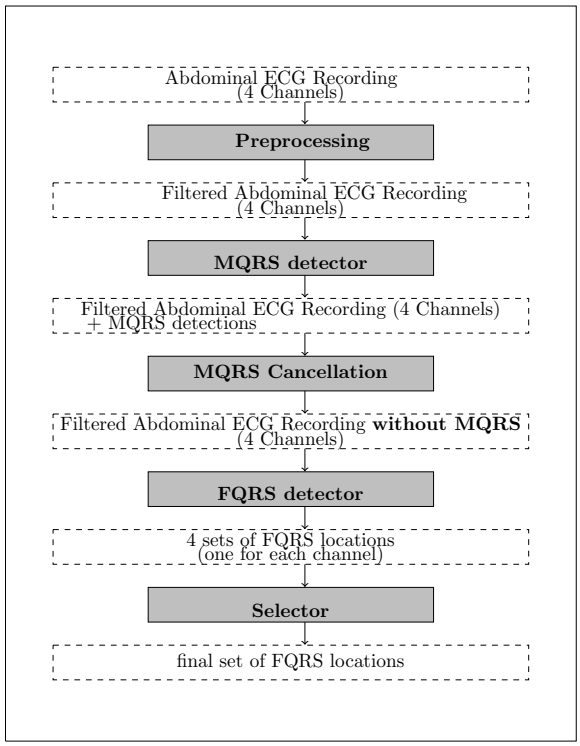

Figure 1. Diagram of the method.

2. The method

2.1. Preprocessing

To obtain an estimate of the baseline, on each channel, we apply median filter with a window of 200 ms. Then we subtract the estimated baseline from the signal.

Next step is to apply a low pass filter and remove possible power line noise with a Notch filter.

Let Z be the median of the set of maximum absolute values of the different channels. Each signal sample is clipped to $\pm 1.2 \times Z$ when its absolute value overpasses $1.2 \times Z$.

2.2. MQRS detection

To detect the maternal QRS (MQRS), we use the four channels. For each channel i, let s_i be the signal with the

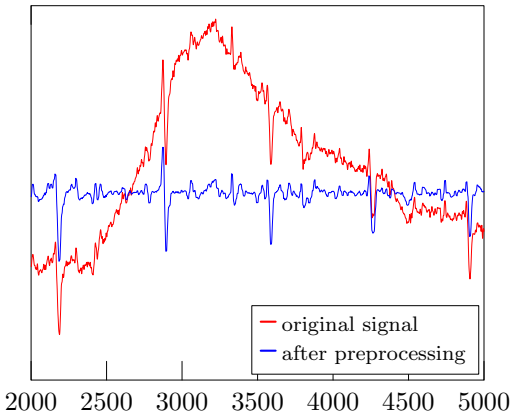

Figure 2. Preprocessing channel 1 from record a17.

consecutive differences of that channel. For each sample t, we compute the correlation of $s_i(t-L), ..., s_i(t+L-1)$ with the vector, consisting of L ones followed by L minus ones. The result is, for each channel i, a signal T_i. We used $L = 20$, as the sampling frequency is 1 kHz. Next we set $T = abs(T_1) + abs(T_2) + abs(T_3) + abs(T_4)$, where abs is the absolute value. The MQRS locations coincide with the maximums of T.

2.3. MQRS cancellation

Cancellation of MQRS on each channel is done using an adaptive filter. The filter produces as output an approximation of a given channel, in a neighborhood of each MQRS, and that takes as input the other three channels. Subtracting from the given channel the filter output, we cancel the MQRS. The output of the filter is only an approximation of the target channel and, often, that approximation is worse when the MQRS coincides with an FQRS, remaining a residual that might be later detected as a FQRS (see figure 3).

2.4. FQRS detection on each channel

After MQRS cancellation, each channel is smoothed with a low pass filter. Then, on each channel, a peak detector takes a first approach to FQRS locations, using general estimates of maximum fetal RR intervals, M =550 ms, and minimum fetal RR interval, m =320 ms. With the results of the first approach, we get, on each channel, new estimates for M and m:

$$M = \frac{9}{8}K \text{ and } m = \frac{6}{7}K$$

where K is the third decile of the RR intervals.

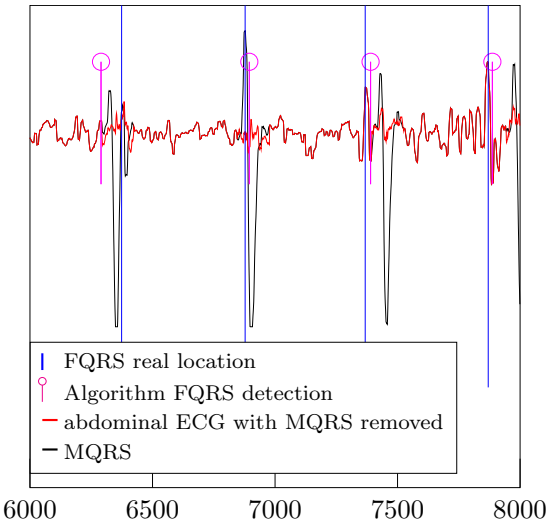

Figure 3. Channel 1 from record a03.

After running again the peak detector with the new values for M and m, we get, for each channel, a set of FQRS locations (see figure 4).

2.5. Selecting the final set of FQRS locations

The final step of this method is selecting one of the four sets of FQRS locations.

We compute for each channel i:

$$S_i = \text{number of FQRS detections} - 0.5 \times std(\text{ RR intervals})$$

where std is standard deviation.

We choose the set of FQRS detections corresponding to the highest S_i.

3. Data

The data used in these work are PhysioNet/Computing in Cardiology Challenge 2013 sets A and B [5]. Set A consists of 75 recordings with reference annotations marking the locations of each fetal QRS complex. Set B contains 100 recordings but no reference annotations. Additionally, in the Challenge, there is a set C but it is not publicly available.

4. Results

PhysioNet/Computing in Cardiology Challenge 2013 is structured as 5 events [3].

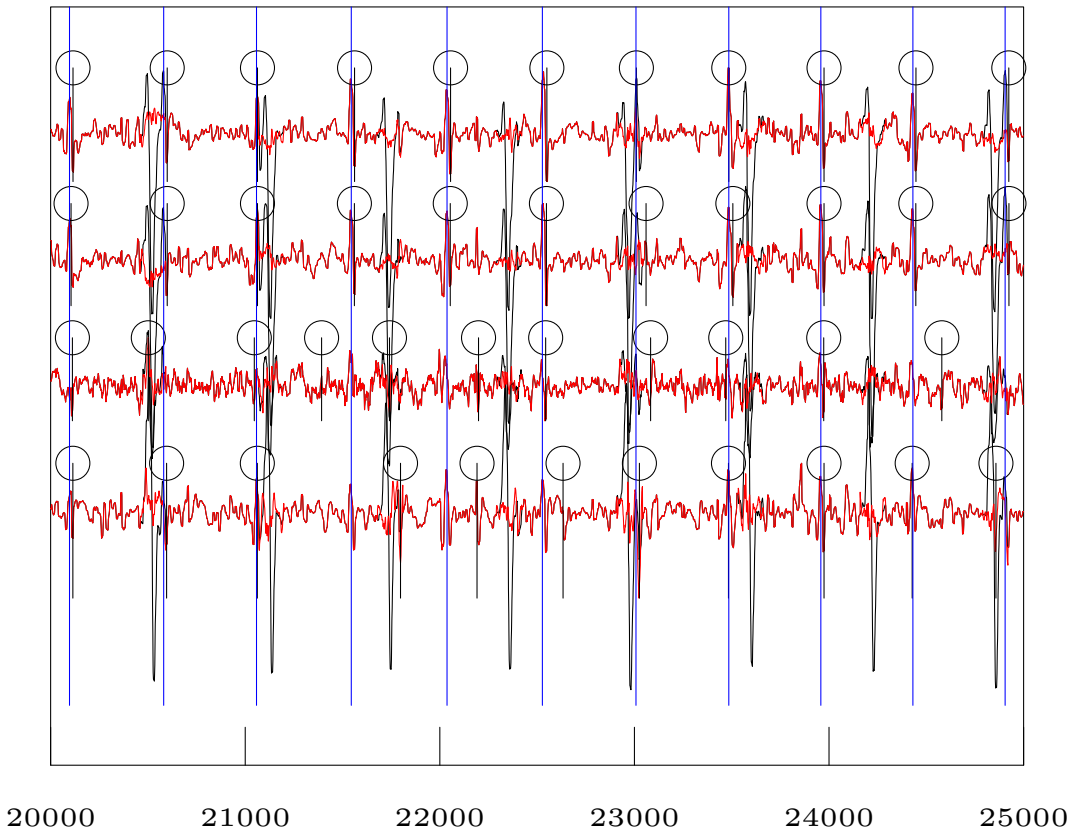

Figure 4. Different FQRS detections for different channels: record a14.

- The goal of events 1 and 4 is to estimate a time series of heart rate (FHR) measurements on recordings from sets C and B respectively. Scores on these events are computed from the differences between the algorithm FHR measurements and the reference values.
- The goal of events 2 and 5 is to determine a time series of Fetal RR intervals on recordings from sets C and B respectively. Scores on these events are computed from the differences between the algorithm RR intervals and the reference values.
- The goal of event 3 is to estimate the median of fetal QT interval. This method does not estimate fetal QT interval.

The scores of this method on the challenge are:

event 1: 278.755
event 2: 28.201
event 4: 124.803
event 5: 14.351

5. Discussion

The most obvious weakness of the method is detecting steep T and P waves as FQRS locations, as it happens in

records *a43*, *a64* and *a75* (see fig. 5).

The criteria to choose the channel from where all the FQRS locations are taken does not always lead to the best results. So far we do not envisage a better criteria, perhaps the best would be to take into account simultaneously the contribution of all leads to locate the FQRS occurrences.

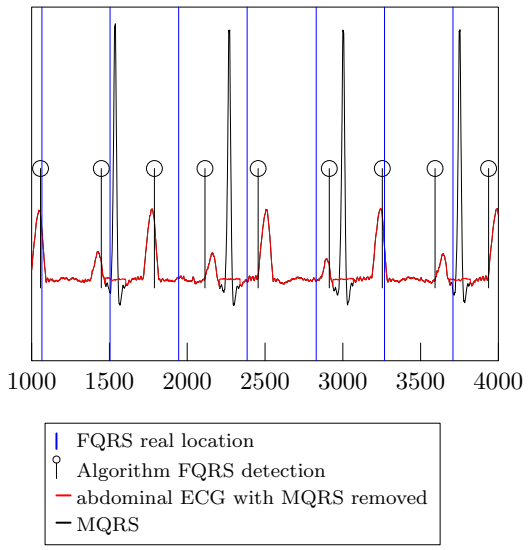

Figure 5. Record a64, channel 4: all P and T waves are detected as FQRS

Acknowledgments

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