Adaptive Procedure for ECG Baseline Wandering Suppression

Gitanjili Puri and Serafim Dimitrov Tabakov

Abstract: **Removal of baseline wander (BW), which includes motion and respiratory artifacts, from the long-term ECG recordings can be difficult because the spectrum of noise often overlaps with the spectrum of cardiac signal. Due to the changing frequency of BW none of the methods provide a general solution to the problem but several adequately detect and track the major changes in the P and QRS complexes. Using detailed analysis of various types of residual errors we designed a two step procedure (combining move averaging and noise subtraction), for selective filtering of ECG and removal of residual error with minimal distortion of cardiac complexes. The procedure activated only if BW exceeds predetermined thresholds.**

Keywords: **ECG processing, ECG baseline wander, selective digital filter.**

I. Introduction

Baseline wandering is a noise artifact, typical for ECG signals. The BW caused by the subject's movement or breathing, might induce misleading measurement and annotation of the signal's features. The spectrum of the distortion overlaps with the ECG spectrum. In the electrocardiogram there are low frequency components between S–T components. The low frequency drift must be removed, but the signal itself must not be changed. To prevent from mistakes, a high-pass filtration with cutoff frequency higher than the drift's (about 0.05 Hz) has to be used.

Several decisions of both analogue and digital filters are found place in the practice. Jane et al. [1] proposed an adaptive technique by that applies a combination of a Least Mean Squares (LMS) driven adaptive impulse correlated filter and a two stage cascade filter for the removal of baseline wandering.

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This technique requires detection of the QRS complex and the frequency analysis of the signal in order to determine the transfer function of the cascade filter. Daqrouq et al. [2] have proposed a baseline wandering reduction technique that requires decomposition and reconstruction of the signal after signal filtration. Therefore, these techniques require certain knowledge (RR interval) of the patient prior to applying the filtering technique. Lisheng et al. [3] used a combination of Meyer wavelet filter and spline interpolation for the removal of the baseline wandering.

The described bellow procedure for BW removal, based on the approach, proposed by Iliev et al. [4]. The program realizes the so called "Filter 10x17". This is a digital filter, which's purpose is to suppress the baseline wander and the 50Hz – distortion. The procedure is quite similar to the subtraction method. The filter averages values. The removal of the drift is realized by subtracting the averaged from the original values. The values received after the subtractions are the distortion ones. The 50Hz – distortion is suppressed by calculating the number of the samples, being averaged and the high-pass cutoff frequency. In practice it has been proven that averaging 17 samples distanced by 10 samples is the best combination with a zero at 50Hz and high-pass cutoff at 1.1Hz.

II. Method

In order to receive the baseline drift the first step of adaptive procedure is the moving averaging procedure (Equation 1, similarly with Filter 10x17).

$$Y(nT) = \frac{1}{N}[X(nT - D\frac{N-1}{2}) + ... + X(nT) + ... + X(nT + D\frac{N-1}{2})] \qquad (1)$$

$X(nT)$ is input sample by index n, $Y(nT)$ is corresponding output sample. The obtained signal represents baseline wander. The proposed procedure analyses and estimates the wander and takes decision depending of the wander intensity (amplitude). If the amplitude is higher than predetermined thresholds, the Filter10x17 is turned on. The filtration not executed if the BW not overcomes the threshold.

The program, realizing this equation is written in C. We tested it with signals of databases. The block diagram of the program is given in fig. 1.
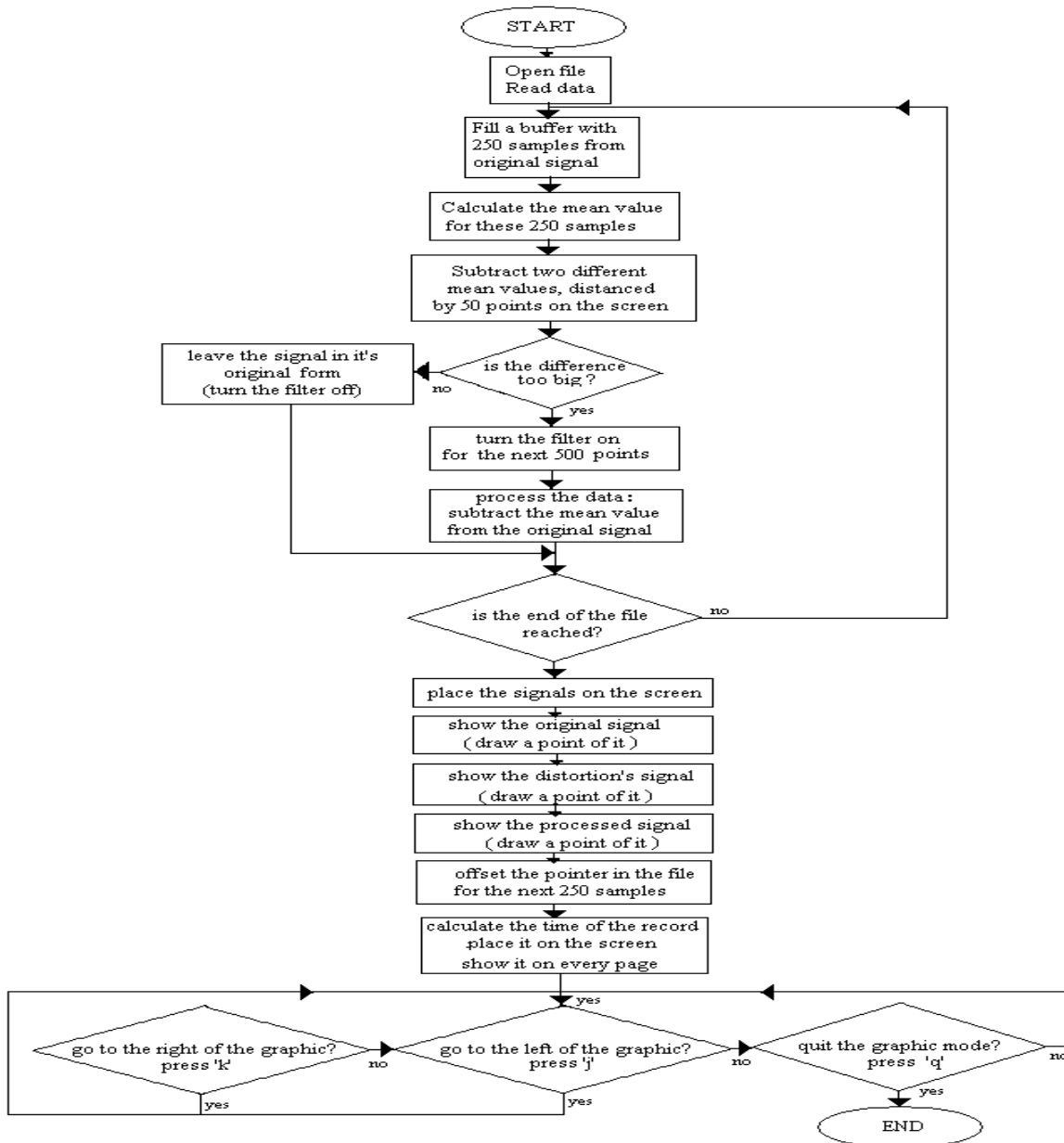
Fig. 1. Block diagram of the algorithm

The program includes the following steps:
- open a file with recorded signal;
- display it on a screen;
- data processing;
- take decision for filter on/off;
- display the filtered signal;
- display the BW, which was removed.

In the beginning it verifies if the file was successfully opened (otherwise it goes directly to the end). The second task is to fill a buffer with 250 cells with the first 250 samples of the file. The third task is to calculate the mean value for the middle cell (90). 17 values are taken, distanced by 10 ones, and summarized. The received value is divided by the number of the summarized cells (17). For the first 50 samples the mean values are directly subtracted

from the original ones. The result of the subtraction is the distortion. After the processing of the 50-th sample, a calculation is made: if the difference between two samples, distanced by 50 samples, is bigger than a predetermined threshold (if there is a considerable base – line wander), a filter is turned on. It subtracts the mean value from the original. It is possible to process all the data in the file, or part of it. In every cycle the program verifies if the end of the file has been reached. When all of the values, chosen were processed, the signals are displayed on the screen. On first screen is the original one (fig. 2). Then the distortion is displayed (fig. 3), in the end - the processed signal (fig. 4). The program calculates and pointed by marks the time of when this signal had been recorded during the test and also displays it on the screen (fig. 5).
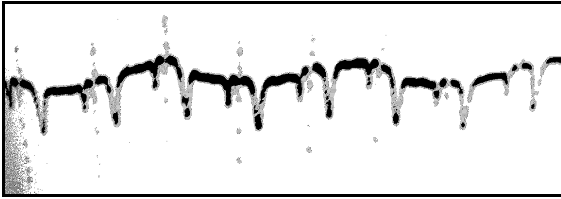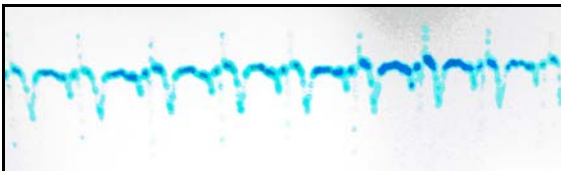
Fig.2

Fig.3

Fig.4

Fig.5

III. CONCLUSION

An adaptive procedure for BW removing is developed and presented. The main advantage of the procedure is possibility to take decision for filter activation, depending of baseline drift intensity. The procedure has been tested with the signals from standard databases. The full screen of the program application is shown on fig. 6.
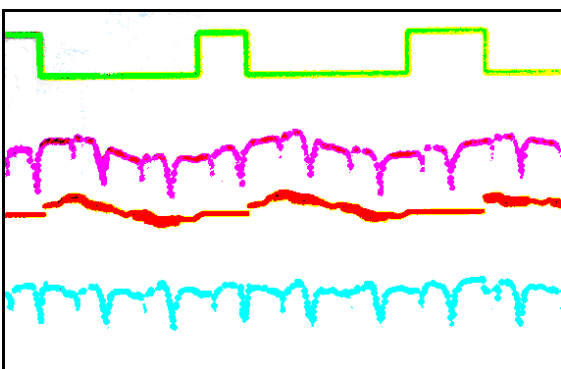

Fig.6

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