Detection of Time-Intervals in Biomedical Signals Using Template Matched Filter

[1]S. Kumar, [2]S. Anand, [2]A. Sengupta

[1]National Institute of Technology, Jalandhar, India
[2]AIndian Institute of Technology, Delhi, India
Email: pahujas@nitj.ac.in

Abstract. *Fetal Heart Rate Variability (FHRV) is a reliable quantitative marker of autonomic nervous system (ANS) activity of the fetus and its analysis has gained importance in medical research and clinical applications. Fetal Electrocardiograph (FECG) is clinically used to help doctors diagnose various diseases. One of the popular measurements is FHR and other physiological parameters. World wide, the standard method of monitoring the fetus during labor is the display of continuous fetal heart rate (FHR) and the uterine activity with the help of cardiotocogram (CTG). By analysis and appropriate interpretation of changes in the CTG obstrician hope to prevent the delivery of dead or impound babies who had suffered as a result of a lack of oxygen during labor and delivery. These signals are analyzed using an automatic PC-Based virtual instrument in LabVIEW. A template matching technique works well in the calculation of R-R interval of the ECG/FECG data and peaks of the biomedical signals.*

Keywords: FHRV, ECG, uterine contractions, fetal movements, R-R interval

1. Introduction

Fetus in situ initiates compensatory protective mechanism to sustain pregnancy, which enables fetus in utero and mother to adapt and acclimatize to an altered state of pregnancy. Therefore it is imperative to monitor vital parameters at a regular interval and at times continuously (fetal autonomic nervous system, fetal movement and uterine contractions) throughout pregnancy and labor for an optimal pregnancy outcome. There for continuously monitoring of fetal and maternal activities antenatal and intra-partum is important to detect in advance fetal problems that could result in irreversible neurological damage or even fetal death during labor. The FECG signal was obtained by measuring (invasively) differentially between an electrode on the fetal scalp and a standard skin electrode placed on the maternal thigh, and a second maternal electrode was used a earth [1]. Non-invasively, the ECG and FECG signals are commonly measured at two locations; the chest and the abdomen. The analysis of the electrocardiogram (ECG) signal has been known as a fairly reliable technique for cardiac disease diagnosis. ECG, recorded from maternal abdomen, can in principle be used to monitor the electrical activity of the fetal heart during pregnancy period. In abdominal FECG recording, the mother ECG (MECG) represents an additional and predominant source of interference. Numerous attempts have been made to detect the FECG in abdominal recording. To this and ,the authors have mainly focused on the removal of the MECG using classical filtering techniques (Bemmel and van der Weide 1966) or estimating technique , such as adaptive filtering (Windrow et al 1975) , subtraction (Meijer 1981) and averaging (Abboud and Sadeh 1989, Cerutti et al 1986). However none of these proposed methods have been validated on a large database of real abdominal ECG measurements. This limited reproducibility of the measurement may suggest a scarce performance due to the inaccurate removal of the MECG and to presence of other significant interference signals.

Recently, a completely different approach for FECG detection has been considered. Some authors formulated the FECG detection as a blind source separation (BSS) problem (Callaerts et al 1986, Zarzoso et al 1997, Lathauwer et al 2000). BSS method e.g., principal component analysis (PCA) and independent component analysis (ICA), are algebraic methods for the estimation of unobserved component from multidimensional data. The alterations of the heart beat or HRV is a useful tool for assessing the status of the ANS non-invasively. These concepts were successfully used for separating mutually independent signals in biomedical signal processing. On the other hand, Barros and Ohnishi proposed a new method called heart instantaneous frequency (HIF) which showed to be an efficient estimator of HRV using the spectral response of the cardiac signal. The most common approach for HRV calculation is based on QRS complex detection. HRV is calculated from an electrocardiogram (ECG), after detecting the QRS complex (Fig. 1), and then computing the time difference between two successive R-waves. The spectral analysis of HRV signal (R-R time series) allows quantitatively evaluating and distinguishing between the different activities of the ANS such as high frequency component, a low frequency component and a very low frequency [2-4].

2. Algorithm

The various techniques are used to detect QRS complex like linear digital filters, nonlinear transformations, decision processes, and template matching. Typically, two or more of these techniques are combined together in a detector algorithm. The most common approach for QRS detection is based on template matching. A model of the normal QRS complex, called a template, is extracted from the filtered ECG [5]. This template is compared with the subsequent incoming real-time ECG to look for a possible match, using a mathematical criterion. A close enough match to the template represents a detected QRS complex. If a waveform comes along that does not match but is a suspected abnormal QRS complex, it is treated as a separate template, and future suspected QRS complexes are compared with it. From the QRS detector, the RR intervals are determined [7]. The ECG signal is then classified based on the QRS duration and the RR interval, hence HR. The same way the peaks are identified from the fetal movements and uterine contractions for finding their intervals.

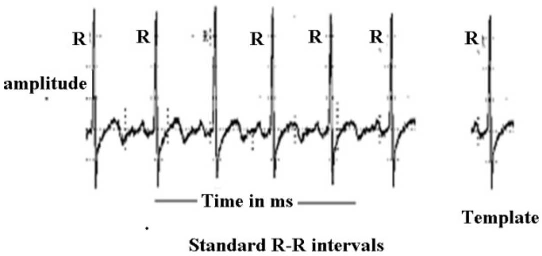

Fig. 1. A standard ECG signal with R-R intervals and template

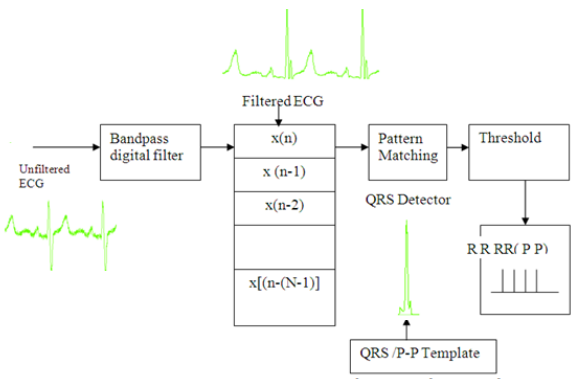

Fig. 2. General Block Diagram of QRS complex and P-P detection from unfiltered ECG / biomedical signal

A general block diagram of the QRS/P-P detection process is shown in figure 2. The unfiltered biomedical signal is first passed through a band pass filter/ Notch filter (as shown in Figure 3) to reduce the effect of noise. The filtered data samples are stored in the file for comparison with the QRS template in the QRS detector. When it is matched, the output of the QRS detector is then one (unit impulse signal for each matching) [7].

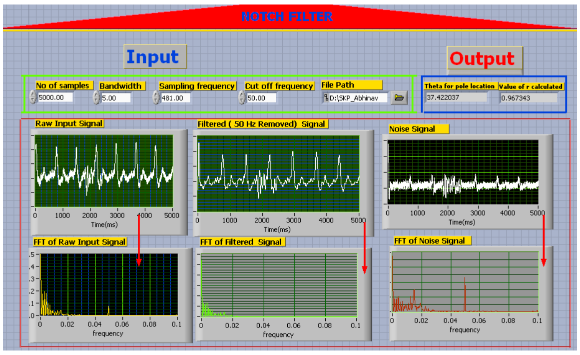

Fig. 3. Snap shot of the real time notch filter

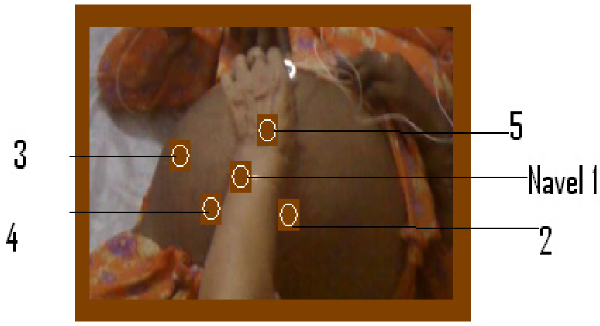

Fig. 4. Fetal movement and uterine contractions

3. Data Recording

Signals were recorded non-invasively using BIOPAC with sampling frequency was 1000 samples per seconds while the ECG and FECG are recorded by Ag-Ag/Cl electrodes on the thoracic region and abdomen region. Uterine and fetus movements were recorded non-invasively by pressure sensors placed on various positions on the abdomen of the subjects as shown in figure 4 while some phantom data was also recorded to depict fetal movements with the help of IPG instrument. The instrument records the signal and any variations inside the phantom/abdomen as shown in figure 5.

4. Implementation Of The Algorithm And Result

The algorithm discussed here is designed in LabVIEW, a graphical programming system with a large built-in library for data acquisition, processing, analysis, and display. Bandpass filter reduces the influences of muscle noise, power line frequency, baseline wander, and T-wave interference. The desirable pass band to maximize the QRS energy is approximately 5-15 Hz [6]. The unfiltered ECG (fig.6 (a) and pulse signals are passed through the band pass or notch filter. The filtered output is shown in fig 6(b). The reference signal (fig.6(c)) is compared with the subsequent incoming ECG samples for a possible match, using a mathematical criterion. A close match to the template represents an impulse of unity gain as shown in fig 6(d). It shows the time interval of 830ms and HR of 72.29 between 2 and 3 R-R interval as shown in fig.6 (e). Figure 7 shows the result of fetal movements.

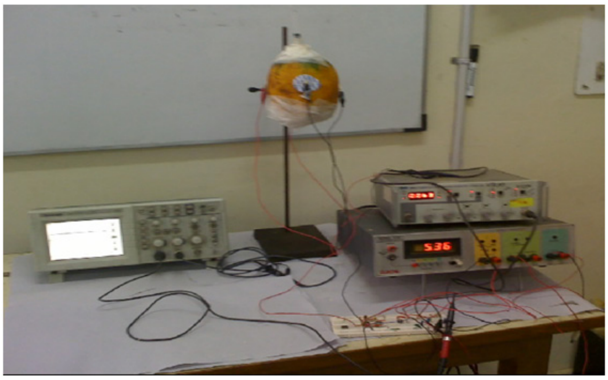

Fig. 5. Phantom for recording changes inside the papaya to depict fetal movements

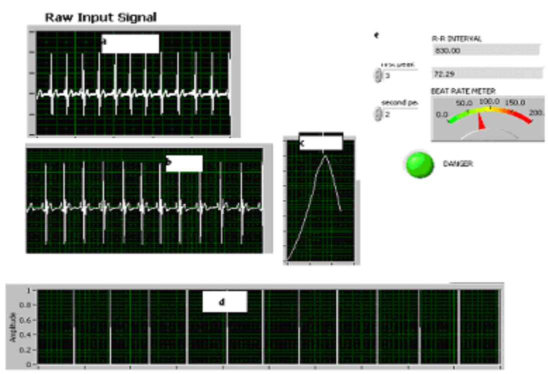

Fig. 6. (a) Unfiltered ECG, (b) filtered signal, (c) ref. signal, (d) matched signal, (e) R-R interval and HR

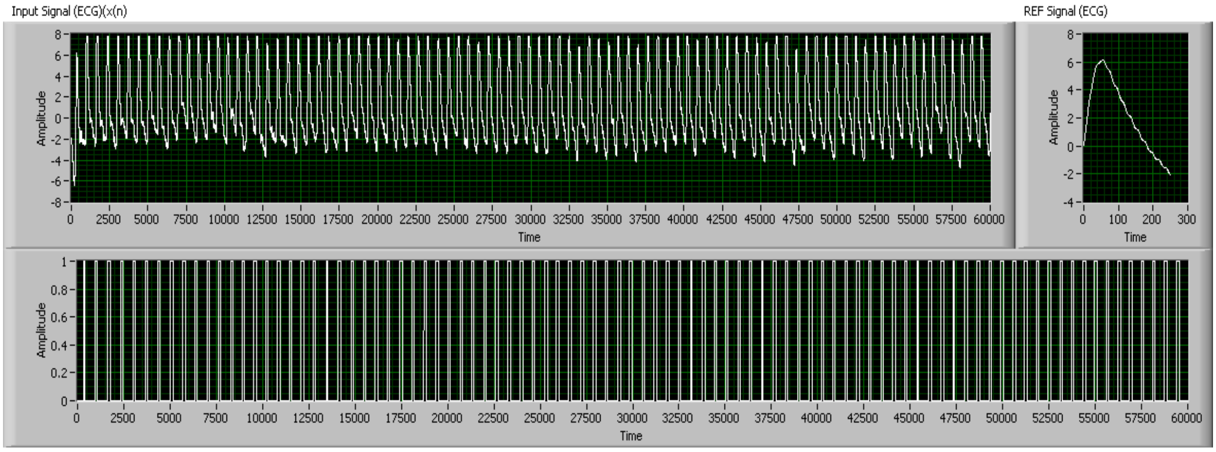

Fig.7. Result of fetal movements using template matching.

5. Conclusions

If conclusions are stated in a separate section, they should be clear and concise. In this paper we have tested a template matching algorithm for QRS complex detection on the different signals, i.e. ECG, FECG, and fetal movements. ECG has been extensively studied because of its great clinical significance in diagnosing heart diseases. QRS complex detection is the most important problem in ECG signal analysis. A number of QRS detectors have been designed for measurement of R-R interval. ECG signal is an electrical signal while the radial artery signal is a mechanical signal. Here, a template matching method is used for the determination of QRS complex of the ECG signal, hence R-R interval and P-P interval from the fetal movements. ECG signals showed heart rate of various signals. Future research will concentrate on the diagnosis of disease using the system designed and in various feto-maternal well being studies.

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