Fetal Heart Monitoring From Maternal ECG

M. Manikandan, Jayasubha R Y, Dr. S. Krishna Kumar

Abstract: Observing fetal health is very important for mothers and the fetus well-being. Most of the conditions can be monitored via ECG, so Fetal ECG extraction plays an important role. Extracting Fetal ECG implies filtering maternal ECG and other artifacts and due to the presence of reference signal which is mothers ECG from chest adaptive filter is used much often. This paper proposes adaptive noise cancellation technique using LMS algorithm and heart rate detection algorithm. The method can also be used for a model based design to achieve result on hardware platform.

Index Terms: Fetal Electrocardiogram, Adaptive Noise Cancellation, LMS Filter, Maternal Hear beat, LMS algorithm, peak detection, convergence

1 INTRODUCTION

Neonatal healthcare is always associated with foetus health as if any conditions can be diagnosed, then there are maximum chances that the condition can be treated before the birth. Diagnosing any pathological condition during pregnancy normally asphyxia [1] is very important. Electrocardiogram or called as ECG is one of the simplest and painless non-invasive diagnosis method to estimate the heart condition. Fetal ECG (FECG) signal provides valuable information of the foetus physiological state, this is acquired by placing skin electrodes on the mother's abdomen [2]. As ECG is measuring the electrical activity, ECG from the abdomen (AECG) is usually corrupted or has interferences which basically can be categorised as noise. During a cardiac cycle ECG signal consists of P, QRS, and T wave. Detecting R peak from QRS complex from abdominal ECG is very important. ECG for an adult is measured from chest, so considering this maternal ECG can be obtained from chest which would not have Fetal ECG. . Various researchers have put forward the technique of extracting Fetal ECG by taking maternal ECG from two location chest and abdomen [3].The abdominal signal is a composite signal of Fetal ECG and maternal ECG whereas chest lead signal consist of only maternal ECG. Various techniques have been proposed by researchers such as wavelet filtering, correlation technique, filtering technique. The fundamental objective of the paper is to monitor fetal heart based on adaptive filtering using Matlab ® environment. Adaptive filter acts as a noise canceller and its task is to extract Fetal signal, noise canceller needs a reference signal which is given in the form of maternal electrocardiogram signal. To understand how it works every heartbeat is an electrical signal which spreads from the chest to the bottom, and process repeats where the signal set a rhythm which can be seen as a heartbeat [4-5]. The signal contains information within a frequency range of 50 Hz .Rest of the paper is organized as Methodology, result and conclusion.

- *M. Manikandan has completed his B.Tech in Biomedical Engineering from Satyabhama University, Jeppiar Educational Trust, Chennai. Email: bluredora@gmail.com*
- *Jayasubha R.Y has completed her engineering from VIT ,Vellore .email: jayasubha.j@gmail.com*
- *Dr. S. Krishna Kumar has received his PhD from Manonmanium sundaranar university,Tirunelveli, Tamil Nadu.and currently he is a professor at Sathyabama University. Email: drkrishnakumar_phd@yahoo.com*

2 Methodology

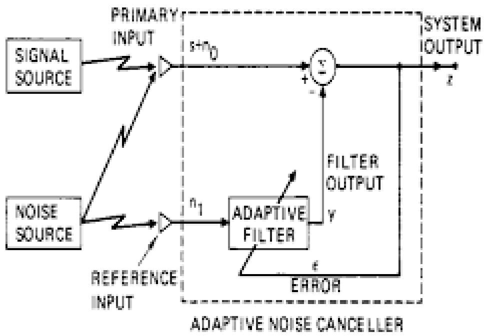
The signal is acquired from physionet database were we have two sets of signal first set contains signal from mothers abdomen consisting of fetal ECG, maternal ECG and noise. In the second set we have maternal ECG taken from the mother's chest. Heartbeat of the fetus is noticeably higher than mother ranging till 160 beats per minute [6]. Fetal electrocardiogram amplitude is weaker than that of the maternal which corresponds to peak voltage of 0.25 millivolts. For extraction of fetal ECG we utilize adaptive filter by the application of two signal an input and reference. Figure 1 shows the schematic diagram of adaptive filter .The performance of adaptive filter has a well orientation and constant shape [7]-[10] under stationary environment. Under non stationary condition, error rate continuously moves with change in curvature and surface. So under non stationary the filter has to continuously seek from the bottom of error performance with tracking If step size parameter is chosen and tap weight vector is computed for an optimum solution then exact measurement at each iteration is possible. The tap weight vector gets updates as the algorithm adapts itself for incoming data. LMS or least mean square algorithm is used for changing tap-weight vector as in (1)

$$HeartRate = \frac{SamplingRate \times 60}{RR}$$

Figure 1. *Adaptive noise canceller block diagram*

$$L_{k+1} = L_k + 2\,\mu\, \varepsilon_k X_k \qquad (1)$$

Here L_k is the tap-weight vector at kth iteration, μ is the step size parameter, ε_k is the error at kth iteration, Xk is the input signal vector. FIR and IIR filters are the two types of filters used in signal processors. For signals not intended to distort phase we use FIR filters and generally suited for multirate application like reducing or increasing sampling rate application or both and FIR filters allow us to omit some of the calculation making it computing efficient. So to extract the peaks i.e. the R wave, FIR filter with filter coefficient is used to remove high frequency with a threshold value. Thus from this fetal heart beat can be extracted. The next section details out the methodology used for heart rate detection. R- R interval estimates the accuracy of any algorithm so this is a critical step, so a robust and efficient algorithm is necessary which would adapt to any given data. The algorithm is implemented in such a way that it first detects all peaks with a reference threshold which can be manually adjusted and as a threshold value is set the algorithm automatically checks for 5% above and below the threshold so that no peak points should be missed and a wrong peak should not be selected. Below a code snippet is provided in fig 2 which shows the algorithm implementation




```
Function rr_p (object, eventdata, handles)
f_fin=handles.fsig;
max_f= (th*max (handles.fsig));
mx= [];pos=[];
for j = 2: length (f_fin)-1;
If (fsig (j) > fsig (j-1) && fsig (j) > fsig(j+1)
&& fsig (j) > (max_f))
Mx (j)=fsi2(j); pos(j)=[j-1]/1000;end, end
mx(mx==0)=[] ; mx(pos==0)=[];
guidata (hObject,handles)
```

Figure 2: *Code Snippet*

The algorithm next evaluates consecutive peaks and then difference of consecutive peaks are set into a temporary variable as RR interval. The interval difference is given in (2)

$$RR\_fecg_i = tfe_i - tfe_{i-1} \quad (2)$$

$$RR_{avg} = \frac{1}{N}\sum_{i=1}^{N} RR_i \quad (3)$$

This interval gives a time series that can be shown as a function of time, Heart rate can be calculated using (3-4).

3 Results

The goal set out in the work was to filter out everything except the fetal heart ECG, so in the process our first stage was noise cancellation which is shown in Figure 3.

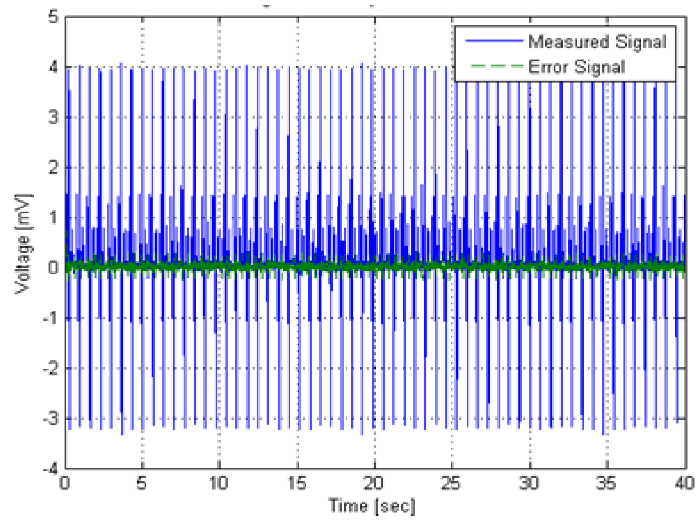
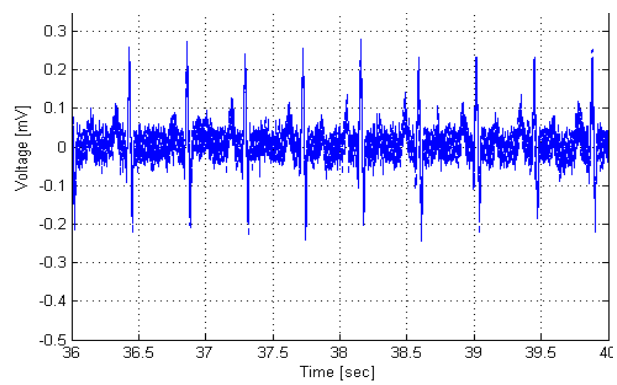
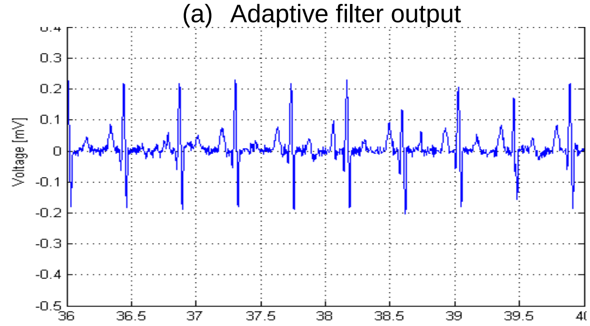


Figure 3: *Noise canceller output*

The figure shows the measured signal. In this algorithm we have used LMS algorithm with 16 coefficients and a step size of 0.00068, by using this convergence takes place after few seconds which is a reasonable period for adaptation. Figure 4 demonstrates the filtered fetal signal where 4(a) states the raw form of the output, 4(b) shows the final filtered fetal signal which can be used for peak detection as described in the methodology section. Figure 5 shows the peak detection where each peak is detected and then the last step was to estimate heart beat which can be seen in fig 6. The algorithm was tested on 17 data sets and all the recordings were normal condition with average heartbeat of 138.



(a) Adaptive filter output



(b) *post processed output*

Figure 4. *Filtered fetus signal*

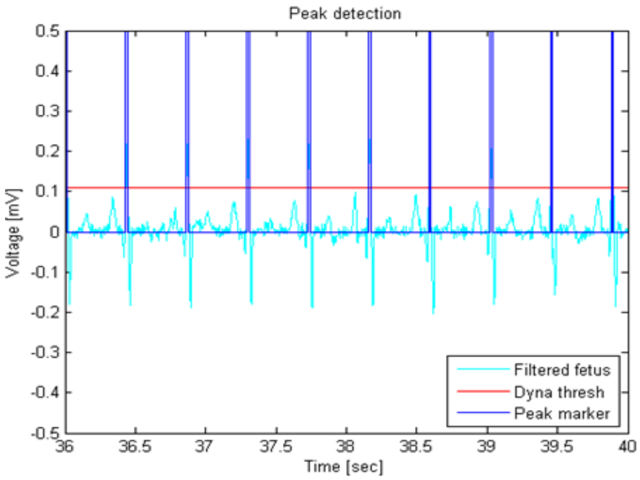


Figure 5: *Peak detection*

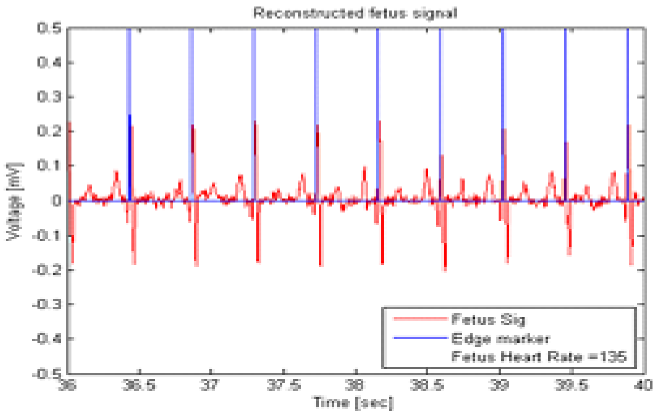


Figure 6. *Heart rate detection*

REFERENCES

[1] Freeman, R. K., Garite, T. J., Nageotte, M. P., and Miller, L. A., “Fetal heart rate monitoring”, Edition: 4, Wolters Kluwer, LWW, 17th may 2012.

[2] Kumar, A., Dewan, L., Singh, M., and Kurukshetra, H., “Realtime monitoring system for ECG signal using virtual instrumentation”, IEEE Transactions on Biology and Biomedicine, vol. 3, pp. 638–643, 2006.

[3] Ferrara, E. R., and Widrow, B., “Fetal electrocardiogram enhancement by time-sequenced adaptive filtering”, IEEE Trans. Biomed. Eng. 29, pp. 458–460, 1982.

[4] Peters, M., Crowe, J., Pieri, J. F., Quartero H., Hayes-Gill, B., James, D., Stinstra, J., and Shakespeare, S., “Monitoring the fetal heart noninvasively: a review of methods”, Journal of perinatal medicine, vol. 29, no. 5, pp. 408–416, 2001.

[5] Ananthanag, K., and Sahambi, L., “Investigation of blind source separation methods for extraction of fetal ECG”, In Canadian Conference on Electrical and Computer Engineering. May 2003.

[6] Jafari, M. G., and Chambers, J. A., “Fetal electrocardiogram extraction by sequential source separation in the wavelet domain”, IEEE Transactions on Biomedical Engineering, vol. 52, no. 3, pp.390–400, 2005. [

[7] Haykin, S., “Adaptive Filter Theory”, 3rd Edition, Prentice Hall 2002

[8] Widrow, B., “Adaptive Noise Cancelling: Principles and Applications”, Proc. IEEE, vol. 63, pp.1692-1716, Dec. 1975.

[9] John, R. G. Jr., “Adaptive Noise Canceling Applied to Sinusoidal Interferences”, IEEE Trans. ASSP, Vol. ASSP-25, no. 6, pp. 484-491, Dec.1977

[10] Shik Ryu, B., and Lee, J. K., “The Performance of an adaptive noise canceller with DSP processor”, 40th Southeastern Symposium on System Theroy, New Orleans,USA, March 16-18, pp 42-45, 2008.