Fetal ECG detection

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ABSTRACT
The project report describes the methods implemented in trying to solve the problem statement.

1. INTRODUCTION
The non-invasive fetal electrocardiogram (fECG) techniques has recently received considerable interest in monitoring fetal health. The task was to develop a Matlab algorithm which analyses the given Electrocardiogram (ECG) signal and determines the length and location of the fetal's QRS complex.

2. DATA-SET DESCRIPTION
We are provided with two data-sets namely "set-ar" (A) and "set-b" (B), which contained a number of multi-channel ECG recordings that were recorded during the examination of fetal heart-rate and rhythm of pregnant women.

Few ECG recording's in set-ar (A),contains five channels and some of them has six channels, the first channel contains maternal ECG recordings and the remaining ECG's are from the Abdominal region.The recordings are less noisy where as in the set-b (B) most of the ECG's are very noisy and contained base-line wander. These were recorded from four different channels.

3. APPROACH
3.1 Glimpse of the scripts provided
Upon initial inspection of the provided scripts, i could see that the get results.m script was the main script which loads all the ECG recordings (.dat) file from the selected data-set with the rdsamp() function of the WFDB toolbox. Running the main script calls the 'bspfecg2021()' function on the loaded data-set(.dat files). Main task was to implement an algorithm which analyzes the given ECG recording and returns the fetal QRS complex positions and the QT intervals. Finally, the getresults.m script calls the plotecgs() function to plot the final results. Initially, upon running the getresults.m i got an error so i modified the return values of the rdsamp() function to [ecgs,Fs,tm] as we were using version 0.10.0 of the WFDB toolbox.

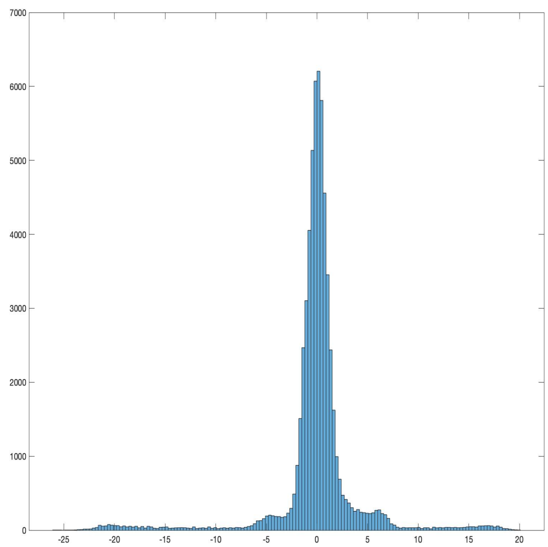

Figure 1: Histogram showing Data distribution of an ECG signal.

3.2 Pre-processing:Filtering
Since the recorded ECG signal contained noises of different frequencies mainly Baseline wander, Power line interference and Motion artifacts, their removal is the first crucial step in preparing the signal for further analysis. Hence,after loading the signal,i filtered out the unwanted frequencies with a designfilt() function which was later changed to, third order butter-worth filter having a pass-band of 8-45 Hz which was implemented in bspfecg2021() function to filter all of the channels in the given ECG signal.

3.3 QRS-Detection
As the unwanted frequencies were removed from the ECG signal, i tried to locate the maternal QRS complex and R peaks in the first channel with the findpeaks() function using MinPeakDistance as 0.6 times the sampling frequency. I tried a different combination of values for MinPeakDistance like 0.3,0.4,0.5 times the sampling frequency, however i could see that using 0.6 times the sampling frequency gave the best results. Once, the peaks are found their locations

were stored in a vector for further analysis. To detect the fetal QRS complex, i selected the second channel from the filtered signal as the fetal QRS complex were more prominent in that channel. So, i tried to select a window of size 0.07 times the sampling frequency to cut-out a part where two maternal R peaks were found, and tried to analyze them to detect the fetal QRS location between them. Selecting the optimum window size was a challenging task as the signal contained a lot of smaller peaks similar to fetal QRS. On, the particular part of the signal i used findpeak() function to detect the fetal QRS location,and used parameters like minimum peak prominence which has a value of 2.5 time the mean value of the absolute of the selected signal part (2.5*mean(abs(cutecg))) and a minimum peak distance of 0.2 times of the sampling frequency(0.2*Fs). The prominence of a peak measures how much the peak stands out due to its intrinsic height and its location relative to other peaks. A low isolated peak can be more prominent than one that is higher but is an otherwise unremarkable member of a tall range. MinPeakDistance sets the neighborhood threshold in units of sample counts. Starting with the highest peak, other peaks within the specified half interval are ignored. To get the optimum values of Minimum peak prominence and minpeakdistance i tried a number of different combinations to find the optimum values. However, these values can be tuned still to obtain better results.The detection of the fetal QRS complex was in the selected window was the quite challenging.

4. PAN-TOMPKINS ALGORITHM

This algorithm is used for real-time detection of the QRS complexes of ECG signals. It reliably recognizes QRS complexes based upon digital analyses of slope, amplitude, and width. A special digital band pass filter reduces false detection caused by the various types of interference present in ECG signals. This filtering permits use of low thresholds, thereby increasing detection sensitivity. The algorithm automatically adjusts thresholds and parameters periodically to adapt to such ECG changes as QRS morphology and heart rate. My approach was to use the pan-Tompkins's algorithm to detect the maternal QRS complex present in the signal, and to determine the corresponding R-R peaks. Once the maternal R peaks are determined, pan-Tompkin's algorithm can be used again to detect the fetal's QRS complex in the determined maternal R-R region. I tried to implement the Pan-Tompkins algorithm in my code and i could see some prominent results, however due to time-constraint i wasn't able to implement the whole idea.

5. EXTENSIONS:PCA AND ICA

The application of ICA after pre-processing aims at separating the fECG from the mECG and the other components. These components include the electromyographic signal, residual noise and artefacts. Among the different approaches proposed for fECG extraction, Blind source separation(BSS) is one of the most commonly applied. It attempts to decompose the multi channel abdominal mixture into the different components i.e., mECG, fECG and noise. Blind source sepration (BSS) can be performed using PCA, which assumes that the signals are a linear combination of the sources, that large variance represents interesting structures and that the principal components are orthogonal. However, the second assumption could not be satisfied, which means the maximization of variance criterion does not comply with fECG, mECG and noise source separation. Conversely ICA, beyond the linear mixing, assumes that the sources are statistically independent, non-Gaussian and/or auto-correlated. After the separation of the components constituting the abdominal mixture, mECG canceling can be applied estimating and subtracting the component due to the maternal ECG from the signals. Indeed, the maternal component is the main interference in abdominal fetal ECG recordings. Thus, mECG canceling procedure is the most common approach in fECG extraction and its robustness makes it a basilar in any non-invasive fECG analysis system. Maternal ECG canceling consists of the construction of an estimate of the mECG component and in its subtraction from the abdominal signals.The QRS can be then detected with an adaptive threshold on derivative amplitude, initialized and recursively updated depending on the temporal distance from the previous QRS detection.

6. RESULTS

The final results of algorithm are shown in the figures below. The results are plotted using the original ECG signals and filtered signals. When evaluating the results, i concluded that in most of the cases the algorithm was able to spot the fetal's QRS complex in the filtered recordings and in the original signal. However in some cases where the signals were very noisy, the algorithm showed less accurate results. Also, in some cases where the maternal ECG is very noise and the R peak are not prominent, this method exhibits a low accuracy.

7. CONCLUSIONS

While working on this assignment, i have tried to implement different techniques, which i learned during the course. I enjoyed working on the assignment and learned a lot of things during completion. Also, i got the feel of how a real world ECG is recorded and how to process it to determine various significant features. The implemented algorithm in most of the cases was able to determine the fetal's QRS complex in the filtered ECG recording. However in some cases where the signals were very noisy, the algorithm had less accurate results. I wasn't able to implement other ideas which i had, but i would like to implement them in future to asses the improvement in the algorithm.

8. REFERENCES

[1] J. Pan and W. J. Tompkins, "A Real-Time QRS Detection Algorithm," in IEEE Transactions on Biomedical Engineering, vol. BME-32, no. 3, pp. 230-236, March 1985, doi: 10.1109/TBME.1985.325532.

[2] A Combined Independent Source Separation and Quality Index Optimization Method for Fetal ECG Extraction from Abdominal Maternal Leads

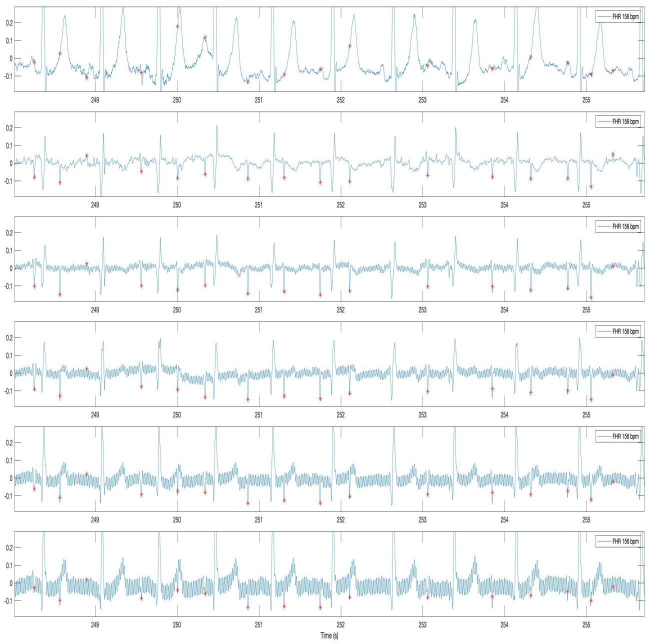

Figure 2: Result-set-ar: Detection of fECG peaks in the given ECG signal

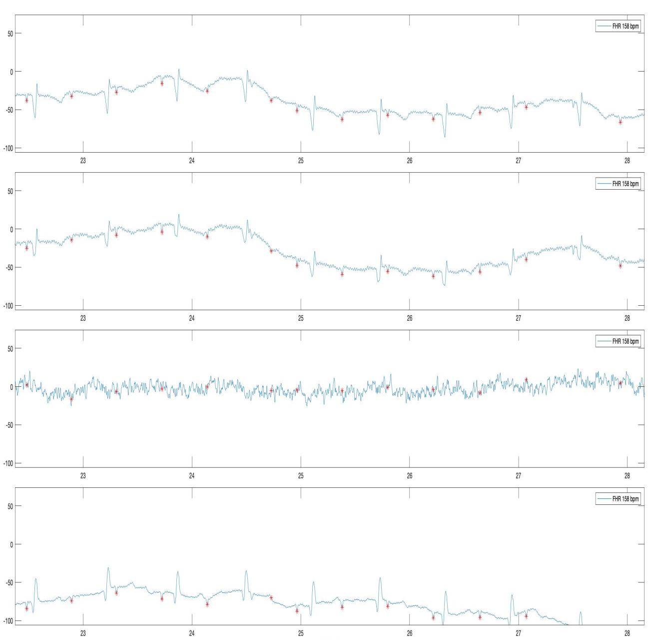

Figure 3: Result-set-b: Detection of fECG peaks in the given ECG signal