PROCESSING OF ECG SIGNALS TO DETECT CARDIOVASCULAR DISEASES

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***Abstract:* Electrocardiogram (ECG) has been the preliminary diagnostic tool to detect cardiovascular diseases. ECG is generally recorded on a thermal paper which cannot be stored for a long time for analysis, as the thermal trace gets erased gradually. To store the trace, the records are scanned and saved as images to maintain medical record. The memory occupied by this method is high and the regeneration of signal accuracy is less.**

***Keywords:* EMR,CVD,QRS Complex, and LMS adaptive filter.**

I. INTRODUCTION

Cardiovascular disease (CVD) is one of the widely spread lifestyle disease worldwide. Electrocardiogram (ECG) system has been adopted for almost a century to monitor the heart. Thus, to monitor the heart's condition and measure progress continuously, ECG is recorded on a regular basis on thermal paper. These ECG records are scanned and stored as images in hospitals for the assessment of patient's rehabilitation. The storage space required for these images is high and increases as the number of records per patient increases. Further, the retrieval time also increases, which plays a key role in the Electronic Medical Record (EMR) systems. On the other hand, regeneration of scanned image accuracy is less. To overcome this problem, the ECG trace from the scanned image is extracted using an improved method of binarization. The extracted trace is converted into a digital time series signal for further processing. Majority of the ECG's clinically information is said to be found in the intervals and amplitudes defined by its features (characteristic wave peaks and time durations). According to author's knowledge, few researchers [1]-[4] have approached ECG digital time series signal extraction as a research problem. Lawson et al., [5], chose a scanning resolution of 200 dpi and used global threshold to separate the ECG trace from the background grid lines. The low resolution results in loss of data accuracy and global threshold results in missing pixels which are replenished by linear interpolation. Fabio Badilini et al., [6] developed an application for extraction of the ECG trace from the image. But the method requires the user to fix anchor points for missing peaks and thus the accuracy comes down. Shen et al., [7] separated the ECG trace from the background grids using the histogram. The missing pixels are replenished by checking the value of the pixel in the original image. This is a tedious process. Tsair Kao et al., [1] employed a colour filter to remove the background gridlines in the colour image. There was a problem of missing pixels in the process which was replenished by linear interpolation. Jalel Chebil et al., [3] did a comparative study of the extracted trace accuracy by scanning the image at various resolutions. Global thresholding and median filtering were employed to remove background grids. The threshold to separate the trace from the background should be selected based on the nature of the image to avoid any missing pixels. All conventional techniques use morphological operations such as erosion, dilation, thinning etc. to extract the ECG trace from the background. However, all the above work addresses the issue of one-dimensional time series signal alone.

II. TYPICAL QRS DETECTION SYSTEM

QRS detectors, Arrhythmia monitors (recent commercial implementation of QRS detectors) and such similar manifestations, typically, include the following functional blocks :

1. Data acquisition
2. Signal conditioning
3. Linear digital filtering
4. Non-linear transformation
5. Decision mechanism

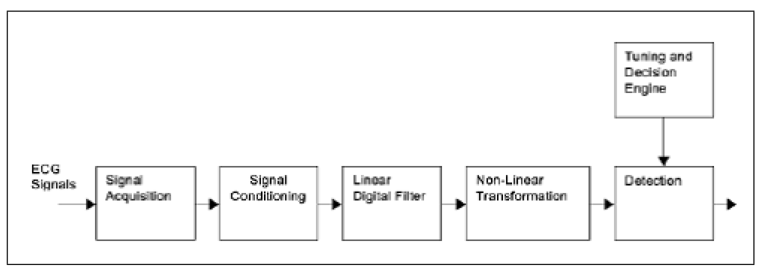

Figure 1: Functional schematic of a typical ECG signal analysis system

Digital Filter Block

Digital Filter Block is, essentially, a band pass filter that is, possibly, built as a cascade of a Low Pass Filter (LPF) and a High Pass Filter (HPF). The use of band pass filter improves the Signal-to-Noise (S/N) ratio and hence enables the use of lower thresholds thus leading to improved detection sensitivity.

Non Linear Transformation

Non Linear Transformation is, essentially, implemented as a differentiator. Although this exercises an ideal attempt in detecting the QRS complexes, this functional block has its intrinsic impact owing to which there exists reasonable compromise on the width of the QRS complex and also its amplitude.

Squaring Process

Squaring Process intensifies the slope of the frequency response curve of the derivative and helps restrict false positives caused by T waves with higher than usual special energies. The output of the squaring block shall be passed through the decision making mechanism which, effectively, detect the QRS complexes. The decision mechanism, nominally, include a sets of thresholds to be applicable, mainly, based on the input signal strength, noise immunity (internal to the system or exterior to it), etc.

III. LITERATURE SURVEY

The filtering techniques are primarily used for preprocessing of the signal and have been implemented in a wide variety of systems for ECG analysis. Filtering of the ECG is contextual and should be performed only when the desired information remains ambiguous. Many researches have worked towards reduction of noise in ECG signal.

Most types of interference that affect ECG signals may be removed by band pass filters; but the limitation with band pass filter is discouraging, as they do not give best result. At the same time, the filtering method depends on the type of noises in ECG signal. In some signals the noise level is very high and it is not possible to recognize it by single recording, it is important to gain a good understanding of the noise processes involved before one attempt to filter or preprocess a signal. The ECG signal is very sensitive in nature, and even if small noise mixed with original signal the characteristics of the signal changes. Data corrupted with noise must either filtered or discarded, filtering is important issue for design consideration of real time heart monitoring systems.[Himanshu, S. et al (2010)], designed amplifier using instrumentation amplifier AD620 (Analog Devices) to bring the peak value into a range of 1v; having gain of 1000. For collection of ECG signal he has used band pass filter with cutoff frequency 0.5Hz-150 Hz on NI ELVIS (National Instruments Educational Laboratory Virtual Instrumentation Suite) board.as shown in fig-1.

After the filtration the output of the analog filter is fed to the NI ELVIS. It has inbuilt data acquisition card. DAQ assistant is used to collect the signal after passing through the band pass filter. The data sampled at a rate of 1 KHz. After acquiring the signal it is processed by Butterworth (IIR) 3rd order digital filter. The first digital filter is band stop filter between 49.5 to 51.4Hz to eliminate power line interference. Butterworth filter having various orders, the lowest order being the best in time domain, and higher order being better in frequency domain. It is having monotonic amplitude frequency response, which is maximally flat at zero frequency response, and amplitude frequency decreases logarithmically by increasing frequency.

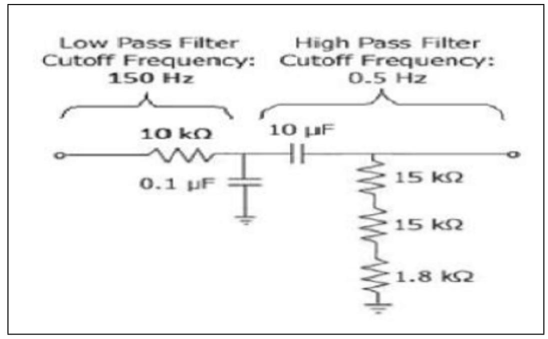

Figure 2: Band pass filter[Himanshu, S. et al (2010)]

The main source of baseline wandering is respiration. It is having the frequency range between 0.15 to 3Hz. They used the wavelet transform to eliminate the Baseline wandering which is an effective way to remove the signal in specified sub-bands. After the removal of baseline wandering, the resulting ECG signal is more stationary and explicit than the original signal. For removing the wideband noises, using Wavelet Denoise Express VI, which is one of the tool of ASPT [Himanshu, S. et al (2010)]. Power line interference is due to improper grounding of ECG equipment and interference from near by equipment. It is removed by using notch filter. The power line interference is more influential on the signal compared to the other types of artifact [Correia, S. et al (2009)]. The major source of such noise is electrical activity of the muscles that should be removed i.e. the noise present due to power line interface (50HZ) is also to be removed as shown in fig-3. Even though the analog amplifier having high Common Mode Rejection Ratio (CMRR), the ECG signals is contaminated by power line interference (50 HZ in India). In order to discard the sources of noise, proper filtration is required. The suppression of Baseline Wander and Power Interference can be done using digital IIR filter.

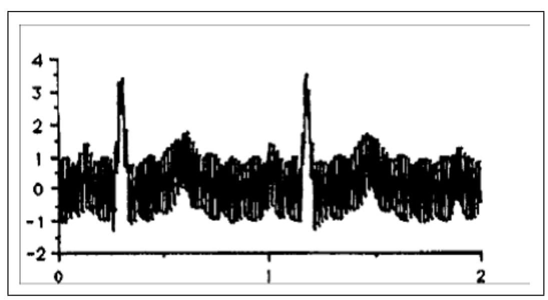

Figure 3: ECG corrupted due to power line interference

[Padma T. et al (2009)] , used adaptive noise filtering for removal of 50 Hz that is the power line interference because, the ECG signal also contains 50 Hz signal and if normal band reject filter is used, then the 50 Hz signal which is very important in the ECG signal will be lost. Therefore by opting adaptive noise filtering, the power line frequency can be eliminated at the same time retaining the 50 Hz signal in the original waveform.

Eduardo P. et al demonstrated in such a way that the signal from the ECG leads is applied to the inputs of an instrumentation amplifier scheme with a high common mode rejection ratio. The amplified signal is then filtered using a set of active filters in order to increase the SNR (Butterworth 50 mHz high-pass filter (HPF) to diminish baseline wandering and slow motion interferences and Butterworth 150Hz low-pass filter (LPF) to diminish the EMG interference .For 50Hz interference a 10th order notch digital filter was implemented as part of the digital signal processing. After analog filtering, the signal is acquired by a multifunction I/O board (NI USB-6008 with 12 bit resolution and 10 kS/s maximum sampling rate). The hardware is developed in order to create a portable system based on a Laptop where the data acquisition device (DAQ) is USB bus-powered and the ECG conditioning circuits are powered using two 9V (2500mAh) batteries incorporated in the system (the lifetime of the batteries is large, as the power consumption is only of 25 mA). The active high-pass filter removes the baseline fluctuations; the implemented digital filtering block consists of a 150 Hz Bessel LPF and the 50Hz notch filter in order to obtain a better SNR. After digital filtering the digital signal is processed using an ECG analysis block.

[Ju-Won Lee et al (2005)] used LMS adaptive filter to filter the ECG signal, but its convergence and performance cause distortions and even poor performance, depending on the environment and the patient's condition. They proposed DSAF, which provided better performance in the experiment and hence suggested LMS adaptive filter (DSAF) applied to ECG signal processing.

[Dehghani, M. J. et al (2010)] used computer based signal processing and analysis. Baseline wandering is usually in amplitude of around 15%, full-scale deflection at a frequencies wandering between 0.15 and 0.3 Hz and a high pass digital filter can only suppress it. They used a Kaiser Window FIR high pass filter to remove the baseline wandering. They found that there are still other types of noise, which still affect the ECG signal, after removing baseline wandering. This noise may be stochastic processes within a wideband so it cannot be removed by using traditional digital filters. For removing wide band noises, undecimated wavelet transform (UWT) is applied, which has a better balance between smoothness and accuracy than the discrete wavelet transforms (DWT). [Chavan M. S et al (2006)] designed equiripple notch filter having minimum order 580 and sampling frequency of 1000 Hz and performed using FDA tool in MATLAB. They found the reduction in signal power of 50 Hz is more in the equiripple and least squares methods when compared with the window method reduction. [Leif, S et al (2006)] designed a linear, time-invariant, high pass filter for removal of baseline wander involving several considerations, of which the most crucial are the choice of filter cutoff frequency and phase response characteristic. The cutoff frequency should obviously be chosen so that the clinical information in the ECG signals remains undistorted while as much as possible.[Pedro R. G. et al (2007)] used two Butterworth filters in ECG acquisition system for reducing the 50 Hz noise and for eliminating the DC component of the signal and to achieve the peaks P, Q, R, S, and T without noise and their correspondent position in the array. [Heyoung Lee et al (2008)] designed a 24-hour health monitoring system in a smart house using a high pass filter with cut-off frequency 0.1 Hz. It prevents introducing drift noise in the measured signal and the notch filter removes the 60 Hz power line noise.

IV. CONCLUSION

This paper has presented an initial work of the authors in their attempt to architect a flexible platform for ECG analysis. Whereas the technologies available for the realization of this architecture are very mature, identification of the interfaces in this architecture along with their definitions need be done very carefully to, fully, ensure extensibility of the ECG analysis, which can be scheduled on this architecture whereas Support vector machine with discrete wavelet transform and principle component analysis is a good performance ECG beat classifier. For integrate this classifier with ECG beat detection for ECG printout, the improvement of image processing techniques is required.

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