Review of Different ECG Signal Denoising Techniques

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***Abstract*—** The ECG signal is of the most interest for the digital signal processing engineers for algorithm analysis and testing. A lot of research has undergone in developing the algorithms for ECG signal de-noising. Some most popular techniques include FFT, wavelet based approach, ICA/PCA and STFT based approach. Other than these there many more algorithms in different form of the mentioned techniques. Further, ECG classification is another important field when analyzing an ECG. For classification as well, there are many techniques like, neural network, fuzzy logic and, support vector machine algorithms. Primarily, the denosing techniques are classified into two categories: frequency domain and time domain. Frequency domain techniques give added advantage in terms of processing time. However, the time domain techniques work directly on ecg signal and user may see exactly what is happening to the signal. Also, once the signal is analyzed in frequency domain, it has to be transformed into time domain for real time view.

Keywords*— *ICA, ECG, SVD

I. INTRODUCTION

ECG reflects the state of cardiac heart and hence is like a pointer to the health conditions of a human being. ECG, if properly analyzed, can provide us information regarding various diseases related to heart. However, ECG being a non-stationary signal, the irregularities may not be periodic and may show up at different intervals. In the existing work, it has been observed that denoising of ECG is done in stationary condition i.e. when the patient under scanner is lying on bed or in rest condition. This is very common case and the noise added in this condition can be removed by many different methodologies like FFT, wavelet, ICA etc.

However, when the ECG is monitored in dynamic condition e.g., on tread mill testing, the noise inserted due to motion artifact is of entirely of different nature as compared to that of the static condition. In the presented work, the focus is on denoising of ECG signal corrupted by motion artifact conditions. The fundamental aim of thesis is to denoisethe random noise from ECG signal starting a simple approach from fundamentals of independent component analysis method. The random noise impacts on the ECG signal that can be modeled in MATLAB software simulation. The main objective is to remove noises from ECG signal by using ICA method. This method can be employed in a number of bio-medical signal processing applications in which the prime concern is to get the original signal and the contaminated entities are critically removed.

II. RELATED WORKS

Joshi et.al [1] proposed ECG Signal denoising techniques. Noise always degrades the quality of ECG signal. ECG noise removal was very difficult task due to time varying nature of ECG signal. Good quality signal was required. ECG signal is used for analysis of heart diseases. Noise corrupts the ECG signal. Removal of noise was very important during ECG acquisition. Different types of methods were discussed such as wavelet transform, fuzzy logic, and FIR filtering, Empirical mode decomposition. ECG is a weak non-stationary signal which is interfered by various noises e.g. power line interference, baseline drift, electrode contact noise, EMG interference. Different FIR structures for Power Line Interference (PLI) reduction were compared. Complexity of FIR and IIR filters was also compared. In the paper the mean Percent Root mean square Difference(PRD) of different denoising methods and different wavelets comparison between baseline removal techniques was also compared. Equiripple notch filter is used to remove power line interference while to remove motion artifact and EMG noise discrete Meyer wavelet was selected and improved thresholding function which combines features of hard and soft thresholding was applied. Empirical mode decomposition based approach was used to remove baseline wander noise.

Enzeet.al [2] analysed the pulse rate variability and heart rate variability and the relationship between pulse rate variability and heart rate variability were studied in time domain, frequency domain and nonlinear analysis and also compared pulse rate variability and heart rate variability. Parameters of the PRV and HRV of 30 health subjects were studied. In the field of clinic applications, such as diagnosis the patient without atrial fibrillation (AF), the PRV and HRV are basically consistent. In the nonlinear analysis, the PRV can be used as a surrogate of heart rate variability.HRV and PRV usually have a delay, ranging from 6% to 20% of a heartbeat. The difference of parameters in time domain are less than 3%; the difference of parameters in frequency domain is less than 9%, the difference of nonlinear parameters is less than 9%,the nonlinear parameters of PRV are not all higher than HRV. The breathing more greatly influences the PRV than HRV.

MrinalPhegade,P.Mukherji[3] denoised the ECG signal by ICA method. Independent component analysis (ICA) is a blind source separation technique that can be used for removal of noises and artifacts. Different types of algorithms were also discussed such as JADE, FAST, CONSTRAINED and applied for ECG denoising. Data base used is MIT-BIH database.FAST and Constrained ICA methods were applied for denoising from ECG signals. Signal to noise ratio and mean square error values for both algorithms were calculated. ECG data is utilized in statistical domain and not in frequency or time domain. ICA had been considered as a good substitute to higher order digital filters for increasing the SNR in noisy cardiac signals.

Maniewskiet.al [4] discussed the applications of Independent Component Analysis for Rejection of Motion Artifact in Body surface potential mapping Recorded During Exercise. Two different algorithms of ICA such as fast ICA and temporal decorrelation were applied for rejection of interferences. For quantification of results, signal to noise ratios were compared after suppressing the motion artifacts. ECG signals showed an improvement of about 4 to 10dB.Thirteen healthy volunteers were recorded during exercise on supine ergometer using a high resolution Body surface potential mapping system with 64 leads covering the whole thorax. For assess quality of denoising, the root-mean-square at every channel was computed before and after suppression of component related to motion and then the signal-to-noise ratio (SNR) in the corresponding sensor was calculated. The mean values of SNR calculated for each measured ECG channel showed a considerable benefit of using ICA based ECG denoising methods.

Sutaret.al [5] explained the removal of noises and artifacts and source separation. Several techniques had been proposed to extract the ECG components contaminated with noise and allow the measurement of components in the ECG signal.Different schemes such as jade, fast, constrained, hybrid algorithm using fast ICA for noise removal and cICA had been proposed along with their results. FASTICA technique wasintroduced to solve the problem of noise and artifacts and that technique was based on statistical indices and successfully tested on real ECG data. ICA had been considered as a good substitute to higher order digital filters for increasing the SNR in noisy cardiac signals.

Md. AshfanoorKabir, Celia Shahnaz [6] discussed on the Electrocardiogram (ECG) denoising approaches based on noise reduction algorithms in Empirical Mode Decomposition (EMD) and Discrete Wavelet Transform (DWT) and compared with other denoising methods like filtering, ICA and PCA, neural networks, and adaptive filtering, EMD and wavelet domain denoising algorithms. Simulations were carried out using MIT-BIH database and performances were evaluated in terms of standard metrics namely, SNR improvement in dB, Mean Square Error (MSE) and Percent Root Mean Square Difference (PRD). Because of the adaptively of EMD and DWT methods, a denoising scheme based on enhancements employed in the EMD and wavelet domains was far more effective in reducing noise. The comparison under several standard metrics showed that combined EMD and DWT domain based noise reduction algorithms enhanced the noisy ECG signal more effectively as compared to denoising schemes based on only EMD or DWT domain.

Vanathiet.al [7] proposed separation of maternal and fetal ECG signals from mixed source signal using fastICA. Blind source separation techniques were used for separating source signals. ICA was applied on mixed signals and separated signals were reconstructed using wavelet reconstruction. In this paper, graphical image is read and then converted into binary format and finally it is scanned and mapped to two-dimensional format. This signal is then preprocessed using Wavelet transform to remove noise. It is then decomposed to time-frequency domain using Wavelet Lifting decomposition. The noisy FECG signal is decomposed to five levels of wavelet transform. The fetal and maternal signals are then separated by applying FAST ICA algorithm to the decomposed signal. The separated signals are finally reconstructed using the Inverse Wavelet Lifting Transform. Wavelet Transformation and FASTICA algorithm produced the best SNR value of 11.39 for maternal and 10.10 for fetal Electrocardiogram signals.

Langley et.al [8] evaluated Fetal ECGs from 4-channel Non-invasive Abdominal Recordings. Fetal ECG is one of the most valuable tools for monitoring the health of fetus throughout pregnancy. Signals were preprocessed by combination of frequency filtering and wavelet denoising. Adaptive cancellation of the maternal ECG (mECG) was performed using maternal QRS time markers obtained from the principal component containing the largest mECG. Following further wavelet de-noising of the residuals, the fetal QRS time markers were computed with a local peak detection algorithm from the first principal component. The derived fetal HR and fetal RR time series were compared to the reference values obtained from an electrode signal. This method used a combination of frequency filtering and wavelet de-noising for the preprocessing; adaptive cancellation of the mECG; PCA for isolating the best component for maternal and fetal Rpeaks detection. The algorithm performed well with good quality signals and also with noisy signals .Large-amplitude noise probably also corrupted the scalp signal as no reference points were provided for the period during which the noise appeared.

Ganesh R. Naik, Dinesh K Kumar [9] proposed fundamental concepts involved in ICA techniques and their applications. ICA is a blind source separation technique which had been an area of interest for researchers for many practical applications in various fields of science and engineering. Different ICA schemes were also discussed. In this paper, some inherent ambiguities of the BSS/ICA framework were examined as well as the two important preprocessing steps of centering and whitening. Specific details of the approach to solving the mixing problem were presented.

III. ALGORITHM

In ICA, the measured signal should be linear combinations of independent source signals, and the independent signals should be non-Gaussian in nature.

The noisy signal is given by:

$$x = A.s + n$$

Where $x(t) = [x_1, x_2, x_3, \ldots\ x_p]^T$

$s(t) = [s1, s2, s3, \ldots\ Sq]^T$ where $q < p$ such that

$$x(t) = A.s(t)$$

When demixing matrix W is multiplied by vector x it can recover the original signals contained in s. So the major aim of ICA algorithm is to compute the demixing matrix W, such that: $s(t) = W.x(t)$

Thus, making $W = A^{-1}$.

Generally, ICA input signals are the observed signals, which may be measurement time series, such as sampled voltage values in time as in the case of ECGs, image pixel values, or basically any sets of values fulfilling the assumptions of ICA. In the sequel, the term 'measured signals' refers to a set of simultaneously measured digital discrete-time signals with constant interval between the measured signal samples. All signals are assumed to be sampled at the same time instances. ICA is realized by an iterative numerical algorithm, several of which exist.

IV. RESULTS AND CONCLUSION

The different techniques for ECG denosining and classification differs on account of their accuracy in processed signal information content. The performance may be measured by analyzing the entropy, peak signal to noise ration and mean square error. The minimum of MSE and maximum of PSNR are of prime importance while adjudging the algorithm performance.

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