Journal of Engineering and Applied Sciences 13 (20): 8624-8628, 2018
ISSN: 1816-949X

Separation Enhancement of Power Line Noise-50 Hz from ECG Signal by Modified Blind Source Extraction Technique

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Abstract: The health checking tools represent one of the most important things in the lifestyle for investigative and evaluation of the body. The ECG signals are essentially refer to the function of the heart, several features are extracted from ECG signal may carry significant information about the body health, therefore, it's very important to get pure and clean signals. The interference signal from power line noise represent one of the most significant problem. The power line interference signal has high amplitude with 50 or maybe 60 Hz. The notch filter is used to cut the power line signal from raw ECG signal to reduce the effect of this signal but this method not very acceptable due to cut high range of the raw signal and remove some useful information about original ECG signal, therefore, modified blind source separation technique is presented to separate this signal from mixture ECG signal without effect on the original ECG signal and no needs any reference input to detect or cancel the power line noise signal. Simulated and real ECG data are taken based on MIT-BIH databases for recording different ECG data. The gotten result can be used for medical analysis by the doctor and supportive in discovery numerous defects in the heart.

Key words: Power line interference signal, artifact removing techniques, ECG signals analysis, blind source extraction, discovery, heart

INTRODUCTION

The ECG device is used to draw the graph of the signal from heart to measure the activity and used to clinical analysis according to the shape of the ECG signal to judge and gives accurate diagnosis for the heart disease where each part from ECG signal reflect the operation of a part in the heart to check the normal or abnormal heart work many interferences external signals or noise are effects on the ECG signal during collecting and measuring the patent's ECG, so, it's very important to get pure ECG signal from noise and another external signals like power line interface signal by different ways, one of these way using filter or blind source separation (Kumar and Malik, 2010). Numerous techniques are used to solve the problem of mixing power line noise interference with ECG signal such as using blind source extraction techniques and filtering process. Empirical mode decomposition technique is used as a powerful method for removing this noise as demonstrated by Blanco-Velasco *et al.* (2008), ICA techniques are used also from numerous academics as a probable line for solving the power line noise problem (Abdullah *et al.*, 2014a, b). An efficient algorithm and easily for implementation is proposed by Singh and Priya (2015) based on three steps (recording data, cancelling the noises ands detection), the Simulink MATLAB is used to analysis the ECG signal and apply different filters to cancel the power line noise which mixed during the recording process. One of the probable technique to extract the deviations of the frequency of outdoor power line reference based on adaptive filters but in that time this task is difficult or impossible for implementation (Ziarani and Konrad, 2002). Different researcher deals with ECG signal cleaning from many artifacts like power line based on wavelet (Mahmoodabadi *et al.*, 2005), Fourier, neural (Gothwal *et al.*, 2011), filters and other analytic tools to get pure ECG from raw ECG . The Adaptive filter is suitable but it enlarged the S-part in ECG signal (Singh and Priya, 2015). The researchres by Warmerdam *et al.* (2017) demonstrate Kalman smother mixed with adaptive filter to remove the power line noise from raw ECG signal. The performance is tested by removing the Power Line Noise Intereference (PLNI) from despoiled fresh neonatal ECG signal with power line. The researchers by Patro and Kumar (2015) suggest an smart adaptive filter for cancel the noise and the harmonics, the suggested system guess the frequency and the harmonic frequency without any reference and founded by state space system. The system based on kernel function is designed by Ploysuwan and Atsawathawichok (2015) to cancel the power line noise from ECG waveform also the mathematic system is expressed to remove the interface and compare results with state space recursive least squares system.

MATERIALS AND METHODS

ECG signal and Power Line Noise Interference (PLNI): The ECG signal is a biomedical waveform that generated from the heart electricity and sensed from the surface of the body. This analysis of this signal is important for the cardiac disease. The electrocardiogram ECG waveform is constricted from P, T, U, QRS waves as shown in Fig. 1, P waveform represent the rises depolarization of atrium and the QRS waveform indicted by ventricles depolarization also T w aveform represent the ventricle muscle re-polarization (Kumar and Malik, 2010).

Generally, the Power Line Noise Interference signal (PLNI) is represent one of the most interferences signals during ECG signal recording where the field nearby the lines will be effect on patient ECG signal. the different impedance of sensor leads to different measuring of the output signal. The noise can be decreased by shielding the cable but really its unsatisfactory to remove all the noises, the power line noise is surpassing amplitude of ECG (Warmerdam *et al*., 2017). The power line noise is generated from the tools at near body also its generated from the bad grounding of the ECG system. The typical of power line noises are sin wave with 50/60 Hz based on the country in Asia countries the frequency is 50 and 60 Hz in USA. The PLNI will effect on the quality and features of biomedical signal because the PLNI has narrow band <1 Hz but its and the effort of 50/60 Hz (Abdullah *et al*., 2014a, b; Zhang *et al*., 2016).

Removing method based on filtering process: The ECG signal is effected strongly by power line noise interference signal, therefore, the removing method represent one of the important part in ECG signal analysis. The classical method to remove the ECG interface signals based on filtering process but this type of method gives not acceptable results due to cutting the useful information during the filtering process (Kumar and Malik, 2010). Also, some interface signal has high amplitude value and many be its not recognized as interface therefore, should have very good knowledge about the noise and interface signals (Rangayyan, 2002). Different methods for removing PLNI signal are explained as:

Notch filter: The notch filter represents one of the simple way to remove the unwanted part in the signal. Power line noise interface signal represent the unwanted signal by calculating the Fourier and inverse of the signal (Blanco-Velasco *et al*., 2008). Two ways for operation this type of filter, the first way based on removing the artifact or make it zero value, the second one calculate the average value at 50 Hz.

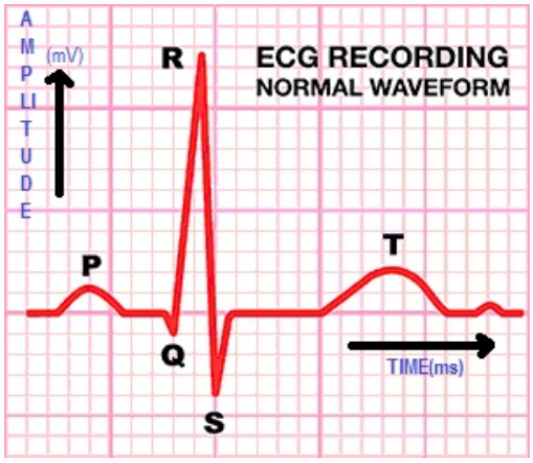

Fig. 1: ECG waveform (Das *et al*., 2016)

Wiener filter: This filter represents one of the fixed type of filter and using statistical features for cancelling the noise or interface. The parameter is changed to obtain the best or optimal results, therefore, some time its named optimal filter (Ploysuwan and Atsawathawichok, 2015). The statistical features or characteristics are taken to get the optimal filter based on optimize the parameters according to some criteria.

Adaptive filter: This type of filter is self-design algorithm according to the procedure which lets the learning process as initial or candidate inputs filter. The uncorrelated signal like noise will be canceled and guess the deterministic one by this filter (Abdullah *et al*., 2014a, b) based on least mean square procedure to regulate the weight to reduce the error signal and guess the factors (Gothwal *et al*., 2011).

Proposed algorithm: The proposed algorithm is shown in Fig. 2 that based on the mixing between efficient fast ICA technique with wavelet transform to get pure ECG waveform cleaned from PLNI, this algorithm is called W-EFICA. The efficient-FastICA is presented by Koldovsky *et al*. (2006) which consist of three steps as shown in Fig. 2. For more simplicity the proposed work is explained by two steps as shown bellow.

Step 1: Running efficient fast-ICA technique to separate the signals from mixtures, the EFICAI is constructed from three steps (Symmetric fastICA, Adaptive choose of nonlinearity, Refinement)

Step 2: Smoothing the constructed signal by Wavelet Transform (WT). Each part in Fig. 3 will be explained in detials as shown bellow:

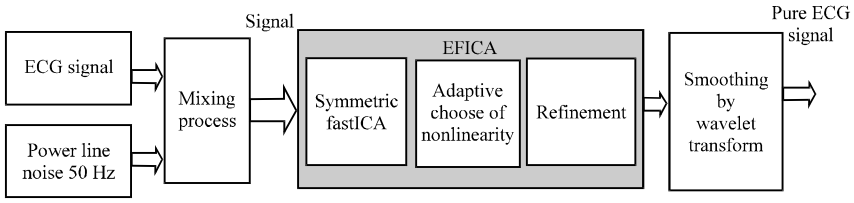

Fig. 2: Proposed work (W-EFICA)

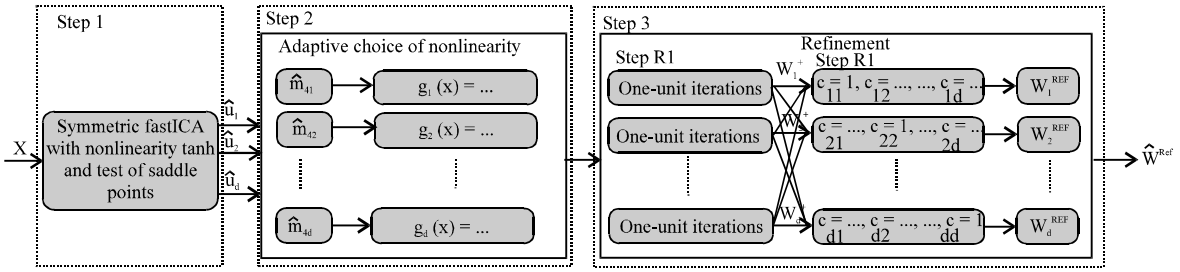

Fig. 3: Efficient-fast ICA (Koldovsky *et al*., 2006)

The ECG signal is measured by ECG device and mixed by PLNI signal to produce raw ECG signal. The tested signal is real and taken from MIT-BIH NSR database (Abdullah and Zhu, 2014). This signal can be represented by Eq. 1:

$$Y[n]_{Raw\ ECG} = S_{ECG}[n] + N_{PLNI}[n] \quad (1)$$

Where:

$Y[n]_{Raw\ ECG}$ = The raw signal consist of pure
E_{CG} = Signal
$S_{ECG}[n]$ = Mixed with noise signal ($N_{PLNI}[n]$)

The Power Line Noise (N_{PLNI}) is represented and simulated by:

$$N_{PLNI}(t) = A(t)\cos(2\pi f(t)\, t + \phi) \quad (2)$$

The PLNI is represented by sinusoidal with frequency varies from 48-52 Hz and epoch about 5 seconds, the input signal to noise ratio from (-20-10 with 5 dB steps). Efficient-Fast ICA technique is consisting of three steps as shown in Fig. 3 (Koldovsky *et al*., 2006; Abdullah and Zhu, 2014a, b):

- Step 1: symmetric-FastICA is implemented up to convergence based on using nonlinear function:

$$g(s) = \tanh(s) \quad (3)$$

- Step 2: guess the score functions of the extracted sources from step one by adaptive nonlinearities chooses g_k
- Step 3: refinement process using the equations shown below:

$$W^{+} \leftarrow g(WZ)Z^{T} - \mathrm{diag}\left[g(WZ)1N\right]W$$
$$W^{+} \leftarrow \mathrm{diag}[c_1,\ldots,c_d].W^{+} \quad (4)$$
$$W \leftarrow \left(W^{+}W^{+T}\right)^{\frac{1}{2}}W^{+}$$

The smoothing technique is based on the wavelet technique to smooth the recovered signal the WT is novel approach or technique for multiresolution analysis for the signals where the signal with different frequencies gives different resolutions. The main meaning of wavelet is a short signals or waves have oscillation. Based on Morlet, the wavelet is a colony function arranged by Mother Wavelet ($\psi(t)$) function (Das *et al*., 2016).

RESULTS AND DISCUSSION

Data: Real ECG data are taken from MIT-BIH database (Abdullah and Zhu, 2014) and simulated by last version of MATLAB program in "xxx. mat" format with sampling frequency 360 sample/second.

Performance criteria: The performance of the proposed algorithm is measured based on Signal-to-Noise Ratio (SNR) and the Mean Square Error (MSE) (Chaozhu *et al*., 2013):

$$SNR_o = 10\log_{10}\frac{\sum_{i=0}^{N-1} x_d^2(i)}{\sum_{i=0}^{N-1}\left[x(i)-x_d(i)\right]^2} \quad (5)$$

$$MSE = \frac{1}{N}\sum_{i=1}^{N}\left[x(i)-x_d(i)\right]^2 \quad (6)$$

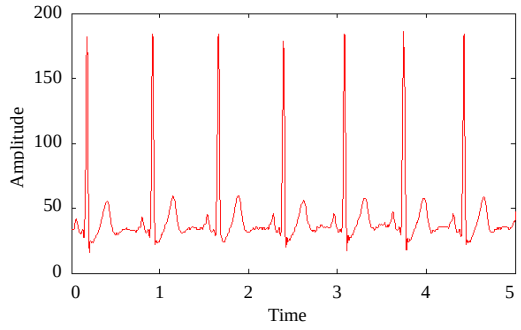

Fig. 4: Raw ECG data

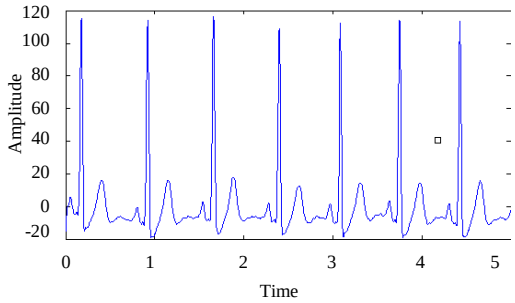

Fig. 5: Clean ECG waveform based on classical technique (adaptive filter)

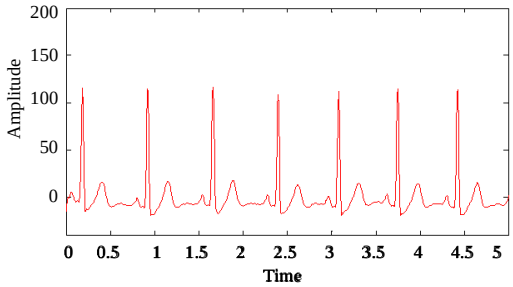

Fig. 6: Clean ECG waveforms based on proposed algorithm (W-EFICA)

Table 1: Performance analysis based on SNR and MSE for different techniques

Method	SNR_0	MSE
Adaptive filter	21.26	0.0056
Proposed method	33.48	0.0014

where, x_d is the denoised signal, the main goal is to get high value of SNR and low MSE. The main aim of the proposed research is to design and simulation a novel modified blind source extraction technique based on efficient fast ICA mixed with wavelet technique for removing PLNI from ECG waveform. The results of the proposed research is compared with classical method based on IIR notch filtering. The IIR filter is designed with notch at 50 Hz and a -3 dB bandwidth of 1 Hz. The last version of MATLAB is used to implement the proposed research (Fig. 4-7 and Table 1).

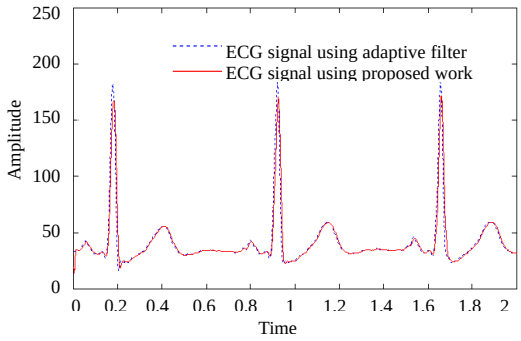

Fig. 7: ECG signal for three times based on classical and proposal appraoch

CONCLUSION

The proposed algorithm represent one of the a nevol methodology to solve the PLNI proplem in ECG signal analysis based on the mixing between EFICA with wavlet called W-EFICA algorithm. Pure ECG signal is obtained by proposed research as shwon when apply it on the real ECG data in the result section. The result section shown the performance of the proposed research is very efficient compared with classical and filter approachs to clean the ECG signl. SNR criteria is used to measure this performance where the SNR after wavelet step is better than SNR befor this step due to smoothing and remove all the ridandant noise in the extracted or reconstracted signal. Finally the gotten ECG signal is acceptable different applications in real time.

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