

Comparison of Non Local Means Filtering with Wavelet Transform Technique for Denoising ECG signal

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ABSTRACT: Digital filters are a very important part of digital signal processing, especially for biomedical signal processing. In fact, their extraordinary performance is one of the key reasons that signal processing has become so popular. Digital filters have two primary functions: signal separation and signal restoration. Signal separation is needed when a signal has been contaminated with interference, noise, or other undesirable signals. In this work, two methods, that is, wavelet and non local means (NLM) filtering technique is explored for denoising the ECG signal. The noisy ECG signal is synthesized by adding pulse signals and is then denoised at different levels by optimising different parameters. The experimental results showed that the proposed techniques successfully denoised the noisy ECG signals by selecting appropriate input parameters. Finally, the peak signal to noise ratio (PSNR) and mean square error (MSE) were also evaluated to compare the performance of both evaluated methods.

KEYWORDS: ECG signals, non-local filtering, wavelet technique, denoising.

I. INTRODUCTION

The electrocardiogram is the recording of the electrical potential of heart versus time. The analysis of ECG signal has great importance in the detection of cardiac abnormalities. The electrical activity of the heart during its contraction and expansion can be seen using electrocardiogram (ECG) signal [1]. It is an important biomedical tool used by medical practitioners to examine the pathological condition of the heart. But sometimes, due to introduction of noise while acquisition, an accurate analysis of ECG signals becomes complicated. Thus, to recover the accurate signal, filtering/denoising technique becomes an important assignment during ECG pre-processing [2]. Noises that commonly disturb the basic electrocardiogram are power line interference, instrumentation noise, external electromagnetic field interference, noise due to random body movements and respiration movements [3]. These noises can be classified according to their frequency content. Different types filters have been proposed to remove these noises. Performances of the filters are compared based on the PSNR values [4]. It is difficult to apply filters with fixed filter coefficients to reduce the instrumentation noise, because the time varying behaviour of this noise is not exactly known. Adaptive filter technique is required to overcome this problem, as the filter coefficients can be varied to track the dynamic variations of the signals. In wavelet transform, a signal is analyzed and expressed as a linear combination of the summation of the product of the wavelet coefficients and mother wavelet [5]. The wavelet decomposition offers an excellent resolution both in time and frequency domain. Better estimation of the amplitudes is also obtained in wavelet based denoising [6]. Non local means (NLM) filtering is another technique also known as statistical neighbourhood filter [7]. This filtering technique can fix the problems associated with local smoothing filters by calculating the smoothed value as a weighted average of other values in the time series based upon the similarity between the neighbourhoods around the time series values [8-10]. Non-local means has primarily been used for image processing, but it has been reported in a 1D context in several papers.

In this paper, we compared both wavelet and non-local means filtering techniques for denoising ECG signal. Both techniques have denoised the ECG signal successfully and the comparative analysis showed some interesting facts.

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This paper is organized as follows. Section II explains the proposed method and Section III shows the results and discussions. Finally the conclusion is given in section IV.

II. METHODOLOGY

In this experiment, ECG signal is synthesized by setting and optimizing different parameters. For creating ECG signal, time series elements were synthesized that contain features similar to those in real world data. The proposed noise removal methods using wavelet technique and non local means technique is illustrated by a single flow chart shown in Fig. 1. The noisy signal $s(t)$ is introduced in the synthesized ECG signal as $s(t) = x(t) + n(t)$ where $x(t)$ is the original ECG and $n(t)$ is the noise signal. The added noise signal is a pulse signal with 10 dB signal power.

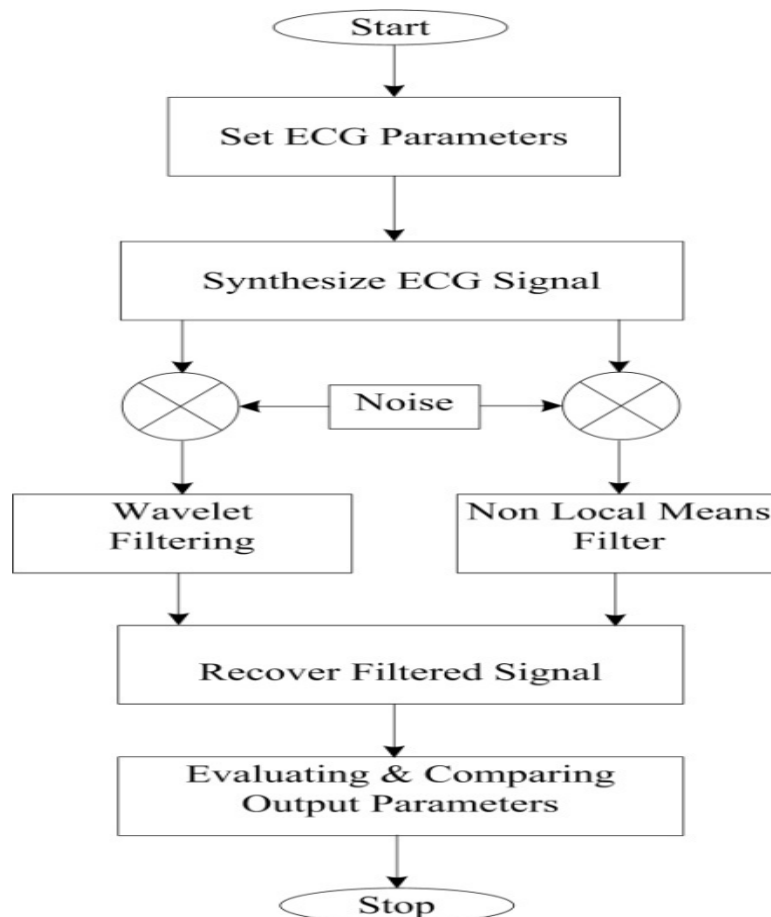


Fig. 1. Flow chart showing experimental steps followed in a sequential manner.

The noisy input signal is then processed by two methods, that is, wavelet method and a non local means filter that automatically adjusts its own impulse response through a least-squares algorithm. For wavelet method, the denoising technique involves stationary wavelet transform (swt). The technique used is coiflet with 2nd level. The thresholding used is soft which can be varied in between 0 and 1. The signal is decomposed, denoised and then again reconstruct. Using non-local technique, the size of the small features in samples were varied in between 1 to 20. Also, the neighbourhood search width was set in-between 700 and 1000. The bandwidth was adjusted at 60%. The objective is to produce an output signal that is a best fit in the required domain to smooth the signal. This is accomplished by optimizing the maximum search distance and adjusting the filter through the proposed algorithm to minimize the total

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signal power. It is pertinent to mention that the basic parameters for both the methods are approximately same. Theoretically, non-local means should work better on longer time series. An area of future research would be to consider this stability analysis on significantly longer time series. It is known that the computation time is much longer and the pre-selection is much more significant for non-local means on large time series.

III. RESULT AND DISCUSSION

In our simulation, we employ wavelet and non-local means filtering technique for analyzing and denoising ECG signals. In this, a single ECG signal is synthesized by selecting and optimizing different parameters as shown in Fig 2.

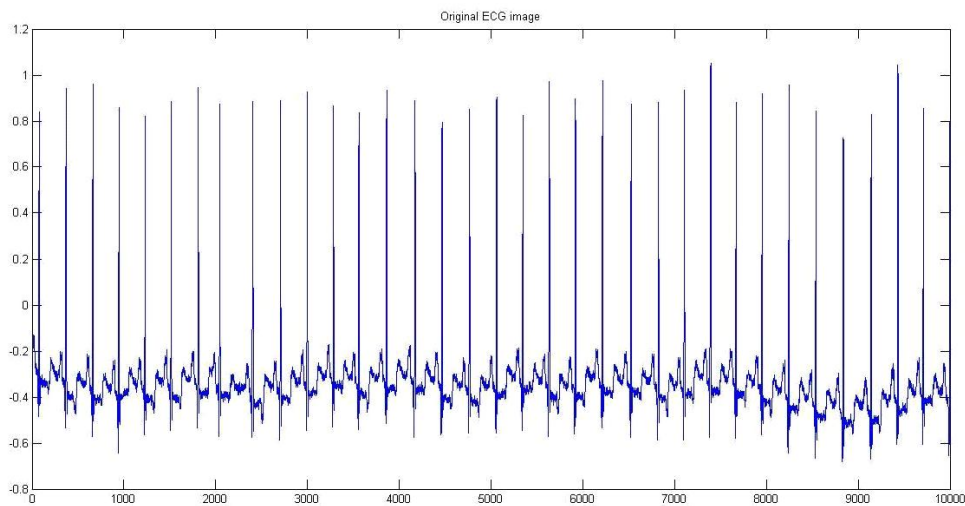


Fig. 2. Original synthesized ECG signal.

The testing was initiated by applying the proposed algorithm to an original signal. The results showed that the original signal and the denoised signal as shown in Fig. 2, Fig. 3 and Fig. 4 are more or less same. After that, noise was introduced into the original signal as shown in Fig. 5. After adding noise, the signal is to be filtered. The noisy signal was then filtered out by selecting different wavelet and NLM parameters. In both the cases, the neighbourhood search width, P was selected to be at 1000 while size of smallest feature in a sample was selected to be 5.

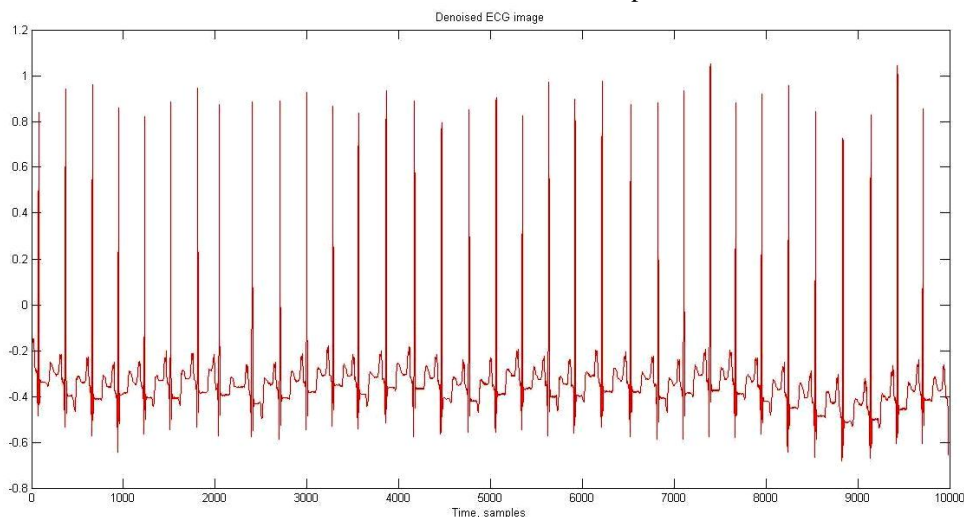


Fig. 3. Original ECG signal after denoising by NLM technique.

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Figure.3 shows the original ECG signal after denoising by using the non local mean filtering technique by selecting P to be at 100 while size of smallest feature in a sample was selected to be 5.

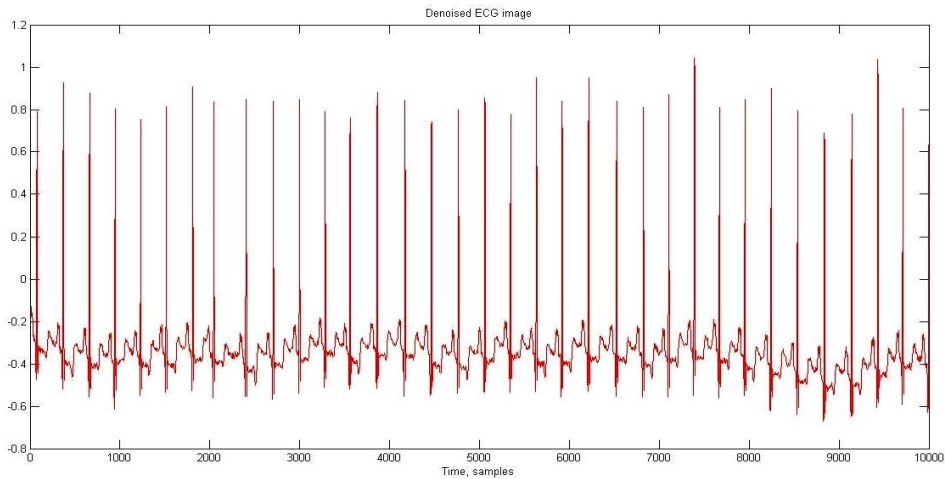


Fig. 4. Original ECG signal after denoising by wavelet technique.

Figure.4 shows the original ECG signal after denoising by using the Wavelet filtering technique by selecting P to be at 1000 while size of smallest feature in a sample was selected to be 5.

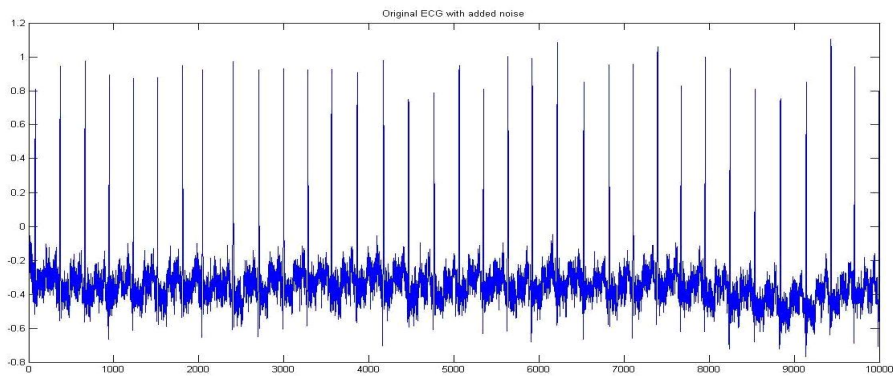


Fig. 5. Original ECG signal added with noise.

The noise signals generated are added with the ECG signal to get the corrupted ECG. Fig. 5 shows the corrupted ECG or noise added in original ECG.

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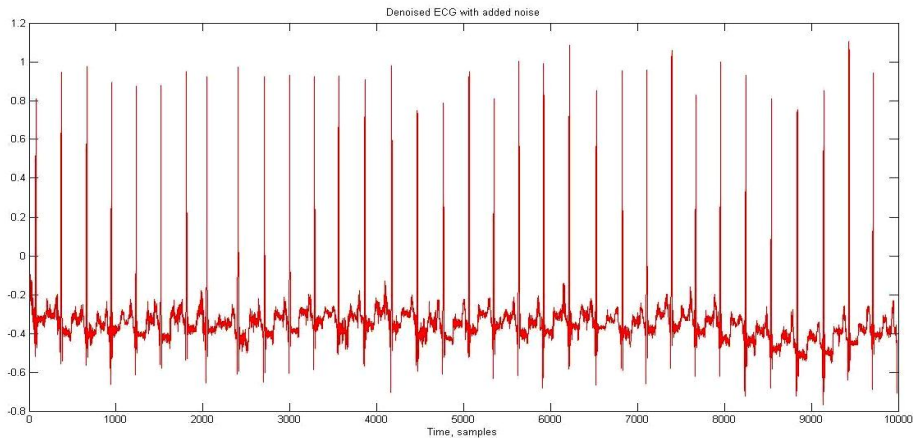


Fig. 6. Denoised ECG signal with P=1000 by NLM technique.

Figure.6 shows the original ECG signal after denoising by using the non local mean filtering technique by selecting P to be at 1000 while size of smallest feature in a sample was selected to be 5.

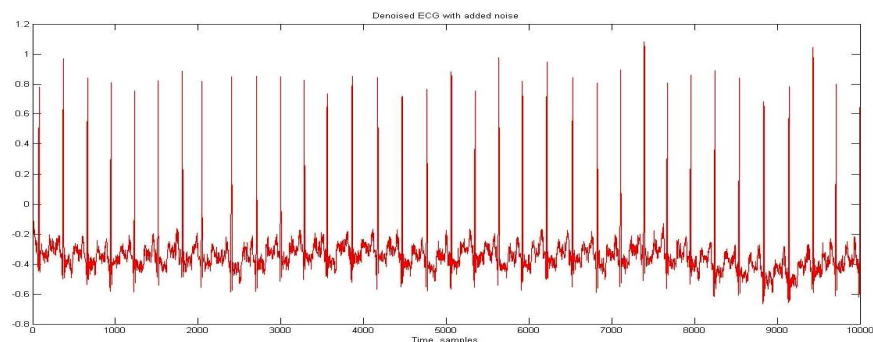


Fig. 7. Denoised ECG signal with P=1000 by wavelet technique.

The resultant filtered signals obtained are shown in Fig. 6 and Fig. 7. For this experiment, 10000 samples were considered. The obtained results were then compared for both the evaluated methods by evaluating their peak signal to noise ratio (PSNR) and mean square error (MSE) as shown in table 1.

Table 1: Comparison of PSNR and MSE for different ECG signals

Comparison between signals using both methods with P=1000	Peak Signal to Noise Ratio (PSNR) dB			Mean Square Error (MSE) %		
	R	G	B	R	G	B
Original and denoised ECG signal using NLM method	44.73	39.34	34.99	2.20	7.63	20.76
Original and denoised ECG signal using wavelet method	44.20	39.12	34.89	2.49	8.01	21.24
Noisy and denoised ECG signal using NLM method	45.94	40.31	34.83	1.67	6.09	21.52
Noisy and denoised ECG signal using wavelet method	45.60	40.17	34.46	1.80	6.29	23.44

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IV. CONCLUSION

Two different methods, that is, wavelet and non local means based filtering method is proposed in this work. The results showed that the NLM based filtering technique is more effective and less time consuming than wavelet technique for denoising ECG signals. No doubt that both methods are effective to remove noise upto the satisfactory level when optimized, but the measured parameters, as shown in table 1, showed that the PSNR and MSE values are better for NLM method. However if we keep on increasing the bandwidth, then the resultant denoised signals will gets saturated. Non-local means offers a consistent improvement in PSNR, and the parameter β has an important impact on the performance of non-local means. In our future work, other methods will also be explored for parameter settings and evaluating results.

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