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DENOISING OF ECG SIGNAL USING UNDECIMATED WAVELET TRANSFORM

Baliram S. Gayal[1], F.I. Shaikh[2]

Assistant Professor, Dept. of E&TC, Indira College of Engg. and Management, Pune, India [1]

And ME (Digital System) Student, Dept. of Electronics, J.N.E.C., Aurangabad , India[1]

Associate Professor , Dept. of Electronics, J.N.E.C, Aurangabad, India [2]

ABSTRACT: We are Using an individual's electrocardiogram (ECG) as a means for checking individuals heart functioning and abnormalities (diseases) occurred in it. However, the presence of noise in an ECG trace complicates the analysis of ECG signal for identification of functioning and abnormalities in the heart. The primary noise sources in ECG are power line interference, electromyography (EMG) noise, electrode contact noise, motion artifacts, and instrumentation noise. In this research work described elimination of the noises occurred in ECG. Purpose of denoising ECG is to obtain reliable and clear signal for diagnosis purpose while preserving as much of the underlying subject information as possible. This research work is based on the use of the Undecimated Wavelet Transform (UWT)[1] To get a better identification of ECG. To read ECG samples from MIT database we required WFDB toolbox. ECG Denoising is carried out using the Wavelet Coiflet and Daubechies filter. These were chosen because their scaling functions are closely related to the shape of the ECG and fitting very well with the applications constraints [2].Here ECG signal samples were taken from MIT/BIH data base and processed in MATLAB using UWT.

Keywords: Electrocardiogram (ECG),WFDB,UWT,MIT/BIH database

I.INTRODUCTION

Heart is very important organ of a human body. Now a days number of peoples are suffering from heart diseases and this number is increasing continuously. Correct and in time diagnosis is very important. Capturing of ECG signal may be a easier process but obtaining a clear, reliable, noise free ECG is a very difficult task. Reliable ECG is required for diagnosis purpose for expert. If ECG is contaminated with noise then diagnosis for a patients may went wrong and this is fetal for patients lives. Hence denoising of ECG signal is very important previous to diagnosis. ECG contaminating agents are as,

1. AC Line interference

2 Noise by contact in the electrode

3.Electrical coupling of the electrodes and the board

4. Electromyography (EMG) noise

5. Motion artifacts, and

6. Instrumentation noise

The advantage of effectively denoising the ECG signals is to determine in a clear and simple way the PQRST complex, that helps the specialist identify different types of arrhythmias, like the tachycardia or the bradycardia and variations in the heart rate; as well as determine other types of abnormalities in the myocardium [3].

The Electrocardiogram (ECG) is a technique of recording bioelectric currents generated by the heart which will help clinicians to evaluate the conditions of a patient's heart. So it is very important to get the parameters of ECG signal clear without noise. Many of the wavelet based denoising algorithms use DWT (Discrete Wavelet Transform) in the decomposition stage which is suffering from shift variance. To overcome this in this paper we are proposing the denoising method which uses Undecimated Wavelet Transform to decompose the raw ECG signal and we performed the shrinkage operation to eliminate the noise from the noisy signal. In the shrinkage step we used semi-soft and stein

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thresholding operators along with traditional hard and soft thresholding operators and verified the suitability of different wavelet families for the denoising of ECG signals. The results proved that the denoised signal using UDWT (Undecimated Discrete Wavelet Transform) have a better balance between smoothness and accuracy than the DWT

II. ECG THEORY

Electrocardiography (**ECG**) is a transthoracic (across the thorax or chest) interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the surface of the skin and recorded by a device external to the body. The recording produced by this noninvasive procedure is termed an **electrocardiogram** (also ECG or EKG). An ECG is used to measure the rate and regularity of heartbeats, as well as the size and position of the chambers, the presence of any damage to the heart, and the effects of drugs or devices used to regulate the heart, such as a pacemaker.Most ECGs are performed for diagnostic or research purposes on human heart.

The ECG records the electrical activity of the heart, where each heart beat is displayed as a series of electrical waves characterized by peaks and valleys. Any ECG gives two kinds of information. One, the duration of the electrical wave crossing the heart which in turn decides whether the electrical activity is normal or slow or irregular and the second is the amount of electrical activity passing through the heart muscle which enables to find whether the parts of the heart are too large or overworked. Normally, the frequency range of an ECG signal is of 0.05–100 Hz and its dynamic range – of 1–10 mV. The ECG signal is characterized by five peaks and valleys labelled by the letters P, Q, R, S, T. In some cases we also use another peak called U. The performance of ECG analyzing system depends mainly on the accurate and reliable detection of the QRS complex, as well as T- and P waves.

The P-wave represents the activation of the upper chambers of the heart, the atria, while the QRS complex and T-wave represent the excitation of the ventricles or the lower chamber of the heart. The detection of the QRS complex is the most important task in automatic ECG signal analysis. Once the QRS complex has been identified a more detailed examination of ECG signal including the heart rate, the ST segment *etc.* can be performed [3]. In the normal sinus rhythm (normal state of the heart) the P-R interval is in the range of 0.12 to 0.2 seconds. The QRS interval is from 0.04 to 0.12 seconds. The Q-T interval is less than 0.42 seconds and the normal rate of the heart is from 60 to 100 beats per minute. So, from the recorded shape of the ECG, we can say whether the heart activity is normal or abnormal. The electrocardiogram is a graphic recording or display of the time variant voltages produced by the myocardium during the cardiac cycle. The P-, QRS- and T-waves reflect the rhythmic electrical depolarization and repolarization of the myocardium associated with the contractions of the atria and ventricles. This ECG is used clinically in diagnosing various abnormalities and conditions associated with the heart.

Amplitude P-wave — 0.25 mV
R-wave — 1.60 mV
Q-wave — 25% R wave
T-wave — 0.1 to 0.5 mV
Duration P-R interval : 0.12 to 0.20 s
Q-T interval : 0.35 to 0.44 s
S-T interval : 0.05 to 0.15 s
P-wave interval : 0.11 s
QRS interval : 0.09 s

III. METHODOLOGY

Here denoising of ECG signal process is carried out in the MATLAB. ECG signal samples are taken from MIT/BIH database. To read data from database used WFDB toolbox. The WFDB Toolbox for MATLAB is a collection of MATLAB functions for reading, writing, and manipulating (processing) PhysioBank data, implemented as system calls to WFDB Software Package applications through Java and MATLAB wrappers.Using the WFDB Toolbox, MATLAB users have direct access to over 50 PhysioBank databases (over 3 TB of physiologic signals including ECG, EEG, EMG, fetal ECG, PLETH, ABP, and more). Addionally, most of these databases are also accompanied by meta-data such as expert annotations of physiologically relevant events (WFDB annotation files). These can include, for example,

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cardiologist annotations on ECGs for classifying different arrythmias, or sleep expert annoations on EEG for segmenting different sleep stages. All of these physiologic signals and annotations can be read on demand from the PhysioNet web server and its mirrors using the toolbox functions, or from local copies if you choose to download them.
UWT techniques is used in this research work for denoising purpose. The basic idea of UWT is simply to apply appropriate low and high pass filters to that data at each level to produce two sequences to the next level. The resultants are not decimated and two new sequences have the same length as the original sequence. The multiresolution is achieved by modifying (upsampling) the filter at each level. Translation-invariance is achieved by removing the down samplers and up samplers in the DWT and up sampling the filter coefficients by a factor of $2^{(j-1)}$ in the *j*th level of the algorithm. The SWT is an inherently redundant scheme as the output of each level of SWT contains the same number of samples as the input – so for a decomposition of N levels there is a redundancy of N in the wavelet coefficients. This algorithm is more famously known as "*algorithme à trous*"
The most important gain from un-decimated wavelet transform is that it provides more information about the analyzed image. This additional information is of great value for De- noising. The additional coefficients give the possibility for better noise allocation. It further enhances the chance to remove more noise while preserving data.
The unique characteristics of the UWT transform comparing with the DWT are as follow
1. Invariant Translation Characteristic
2. Better Capacity to reduce noise
3. Better peak detection

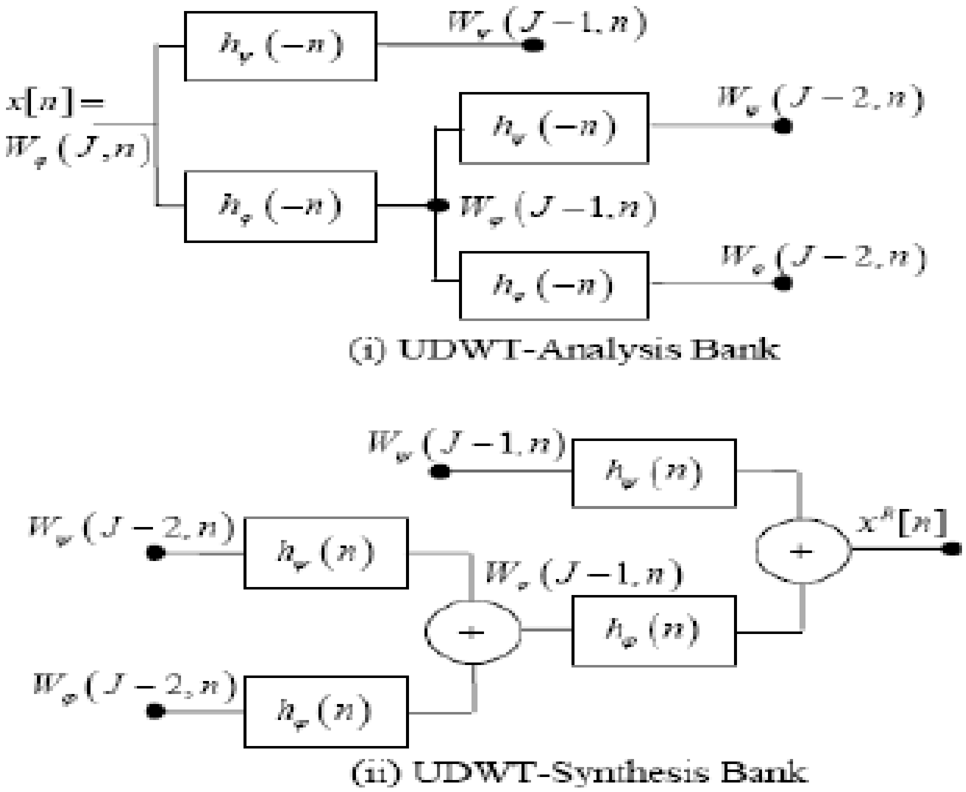

Fig. 1. Implementation of UWT

The Wavelet function selection depends on the application or the application for which it's going to be used. Selecting a Wavelet function that looks like the signal that will be processed is the most convenient selection. Here selected function as Coiflet and Daubechies from wavelet family has similar in shape to the QRS complex [7].
Denoising Algorithm used in this work is as follows ,

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1.Read ECG signal in MATLAB using WFDB toolbox installed in PC.
2. Measures the power of signal with noise.
3. Now apply UWT for denoising ECG signal.
4.Measure the power of denoised signal.
5. Calculate SNR / PSNR for each ECG sample.

To run this UWT algorithm we need to specify certain things as follows.

i.Specify which wavelet family we are going to use in wavelet classification.
In our task we have used coiflet and daubechies family filters.

ii.Specify level of decomposion.
Better the level of decomposion , we can seperate out more detail data. So we have selected level 5 for decomposion.

iii.Select mode of thresholding .
Whether it is hard or soft. Soft thresholding technique always perform better because thresholds gets adjust with signal power and noise.

iv.Select threshold values.
These are selected by trial and error and some values are defined according to family.

v. Apply interval based denoising function
This function scales its filter coefficient values at each decomposion level but do not up sample or down sample data. So it is UWT.

In figure 2 shown below the first signal is original ECG signal read from MIT/BIH database with the help of WFDB toolbox of Matlab. Second signal in the fig. 2 shows a ECG signal contaminated with noise. Due to noise changes occurred in the parameter of ECG signal. This signal is not reliable for clinical analysis by the expert. This noisy signal is then applied to the coiflet-UWT filter and the daubechies UWT filter. Third and fourth signals in figure 2 is available at the output of Coiflet UWT filter and daubechies UWT filter. Here we observe that noise in ECG signal is removed here.

After denoising some quality measures implemented like signal to noise ratio (SNR), PSNR to prove efficiency of our algorithm.

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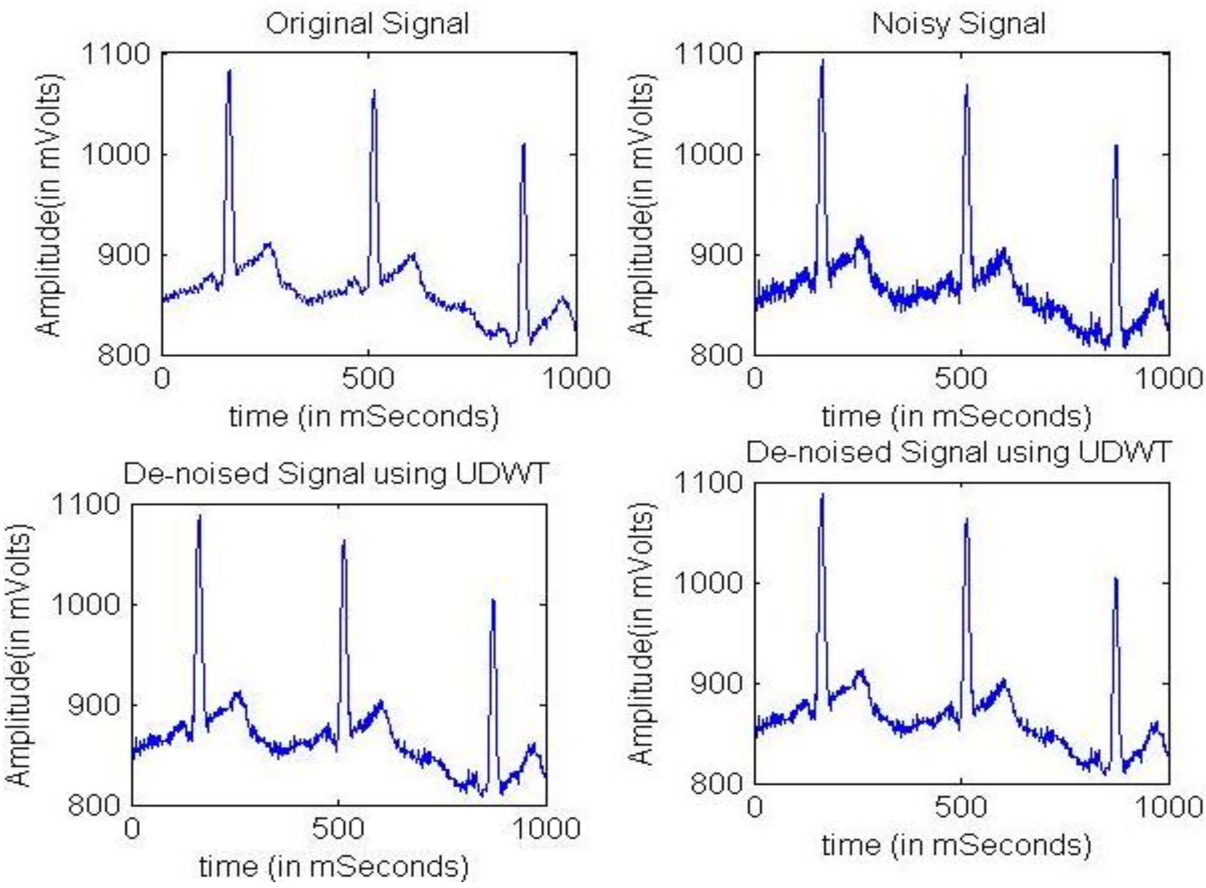

Figure 2 ECG Original,Noisy and Denoised signals

IV.RESULT AND DISCUSSION

In Figure 2 shown the third ECG signal at the output of the Coiflet -UWT wavelet filter, where we can observed a well known improvement in clarity of the complex P,Q,R,S,T, although also small peaks can be observed right before beginning the QRS wave. Fourth signal shows the application of Daubechies UWT Wavelet filter where it is observed that the isoelectric line of the ECG signal is straight and clear as compared to coiflet UWT filter. In above figure shown only 121 number sample of ECG signal from MIT/BIH database and its noisy and denoised signals. But this research is carried out on number of signal from database. Following table 1 and table 2 gives some results when Coiflet and Daubechies UWT filters applied respectively to noisy ECG signal samples. Daubechies UWT filter gives gives better and clear results and also good performance as compared to Coiflet UWT filter.

Table 1. Results of Coiflet UWT filter

Sr. No.	ECG Sample No.	SNR of Noisy Signal (db)	SNR of Denoised Signal (db)	PSNR Of Noisy Signal (db)	PSNR Of Noisy Signal (db)
1	100	16.03	18.98	35.26	36.70
2	111	16.68	19.26	33.62	35.51
3	121	19.26	22.52	34.34	36.35
4	200	23.92	26.19	41.16	41.40

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Table 2. Results of Daubechies UWT filter

Sr. No.	ECG Sample No.	SNR of Noisy Signal (db)	SNR of Denoised Signal (db)	PSNR Of Noisy Signal (db)	PSNR Of Noisy Signal (db)
1	100	15.98	18.92	35.50	38.27
2	111	16.85	19.63	32.39	36.61
3	121	19.27	22.53	35.13	39.10
4	200	24.14	26.59	40.99	44.05

V.CONCLUSION

Daubechies UWT Wavelet filter show better results in contrast with the Coiflet UWT Wavelet filter. Different samples for their analysis were taken from MIT/BIH database using WFDB toolbox of Matlab installed on system.These samples were processed latter on by UWT transform using Coiflet and Daubechies wavelet filters. Obtaining a suitable ECG signal for telemedicine applications is a fundamental task in order to have accuracy of every wave that it is formed of. In fact besides processing, it is ecessary to detect it with accuracy and to identify each feature of it in order to determine an accurate heart rate, different types of arrhythmias like the bradycardia, tachycardia and variations in the heart rate, as well.

In this work we have presented an alternative to filter the ECG signal and thus obtain signals easier to interpret, that serves as a biomedical signal processing and that can be applied in other areas of research.

VI.FUTURE SCOPE

In this work, we presented a proposal for noise reduction using Undecimated Wavelet transform in order to improve the accuracy and reliability of ECG signal for diagnosis purpose by clinical expert. The future work includes the online processing and noise reduction of bioelectrical signals applied to telemedicine applications.

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