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ORIGINAL ARTICLE

ECG SIGNAL DE-NOISING USING DIFFERENT WAVELET TRANSFORM

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Abstract:

The wavelet transformation is based on a set of analyzing wavelets allowing the decomposition of ECG signal in a set of coefficients. Each analyzing wavelet has its own time duration, time location and frequency band. In the wavelet based algorithm, the ECG signal is de-noised by removing the corresponding wavelet coefficients at higher scales. One of the main applications of a filter is to sort out the unwanted parts of an input signal. These unwanted parts might be noise pre- sent out of the frequency band in the desired signal. During transforming the corrupted signal into the frequency domain, the frequencies that belong to the external noise can be easily detected.

KEYWORDS:

De-Noising , analyzing wavelets , ECG signal .

INTRODUCTION

Wavelet transform are used to compress the ECG signal. The main challenge in an ECG compression method is to minimize the storage requirements without losing the clinically significant information which can be achieved using Wavelet transform. Small variations in normal and noise corrupted ECG signal can been extracted using wavelet function.

The wavelet based signal de-noising is performed us-

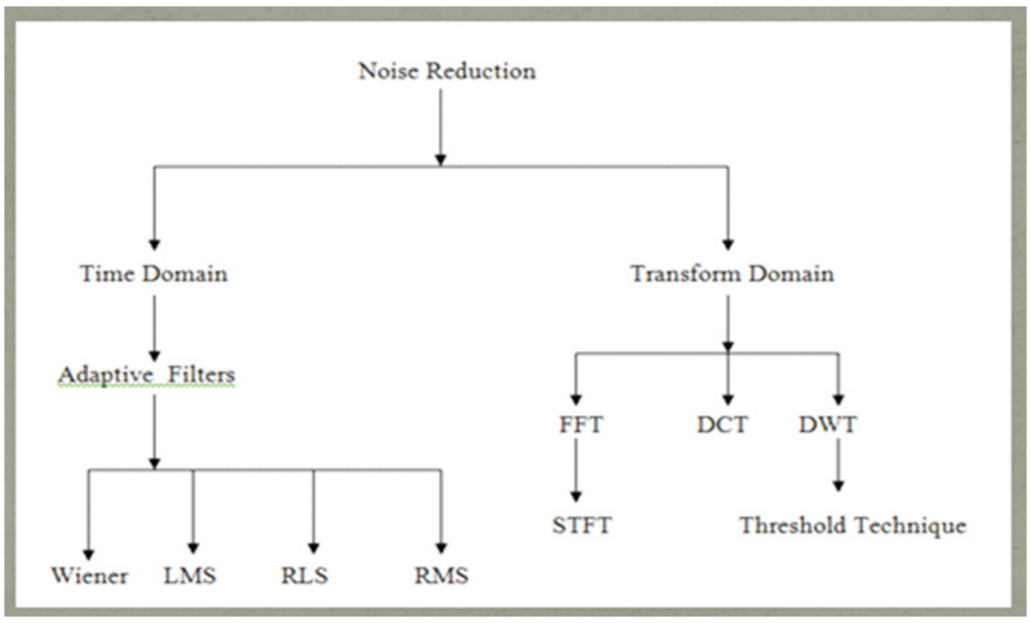
ing wavelet shrinkage and thresholding technique. There are two types of thresholdings; hard and soft. In hard threshold, the elements whose absolute value is lower than the threshold are set to zero. Soft threshold is an extension of hard threshold. Here, the elements whose absolute values are lower than the threshold are first set- tled to zero, and then shrinking the nonzero coefficients towards 0.

The series connection of Discrete Wavelet Transform, thresholding and Inverse Discrete Wavelet Transform can remove the noises and achieve high Signal-to-Noise ratios. This is due to the concentrating ability of the wavelet transform. The combination of Shannon energy envelope estimator and Hilbert-transform technique can detect R-peaks in case of wider and small QRS complexes, negative QRS polarities, and sudden changes in QRS amplitudes.

Sharing the patient information and exchange of medical images and Electronics Patient Record between networked hospitals and healthcare centers is witnessed nowadays. Discrete wavelet packet transforms is used to protect the patient information in the form of watermark on the medical image using the hospital logo as a refe- rence image. Since wavelet based watermarking method is robust against a wide range of attacks such as JPEG image format, contrast adjustment, Gaussian noise, his- togram equalization, gamma correction etc.

Title: “ECG SIGNAL DE-NOISING USING DIFFERENT WAVELET TRANSFORM”.Source: Review of Research [2249-894X] GOHIL NARENDRASINH BABUBHA yr:2013 vol:3 iss:3

Classification of different Types of Noise Reduction Technique



NOISE REDUCTION USING FIR FILTERS

FIR filter is one of the techniqu es successfully employed in processing ECG signals for measurement and noise reduction. They are used to modify the bio-signal by removing noise and the effect of a system on the input signal can be described in both time and frequency do- mains. The time domain method of ECG signal analysis is not always sufficient to study all the features of ECG signals. Therefore, the frequency representation of a signal is required. Hence, filters are designed in frequency domain so that the noisy signals can be filtered from the measured bio-signals. If this filters where designed in time domain it would not be possible to remove the noises effectively since the frequencies that belong to the external noise cannot be detected easily. In this sec- tion more details about the filters and filtration process are presented.

Notch Filter (NF)

The noise presented at 50/60 Hz is known as a power line hum (noise), caused by any electrical appliances and lights. NF is used to filter this noise. The frequency response of NF is shown in and the transfer function of a NF is given by,

Low Pass Filter (LPF)

The LPF removes the corrupting high frequency noises in ECG. The transfer function of an ideal LPF is given by Equation (4). Here the LPF is designed with the cut off frequency (fc) 100 Hz with the sampling frequency (fs) of 6 KHz.

Fast Fourier Transforms (FFT)

The Fast Fourier Transforms (FFT) produces the signal into an infinite length of sine and cosine functions. However, the transform losses the information is about time domain and gives only spectral information in the frequency domain and vice versa.

Short Term Fourier Transform (STFT)

Short Term Fourier Transform (STFT) - provides both time and frequency information, but resolves all frequencies equally. Short Time Fourier Transform (STFT) was proposed and it represents the signal in both time and frequency domains using moving window function. In this method, the window should always have a constant size, and thereby it does not give multi resolution information on the signal.

Kaiser Window (KW)

Kaiser based FIR filter is designed to remove the un- wanted frequency component which corresponds to the noise. Kaiser window has very desirable characteristics both in time domain and frequency domain. A good window should be a time limited function with a Fourier trans- form that is band limited and Kaiser Window possesses such characteristics.

Wavelet Transform

A signal as the function of f (t) can often be better analyzed and expressed as a linear decomposition of the sums; coefficient products and function. In the wavelet transform, the original signal is transformed using predefined wavelets. These wavelets are orthogonal, orthonormal, bi orthogonal, scalar or multi wavelets. The wavelet transform is a convolution of the wavelet function

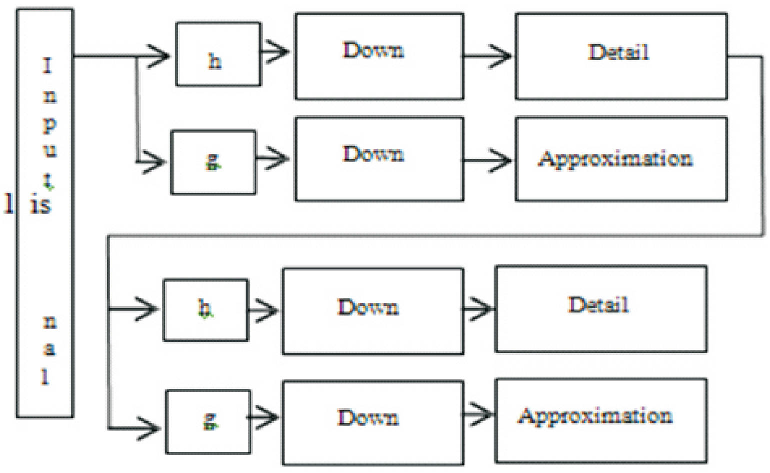


Figure 6. Filter bank tree decomposition.

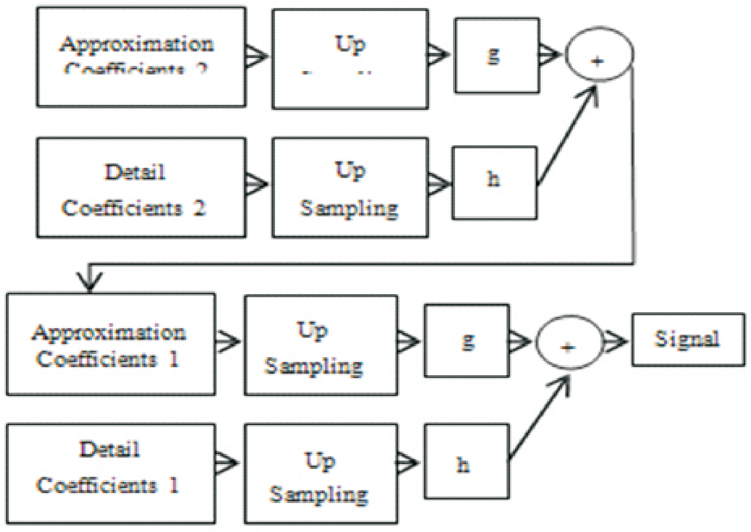


Figure 7. Filter bank tree reconstruction.

The original signal can be reconstructed by choosing orthonormal wavelet with the approximation coefficient as,

Wavelet denoising

Continuous wavelet transform (CWT)

The CWT -*Wf(s,τ)*- is the inner product of a time- varying signal f(t) and the set of wavelets *ψs,τ(t)* given by

$$Wf(s,\tau)|=<f,\psi_{s,\tau}>=\frac{1}{\sqrt{s}}\int f(t)\psi^{*}(\frac{t-\tau}{s})dt$$

The scaling and shifting the mother wavelet (ψ) with factors of s and τ (with s>0), respectively, generate a family of functions called wavelets given by

$$\psi_{s,\tau}(t)=\frac{1}{\sqrt{s}}\psi(\frac{t-\tau}{s})$$

Discrete wavelet transform (DWT)

A very common discretization of the CWT, which is a very redundant representation, consists of setting the scale and shift value as: s= s0i and t=kt0s0i with i and k are integers and s0 is a real value >1. A practical choice of t0 and s0 consists on setting s0 to 2 and t0 to1 that is s=2i and t=k. 2i. This is called dyadic wavelet transform. In this case, the wavelet functions become

$$\psi_{i,k}(t)=2^{-1/2}\psi(2^{-i}t-k)$$

Meyer has demonstrated that this setting form of scale and shift parameters constitutes an orthonormal basis for $L^2(R)$, that is

$$d_{i,k}(t)\equiv<f(t),\psi_{i,k}(t)>\equiv\int f(t)\psi_{i,k}(t)dt$$

and

$$f(t)=\sum_{i}\sum_{k}d_{i,k}(t).\psi_{i,k}(t)$$

The DWT consists of applying the discrete signal to a bank of octave band filters based on low and high pass filters l(n) and h(n) respectively; more precisely, the function f(t) would be expressed as follows

$$f(t)=\sum_{k\in Z}a_{L}(k)\phi_{L,k}(t)+\sum_{j=1}\sum_{k\in Z}d_{j}(k)\psi_{j,k}(t)$$

with:

$$d_{j}(n)=<f,\psi_{j,n}>=\Sigma k\ g'(2n-k)\ a_{j-1}(n)$$

$$a_{L}(n)=<f,\phi_{j,n}>=\Sigma k\ h'(2n-k)\ a_{L-1}(n)$$

where f(t) is called the scaling function associated to the wavelet function y(t) governed by the following condition:

Denoising:-

The objective of wavelet based de noising process is to estimate the signal of interest s(t) (equation 9) from the composite one f(i) by discarding the corrupted noise e(I)

$f(i) = s(i) + e(I)$

The underlying model for the noisy signal is the superposition of the signal –s(i)- and a Gaussian zero mean white noise with a variance of σ². The threshold value is computed according to the model of the signal of interest to be estimated -s(i)- and the corrupted noise –e(i)-. Donoho and Jonhstone proposed the universal 'VisuShrink' threshold given by

$$Thr = \sigma\sqrt{2.\log(N)}$$

In the case of white noise, its standard deviation can be estimated from the median of its detail coefficients (dj), with j=1..L, and is computed as follows

$$\sigma = \frac{MAD(|d_j|)}{0.6745}$$

where MAD is the median absolute deviation of the corresponding sequence. Two algorithms of thresholding exist: Hard and Soft thresholding algorithms (Tsoft and Thard respectively) expressed as follows

$$T_{soft} = sgn|(|x).(x.Thr)$$

$$T_{hard} = |\ x|.1\ (x > Thr)$$

The wavelet based denoising process is summarized as follows: the resulting DWT detail coefficients are thresholded by either shrinkage (soft) or crude (hard) strategy. Reconstructing the original sequence from the

Our denoising algorithm is composed of two successive phases: the pre-processing and the smoothing process.

Wavelet Thresholding

1. Hard Thresholding and Soft Thresholding

Wavelet thresholding is the signal estimation technique that exploits the capabilities of signal denoising. Thresholding methodis categorized into two types such as hard thresholding and soft thresholding. The Figure shows the soft and hard thresholding of the original signals.Performance of thresholding is purely depends on the type of thresholding method and thresholding rule used for the given application. The hard threshold function tends to have bigger variance and it is unstable (sensitive even small changes in the signal) shown in Eqn. 3. However, soft thresholding function is much stable than hard thresholding and it tends to have a bigger bias due to the shrinkage of larger wavelet coefficients descrbed in Eqn.3. In addition to these methods, the hyper-trim shrinkage with α- trim thresholding is proposed for signal denoising. In general, most of the researchers have proved that, the soft thresholding method gives the best results with other methods on denoising the ECG signal

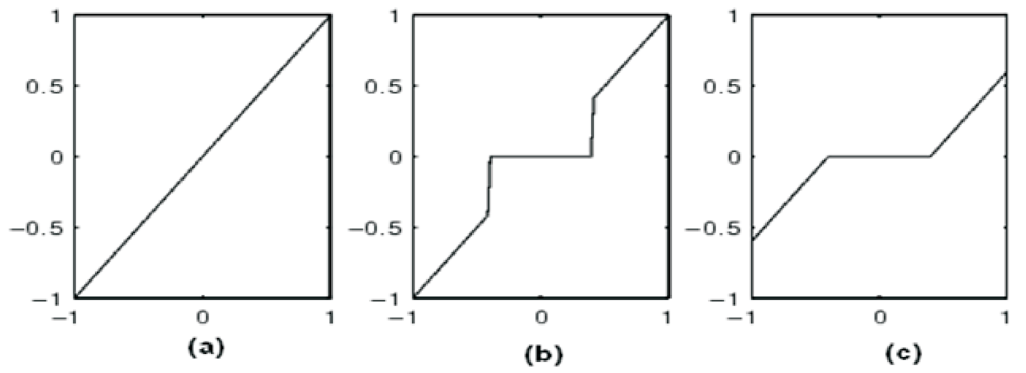


Figure (a) Original signal; (b) Hard threshold signal; (c) Soft threshold signal

Comparision Between Haar & Debauchees Wavelets

Wavelet	The number of multiplications and additions for classical wavelet transform	The number of multiplications and additions for lifting-based avelet transform	Speedup (%)
Haar	10	8	25
DB4	34	20	70
DB6	50	28	78
DB8	66	36	83

WAVELET TRANSFORMS VERSUS FOURIER TRANSFORMS

SIMILARITIES BETWEEN FOURIER AND WAVELET TRANSFORMS

The fast Fourier transform (FFT) and the discrete wavelet transform (DWT) are both linear operations that generate a data structure that contains log2 n segments of various lengths, usually lling and transforming it into a di®erent data vector of length 2n.

The mathematical properties of the matrices involved in the transforms are similar as well. The inverse transform matrix for both the FFT and the DWT is the transpose of the original. As a result, both transforms can be viewed as a rotation in function space to a di®erent domain. For the FFT, this new domain contains basis functions that are sines and cosines. For the wavelet transform, this new domain contains more complicated basis functions called wavelets, mother wavelets, or analyzing wavelets. 6 Amara Graps

Both transforms have another similarity. The basis functions are localized in frequency, making mathematical tools such as power spectra (how much power is contained in a frequency interval) and scalegrams (to be de¯ned later) useful at picking out frequencies and calculating power distributions.

DISSIMILARITIES BETWEEN FOURIER AND WAVELET TRANSFORMS

The most interesting dissimilarity between these two kinds of transforms is that individual wavelet functions are localized in space.

Fourier sine and cosine functions are not. This localization feature, along with wavelets' localization of frequency, makes many functions and operators using wavelets\sparse" when transformed into the wavelet domain. This sparseness, in turn, results in a number of useful applications such as data compression, detecting features in images, and removing noise from time series.

One way to see the time-frequency resolution differences between the Fourier transform and the wavelet transform is to look at the basis function coverage of the time-frequency plane. Figure shows a windowed Fourier transform, where the window is simply a square wave. The square wave window truncates the sine or cosine function to a window of a particular width. Because a single window is used for all frequencies in the WFT, the resolution of the analysis is the same at all locations in the time-frequency plane.

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