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An Enhanced Strategy of Audio Denoising Based on Wavelet Transform

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Abstract: The recuperation of unique signals from the correspondence channel with no noise is a troublesome errand. Numerous denoising methods have been proposed for the expulsion of noises from a digital signal. Wavelet denoising utilizing edge calculation is an effective strategy for stifling noise in digital signals. In this paper, a sound denoising procedure in light of DDDTWT utilizing a level ward edge calculation is actualized. Sound signal debased with Additive White Gaussian Noise is decided for the execution. The outcomes as far as SNR and RMSE are contrasted and the estimations of DTDWT and DDDWT techniques and furthermore with worldwide thresholding strategy. The consequences of MATLAB re-enactments demonstrate that the proposed technique is more compelling and gives better execution for denoising sound signals as far as both SNR and RMSE.

Keywords: Signal to Noise Ratio; Root Mean Square Error; Double Density Dual Tree Discrete Wavelet Transform; Dual-Tree Discrete Wavelet Transform; Double-Density Discrete Wavelet Transform.

I. INTRODUCTION

Wavelets have been observed to be an intense instrument for disposing of noise from a wide assortment of signals. The capacity of the wavelet transform to break down a signal into various scales is vital for denoising and it enhances the investigation of the signal essentially. Wavelet denoising techniques in view of thresholding calculation was first presented by Donoho in 1993[1]. Wavelet edge denoising techniques misuse the spatially adaptive multi-resolution highlight of the wavelet transform. The upsides of these denoising strategies are quick calculation speed, wide versatility and best estimation than some other straight gauges give.

Deciding an ideal incentive for the threshold is the principle test of wavelet threshold denoising strategy. A little threshold esteem won't evacuate all the noisy coefficients and consequently the resultant denoised signal may even now be noisy; though an extensive threshold esteem sets more number of coefficients to zero; henceforth expels points of interest from the decayed information and the resultant denoised signal might be obscured [2]. As such, the hard threshold work cause wavering in signal recreation and create visual contortion and the soft threshold work delivers a consistent deviation between the remade signal and the first signal which causes obscuring of edges amid signal remaking [3].

The target of sound denoising is to lessen the noise while recuperating the first signals. The denoised signal acquired after any sound denoising strategy may not be absolutely free from noise. A few strategies have been proposed for the expulsion of noise from a sound signal, however the efficiency remains an issue in the greater part of them. In techniques, for example, Gaussian filters and anisotropic diffusion, the signal is denoised in light of the watched estimations of the neighbouring focuses. To conquer this area property different creators proposed numerous worldwide denoising approaches [4]. In [5], an adaptive square system in light of the dyadic CART calculation for signal denoising was proposed.

In this work, complex wavelets are utilized for sound signal denoising as they secure period of the signals. The residual noise antiquities in recreated signals are dispensed with by means of square constriction. The paper [6] presents a novel approach for sound signal denoising utilizing Discrete Wavelet Transform where the wavelet coefficients are demonstrated on the premise of Heavy Tailed Distribution work. It gives a decent portrayal contrasted with Gaussian dissemination work concerning filtering of noise from the signal. The signal denoising techniques in view of double-density DWT and dual-tree DWT are actualized in [7]. The ideal estimations of threshold point and decomposition level are resolved. These denoising strategies give better

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execution as far as SNR and RMSE when contrasted and the ordinary DWT technique.

In this paper, a sound denoising strategy in view of double-density dual-tree discrete wavelet transform (DDDTDWT) utilizing a level ward threshold is actualized. The threshold point and the decomposition stages for the wavelet denoising techniques rely upon the force of the noise exhibit in the signal. In the proposed work, the threshold in VisuShrink strategy or general threshold presented by Donoho [8] is adjusted and connected to various phases of DDDTDWT. Sound signal debased with Additive White Gaussian Noise is taken for the usage. The execution of the denoising technique is assessed in light of signal to noise ratio (SNR) and root mean square error (RMSE). The test comes about are contrasted and that of different strategies for DWT, for example, double-density DWT and dual-tree DWT and furthermore with the aftereffects of worldwide threshold denoising strategy.

The paper is composed as takes after. Section 2 gives a short foundation to proposed wavelet denoising technique. Section 3 gives the depiction of the proposed work, its simulation results and exchanges are introduced in Section 4 and Section 5 closes with useful suggestions.

II. Procedure

A. Denoising Audio Signal

The slightest troublesome wavelet transforms used for treatment of mechanized data is the fundamentally examined unmistakable wavelet transform. Filter banks accept an essential part in playing out the examination of discrete wavelet transform. A one-dimensional filter bank including an examination and a union filter bank is appeared in below figure. Filter banks which satisfy admire diversion property include the two filters, a Low and High pass filter. The examination filters crumble the information signal into sub bunches which after down analysing is taken care of and the blend filter bank imitates the principal signal after up-testing the signals.

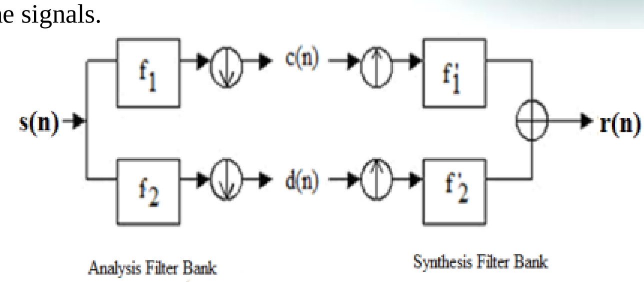

Fig. 1. 1-D Filter Bank

B. Wavelet Transform

Both the double-density DWT and the double tree DWT have their own specific characteristics and positive conditions, and in this manner, it was quite recently ordinary to join the two into one transform called the double-density complex (or double-density double tree) DWT. To join the properties of both the double-density and double tree DWT we ensure that: one arrangement of the four wavelets are intended to be counteracted the other match of wavelets with the objective that the number unravels of one wavelet consolidate fall somewhere between the entire number deciphers of the other consolidate Equation (1), and (2) one wavelet coordinate is intended to be construed Hilbert transforms of the other consolidate of wavelets. By doing this, we are then prepared to use the double-density complex wavelet transform to execute many-sided and directional wavelet transforms.

To realize the double-density double tree DWT, we should first diagram a legitimate filter bank structure (one that combines the characteristics of the double-density and double tree DWTs). We have seen what kind of filter bank structure is connected with the double-density DWT in the past ranges (generally that it is made out of two high pass wavelet and one low pass filters), so we will now swing to the properties of the double tree DWT. The double tree DWT is developed chiefly in light of connecting two on a very basic level analysed DWTs. We do this by building up a filter bank that plays out different cycles in parallel. More knowledge about the double tree DWT can be found at this site. Hence, the filter bank structure contrasting with the double-density complex DWT contains two oversampled iterated filter banks working in parallel on a comparative data. The iterated oversampled filter bank coordinate, identifying with the simultaneous execution of the double-density and double tree DWTs, is appeared in Figure 2 underneath.

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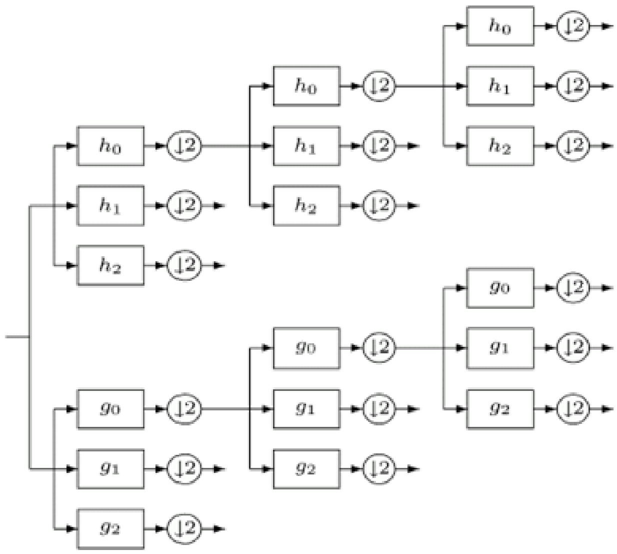

Fig. 2. Iterated Filter bank for the Double-Density Complex DWT

III. METHODOLOGY

Threshold calculation for wavelet transform is the capable strategy to pack noise in digital signals. A sound signal which contains Gaussian noise is utilized for the strategy. The pack levels and a threshold estimation of the denoising methods in view of the saturation of the noise executed in the signal.

This procedure involves in the audio denoising process which are described as follows.

l) Read an audio signal s(i).

2) Add Gaussian noise to this signal to form noised signal r(i). The best technique is to test the effect of noise on a signal is to add Additive White Gaussian Noise.

The noised signal is in the form of equation (1).

$$r(i) = s(i) + \sigma\varepsilon(i), i = 0,1,2 \ldots, k \qquad (1)$$

Where r(i) is the noisy signal, s(i) is the noise-free signal to be detected, (i) is the noise signal, o - noise intensity and k is the length of the signal.3) Tally the SNR in decibels and RMSE of the noised signal use the formula in equations (2) and (3) respectively.

$$SNR(dB) = 10\log_{10}\left[\frac{\sum_{i=1}^{k} x_i^2}{\sum_{i=1}^{k}(r_i - s_i)^2}\right] \qquad (2)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{k}(r_i - s_i)^2}{k}} \qquad (3)$$

3) Where s is a starting signal, r is the noised signal/ restored signal and k is the magnitude of the signal.

4) For the observed SNR/RMSE of the received signal, compute the threshold value for wavelet thresholding algorithm. The level dependent threshold value is computed using the modified form of the universal threshold introduced by Donoho as given by equation (4).

$$T_{new} = \sqrt[\sigma]{2\log\frac{N}{2^I}} \qquad (4)$$

Where σ is the noise intensity, N represents the number of samples and I is the decomposition stage. The global threshold algorithm uses the universal threshold given by equation (5).

$$T = \sqrt[\sigma]{2\log N} \qquad (5)$$

5) To disintegrate the current signal into wavelet coefficients using the corresponding examination filter banks for DDDTDWT/D^{2}DWT/DTDWT staffing from the first stage. Utilize different filter bank for all the levels.

6) Threshold wavelet coefficients: Process the each sub band individually in a loop. Apply threshold value to the disintegrate coefficient of wavelet through all scales and sub bands using level dependent and global threshold values. Selecting the threshold value is more essential in wavelet threshold denoising technique. The selection of threshold value is too big or too small, the signal can't be exactly measured. Hard and soft threshold are the types of thresholding signal used for wavelet denoising and they are given by equations (6) and (7).

$$Soft\ threshold : \{r = sign(s)(|s| - T) \qquad (6)$$

$$Hard\ threshold : \begin{cases} r = s, if\ |s| > T \\ r = 0, if\ |s| < T \end{cases} \qquad (7)$$

Where s will be the input signal, r will be the signal subsequent to apply the threshold signal and T is the threshold point.

7) Restoring the signal: Consider the restoration using the threshold wavelet coefficients with the synthesis filter banks for DDDTDWT DDDWT DTDWT.

8) Calculate SNR (signal to noise ratio) and RMSE (root mean square error) of the denoised signal using equations (2) & (3). The obtained values are then compared with the values of previous step 2 for grading the execution. Higher

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the SNR or lower the RMSE will decide the realization of the denoising technique.

9) Repeat the above steps for different decomposition stages. For each stage, the SNR/RMSE is calculated. The decomposition stage that gives highest SNR or least RMSE is the optimum stage. Figure 3 shows the necessary steps presented in the denoised processing.

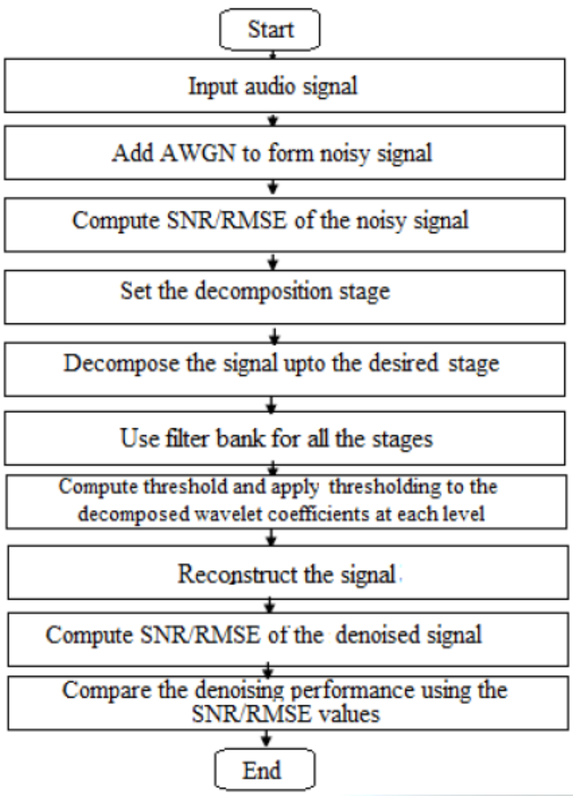

Fig. 3. Work flow of the Denoising Technique

IV. Results

The above-found innovation has been executed in MATLAB a2011b. A sound signal appeared in Figure 4 is decided for execution. Additive White Gaussian Noise (AWGN) is added to the first signal to frame the noisy signal. The denoising is performed with various noise forces and for various decomposition stages. The noise force 'σ' of the noisy signal is fluctuated in view of the pixel estimation of the signal and decomposition stages. SNR/RMSE esteems are then processed for different noise levels and decomposition stages.

A. *True Audio Signal*

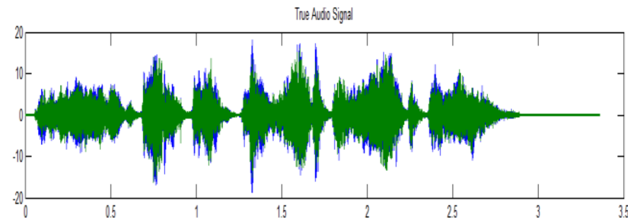

Fig. 4. True Audio Signal

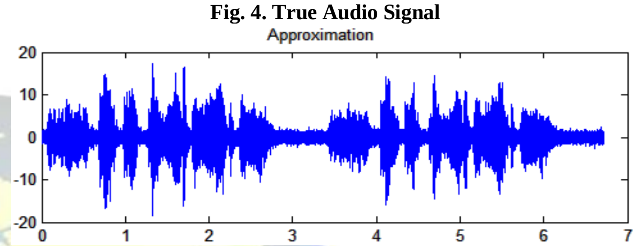

Fig. 5. Approximation of True Signal

B. *DWT (Dual Tree Wavelet Transform)*

- Considering the signal to noise ratio per sample in dB, so the input can be select from a specific wavelet like dB13, dB40, sym13 or sym21.
  For sym21:
  Threshold = **4.0804**
- Considering the threshold value can be heursure, rigrsure, minimaxi, & sqtwolog which are selection rules.
  For sqtwolog:
  Noised SNR = **4.0021**
- Considering the threshold type like soft or hard.
  For hard threshold:
  Denoised SNR = **8.8357**

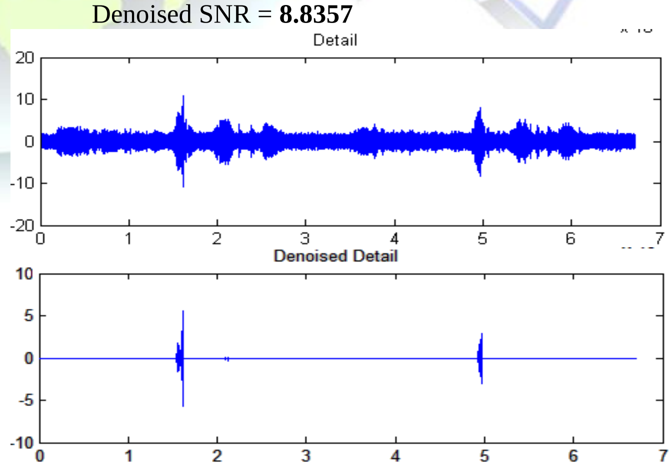

Fig. 6. Noise and Denoised Signal at Filter-1

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C. DDWT (Dual Tree Density Wavelet Transform)

- Considering the signal to noise ratio per sample in dB, so the input can be select from a specific wavelet like dB13, dB40, sym13 or sym21.
  For sym21:
  Threshold = **4.0804**
- Considering the threshold value can be heursure, rigrsure, minimaxi, & sqtwolog which are selection rules.
  For sqtwolog:
  Noised SNR = **4.0010**
- Considering the threshold type like soft or hard.
  For hard threshold:
  Denoised SNR = **8.8319**

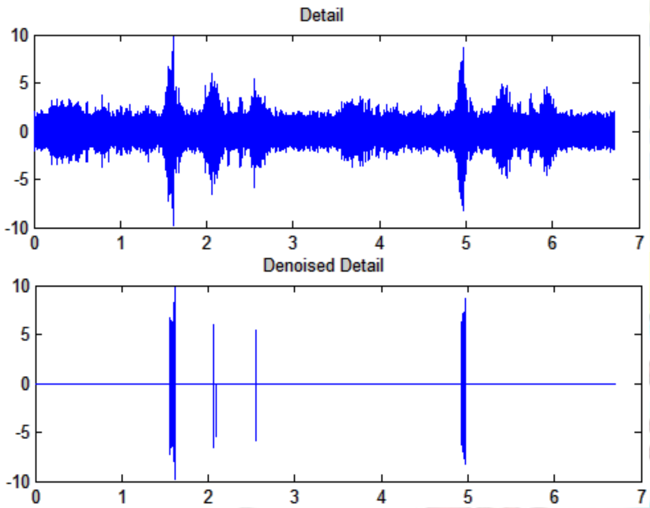

Fig. 7. Noise and Denoised Signal at Filter-2

D. DDDWT (Dual Tree Density Discrete Wavelet Transform)

- Considering the signal to noise ratio per sample in dB, so the input can be select from a specific wavelet like dB13, dB40, sym13.
  For sym13:
  Threshold = **4.0804**
- Considering the threshold value can be heursure, rigrsure, minimaxi, & sqtwolog which are selection rules.
  For sqtwolog:
  Noised SNR = **3.8958**
- Considering the threshold type like soft or hard.

For soft threshold:
Denoised SNR = **8.8293**

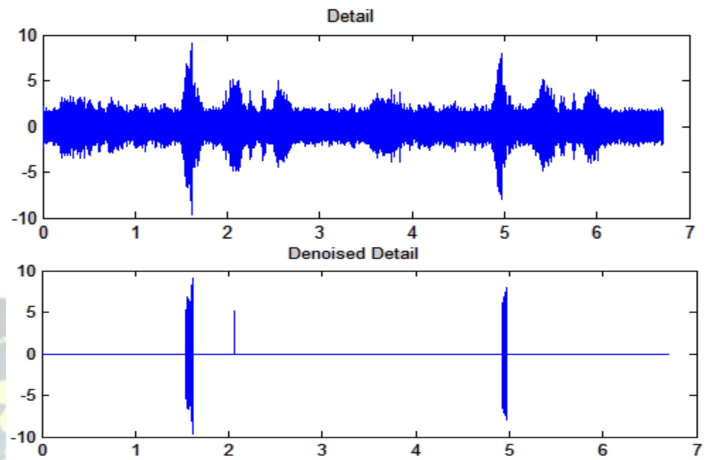

Fig. 8. Noise and Denoised Signal at Filter-3

At last the final Noisy and Denoised Audio Signal are as follow, according to below-mentioned value.

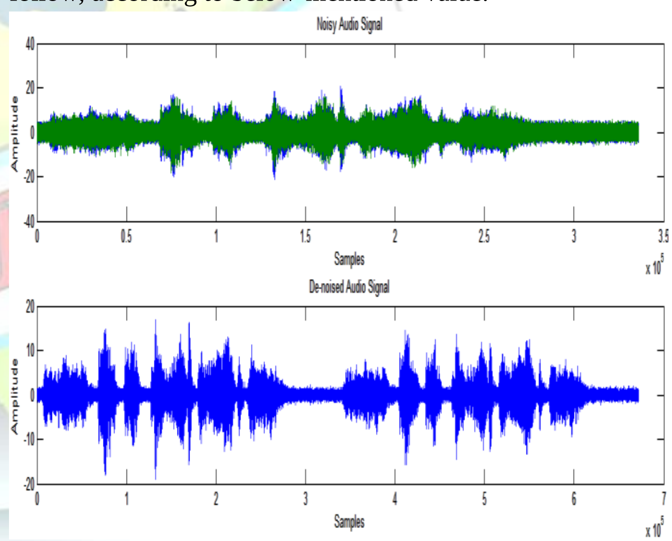

Fig. 9. Final Output of Audio Signal

TABLE 1 SOFT THRESHOLD

Values / Filters	*Threshold value*	*Noisy SNR*	*Denoised SNR*
DWT	4.0804	4.0076	8.8900
DDWT	4.0804	4.0052	8.7072
DDDWT	4.0804	4.0035	8.6969

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TABLE 2 HARD THRESHOLD

Values / Filters	***Threshold value***	***Noisy SNR***	***Denoised SNR***
DWT	4.0804	4.0031	8.8357
DDWT	4.0804	4.0010	8.8319
DDDWT	4.0804	3.8958	8.8293

V. CONCLUSION

Audio denoising is a technique on the base of block coordinated technique. This technique is based on the denoising strategy and its efficient work was presented in full detail. The implementation results have discovered that the process of block coordinated has achieved a state-of-heathenizing performance in terms of both peak signal-to-noise ratio and subjective advance in the audible quality of the audio signal. Grouping of the same blocks improved the efficient operation of the technique. The blocks were filtered and recharged in their original positions from where they were obtained. The grouped blocks were lap-jointed each other and thus for every single element, a much variation estimation was found for combined to the removal of noise from the input signal. The decrease in the noise level interprets that the technique has been secure the vital unique characteristic of each individual block even though the finest details were contributed by grouped blocks. In addition, the technique can be limited for various other audio signals as well as for other problems that can be useful for highly linear signal representations.

VI. FUTURE SCOPE

The research for an effective signal denoising techniques is still stood for a valid exception. Wavelet fills in as power all apparatus for the assignment of signal denoising and the denoising effectiveness can be produced by utilizing the far reaching types of DWT. In this paper, an audio denoising strategy in view of double-density dual-tree DWT utilizing a level depended threshold calculation is actualized. The denoising capacity of double-density dual- tree DWT is then compared with the results of double-density DWT and dual-tree DWT technique. The graphical analysis and tabular results demonstrate that DDDTDWT gives more SNR and less R2v1SE values than alternate strategies. This is accomplished at various decomposition stages and noise levels. The results of level dependent threshold algorithm are also compared with that of global thresholding technique it is clear that the denoising techniques and their parameters should be chosen according to the signals in hand.

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