Reduction of Noise from Speech Signal using Haar and Biorthogonal Wavelet

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Abstract

Clear speech sometimes will be polluted by noise. Reduction of noise aims at reducing noise from noisy speech signal and extracting the clean speech. As speech is transmitted and received using various media it introduces distortions and have bandwidth constraints. These degradations lower intelligibility of speech message causing severe problems in downstream processing and user perception of speech signal. There has been a lot of research in speech denoising so far but there always remains room for improvement. The motivation to use wavelet as a possible alternative is to explore new ways to reduce computational complexity and to achieve better noise reduction performance. Wavelet denoising technique is simple and efficient. In this paper wavelet is used as denoising algorithm. Performance of haar and biorthogonal wavelets are experimentally evaluated.

Keywords

Wavelet Thresholding, signal denoising, haar wavelet, biorthogonal wavelet, wavelets comparison.

I. Introduction

The interest in the field of speech enhancement [2] emerges from the increased usage of digital speech processing applications like mobile telephony, digital hearing aids and human-machine communication systems in our daily life. Speech enhancement includes improving the speech quality, its intelligibility and reducing listener's fatigue. So speech enhancement can be carried out by denoising [4]. Denoising is to reduce noise levels while the signal degradation is minimized. As noise is found in everywhere and usually corrupted with signals, denoising is important and useful in many engineering applications. Among the existing denoising algorithms, wavelet denoising algorithms (Thresholding is applied on the wavelet coefficients.) are the most common approaches for denoising because wavelets exploit both the time and the frequency domain information of signals and hence wavelet denoising approaches can achieve good performances.

II. Types of Wavelets

- Haar
- Daubechies
- Biorthogonal
- Coiflets
- Symlets
- Morlet
- Mexican Hat
- Meyer

Wavelets used in this work are:

A. Haar

Haar wavelet, the first and simplest. Haar wavelet is discontinuous, and resembles a step function as shown in Fig. 1. It represents the same wavelet as Daubechies db1 [5].

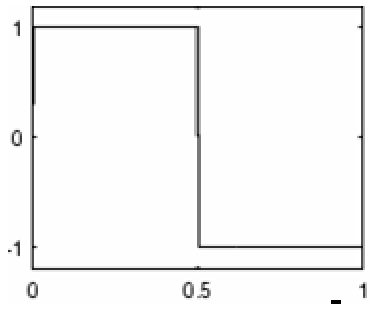

Fig. 1: Haar wavelet transform [3]

B. Biorthogonal

This family of wavelets exhibits the property of linear phase, which is needed for signal and image reconstruction. By using two wavelets, one for decomposition and the other for reconstruction (as shown in Fig.s 2 to 9) instead of the same single one, interesting properties are derived.

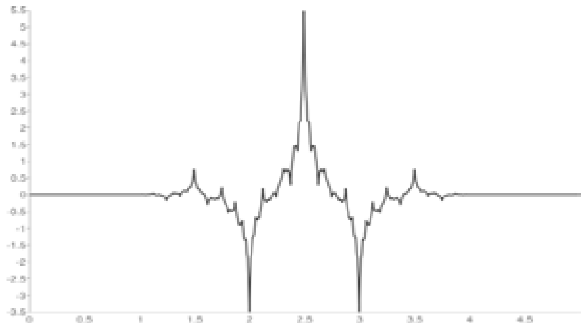

Fig. 2: Decomposition wavelet bior2.2[3]

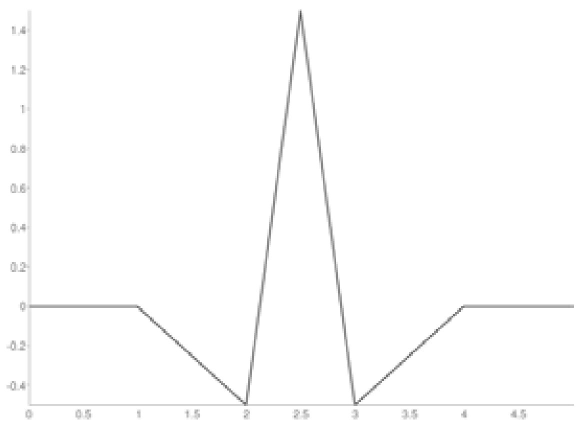

Fig. 3: Reconstruction wavelet bior2.2[3]

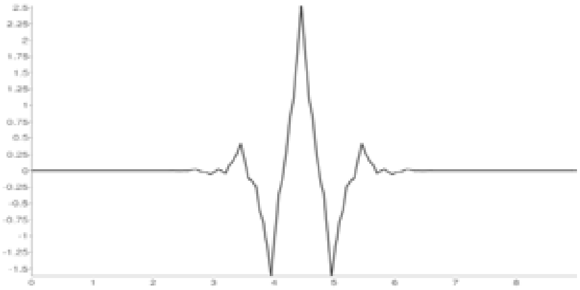

Fig. 4: Decomposition wavelet bior2.4 [3]

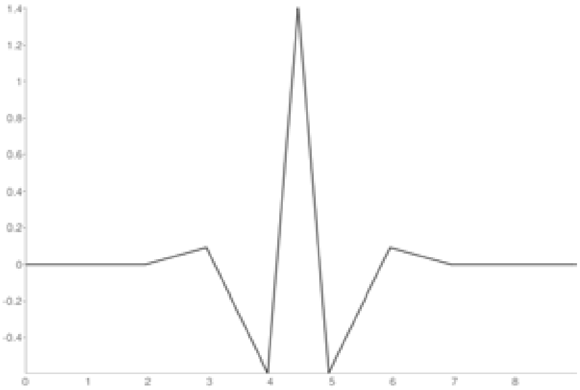

Fig. 5: Reconstruction wavelet bior2.4[3]

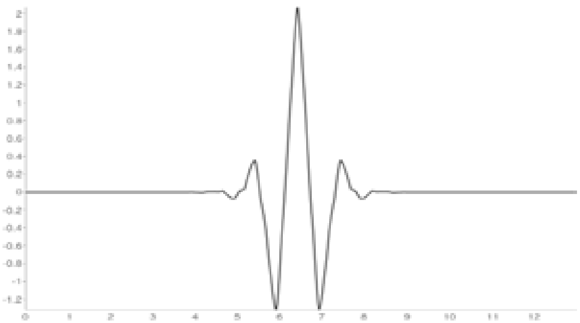

Fig. 6: Decomposition wavelet bior2.6[3]

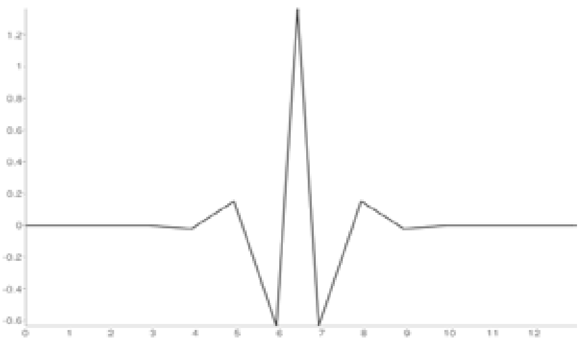

Fig. 7: Reconstruction wavelet bior2.6[3]

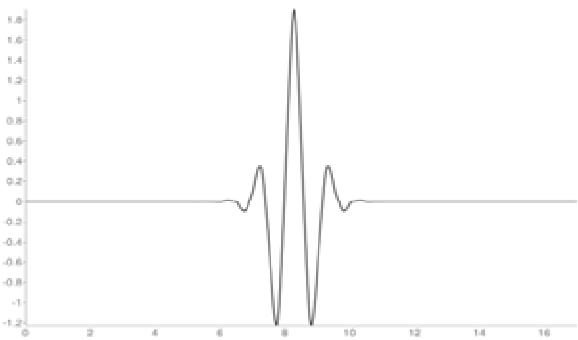

Fig. 8: Decomposition wavelet bior2.8 [3]

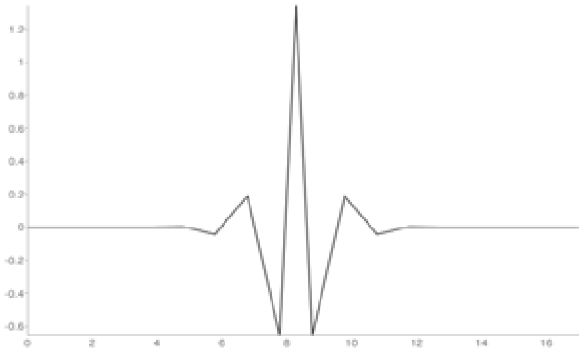

Fig. 9: Reconstruction wavelet bior2.8 [3]

III. Thresholding

The wavelet denoising technique is called thresholding. It is divided in three steps as shown in Fig. 10. The first one consists in computing the coefficients of the wavelet transform (WT) which is a linear operation. The second one consists in thresholding these coefficients. The last step is the inversion of the thresholded coefficients by applying the inverse wavelet transform, which leads to the denoised signal.

A. Types of Thresholding

(i) Hard Thresholding: Hard Thresholding is the simplest method. Soft Thresholding has nice mathematical properties and the corresponding theoretical results are available. Let t denote the threshold. The hard threshold signal x is x if |x| > t, and 0 if |x|< t [1](Fig. 11).

(ii)Soft Thresholding : The soft threshold signal x is sign(x)(|x| - t) if |x| > t, and 0 if |x| < t.(Fig. 11)

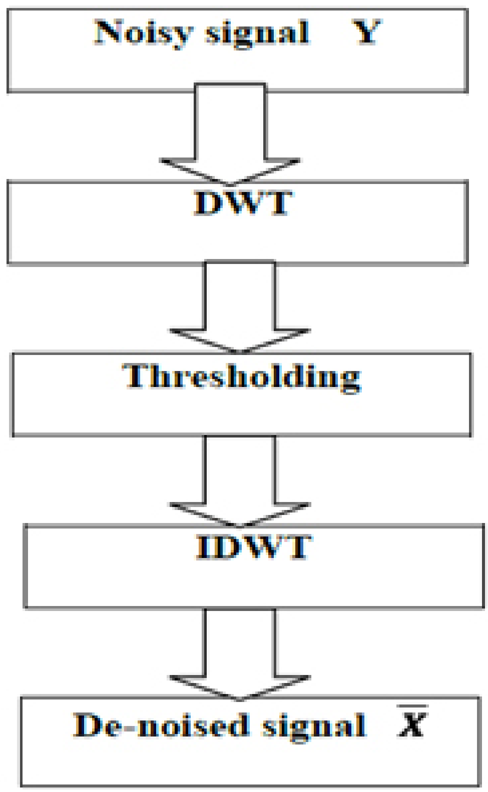

Fig. 10: Flow Chart of Denoising Algorithm

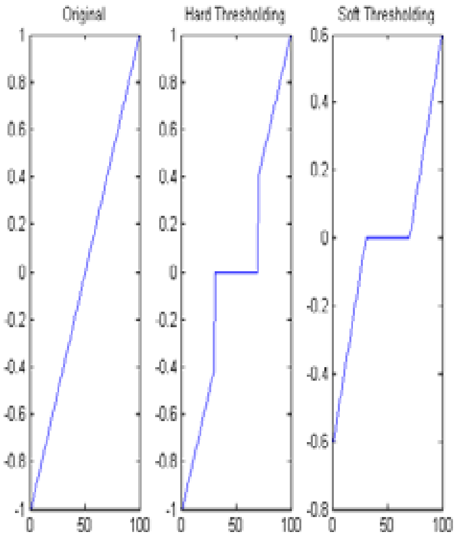

Fig. 11: Original Signal, hard thresholding and soft thresholding

Hard thresholding can be described as the usual process of setting to zero the elements whose absolute values are lower than the threshold. Soft thresholding is an extension of hard thresholding, first setting to zero the elements whose absolute values are lower than the threshold, and then shrinking the nonzero coefficients towards 0. The hard procedure creates discontinuities at x = ±t, while the soft procedure does not [1].

IV. Choosing a wavelet:

Choosing a wavelet that has compact support in both time and frequency in addition to significant number of vanishing moments is essential for an algorithm. Several criteria can be used in selecting an optimal wavelet function. The objective is to minimize reconstructed error variance and maximize signal to noise ratio (SNR). Optimum wavelets can be selected based on the energy conservation properties in the approximation part of the coefficients. Wavelets with more vanishing moments should be selected as it provides better reconstruction quality and introduce less distortion into processed speech and concentrate more signal energy in few coefficients.[1] Computational complexity of DWT increases with the number of vanishing moments and hence for real time applications it cannot be suggested with high number of vanishing moments.

V. Results

The simulator used is MATLAB R2008a to plot graphs and spectrograms of original, noise and denoised signal. Here Fig. 12 shows the plots of original, noised and mixed signals. Fig. 13-17 shows the comparison between original and denoised signals using wavelets (haar, bior2.2, bior 2.4, bior2.6, bior2.8).

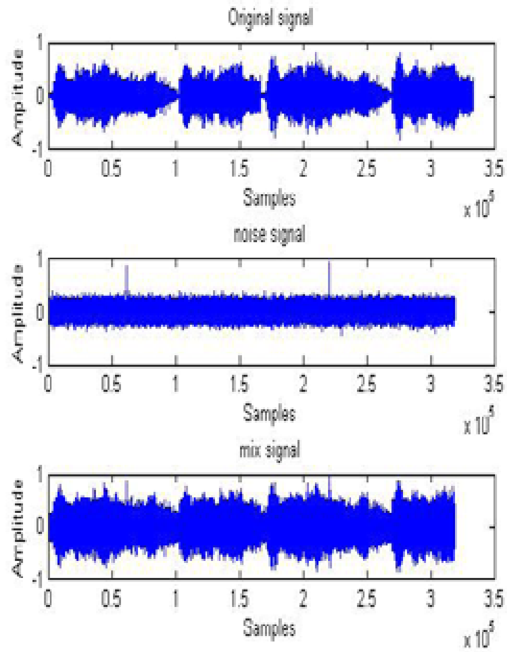

Fig. 12: plots of Original, noise and Mixed Signals

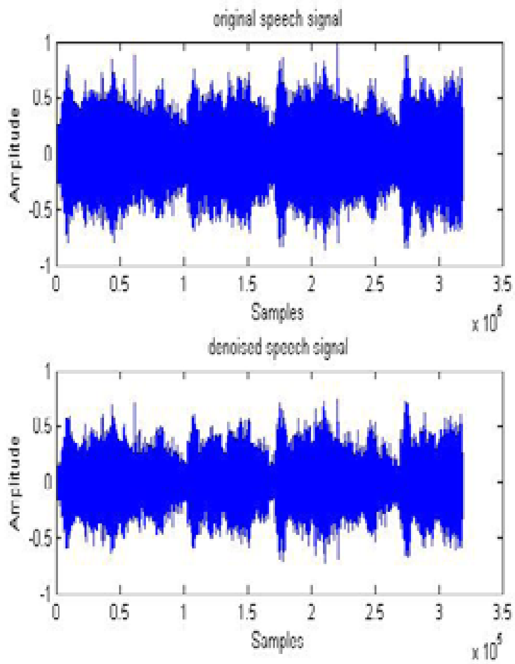

Fig. 13: plots of Original and Denoised Signals using Haar wavelet

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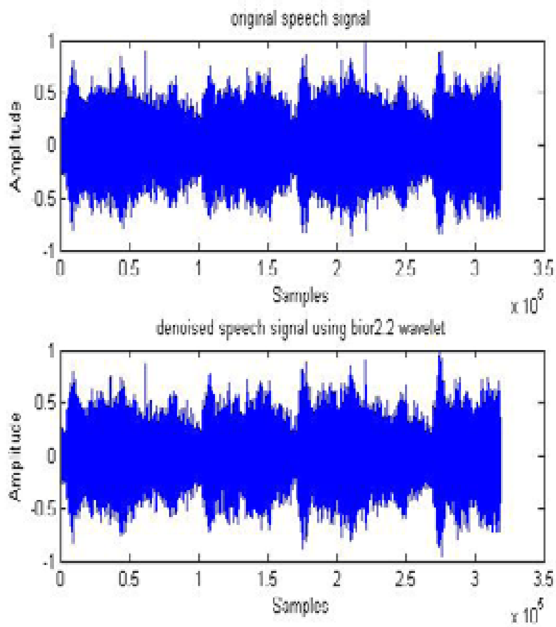

Fig. 14: plots of Original and Denoised Signals using bior2.2 wavelet

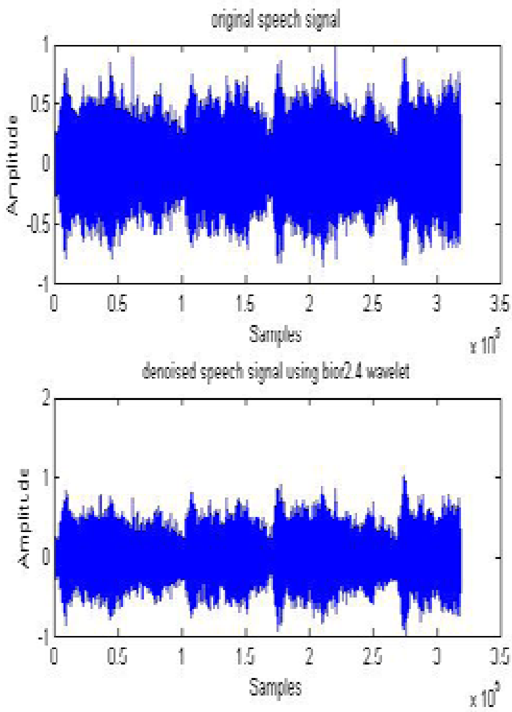

Fig. 15: plots of Original and Denoised Signals using bior2.4 wavelet

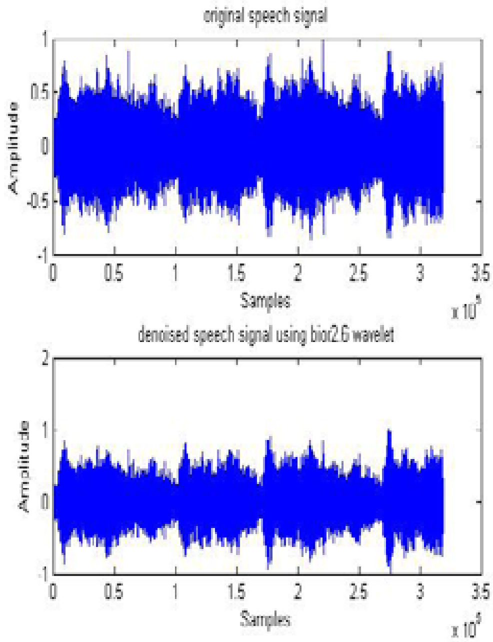

Fig. 16: plots of Original and Denoised Signals using bior2.6 wavelet

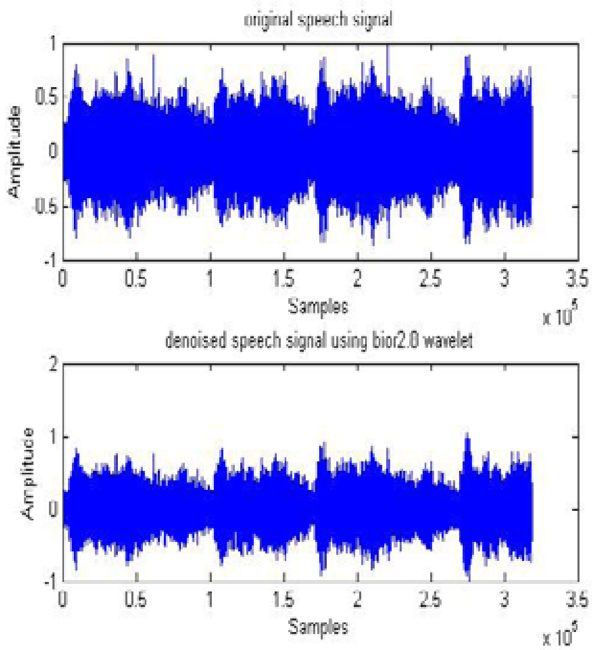

Fig. 17: plots of Original and Denoised Signals using bior2.8 wavelet

Spectrogram of original signal, noise signal and mixed signal is shown in Fig. 18 – 20.
Fig. 21 – 25 shows the spectrograms of denoised signals using wavelets (haar, bior2.2, bior 2.4, bior2.6, bior2.8).

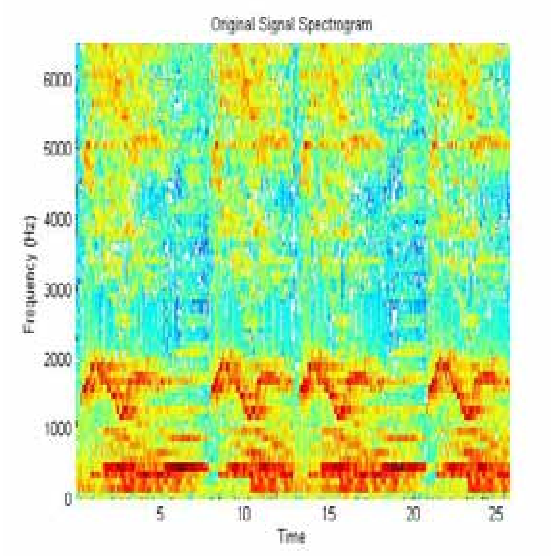

Fig. 18: Spectrogram of Original Signal

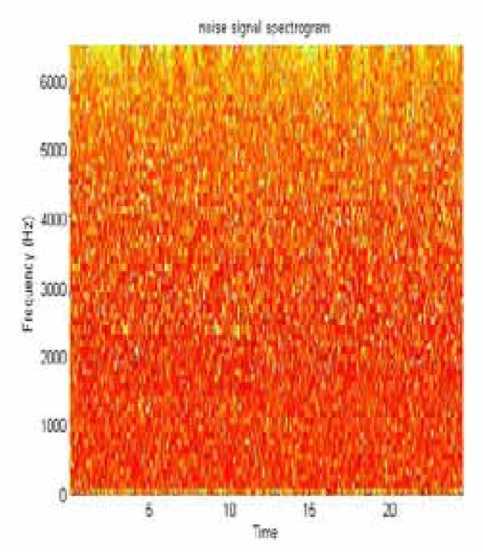

Fig. 19: Spectrogram of Noise Signal

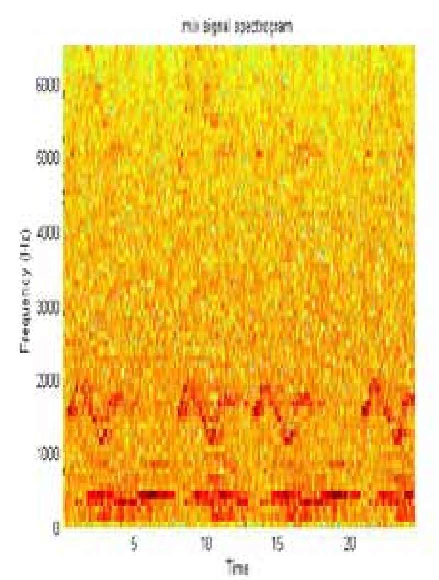

Fig. 20: Spectrogram of Mix Signal

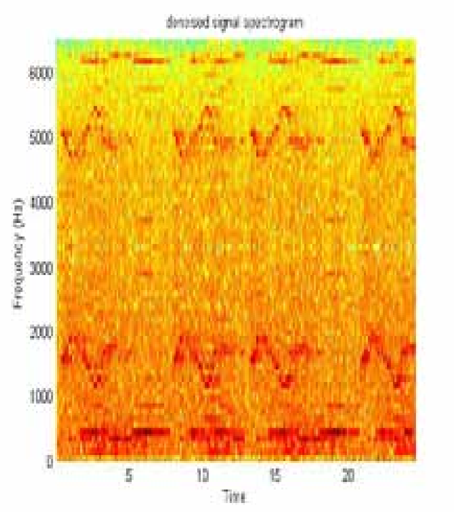

Fig. 21: Spectrogram of Denoised Signal using Haar Wavelet

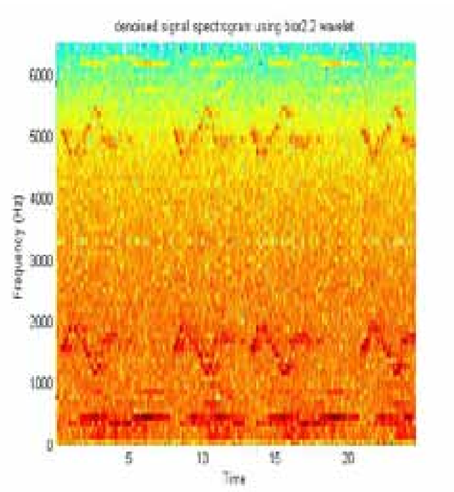

Fig. 22: Spectrogram of Denoised Signal using bior2.2 Wavelet

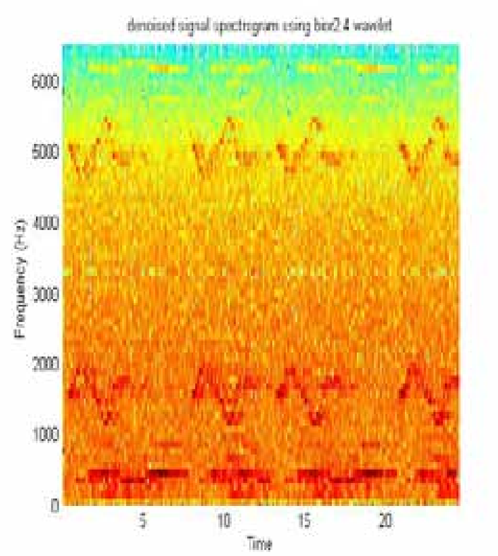

Fig. 23: Spectrogram of Denoised Signal using bior2.4 Wavelet

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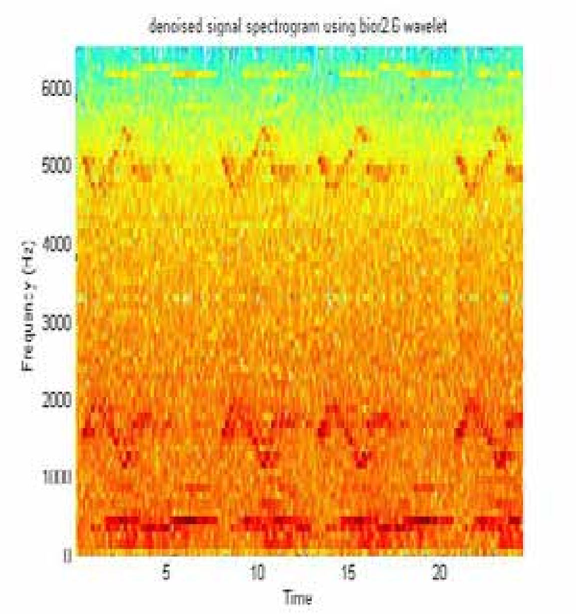

Fig. 24: Spectrogram of Denoised Signal using bior2.6 Wavelet

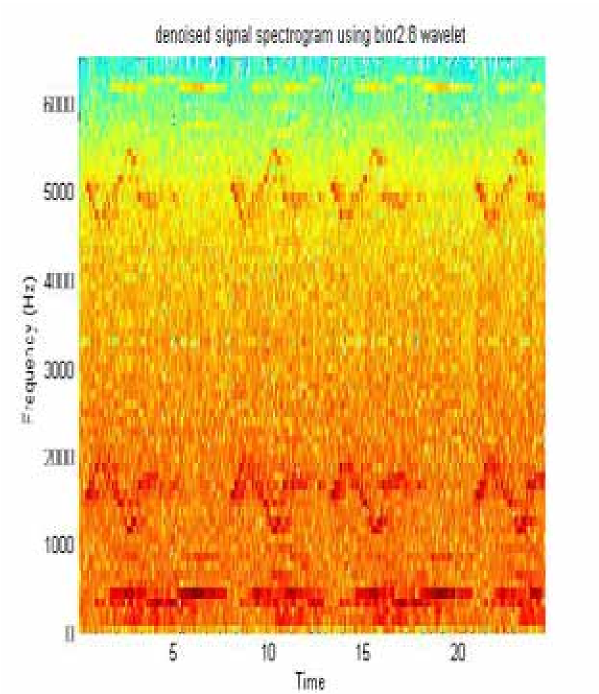

Fig. 25: Spectrogram of Denoised Signal using bior2.8 Wavelet

Table 1 -5 shows the comparison of different wavelets on the basis of SNR (signal to noise ratio) which is calculated as SNR= (power of signal) / (power of noise).

And here, we also increased the decomposition level (N) as shown in tables 1- 5.

SNR of mix signal = 7.158dB

Table 1: Comparison of haar and biorthogonal wavelets (N=1)

Decomposition Level (N) =1		
	SNR (Signal to Noise Ratio) in dB	
Name of Wavelet	Hard Thresholding (dB)	Soft Thresholding (dB)
Haar	18.530	18.544
Bior2.2	19.846	19.847
Bior2.4	20.02	20.11
Bior2.6	20.08	20.24
Bior2.8	20.1	20.3

Wavelet which shows better SNR (signal to noise ratio) as compare to other wavelets is shown in bold. In Table 1 bior2.8 in case of hard thresholding and bior2.6 in case of Soft Thresholding show better result.

Table 2: Comparison of haar and biorthogonal wavelets (N=2)

Decomposition Level (N) =2		
	SNR (Signal to Noise Ratio) in dB	
Name of Wavelet	Hard Thresholding (dB)	Soft Thresholding (dB)
Haar	18.660	18.860
Bior2.2	20.255	20.385
Bior2.4	20.428	20.508
Bior2.6	20.495	20.616
Bior2.8	20.525	20.595

Table 3: Comparison of haar and biorthogonal wavelets (N=3)

Decomposition Level (N) =3		
	SNR (Signal to Noise Ratio) dB	
Name of Wavelet	Hard Thresholding (dB)	Soft Thresholding (dB)
Haar	18.661	18.996
Bior2.2	20.256	20.425

Bior2.4	20.429	20.544
Bior2.6	20.496	20.651
Bior2.8	20.526	20.624

Table 4: Comparison of haar and biorthogonal wavelets (N=4)

Decomposition Level (N) =4		
	SNR (Signal to Noise Ratio) dB	
Name of Wavelet	Hard Thresholding (dB)	Soft Thresholding (dB)
Haar	18.661	19.031
Bior2.2	20.257	20.500
Bior2.4	20.446	20.605
Bior2.6	20.497	20.718
Bior2.8	20.527	20.668

Table 5: Comparison of haar and biorthogonal wavelets (N=5)

Decomposition Level (N) =5		
	SNR (Signal to Noise Ratio) in dB	
Name of Wavelet	Hard Thresholding (dB)	Soft Thresholding (dB)
Haar	18.661	19.059
Bior2.2	20.259	20.499
Bior2.4	20.446	20.609
Bior2.6	20.499	20.725
Bior2.8	20.529	20.679

VI. Conclusion

Biorthogonal Wavelet de-noising is a superior method to de-noise a speech signal as compared to Haar Wavelet. Soft thresholding is a superior method as compare to hard thresholding.

bior2.6 wavelet has better results as compared to other wavelets in case of soft thresholding but bior2.8 give better results in hard thresholding.

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