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Denoising of Speech using Wavelets

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Abstract— Wavelet analysis is new method for solving problems in engineering, mathematics, physics with modern applications like data compression, signal processing, image processing. Wavelet allows complex information like speech, music to be decomposed into elementary forms with different position and scales and subsequently reconstructed with high precision. This paper describes the use of wavelet transform for denoising speech signals contaminated with noise. The practical results are obtained for variations in Family of wavelet selected and different types of noise for Haar family. Simulation and results are performed in MATLAB r2014a.
Keywords- MATLAB; Wavelet1-D; Daubechies; Haar; Symlet

I. INTRODUCTION

Wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions. Wavelet transform enables to represent signal with high degree of sparsity. This is the principle behind nonlinear wavelet based estimation technique known as wavelet denoising. Wavelet denoising attempts to remove noise present in signal while preserving signal characteristics, regardless of its frequency content. Wavelet denoising has wide range of applications like signal processing, data mining, medical signal or image analysis, radio astronomy image analysis. Denoising (noise reduction) is the first step in many applications.

II. PREVIOUS WORK

Recently various wavelet based methods have been proposed for speech denoising. The wavelet split coefficient method removes noise by shrinking wavelet coefficient. This method is based on thresholding in signal such that each wavelet coefficient of signal is compared to given threshold. The coefficient if smaller than threshold is set to zero otherwise is kept or slightly reduced in amplitude. [1] Wavelet shrinkage method has been extensively used to remove noise from degraded signal. To increase the quality and intelligibility of speech signal by threshold method Bahoura and Rouat used Teager Energy operator (TEO) with wavelet packet coefficient to reduce distortion of unvoiced segment (noisy signal).However this method suffers from threshold problem in speech enhancement applications. Instead of using wavelet packet transform (WPT), a perceptual wavelet was developed which relates to human psychoacoustic model. PWPT is suited for real time speech enhancement for various noise types like white noise, exhibition noise, street, babble, train etc.[2] Further a more sophisticated packet division a bark scaled wavelet packet decomposition tree was introduced which resembles bark scale. Time frequency adaptation based Wavelet Transform coefficient was introduced for wavelet threshold method. Soft and hard thresholding methods are also used for denoising of signals.[3] Using wavelets to remove noise from the signal requires identifying which part of component contains noise and then reconstructing the signal without those components.

III. WAVELET 1-D

The basic function of wavelets are produced from two units namely Father wavelet (scaling function)$\phi(t)$ and Mother wavelet (translation function) $\psi(t)$.Depending on the extent of basic functions there are two types of wavelet, discrete and continuous. The key equation common to all wavelets is given by:

$$\phi(t) = \sum_n h(n) \sqrt{2}\, \phi(2t-n) \tag{1}$$

$$\Psi(t) = \sum_n \tilde{h}(n) \sqrt{2}\, \phi(2t-n) \tag{2}$$

Here $h(n)$ and $\tilde{h}$ (n) take finite number of values and are respectively known as low pass or average and high pass or detail filter coefficients.

A. Wavelet Decomposition

Wavelet decomposition results in levels of approximated (A) and detailed (D) coefficients. The maximum level to apply wavelet transform depends on how many data points are contained in dataset since there is down sampling by two from one level to next one. The decomposition process can be iterated with successive approximations being decomposed in turn, so that one signal is broken down into many lower resolution components. This is called Wavelet decomposition tree. The fig.1 shows wavelet decomposition using Haar wavelet at level 5.

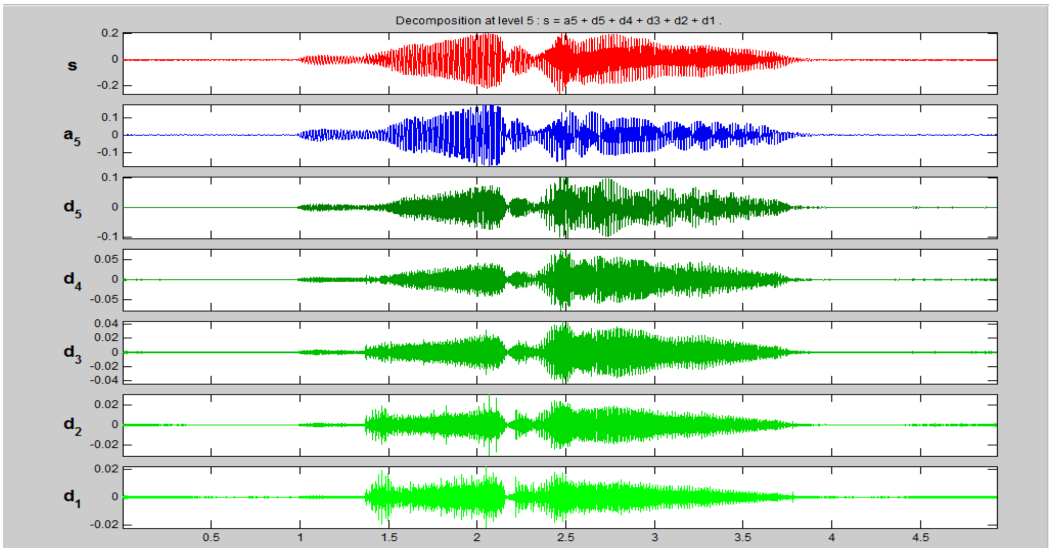

Figure 1. Wavelet decomposition using Haar wavelet at level 5

B. Threshold Limit

The threshold limit is selected such that satisfactory noise removal is achieved. Two rules are used for thresholding wavelet coefficients (hard and soft). Hard thresholding sets zero for all wavelet coefficients whose absolute value is less than specified threshold limit. Soft thresholding shrinks coefficients above threshold in absolute values.

C Wavelet Functions

The difference between different mother wavelet functions (Daubechies, Haar, Symlet) consist in how these scaling signals and wavelets are defined. The choice of wavelet determines final waveform shape.

a. Daubechies Wavelet

Daubechies designed a type of wavelet such that filter size is two times the vanishing moment. Daubechies wavelets are used in solving variety of problems. E.g. self similarity properties of signal, fractal problems, signal discontinuities.

b. Haar Wavelet

Haar wavelet is a sequence of rescaled square shaped function which together forms wavelet family. For the Haar wavelet, mother wavelet function $\psi(t)$ is given as

$$\Psi(t) = \begin{cases} 1 \\ -1 \\ 0 \end{cases} \begin{pmatrix} 0 \le t < 1/2 \\ 1/2 \le t < 1 \\ otherwise \end{pmatrix} \tag{3}$$

c. Symlet Wavelet

Symlet are symmetrical, orthogonal wavelet efficient in denoising application. Symlet when applied to signal performs better with improved signal to noise ratio (SNR).They are modified version of Daubechies wavelet with increased symmetry.

D Wavelet based Denoising

The general wavelet denoising procedure is as follows: [4]

1. Apply wavelet transform to noisy signal to produce noisy wavelet coefficients to the level which can properly distinguish PD occurrence.
2. Select appropriate threshold limit at each level and threshold method (hard or soft) to best remove the noise.
3. Apply Inverse Wavelet Transform of threshold wavelet coefficients to obtain denoised signal.

IV. RESULTS

We worked on speech signal of 49321 samples at sampling frequency (f_s) of 44100 Hz. The results for denoising are obtained by varying two parameters namely the Level of decomposition for type of wavelet family selected and Types of noise for Haar wavelet at level 5 of decomposition which are shown in table 1 and table 2 respectively.

Table 1. Family of wavelet selected versus Level of decomposition

1. Haar wavelet

Sr.No	Level of decomposition	Mean	Median	Standard Deviation
1.	1	0.00138	0.00038	0.0025
2.	3	0.0045	0.0010	0.00892
3.	5	0.0155	0.0030	0.2909

2. Symlet Wavelet

Sr.No	Level of decomposition	Mean	Median	Standard Deviation
1.	1	0.00071	0.00018	0.00163
2.	3	0.00208	0.00052	0.00397
3.	5	0.01179	0.0021	0.02319

Table 2. Types of noise for Haar Wavelet at Level 5 of decomposition

Sr.No	Type of Noise	Mean	Median	Standard Deviation
1.	Unscaled white noise	0.0155	0.0030	0.0290
2.	Scaled white noise	0.0016	0.0010	0.0022
3.	Non white noise	0.0098	0.0026	0.0016

V. CONCLUSION & FUTURE WORK

From the results obtained it is observed that denoising of signal depends on optimum value of level of decomposition for family of wavelet selected. It is observed that best results for denoising are obtained for Symlet wavelet for different levels of decomposition. After denoising the signal using thresholding techniques the concept of quantization can be applied to improve denoising and speed of computation.

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