Performance Comparison of Wavelet Denoising and Median Filter Denoising over AWGN Channel

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Abstract

This paper presents approach towards Wavelet Transform and Median Filter for image reconstruction. In the past two decades, many noise reduction techniques have been developed for removing noise and retaining edge details in images. The primary goal of noise reduction is to remove the noise without losing much detail contained in an image. Wavelet transforms are specially used for compression, Denoising, Thresholding, Error reduction, reconstruction, and for image synthesis. There are different types of wavelets transform and filters are used for image reconstruction. For different value of signal to noise ratio (SNR), Bit Error Rate (BER), Root Mean Square Error (RMSE) and Peak Signal to Noise Ratio (PSNR) will change. We are using Wavelet and Median Filter for finding BER, RMSE and PSNR. The challenge is to find the best reconstruction methods for BER, RMSE, PSNR and a good perceptual result.

Keywords: WT, Image, Median Filter, SNR, RMSE, PSNR, BER, Reconstruction, Decomposition

Introduction

The objective of image reconstruction is to reduce irrelevance and redundancy of the image data in order to be able to store or transmit data in an efficient form. Wavelet transform and median filter are used for image reconstruction & denoising, for that best perceptual result Phase Shift Key (PSK) technique is used. Phase-shift keying is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal. For that simply load a image then we have to convert image into binary data. This binary data convert into serial form then it can be modulate and then demodulate using PSK technique. Again we have to convert serial into parallel form. Inverse Wavelet Transform as well as median filter is used for image reconstruction. We get maximum PSNR and minimum RMSE using Median Filter as compare to inverse Wavelet Transform.

Wavelet Transform

A 'wavelet' is a small wave which has its energy concentrated in time. It has an oscillating wavelike characteristic & it as time-scale and time-frequency analysis tools have been widely used in topographic reconstruction and still growing.

Discrete Wavelet Transform

Image Reconstruction with wavelet transform used 2D version of the analysis and synthesis filter banks. In the2D (image) case, the 1D analysis filter bank is first applied to the columns of the image and then applied to the rows. If the image has N1 rows and N2 columns, then after applying the 1D analysis filter bank to each column, two subband images are created, each having N1/2 rows and N2 columns; after applying the 1D analysis filter bank to each row of both of the two subband images, four subband images are generated, each having N1/2 rows and N2/2 columns.

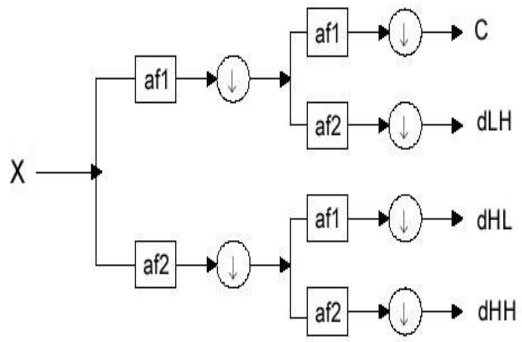

Figure 1: One stage in multi-resolution wavelet decomposition of an image

Two Dimensional Discrete Wavelet Transform (2-D DWT)

The DWT is extensively used in its non-redundant form known as standard DWT. The filter bank implementation of standard DWT for images is viewed as 2-D DWT. There are certain applications for which the optimal representation can be achieved through more redundant extensions of standard DWT such as WP and SWT. Image-processing applications require two-dimensional implementation of wavelet transform. Implementation of 2-D DWT is also referred to as 'multidimensional' wavelet transform in literature.

The implementation of an analysis filter bank for a single level 2-D DWT is shown in figure.

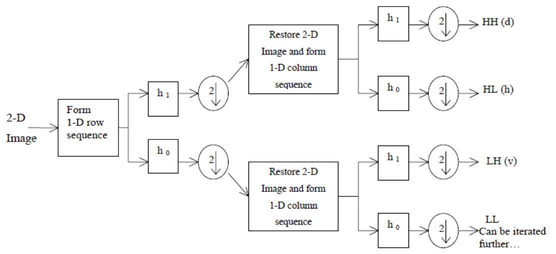

Figure 2: Single level analysis filter bank for 2-D DWT

This structure produces three detailed sub-images (HL, LH, HH) corresponding to three different directional-orientations (Horizontal, Vertical and Diagonal) and a lower resolution sub-image LL. The filter bank structure can be iterated in a similar manner on the LL channel to provide multilevel decomposition. Multilevel decomposition hierarchy of an image is illustrated in figure .

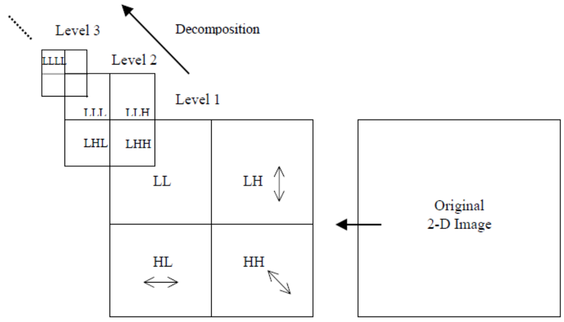

Figure 3: Multilevel decomposition hierarchy of an image with 2-D DWT

Each decomposition breaks the parent image into four child images. Each of such sub-images is of one fourth of the size of a parent image. The sub-images are placed according to the position of each subband in the two-dimensional partition of frequency plane as shown in above fig 4. The structure of synthesis filterbank follows the reverse implementation of analysis filterbank but with the synthesis filters. Figure shows original image of BabyGrow and it's lower resolution, horizontal, vertical & diagonal images are presented of 1st decomposition.

Figure 4: Original Image

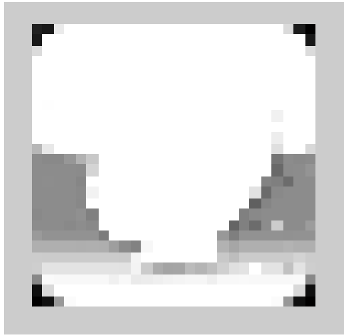

Figure 5: Lower resolution image

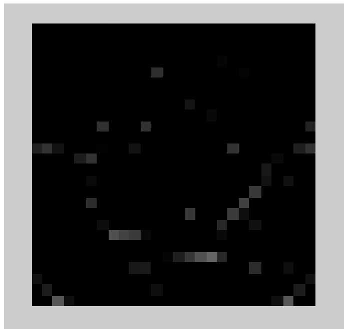

Figure 6: Horizontal Image

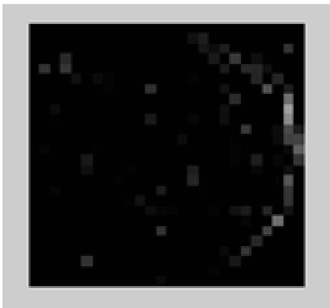

Figure 7: Vertical Image

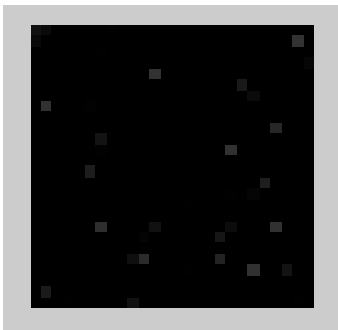

Figure 8: Diagonal Image

Haar Wavelet Transform

The Haar Wavelet is a certain sequence of rescaled "square-shaped" functions which together form a wavelet family.

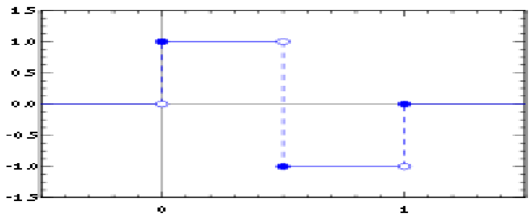

Figure 9: Haar wavelet Transform

The Haar wavelet's mother wavelet function $\psi(t)$ & its scaling function $\phi(t)$ can be described as

$$\psi(t) = \begin{cases} 1 & 0 \le t < 1/2, \\ -1 & 1/2 \le t < 1, \\ 0 & \text{otherwise.} \end{cases}$$

$$\phi(t) = \begin{cases} 1 & 0 \le t < 1, \\ 0 & \text{otherwise.} \end{cases}$$

Phase Shift Key (PSK) Modulation and Demodulation

Phase-shift keying (PSK) is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal. PSK modulation in Matlab can be simulated using the pskmod() function and demodulation can be performed using pskdemod(). The pskmod() produces a sequence of channel symbols (e.g. fs3, s3, s5, s6, s1, : : :g).

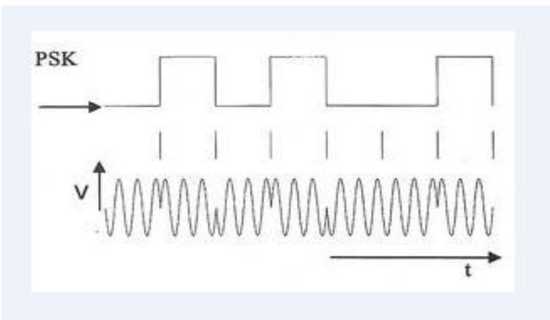

Figure 10: PSK Waveform

Communication Channel

A communication channel is used to convey an information signal, for example a digital bit stream, from one or several senders (or transmitters) to one or several receivers. A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in bits per second.

Noise in Images

Image noise is random variation of brightness or color information in images, and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of a scanner or digital camera. Noisy image can be modeled as

$$Y_{i,j} = X_{i,j} + n_{i,j}$$

Where i, j = 1: N

Effects of Noise on Images

Noise gives an image a generally undesirable appearance, the most significant factor is that noise can cover and reduce the visibility of certain features within the image. The loss of visibility is especially significant for low-contrast objects.

Additive white Gaussian noise (AWGN)

The standard model of amplifier noise is additive, Gaussian, independent at each pixel and independent of the signal intensity, caused primarily by Johnson–Nyquist noise (thermal noise). In color cameras where more amplification is used in the blue color channel than in the green or red channel, there can be more noise in the blue channel.

Amplifier noise is a major part of the "read noise" of an image sensor, that is, of the constant noise level in dark areas of the image.

Median Filter

Median Filter is able to perform some kind of noise reduction on an image or signal. The median filter is a nonlinear digital filtering technique, often used to remove noise. Such noise reduction is a typical pre-processing step to improve the results of later processing.

The median is calculated by first sorting all the pixel values from the surrounding neighbourhood into numerical order and then replacing the pixel being considered with the middle pixel value.

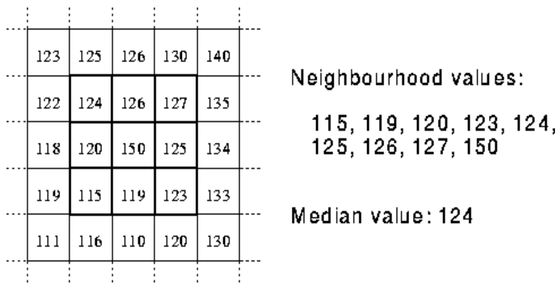

Figure 11: Median Filter

Results

Figure 12 shows original image of BabyGrow

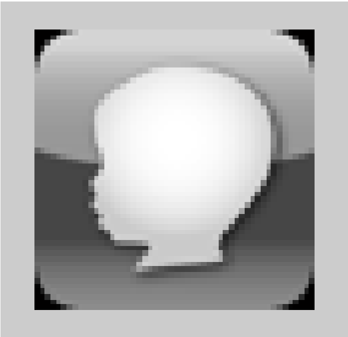

Figure 12: Original Image

Figure 13 shows reconstructed image using Inverse discrete wavelet transform (idwt)

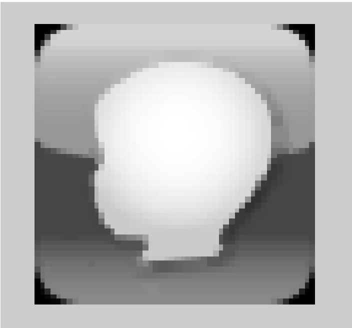

Figure 13: Reconstructed image using Inverse discrete wavelets transform

Figure 14 shows reconstructed image using Median Filter

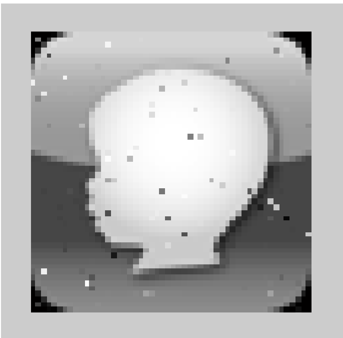

Figure 14: Reconstructed image using Median Filter

Figure 15 shows Bit Error Rate (BER) performance of PSK channel for image. It has been observed that with increase in SNR values BER values decreases.

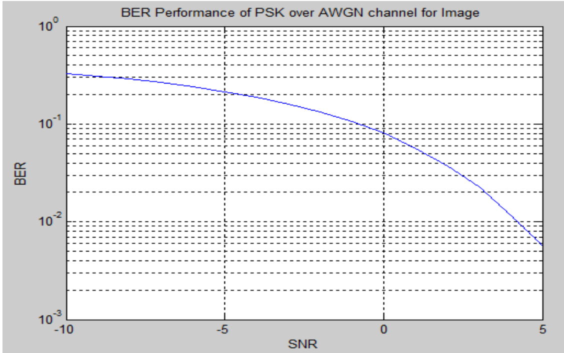

Figure 15: BER performance of PSK channel for Image

Figure 16 shows Root Mean Square Error (RMSE) performance of PSK channel for image using WT and Median Filter. It has been observed that with increase in SNR values RMSE values decreases.

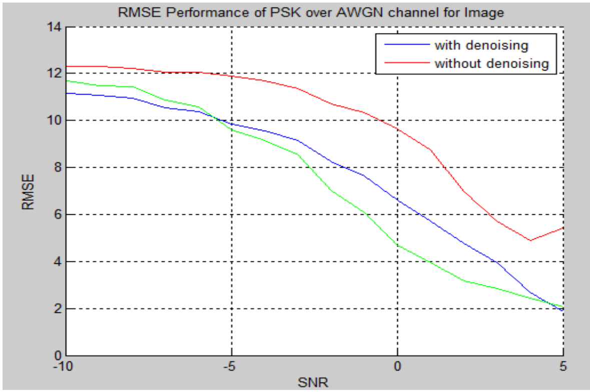

Figure 16: RMSE performance of PSK channel for Image

Figure 17 shows Peak Signal to Noise Ratio (PSNR) performance of PSK channel for image using WT and Median Filter. It has been observed that with increase in SNR values PSNR values increases

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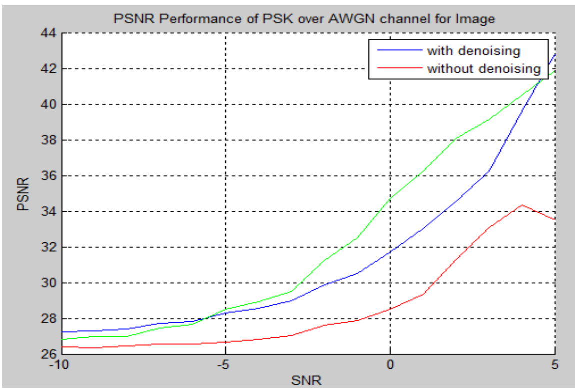

Figure 17: PSNR performance of PSK channel for Image

snr	ber	rmse	psnr	rmse_wt	psnr_wt	rmse_med	psnr_med
-10	0.324242	11.30723	27.09767	12.46605	26.25022302	11.86370141	26.68039515
-9	0.311622	11.02373	27.31823	12.3093	26.36013234	11.28133375	27.11759035
-8	0.286797	10.85711	27.45051	12.32457	26.34936537	11.34313845	27.07013465
-7	0.258922	10.6523	27.61593	12.29911	26.36732517	11.06008335	27.28963131
-6	0.237565	10.38999	27.8325	12.07816	26.52478143	10.59205212	27.66519713
-5	0.213526	9.94915	28.20908	11.71695	26.78850572	9.896001374	28.25560437
-4	0.179872	9.508599	28.60247	11.71162	26.79246178	9.172149606	28.91537671
-3	0.157637	8.873265	29.20313	11.3389	27.07338138	7.965207256	30.14085769
-2	0.130917	8.303908	29.77915	10.87964	27.43251146	6.924438969	31.35710747
-1	0.103412	7.50456	30.65829	10.35241	27.86397228	5.655710054	33.11505657
0	0.079096	6.773928	31.54799	9.826453	28.31686399	4.982254011	34.216282
1	0.05649	5.878611	32.77931	8.997514	29.08234904	4.08593887	35.93896201
2	0.038184	4.659128	34.79871	7.030102	31.2255665	3.113900406	38.29870494
3	0.023206	3.6337	36.95782	5.205645	33.83530791	2.497483941	40.21474522
4	0.013082	2.938535	38.80218	4.659763	34.79752346	2.458682237	40.35075123
5	0.006287	2.10012	41.71992	5.555463	33.2703946	2.141016045	41.55240087
5	0.005594	1.923462	42.48313	5.470131	33.40484417	2.13686645	41.5692517
5	0.005131	1.441025	44.99137	5.301313	33.67713028	4.431305056	35.23416634

Table 1: SNR , BER, RMSE and PSNR performance of PSK channel for Image using Wavelet Transform and Median Filter

Conclusion

Table 1 shows the performance of PSK channel for image using WT and Median Filter. It has been observed that with increase in SNR values BER values decreases, RMSE values also decreases and PSNR values increases. Image has been more denoised and reconstructed using Median Filter as compare to Wavelet transform.

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