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 the 2D (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.

![Image 1: One stage in multi-resolution wavelet decomposition of an image](image-url)

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.

Haar Wavelet Transform

The Haar Wavelet is a certain sequence of rescaled "square-shaped" functions which together form a wavelet family.
The Haar wavelet’s mother wavelet function $\psi(t)$ & its scaling function $\phi(t)$ can be described as

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

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

**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. s3, s5, s6, s1, ...).

**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

$$X_{i,j} = X_{i,j} + \epsilon_{i,j}$$

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.

$$
\begin{array}{cccc}
123 & 125 & 126 & 130 \\
125 & 124 & 126 & 130 \\
126 & 120 & 125 & 130 \\
120 & 115 & 120 & 135 \\
115 & 110 & 116 & 130 \\
116 & 110 & 116 & 130 \\
110 & 115 & 116 & 130 \\
115 & 110 & 110 & 130 \\
\end{array}
$$

**Neighbourhood values:**

$$
\begin{array}{cccc}
115 & 119 & 120 & 123 \\
119 & 119 & 123 & 133 \\
124 & 125 & 126 & 127 \\
126 & 126 & 127 & 135 \\
115 & 119 & 123 & 125 \\
\end{array}
$$

**Median value:** 124

**Figure 11: Median Filter**
Results

Figure 12 shows original image of BabyGrow

![Original Image](image1)

**Figure 12: Original Image**

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

![Reconstructed Image](image2)

**Figure 13: Reconstructed image using Inverse discrete wavelets transform**

Figure 14 shows reconstructed image using Median Filter

![Reconstructed Image](image3)

**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.

![BER Performance](image4)

**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.

![RMSE Performance](image5)

**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.

![PSNR Performance](image6)

**Figure 17: PSNR performance of PSK channel for Image**
Table 1: SNR, BER, RMSE and PSNR performance of PSK channel for Image using Wavelet Transform and Median Filter

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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.

**References**

[1] Reeta Charde, "Study of Image Reconstruction and Denoising using Wavelet transform ",1<sup>st</sup> National Conference in BM college Indore ,27<sup>th</sup> April 2012


