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An Improved Threshold Value for Image Denoising Using Wavelet Transforms

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ABSTRACT
The denoising of a natural image suffered from some noise is a long established problem in signal or image processing field. Many image denoising techniques based on filtering and wavelet thresholding have been published in earlier research papers and each technique has its own assumptions, advantages and limitations. Image filtering and wavelet thresholding algorithms are applied on different image samples to eliminate noise which is either present in the image during capturing or injected into the image during transmission.
This paper deals with Performance comparison of Median filter, Wiener filter, penalized thresholding, global thresholding and proposed thresholding in Image de-noising for Gaussian noise, Salt & Pepper noise.
Keywords -Wavelet-transform; MATLAB; Threshold function; Gaussian noise; Salt & Pepper noise; Median filter; Wiener Filter; PSNR.

I. INTRODUCTION

In several applications, it might be essential to analyze a given signal. The structure and features of the given signal may be better understood by transforming the data into another domain. There are several transforms available like the Fourier transform, Hilbert transform, wavelet transform, etc. However the Fourier transform gives only the frequency-amplitude representation of the raw signal. So we cannot use the Fourier transform in applications which require both time as well as frequency information at the same time. The Short Time Fourier Transform (STFT) was developed to overcome this drawback [2].The following equation can be used to compute a STFT.

$$\textbf{STFT}(t, f) = \int [x(t) \cdot \omega^*(t-T)] \cdot e^{-j2\pi ft}\, dt$$

Where x(t) is the signal itself, ω(t) is the window function and * is the complex conjugate.
It is different to the FT as it is computed for particular windows in time individually, rather than computing overall time (which can be alternatively thought of as an infinitely large window).

II. MEDIAN FILTER

The Median Filter is performed by taking the magnitude of all of the vectors within a mask and sorted according to the magnitudes [12]. The pixel with the median magnitude is then used to replace the pixel studied.
The Simple Median Filter has an advantage over the Mean filter since:
(a) Median of the data is taken instead of the mean of an image. The pixel with the median magnitude is then used to replace the pixel studied. The median of a set is more robust with respect to the presence of noise [12].
(b) Median is much less sensitive than the mean to extreme values (called outliers), therefore, median filtering is able to remove these outliers without reducing the sharpness of an image.

<u>The median filter is given by -</u>

Median filter(x1…xN)=Median(||x1||2……||xN||2)

III. WIENER FILTER

The goal of the Wiener filter is to filter out noise that has corrupted a signal. It is based on a statistical approach [12]. Typical filters are designed for a desired frequency response. The Wiener filter approaches filtering from a different angle. One is assumed to have knowledge of the spectral properties of the original signal and the noise, and one seeks the LTI filter whose output would come as close to the original signal as possible [1]. Wiener filters are characterized by the following:
a) **Assumption**: signal and (additive) noise are stationary linear random processes with known spectral characteristics.
b) **Requirement:** the filter must be physically realizable, i.e. causal (this requirement can be dropped, resulting in a non-causal solution).
c) **Performance criteria**: minimum mean-square error.

<u>The Wiener filter is:</u>

$$G(u, v)=H^*(u,v) / (|H(u,v)|^2 Ps(u,v)+Pn(u,v))$$

Where

H(u, v) = Degradation function
H*(u, v) = Complex conjugate of degradation function
Pn(u, v) = Power Spectral Density of Noise
Ps(u, v)= Power Spectral Density of un-degraded image.

IV. WAVELET THRESHOLD DENOISING PRINCIPAL

In the wavelet domain, it can make the signal energy concentrate in a few large wavelet coefficients, while the noise energy is distributed throughout the wavelet domain. Therefore, by wavelet decomposition, the signal amplitude of the wavelet coefficients of magnitude greater than the noise factor, we can also say that the relatively large amplitude of the wavelet coefficients is mainly signal, while the relatively small amplitude coefficient is largely noise. Thus, by using threshold approach we can keep the signal coefficient, reducing most of the noise figure coefficient to zero. If its threshold is bigger than the specified threshold, it can be seen that that this factor contains a signal component and is the result of both signal and noise, which shall be maintained, if its threshold is less than the specified threshold, it can be shown that this factor does not contain the signal component, but only the result of noise which should be filtered out [11]. The soft and hard threshold function method proposed by Donoho has been widely used in practice. In the hard threshold method, the wavelet coefficients processed by the threshold value have discontinuous point on the threshold λ and - λ , which may cause Gibbs shock to the useful reconstructed signal. In the soft-thresholding method, its continuity is good, but when the wavelet coefficients are greater than the threshold value, there will be a constant bias between the wavelet coefficients that have been processed and the original wavelet coefficients, making it impossible to maintain the original features of the images effectively.

V. GLOBAL THRESHOLD FUNCTION

After several decades of research & development, it has been found that shrinkage function is of many types, such as, soft shrinkage function, hard shrinkage function[3], firm shrinkage function[4], hyper-trim shrinkage function[5], multi-parameter best basis thresholding shrinkage function[6], Yasser shrinkage function [7]. All these thresholds and shrinkage functions promoted the application of wavelets in signal denoising extremely. The soft- and hard-thresholding schemes are defined by [8]:

(a) Hard-Thresholding:

The Hard-Thresholding function keeps the input if it is larger than the threshold; otherwise, it is set to zero [8]. It is described as:

$$\hat{W}_{j,k} = \begin{cases} w_{j,k}, & |w_{j,k}| \geq \lambda \\ 0, & |w_{j,k}| < \lambda \end{cases} \qquad \text{……(1)}$$

(b) Soft- thresholding:

The soft-thresholding function has a somewhat different rule from the hard-thresholding function. It shrinks the wavelet coefficients whose values are less than threshold value, and keeps the wavelet coefficients whose values are larger than threshold value [8], which is the reason why it is also called the wavelet shrinkage function.

$$\hat{W}_{j,k} = \begin{cases} \mathrm{sgn}(w_{j,k}).(|w_{j,k}|-\lambda), & |w_{j,k}| \geq \lambda \\ 0, & |w_{j,k}| < \lambda \end{cases} \qquad \text{… (2)}$$

Where sgn(*) is a sign function, $w_{j,k}$ stands for wavelet coefficients, $\hat{w}_{j,k}$ stands for wavelet coefficients after treatment, λ stands for threshold value and it can be expressed as follows:

$$\lambda = \sigma\sqrt{2\ln(N)} \qquad \text{…..(3)}$$
$$\sigma = \mathrm{median}(|c|)/0.6745 \qquad \text{…(4)}$$

where N is the image size, σ is the standard deviation of the additive noise and c is the detail coefficient of wavelet transform.
The soft-thresholding rule is chosen over hard-thresholding, for the soft-thresholding method yields more visually pleasant images over hard thresholding [11].

VI. PENALIZED THRESHOLDING

In this, the value of threshold is obtained by a wavelet coefficients selection rule using a penalization method provided by Birge-Massart.

MATLAB code for Penalized Threshold

```
THR=wbmpen(C, L, Sigma, Alpha)
```

Where
[C,L] is the wavelet decomposition structure of the signal or image to be de-noised.
SIGMA is the standard deviation of the zero mean Gaussian white noise in de-noising model (see wnoisest for more information).
ALPHA is a tuning parameter for the penalty term. It must be a real number greater than 1. The sparsity of the wavelet representation of the de-noised signal or image grows with ALPHA. Typically ALPHA = 2.

VII. PROPOSED THRESHOLD

Finding an optimized value (λ) for threshold is a major problem. A small threshold will surpass all the noise coefficients so the denoised signal is still noisy. Conversely a large threshold value makes more number of coefficients as zero which leads to smooth signal and destroys details that may cause blur and artifacts [11]. So, optimum threshold value should be found out, which is adaptive to different sub band characteristics. Here we select an efficient threshold value for different types of noise to get high value of PSNR as compared to previously explained methods.

The threshold value which we are using here is 55 (Using heat and trial method).

VIII. IMAGE NOISE

Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector [9]. Image noise is generally regarded as an undesirable by-product of image capture. Although these unwanted fluctuations became known as "noise" by analogy with unwanted sound they are inaudible and actually beneficial in some applications, such as dithering. The types of noise which are mostly present in images are:-

i) Gaussian noise

The standard model of amplifier noise is additive, Gaussian, independent at each pixel and independent of the signal intensity. 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[9].

ii) Salt-and-pepper noise

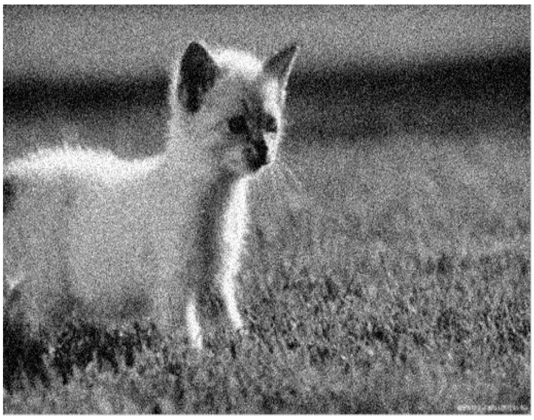
An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions [9]. This type of noise can be caused by dead pixels, analog-to-digital converter errors, bit errors in transmission, etc. This can be eliminated in large part by using dark frame subtraction and by interpolating around dark/bright pixels.

IX. SIMULATION RESULTS

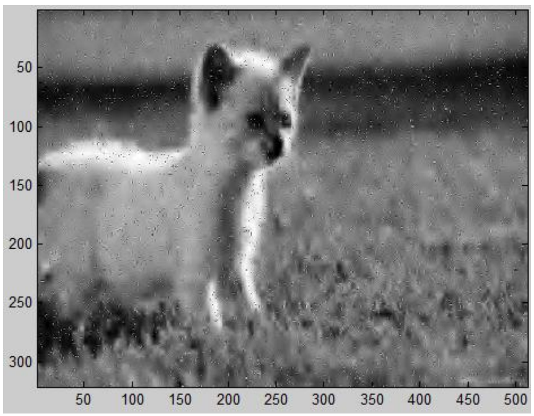
The Original Image is natural image, adding three types of Noise (Gaussian noise, Speckle noise and Salt & Pepper noise) and De-noised image using Median filter, Wiener filter, Penalized Threshold, Global Threshold and Proposed Threshold and comparisions among
them is given below:-

i) **original gray scale image**

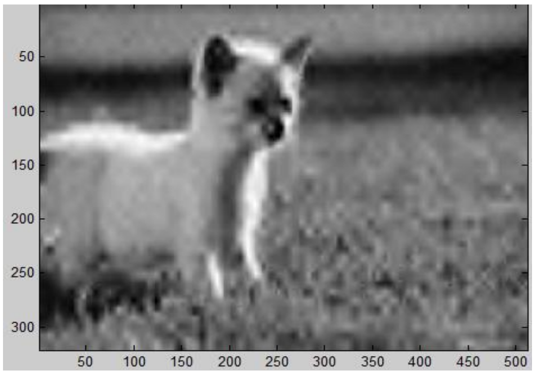
ii) image with salt & pepper noise



iii) image with Gaussian noise

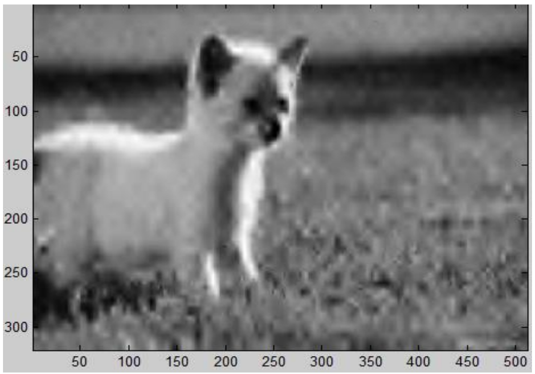


iv) image denoising using proposed threshold (for salt &pepper noise)

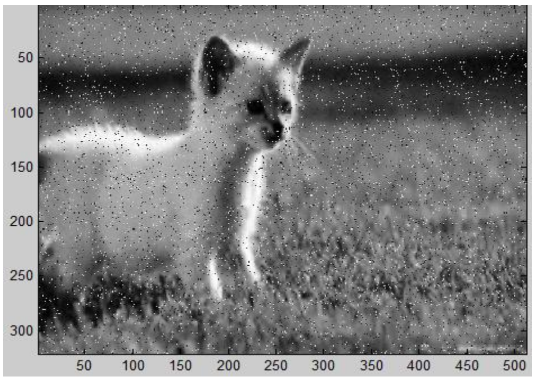


v) image denoising using proposed threshold (for Gaussian noise)

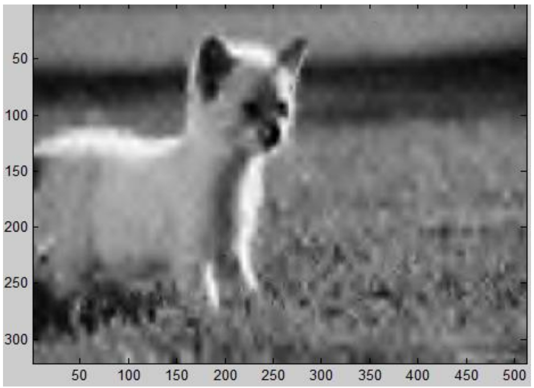
vi) image denoising using wiener filter (for salt &pepper noise)



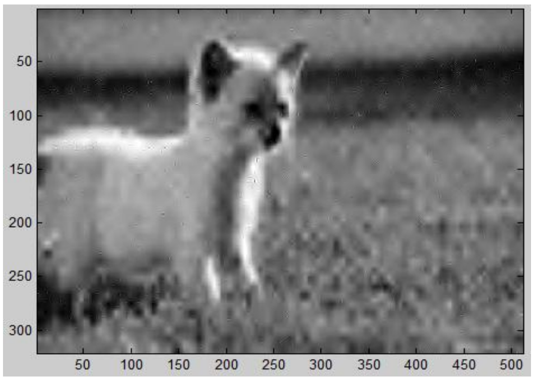
vii) image denoising using penalized threshold (for Gaussian noise)



viii) denoising using global threshold (for salt & pepper noise)



ix) image denoising using penalized threshold (for Gaussian noise)



x) image denoising using penalized threshold (for salt &pepper noise)

xi) image denoising using median filter (for Gaussian noise)

xii) image denoising using median filter (for salt &pepper noise)

xiii) image denoising using wiener filter (for Gaussian noise)

Table which shows the Performance analysis of Median filter, Wiener filter, penalized threshold, global threshold and proposed threshold for different type of noise is given below:

Typ-es of nois-e	**Penaliz-ed thresh ol-ding**	**Wie-ner filter**	**Med i-an filter**	**Global thresh -olding**	***Propos-ed threshold***
Salt & pep-per	23.4923	26.7013	31.4058	31.4058	47.7422
Gaussia-n	47.8929	28.0751	26.7564	47.9475	48.0236

Table: PSNR of test image corrupted by different types of noise using various denoising methods

X. CONCLUSION

In this paper, we have proposed a new threshold technique in which a gray scale image in ‘jpg’ format is injected noise of different types such as Gaussian and Salt & Pepper. Further, the noised image is denoised by using different filtering and denoising techniques. From the results (figure (iv) to figure (xiii)) we conclude that:-

The proposed threshold mentioned in this paper shows better performance over other techniques. Thus we can say that the proposed threshold may find applications in image recognition system, image compression, medical ultrasounds and a host of other applications.

REFERENCES

[1] Wavelet domain image de-noising by thresholding and Wiener filtering. Kazubek, M. Signal Processing Letters IEEE, Volume: 10, Issue: 11, Nov. 2003 265 Vol.3.

[2] Wavelet Shrinkage and W.V.D.: A 10-minute Tour Donoho, D.L; (David L. Donoho's website).

[3] D.L.Donoho and I.M.John stone. Adapting to Unknown Smoothness via Wavelet Shrinkage [J]. Journal of American StatAssoc, vol.12, pp.1200- 1224, 1995

[4] Peng-Lang Shui. Image Denoising Algorithm via Doubly Local Wiener Filtering With Directional Windows in Wavelet Domain [J]. IEEE SIGNAL PROCESSING LETTERS, VOL. 12, NO. 10, OCTOBER 2005.

[5] D.L. Donoho. Denoising by Soft thresholding, IEEE Trans. Inform Theory, 1995,vo1.41 (3),pp.613-627.

[6] Adelino R., Ferreira da Silva, “Wavelet denoising with evolutionary algorithms,” Digital Signal Processing, vol. 15, 2005, pp382–399.

[7] Yasser Ghanbari, Mohammad Reza Karami-Mollaei, “A new approach for speech enhancement based on the adaptive thresholding of the wavelet packets, ” Speech Communication, vol. 48, 2006, pp927–940.

[8] Donoho D L, John stone IM. Ideal spatial adaptation via wavelet shrinkage [J]. Biometrika, 1994, 81 (3): 425～455.

[9] Image Denoising using Wavelet Thresholding and Model Selection. Shi Zhong Image Processing, 2000, Proceedings, 2000 International Conference on, Volume: 3, 10-13 Sept. 2000 Pages: 262.

[10] Sedef Kent, Osman Nuri Oçan, and Tolga Ensari (2004). "Speckle Reduction of Synthetic Aperture Radar Images Using Wavelet Filtering". in ITG, VDE, FGAN, DLR, EADS, astrium. EUSAR 2004 Proceedings, 5th European Conference on Synthetic Aperture Radar, May 25–27, 2004, Ulm, Germany.

[11] S. Sudha, G. R. Suresh, R. Sukanesh (2007). “wavelet based image denoising using adaptive thresholding”. International Conference on Computational Intelligence and Multimedia Applications 2007, pp296-299.

[12] Suresh Kumar, Papendra Kumar, Manoj Gupta, Ashok Kumar Nagawat (2010). ”Perfprmance Comparison of Median and Wiener Filter in image denoising”. International journal of Computer Applications (0975 - 8887) Volume 12 - No.4, November 2010, pp27 – 31.