Comparison of Noise Removal Technique for Image Enhancement

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Abstract

An image enhancement scheme is presented by using cascaded blocks of non-linear filtering and comparing it with the output presented by discrete wavelet transform and non-linear filtering. In non-linear filtering, the cascaded blocks performs smoothing and sharpening whose behaviour is finely controlled by a set of parameters. Smooth approximation of piecewise linear filter is done to obtain smoothing parameter. The smoothing parameter smoothens out the Gaussian noise present in any image. In the other technique, discrete wavelet transform (DWT) is used with piecewise linear filter. DWT decomposes the image into four sub-bands. The lower sub-band is smoothed and the higher sub-bands are sharpened by using non-linear piecewise filter while removing noise. The experimental result shows the comparison of two techniques and gives an efficient noise removal technique.

Keywords: *Gaussian noise, image enhancement, non-linear filters, Discrete Wavelet Transform.*

1. Introduction

Image enhancement plays very important role in image processing. Visual effects can be improved by enhancing some information and restraining other. The quality of image is mainly affected by the presence of noise in it. Many linear filtering approaches were used to remove noise but it resulted in the blurring of output image. To overcome the drawback of linear filters, non-linear filtering approach is considered, as non-linear models can effectively combine noise reduction and edge enhancement. If the sharpening is increased it results in increasing the noise, it (noise) can be limited during the sharpening process. Better results can be produced by nonlinear approaches, because they can realize a more satisfactory compromise between edge enhancement and noise cancellation. A class of method which do not follow classical unsharp masking approach are the piecewise linear filters. Advantage of using this filter is easy control of sharpening and smoothing. Another technique for image enhancement is by using discrete wavelet transform and non-linear piecewise filters. By using discrete wavelet transform image resolution enhancement technique was proposed by Demiral and Anbarjafari [1,2]. A satellite image enhancement based on the discrete wavelet transform (DWT) and singular value decomposition (SVD) was presented by Demirel [3]. Discrete wavelet transform decomposes the image in to four sub-bands. DWT helps in edge detection process.

In this paper, comparison of both the techniques is presented to obtain the efficient method for noise removal and image enhancement. Behaviour of non-linear filters is analyzed with respect to the noise present in image.

This paper is organized as follows: section 2 gives the description about combination of DWT and Filtering method, section 3 gives the description about Non linear Filtering Method used for image enhancement, section 4 gives comparison of results of both the methods, section 5 is about the numerical comparison. Section 6 Concludes the paper.

2. Description about Discrete Wavelet Transform and non-linear filtering Method.

The flow chart of this technique is shown in figure 1. The input image is decomposed by using Haar discrete wavelet transform into four sub-bands, as the decomposition is of 1 –level. The four sub-bands are as follows : Low-Low (LL), High –Low (HL), Low-High (LH), High-High (HH). The smoothing of lower frequency sub-band results in noise removal, it is achieved by smooth approximation of piecewise linear filter. The input images used in this paper are gray scale images in which each pixel carries only intensity information. The value of gray level lies form 0 to 255. Where the lowest pixel indicates black and the highest pixel indicates white, this is known as gray scale of any image. The size of image considered is of 256x256.

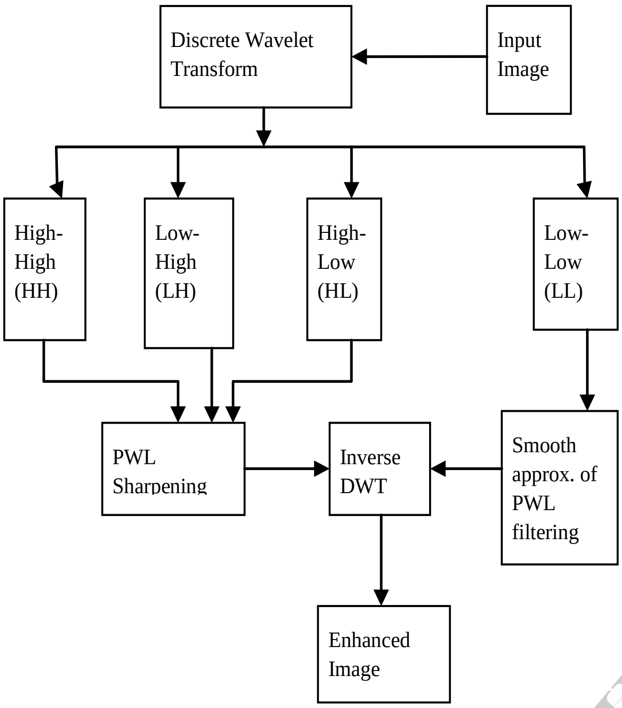


Figure 1. Block diagram of Discrete Wavelet Transform Followed by non-linear filtering.

A. Wavelet Transform

Wavelets transform is an efficient tool to represent an image. It allows multi resolution analysis of an image. The aim of this transform is to extract relevant information from an image. Wavelet transform has received considerable attention in the field of image processing due to its ability in adapting to human visual characteristics. It divides the signal into number of segments, each corresponds to a different frequency band. Wavelet transform provides a time- frequency representation of the signal. Wavelets have been used for feature extraction, denoising, compression, face recognition and image resolution enhancement. Due to intrinsic deformation and extrinsic factors there is change in frequency of the pixels. Frequency components are isolated by using wavelet transform into certain sub-bands. Figure 2 shows the sub-bands obtained.

Low-Low (LL)	**High-Low (HL)**
Low-High (LH)	**High-High (HH)**

Figure 2. Sub-bands

B. PWL Filtering

This is a class of non-linear filters. In mathematics, a piecewise linear function is a function composed of straight-line sections. It is a piecewise-defined function whose pieces are affine functions.

If the function is continuous, the graph will be a polygonal curve.

The function defined by:

$$f(x) = \begin{cases} -x-3 & if\ x \le -3 \\ x+3 & if\ -3 < x < 0 \\ -2x+3 & if\ 0 \le x < 3 \\ x-6 & if\ x \ge 3 \end{cases} \qquad (1)$$

This block performs the smooth approximation of low frequency sub-band by using piecewise linear filter. This processing deals with four different pixels subsets as follows: W1, W2, W3, W4. The four different subset obtained is as follows:

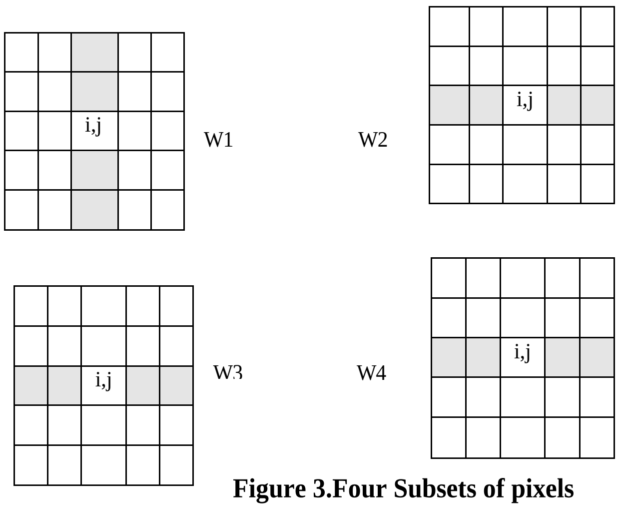


Figure 3.Four Subsets of pixels

The four different subsets of pixels are defined as:

$W1=\{x_{i-2,j},x_{i-1,j},x_{i+1,j},x_{i+2,j}\}$ (i)

$W2=\{x_{i,j-2},x_{i,j-1},x_{i,j+1},x_{i,j+2}\}$ (ii)

W3={$x_{i-2,j-2}$,$x_{i-1,j-1}$,$x_{i+1,j+1}$,$x_{i+2,j+2}$} (iii)

W4={$x_{i+2,j-2}$,$x_{i+1,j-1}$,$x_{i-1,j+1}$,$x_{i-2,j+2}$} (iv)

This blocks performs filtering while preserving thin lines in image.

The output $y_{i,j}$ is given by the relation:

$$y_{i,j} = x_{i,j} + \frac{1}{4} \sum_{x_{m,n} \in w_p} \beta(x_{m,n}, x_{i,j}, a1, b1, c1) \quad (2)$$

Where $\beta(u,v,a,b,c)$ is a three-parameter seven-segment PWL function is shown in figure 5(a) and the set W_p is such that the following quantity is minimized.

$$\left|\sum_{x_{m,n} \in w_k} \beta(x_{m,n}, x_{i,j}, a1, b1, c1)\right| \quad (3)$$

where k= 1,2,3,4.

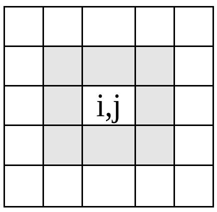
To further reduce the noise another pixel subset is selected by resorting to maximum operator:

$$y_{i,j} = x_{i,j} + \frac{1}{4} \sum_{x_{m,n} \in w_p} \beta(x_{m,n}, x_{i,j}, a2, b2, c2) \quad (4)$$

$$\left|\sum_{x_{m,n} \in w_k} \beta(x_{m,n}, x_{i,j}, a2, b2, c2)\right| \quad (5)$$

where k= 1,2,3,4

For performing sharpening of higher sub-band by using PWL sharpening filter, one pixel sub-set is chosen such that:



W5

W5= { $x_{i-1,j-1}$, $x_{i-1,j}$, $x_{i-1,j+1}$, $x_{i,j-1}$, $x_{i,j+1}$, $x_{i+1,j-1}$, $x_{i+1,j}$, $x_{i+1,j+1}$ } (v)

The output $y_{i,j}$ of sharpener is defines as:

$$y_{i,j} = x_{i,j} + \frac{1}{8} \sum_{x_{m,n} \in w_5} \gamma(x_{m,n}, x_{i,j}, d, e, f, g) \quad (5)$$

Where $\gamma(u,v,d,e,f,g)$ is the four parameter three segment PWL function as shown in figure 5(b).

After applying the above mentioned technique Inverse Discrete Wavelet Transform (IDWT) is applied on the output of the smooth approximation and sharpening to obtain enhanced output.

3. Description about Non-Linear Filtering Method.

The flow chart of this particular technique is shown in figure 4. The input image is filtered by two kind of PWL smoothers and the output of directional smoother 2 is sharpened by PWL sharpener. According to the intensity of Gaussian noise the amount of smoothing and sharpening are chosen. Input image chosen is a gray scale image of size 256x256, i.e. having L gray levels where L=256. Let $x_{i,j}$ be the pixel luminance at location [i,j]. The image pixels luminance varies from (0<= $x_{i,j}$ <= L-1).

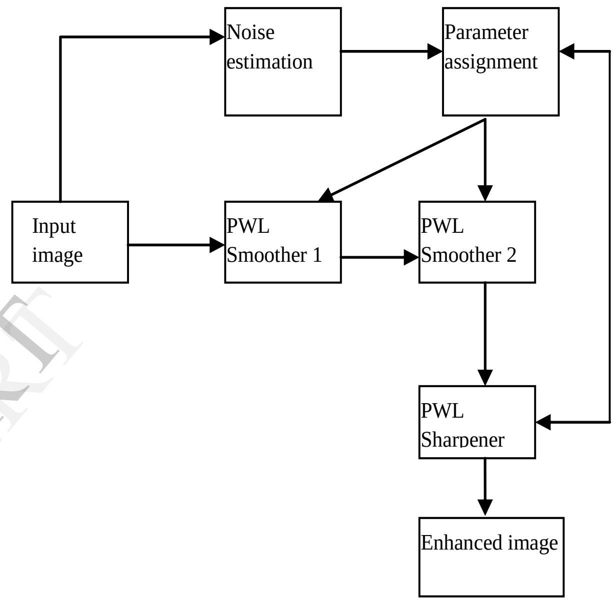


Fig. 4 Block diagram of Non-Linear Filtering using Piecewise Linear Filter

A. PWL Directional Smoother 1

This block in particular performs noise smoothing based on the directional filter, which aims at preserving thin lines in the image. The processing deals with four different subsets of pixels:

W1= { $x_{i-2,j}$, $x_{i-1,j}$, $x_{i+1,j}$, $x_{i+2,j}$ } (vi)

W2= { $x_{i,j-2}$, $x_{i,j-1}$, $x_{i,j+1}$, $x_{i,j+2}$ } (vii)

W3= { $x_{i-2,j-2}$, $x_{i-1,j-1}$, $x_{i+1,j+1}$, $x_{i+2,j+2}$ } (viii)

W4= { $x_{i+2,j-2}$, $x_{i+1,j-1}$, $x_{i-1,j+1}$, $x_{i-2,j+2}$ } (ix)

The output $y_{i,j}$ is given by the relation:

$$y_{i,j} = x_{i,j} + \frac{1}{4}\sum_{x_{m,n}\in w_p} \beta(x_{m,n}, x_{i,j}, a1, b1, c1) \quad (6)$$

Where *β(u,v,a,b,c)* is a three-parameter seven-segment PWL function is shown in figure and the set W_p is such that the following quantity is minimized.

$$\left|\sum_{x_{m,n}\in w_k} \beta(x_{m,n}, x_{i,j}, a1, b1, c1)\right| \quad (7)$$

where k= 1,2,3,4

One pixel subset is selected and the filtering is performed by using PWL type 1 smoother. This operation is performed by resorting to minimum operator. This block preserves thin lines, and it performs well in the uniform regions. It reduces noisy pixels having large amplitude corresponding to the Gaussian noise present. The behaviour of this type of filter is of main consideration as during the sharpening process amplification of such pixels intensity can cause annoying sharpening which is considered as noise. To avoid such condition smoothing is done as a pre processing step for image enhancement using non-linear filter.

For performing piecewise linear filtering the luminance difference between the central pixel and neighbouring pixels is taken into account. In this approach, small differences (|u-v| <= a) are interpreted as noise which is smoothed out using this filtering mechanism. The output is the arithmetic mean of the luminance values, according to the function β. For large luminance difference between the pixels (|u-v| >= a), it denote object contours. If the values obtained are very different from the central element pixel value, then smoothing is not applicable to them and so the image obtained is not blurred. In this paper, a trapezoid-shaped function β is considered to achieve transition for luminance differences varying from medium value (a<=|u-v|<ba) to large(ba<=|u-v|<ca). Three parameters a, b and c give flexibility in choosing the useful information in defining filtering action. Through this it can be decide how much luminance difference should be considered as useful information or unwanted noise by appropriately choosing these parameters. It aims at noise cancellation and detail preservation for a given noise variance. Parameter *a* is the most important of all as the length of whole function depends on it. The choice of parameter *b* and *c* is less critical. The value of *a* is chosen according to the noise variance.

B. PWL Directional Smoother 2

This block further performs the smoothing by resorting to the maximum operator. This block further aims at noise removal. The output of this filter is given by:

$$y_{i,j} = x_{i,j} + \frac{1}{4}\sum_{x_{m,n}\in w_p} \beta(x_{m,n}, x_{i,j}, a2, b2, c2) \quad (8)$$

$$\left|\sum_{x_{m,n}\in w_k} \beta(x_{m,n}, x_{i,j}, a2, b2, c2)\right| \quad (9)$$

where k= 1,2,3,4

This filter is used with PWL directional smoother1 in cascaded form so as to give more efficient output. The output of this filter which is smoothed and is of less noise content is sharpened with the help of PWL sharpener.

C. PWL Sharpening

This block performs sharpening of the image output of cascaded smoothers. A sub-set of pixels is considered as follows:

$$W5= \{ x_{i-1,j-1}, x_{i-1,j}, x_{i-1,j+1}, x_{i,j-1}, x_{i,j+1}, x_{i+1,j-1}, x_{i+1,j}, x_{i+1,j+1} \} \quad (x)$$

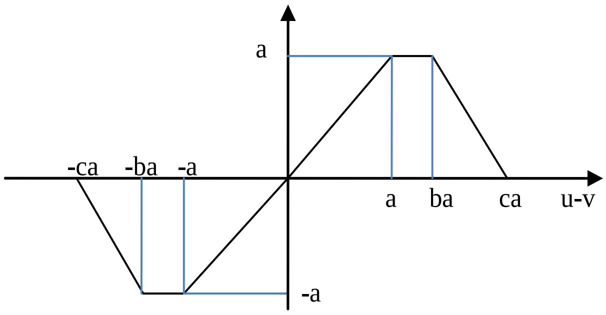
The output $y_{i,j}$ of the sharpener is as follows:

$$y_{i,j} = x_{i,j} + \frac{1}{8}\sum_{x_{m,n}\in w_5} \gamma(x_{m,n}, x_{i,j}, d, e, f, g) \quad (10)$$

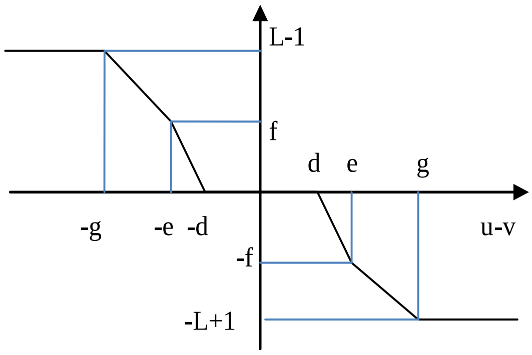
Where *γ(u,v,d,e,f,g)* is the four parameter three segment PWL function.

Sharpening is used to highlight edges in any image, it is quite opposite of smoothing [4],[5]. If γ <= 0 when *u-v*>= 0 and γ >= 0 when *u-v*< 0. effective sharpening results are obtained. γ function aims at better controlling of sharpening. Function states that if the luminance difference is small *(*|*u-v*|<*d*), no sharpening is performed the function is flat in order to avoid noise increase. When the luminance differences are not small (|*u-v*|>=*d*), sharpening of image starts. For medium differences (*d*<|*u-v*|<=*e*), the output gives stronger sharpening in order to highlight image details. But if the differences are very large (*e*<|*u-v*|<=*g*) the sharpening again gets reduced as to avoid annoying sharpening which is considered as noise. By choosing a set of parameters {*d, e, f, g, L*}the effect of sharpening can be obtained. Where *m1= f /(e-d)* and *m2= (L-1-f)/(g-e)* denote the slope of the function.

After applying the above mentioned technique the output image obtained is more sharpened and noise level is comparatively smoothened.



(a)



(b)

Fig. 5. Parameterized PWL functions (a) Function *β*. (b) Function *γ*.

4. Experimental Observation

Based on Piecewise linear filtering, the input image when there is no external added noise present and when corrupted with less amount of Gaussian noise is presented in (a) and (b) respectively. The output image is depicted in (c) and (d) after applying the non-linear filtering in fig 6.

(a)

(c)

(b)

(d)

Fig. 6 (a) input image with no noise
(b) input image with less noise
(c) output enhanced image
(d) output enhanced image

Based on Discrete Wavelet Transform, the input image corrupted with internal noise and external Gaussian noise is considered as above. The input images are shown in (e) and (f) respectively and output is shown in (g) and (h) respectively.

(e)

(g)

(f)

(h)

Fig. 7 (e) input image with no noise
(f) input image with less noise
(g) output image
(h) output image

5. Result Analysis

A number of quantitative measuring parameters can be used to evaluate the performance of the various types of filters in terms of restoring damage signals quality and quantity after filtering out impulse noise (salt and pepper). The following measuring parameters are used:

- Mean Square Error (MSE)
- Peak Signal-to-Noise Ratio

Mean square error of two separate images is computed for various types of filters. The MSE is the cumulative squared error between the noisy image and the filtered image. The mathematical formula for the MSE is:

$$MSE = \frac{1}{MXN}\left(\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}[f(x,y) - \hat{f}(x,y)]^2\right)$$

Where, M and N are the total number of pixels in the column and row of the image respectively. f denotes the noisy image and $\hat{f}$ denotes the filtered image.

The peak signal-to-noise ratio is one of the best known techniques for assessing the amount of noise that an image is polluted with and, for that matter, the amount of noise left in a filtered image. The peak signal-to-noise criterion is adopted to measure the performance of various digital filtering techniques quantitatively. It is the measure of the peak error:

$$PSNR\ in\ db = 10\ log_{10}\left(\frac{255^2}{MSE}\right)$$

A lower value for MSE means lesser error, and as seen from the inverse relation between the MSE and PSNR, this translates to a high value of PSNR. Logically, a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction or restoration. So, if you find a filtering or compression scheme having a lower MSE and a high PSNR, you can recognize that it is a better one.

Table 1 shows the quantitative result of peak signal to noise ratio values and mean square error values.

Table 1 PSNR and MSE

Technique used	PSNR	MSE
Using Non-linear filtering(for noise present internally)	36.831	21.68
Using Non-linear filtering(for noise present externally)	35.172	23.13
Using DWT and non-linear filtering.(for noise present internally)	27.46	116.4241
Using DWT and non-linear filtering.(for noise added to the image)	27.18	124.2661

6. Conclusion

By comparing non-linear filtering technique and noise removal filtering(based on discrete wavelet transform), it is concluded that the non-linear filtering technique using PWL filter is more efficient and appropriate.

7. References

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