

IMAGE DE-NOISING USING WAVELET TRANSFORM

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Abstract

Digital Image processing is a systematic procedure to translate an image into digital information and then perform some operations on it, with an objective of getting an enhanced image in terms of its quality or to extract some useful information from it. Image processing is one among the rapidly growing technologies today, with its applications in various fields.

Image denoising is a key issue in all image processing researches. It is the first preprocessing step in dealing with image processing where the overall system quality should be improved. Generally, the quality of an image could be corrupted by a lot of noise due to the undesired conditions of image during its acquisition, processing, compression, reproduction and transmission. The great challenge of image denoising is how to preserve the important features and all fine details of an image when reducing the noise. There are many algorithms for denoising the image. Here in this paper, wavelet transform is used in the image denoising.

Key words; de-noising wavelet transform etc

Introduction:

Noise reduction plays a fundamental role in image processing, and wavelet analysis has been demonstrated to be a powerful method for performing image noise reduction [1]. The procedure for noise reduction is applied on the wavelet coefficients achieved using the wavelet decomposition and representing the image at different scales. After noise reduction, the image is reconstructed using the inverse wavelet transform. PSNR and MSE values are calculated for different images.

Noise:

We may define noise to be any degradation in the image signal, caused by external disturbance. If an image is being sent electronically from one place to another, via satellite or wireless transmission, or through network cable, we may expect errors to occur in the image signal. These errors will appear on the image output in different ways depending on the type of disturbance in the signal.

Types of Noise:

We will see four different types of noise.

- **Salt and pepper noise**

It is also called as impulse noise, shot noise, or binary noise. This degradation can be caused by sharp, sudden disturbances in the image signal, its appearance is randomly scattered white or black (or both) pixels over the image.

- **Gaussian noise**

It is an idealized form of white noise, which is caused by random fluctuations in the signal. Gaussian noise is white noise which is normally distributed. If an image is represented as I and the Gaussian noise by N , then we can model a noisy image by simply adding the two:

$I+N$

- **Speckle noise**

It can be modeled by random values multiplied by pixel values, hence it is also called as multiplicative noise. Speckle noise is a major problem in some radar applications.

- **Periodic noise**

If the image signal is subject to a periodic, rather than a random disturbance, we will obtain an image corrupted by periodic noise. The effect of bars over the image. The function $imnoise$ does not have a periodic option, but it is quite easy to create our own, by adding a periodic matrix.

Wavelet Transform

The wavelet transform’s property of energy transformation comes handy in denoising. The wavelet transform has energy compactness property which could contain most of the signal energy in a few large wavelet coefficients thus quantizing energy in which a small portion of the energy is spread across a big number of little wavelet coefficients. These types of coefficients will show details but at the same time it is also marred with high frequency noise. By congruously thresholding these selective wavelet coefficients, the image denoising is done while preserving fine details in the image. The other properties of the wavelet transform that help in the image denoising are sparseness, clustering, and correlation between neighboring wavelet coefficients. The wavelet coefficients of natural images are sparse.

Wavelet transform decomposes the image into several components based on the frequency characteristics of the signal. Wavelet transform converts the signal information bits in the frequency showing coefficients which are distributed in horizontal, vertical and diagonal parts of the image. These are known as the decomposed frequency components of the under observation image. This wavelet is an efficient means of spreading the energy of image. The multi resolution analysis can be done by wavelets which is one of the advantages of the wavelet transform.

Wavelets show best results for the localized details like edges and curves. In wavelet transform, the basic image is transformed into four elements also known as sub-bands namely LL, HL, LH, and HH. The LL piece or sub-band is known as the approximation or average of the original image. The other three sub-bands are known as details representing components of wavelet coefficients namely the vertical details, diagonal details and horizontal details respectively.

The wavelet transform can be divided into the three components. The first is image decomposition in which an image is divided into its relative sub bands. Then it undergoes wavelet thresholding which will select and sparse selected wavelet coefficients or modified ones and the last one is the inverse wavelet transform to reconstruct the original image.

Wavelet de-noising

Many techniques of image denoising using wavelets are based on wavelet shrinkage and wavelet thresholding. The computational advantage of using such estimation approaches is provided by algorithm of fast implementation. The main idea behind it is that, if the wavelet coefficients’ estimates the bigger in absolute value than a certain specified threshold then the same value is either retained as such or is diminished by the amount corresponding to the threshold. The smaller coefficients are instead eliminated, hence specifying the wavelet expansion.

y (t_i) = f (t_i) + σε (t_i)

Wavelet Decomposition

To start with, the image is high and low – pass filtered along the rows and the results of each filter are down sampled by two. Those two sub-signals correspond to the high and low frequency components along the rows. Then each of these sub-signals is again high and low-pass filtered, along the column data. The results are again down sampled by two. As a result the original data is split into four sub-images containing information from different frequency components. Figure 1 shows the level one decomposition step of two dimensional image. Figure 2 shows the four sub bands in the typical arrangement.

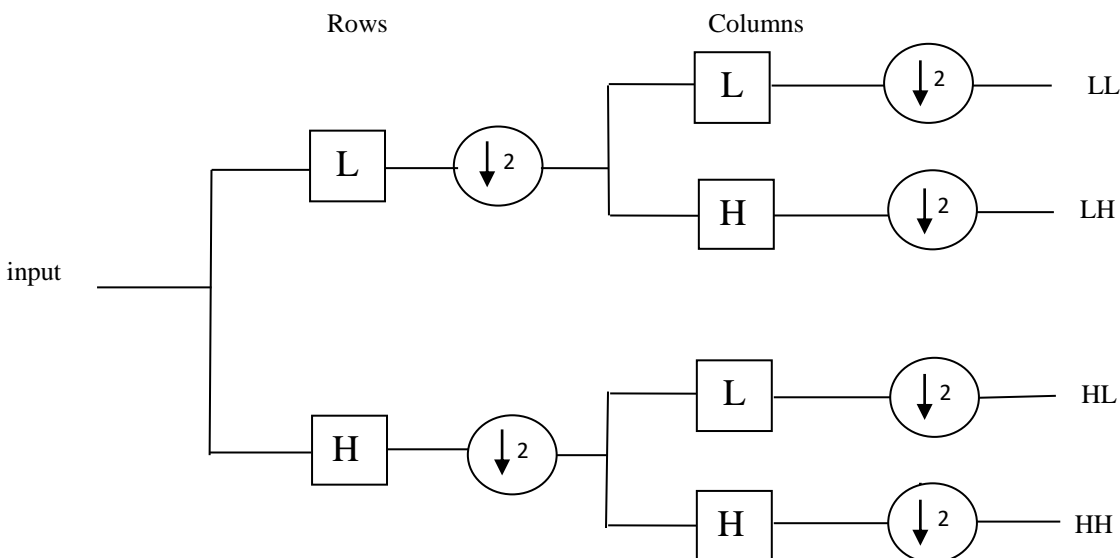


Figure 1: One decomposition step of the two dimensional image

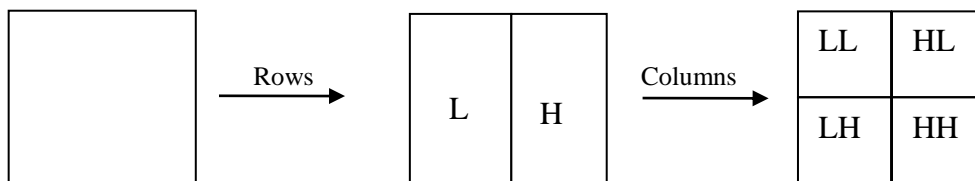


Figure 2: One DWT decomposition step

Composition Process:

The inverse process is shown in figure 3. The information from the four sub images is up-sampled and then filtered with the corresponding inverse filters along the columns.

The two results that belong together are added and then again up-sampled and filtered with the corresponding inverse filters. The result of the last step is added together in order to get the original image again.

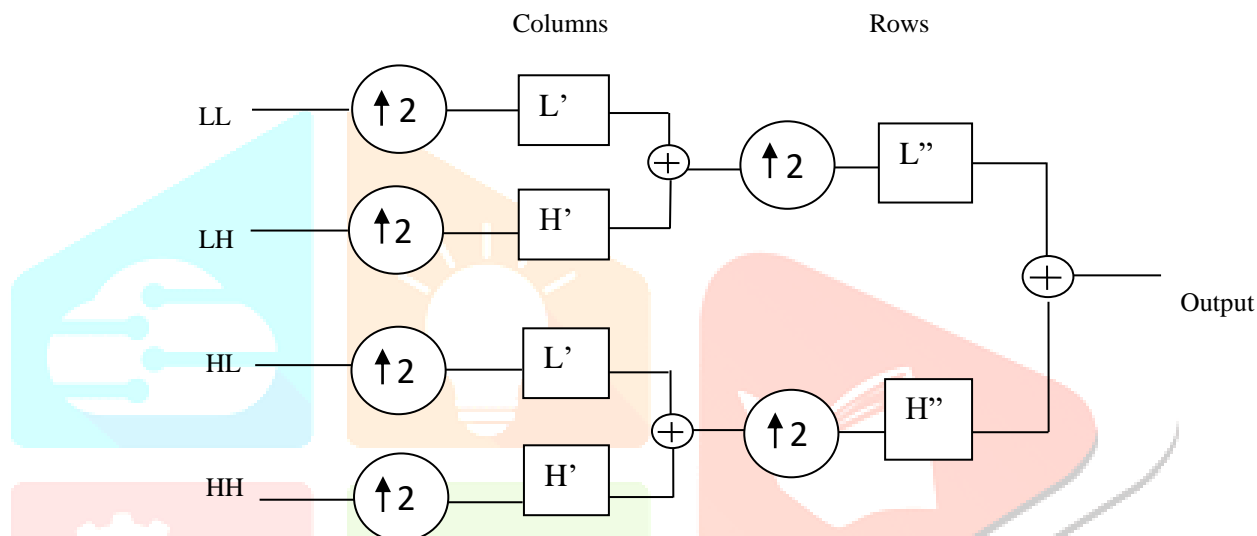


Figure 3: One composition step of the four sub images

Algorithm for image denoising

Step1: Read the original standard image

Step2: Resize the loaded image to a standard size of 512x512. The images taken for testing, have a lot of variation in their sizes and hence cannot be compared on the same basis.

Step3: Gaussian noise is added to the standard test image. This type of noise adds normal distributed noise to the original image. The noise is independent of the image it is applied to. The value of pixel is altered by the additive Gaussian noise as $x = y + 10*y$ where x is the noise. $10*y$, being distributed normally along the size of original image. The noisy pixels which are generated are anywhere between black and white, distributed according to the Gaussian curve.

Step4: Make the noisy image to undergo wavelet transform, SWT.

Step5: After the noisy image is decomposed into approximation and details coefficients using wavelet transform, it is made to undergo thresholding rules (soft and hard) having various thresholding values.

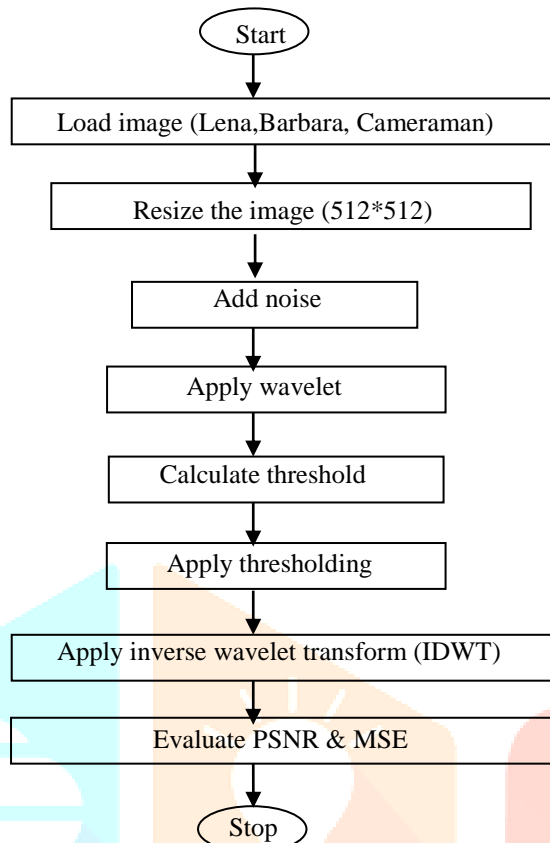
Step6: Denoised image is reconstructed using inverse wavelet transform – ISWT

Step7: Then two parameters, PSNR (peak signal to noise ratio) and MSE (mean square error) are calculated for all standard images with their noisy and denoised counterparts respectively.

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} |I(i, j) - K(i, j)|^2$$

$$PSNR = 10 * \log_{10} \left(\frac{MAX\ i^2}{MSE} \right)$$

Flow chart for Image denoising algorithm using wavelet transform

**Thresholding Techniques:**

Thresholding is a simple non linear technique, which operates on one wavelet coefficient at a time. In its most basic form, each coefficient is thresholded by comparing against threshold, if the coefficient is smaller than threshold, set to zero; otherwise it is kept or modified. Replacing the small noisy coefficients by zero and inverse wavelet transform on the result may lead to reconstruction with the essential signal characteristics and with less noise.

There are two types of thresholding

- i) Hard thresholding
- ii) Soft thresholding

Hard thresholding:

$$Y = T(x,y) = \begin{cases} X & \text{where } |X| > \lambda \\ 0 & \text{where } |X| \leq \lambda \end{cases}$$

In the hard thresholding scheme given in the equation, the input is kept if it is greater than the threshold λ , otherwise it is set to zero. The hard thresholding procedure removes the noise by thresholding only the wavelet coefficients of the detailed sub bands, while keeping the low resolution coefficients unaltered. If the input that is less than λ is forced to zero otherwise.

Soft thresholding:

$$Y = T(X,Y) = \begin{cases} \text{sign}\{X\}(|X| - \lambda) & \text{where } |X| > \lambda \\ 0 & |X| \leq \lambda \end{cases}$$

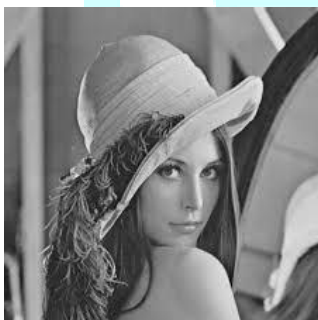
The soft thresholding scheme is an extension of hard thresholding. If the absolute value of the input X is less than or equal to λ then the output is forced to zero. If X is greater than λ then the output is $|Y| = |X| - \lambda$. When compared both hard and soft shrinking schemes, it can be seen that hard thresholding exhibits some discontinuities at λ and can be unstable or more sensitive to small changes in the data while soft thresholding avoids discontinuities and is therefore more stable than hard thresholding.

In practice, soft thresholding is more popular than hard thresholding because it reduces the abrupt sharp changes but occurs in hard thresholding and provides more visually pleasant recovered images.

Results:

DB ₁ Thresholding				Coiflets Thresholding	
	Sigma value	PSNR	MSE	PSNR	MSE
Lena	10	25.8239	170.0955	26.1307	158.4920
	20	22.0429	406.2483	22.2372	388.47
	30	19.4890	731.4464	19.6892	698.4952
	40	17.6008	1.1298e+003	17.7918	1.081e+003
	50	16.0779	1.6943e+003	16.2452	1.5437e+003
Cameraman	10	26.2484	154.2548	26.4579	146.9900
	20	22.1239	368.7434	22.2328	388.8638
	30	19.4413	739.5191	19.5626	719.1534
	40	17.5253	1.1495e+003	17.6445	1.1185e+003
	50	16.0067	1.6308e+003	16.1106	1.5923e+003
Barbara	10	24.2477	244.5156	24.7552	217.5529
	20	21.5020	460.1330	21.8166	427.9773
	30	19.3204	760.3912	19.5775	716.6941
	40	17.5780	1.1358e+003	17.7884	1.0820e+003
	50	16.1110	1.5921e+003	16.2782	1.5320e+003

Images used for Results:



Lena



Cameraman



Barbara

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