ISSN: 2321-7782 (Online)
e-ISJN: A4372-3114
Impact Factor: 6.047

Volume 5, Issue 8, August 2017

International Journal of Advance Research in Computer Science and Management Studies

Research Article / Survey Paper / Case Study

Available online at: www.ijarcsms.com

Image De-Noising using Wavelets a new proposed Method

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Abstract: In the process of image acquisition and transmission, noise is always contained inevitably. So it is necessary for image de-noising processing to improve the quality of image. Generally speaking, each algorithm has some filtering and threshold parameters. Taking various kinds of images into account, it is a key problem of how to set these parameters in de-noising algorithms under different conditions to achieve better performance. There are many algorithms for the determination of the parameters, and each of them has its own application field. Wavelet transform has good performance, therefore, it has been widely applied as a kind of signal and image processing tool. In this paper, wavelet transform is used in the image de-noising and we propose a new algorithm that doesn't use the traditional soft/hard thresholding method that leads to loss of information in detailed coefficient to some extent, instead we take a different approach which gives better performance and experimental results show the validity of the new algorithm.

I. Introduction

Images are produced to record or display useful information. Due to imperfections in the imaging and capturing process, however, the recorded image invariably represents a degraded version of the original scene. The undoing of these imperfections is crucial to many of the subsequent image processing tasks. There exists a wide range of different degradations that need to be taken into account, covering for instance noise, geometrical degradations (pin cushion distortion), illumination and color imperfections (under/over-exposure, saturation), and blur.

Digital images are typically picture elements in a grid formation known as pixels. Each pixel holds a value which is quantized that represents the tone at a specific point. Images are obtained in areas ranging from everyday photography to astronomy, remote sensing, microscopy, medical imaging etc. Image restoration uses a priori knowledge of the degradation. It formulates and evaluates the objective criteria of goodness. The distortion in image can be modeled as noise or blur or a degradation function. Unfortunately all images are more or less blurry. This is due to the reason that there is a lot of interference in the camera as well as in the environment. Blurring of an image can be caused by many factors such as movement during the capture process, using wide angle lens, using long exposure times, etc.

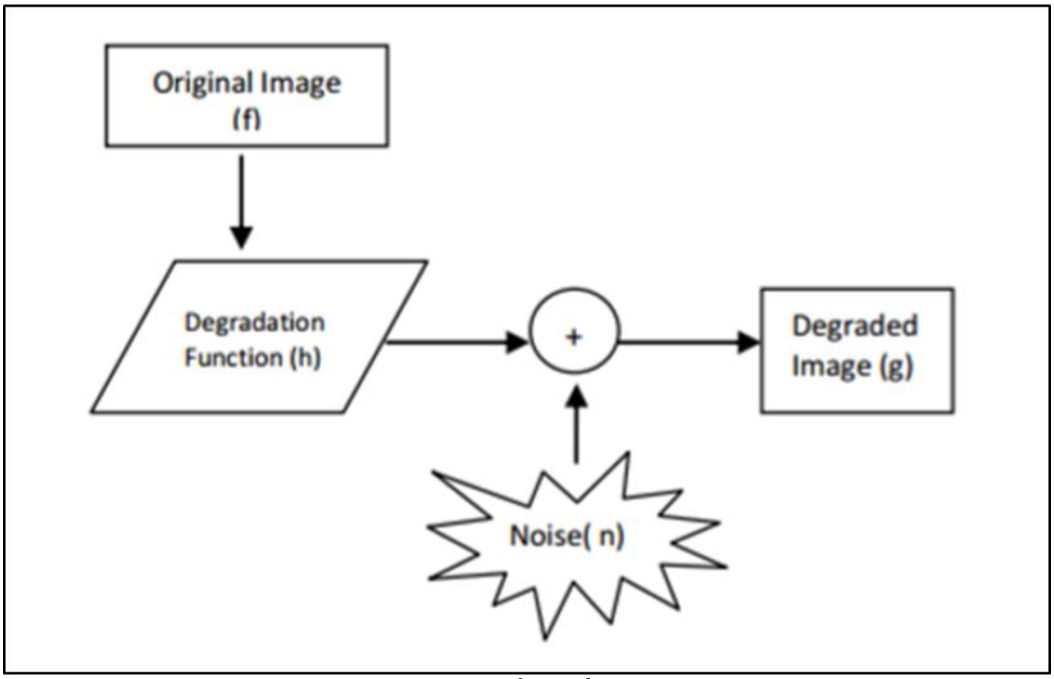


Fig. 1 Degradation of Image

In the process of image acquisition and transmission, noise is always contained inevitably. So it is necessary for image de-noising processing to improve the quality of image.

Much practical noise can be approximated as white noise with Gaussian distribution, and removal of superposition of Gaussian white noise has become an important direction in image de-noising research.

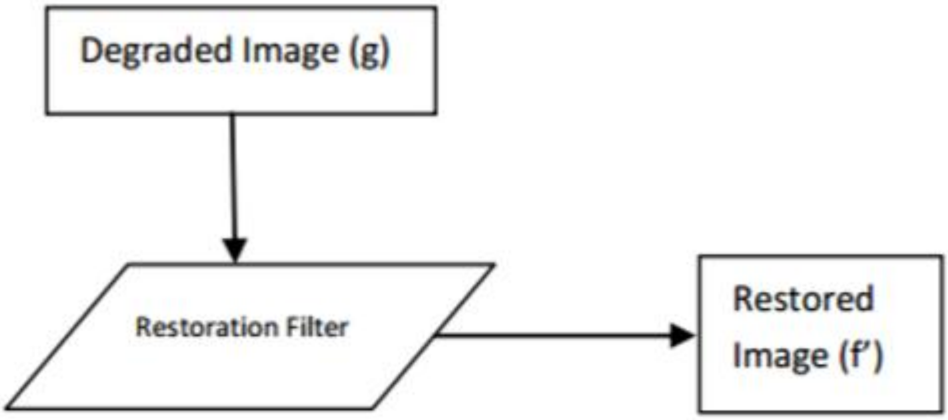


Fig. 2 Restoration of Image

At present, the noisy image restoration methods are mainly the following three:

1. Mean Filter Principle -

Mean filter is also known as the linear filter, and the main methods are the neighborhood average method. The basic principle of linear filtering is to replace the original image pixel values with mean values. That is to say, for the current pixel(x, y), we should select a template, which is composed of a plurality of pixels in its neighbor. Mean values for all pixels would be calculated and the give the mean values to the current pixel(x, y) as the gray(x, y) in the points on the process image. This means:

$$g(x,y) = \frac{1}{M}\sum_{f\in s} f(x,y)$$

Where, s means template, and M is the total number of pixels including current pixel the template. Mean filter using neighborhood average method is applicable to remove granular noise in the scanning image. Neighborhood average method effectively suppresses the noise. But during the process of calculating the average value, scenery edge points would be processed too. Then, the image would be in the state of low resolution. Based on this situation, the improved algorithm is proposed to realize various mean filters, and new mean filter is developed, such as weighted mean filter, gray minimum variance mean filter, K nearest neighbor mean filter, symmetric neighbor mean filter and so on. When these filters are working, scene boundary smoothing is avoided, and it can greatly reduce the fuzzy image.

2. The Median Filter -

The median filter is a kind of effective noise suppression of nonlinear signal processing technology based on the order statistical theory. The basic principle of the median filter is a sample value replaced with the median value of points in neighborhood point set. Pixel gray value, which is different with surrounding pixel gray values, would be replaced by the close value with the neighborhood points. Then, isolated noise points would be removed. The main idea of the method is establishing a two-dimensional sliding template, in which the pixel values would be ordered by size. Two-dimensional data sequence would be generated monotonically increasing (or decreasing). Two dimensional median filter output is-

$$\bar{g}(x,y) = Med\{f(x-\bar{k}, y-l), (k,\bar{l}) \in W\}$$

Where f(x, y) are the original images and g(x, y) are the processed images. W is a two-dimension template with usually 33 X or 55 X area, and it can be in different shapes, such as linear, circular, figure ten, ring, etc. Median filtering is a nonlinear filtering technique. The advantage of the median filter is simple operation and faster speed, and it has excellent performance in filtering added white noise and long tail noise. But for some more details, especially for a point, line and multi spire image should not use median filtering. In order to expand the scope of its application, the median filter has many improved algorithms, such as weighted median filter, switching median filter algorithm based on threshold, and adaptive median filter. In the weighted median filter, pixels within the window are to assign different weights to adjust the contradiction between noise suppression and detail preservation. However, the method obtains more effective detail preserving ability at an expense of noise suppression compared with a traditional filter. In switching median filter algorithm, it is based on threshold and gets the better effect by median filter for noise point and the flat region. This algorithm does not deal with the details in order to obtain good protection effect. For adaptive median filter, it can be used to deal with a high probability impulse noise. When it is processing, its neighborhood region can be changed relying on a certain condition. Its advantage is saving details in processing the smooth non impulse noise.

3. Wiener Filtering -

The inverse filtering is a restoration technique for deconvolution, i.e., when the image is blurred by a known low pass filter, it is possible to recover the image by inverse filtering or generalized inverse filtering. However, inverse filtering is very sensitive to additive noise. The approach of reducing single degradation at a time allows us to develop a restoration algorithm for each type of degradation and simply combine them. The Wiener filtering executes an optimal tradeoff between inverse filtering and noise smoothing. It removes the additive noise and inverts the blurring simultaneously.

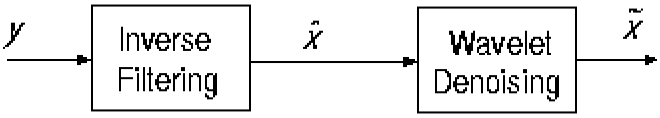
The Wiener filtering is optimal in terms of the mean square error. In other words, it minimizes the overall mean square error in the process of inverse filtering and noise smoothing. The Wiener filtering is a linear estimation of the original image. The approach is based on a stochastic framework. The orthogonality principle implies that the Wiener filter in Fourier domain can be expressed as follows-

$$W(f_1, f_2) = \frac{H^*(f_1, f_2)S_{xx}(f_1, f_2)}{|H(f_1, f_2)|^2 S_{xx}(f_1, f_2) + S_{\eta\eta}(f_1, f_2)},$$

Where Sxx (f1, f2) are the power spectra of the original image and Snn (f1, f2) the additive noise, and H(f1, f2) is the blurring filter. It is easy to see that the Wiener filter has two separate parts, an inverse filtering part and a noise smoothing part. It not only performs the de-convolution by inverse filtering (high-pass filtering) but also removes the noise with a compression operation (low-pass filtering).

4. Wavelet Transform

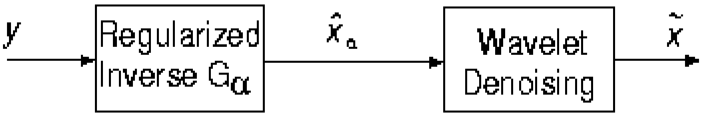
Although the Wiener filtering is the optimal tradeoff of inverse filtering and noise smoothing, in the case when the blurring filter is singular, the Wiener filtering actually amplify the noise. This suggests that a de-noising step is needed to remove the amplified noise. Wavelet-based de-noising scheme, a successful approach introduced recently by Donoho, provides a natural technique for this purpose. Therefore, the image restoration contains two separate steps: Fourier-domain inverse filtering and wavelet-domain image de-noising. The diagram is shown as follows-



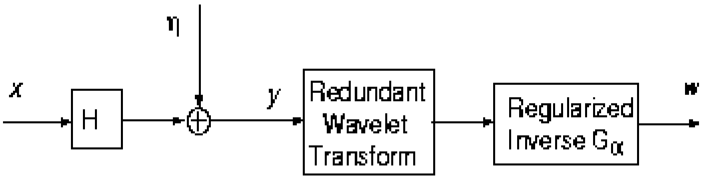
Donoho's approach for image restoration improves the performance; however, in the case when the blurring function is not invertible, the algorithm is not applicable. Furthermore, since the two steps are separate, there is no control over the overall performance of the restoration. Recently, R. Neelamani et al. proposed a wavelet-based deconvolution technique for ill-conditioned systems. The idea is simple: employ both Fourier-domain Wiener-like and wavelet-domain regularization. The regularized inverse filter is introduced by modifying the Wiener filter with a new-introduced parameter:

$$G_\alpha = \frac{H^* S_{xx}}{|H|^2 S_{xx} + \alpha S_{\eta\eta}}.$$

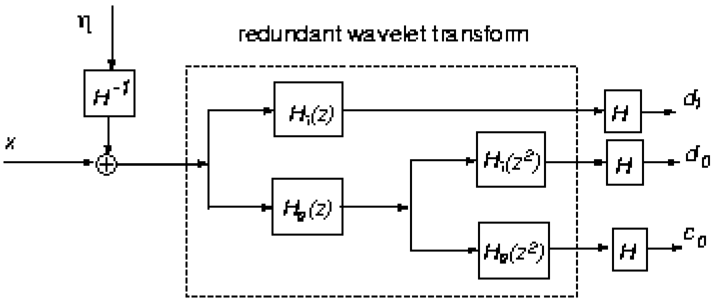
The parameter alpha can be optimally selected to minimize the overall mean-square error. The diagram of the algorithm is displayed as follows.



The implementation of the regularized inverse filter involves the estimation of the power spectrum of the original image in the spatial domain. Since wavelet transforms have good decorrelation property, the wavelet coefficients of the image can be better modeled in a stochastic model, and the power spectrum can be better estimated. This inspires a new approach: changing the order of the regularized inverse filtering and the wavelet transform. (See the following diagram).



This way the both inverse filtering and noise smoothing can be performed in wavelet domain. Specifically, the power spectrum of the image in a same sub-band can be estimated under the assumption that the wavelet coefficients are independent. Therefore, the power spectrum is just the variance of the wavelet coefficients. We note that the exchange of the order of inverse filtering and wavelet transform is valid only when un-decimated wavelet transform is used and the blurring function is separable. Therefore, for interpretation we can exchange the order of the blurring operation and the wavelet transform, which means that the inverse filtering cancels the blurring in the wavelet domain. So, wavelet thresholding results in a reasonable estimate. The above explanation can be visualized using the following figure.



Because the wavelet transform has good local character, therefore, it has been widely applied as a kind of signal and image processing tools. Since the concept of wavelet threshold has been proposed, because it can obtain the optimal estimate in the Besov space and other linear estimators cannot get the same result, much attention has been paid on it. Wavelet thresholding is a nonlinear method, and de-noising purpose can be achieved according to the process of wavelet coefficients in the wavelet domain. Its theoretical premise is coefficients of the image followed Gauss distribution, and wavelet coefficient with absolute larger magnitude is mainly obtained from the transformed signal and wavelet coefficient with absolute smaller magnitude is mainly obtained from the noise signal transformed. Then we can clear the noise by setting a threshold.

In this paper, wavelet transform is used in the image de-noising, and a new type of algorithm is used to de-noise image. The main contribution of the paper is to the proposal of a new algorithm for image de-noising using wavelet transform

II. Finite Duration Impulse (FIR)

In digital image processing, two-dimensional finite duration impulse (FIR) filters (also called non-recursive filters) are often used to improve the utility of a given image for a specific application. Techniques used to design a filter for one application may not be suitable for another. It is desirable, therefore, to develop filter design techniques that are flexible enough to encompass a large number of applications without sacrificing performance for any individual filtering problem. A filtering design tool that can be easily modified to accommodate a wide range of applications, such as smoothing or edge sharpening, would be of great value to a filter designer.

For a given FIR filter, there is a unique frequency response that is the Discrete Fourier transform (DFT) of the filter. The FIR filter can be obtained by performing the inverse Fourier transform on desired frequency response and truncating the result. This truncation, however, distorts the desired frequency response.

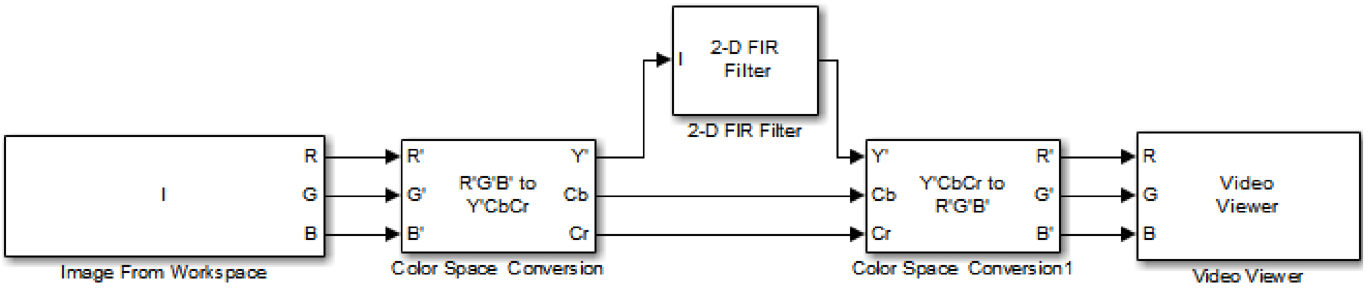
It is not possible to construct a linear, discrete FIR filter with a DFT that exactly matches all desired frequencies. Thus, techniques used in digital filter design attempt to compromise the trade-off between matching desired frequency responses with computed frequency response, and controlling the effects of spatial truncation.

III. Scope of the Study

Digital images need sharpening to overcome the effects of interpolation and anti-aliasing filters. Additional sharpening is often needed for creative effect, and a third round of sharpening is often needed for optimal reproduction, whether that is on screen or in print.

Sharpening of digital image files is one of the most important aspects of image quality and arguably one of the least understood. Sharpening brings out detail and gives an image presence, but not all images should be sharpened the same and even areas within an image often need a specific sharpening treatment. When it comes to sharpening, there are many factors that need to be considered.

To sharpen a color image, you need to make the luma intensity transitions more acute, while preserving the color information of the image. To do this, you convert an R'G'B' image into the Y'CbCr color space and apply a high pass filter to the luma portion of the image only. Then, you transform the image back to the R'G'B' color space to view the results. To blur an image, you apply a low pass filter to the luma portion of the image. The prime notation indicates that the signals are gamma corrected.



IV. Motivation

In wavelet based filtering we first break image into detailed and approximate coefficients then we set threshold for the particular image which can be calculated using various techniques like visu-shrinkage, mean thresh-holding etc. and then apply soft or hard thresh-holding on detailed coefficients and then apply inverse wavelet transform to get the filtered image. But in this method we lose information stored in detailed coefficients due to thresholding .we hereby propose an algorithm that minimizes this problem and gives a better restored image.

V. Algorithm

Usually thresholding is used in wavelet based transform but we have used image sharpening technique which has FIR filter which doesn't indiscriminately remove pixels from the detailed coefficients which enhances the edges of the image which are generally stored in detailed coefficient's of image and reduces the noisy components in process. This is a 3 step algorithm -

Algorithm step wise-

Step 1 - Apply wavelet transform on the given image so that we can have its detailed and approximate coefficients, we have used dwt () in-built function in Matlab for this step.

Step2-a-) Then we decide the parameters required for applying sharpening technique like Radius — Standard deviation of the Gaussian low pass filter, 'Amount' — Strength of the sharpening effect and 'Threshold' — Minimum contrast required for a pixel to be considered an edge pixel.

We have used imsharpen() function of Matlab so if we want to skip this step Matlab assign a default value for them as radius = 1, amount = 0.8 and threshold = 0, although it would be advisable to manually decide these parameters depending of type of noise and type of result we are expecting.

Step2-b-) Then we apply sharpening technique on the detailed coefficient's and obtain the enhanced detailed coefficients for that we have used Matlab imsharpen() function of Matlab to get our work done as this is already provide by Matlab.

Step4 - Now we apply inverse wavelet transform to get the de-noised image back image we get have not been penalized as the edges of detailed coefficients were enhanced using sharpening techniques which uses FIR technique. We have used Idwt () Matlab function for this step.

VI. Result

To check the validity of our algorithm we have taken a dataset of handwritten digits (easily available on web) which contains 5000 images of handwritten digits and size of each image is 20x20 pixels. Then we have used the neural network in Matlab and we are able to obtain accuracy of 95.2% on the original dataset after training neural network for the same.

Then we contaminate our dataset with Gaussian noises Then we applied median filter, simple wavelet filter and our modified algorithm filters and accuracy of various is shown below.

Table 1.1

Type of dataset	Accuracy
Original dataset (part of dataset on which neural network was trained)	95.2%
Noisy dataset (with Gaussian noise of mean=0.02 and variance =0.08)	20.46%
Median filtered noisy dataset	84.78%
Simple wavelet filtered dataset	80.62%
Proposed algorithm filtered dataset	85.48%

Clearly, our proposed algorithm outperforms the tradition wavelet filter by more than 5% accuracy and median filter smoothing by almost 1% thus proving the superiority of proposed algorithm.

VII. Conclusion

It is necessary to image de-noising processing to improve the quality of image. Much practical noise can be approximated as white noise with Gauss distribution, and removal of superposition of Gauss white noise has become an important direction in image de-noising research. Since the concept of wavelet threshold has been proposed, for its optimal estimate in the Besov space, much attention has been paid on it and various algorithms based on it have been developed. Wavelet thresholding used for de-noising is according to the adjustment of wavelet coefficients in the wavelet domain. In this paper, wavelet transform is used in the image de-noising, is used to estimate the de-noising results and algorithm proposed outperforms the traditional method by 5% and median filter by 1% thus giving us better performance. In future, we can automate the parameters required by sharpening function so that it can automatically choses the radius, amount and threshold according to type of noise in the image.

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