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A Novel Technique for Image Restoration Using Matching Filters

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Abstract- In image processing, an efficient method of removing noise from the images, before processing them for further analysis is a great challenge for the researchers. Image de-noising occurs due to transmission channel error, camera mis-focus, atmospheric turbulence, relative object camera motion etc…Such degradations are unavoidable while a scene is captured through a camera. Restoration of such image is an extremely essential in many practical applications. Image de-noising involves the manipulation of the image data to produce a visually high quality image. The kind of noise removal algorithms to remove the noise depends on the type of noise that occur during transmission and capturing .To remove these types of noise we have many filters like mean filter, median ,inverse filter, wiener filter, pseudo inverse filter. No single filter can remove both type of noise. In this paper various special types of noises applying to image and investigates the result of noise reduction techniques by applying the various filter.

Indexed Terms-Image restoration model; Image noise model; Wiener filter; Pseudo Inverse filter; Inverse filter.

1. INTRODUCTION

Visual information transmitted in the form of digital images is becoming a major method of communication in the modern age, but the image obtained after transmission is often corrupted with noise. [2] The received image needs processing before it can be used in applications. Image de-noising involves the manipulation of the image data to produce a visually high quality image. This paper gives us a brief idea about various image de-noising methods. The numerical computation has been done using MATLAB 7.8.0.

Image de-noising is often used in the field of photography or publishing where an image was somehow degrades but needs to be improved before it can be printed. For this type of application we need to know something about the degradation process in order to develop a model for it. When we have a model for the degradation process, the inverse process can be applied to the image to restore it back to the original form.

2. VARIOUS CAUSES OF NOISE IN IMAGES

Noise is introduced in the image at the time of image acquisition or transmission. Different factors may be responsible for introduction of noise in the image. The number of pixels corrupted in the image will decide the quantification of the noise. The principal sources of noise in the digital image are:

- Insufficient light levels and sensor temperature may introduce the noise in the image.
- Interference in the transmission channel may also corrupt the image.
- If dust particles are present on the scanner screen, they can also introduce noise in the image.

3. TYPES OF NOISE

Noise in image is caused by fluctuations in the brightness or color information at the pixels. Noise isa process which distorts the acquired image and is not a part of the original image. Noise in images can occur in many ways. During image acquisition the optical signals get converted into electrical which then gets converted to digital signal. At each process of conversion noise gets added to the image. The image can also become noisy during transmission of the image in the form of digital signals. The types of noises are:

(1) Gaussian noise
(2) Salt and pepper noise
(3) Shot noise (Poisson noise)
(4) Speckle noise

4. VARIOUS TYPES OF IMAGE DENOISING TECHNIQUES

An image is often corrupted by noise in its acquisition and transmission. Image de-noising is used to remove the additive noise while retaining as much as possible the important signal features. In the recent years there has been a fair amount of research on wavelet thresholding and threshold selection for signal de-noising[1],[2], because wavelet provides an appropriate basis for separation noisy signal from the image signal. The motivation is that as the wavelet transform is good at energy compaction, the small coefficient is more likely due to noise and large coefficient due to important signal features. These small coefficients can be threshold without affecting the significant features of the image.

Thresholding is a simple non-linear technique, which operates on one wavelet coefficient at a time. In its most basic form, each coefficient is threshold 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.

Other methods include filtering approach objectives of any filtering approach are:

- To suppress the noise effectively in uniform regions.
- To preserve edges and other similar image characteristics.
- To provide a visually natural appearance [3].

4.1. Importance of linear and non-linear de-noising

Image de-noising is very important task in image processing for the analysis of images. De-noising methods can be linear as well as non-linear .Where linear methods are fast enough, but they do not preserve the details of the images, whereas the non-linear methods preserve the details of the images. Broadly speaking, de-noising filters can be categorized in the following categories:

(1) Average filter
(2) Order statistics filter
(3) Adaptive filter.

4.2. Adaptive filter

Adaptive filters are changing the behavior on the basis of statically characteristics of the image region, encompassed by the filter region. Adaptive filters will provide good stability and efficiency due feedback of coefficients in algorithm.

4.3. Inverse filtering

The inverse filter is a straight forward image restoration method.If we know the exact psf model in the image degradation system and ignore the noise effect, the degraded image can be restored using the inverse filter.

$$g = hf + \eta,[3] \tag{1}$$

$$(f^{\wedge}(x,y) = f^{-1}(\frac{G(i,j)}{H(I,J)}) \tag{2}$$

Where $G(i,j)$is the inverse fourier transform of degraded system and $H\ (i,j)$ is the spectrum of psf.

4.4. Pseudo-inverse filter

$$\frac{\mathbf{1}}{\boldsymbol{H}} = \begin{cases} \frac{\mathbf{1}}{\boldsymbol{H}} & \boldsymbol{if\ H > \epsilon} \\ \boldsymbol{\epsilon} & \boldsymbol{if\ H \le \epsilon} \end{cases}$$

The value of ϵ affects the restored image with no clear objective selection of ϵ,restored images are generally noisy and not suitable for further analysis.

4.5. Wiener filter

The purpose of the wiener filter is to filter out the noise that has corrupted a signal. This filter is based on a statistical approach. Mostly all the filters are designed for a desired frequency response. Wiener filter deal withthe filtering of an image from a different view.

The goal of wiener filter is reduced the mean square error as much as possible. This filter is capable of reducing the noise and degrading function. One method that we assume we have knowledge of the spectral property of the noise and original signal. We used the linear time invariant filter which gives output similar as to the original signal as much possible [3].

4.5.1. Characteristics of the wiener filter are

- **Assumption**

Signal and the additive noise are stationary linear-random processes with their known spectral characteristics.

- **Requirement**

The wiener filter must be physically realizable, or it can be either causal.

- **Performance criteria**

There is minimum mean-square [MSE] error. The Fourier domain of the wiener filter is

$$G\ (u,v) =\ H*(u,v) \tag{3}$$

The Additive Noise Power Spectrum be $s_{nn}(u,v)$ and Image power spectrum be $s_{xx}(u,v)$

In Fourier domain, the wiener filter is expressed as

$$W(U,V) = \frac{H^{*}(U,V)}{|H(U,V)|^{2} + s_{nx}(u,v)} \tag{4}$$

Where $\boldsymbol{s_{nx}(u,v)}$=$\frac{\boldsymbol{s_{nn}(u,v)}}{\boldsymbol{s_{xx}(u,v)}}$ is the noise to signal ratio. This filter is acts like all pass filter.

5. RESULTS

A test image is taken and it is subjected to point spread function to degrade the image .after wards the adaptive linear filters applied to degraded image to get the restored image. To evaluate the fidelity criteria NCC and PSNR &ISNR is computed. In this computation the regression analysis will give a better idea which method is better one to calculate the efficiency of the algorithm.

5.1. Objective fidelity criteria

For comparing original image and restored image, we calculate the parameters

5.2. Mean square error

The MSE is the cumulative square error between the restored image and original image defined by

$$MSE = \frac{1}{M \times N} \sum_{X=1}^{M} \sum_{Y=1}^{N} [f(x,y) - g(x,y)]^2 \quad (5)$$

Where, f is the original image and g is the restored image. The dimension of the image is $M \times N$. Thus MSE should be as low as possible for effective denoising.

5.3. Peak signal to noise ratio (PSNR)

PSNR is the ratio between maximum possible power of a signal and the power of distorting noise which affects the quality of its representation. It is defined:

$$PSNR = 10 \log_{10} \frac{255 \times 255}{\frac{1}{M \times N} \sum_{X=1}^{M} \sum_{Y=1}^{N} [f(x,y) - g(x,y)]^2} dB \quad (6)$$

Where 255(MAX_f) is the maximum signal value that exists in our original "known to be good" image.

Signal to noise ratio is defined as the power ratio between a signal and the background noise.

$$SNR = \frac{P_{signal}}{P_{noise}} \quad (7)$$

Where p is average power .both noise and power must be measured at the same bandwidth.

Normalized correlation coefficient:

$$NCC = \frac{1}{M \times N} \sum_{I=1}^{M} \sum_{J=1}^{N} f(I,J) \times g(I,J) \quad (8)$$

Where $f\ (i,j)$ is the original image and $g\ (i,j)$ is the restored image. This correlation measures the similarity between the original image and restored image

5.4. Improvement in signal to noise ratio

Improvement in signal to noise ratio is used to test the performance of the image restoration algorithm objectively. If $f\ (x,y)$ and $g\ (x,y)$ represent the original and the degraded image the expression of ISNR is given by.

$$ISNR = 10 \log_{10} \frac{\sum_{x,y} [f(x,y) - g(x,y)]^2}{\sum_{x,y} [f(x,y) - h(x,y)]^2} \quad (9)$$

Here, $h\ (x,y)$ is the restored image .this metric can be used for simulation purposes only because the original image is assumed to be available which is not true practically.

Table 1. Results of various degradation models with pseudo inverse filter

Pseudo inverse filter									
	Flower			**Gold fish**			**Hibiscus**		
PSF	**NCC**	**PSNR**	**ISNR**	**NCC**	**PSNR**	**ISNR**	**NCC**	**PSNR**	**ISNR**
ones(9,9)/81	0.45	5.5	0.0052	0.7116	8.02	0.0059	0.6466	6.9428	0.0049
ones(10,10)/100	0.45	5.5	0.0061	0.7116	7.92	0.0066	0.6466	6.8594	0.0056
ones(11,11)/121	0.45	5.4	0.0069	0.7112	7.84	0.0072	0.6465	6.7437	0.0061
average(6,6)	0.45	6.1	0.0025	0.7115	8.37	0.0032	0.6468	7.2619	0.0028
average(7,7)	0.45	6.0	0.0033	0.7114	8.21	0.0043	0.6466	7.1873	0.0034
disk(10)	0.45	5.2	0.021	0.7099	7.62	0.0183	0.6472	6.4323	0.0176
disk(15)	0.45	5.3	0.0381	0.7082	7.50	0.0301	0.6479	6.2976	0.0311
motion(20,10)	0.45	6.0	0.0203	0.7115	8.26	0.0178	0.6467	7.4873	0.0167
motion(30,10)	0.45	6.0	0.0365	0.7115	8.13	0.0285	0.6472	7.1059	0.0296
motion(40,20)	0.45	5.8	0.0508	0.7108	8.07	0.0365	0.6478	7.0373	0.041

Table 2. Results of various degradation models with wiener filter

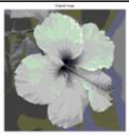
Wiener filter									
	Flower			**Gold fish**			**Hibiscus**		
PSF	**NCC**	**PSNR**	**ISNR**	**NCC**	**PSNR**	**ISNR**	**NCC**	**PSNR**	**ISNR**
ones(9,9)/81	0.98	26.5	8.0237	0.9925	25.10	4.2168	0.9928	26.9062	4.4536
ones(10,10)	0.98	26.0	8.2192	0.9912	24.80	3.871	0.9916	26.6076	4.6006

ones(11,11)/121	0.98	25.7	8.6752	0.9908	24.52	4.0639	0.9921	26.4351	5.0779
average(6,6)	0.99	27.7	5.8333	0.9945	26.12	2.9178	0.9942	27.6432	3.4478
average(7,7)	0.99	27.4	6.7857	0.9937	25.76	3.2308	0.9936	27.357	3.6302
disk(10)	0.97	23.7	14.0981	0.9868	23.00	7.4065	0.9886	25.1783	9.3324
disk(15)	0.96	22.0	13.8108	0.9811	21.54	7.6317	0.9841	23.906	11.8719
motion(20,10)	0.98	24.7	11.5618	0.9927	25.07	6.3666	0.9903	26.0432	7.7017
motion(30,10)	0.97	23.0	10.9237	0.9902	23.92	6.4601	0.9876	24.9909	9.0752
motion(40,20)	0.96	22.0	10.6456	0.9859	22.46	5.9409	0.9842	23.9747	9.2771

Table 3. Results of various degradation models with inverse filter

Inverse filter									
	Flower			**Gold fish**			**Hibiscus**		
PSF	**NCC**	**PSNR**	**ISNR**	**NCC**	**PSNR**	**ISNR**	**NCC**	**PSNR**	**ISNR**
ones(9,9)/81	1.00	64.6	4.19e+10	1	59.09	1.28e+11	1	63.5697	2.44e+11
ones(10,10)/100	1.00	65.1	1.00e+05	1	56.94	1.19e+04	1	63.6066	1.05e+04
ones(11,11)/121	1.00	63.8	5.36e+09	1	57.34	1.97e+10	1	61.6422	2.35e+10
average(6,6)	1.00	69.3	3.89e+04	1	58.96	5.81e+03	1	67.2899	4.77e+03
average(7,7)	1.00	67.2	2.97e+10	1	61.46	1.12e+11	1	65.0773	1.73e+11
disk(10)	1.00	62.2	2.16e+05	1	57.55	7.77e+04	1	61.0632	1.06e+05
disk(15)	1.00	61.5	1.97e+05	1	55.74	9.55e+04	1	60.6391	1.34e+05
motion(20,10)	1.00	69.2	6.56e+07	1	63.75	4.69e+08	1	68.4056	7.87e+08
motion(30,10)	1.00	68.8	2.02e+08	1	63.44	1.60e+08	1	67.9014	3.86e+08
motion(40,20)	1.00	68.4	9.60e+06	1	62.38	1.81e+07	1	66.7248	5.45e+07

Table 4. Figures of (a)original image (b) restored image (c),(d),(e) Degraded images Of Different PSF's

Original image	Restored image	Average PSF	Disk PSF	Motion PSF
				
Fig.(a)	Fig.(b)	Fig.(c)	Fig.(d)	Fig.(e)

6. CONCLUSION

In modern digital world, the electronic industries are launching the electronic gadgets with better features day by day, by providing the better services and developing the next generation networks. To avoid the band width limitations in communications, digital communications such as digital image, video processing and multimedia processing are used. The selection of right de-noising algorithm plays a vital role, it is important to experiment and compare the methods. In this paper, the computational time can be reduced to 7 CPU and also improves the utilization of memory. In this paper, different types of de-noising filters comparisons are discussed.

6.1. Scope of future work

This paper can be extended for video de-noising and will do experiment with hybrid filters ,this algorithm can be apply for color images as future work.

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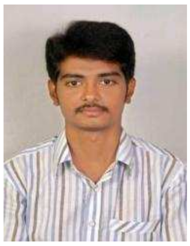

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