University of Science and Technology of Hanoi

Information and Communication Technology Department

Master Thesis

Academic year 2016 - 2017

NOISE EVALUATION AND REDUCTION

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presented by

HOANG DUC VIET

registered at University of Science and Technology of Hanoi(USTH)

supervised by Ph.D Tran Giang Son

Host organization : ICTLab - USTH

Ha Noi - Viet Nam

ATTESTATION

I hereby, HOANG DUC VIET, certify that my report doesn't contain plagiarism (copy/paste) from other sources.

In case of plagiarism in my report, I know the consequences and I understand that my report won't be evaluated. In this case, my M2 internship will be noted as "fail".

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Acknowledgements

Asbtract

A long time ago, image processing have met problem about image quality. Noise usually appear in image and it is main cause to promote technology find solve to remove noise. Nowaday, science and technology develop to build denoise methods which to help images have best quality. In this report, we propose 4 method: median filter, average filter, gaussian filter and wiener filter. Methods participate which help SWARMS project to obtain best result.

Contents

Chapter 1

Introduction

1.1 Context

Moreover, noise also appears in the images. Image noise is created by the sensor and circuitry from scanner or digital camera. Film grain and noise of an ideal photon detector are one of cause. So brightness or color information in images will be changed. Image noise is not same as normal image that have many different information.

Although camera technology is very improve over the past decade, it still has not totally remove noise for images. So now, researchers still find to way which improve about camera to have better images is better. Noise can appear in our photo for different reasons. Noise signal with the light signal increase when high ISO is used. Camera need lighter to creat good image, but noise also more appear. When the image sensor is hot, photons evacuate from the images and damage other images. Long exposures is one of cause to appear noise in image becaue the sensor open to have more image information and electrical noise will appear.

Denoise is a process of remove noise to images. There are ways to noise removal in image, data. With image denoise model is completely remove noise and protect edges. Basically, there are two types of models : linear and non-liner. Linear models is removing models is the speed also as limitations of itself. It's not able to protect edges which are recognized as discontinuities in the image. It's not able to protect edges which are recognized as discontinuities in the image. So, blur edges could appear in images.

On the other hand, non-linear models can solve edges problem much better than linear models. We suppose non-linear image denoising model use the Total Variation (TV)- filter. Denoise a degraded image X by X = S + N, meaning sum of S (original image) and N (Gaussian noise) with unknown value. We call unknown value is (σ) which is the standard deviation of the distribution.

1.1.1 Internship context

One of the major problems in document digitalization is noise. Image noise is random (not present in the object imaged) when it change brightness level or color in images. It can be generated in many scanning steps, such as grayscaling or thresholding. It can also be caused by image lossy compression algorithms, such as JPEG's discrete cosine transformation and thresholding. Noise is one of the main factors contributing to degratation of accuracy in optical character recognition of the scanned documents, a process aiming at providing a high semantic description of the content of the document. At ICTLab, we have been dealing with scanned document in the context of project ARCHIVES. A good noise evaluation and reduction algorithm will improve our document analysis (including optical character recognition)

results. We are going to survey different denoising methods. From this, we will compare result of methods as : Median filter, Average filter, Gaussian filter, Wiener filter by we are using PSNR and MSE. Based on the quality characteristics of two methods MSE & PSNR to compare. Created comparison table and showed image result, finally we will know method is the best. Although, images processing has many method to remove noise but due to limited time, many other methods can not be explored and the results are only relative.

1.2   Problematic

We have two problems in this topic:

Noise

- Noise is the cause of errors from image when in pixel values that do not reflect the true intensities of the real scene.

- ISO values: a standard of absolute sensitivity to light.

There are 3 type of noise:

Fixed pattern noise appears during long exposures. When the camera is working for long periods of time and it heats up, the sensor starts to produce these strange dots of color in our image. Our camera is hotter, more fixed pattern noise will appear. Fixed pattern noise usually easier to remove since it is repeatable. A camera just has to know the pattern and it can remove fixed pattern.
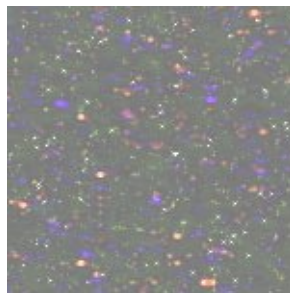
Long Exposure
Low ISO Speed

Random noise may be the most common image noise. Random noise appears whenever we are using high ISO values. ISO has mean is a standard which describes its absolute sensitivity to light. Quality of camera is good when it remove random noise through software. Example: Neat Image and Noise Ninja programs, they can be removing noise and protect image information. When technology continues to improve, we can shoot in low light situation.

Short Exposure
High ISO Speed

Banding noise is dependent on what type of camera we are using. With high end cameras, we have never seen banding noise. Banding noise will appear when lower quality photograph are shot with higher ISO value. There are causes help banding noise appear: in the dark of photos or increase exposure too much and digitally make a photograph too bright. We may also see more banding noise in certain white balances which is the process of removing unreal color.

Susceptible Camera
Brightened Shadows

Denoise

Noise removal is very important task in image processing. It will help to remove the noise from the image and rebuild to original image is the best quality. In modern digital image processing, data denoising is a hard problem and it used to application areas. Noise removal is popular solution for photography or improve the image was degraded.

Filtering is technique which can be decreasing or increasing an image.It's processed value for current pixel will depends itself and surrounding pixels . The value of any pixel in the output image is used by applying algorithms to the values of the pixels in the place which corresponding input pixel.

1.3   Report organization

In this report, we have 5 chapters as below :

- Chapter 1 : Introduction

  This chapter included presentation of: Context and Problematic. Context is the part that describe about problems and solutions through this report. Problematic is determination and analysis to problem in this topic.

- Chapter 2 : State Of The Art

  Collected different papers addressing the same topics of internship. Next to explain the work published, by giving the context of the work, the main idea, the main results. From this, we can learn more about how to present and solve problems of the authors.

- Chapter 3 : Contribution

  In this part, proposed method to solve the problem in the introduction chapter. Beside this, explain method/algorithm/system in proposition.

- Chapter 4 & 5 : Result & Conclusion

  This part include the result of the method/algoritm/system developed. Moreover, it contain comparisons table, figures, graphics and comment. Recall the problematic, methods used, contribution, results obtained and future developed.

Chapter 2

State of the art

2.1 Noise Removal in Image Processing using Median [2]

This paper was written by Monika Kohli and Harmeet Kaur. Authors research and analyze median filter. From this, the filter is compared with median and Adaptive median filter.

Types of noise

Impulse noise (Salt & pepper noise): Used for this type of noise Black and white dots appear in this noise so the name salt & pepper noise.

Amplifier noise (Gaussian noise): is the sum of the actual pixel value and a random

Quantization noise (Uniform noise): It appears because quantization process the pixels to a number of discrete levels

Multiplicative noise (Speckle noise): It appears because random value multiplications with pixel values of the image as modeled process.

Periodic noise(Stationary noise): It appears because attend between electronic components and appear from interference during image acquisition.

After image noise can be classified as above, characteristics of each type are specified. They analyse algorithm of filters : Median filter, Adaptive median filter, Proposed Median Filter.

Finally, Comparison of filters when used PSNR to calculate quality of images with 3 methods : Median filter, Adaptive median filter, Proposed Median Filter. They obtained result show that the proposed method is the best. In future, result can be improved by different noise such as : Gaussian noise, Speckle noise etc

2.2   The Sure-Let Approach to Image Denoising [3]

[Thierry Blu & Florian Luisier]

It's a new approach to noise removal by the image-domain minimization of an estimate of the mean squared error(MSE). They called Stein's unbiased risk estimate (SURE). They called Linear expansion of thresholds (LET) by combination of elementary denoising processes. Evaluate this denoising performances by comparing PSNR. Combined 3 step above to SURE-LET Approach.

Result:
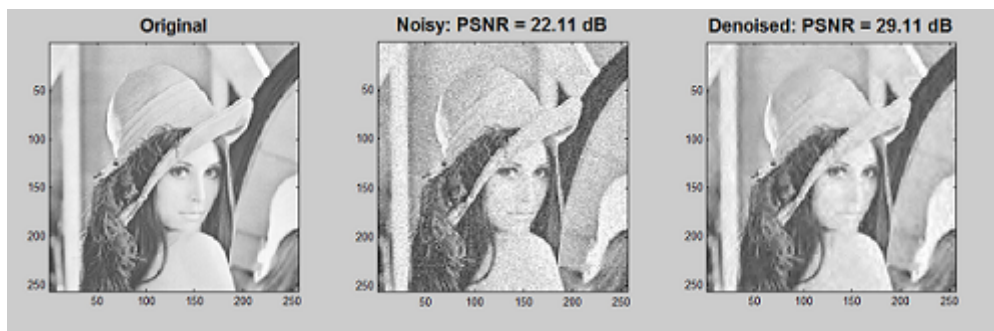
Follow SURE-LET program in Matlab, input MSE is compare between noisy image and original image, output MSE is compare between denoise image and original image. So they use output MSE result to table of Comparison Of The Results.

2.3   Study on Methods of Noise Reduction in a Stripped Image [4]

[Chi Chang-yan, Zhang Ji-xian, Liu Zheng-jun]

Noise is one of image quality problem in the image processing major. Noise reduction is necessary for us to do remove noise and description useful information more prominent. The Gray Value Substitution and Wavelet Transformation are methods in noise removal. Finally, MSE and PSNR are evaluated the processed image suitable in this paper.
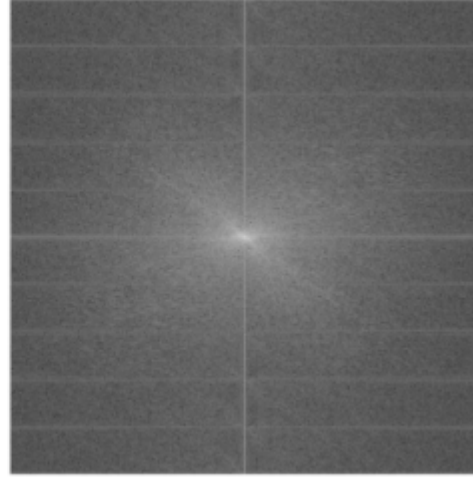
Image processing results of gray value substition

We can see from this image, most noise line is changed and it is not affected by this method. However, some small noise still appear, and the brightness after processing is stronger than that before.
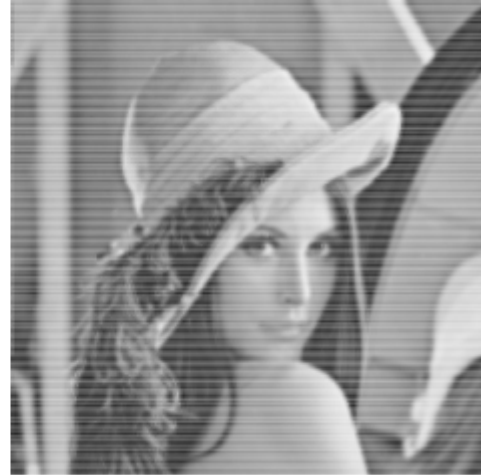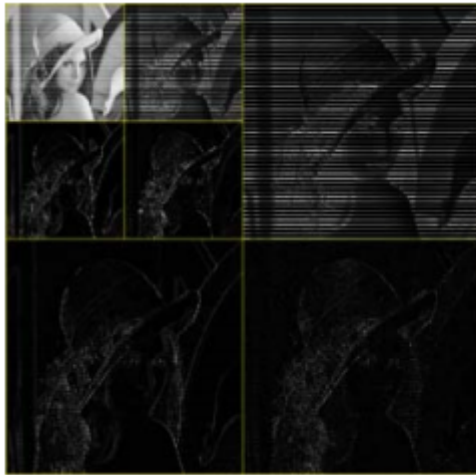
Image decomposition using Wavelet and usual wavelet denoising result

Wavelet method haven't solution remove noise in the horizontal domain, the vertical and cross part of image. Moreover this image haven't much noise so they obtain result as above.

From result tables, they can see that, low pass filter can't use to remove noise. And the other two methods is relatively accepted

2.4 Different Noise Types and Digital Image Processing[5]

[Gursharan Kaur, Rakesh Kumar, Kamaljeet Kainth]

As know, image is used in various fields like medical and education. Noise appear everywhere including images. From this, noise reduction is the main focus to retain the quality of the image.This paper is review problem to types of noise and solution.

Types of noise: Gaussian noise, Salt and pepper noise, Poisson noise

Different types of linear and non-linear filters.

Mean Filter: Mean filter is a type of linear filter that computes average value of the corrupted image.

Median Filter: Median filter is a type of non-linear filter. It used to reduce the measure of intensity variation between one pixel and the other pixel.

In this paper, the purpose is denoising of the images. Techniques that are already using may not be able to find the best result so in the future they may find the techniques that provide optimum solution to the noise.

2.5   Impulse Noise Reduction methods in Digital images [6]

[Himani Goel, Seema Rani]

They review this paper about denoise. From this, compare results by PSNR and MSE to obtain best result.

Linear Filters: Mean filter, Wiener filter.

Non Linear filters: Adaptive median filter, Improved progressive switching median filter.

By the results, they see the median filtering is better than mean or average filter to remove impulse noise but it affect the edge details.

2.6   Optimal Gaussian Filter for Effective Noise Filtering [7]

[Sunil Kopparapu and M Satish]

Noise removal is important problem in many signal processing applications. In this paper, they have show the optimal Gaussian filter that best filters noise, with the noise is AWGN. The contribution of this paper is identification of a method to obtain the optimal Gaussian filter which best filters a signal contaminated with AWGN.

Gaussian Approach

There are basic two ways of remove noise in the signal:

Pre-processing of the signal to enable noise removal

Use of a set of robust algorithms that can compensate for the inherent noise.

In signal processing, pre-processing of the signal is the preferred approach.

They have shown that the method works well for signals whose bandwidth and the input signal . We are in the process of verifying the validity of their approach for practical signals and finish in the next time.

2.7 Image Enhancement with Noise Reduction in Spatial Domain[8]

[S. Shyam Prasad, R. Priya]

Digital images are mostly corrupted by mixed noise from several sources. It is a big problem have long existed. Generally, some filters can reduce additive or impulse noise, but it can't remove impulsive noise and additive noise. This paper propose change mutual filtering method, which can remove both impulsive and additive noise, when compared to average filter and median filter. The solve show that the proposed filtering action can remove impulsive and additive noise while protecting edge.

MODELING NOISE OF THE IMAGES

Additive Noise:

Additive noise is noise of an image sensor. It's meaning the constant noise in dark areas of the image.

Impulse Noise:

Impulse noise is called Salt and pepper noise or spike noise.

Mixed Noise:

Mixed noise is the combination of additive noise and impulse noise.

REMOVING NOISE FROM IMAGES BY FILTERING

Linear Filter
Average filter is one of the linear filter.

Non-Linear Filters
Median filter and Bilateral filter are the non linear filters.

PROPOSED APPROACH

Average Filter
The idea of average filtering is simply to replace each pixel value in an image with the average value of its area, including itself.

Median Filter
The median filter is popular technique nonlinear in digital filtering.It removes noise from an image or signal (speckle noise & salt-pepper noise).

Bilateral Filter

This is a non-linear technique which can blur an image while taking strong edges. Solve to by combine nonlinear means with nearby image values.
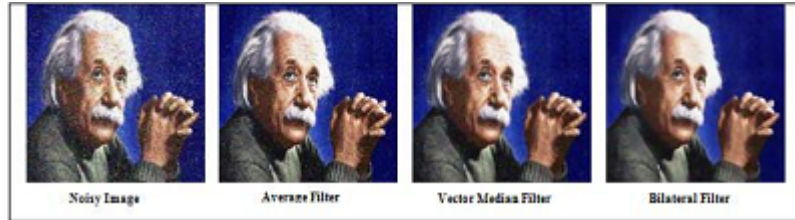
Quality Measures of Einstein image

Bilateral filtering method is changed in this paper. It can removed 2 types of noise : impulsive noise and additive noise.

Chapter 3

Contribution

Spatial filtering is a types of finite impulse response (FIR) filtering. It is a mask of weights with shape as rectangular. It mean that sliding the mask along the image and apply to multiplication and collection operation on the pixels protected by the mask.

Original Image

First, we are going to read and show original image as below :

Original Image

Add noise (gaussian noise & 0.05 variance.)

3.1 Median Filter

Median Filter is family of order filters. It has process : Replace the value of a pixel with the median value of the neighborhood.

$I_{median} = median(I[i,j])$ with $(i,j) \in neighborhood$

30	10	20
10	250	25
20	25	30

$\Rightarrow$ 10 10 20 20 **25** 25 30 30 250
$\uparrow$
median

The median filter method is very popular in image processing and it protects edges while removing noise in certain environment.

Filter 3×3

Filter 5×5

Filter 7×7

3.2   Average Filter

Feature:

Average Filter is spatial filter that applies to a neighborhood (local method). It's a linear filter as a convolution. This mean a pixel is replaced by the average of itself and its neighbours which size determines the amount of smoothing. And equivalent to a filtering operation lowpass.

Average Filter have:

Filter 3×3

$$\frac{1}{9}\begin{array}{|c|c|c|} \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}$$

Filter 5×5

$$\frac{1}{25}\begin{array}{|c|c|c|c|c|} \hline 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 \\ \hline \end{array}$$

Filter 7×7

$$\frac{1}{49}\begin{array}{|c|c|c|c|c|c|c|} \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline \end{array}$$

Average filtering is simply to replace each pixel value in an image with the average value of its area, including itself. Its meaning is remove pixel values which aren't types of their environment.

Filter 3×3

Filter 5×5

Filter 7×7

3.3 Gaussian Filter

The Gaussian kernel in dimension 2:

$$G(x, y) = \frac{1}{2\pi\sigma^2} \exp\left[-\frac{(x - \mu_x)^2 + (y - \mu_y)^2}{2\sigma^2}\right]$$

Define the Gaussian mask($\sigma = 2$):

Filter 3×3

$\frac{1}{16}$

1	2	1
2	4	2
1	2	1

Filter 5×5

$\frac{1}{273}$

1	4	7	4	1
4	16	26	16	4
7	26	41	26	7
4	16	26	16	4
1	4	7	4	1

Filter 7×7

$\frac{1}{1003}$

0	0	1	2	1	0	0
0	3	13	22	13	3	0
1	13	59	97	59	13	1
2	22	97	159	97	22	2
1	13	59	97	59	13	1
0	3	13	22	13	3	0
0	0	1	2	1	0	0

Gaussian filters never go through to function input while minimizing the time.

From theory above, we are going to build function for gaussian filter :

Filter 3×3

Filter 5×5

Filter 7×7

3.4 Wiener Filter

The Wiener filter decreases the mean square error between the random process and the desired process.

Original Image   Added Gaussian Noise   Denoise by Wiener Filter
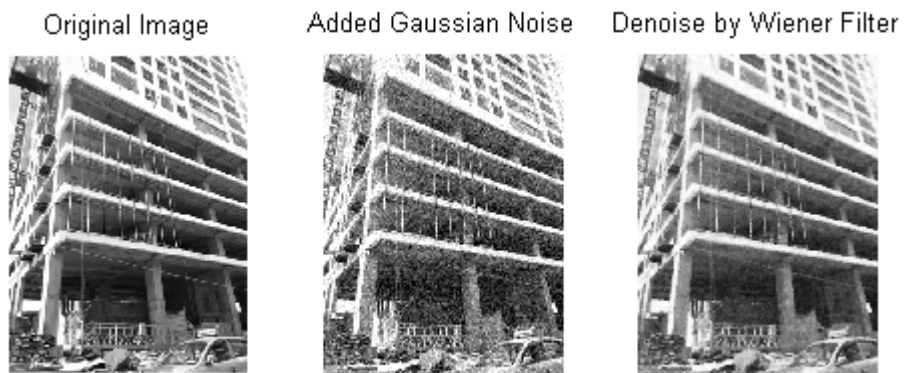
Filter 3×3

Original Image   Added Gaussian Noise   Denoise by Wiener Filter

Filter 5×5

Original Image   Added Gaussian Noise   Denoise by Wiener Filter

Filter 7×7

Chapter 4

Results

Mean Square Error

In statistics, the mean squared error (MSE) is used to calculate the average of the squares of the errors. It mean that the difference between the estimator and what is estimated. The MSE is one of quality evaluation method. In this internship, it help us to know best result when it is the smallest.

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (\hat{Y}_i - Y_i)^2$$

Peak signal to noise ratio

The PSNR is also one of quality evaluation method. In this internship, it help us to know best result when it is the biggest.

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

Construction Image

(a) Original 1

(b) Original 2

(c) Original 3

(d) Original 4

(e) Original 5

			Median	Average	Gaussian	Wiener
Original 1	Noise	MSE	0.0125	0.0251	0.012	0.0084
		PSNR	67.1535	64.1264	67.3409	68.8738
	Denoise	MSE	0.0097	0.022	0.0095	**0.007**
		PSNR	68.269	64.7115	68.3762	**69.6511**
Original 2	Noise	MSE	0.0096	0.0219	0.0096	0.0075
		PSNR	68.298	64.7271	68.2967	69.3898
	Denoise	MSE	0.0055	0.0166	0.0056	**0.0044**
		PSNR	70.7071	65.9348	70.6237	**71.654**
Original 3	Noise	MSE	0.0078	0.0178	0.0077	0.0061
		PSNR	69.2093	65.638	69.2572	70.2559
	Denoise	MSE	0.0034	0.0122	0.0035	**0.0028**
		PSNR	72.761	67.2713	72.6781	**73.6324**
Original 4	Noise	MSE	0.0065	0.0183	0.0067	0.0054
		PSNR	69.9904	65.5003	69.8929	70.8107
	Denoise	MSE	0.0026	0.0144	0.0031	**0.0022**
		PSNR	73.9221	66.5571	73.1714	**74.65**
Original 5	Noise	MSE	0.0125	0.0351	0.0131	0.0098
		PSNR	67.1789	62.6729	66.9615	68.2047
	Denoise	MSE	0.0048	0.0243	0.0056	**0.0046**
		PSNR	71.3083	64.2764	70.6356	**71.5275**

Comparison Table

Rubbish Image

(a) Original 1   (b) Original 2   (c) Original 3   (d) Original 4   (e) Original 5

			Median	Average	Gaussian	Wiener
Original 1	Noise	MSE	0.007	0.0198	0.007	0.0053
		PSNR	69.6741	65.1589	69.6536	70.8804
	Denoise	MSE	0.0032	0.0156	0.0036	**0.0025**
		PSNR	73.1106	66.1969	72.5825	**74.1694**
Original 2	Noise	MSE	0.0078	0.0173	0.0076	0.0061
		PSNR	69.2119	65.7582	69.3064	70.2561
	Denoise	MSE	0.0036	**0.00126**	0.0038	0.0029
		PSNR	72.5146	67.1263	72.3851	**73.4524**
Original 3	Noise	MSE	0.0158	0.0336	0.015	0.0115
		PSNR	66.1394	62.8625	66.3823	67.5195
	Denoise	MSE	0.0083	0.0246	0.0081	**0.0063**
		PSNR	68.9656	64.2139	69.0718	**70.1636**
Original 4	Noise	MSE	0.0313	0.0567	0.0287	0.0235
		PSNR	63.1696	60.5959	63.5549	64.4181
	Denoise	MSE	0.0207	0.0424	0.0185	**0.0161**
		PSNR	64.9661	61.8601	65.4527	**66.0756**
Original 5	Noise	MSE	0.0096	0.0176	0.0092	0.007
		PSNR	68.3119	65.677	68.4872	69.698
	Denoise	MSE	0.0055	0.0123	0.0053	**0.004**
		PSNR	70.7050	67.2474	70.9133	**72.0813**

Comparison Table

Pagoda Image

(a) Original 1   (b) Original 2   (c) Original 3   (d) Original 4   (e) Original 5

			Median	Average	Gaussian	Wiener
Original 1	Noise	MSE	0.013	0.0168	0.0115	0.0068
		PSNR	66.9999	65.8739	67.5091	69.7993
	Denoise	MSE	0.0098	0.0141	0.0093	**0.0055**
		PSNR	68.2117	66.6490	68.4598	**70.7544**
Original 2	Noise	MSE	0.0138	0.0189	0.0122	0.0076
		PSNR	66.7404	65.3739	67.2818	69.3011
	Denoise	MSE	0.0098	0.0145	0.0088	**0.0053**
		PSNR	68.2338	66.5220	68.6970	**70.9009**
Original 3	Noise	MSE	0.0150	0.0215	0.0131	0.0081
		PSNR	66.3743	64.8131	66.9631	69.0515
	Denoise	MSE	0.0114	0.0177	0.0102	**0.0065**
		PSNR	67.5543	65.6549	68.0291	**70.0034**
Original 4	Noise	MSE	0.0116	0.0229	0.0106	0.0069
		PSNR	67.4972	64.5418	67.8751	69.7300
	Denoise	MSE	0.0080	0.0188	0.0072	**0.0047**
		PSNR	69.1060	65.3952	69.5399	**71.4029**
Original 5	Noise	MSE	0.0141	0.0230	0.0125	0.0086
		PSNR	66.6335	64.5060	67.1643	68.8033
	Denoise	MSE	0.0104	0.0179	0.0087	**0.0062**
		PSNR	67.9741	65.6092	68.7310	**70.2064**

Comparison Table

Pond Image

(a) Original 1   (b) Original 2   (c) Original 3   (d) Original 4   (e) Original 5
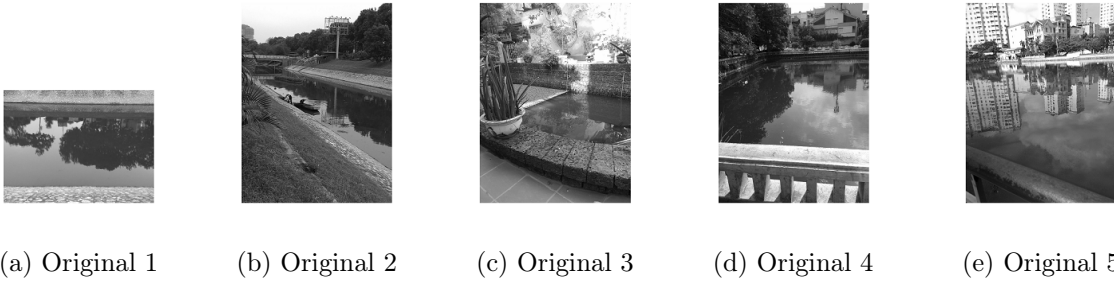
			Median	Average	Gaussian	Wiener
Original 1	Noise	MSE	0.0151	0.0374	0.0148	0.0116
		PSNR	66.3488	62.4067	66.4381	69.5
	Denoise	MSE	0.0071	0.0267	0.0071	**0.0057**
		PSNR	69.6156	63.8625	69.6193	**70.5647**
Original 2	Noise	MSE	0.009	0.0161	0.087	0.0066
		PSNR	68.5651	66.0539	68.7473	69.9595
	Denoise	MSE	0.0049	0.0118	0.0049	**0.0037**
		PSNR	71.1950	67.4075	71.1985	**72.4594**
Original 3	Noise	MSE	0.0103	0.0181	0.0095	0.0071
		PSNR	68.0057	65.5457	68.3309	69.5910
	Denoise	MSE	0.0063	0.0136	0.0059	**0.0045**
		PSNR	70.1294	66.7905	70.4278	**71.5971**
Original 4	Noise	MSE	0.0085	0.0148	0.0082	0.0062
		PSNR	68.8176	66.4207	68.9979	70.1919
	Denoise	MSE	0.0044	0.0103	0.0045	**0.0034**
		PSNR	71.7345	67.9993	71.5601	**72.7996**
Original 5	Noise	MSE	0.0111	0.0191	0.0098	0.0068
		PSNR	67.6856	65.3228	68.2256	69.7923
	Denoise	MSE	0.0076	0.0149	0.0065	**0.0044**
		PSNR	69.3244	66.4011	70.0243	**71.7026**

Comparison Table

Normally paper in the chapter 2 as we see, they usually use PSNR or MSE to quality comparison of image after denoise. But in this report, we used 2 methods to obtain best result and showed best noise removal method. With 4 images class, value comparison by MSE and PSNR. We have best of results Wiener filter with MSE is minimum mean square error and it is maximum PSNR.

Chapter 5

Conclusion

Problematic of internship is images noise and denoise. Because all of image noise will be the main cause of image degradation. Denoise solution is very popular to remove noise. In this report we propose main method : median filter, average filter, gaussian filter and wiener filter. MSE and PSNR are 2 quality evaluation method for image when image was remove noise. With values of comparison table, we obtain Wiener filter is the best method. In the future, we will research and improve new methods to solve noise problems in better images.

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[2] Assistant Professor Monika Kohli, G.C.G Ludhiana

Assistant Professor Harmeet Kaur, G.C.G Ludhiana

Noise Removal in Image Processing using Median, Adaptive Median and Proposed Median Filter and Respective Image Quality Comparison

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The SURE-LET Approach to Image Denoising

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