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NOISE EVALUATION AND REDUCTION

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presented by

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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".

Date 15/09/2017

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Finally, I would like to thank my family all for their loves and their supports to me. My parents and younger sister help me very much. From this, I can devote all time to the graduation internship.

Asbtract

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 unlike by product of image capture 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 increases with the light signal when high ISO is used, therefore our camera will capture more light to illuminate the scene, but graininess will be more apparent. When an image sensor heats up, photons separate from the images and destroy other images. Long exposures also give our image greater risk of showing image noise, since the sensor is left open to gather more image data and this includes electrical noise.

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. Good feature of linear noise 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. 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) variation of brightness or color information 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:

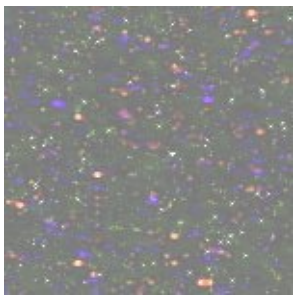
- **Noises**

  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. Cameras are good at reducing the amount of random noise seen in photographs through technology. Example: Neat Image and Noise Ninja programs, they can be reducing noise while still retaining actual 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.

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 true pixel value and a random

Quantization noise (Uniform noise): It is caused by quantizing the pixels to a number of discrete levels called as quantization noise.

Multiplicative noise (Speckle noise): can be modeled by random value multiplications with pixel values of the image.

Periodic noise(Stationary noise): It is caused by interference 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.

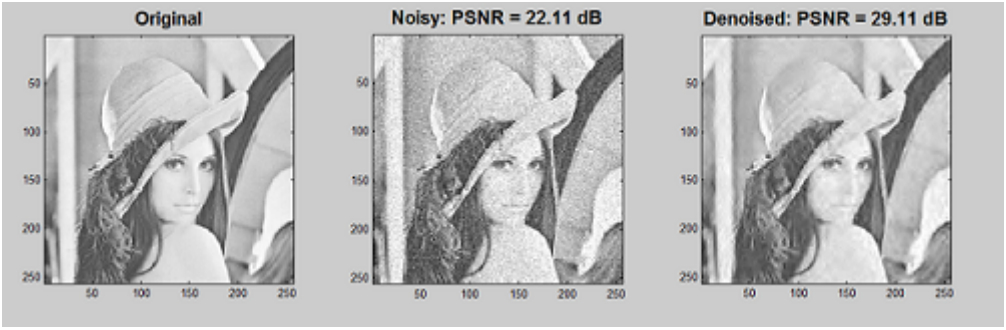
Finally, Comparison of filters when used PSNR to calculate quality of images with 3 methods : Median filter, Adaptive median filter, Proposed Median Filter. They obtained result show that the proposed method is the best. In future, result can be improved by different noise such as : Gaussian noise, Speckle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

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

The paper was written by Thierry Blu and Florian Luisier. It's a new approach to image denoising, based on the image-domain minimization of an estimate of the mean squared error(MSE).

A new approach to image denoising, based on the image-domain minimization of an estimate of the mean squared error: Stein's unbiased risk estimate (SURE). The denoising process can be expressed as a linear combination of elementary denoising processes: Linear expansion of thresholds (LET). 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.

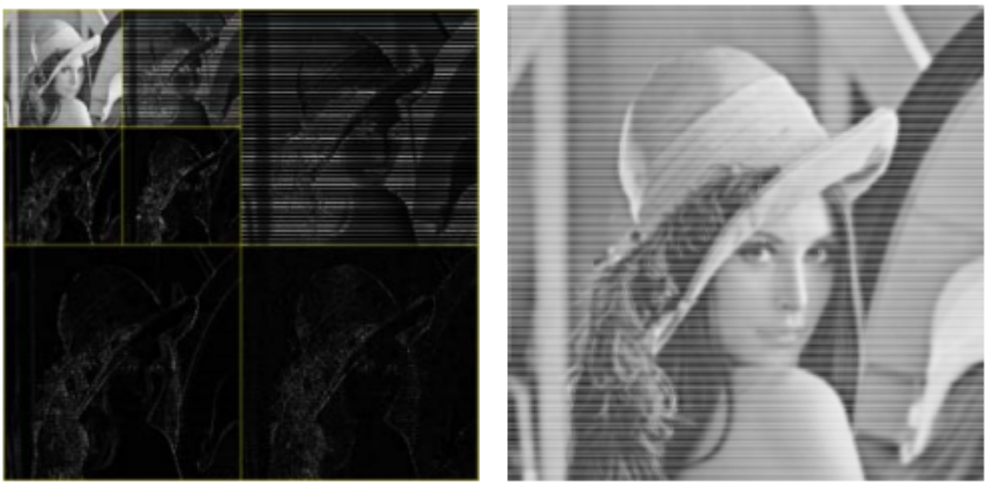


Image decomposition using Wavelet and usual wavelet denoising result

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 amount of intensity variation between one pixel and the other pixel.

In this paper, the main focus is on the 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 a major part of the noise of an image sensor. It means of the constant noise level 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.

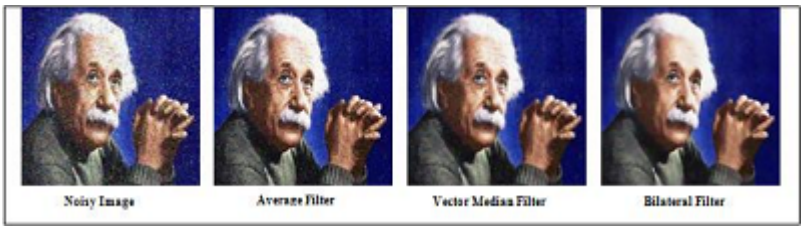
PROPOSED APPROACH

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

Median Filter
The median filter is a nonlinear digital filtering technique, often used to remove noise from an image or signal (speckle noise & salt-pepper noise)

Bilateral Filter

The bilateral filter is a non-linear technique that can blur an image while taking strong edges, by means of a nonlinear combination of nearby image values.



Quality Measures of Einstein image

A modified bilateral filtering method is implemented in this paper, which can effectively removed both impulsive noise and additive noise. Moreover MSE and PSNR of this method is the best.

Chapter 3

Contribution

Spatial filtering is a form of finite impulse response (FIR) filtering. The filter is a mask of weights arranged in a rectangular pattern. It mean that sliding the mask along the image and performing a multiply and accumulate operation on the pixels covered by the mask.

Original Image

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

```
I = imread('lena.tif');
F = imshow(I);
```

Result:

Original Image

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 $(i,j) \in neighborhood$

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

```
function F = median(I,w)
s=size(I);
for i=floor(w/2)+1:s(1)-floor(w/2)
  for j=floor(w/2)+1:s(2)-floor(w/2)
    for k=1:w
      for l=1:w
```

```
            vect(w*(k-1)+l)=I(i-floor(k/2)+2,j-floor(l/2)+2);
        end
      end
      B=sort(vect);
      I(i,j)=B(floor(size(B,2)/2)+1);
   end
end
figure;

imshow(I);
```

Result:

median x 7

3.2 Average Filter

Feature:

A spatial filter that applies to a neighborhood (local method).

A linear filter, speaking as a convolution.

A pixel is replaced by the average of itself and its neighbours.

The neighborhood size determines the amount of smoothing.

Equivalent to a filtering operation lowpass.

Average Filter have:

Filter 3×3

$$\frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Filter 5×5

$$\frac{1}{25}\begin{bmatrix}1&1&1&1&1\\1&1&1&1&1\\1&1&1&1&1\\1&1&1&1&1\\1&1&1&1&1\end{bmatrix}$$

Filter 7×7

$$\frac{1}{49}\begin{bmatrix}1&1&1&1&1&1&1\\1&1&1&1&1&1&1\\1&1&1&1&1&1&1\\1&1&1&1&1&1&1\\1&1&1&1&1&1&1\\1&1&1&1&1&1&1\\1&1&1&1&1&1&1\end{bmatrix}$$

```
function F=average(I)
s=size(I);
F_size=7;
F=double(zeros(s(1),s(2)));
   for i=floor(F_size/2)+1:s(1)- floor(F_size/2)
      for j=floor(F_size/2)+1:s(2)- floor(F_size/2)
         for k=1:F_size
            for l=1:F_size
               F(i,j)=F(i,j)+double(I(i+k-(floor(F_size/2)+1),j+l-(floor(F_size/2)+1)));
            end;
         end;
         F(i,j)=round(F(i,j)/(F_size*F_size));
         end;
      end;
F=uint8(F);
figure;
imshow(F);
```

Result:

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:

Filter 3×3

$$\frac{1}{16}\begin{array}{|c|c|c|}\hline 1 & 2 & 1 \\ \hline 2 & 4 & 2 \\ \hline 1 & 2 & 1 \\ \hline\end{array}$$

Filter 5×5

$$\frac{1}{273}\begin{array}{|c|c|c|c|c|}\hline 1 & 4 & 7 & 4 & 1 \\ \hline 4 & 16 & 26 & 16 & 4 \\ \hline 7 & 26 & 41 & 26 & 7 \\ \hline 4 & 16 & 26 & 16 & 4 \\ \hline 1 & 4 & 7 & 4 & 1 \\ \hline\end{array}$$

Filter 7×7

$$\frac{1}{1003}\begin{bmatrix} 0 & 0 & 1 & 2 & 1 & 0 & 0 \\ 0 & 3 & 13 & 22 & 13 & 3 & 0 \\ 1 & 13 & 59 & 97 & 59 & 13 & 1 \\ 2 & 22 & 97 & 159 & 97 & 22 & 2 \\ 1 & 13 & 59 & 97 & 59 & 13 & 1 \\ 0 & 3 & 13 & 22 & 13 & 3 & 0 \\ 0 & 0 & 1 & 2 & 1 & 0 & 0 \end{bmatrix}$$

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

```
% Read an image
I = imread('lena.tif');
% Create the gaussian filter with hsize = [x y] and sigma = 2
G = fspecial('gaussian',[x y],2);
% Filter it
F = imfilter(I,G,'same');
% Display
imshow(F)
```

Result:

Filter 3×3

Filter 5×5

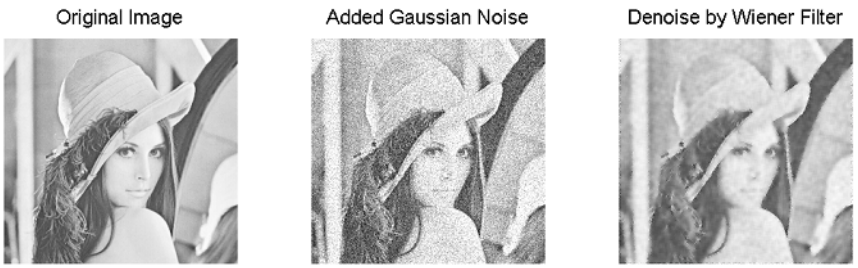
Filter 7×7

3.4 Wiener Filter

```
%Add noise
subplot(2,2,1);
I = imread('lena.tif');
J = imnoise(I,'gaussian',0,0);
imshow(J(100:256,1:256));
title('Added Gaussian Noise');

%Remove noise
subplot(2,2,2);
K = wiener2(J,[5 5]);
D = imshow(K(100:256,1:256));
title('Noise Removed by Wiener Filter');
```

Result:



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.

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

Lena Image

Lena.tif

Filter	MSE	PSNR
Median	0.0372	62.4258
Average	0.0184	65.4860
Gaussian	0.0041	72.0197
Weiner	0.0366	62.4964

Comparison Table

Cameraman Image

Cameraman.tif

Filter	MSE	PSNR
Median	0.1060	57.8789
Average	0.0145	66.5120
Gaussian	0.0059	70.3933
Weiner	0.1148	57.5314

Comparison Table

Coco Image

Coco.tif

Filter	MSE	PSNR
Median	0.0684	59.7830
Average	0.0096	68.3246
Gaussian	0.0016	75.9843
Weiner	0.0762	59.3135

Comparison Table

House Image

House.tif

Filter	MSE	PSNR
Median	0.0521	60.9607
Average	0.0132	66.9250
Gaussian	0.0027	73.7704
Weiner	0.0580	60.4962

Comparison Table

Peppers Image

Peppers.tif

Filter	MSE	PSNR
Median	0.0827	58.9580
Average	0.0105	67.9129
Gaussian	0.0040	72.1321
Weiner	0.0908	58.5492

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 5 images above, value comparison by MSE and PSNR. We have best of results Gaussian 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 gaussian 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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