Savonia
University of Applied Sciences

**Degree Program in Information Technology**

**Telecommunication Engineering**

# Bachelor's Thesis

# Research on Image De-Noising Enhancement

**Mengqi Li**

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Abstract

The purpose of this final project was to understand the aim of image filtering; algorithms and their typical characteristics. The filter types include: mean filter, median filtering, Gaussian filtering and Bilateral filtering.

The main measure method was to use the smoothing filter method to do de-noising processing. It is based on median filtering and Gaussian filtering theory. At the same time, some shortcomings were enhanced. It was necessary to research the advantages and disadvantages of Gaussian filtering and improve deficiency. Finally, Matlab was used to modify algorithm.

As a result, it was found out through four different group of image data that filtering de-noising plays an important role in the image processing field. Therefore, it is necessary to delete defects and enhance the stability of image processing results.

Keywords

Matlab, de-noising, median filter, mean filter, Gaussian filtering

Confidentiality

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Abstrakti

Tämän opinnäytetyön aiheena oli ymmärtää tavoitteena kuvan suodatus, algoritmit ja niiden tyypilliset ominaisuudet.Suodattimen tyyppejä ovat: keskimääräinen suodatin, mediaani suodatus, Gaussin suodatus ja kahdenvälisen suodatus.

Pääasiallisena mittana menetelmä oli käyttää tasoitussuodatin tapa tehdä de-noising käsittely. Se perustuu mediaani suodatus ja Gaussian suodatuksen teoria. Samaan aikaan, joitakin puutteita parannettu. Oli välttämätöntä tutkimusta edut ja haitat Gaussin suodatus ja parantaa puutos. Lopuksi Matlab käytettiin muuttaa algoritmia.

Tämän seurauksena selvisi läpi neljä eri ryhmää kuvadatan että suodatus de-noising tärkeä rooli kuvankäsittelyn alalla. Siksi on tarpeen poistaa virheitä ja parantaa vakautta kuvankäsittelyn tuloksia.

Avainsanat

Matlab, de-noising, median filter, mean filter, Gaussian filtering

Luottamuksellisuus

julkinen

## Acknowledgements

Looking back at the past four years, I think that they are the most memorable parts in my life. I got to know different friends and teachers, they helped me and taught me knowledge. Here, I want to heartily say "Thank you" for them.

This design was done with the help of many people. Firstly, I want to say that my supervisor Mr. Seppo Karjalainen gave me many useful suggestions and help. I really want to express the highest respect for him. The beautiful time is always short, but I will not forget all the things here.

Finally, I want to thank my parents. They give me support in many ways. I love you.

Mengqi Li
19 September, 2011
Kuopio Finland

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# 1. INTRODUCTION

Image is an important source of information. People can know the intension of information through the image processing technology. Digital image noise removal involves optical systems, micro-electronics technology, computer science, mathematical analysis and other fields. That is a very complex edge science. It is already a comprehensive theoretical system. Its practice is widely used in medicine, military, art, agricultural field.

Enhancing useful information of image, it was a distortion process in image field. The aim of image enhancement was to improve visual image. For the given image application, people can emphasize the overall image or local characteristics. And then make the original image become clear or emphasize certain traits of interest. This step also can enlarge division of different object feature in image. In this way, it is possible to improve the image quality and rich amount of information.

Image generation and transmission is often under various noise interference and influence. It will reduce image quality. Similarly, it will affect the follow-up image processing (such as segmentation, compression and image understanding, etc.). There are many different types of noise, such as: electrical noise, mechanical noise, channel noise and other noise. In image processing field, image de-noising is an eternal theme. In order to suppress noise and improve image quality, it is necessary to do the pre-processing of de-noising for image.

Computer image processing methods mainly take two categories. First, the space domain processing; that is in the image space of the image processing. The other is the image spatial domain. It should be use frequency domain through the orthogonal transformation in various frequency domain. Next, do reversal processing further and then it can be finish processing for image. It is also based on the actual characteristics of the image, noise and spectral distribution of the demographic characteristics of the law. Scientists derived many de-noising approaches. One of the most intuitive ways of noise energy is generally concentrated in high-frequency and spectral images located in a limited range of this characteristic. And then low-pass filtering approach is used to de-noising or smoothing the image processing. This is the first class of image processing methods. Another way is processing in the frequency domain. (such as: Fourier transform, wavelet transform.)

The purpose of this project was to use Matlab2010b to process the image and compare the image clarity under a variety of filtering. The research was to determine filtering denoising play an important role in image enhancement field. Good de-noising results for the latter to further enhance the accuracy of the image play a fundamental role.

Therefore, it needs to have continue improvement of filtering algorithm. Similarly, it is necessary to delete shortcomings and enhance the stability of image processing results.

# 2. De-Noising Filter

## 2.1 Introduction

In fact, each captured image contains noise. Due to various interferences, noise, the image definition gets bad influence. At the same time, noise making the image blurred. The bad condition was submerged fully. It gives analysis big difficulty. Therefore, people need to suppress unwanted noise to improve image quality. For digital image noise reduction, the basic filtering algorithms are used. It includes mean filtering, median filtering, Gaussian filtering, bilateral filtering.

### 2.1.1 Mean Filter De-Noising

Mean filter is a linear filter algorithm. That means it increases a template on the target pixel, and then uses all the average of pixel value instead of the original pixel value. The template size and shape can often be based on the characteristics of images to be processed to determine size. Generally speaking that the size of the template is m x m. (m is odd). [1]

Assumed the digital image is f(x, y), with a mean filter to get digital image is g(x, y),

$$g(x,y) = \frac{1}{M}\sum f(i,j) \qquad (i,j) \in s \qquad (2.1)$$

In equation 2.1, S is the neighborhood to take the coordinates of each pixel set; M expresses the sum of pixels within the set of S.

(a) before processing (b) after processing

Figure 2.1.1 Comparison of image effects before and after processing using mean filter

Figure 2.1.1 shows the mean filterer processing. The mean filter is blurring at the expense of noise suppression. When the template is enlarged, the picture becomes clearer than before. It is important to note that details of the picture are a little vague. [1]

### 2.1.2 Median Filter De-Noising

Median filtering is a nonlinear smooth technology. Each pixel of the gray value of a neighborhood has its own pixel gray value of the median. That means all pixels within the neighborhood sort by gray value, taking the median of the group as a neighborhood center pixel output value. Suppose the neighborhood is S, it can get following equation 2.2

$$g(x, y) = med\left\{ f(i, j), (i, j) \in S \right\} \tag{2.2}$$

(a) before processing (b) after processing

Figure 2.1.2 Comparison of image effects before and after processing using median filtering

Figure 2.1.2 shows that through the median filtering processing, the picture is clearer than before. [2]

When a pixel in the neighborhood of pixels is odd, take the gray value of pixels in the field. That means the middle of the order value. When a pixel neighborhood of pixel number is even, take the pixel gray value of the field. That means the middle of sort value of two scale. [2]

### 2.1.3 Gaussian Filtering De-Noising

The Gaussian filtering is an important space for the weighted mean filter. It is based on the shape of the Gaussian function to select the right value of linear smoothing filter. It usually uses the Gaussian function of discrete two-dimensional by zero-mean to be smoothing filter. The following equation 2.3 as below:

$$g(x,y) = \frac{1}{M}\sum f(x,y)\exp\left[-\left((x-i)^2+(y-j)^2\right)/2\sigma^2\right] \qquad (i,j)\in S \quad (2.3)$$

In the equation, S shows each pixel set in the neighborhood.
And the equation 2.4 show as below:

$$M = \sum \exp\left[-\left((x-i)^2+(y-j)^2\right)/2\sigma^2\right] \qquad (2.4)$$

The equation expresses the collection of pixels and the corresponding weights of set S.

It is possible to learn through Figure 2.1.3 how to use a more intuitive picture to process the Gaussian filtering. The Gaussian filter for the elimination of the Gaussian normal distribution noise is very effective. [3]

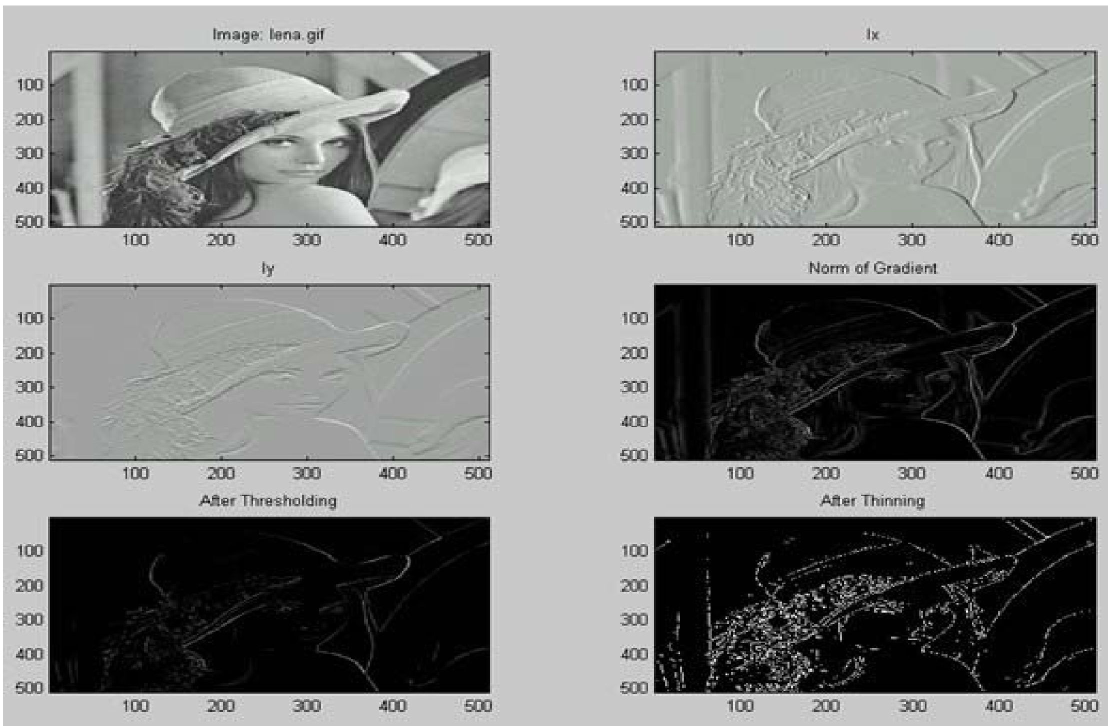



Figure 2.1.3 The process of using Gaussian filtering

### 2.1.4 Bilateral Filtering De-Noising

If the image point in traditional low-pass filter is similar to gray point, the noise is irrelevant. The edge on both sides of a point on it has a very different point. The filtering processing has high-frequency components. In addition to the image, the result shows in the loss of the edge.

Bilateral filtering method is based on the Gauss filtering method proposed in dealing with each adjacent pixel gray values. Not only does it take into account the close relationship between space, but also takes into account the gray similar relationship. It is mainly aimed at Gauss filtering, the Gaussian weighting coeffient direct convolution with image filtering principle. The filter optimizes the image brightness into the Gauss function and products information. The researcher optimize the weights before and after the image information for convolution, so it will be able to filter the image information taking into account the edge information in images. The image is filtered in the normal Gaussian filtering maintained clear and smoother edge. This method for color and grayscale images of the filter is applicable, and highly practical. [4]

The f(x) represents that using the low-pass filter in space. It can be get the image I(x), equation 2.5 show as below:

$$I(x)=k_d^{-1}(x)\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} f(\varepsilon)c(\varepsilon,x)\,d\varepsilon \qquad (2.5)$$

Where $c(\varepsilon,x)$ represent the center and its neighboring point $\varepsilon$ of the degree of spatial proximity. Assuming x=(x1, x2), $\varepsilon=(\varepsilon 1,\varepsilon 2)$ are the space coordinates of image. If the low-pass filter retains the signal of the DC branch, the equation 2.6 show as below

$$k_d(x)=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} c(\varepsilon,x)\,dx \qquad (2.6)$$

If the filter has a shift invariance, $c(\varepsilon,x)$ is the vector difference between $\varepsilon$ and $x$. Similarly, the filtering method in grayscale is similar to space domain method. The result is showed as equation 2.7:

$$I(x)=k_r^{-1}(x)\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}f(\varepsilon)s(f(\varepsilon),f(x))d\varepsilon \qquad (2.7)$$

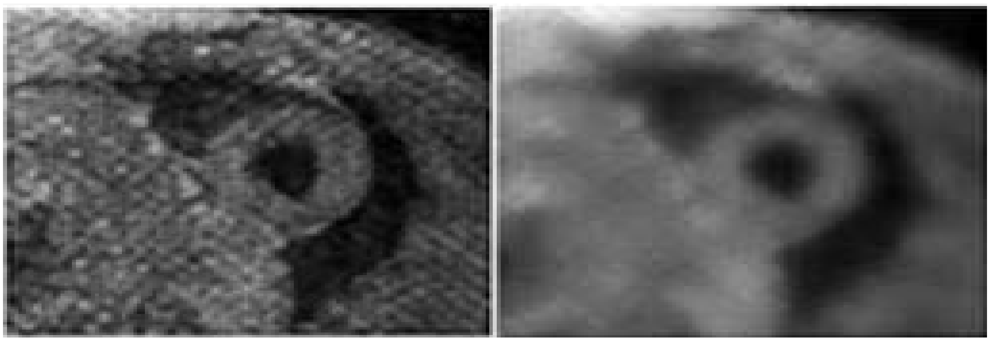
Where $s(f(\varepsilon),f(x))$ represents the center point of $x$ and $\varepsilon$. At this point, it can be show as equation 2.8:

$$k_r(x)=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}s(f(\varepsilon),f(x))d\varepsilon \qquad (2.8)$$

With varying degrees of spatial proximity, gray image have many differences with a two gray scale value. According to equation 2.7 and 2.8, the next function can be generated. The output image show as equation 2.9:

$$k_r(x)=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}c(\varepsilon,x)s(f(\varepsilon),f(x))d\varepsilon \qquad (2.9)$$

The following picture is a set of bilateral filtering processed pictures and results. (Figure 2.1.4)



(a) before processing (b) after processing

Figure 2.1.4 Comparison of image effects before and after processing using Bilateral filtering

This spatial proximity and gray will be a combination of the similarity method. It is called bilateral filtering. Bilateral filter is characterized by the image of each point with its close proximity and gray-scale pixel average to replace the original value. Then it is possible to achieve the filtering effect. It can be seen that a small neighborhood of gray image has not a big change. It is approximately constant. The standard bilateral filter will enter into the low-pass spatial filter. Bilateral filtering can achieve not only the effect of filtering but also the image of the edge detail. So, this is a great method for application value filtering. [4]

## 2.2 Overview of Image Noise

### 2.2.1 The Concept of Image Noise

Noise can be understood as a barrier to the sense organs of the received source information to understand the factors. For example, a black and white picture, the surface brightness distribution is assumed to be f (x, y). Then the interference it receives from the brightness distribution of R (x, y) can be called image noise. However, the noise in theory can be defined as unpredictable. It can be used statistical methods to understand the probability of random error. Therefore, the image noise as a multidimensional random process is appropriate. So, it can be described noise is completely random process can borrow the description which uses the probability distribution function and probability density function. However, in many cases, this description is very complicated. The practical application is often unnecessary. That is mean-variance, correlation function and so on. Because the digital features can be reflected in some aspects of noise characteristics. [5]

In most of digital imaging systems, the input images are used to first freeze and then scanning the image into a one-dimensional multi-dimensional signal. Next its processing, storage, transmission and other processing transformation. Finally, it is necessary to make up the multi-dimensional image signal and image noise will be equally subject to such a decomposition and synthesis. In these processes affect the electrical system and the outside world will allow the precise analysis of image noise becomes very complicated. The other image can transmit visual information media. The image information of the knowledge to understand the human visual system is determined. Different image noise, people have the different feeling. This is the so-called visual noise characteristics of the human subject. [5]

Image noise in digital image processing technology is growing in importance. Such as in high magnification of the interpretation of aerial photographs and X-ray imaging systems in the removal of noise has become an indispensable technical step. [5]

### 2.2.2 Classification of Image Noise

Image noise can be divided to two types: external and internal noise.
External noise, means that the system or external electromagnetic interference to the string into the power caused by noise within the system. External noise include: electrical equipment, celestial phenomena caused by the discharge noise. [6]

Internal noise in general can be divided into the following four types:

(1) The basic properties of light caused by electrical noise. Like the current generation is a collection of particles electrons or holes. The formation of directional movement. Because these particles in the random formation of shot noise; conductor free electrons irregular thermal motion of the formation of thermal noise. [6]

(2) Electrical noise generated by the mechanical movement. Jitter caused by a variety of joints such as the current change due to the noise generated; heads, tape, etc. [6]

(3) Equipment, material itself due to noise. Such as positive and negative particles and the surface of the disk surface defects produced by tape noise. With the development of materials science, it expected to continue to reduce the noise. [6]

(4) Equipment within the system caused by circuit noise. It has the introduction of the AC power supply noise; deflection system and clamp circuit caused by the noise. [6]

Image noise from the viewpoint of statistical theory can be divided into two kinds of stationary and nonstationary noise. In practice, they do not pursue a strict mathematical definition. These two types of noise can be understood as: statistical properties of noise do not change over time It called stationary noise. Its statistical properties change with time, and called for non-stationary noise. [6]

# 3. Traditional Image Enhancement Techniques

## 3.1 Introduction

Enhancement technology currently used for a whole can be divided into two categories: the spatial domain-based enhancement method and the frequency domain based enhancement methods. The former is located directly in the processing of a two-dimensional space. That is directly on the gray value of each pixel processing. The spatial domain-based enhancement method processes image in two dimensional space directly; frequency domain based enhancement method and it used transformation model change from spatial domain to frequency domain. [7]

## 3.2 Image Enhancement based on Spatial Domain

In image processing, airspace is composed of pixels of space. The spatial enhancement refers to a direct effect on the pixels of the enhancement methods. It can be expressed as:

$$g(x,y)=EH[f(x,y)]$$

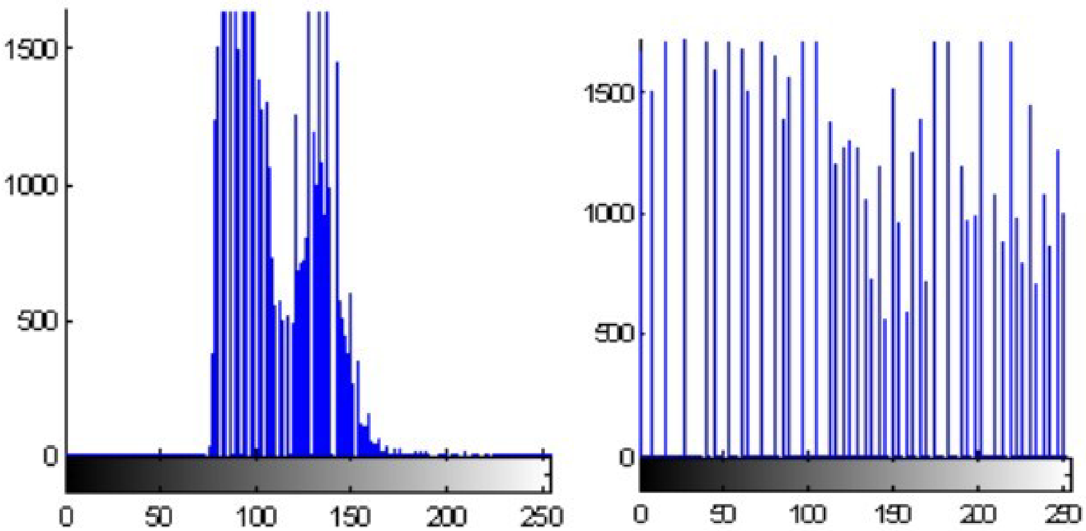
The f (x,y) and g (x,y) means before and after images were enhanced. If the EH is defined in each (x, y), then it get the point of operation EH; if EH is defined in the (x, y) of a neighborhood, then EH is called the template operation. EH can either act as an image f (x,y), it can also act on a series of images {f1 (.), f2 (.),..., fn (.)}. Based on the spatial domain approach can make histogram equalization better. This is a significant enhancement way in statistics. But in the image processing field, it will be underexposed or overexposed. An image histogram is the corresponding image pixel gray level of each approximation of the distribution of the probability density function. Histogram equalization is a classical image enhancement technology. [8]

The histogram equalization process is based on distribution function of transform. It is like the basis of the histogram correction method. The basic idea is to use the cumulative distribution function as a transformation function to transform the original image histogram form for the uniform distribution, thus increasing the dynamic range of pixel gray values to achieve the effect of enhancing the overall image contrast. [8]

In fact, histogram is the approximate probability and density function. With discrete gray levels for the transformation can be completely. This is the inevitable result of the pixel gray. For these reasons, the digital image can only be an approximate histogram equalization. [8]

(a) before balancing (b) after balancing

Figure 3.2(1) Comparison of image effects before and after balancing




(c) before balancing (d) after balancing

Figure 3.2(2) Comparison of image histogram before and after balancing

It can be seen from Figure 3.2.1 (a) and Figure 3.2.1 (b) that the dynamic range of gray is too narrow. It results in leaving the whole image contrast too vague. After the histogram equalization process, the grayscale dynamic range is pulled close. And also the processed image becomes clearer. Many of the details in the image were highlighted. The image histogram of distribution is equally than before. And each gray level image has own pixels. However, with histogram equalization, there are three drawbacks:

(1) Transforming to reduce the gray-scale image, some of the details disappear.

(2) In some images, histogram has a peak after treatment to enhance the contrast too unnatural.

(3) Histogram supporting a complete description of an image, an image corresponding to a histogram. In fact, the histogram has only one image. The several images of histogram have same density as long as the gray scale. Then their histograms are the same. [8]

## 3.3 Image Enhancement based on Frequency Domain

In order to effectively and quickly process and analysis the image, it is necessary to require the original image defined in the image control in some form of conversion to other controls. And it is necessary to use the unique nature of these controls convenient for certain processing. Finally, it need convert back to image space, and then obtain desired result. The most commonly used way is the frequency space transformation to another space. The spatial frequency enhancement methods have two rules:

(1) The original image from the image space to frequency space, the lock needs change (indicated by T). Next, it need convert back to frequency space images from the image space (indicated by T2);

(2) In the frequency space, it is needed to enhance image processing operations. Corresponding increase at this time can be expressed as:

$$g(x,y)=T2\{EH[T[f(x,y)]]\}$$

The frequency enhancement methods are: low-pass filter, high pass filter, band pass and band stop filtering and homomorphic filtering and so on. Homomorphic filtering solution is non-uniform illumination. The image in the dynamic range is not clear images. The high-pass filter method always ignores image part and highlighting details. That can represent high frequency components, enhancing the part of the edge detail. This method is suitable for edge detection of objects in the image. Due to the low frequency method, the visual effect of the processed image is not good. [9]

(a) Original image (b) High-pass filter image

Figure 3.3 high-pass filtering image

It is can be seen from Figure 3.3, that the image is very dark and it has a lot of details visible. When the low-frequency components filtered out, the figure had relatively smooth gray area within the dynamic range will compress in the figure. Thus the whole image has become fuzzy. [9]

# 4. Introduction for Matlab

## 4.1 Overview

Matlab, a Mathworks company in the United States first introduced a set of numerical analysis and high-performance computing software in 1983. Expanding its capabilities, the version was continually upgraded. Now, the latest version is 2010b version. It provides a professional level of symbolic computation, word processing, visual modeling and simulation and real-time control functions. Matlab is a characteristic of all language features and next generation software development platform. [10]

Matlab has become suitable for many disciplines and powerful large-scale software. Most of colleges and universities in Europe and other countries use it. Matlab has become linear algebra, automatic control theory, mathematical statistics, digital signal processing, time series analysis, dynamic system simulation and other advanced courses in the basic teaching tool. In designing the study units and industrial development sector, Matlab is widely used in research and solve specific problems. In China, Matlab has received increasing attention in a short time it will flourish, because no matter which discipline or engineering can be found right from the Matlab function. [10]

Today's information society, the image is mankind's access to information is one of the most important sources. With the rapid development of computer technology, image technology and the continued integration of computer technology to produce a series of image processing software. Matlab has become internationally recognized as the best application of technology. With simple programming and data visualization, it can be seen the operable features. [10]

## 4.2 Development Process for the Matlab

Matlab name story is from the MATrix and LABoratory for the first three years. It was the late 1970s things: then-Head of the Department of Computer Science, University of New Mexico Professor Cleve Moler program for reducing the burden of student motivation for students to design a set of LINPACK and EISPACK library routines called the "common-use "interface, that is written in FORTRAN bud Matlab. [11]

After several years ago, the technology was not so modern. Moler, Steve Bangert cooperation, established in 1984, MathWorks Inc., Matlab and the official market. From this point, Matlab kernel written in C, and in addition to the original value of computing power, but also added a data map of visual function. [11]

Matlab is only a few short years, with its openness and good operating reliability. The original control was in the field of closed-end package. In time into the 1990s, when Matlab has become the acknowledged standard international control calculation software. [11]

The MathWorks introduced in 2010 Matlab7.11 version (ie, 2010b). The new version has many new changes. Release 2010b of MATLAB and Simulink includes several new features and a new product for 85 models of other product updates and bug fixes. [11]

MATLAB product family's new features include: [11]
(1) Add more multi-threaded math functions, enhanced file sharing Dian path management capabilities and improving the MATLAB desktop

(2) Be added for stream processing in MATLAB system objects, and Video and Image Processing Blockset and the Signal Processing Blockset provides more than 140 species in support of algorithms.

(3) For more than 50 functions to provide support and enhance multi-core performance, and Image Processing Toolbox to provide more support for large images.

(4) In the Global Optimization Toolbox and Optimization Toolbox to provide new non-linear solver.

(5) From the Symbolic Math Toolbox to generate Simscape language equations.

(6) Stochastic approximation in SimBiology provides the maximum expected (SAEM)

algorithm and pharmacokinetic dosing programs to support.

In the international academic community, Matlab has been recognized as accurate and reliable scientific computing standard software. In many world-class academic journals, people can find the Matlab application. In designing the study units and industrial sectors, Matlab has been recognized as the efficient research and development of software tools of choice. [11]

## 4.3 Language Features for Matlab

Matlab language has the following characteristics: [12]

(1) Programming efficiency
It is a scientific and engineering calculation for high-level language that allows the form of mathematical programming language. Fortran and C and other languages written in the formula closer to our way of thinking, like using Matlab programming paper in calculus arrange on a formula and solve problems. Therefore, Matlab language, popularly known as the calculus can also be paper-based science algorithm language because it is easier to write. So the programming and high efficiency, everyone can easy to learn.

(2) Easy to use
Matlab language is an interpreted language (in no special tools are compiled before), it is flexible. That means of its rich debugger, debugging speed, less time to learn. Matlab language compare with other languages, has solved these problems, edit, compile, link and execute integration. It can be flexible in the same operation on the screen quickly ruled out entering the program in writing. And Matlab also have grammatical errors as well as semantic errors, thereby speeding up the user to write, modify and debug programs faster. If people used Matlab, people will know Matlab' advantage.

(3) Expansion capability
High version of the Matlab language has rich library functions, when carrying out complex mathematical operations can be called directly. And the Matlab library functions in the form on file with the same user, so users can file as a library of Matlab functions to call. Thus, the user can easily build own needs and the expansion of the new library functions. Using of Matlab in order to improve efficiency and expand its capabilities.

(4) Statement is simple, rich in content

The most important ingredient of Matlab language is the most basic function of a varying number of input variables and different number of output variables, representing different meaning (a bit like object-oriented polymorphism). This is not only makes the Matlab library function more feature-rich, while greatly reducing the need for disk space. Making the Matlab of M-file written in a simple, short and efficient.

(5) Efficient and convenient matrix and array operations

Matlab language provides for matrix arithmetic operators, relational operators, logical operators, conditional operators and assignment operator. But most of these operators can be copied without any change in operations between the array, such as arithmetic operators increase the "•" can be used for operations between arrays. It need not define the dimension of the array, and gives the matrix function. It is much simple, efficient and convenient.

(6) Convenient graphics

Matlab graphics is very convenient. It has a range of drawing functions. In addition, call the drawing function to adjust the color argument can be drawn the same point, line, double line or multiple lines. The design for the sake of this research is a common programming language that fall.

In short, Matlab language design can be said to represent the current high-level computer language development. [12]

## 4.4 The Used Image Processing Functions for Matlab

Matlab7.11 for the user during the image processing provides some common functions: [11]

(1) Read and display file
Function [X,map] play a role in the file, it can be called in the following format:
[X,map]=imread(filename,fmt)， the filename for read the image file name. fmt as the image format.

Imshow function is to display the file, its syntax is as follows:

imshow(BW)

imshow(X,map)

(2) Calculate two-dimensional convolution

Function conv2 format:

C = conv2 (A, B) is considered the role of the convolution matrix A and B.

(3) Matlab implementation of the noise

Function imnoise format:

J=imnoise(I,type)

J = imnoise (I, type, parameter) Returns the image I added the typical noise of the noisy image after the J, parameter type and parameter used to determine the type of noise and the corresponding parameters.

(4) Two-dimensional discrete wavelet transform

Function dwt2 format:

[cA, cH, cV, cD] = dwt2 (X, 'wname') is the wavelet function using the specified "wname" two-dimensional signal X to D Discrete Wavelet Transform, cA, cH, cV, cD are approximate component, the level of detail components, vertical and diagonal detail component detail component.

[cA, cH, cV, cD] = dwt2 (X, Lo_D, Hi_D) is specified decomposition low-pass and high pass filters Lo_D and Hi_D decomposition signal X.

(5) Wavelet decomposition of multi-dimensional signal

Function wavedec2 format:

[C, S] = wavedec2 (X, N, 'wname') using the wavelet function "wname" two-dimensional signal X to N-layer decomposition.

[C, S] = wavedec2 (X, N, Lo_D, Hi_D) using the specified decomposition low-pass and high pass filters Lo_D and Hi_D decomposition signal X.

(6) Two-dimensional discrete wavelet transform

Function idwt2 format:

X = idwt2 (cA, cH, cV, cD, 'wname') by the signal wavelet decomposition of the approximate signal and detail signal cA cH, cH, cV, cD through wavelet transform reconstruction of the original signal X.

X = idwt2 (cA, cH, cV, cD, Lo_R, Hi_R) using the specified low-pass and high pass reconstruction filter Lo_R and Hi_R reconstruct the original signal X.

(7) The multi-dimensional wavelet reconstruction signal

Function waverec2 format:

X = waverec2 (C, S, 'wname') by the result of multi-dimensional wavelet decomposition C, S reconstruct the original signal X.

X = waverec2 (C, S, Lo_R, Hi_R) using the reconstruction low-pass and high pass filters Lo_R and Hi_R reconstruct the original signal. [11]

# 5. Simulation and Analysis of Image De-Noising Enhancement by Using Matlab

## 5.1 Noise Model Simulation and Analysis

### 5.1.1 Salt and Pepper Noise

Salt and pepper noise is a type of black and white points of light and dark noise. The image sensor, transmission channel and decoding processing form salt and pepper noise. Salt and pepper noise is often caused by the cut image. [13]

An effective noise reduction method for this type of noise involves the usage of a median filter or a contra harmonic mean filter. Salt and pepper noise creeps into images in situations where there are quick transients. Through a large number of experimental studies, it can be found that the camera's image are affected seriously by discrete pulses; salt and pepper noise and zero mean the Gaussian noise. [13]

The following group of figures is the target of the experiment after adding salt and pepper noise. After the picture appears on the screen, black and white random noise spots can be seen. Noise intensity is following 0,0.05,0.1,0.3,0.5,0.7.

(a) 0 density noised image (b) 0.05 density noised image

Figure 5.1.1 Salt and pepper input image

By (a) and (b) contrast, it can be seen clearly that the noise level increased to 0.05 when the image become fuzzy.

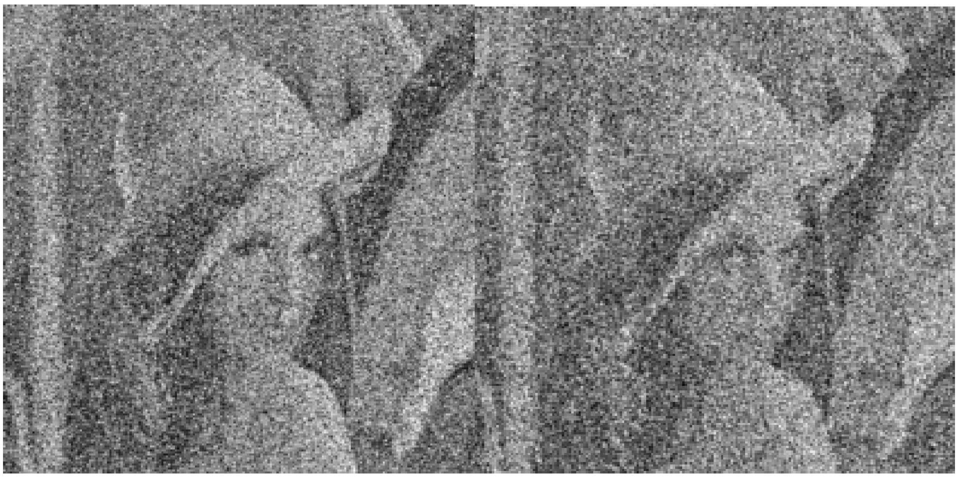
The following figure is a set of noise level when increased to 0.1 and 0.3 after the changes.

(c) 0.1 density noised image (d) 0.3 density noised image

Figure 5.1.1 Salt and pepper input image

Through the observation of figure, when the noise intensity value increases to 0.1 and 0.3, the original images become vague. But it is can be identified also.

Finally, when the noise intensity increases to 0.5 and 0.7, it can be seen from the whole process of changes.



(e) 0.5 density noised image (f) 0.7 density noised image

Figure 5.1.1 Salt and pepper input image

When the noise intensity becomes 0.5 and 0.7, it is difficult to see from the image of the original picture to be presented things. After these three groups of image contrast, it can be found that the picture quality depend on noise intensity value.

### 5.1.2 Gaussian Noise

After the analysis had salt and pepper noise, Gaussian noise, it needs to discuss the changes. Gaussian noise is a kind of normal distribution probability density function of noise. In other words, the value of Gaussian noise, it follows the Gaussian distribution or the energy on each frequency component has a Gaussian distribution. It is universal application of the additive to produce white Gaussian noise.[14]

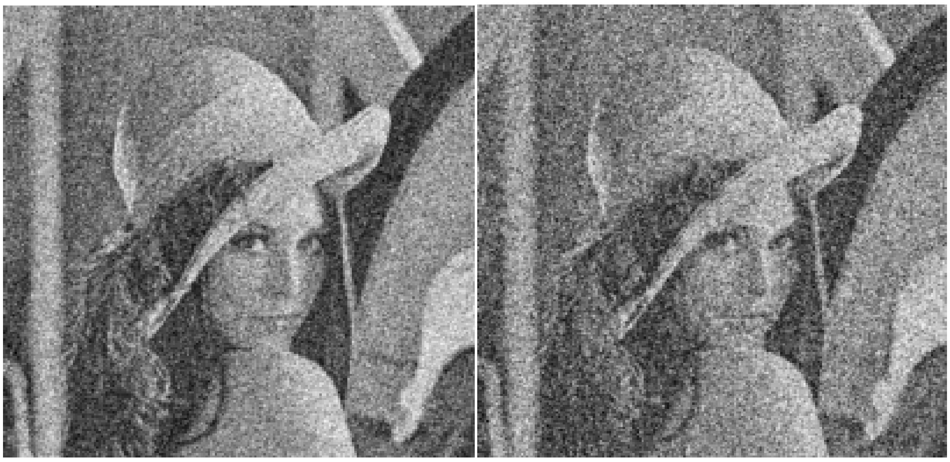
The following figure is added Gaussian white noise, there will be random noise gray spots, noise intensity were following 0,0.05,0.1,0.3,0.5,0.7.

(a) 0 density noised image (b) 0.05 density noised image

Figure 5.1.2 White Gaussian input image

Although the noise level only increases from 0 to 0.05, the contrast has big difference.

Next, the figure shows after being moderate pollution, the noise intensity increases to 0.1 and 0.3.

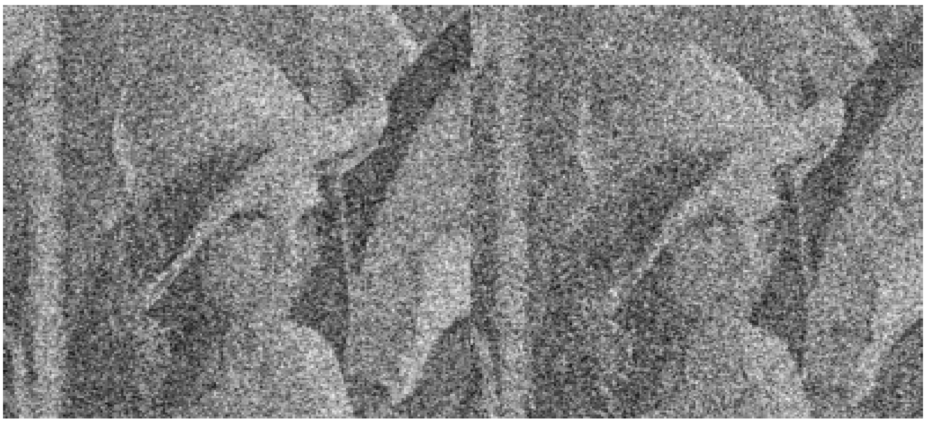


(c) 0.1 density noised image (d) 0.3 density noised image

Figure 5.1.2 White Gaussian input image

In Figure5.1.2, much change cannot be seen. When the noise intensity achieves 0 and 0.05, it is showed that pollution gets worse. [14]

When noise intensity increased to 0.5 and 0.7, the things in the image were difficult to identify.



(e) 0.5 density noised image (f) 0.7 density noised image

Figure 5.1.2 White Gaussian input image

As a result, it can be found that the picture’s quality depends on noise intensity value.

### 5.1.3 Random Noise

The following part is to analyze the images by random noise intensity noise impact on the image resolution.

(a) 0 density noised image

(b) 0.05 density noised image

(c) 0.1 density noised image

(d) 0.3 density noised image

(e) 0.5 density noised image

(f) 0.7 density noised image

Figure 5.1.3 Random input image

These are pictures of random noise added, there will be random noise gray spots, followed by 0,0.05,0.1,0.3,0.5,0.7 noise intensity. [15]

## 5.2 The Simulation and Analysis of the Classic Filter

For the mean filter, median filtering, Gaussian filtering, noise intensity 0.05,0.3,0.7 select three separate noise filter test.

### 5.2.1 Mean Filter

It can be used size of 5 * 5 templates for the three noise pollution pictures mean filtering. [16]

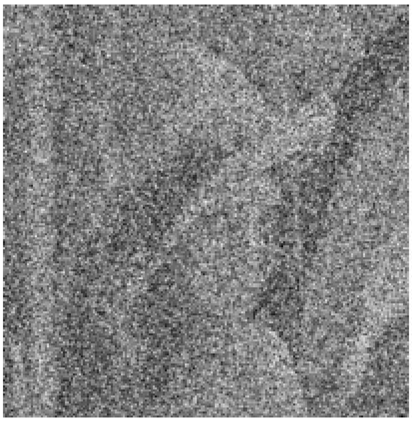
(A) Salt and pepper noise
The following figure were 0.1,0.3,0.7 left column for the strength of the salt and pepper noise pollution pictures. The right as the mean filter denoising results, showing that low-intensity noise filtering effect. It can be seen the picture become blurred; high-strength filter poor results. [13]

(a) 0.1 density noised image

(b) 0.1 density noised image filtered by average filter

(c) 0.3 density noised image

(d) 0.3 density noised image filtered by average filter



(e) 0.7 density noised image

(f) 0.7 density noised image filtered by average filter

Figure 5.2.1(A) Salt and pepper

(B) Gaussian noise

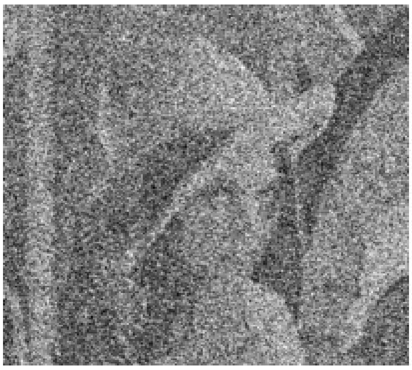
The following picture were 0.1,0.3,0.7 left column for the intensity of the Gaussian white noise (zero mean) pollution picture. The right as the mean filter denoising results, showing that low-intensity noise filtering effect. But the picture was blurred; filter out the effect of high-intensity difference. [14]

(a) 0.1 density noised image

(b) 0.1 density noised image filtered by average filter

(c) 0.3 density noised image

(d) 0.3 density noised image filtered by average filter



(e) 0.7 density noised image

(f) 0.7 density noised image filtered by average filter

Figure 5.2.1(B) White Gaussian

(C) Random noise

The following picture were 0.1,0.3,0.7 left column for the intensity of random noise pollution pictures. The right side picture showed the mean filter denoising results. The picture becomes blurred; high-strength filter poor results. [15]

(a) 0.1 density noised image

(b) 0.1 density noised image filtered by average filter

(c) 0.3 density noised image

(d) 0.3 density noised image filtered by average filter

(e) 0.7 density noised image

(f) 0.7 density noised image filtered by average filter

Figure 5.2.1(C) Random

**5.2.2 Median Filter**

It used size templates for the 5 * 5 pictures of the three noise pollution median filter processing.[17]

(A) Salt and pepper noise

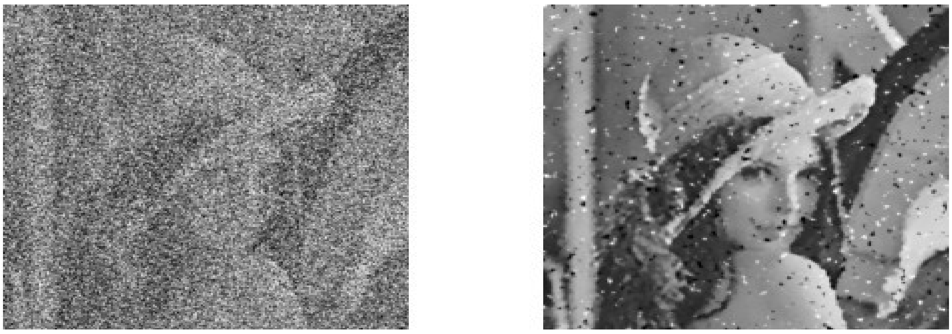
The following picture were 0.1,0.3,0.7 left column for the strength of the salt and pepper noise pollution pictures, right as the median filter denoising results, showing that low-intensity noise filtering effect. The picture becomes blurred; high-strength filter in addition to poor results.[13]

(a) 0.1 density noised image

(b) 0.1 density noised image filtered by median filter

(c) 0.3 density noised image

(d) 0.3 density noised image filtered by median filter

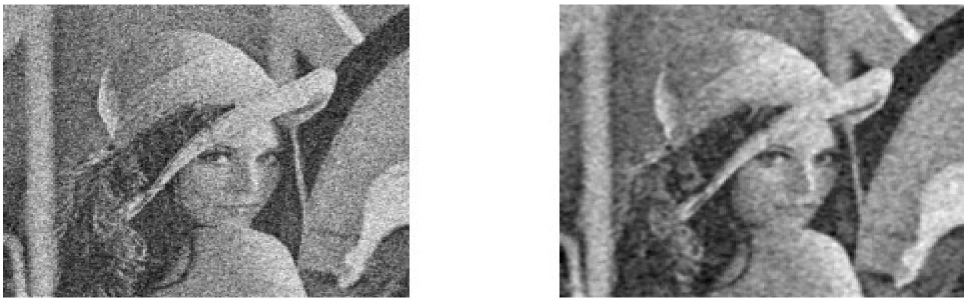


(e) 0.7 density noised image (f) 0.7 density noised image filtered by median filter

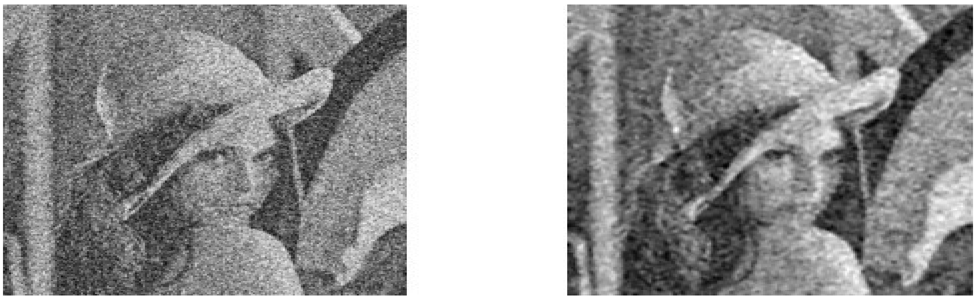
Figure 5.2.2(A) Salt and pepper

(B) Gaussian noise

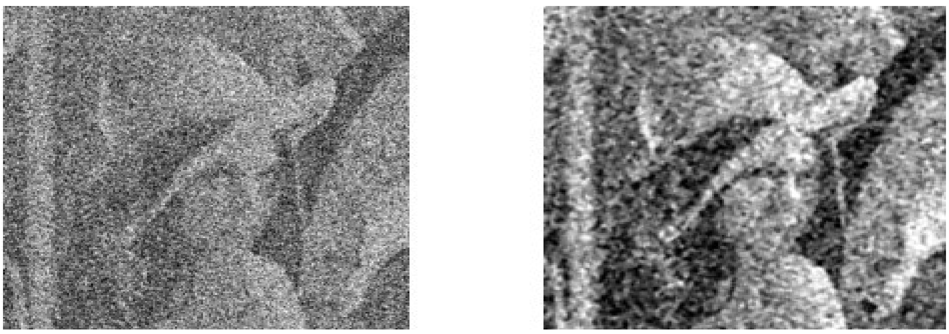
The left column of figure showed 0.1,0.3,0.7 for the intensity of the Gaussian white noise (zero mean) pollution, right column showed the median filter denoising results. It showing that low-intensity noise filtering effect, but the picture becomes blurred; filter out the effect of high-intensity difference. [14]



(a) 0.1 density noised image (b) 0.1 density noised image filtered by median filter



(c) 0.3 density noised image (d) 0.3 density noised image filtered by median filter



(e) 0.7 density noised image (f) 0.7 density noised image filtered by median filter

Figure 5.2.2(B) White Gaussian

(C) Random noise

Next picture were 0.1,0.3,0.7 left column for the intensity of random noise pollution pictures, right as the median filter denoising results, showing that low-intensity noise filtering effect, but the picture becomes blurred; high-strength filter in addition to poor results. [15]

(a) 0.1 density noised image

(b) 0.1 density noised image filtered by median filter

(c) 0.3 density noised image

(d) 0.3 density noised image filtered by median filter

(e) 0.7 density noised image

(f) 0.7 density noised image filtered by median filter

Figure 5.2.2(C) Random

### 5.2.3 Gaussian Filtering

It used size 5 * 5 template images of the three Gaussian noise pollution filtering, the standard deviation of 0.5, with mean 0. [18]

(A) Salt and pepper noise [13]

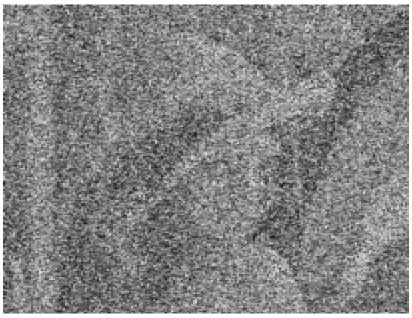
The following group of picture were 0.1,0.3,0.7.The left column for the strength of salt and pepper noise pollution pictures, right column showed Gaussian filter denoising results, showing that low-intensity noise filtering effect. The picture becomes blurred; high-strength filtering in addition to poor results.

(a) 0.1 density noised image

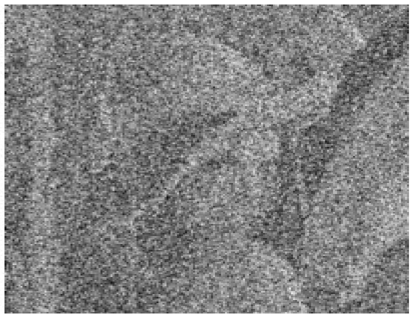
(b) 0.1 density noised image filtered by Gaussian filtering

(c) 0.3 density noised image

(d) 0.3 density noised image filtered by Gaussian filtering



(e) 0.7 density noised image



(f) 0.7 density noised image filtered by Gaussian filtering

Figure 5.2.3(A) Salt and pepper

(B) Gaussian noise

It can be seen in the left column for the intensity, respectively 0.1,0.3,0.7 Gaussian white noise (zero mean) pollution picture, right side showed the Gaussian filter denoising results, showing that low-intensity noise filtering effect, but the picture has become blurred; filter out the effect of high-intensity difference. [18]

(a) 0.1 density noised image

(b) 0.1 density noised image filtered by Gaussian filtering


(c) 0.3 density noised image (d) 0.3 density noised image filtered by Gaussian filtering


(e) 0.7 density noised image (f) 0.7 density noised image filtered by Gaussian filtering

Figure 5.2.3(B) Gaussian

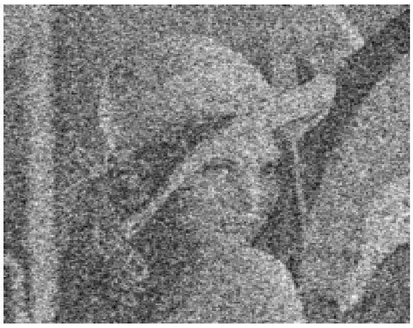
(C) Random noise

Next figure were 0.1,0.3,0.7 left column for the intensity of random noise pollution pictures, right as the Gaussian filter denoising results, showing that low-intensity noise filtering effect, but the picture becomes blurred; high-strength filter in addition to poor results. [15]


(a) 0.1 density noised image (b) 0.1 density noised image filtered by Gaussian filtering


(c) 0.3 density noised image (d) 0.3 density noised image filtered by Gaussian filtering

(e) 0.7 density noised image



(f) 0.7 density noised image filtered by Gaussian filtering

Figure 5.2.3(C) Random

### 5.2.4 Comparative Analysis

The figure showed three kinds of noise, and the filtering effect of contrast. By comparing the values, it can be found that median filtering has a good removal effect for salt and pepper noise; the Gaussian filtering can give Gaussian noise a better de-noising effect; the mean filter give a better affect for random noise. [20]

(A) Mean filter

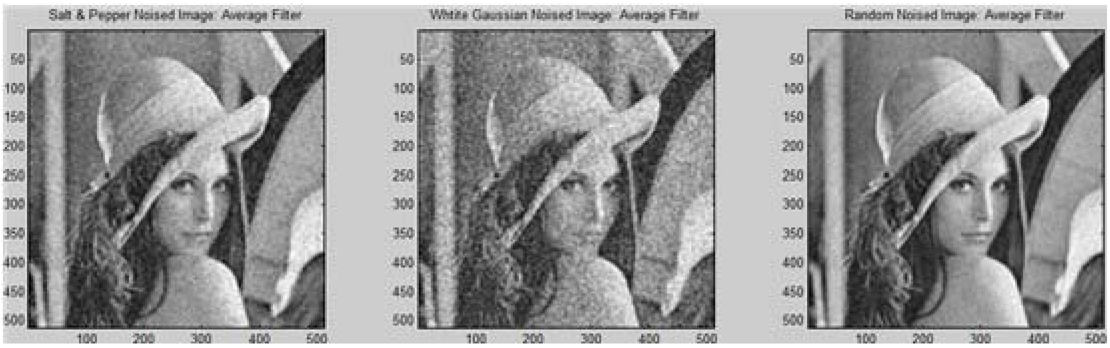



Figure 5.2.4(A) Mean filter

(B) Gaussian filtering

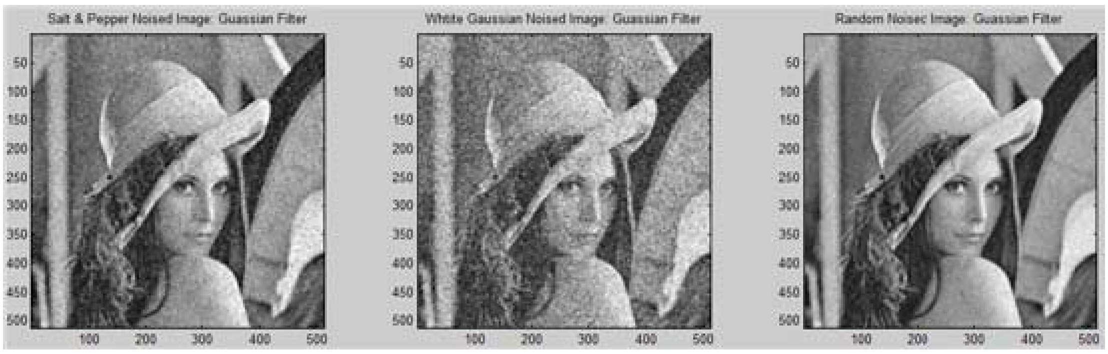



Figure 5.2.4(B) Gaussian filtering

(C) Median filter

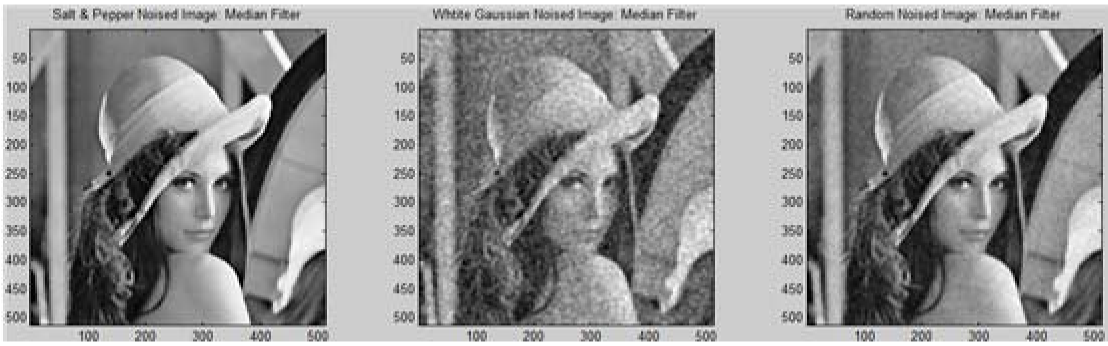



Figure 5.2.4(C) Median filter

## 5.3 Improving Filter for Simulation and Comparative Analysis

The de-noising filter plays an important role in image enhancement. Therefore, the filtering algorithm for improving the mainstream, it is necessary to delete defects and enhance the stability of processing results. [19]

Figure 5.3 shows the procedure edit box, press F5 to run the program.

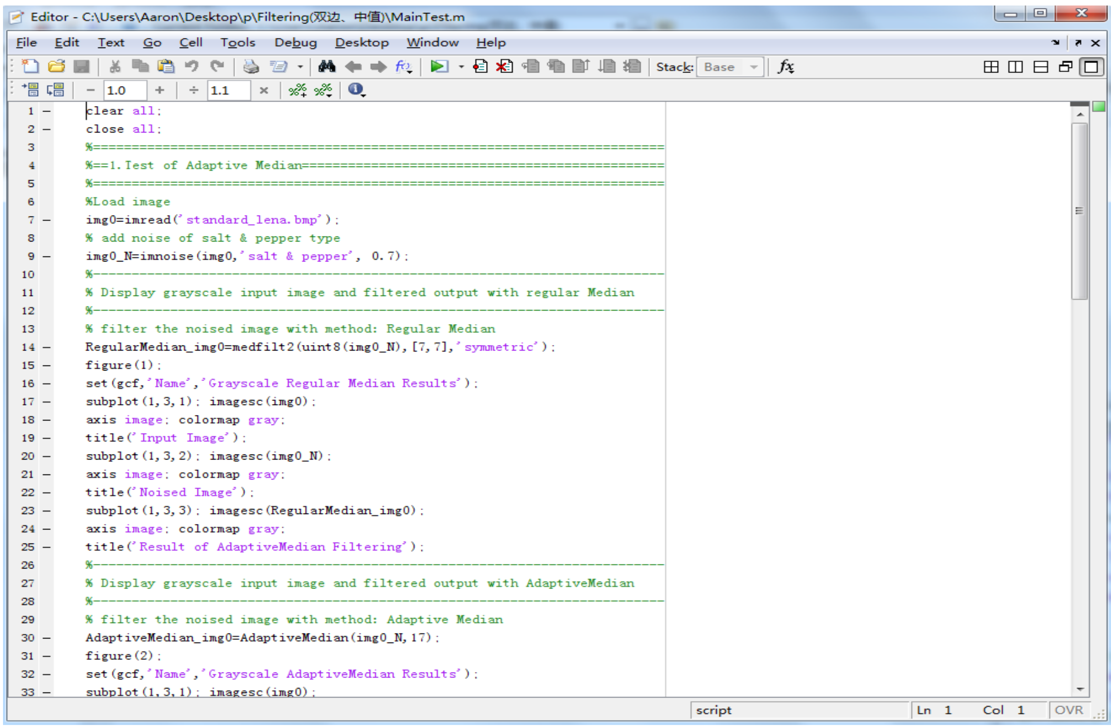



Figure 5.3 Maintest interface

After running the program, four maps will pop up. From left to right, the first picture shows the original image, the second picture shows the original image after the noise (noise pollution map), the third picture shows the results after filtering. [20]

(A) Ordinary median filtering processing

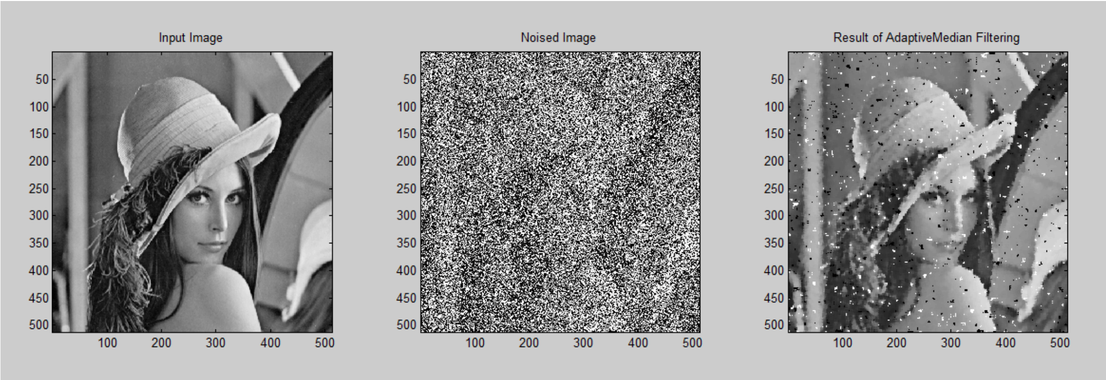



Figure 5.3(A) Ordinary median filtering

(B) Adaptive median filtering processing

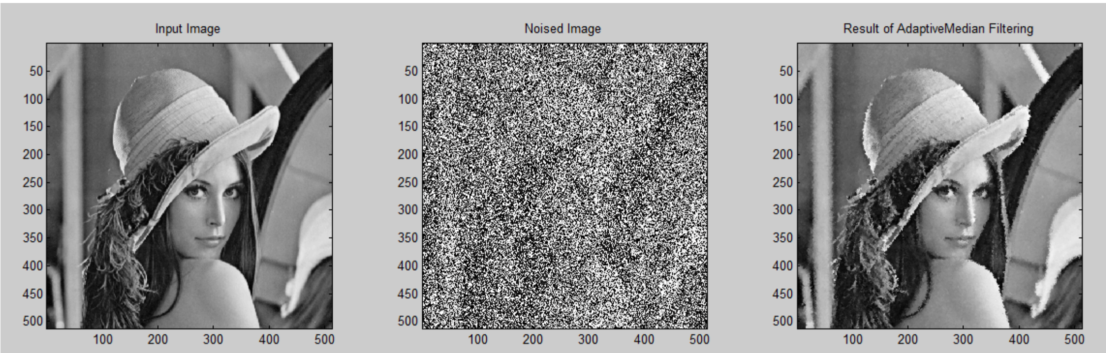



Figure 5.3(B) Adaptive median filtering

(C) Gaussian filtering processing

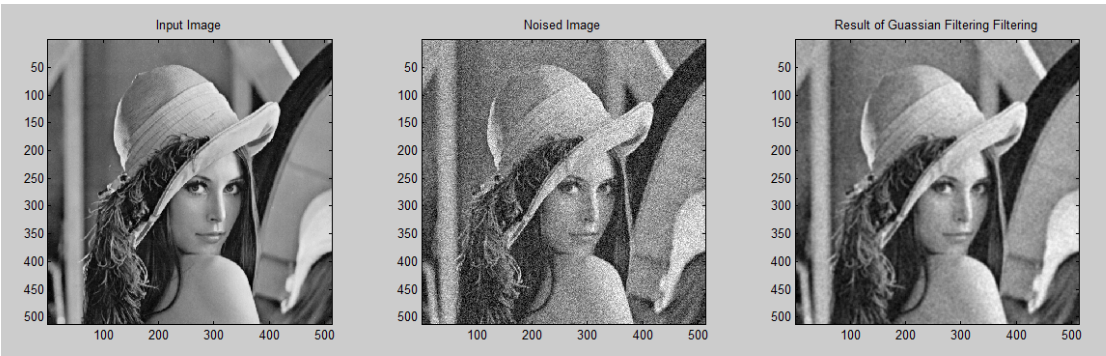



Figure 5.3(C) Gaussian filtering

(D) Bilateral filtering processing

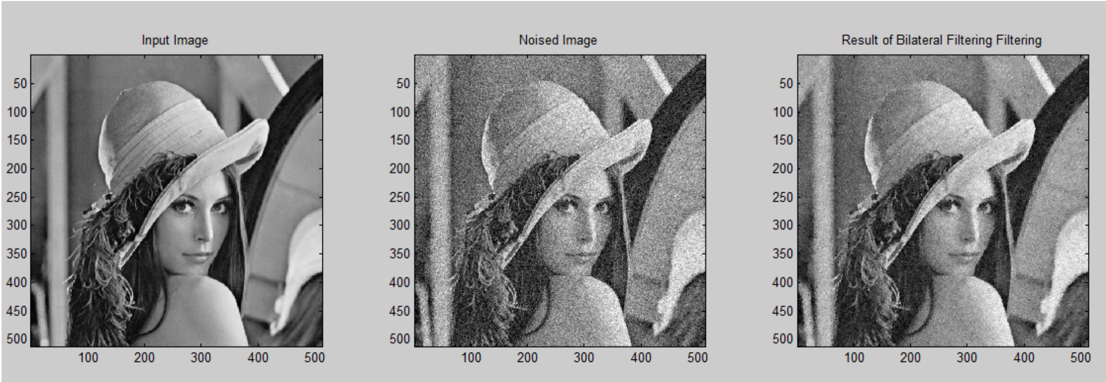



Figure 5.3(D) Bilateral filtering

Median filtering can protect the detail of image, so the image noise reduction processing has been more widely used. [2]

Standard median filter in aspect of image noise suppression and protection in the details exists contradiction: [21]

1) Filter window is so small, it can be protected image of some details.
2) Window filtering large, it can be enhanced the noise immunity. But the details of the protection would be weakened, sometimes filtered images in some of the thin, sharp edges and other important details. Thereby undermining the image geometry.

This contradiction in the image noise is high. Results shown in Figure 5.3(A), there are still a lot of noise spots. [21]

Adaptive median filter was largely palliative the contradiction between noise suppression and protection details. Comparing with the standard median filter has better filtering performance, it provides an effective way. Results shown in Figure 5.3(B) spots have been well filter. [22]

The traditional Gaussian filter assumes that the image point and its neighborhood on the point of gray are similar. And the noise is not relevant. On the edge of the image point and its sides are quite different point, so the filtering process inevitably to high-frequency components in addition to the image, resulting in the loss of the edge. Results shown in Figure 5.3(C) filter out the noise has been very good, but it lost a lot of edge information. [21]

Bilateral filtering method is based on the filtering method proposed by Gaussian theory. The filter weights optimized for image brightness information Gauss function and the product of the optimized weights for further information and images convolution. So it will be able to filter the image information, taking into account the image edge information. So that in the normal Gauss filtered image is blurred to maintain clear edge information and the edges of the image smoother. Results shown in Figure 5.3(D) noise filter, while being well, the edge information has been some reservations. [22]

# 6. Conclusions

Through a series of experimental data presented in this final project thesis, helps people process the image. It can be seen that the de-noising filter in image enhancement field holds an important position. It is necessary to make up for shortcomings and enhance its stability. At the same time, there is a need to solve the problem and improve them. There is also a need to analyze them in the future.

This design and the experiment gave me experience, a lot of suffering and challenges. Through this design I learned much knowledge in image processing field, I got a little practice and progress. Image processing is a great field, this research is not enough. It will continue to improve and perfect. For me personally this is the best way before entering the working life. This final project taught me how to solve problems on own.

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# Appendix A: Codes for Comparative Simulation of Improved Filters.

## 1) Adaptive Median Filter vs Median Filter

```
%Load image
img0=imread('standard_lena.bmp');
% add noise of salt & pepper type
img0_N=imnoise(img0,'salt & pepper', 0.7);
% Display grayscale input image and filtered output with regular Median
filter the noised image with method: Regular Median
RegularMedian_img0=medfilt2(uint8(img0_N),[7,7],'symmetric');
figure(1);
set(gcf,'Name','Grayscale Regular Median Results');
subplot(1,3,1); imagesc(img0);
axis image; colormap gray;
title('Input Image');
subplot(1,3,2); imagesc(img0_N);
axis image; colormap gray;
title('Noised Image');
subplot(1,3,3); imagesc(RegularMedian_img0);
axis image; colormap gray;
title('Result of AdaptiveMedian Filtering');
% Display grayscale input image and filtered output with AdaptiveMedian
filter the noised image with method: Adaptive Median
AdaptiveMedian_img0=AdaptiveMedian(img0_N,17);
figure(2);
set(gcf,'Name','Grayscale AdaptiveMedian Results');
subplot(1,3,1); imagesc(img0);
axis image; colormap gray;
title('Input Image');
subplot(1,3,2); imagesc(img0_N);
axis image; colormap gray;
title('Noised Image');
subplot(1,3,3); imagesc(AdaptiveMedian_img0);
axis image; colormap gray;
title('Result of AdaptiveMedian Filtering');
```

## 2) Bilateral Filter vs Gaussian Filter

```
%Load image
img1=double(imread('standard_lena.bmp'))/255;
% add noise of gaussian type
img1_N = img1+0.1*randn(size(img1));
img1_N(img1_N<0) = 0;
img1_N(img1_N>1) = 1;
% Display grayscale input image and filtered output with Guassian Filtering
```

```
generate Guassian Mask
PSF=fspecial('gaussian',[5,5],3);
% filter the noised image with method: Guassian Filtering
Guassian_img1=imfilter(img1_N,PSF,'symmetric');
figure(3);
set(gcf,'Name','Grayscale Guassian Filtering Results');
subplot(1,3,1); imagesc(img1);
axis image; colormap gray;
title('Input Image');
subplot(1,3,2); imagesc(img1_N);
axis image; colormap gray;
title('Noised Image');
subplot(1,3,3); imagesc(Guassian_img1);
axis image; colormap gray;
title('Result of Guassian Filtering Filtering');
% Display grayscale input image and filtered output with Bilateral
Filtering
%Load image
img1=double(imread('standard_lena.bmp'))/255;
% add noise of gaussian type
img1_N = img1+0.1*randn(size(img1));
img1_N(img1_N<0) = 0;
img1_N(img1_N>1) = 1;
% Set bilateral filter parameters.
% bilateral filter half-width
w = 2;
% bilateral filter standard deviations
sigma = [3 0.3];
% filter the noised image with method: Bilateral Filtering
Bilateral_img1=bfltGray(img1_N,w,sigma(1),sigma(2));
figure(4);
set(gcf,'Name','Grayscale Bilateral Filtering Results');
subplot(1,3,1); imagesc(img1);
axis image; colormap gray;
title('Input Image');
subplot(1,3,2); imagesc(img1_N);
axis image; colormap gray;
title('Noised Image');
subplot(1,3,3); imagesc(Bilateral_img1);
axis image; colormap gray;
title('Result of Bilateral Filtering Filtering');
```

**Appendix B: Codes for Adaptive Median Filter**

This Function perform adaptive median filtering of image g. The median filter starts at size 3-by-3 and iterates up to size Smax-by-Smax. Smax must be an odd integer greater than 1.

```
function f = AdaptiveMedian(g, Smax)
if (Smax <= 1) | (Smax/2 == round(Smax/2)) | (Smax ~= round(Smax))
   error('SMAX must be an odd integer > 1.')
end
%obtain width and height of image g
[M, N] = size(g);
% Initial setup
f = g;
f(:) = 0;
alreadyProcessed = false(size(g));
% Begin filtering
%increase size of filter window from 3 to Smax by 2
for k = 3:2:Smax
%minimum filtering 、maximum filtering and median filtering
zmin = ordfilt2(g, 1, ones(k, k), 'symmetric');
zmax = ordfilt2(g, k * k, ones(k, k), 'symmetric');
zmed = medfilt2(g, [k k], 'symmetric');
%check if zmed is the impulse noise:
%if no,processUsingLevelB=true,and go to Process Level B;vice versa
processUsingLevelB = (zmed > zmin) & (zmax > zmed) & ~alreadyProcessed;
%check if g is the impulse noise:
%if no,zB=true,and go to Process Level B;vice versa
zB = (g > zmin) & (zmax > g);
% if processUsingLevelB and zB are both ture,Zxy is output
outputZxy  = processUsingLevelB & zB;
% if processUsingLevelB is ture and zB is false,Zmed is output
outputZmed = processUsingLevelB & ~zB;
%set Zxy to output
f(outputZxy) = g(outputZxy);
%set Zmed to output
f(outputZmed) = zmed(outputZmed);
%set true pixel already processed,namely relative ouput is already set
alreadyProcessed = alreadyProcessed | processUsingLevelB;
% if all pixel are processed and the outputs are obtained ,filtering is
completed
if all(alreadyProcessed(:))
break;
end
end
```

```
% Output zmed for any remaining unprocessed pixels. Note that this
% zmed was computed using a window of size Smax-by-Smax, which is
% the final value of k in the loop.
f(~alreadyProcessed) = zmed(~alreadyProcessed);
```

**Appendix C: Codes for Bilateral Median Filter**

This function performs 2-D bilateral filtering for the grayscale image A. A should be a double precision matrix of size NxMx1 with normalized values in the closed interval [0,1]. The half-size of the Gaussian bilateral filter window is defined by W. The standard deviations of the bilateral filter are given by [sigma_d,sigma_r], where the spatial-domain standard deviation is given by sigma_d and the intensity-domain standard deviation is given by sigma_r.

```
function B = bfltGray(A,w,sigma_d,sigma_r)
% Pre-compute Gaussian distance weights.
[X,Y] = meshgrid(-w:w,-w:w);
G = exp(-(X.^2+Y.^2)/(2*sigma_d^2));
% Create waitbar.
h = waitbar(0,'Applying bilateral filter...');
set(h,'Name','Bilateral Filter Progress');
% Apply bilateral filter.
dim = size(A);
B = zeros(dim);
for i = 1:dim(1)% search in image A
for j = 1:dim(2)
% Extract corresponding local region in image A.
iMin = max(i-w,1);
iMax = min(i+w,dim(1));
jMin = max(j-w,1);
jMax = min(j+w,dim(2));
I = A(iMin:iMax,jMin:jMax);
% Compute Gaussian intensity weights.
H = exp(-(I-A(i,j)).^2/(2*sigma_r^2));
% Calculate bilateral filter intensity weights by the multiply between
gray-distance-based Gaussian intensity weights and space-distance-based
Gaussian intensity weights.
F = H.*G((iMin:iMax)-i+w+1,(jMin:jMax)-j+w+1);
% Calculate bilateral filter response.
B(i,j) = sum(F(:).*I(:))/sum(F(:));
end
waitbar(i/dim(1));% Diaplay Processing state
end
% Close waitbar
close(h);
```