A Multi Diversified GUI for Analysis of Image Denoising using Various Parameters

Deepti Rai[1], Kusha Shrivastava[2]

[1]Proffessor Electronics and Communication Engineering, Department, Alpine Institute of Technology, Ujjain (M.P), India
[2]PG Student, Department of Electronics and Communication Engineering, Alpine Institute of Technology, Ujjain (M.P), India

Abstract: ***Digital Image Processing is a promising area of research in the fields of electronics and communication engineering, consumer and entertainment electronics, control and instrumentation, biomedical instrumentation, remote sensing, robotics and computer vision and computer aided manufacturing (CAM). For a meaningful and useful processing such as image segmentation and object recognition, and to have very good visual display in applications like television, photo-phone, etc., the acquired image signal must be deblurred and made noise free. The deblurring and noise suppression (filtering) come under a common class of image processing tasks known as image restoration. This research work addresses several issues with image denoising taking into consideration several known parameters. For this purpose a GUI has been developed in Matlab which produced several research parameters.***

Keywords: Haar wavelet, Median filter, Salt and Pepper noise, Gaussian noise, PSNR and RMSE

1. Introduction to Image Processing

Digital image processing generally refers to the processing of a 2-dimensional (2-D) picture signal by a digital hardware. In a broader context, it implies processing of any signal using a dedicated hardware, e.g. an application specific integrated circuit (ASIC) or using a general-purpose computer implementing some algorithms developed for the purpose. An image is a 2-D function (signal), X( ) m, n, where m and n are the spatial (plane) coordinates. The magnitude of X at any pair of coordinates (m, n) is the intensity or gray level of the image at that point. In a digital image, m, n, and the magnitude of X are all finite and discrete quantities. Each element of this matrix (2-D array) is called a picture element or pixel. It is a hard task to distinguish between the domains of image processing and any other related area such as computer vision. Though, essentially not correct, image processing may be defined as a process where both input and output are images. At the high level of processing and after some preliminary processing, it is very common to perform some analysis, judgment or decision making or perform some mechanical operation (robot motion). These areas are the domains of artificial intelligence (AI), computer vision, robotics, etc. Digital image processing has a broad spectrum of applications, such as digital television, photo-phone, remote sensing, image transmission, and storage for business applications, medical processing, radar, sonar, and acoustic image processing, robotics, and computer aided manufacturing (CAM) and automated quality control in industries. Fig. 1.1 depicts a typical image processing system [1, 2].

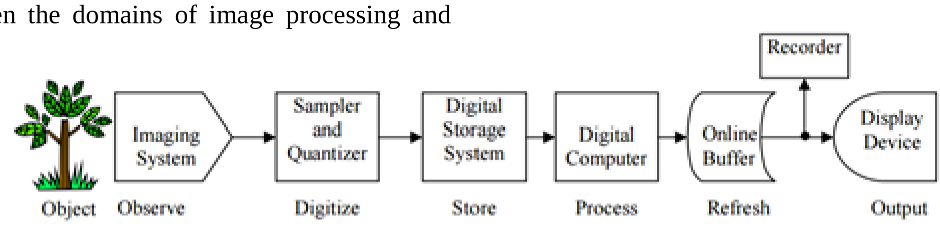

Figure 1.1: A typical digital image processing system

With the exception of image acquisition and display, most of the images processing functions are implemented in software. A significant amount of basic image processing software is obtained commercially. Major areas of image processing are [2]: (a) Image Representation and Modeling (b) Image Transform (c) Image Enhancement (d) Image Filtering and Restoration (e) Image Analysis and Recognition (f) Image Reconstruction (g) Image Data Compression (h) Color Image Processing, etc. Image processing may be performed in the spatial domain or in a transform domain. To perform a meaningful and useful task, a suitable transformer, e.g. discrete Fourier transform (DFT), discrete cosine transform (DCT), discrete wavelet transform (DWT), etc., may be employed. Depending on the application, a suitable transform is used. Image enhancement tech niques are used to highlight certain features of interest in an image. Two important examples of image enhancement are (i) increasing the contrast, and (ii) changing the brightness level of an image so that the image looks better. It is a subjective area of image processing. On the other hand, image restoration is very much objective. The restoration techniques are based on mathematical and statistical models of image degradation. Denoising (filtering) and deblurring tasks come under this category. Image processing is characterized by specific solutions; hence a technique that works well in one area may totally be inadequate in another. The actual solution to a specific problem still requires a significant research and development. 'Image restoration and filtering' is one of the prime areas of image processing and its objective is to recover the images from degraded observations. The techniques involved in image restoration and filtering are oriented towards modeling the degradations and then applying an inverse procedure to obtain an approximation of the original image. There are various types of imaging systems. X-ray, Gamma ray, ultraviolet, and ultrasonic imaging systems are used in biomedical instrumentation. In astronomy, the ultraviolet, infrared and radio imaging systems are used. Sonic imaging is performed for geological exploration. Microwave imaging is employed for radar applications. But, the most commonly known imaging systems are visible light imaging. Such systems are employed for applications like remote sensing, microscopy, measurements, consumer electronics, entertainment electronics, etc. An image acquired by optical, electro-optical or electronic means is likely to be degraded by the sensing environment. The degradation may be in the form of sensor noise, blur due to camera misfocus, relative object camera motion, random atmospheric turbulence, and so on [1, 2]. The noise in an image may be due to a noisy channel if the image is transmitted through a medium. It may also be due to electronic noise associated with a storage-retrieval system. Noise in an image is a serious problem. The noise could be AWGN, SPN, RVIN, or a mixed noise. Efficient suppression of noise in an image is a very important issue. Denoising finds extensive applications in many fields of image processing. Conventional techniques of image denoising using linear and nonlinear techniques have already been reported and sufficient literature is available in this area and has been reviewed in the next section. Recently, various nonlinear and adaptive filters have been suggested for the purpose. The objectives of these schemes are to reduce noise as well as to retain the edges and fine details of the original image in the restored image as much as possible. However, both the objectives conflict each other and the reported schemes are not able to perform satisfactorily in both aspects. Hence, still various research workers are actively engaged in developing better filtering schemes using latest signal processing techniques.

2. Different Types of Noise Associated with Digital Images

In the image denoising process, information about the type of noise present in the original image plays a significant role. Typical images are corrupted with noise modeled with both a Gaussian, uniform, or salt and pepper distribution. Another typical noise is a speckle noise, which is multiplicative in nature. The behavior of each of these noises is described in Section 2.1 through Section 2.4. Noise is present in an image either in an additive or multiplicative form [Im01]. An additive noise follows the rule wxy sxy nxy (,) (,) (,) = +, while the multiplicative noise satisfies wxy sxy nxy (,) (,) (,) = ×, where s(x, y) is the original signal, n(x, y) denotes the noise introduced into the signal to produce the corrupted image w(x, y), and (x, y) represents the pixel location. The above image algebra is done at pixel level. Image addition also finds applications in image morphing [Um98]. By image multiplication, we mean the brightness of the image is varied. The digital image acquisition process converts an optical image into a continuous electrical signal that is, then, sampled [Um98]. At every step in the process there are fluctuations caused by natural phenomena, adding a random value to the exact brightness value for a given pixel.

2.1 Gaussian Noise

Gaussian noise is evenly distributed over the signal [Um98]. This means that each pixel in the noisy image is the sum of the true pixel value and a random Gaussian distributed noise value. As the name indicates, this type of noise has a Gaussian distribution, which has a bell shaped probability distribution function given by,

$$F(g) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(g-m)^2/2\sigma^2},$$

where g represents the gray level, m is the mean or average of the function, and σ is the standard deviation of the noise. Graphically, it is represented as shown in Figure 2.1. When introduced into an image, Gaussian noise with zero mean and variance as 0.05 would look as in Image 2.1 [Im01]. Image 2.2 illustrates the Gaussian noise with mean (variance) as 1.5 (10) over a base image with a constant pixel value of 100.

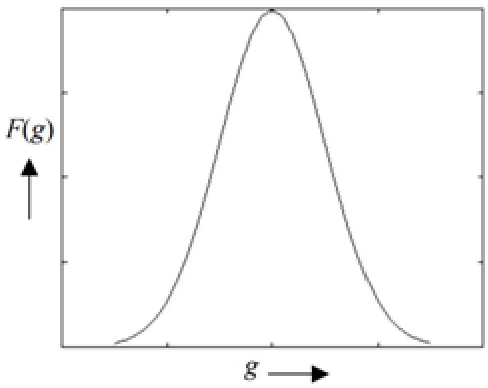

Figure 3.1: Gaussian distribution

2.2 Salt and Pepper Noise

Salt and pepper noise [Um98] is an impulse type of noise, which is also referred to as intensity spikes. This is caused generally due to errors in data transmission. It has only two possible values, a and b. The probability of each is typically less than 0.1. The corrupted pixels are set alternatively to the minimum or to the maximum value, giving the image a "salt and pepper" like appearance. Unaffected pixels remain unchanged. For an 8-bit image, the typical value for pepper noise is 0 and for salt noise 255. The salt and pepper noise is generally caused by malfunctioning of pixel elements in the camera sensors, faulty memory locations, or timing errors in the digitization process. The probability density function for this type of noise is shown in Figure 2.2. Salt and pepper noise with a variance of 0.05 is shown in Image 2.3 [Im01].

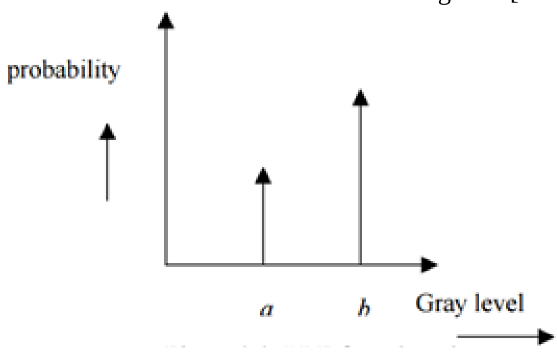

Figure 3.2: PDF for salt and pepper noise

2.3 Speckle Noise

Speckle noise [Ga99] is a multiplicative noise. This type of noise occurs in almost all coherent imaging systems such as laser, acoustics and SAR(Synthetic Aperture Radar) imagery. The source of this noise is attributed to random interference between the coherent returns. Fully developed speckle noise has the characteristic of multiplicative noise. Speckle noise follows a gamma distribution and is given as

$$F(g) = \frac{g^{\alpha-1}}{(\alpha-1)!a^{\alpha}} e^{-\frac{g}{a}},$$

where variance is $a^2\alpha$ and g is the gray level. On an image, speckle noise (with variance 0.05) looks as shown in Image 3.4 [Im01]. The gamma distribution is given below in Figure 3.3.

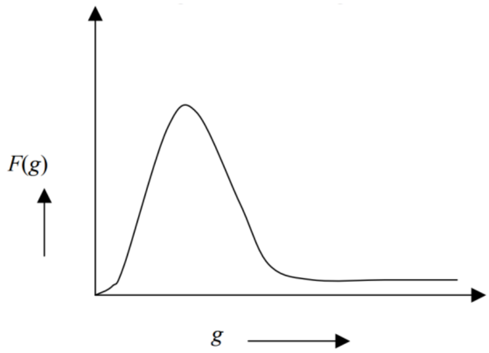

Figure 3.3: Gamma distribution

3. Result and Analysis

A graphical user interface has been developed in MATLAB having the following features:-

- Types of noise

i) salt and pepper
ii) Gaussian
iii) speckle

- Types of filters

i) Average filter
ii) median filter
iii) Gaussian filter
iv) wiener filter

- Types of image color functions

i) Color images
ii) Grayscale images
iii) Inverted color images

- Comparison modes

i) 2d comparison
ii) 3d comparison
iii) comparison by means of MSE (mean square error)

The completed GUI has been shown below for ready reference :-

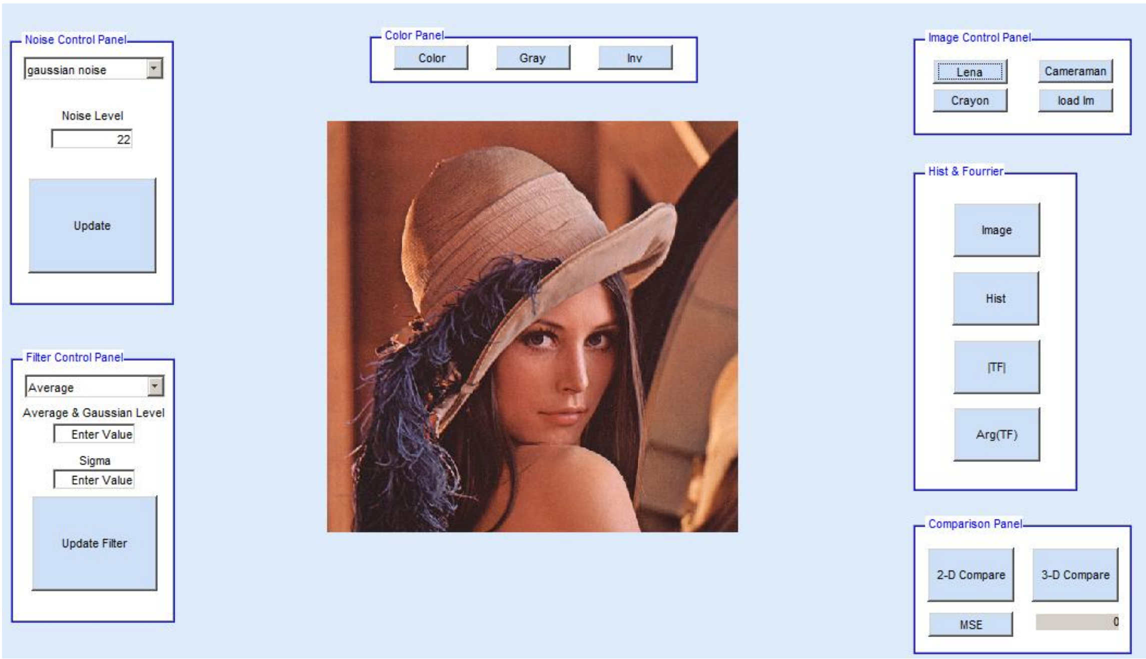

Figure 3.1: Complete graphical user interface

3.1 Results with different parameter sets

- Noise type :- Salt & pepper
- Noise level :- 5 %
- Filter :- Average
- Average level :- 3
- Gaussian level :- 0.25

(a) Image without filter

(b) Image with filter

MSE = 18.05

- Noise type :- Gaussian
- Noise level :- 5 %
- Filter :- Gaussian
- Average level :- 3
- Gaussian level :- 0.25

(a) Image without filter

(b) Image with filter
MSE = 25.5

4. Conclusion

The purpose of this research work is to study and compare various noises present in digital images and methods to remove them. Our focus has been specifically on three types of noise i.e :-

- Salt and pepper noise
- Gaussian noise.
- Speckle noise

To remove these noises from the images we have chosen the following filters for comparison:-

- Average filter.
- Median filter.
- Gaussian filter.
- Wiener filter
- It has been found in our research that for different parameters and noises, different filters are proven to be effective as compared to the others. thus one cannot conclude that any one filter outmatches the other under diversified conditions.

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