DIFFERENT TYPES OF NOISES IN IMAGES AND NOISE REMOVING TECHNIQUE

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ABSTRACT

In this paper, we discuss different types of noises present in the image. Also with this we discuss the different sources which are responsible for producing these noises.

Also we discuss different types of filters which are used to remove these noises.

Index Terms: Sources of Noise, Different Types of Noises, Filters to Remove These Noises, Image De-Noising. Window Concept

I. SOURCES OF NOISE IN DIGITAL IMAGES

With the advancement in computers and digital imaging technologies, the costs of digital cameras and computers are lowering each years,and thus these equipments are becoming affordable these days.The usage of digital images in our daily life is turning common. As more information can be extracted from digital images, as compared to one dimensional signal,many research areas,including material researches,are now utilizing digital images,such as microscopic images and X-ray images, as one of their evaluation tools. As the information from digital images are easier to be evaluated as compared with one dimensional signals, digital images are now commonly used in may research fields. Unfortunately, similar to other digital signals, digital images are also sometimes unintentionally corrupted by unwanted signals, called noise. Image is a powerful medium to convey visual information. In digital Image Processing, removal of noise is a highly demanded area of research. Digital images are often corrupted by noise during their acquisition and transmission. Noisy images can be found in many today's imaging applications. TV images are corrupted because of atmospheric interference and imperfections in the image reception. Noise is also introduced in digital artworks when scanning damaged surfaces of the originals. Impulse noise corruption often occurs in digital image acquisition or transmission process as a result of photo-electronic sensor faults or channel bit errors. Image transmission noise may be caused by various sources, such as car ignition systems, industrial machines in the vicinity of the receiver, switching transients in power lines, lightning in the atmosphere and various unprotected switches. Digital images play an important role both in daily life applications such as Satellite television, Magnetic Resonance Imaging, Computer Tomography as well as in areas of research and technology such as geographical information systems and astronomy .Digital images are often corrupted by different types of noise during its acquisition and transmission phase. Such degradation negatively influences the performance of many image processing techniques and a preprocessing module to filter the images is often required [1, 2].

Noise removal is one of the major concerns in the field of computer vision and image processing. Images are often contaminated by impulsive noise due to noisy sensors or channel transmission errors or faulty storage hardware. The goal of removing impulsive noise is primarily to suppress the noise as well as to preserve the integrity of edges and detailed information. In the field of digital image processing, twoapplications of great importance are noise filtering and image enhancement.

Noise sources

Image acquisition

Image transmission

Noise models

Spatially independent noise models

- Gaussian noise
- Rayleigh noise
- Erlang (Gamma) noise
- Exponential noise
- Impulse (salt-and-pepper) noise

Spatially dependent noise model

- Periodic noise

II. DIFFERENT TYPES OF NOISES IN IMAGES &THEIR MODELS

2.1 Impluse Noise

One of the noises commonly corrupting digital image is the impulse noise. Therefore, impulse noise reduction has become one of the active researches in these recent years. Many impulse noise models have been proposed by researchers for this research purpose. Due to a number of non-idealities in the imaging process the noise usually corrupts images by replacing some of the pixels of the original image with new pixels having luminance values near or equal to the minimum or maximum of the allowable dynamic luminance range. Impulse noise is caused by malfunctioning pixels in camera sensors, faulty memory locations in hardware, or transmission in a noisy channel. Impulse noise can be classified into two types: fixed-valued impulse noise and random-valued impulse noise. The fixed-valued impulse noise is also called salt-and pepper noise where the grayscale value of a noisy pixel is either minimum or maximum in gray-scale images. The grayscale values of noisy pixels corrupted by random-valued impulse noise are uniformly distributed in the range of [0,255] for gray scale images. Impulse noise can be assumed as an additive noise [3], and randomly damages the pixel, at random positions [4].

Normally, impulse noise appears as black and white speckles on the image [5]. Pixels corrupted by impulse noise are normally having either extremely high, or extremely low intensity values [6]. Usually, they have very high contrast towards their clean, uncorrupted smooth surrounding areas [7]. Therefore, impulse noise, even at a low level of degradation, will damage the appearance of digital image According to the distribution of noisy pixel values, impulse noise can be classified into two categories: Fixed-Valued impulse noise and Random-Valued impulse noise. The Fixed Values impulse noise is also known as Salt and Pepper Noise since the pixel value of a noisy pixel is either minimum or maximum value in grayscale images. The values of noisy pixels corrupted by random valued impulse noise are uniformly distributed in the range of [0,255] for gray-scale images. Removal of Random valued impulse noise is more complicated due to the random distribution of the noise pixels.[9]

We can consider a noisy image to be modelled as follows:

$$g(x, y) = f(x, y) + \eta(x, y)$$

where $f(x, y)$ is the original image pixel, $\eta(x, y)$ is the noise term and $g(x, y)$ is the resulting noisy pixel

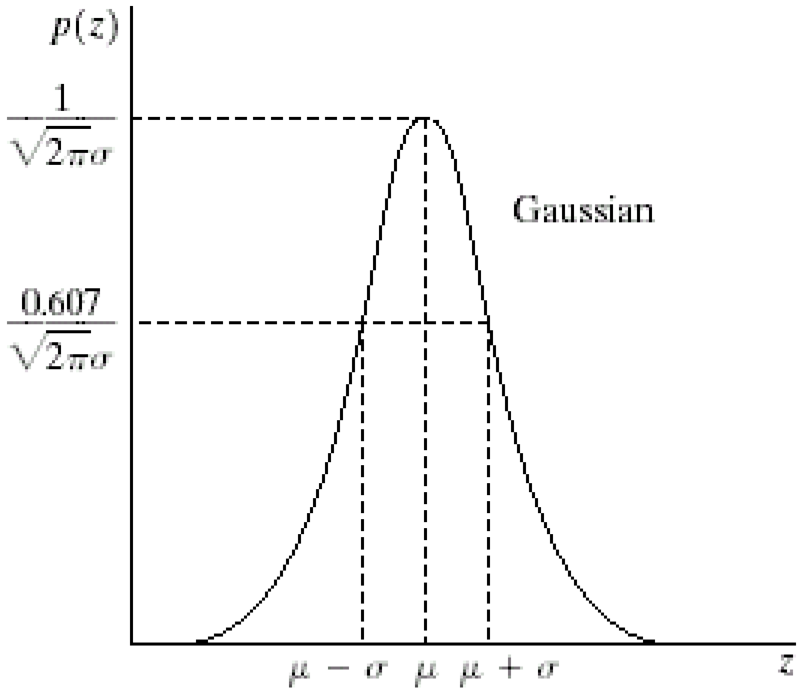
2.2 Gaussian Noise

An image gets corrupted with different types of noise .Noise may be classified as SUBSTITUTIVE NOISE (impulsive noise:salt and pepper noise,random valued impulse noise,etc.) and ADDITIVE NOISE (e.g.additive white Gaussian noise). In many ocasssions,noise in digital images is found to be additive in nature with uniform power in the whole bandwidth with Gaussian probability distribution.such a noise is referred to as additive white Gaussian noise(AWGN). The AWGN is mathematically represeted by,

η NAWGN(t)= ηG(t)σ fAWGN =f(x,y)+ ηG(x,y)----(1)

Where ηG(t) is a random variable that has a Gaussian probability distribution .It is an additive niose that is charactrsed by its variance σ 2. In (1), the noisy image is represented as a sum of the original uncorrupted image and the Gaussian distributed random noise ηG. When the variance of the random noise ηG is very low, ηG(x,y) is zero or very close to zero at many pixel locations.Under such circumstances,the noisy image fAWGN is same or very close to the original image f(x,y) at many pixel locations(x,y).

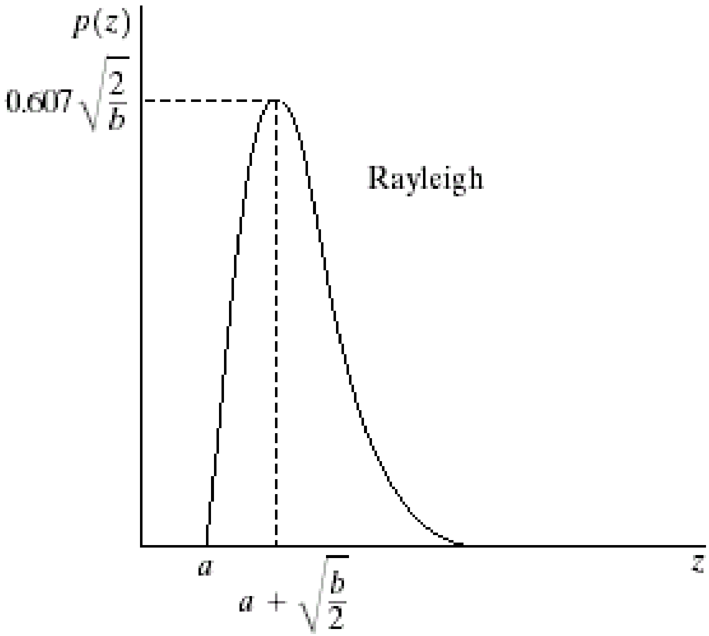
Gaussian noise is generated during film exposure and development of the image.



Other Noise Models

2.3 Rayleigh Noise

Radar range and velocity images typically contain noise that can be modeled by the Rayleigh distribution.



The mean and variance of this density are given by

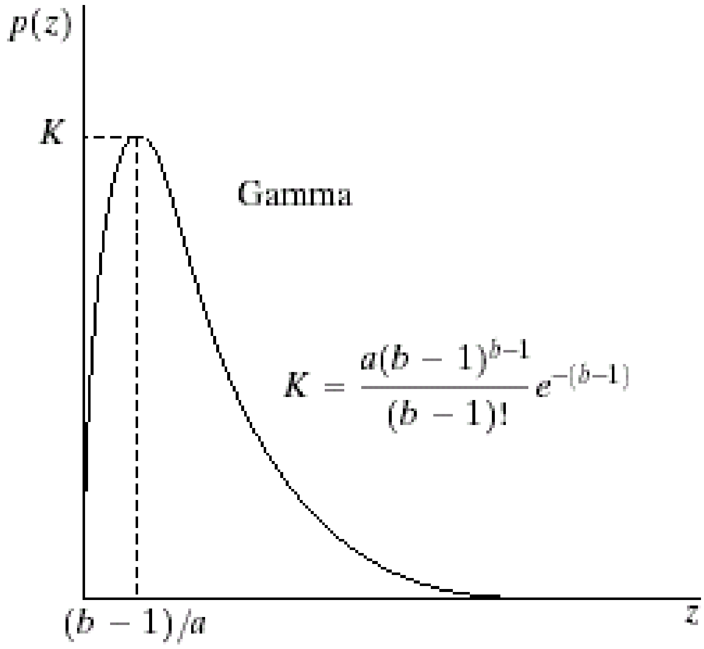
$\mu = a + \sqrt{\pi b/4}$ and $\sigma^2 = \dfrac{b(4-\pi)}{4}$ a and b can be obtained through mean and variance.

2.4 Erlang (Gamma) Noise

$$p(z) = \begin{cases} \dfrac{a^b z^{b-1}}{(b-1)!} e^{-az} & \text{for } z \ge 0 \\ 0 & \text{for } z < 0 \end{cases}$$

The mean and variance of this density are given by

$\mu = b/a$ and $\sigma^2 = \dfrac{b}{a^2}$ a and b can be obtained through mean and variance

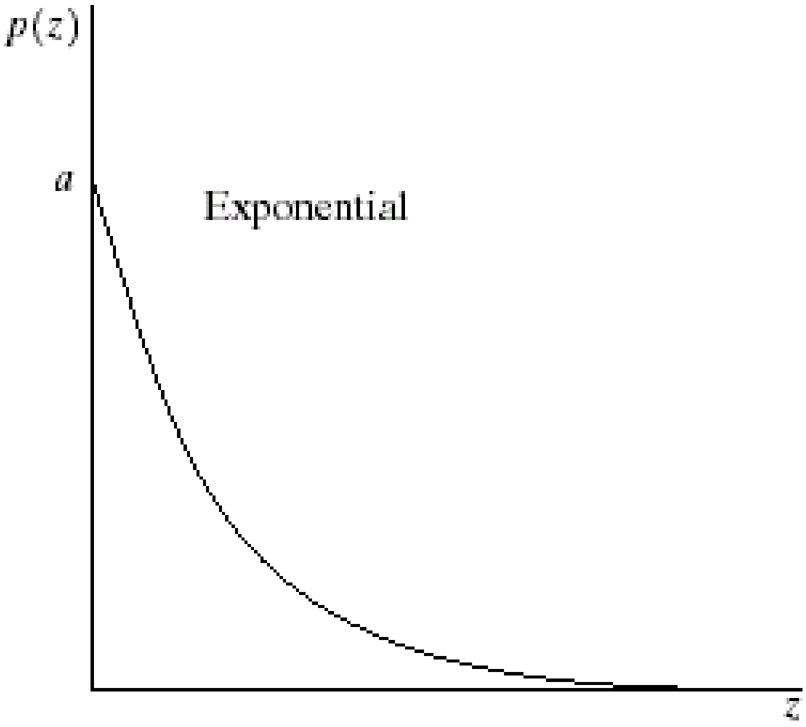


2.5 Exponential Noise

$$p(z)=\begin{cases} ae^{-az} & \text{for } z \geq 0 \\ 0 & \text{for } z < 0 \end{cases}$$

The mean and variance of this density are given by $\mu = 1/a$ and $\sigma^2 = \dfrac{1}{a^2}$

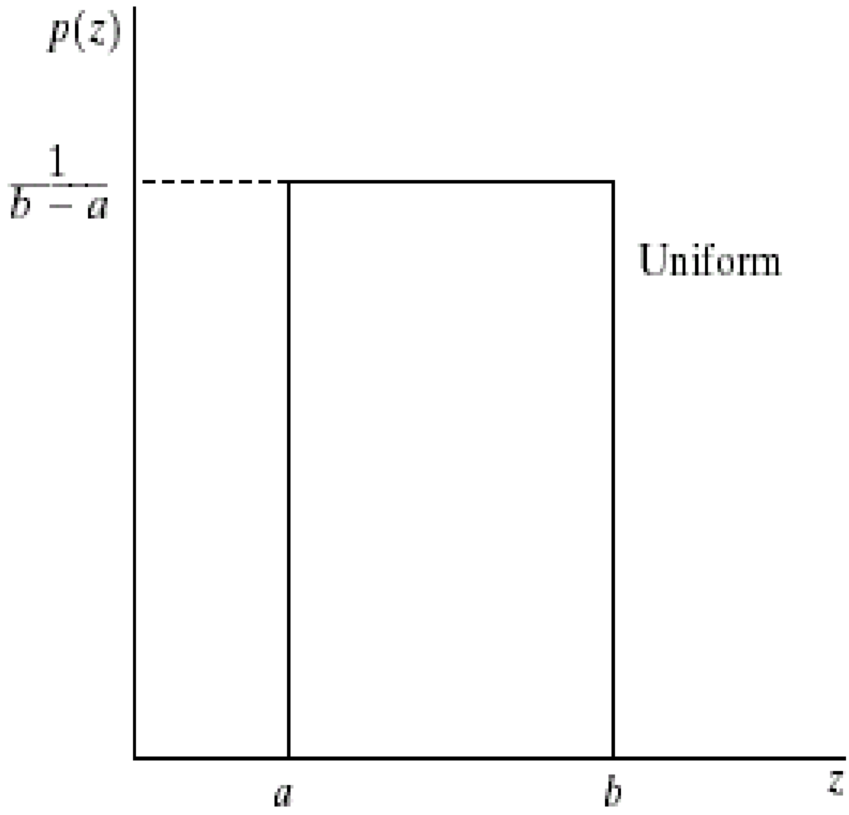
Special case pf Erlang PDF with b=1



2.6 Uniform Noise

The uniform noise cause by quantizing the pixels of image to a number of distinct levels is known as quantization noise. It has approximately uniform distribution. In the uniform noise the level of the gray values of the noise are uniformly distributed across a specified range. Uniform noise can be used to generate any different type of noise distribution. This noise is often used to degrade images for the evaluation of image restoration algorithms. This noise provides the most neutral or unbiased noise .[4] $p(z)=\begin{cases} \dfrac{1}{b-a} & \text{if } a \leq z \leq b \\ 0 & \text{otherwise} \end{cases}$

The mean and variance of this density are given by $\mu = (a+b)/2$ and $\sigma^2 = \dfrac{(b-a)^2}{12}$



2.7 Impulse (Salt-And-Pepper) Noise

The salt-and-pepper noise are also called shot noise, impulse noise or spike noise that is usually caused by faulty memory locations , malfunctioning pixel elements in the camera sensors, or there can be timing errors in the process of digitization. In the salt and pepper noise there are only two possible values exists that is a and b and the probability of each is less than 0.2.If the numbers greater than this numbers the noise will swamp out image. For 8-bit image the typical value for 255 for salt-noise and pepper noise is 0

Reasons for Salt and Pepper Noise:

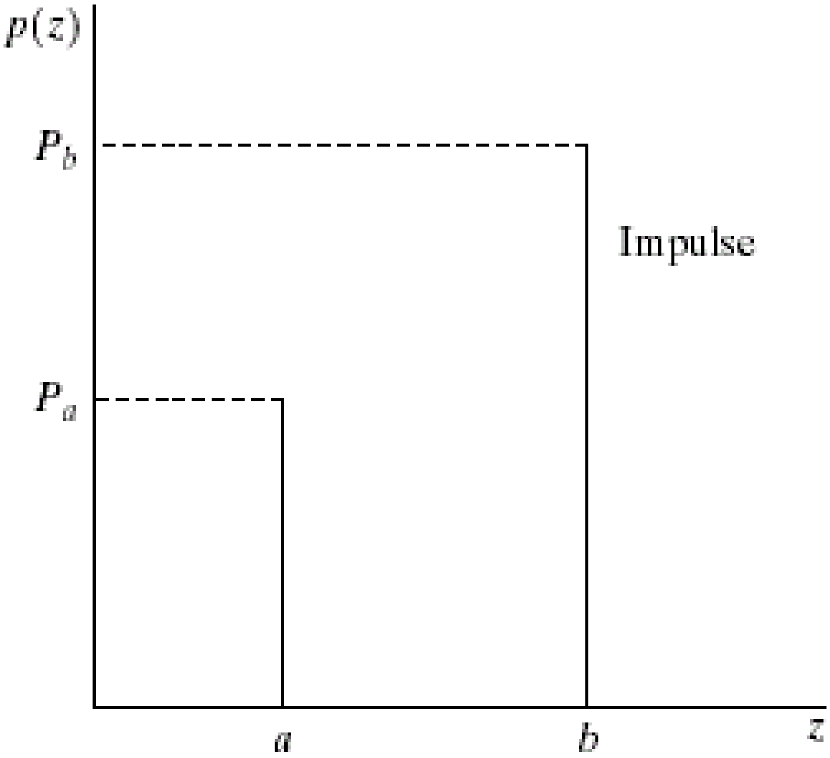
a. By memory cell failure.

b. By malfunctioning of camera's sensor cells.

c. By synchronization errors in image digitizing or transmission.

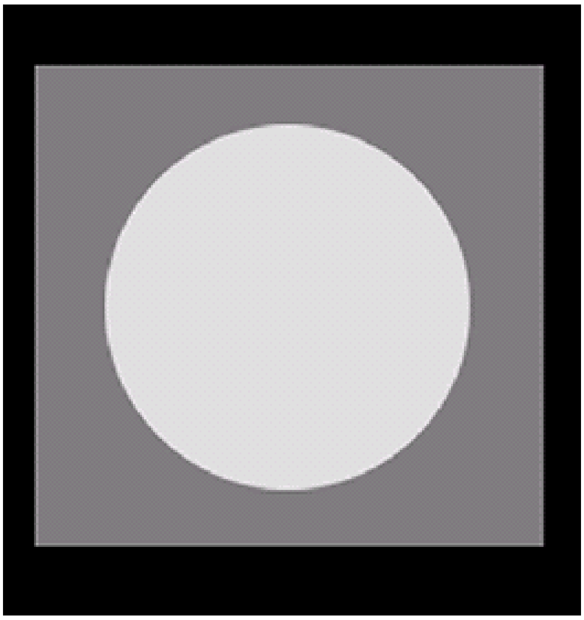
$$p(z) = \begin{cases} P_a & \text{for } z = a \\ P_b & \text{for } z = b \\ 0 & \text{otherwise} \end{cases}$$

If either Pa or Pb is zero, the impulse noise is called unipolar a and b usually are extreme values because impulse corruption is usually large compared with the strength of the image signal It is the only type of noise that can be distinguished from others visually.



Example of effect of these noises on the image

A Sample Image



Effect of Adding Noise to Sample Image

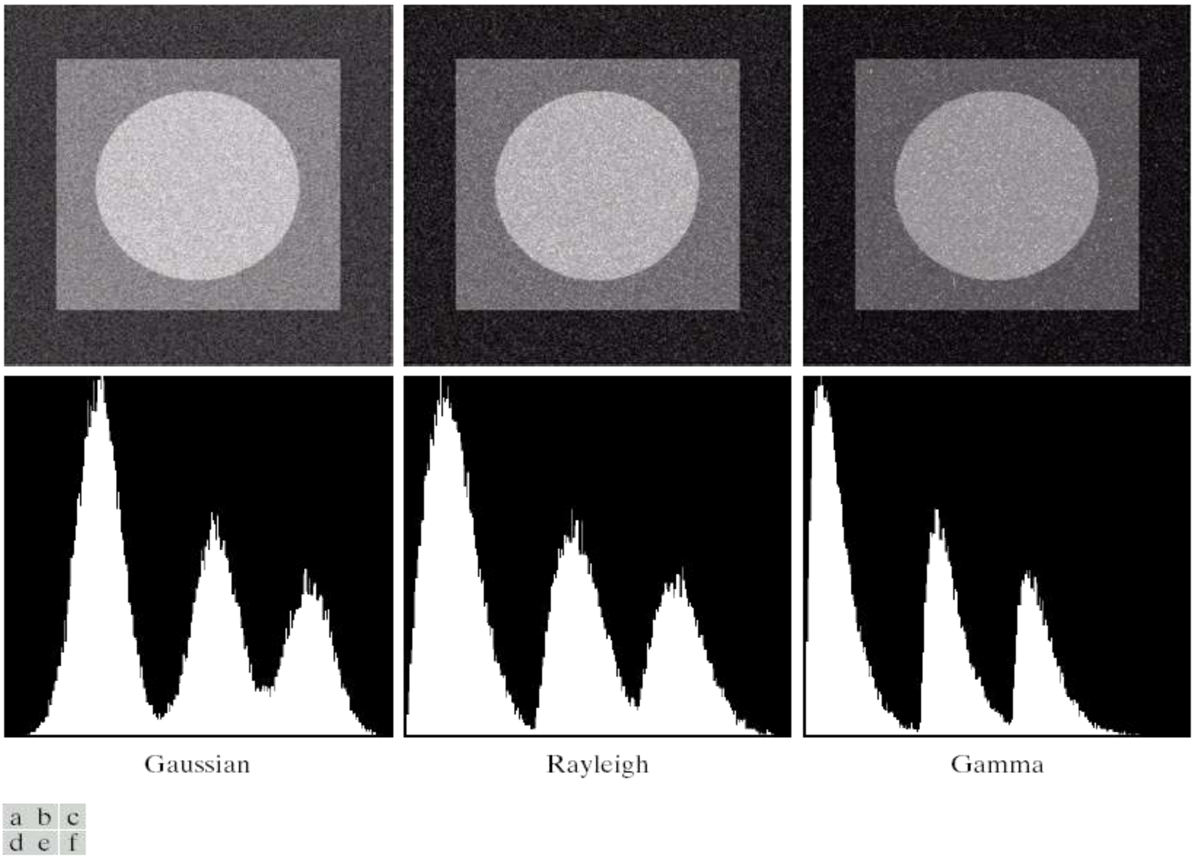


FIGURE 5.4 Images and histograms resulting from adding Gaussian, Rayleigh, and gamma noise to the image in Fig. 5.3.

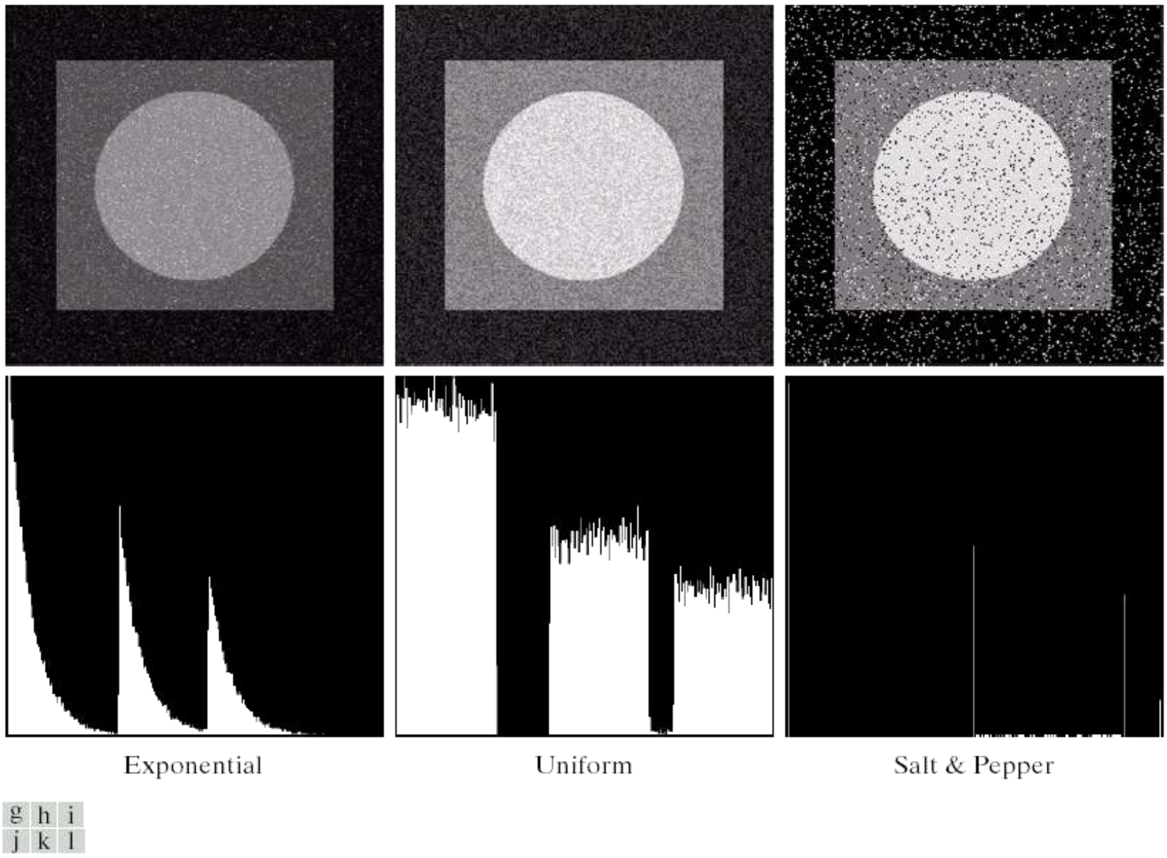


FIGURE 5.4 *(Continued)* Images and histograms resulting from adding exponential, uniform, and impulse noise to the image in Fig. 5.3.

III. IMAGE DE-NOISING

Image de-noising is very important task in image processing for the analysis of images. Ample image de-noising algorithms are available, but the best one should remove the noise completely from the image, while preserving the details. De-noising methods can be linear as well as non-linear. Where linear methods are fast enough, but they do not preserve the details of the images, whereas the non- linear methods preserve the details of the images. Broadly speaking, De-noising filters can be categorized in the following categories:
Averaging filter ,Order Statistics filter and Adaptive filter.

IV. DIFFERENT TYPES OF FILTERS USED TO REMOVE THESE NOISES:

4.1 Mean Filter

Mean filter is an averaging linear filter. Here the filter computes the average value of the corrupted image in a predecided area. Then the center pixel intensity value is replaced by that average value. The mean filter is a simple spatial filter. It is sliding-window filters that replace the center value in the window. It replaces with the average mean of all the pixel values in the kernel or window. The window is usually square but it can be of any shape.

4.2 Median Filter

Median filter is a best order static, non- linear filter, whose response is based on the ranking of pixel values contained in the filter region. Median filter is quite popular for reducing certain types of noise. Here the center value of the pixel is replaced by the median of the pixel values under the filter region .Median[10] Filter is a simple and powerful non-linear filter which is based order statistics. It is easy to implement method of smoothing images. Median filter is used for reducing the amount of intensity variation between one pixel and the other pixel. In this filter, we do not replace the pixel value of image with the mean of all neighboring pixel values, we replaces it with the median value. Then the median is calculated by first sorting all the pixel values into ascending order and then replace the pixel being calculated with the middle pixel value. If the neighboring pixel of image which is to be consider contain an even numbers of pixels, than the average of the two middle pixel values is used to replace. The median filter gives best result when the impulse noise percentage is less than 0.1 %. When the quantity of impulse noise is increased the median filter not gives best result. Median filter is good for salt and pepper noise. These filters are widely used as smoothers for image processing, as well as in signal processing. A major advantage of the median filter over linear filters is that the median filter can eliminate the effect of input noise values with extremely large magnitudes.

4.3 Standard Median Filters

Used to remove impulse noise due to its simplicity and effective noise suppression capability. Median filters are implemented uniformly across the image and thus tend to modify both noisy and non noisy pixels. Effective removal of impulse using median filter is often accomplished at the expense of blurred and distorted features. It is effective only for low noise densities. At high noise densities SMFs often exhibit blurring for large window sizes and insufficient noise suppression for small window sizes.

4.4 Switched Median Filters

Modification of simple median filter. These filters work on the basis of impulse detection and correction. Noise detection process determines corrupted pixels and uncorrupted pixel prior to applying filtering.

4.5 Progressive Switched Median Filter

Decision is based on pre defined fixed threshold value to detect the noisy pixels. It is very difficult to fix a threshold value that can accurately perform well under varying noise densities. At high noise densities the switched filters do not consider any of the local detail of the images and hence edges are not preserved properly.

4.6 Adaptive Median Filter

AMF is a non linear filter. It uses varying window size for noise reduction. AMF fairs well at low and medium noise densities but blurs the image at high noise densities.(Window size is increased which in turn blurs the image)

4.7 Decision Based Algorithm

Processed pixel is identified as noisy if the pixel value is either 0 or 255; else it is considered as not noisy. Under high noise density DBA filter replaces the noisy pixel with neighborhood pixel. Repeated replacement of neighborhood pixels results in streaks in restored image.

4.8 Improved DBA

To avoid streaks in images improved version of DBA is used, where noisy pixel is replaced by the median of unsymmetrical trimmed output. Under high noise densities the pixels could be all 0’s or all 255’s or a combination of both 0 and 255. Replacement with trimmed median value is not possible then.

4.9 Trimmed Median Filters

Trimmed median filter is used to reject the noise from the selected window. Alpha trimmed mean filter (ATMF) is a symmetric filter where the trimming is symmetric at both ends.

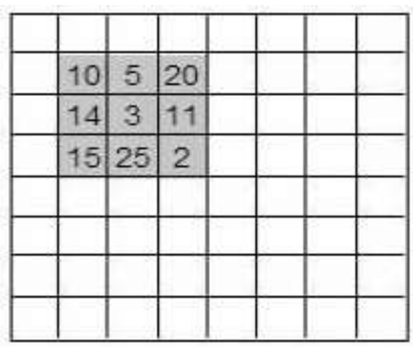
4.10 Unsymmetric Trimmed Median Filter

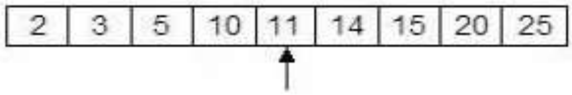
Pixel values 0’s and 255’s are removed hence the name trimmed median filter. Modified decision based unsymmetric trimmed median filter is a non linear filter that can effectively remove high density salt and pepper noise.

V. WINDOW CONCEPT

A standard median operation is implemented by sliding a window of odd size (*e.g.* 3x3 window) over an image.[11][12] At each window position, the sampled values of signal or image are sorted, and the median value of the samples replaces the sample in the center of the window as shown in Figure1.

3 x 3 window





Median

Centre pixel replaced with median value

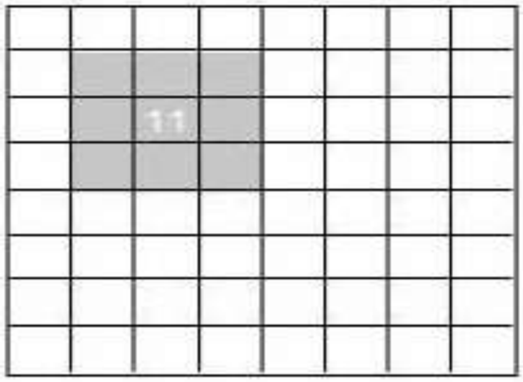


Figure 1. Median Filter

5.1 Order Statistics Filter

Order-Statistics filters are non-linear filters whose response depends on the ordering of pixels encompassed by the filter area. When the center value of the pixel in the image area is replaced by 100th percentile, the filter is called max-filter. On the other hand, if the same pixel value is replaced by 0th percentile, the filter is termed as minimum filter.

5.2 Adaptive Filter

These filters change their behavior on the basis of statistical characteristics of the image region, encompassed by the filter region. BM3D is an adaptive filter. It is a nonlocal image modeling technique based on adaptive, high order group-wise models.

5.3 Order Filters

Given an NxN window, the pixel values can be ordered from smallest to largest as follows:

$I_1 \leq I_2 \leq I_3 \leq ..... \leq I_{N^2}$

- Where $\{I_1, I_2, I_3, ..., I_{N^2}\}$ *are* the gray-level values of the subset of pixels in the image, that are in the NxN window. Different types of order filters select different values from the ordered pixel list.

5.4 Median Filter

Select the middle pixel value from the ordered set. Used to remove salt-and-pepper noise.

5.5 Maximum Filter

Select the highest pixel value from the ordered set. Remove pepper-type noise.

5.6 Minimum Filter

Select the lowest pixel value from the ordered set. Remove salt-type noise. As the size of the window gets bigger, the more information loss occurs. With windows larger than about 5x5, the image acquires an artificial, "painted", effect. Order filters can also be defined to select a specific pixel rank within the ordered set. For example, we may find the second highest value is the better choice than the maximum value for certain pepper noise. This type of ordered selection is application specific. Minimum filter tend to darken the image and maximum filter tend to brighten the image.

5.7 Midpoint Filter

Average of the maximum and minimum within the window. Useful for removing gaussian and uniform noise.

$$\text{Midpoint} = \frac{I_1 + I_{N^2}}{2}$$

5.8 Alpha-Trimmed Mean Filter

The average of the pixel values within the window, but with some endpoint-ranked values excluded.

$$\text{Alpha-trimmed mean} = \frac{1}{N^2 - 2T} \sum_{i=T+1}^{N^2-T} I_i$$

T is the number of pixels excluded at each end of the ordered set

The alpha-trimmed mean filter ranges from a mean to median filter, depending on the value selected for the T parameter. If T = 0, → mean filter. If T = $(N^2 – 1) / 2$, → median filter.The alpha-trimmed mean filter is useful for images containing multiple types of noise.Example: Gaussian + salt-and-pepper.

5.9 Mean Filters

The mean filters function by finding some form of an average within the *N*x*N* window. The most basic of these filters is the arithmetic mean filter. This filter mitigates the noise effect, but at the same time tend to blur the image. The blurring effect is not desirable, and therefore other mean filters are designed to minimize this loss of detail information.

5.10 Arithmetic Mean Filter

Find the arithmetic average of the pixel values in the window.

$$\text{Arithmetic Mean} = \frac{1}{N^2} \sum_{(r,c)\in w} d(r,c)$$

Smooth out local variations in an image.Tend to blur the image. Works best with gaussian and uniform nois

5.11 Contra-Harmonic Mean Filter

$$\text{Contra-Harmonic Mean} = \frac{\sum_{(r,c)\in w} d(r,c)^{R+1}}{\sum_{(r,c)\in w} d(r,c)^{R}}$$

Works for salt OR pepper noise, depending on the filter order R. Negative R → Eliminate salt-type noise. Positive R → Eliminate pepper-type noise.

5.12 Geometric Mean Filter

Geometric mean = $\prod_{(r,c)\in w}[d(r,c)]^{\frac{1}{N^2}}$ Works best with gaussian noise. Retains detail better than arithmetic mean filter. Ineffective in the presence of pepper noise (if very low values present in the window, the equation will return a very small number).

5.13 Harmonic Mean Filter

Harmonic Mean = $\dfrac{N^2}{\sum_{(r,c)\in w}\dfrac{1}{d(r,c)}}$ Works with gaussian noise. Retains detail better than arithmetic mean filter. Works well with pepper noise.

5.14 Y_p Mean Filter

Y_p Mean = Remove salt noise for negative values of P. Remove pepper noise for positive values of P.

VI. CONCLSION

In this way we discuss various types of noises and their sources in images and we discuss various types of filters used to remove these noise.

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