Noises and their Removal using Various Filters: A Review

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Abstract: The use of image is everywhere, from selfie to medical imaging. The quality of an image not only depends on camera type but also on the way it is captured. In real time applications quality of images, is not of that much important. But, in applications such as medical imaging and biometrics, where some information needs to be extracted from the images, quality of images becomes important. In images blurring and noise are two degrading processes, and they need to be suppressed before meaningful information can be extracted. In this paper, various types of noises are discussed along with various filtering mechanism.

Keywords: Noises, Filters, Noise Removal.

1. INTRODUCTION

The field of processing of digital image alludes to the use of computer algorithms to extract helpful data from digital images. The whole procedure of image processing may be divided into three prime stages:

(i) Image acquisition: converting 3D visual information into 2D digital form appropiate for storage, processing and transmission.

(ii) Processing: enhancing quality of image by enhancement, restoration, etc.

(iii) Analysis: drawing out image features; quantifying shapes and recognition [1-10].

Input is an image scene while output is a corresponding digital image at first stage. On the other side both input and output are digital images at second stage of processing, where the output is an enhanced form of the input. In the last stage, input is still a digital image but the output is description of the contents. Figure 2.1 illustrates a block diagram.

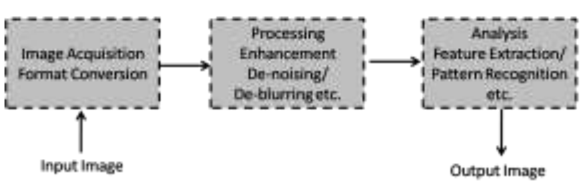

Figure 1 Image processing and noise filtering

Noise of image is the irregular variation of color or brightness information in images created by the sensor and circuitry of a scanner or digital camera. Image noise is taken as an unwanted by-product of captured image. The sorts of noises are as given below:-

(i) Gaussian noise (Amplifier noise) – The standard model of amplifier noise is additive. Gaussian noise is independent at every pixel and it is independent of the signal intensity

(ii) Salt-and-pepper noise - An image comprising salt-and-pepper noise consist of dark pixels in bright regions and bright pixels in dark regions.

(iii) Speckle noise - Speckle noise is a granular noise that inherently exists in and corrupts the quality of the synthetic radar and active aperture radar (SAR) images. SAR is produced by unified processing of backscattered signals from numerous distributed targets.

2. NOISE TYPES

Amongst a vast world of unwanted and undesirable disturbances in an image, these are only a few sorts of noises. Moreover, exposition of earlier said unwanted components is as underneath [11-20].

2.1 Gaussian Noise

Gaussian noise is one kind of noise which is equally distributed over the signal. This implies that in the noisy image, each pixel is the aggregate of the true pixel value and a random Gaussian distributed noise value. As we can predict from the name itself, this kind of noise has a Gaussian distribution, which has probability distribution function of a bell.

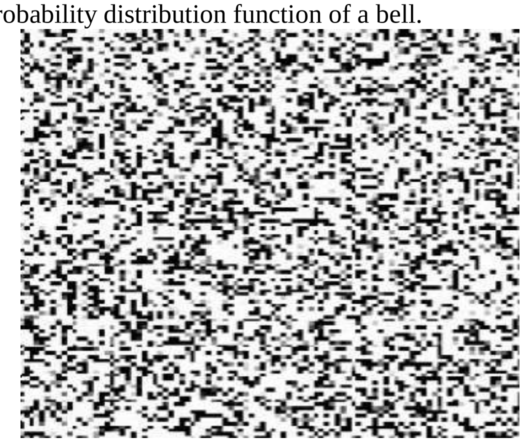

Figure 2 Image Corrupted with Gaussian Noise

Figure 2 describes this noise in a better way.

2.2 Salt and Pepper

Another type of noise is Salt and Pepper noise. Salt and Pepper noise is an impulse noise which indeed is the intensity spikes. This kind of noise arises because of data transmission errors. This noise is commonly produced due to the inefficient functioning of pixel elements in the sensors of camera, inaccurate memory locations, or timing errors in the digitization process. Salt and pepper noise is illustrated as under in figure 3.

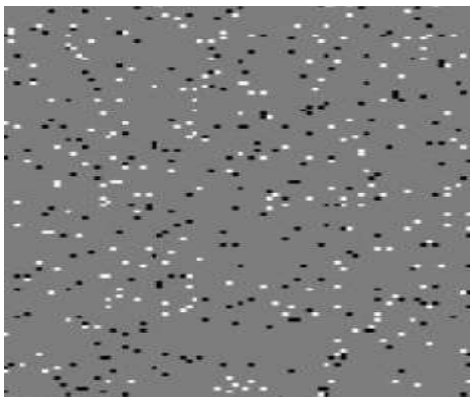

Figure 3 Image Corrupted with Salt and Pepper Noise

2.3 Speckle Noise

This noise could be defined as multiplicative noise. Speckle Noise appearance is observed in coherent imaging system like radar, laser and acoustics and so on. It can remain similar in an image just like as Gaussian noise. Its probability density function follows gamma distribution and provided as in equation (1) [17-19].

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

Further, Speckle noise is another type of noise. Speckle noise is multiplicative noise dissimilar to the Salt and Pepper or Gaussian type noise. This noise happens in all coherent imaging systems like laser, Synthetic Aperture Radar (SAR) or in acoustics. Speckle noise follows a gamma distribution function. The given figure shows speckle noise.

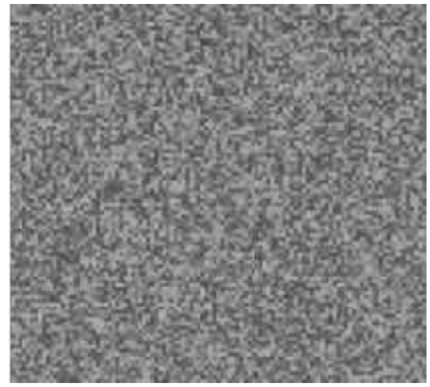

Figure 4 Image Corrupted with Speckle Noise

2.4 Brownian Noise

Brownian noise is placed in the category of fractal or 1/f noises mathematical model of which is known as fractal Brownian motion.

As far as fractal Brownian motion is concerned it is a non-stationary stochastic process that follows a general distribution. It is an uncommon case of 1/f noise. It can be acquired by integrating white noise. Brownian noise looks like follows.

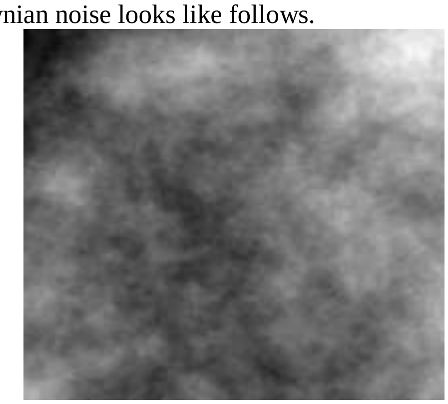

Figure 5 Image Corrupted with Brownian Noise

2.5 Periodic Noise

Periodic noise normally emerges from interference during the acquisition of image. Noise types that are spatially dependent can be efficiently decreased by means of frequency domain filtering. Parameters of noise can frequently be evaluated by observing the Fourier spectrum of the image – Periodic noise tends to create frequency spikes [16] as appeared in figure 6.

This noise is created from electronics interferences, particularly in power signal at the time of image acquisition. This noise has extraordinary attributes such as spatially dependent and sinusoidal in nature at multiples of specific frequency. It's seems to be in the form of conjugate spots in frequency domain. It can be easily uprooted by making use of a narrow band reject filter or notch filter.

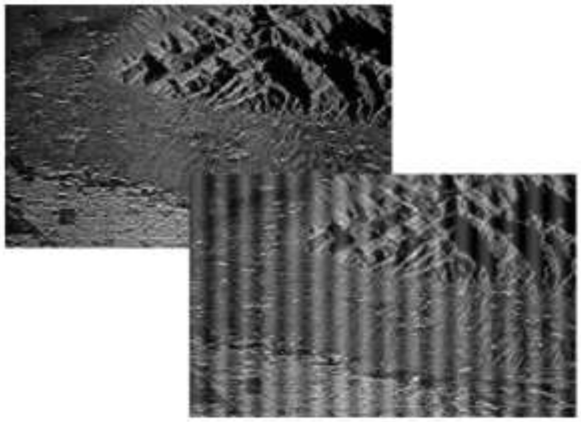

Figure 6 Image Corrupted with Periodic Noise

3. FILTERS

A number of applications [1, 2, 21, 22, 23 and 24] of digital images processing need an estimation of the level of noise that should be local in time and in frequency such that non-stationary and coloured noise can be managed. Noise level estimation is generally done by explicit time segments detection that composes only noise, or amplifies estimation of harmonically related spectral features [25].

Restoration of image, generally, employs diverse filtering methods. Filtering may be done either in frequency domain or in spatial domain. Different spatial domain filtering methods have been examined, analysed and proposed in this thesis. In a broad sense, filters may be grouped into two classes: Linear and Nonlinear.

For blurring and for reduction of noise smoothing filters are used. Blurring is used as a part of pre-processing steps, like separating small details from an image before the extraction of (large) object and bridging of minute gaps in lines or curves. Noise reduction can be done by blurring with a linear filter. It can also be done by nonlinear filtering.

3.1 Linear Filters

If superposition principle is applied to a filter, then the filter is said to be linear filter []. Also a linear filter must satisfy the following properties.

Additive property:

For any x and y $f(x+y)=f(x)+f(y)$ (2)

Homogeneous property:

For any x, $f(\alpha x)=\alpha f(x)$ (3)

If the system doesn't fulfil above two properties, then it is termed as a non-linear filter.

$$y(t)=L[x(t)] \quad (4)$$

Linear filters depend on idea that the impulse function and transfer function of a linear system are inverse Fourier Transform of each other.

Low-pass filters lessen or wipe out high-frequency components in the Fourier domain while it does not have any effect on low frequencies. High-frequency components describe edges and other sharp elements in an image, thus image blurring the resultant impact of low-pass filtering is.

On the other hand, high-pass filters attenuate or remove low-frequency components. The factor behind are responsible for the slowly varying characteristics like overall contrast and average intensity of an image is Low-frequency components. High-pass filtering overall results in decrease of these features and a correspondingly apparent sharpening of edges along with other sharp details.

Band-pass filtering eliminates a particular set of frequency regions between low and high frequencies. Band-pass filters are used for image restoration and are seldom of interest in the enhancement of image.

Though, linear filters do not perform well in the presence of noise. In image processing applications they tend to blur edges, do not eliminate impulsive noise in an effective way, and their performance is poor in the presence of signal dependent noise [21].

If impulse response of a filter contains only finite number of non-zero values, the filter is known as finite impulse response (FIR) filter. Else, it is an infinite impulse response (IIR) filter [22].

The filter is called non-recursive in the event that the filter assesses the output image only with the input image. On the other side, if the process of evaluation needs input image samples along with output image samples, it is termed as recursive filter [4, 21, 23].

Some main types of filters are as follows:

• Low-pass filter: Smoothes the image reduces components of high spatial frequency noise.

• High-pass filter: Improves very low contrast features, when superimposed on a very dark or very light background.

• Band-pass filter: Tends to sharpen the edges and enhance the small details of the image.

3.2 Nonlinear Filters

Same mathematical formulation as in (4) is also followed by nonlinear filters. However, the operator ***L*** is not linear in the discussed case. Convolution of the input with its impulse response doesn't produce the output of a nonlinear filter. This is due to the non-satisfaction of the superposition or proportionality principles or both [21–23].

Gray scale transformations [1, 3, and 6] are the least complex possible nonlinear form transformations. This corresponds to a memory less nonlinearity that maps the signal x to y. The transformation given below in equation 5, may be utilized for transforming one gray scale x to another y.

$$y(t)=tx(t) \quad (5)$$

These sorts of gray level transform are widely used for upgrading the subjective quality of the images as per the requirement of the application. Another form of intensity mapping is Histogram modification where the relative frequency of gray level occurrence in the image is depicted. An image may be provided with a specified histogram by transforming the gray level of the image into another. Histogram equalization is one of such processes that are used for this task. The requirement for it emerges on comparing two images taken under diverse conditions of light. If we want a meaningful comparison, then the two images must be referred to the same base.

For noise removal, order statistic filters [21, 23] are the most famous class nonlinear filters. Various filters fits in with this class of filters, e.g., the stack filter, the median filter, the median hybrid filter etc. Nonlinear filters that are based on order statistics have quite high robustness properties in the presence of impulsive noise.

The advantage of nonlinear filtering methods is also taken by adaptive filtering. Non-adaptive nonlinear filters are generally optimized for a particular kind of signal and noise. However, in the case when the filter is needed to perform in an environment of unknown statistics or a non stationary environment, an adaptive filter gives an elegant option to this issue. Images can be modelled as two-dimensional stochastic methods, whose statistics fluctuate in the different image regions and can be also from applications to applications. In such circumstances, adaptive filters turn into the natural choice and their execution relies on the precision of estimation of some signal and noise statistics [1, 4, 12, 21, 23]. The filter begins from an arbitrary beginning condition, remaining unknown about environment, and continues slowly towards an optimal solution.

Reasonable attenuation has been provided nonlinear estimation of signals corrupted with noise. In spite of remarkable development in recent couple of decades, nonlinear filtering methods still do not have a unifying theory that encompasses existing nonlinear processing techniques.

3.3 Spatial Filtering

We perform filtering to remove any noise in an image. The concept of filtering has it‟s origin in the use of the Fourier transform for processing of signal in the so-called frequency domain. In the case of the filtering operations that are performed directly on the image pixels, we use the term spatial filtering to separate this sort of process from the more conventional frequency domain filtering [26-30].

The method comprises simply moving the filter mask from point to point in an image. The response of the filter at each point (x,y) is evaluated using the predefined relationship. In the case of linear spatial filtering the response is provided by a products sum of the filter coefficients and the corresponding image pixels in the area spanned by the filter mask. Generally, the linear filtering of an image ‘*f*’ of size $M\times N$ with a filter mask of $m\times n$ is given by the expression:

$$g(x,y)=\sum_{s=-a}^{s=a}\sum_{t=-\tau}^{\tau} w(s,t)\,f(x+s,y+t) \qquad (6)$$

Where $a=(m-1)/2$ and $\tau=(n-1)/2$

To produce a complete filtered image this equation must be applied for $x=0, 1, 2 \ldots M-1$ and $y=0, 1, 2\ldots\ldots N-1$.

Spatial domain filtering is very effective, as it provide frequency domain description of an image. Thus designing of filter in frequency region of interest can be easily implemented. Frequency domain picture is also very effective in various types of noise. Moreover, DFT or FFT has inherent capacity of noise removal. Thus quality of an image enhances by using different transform, therefore in the image enhancement techniques DFT and FFT is used. In figure 7, spatial filtering is shown, and Broad SF, High SF and LOW SF is shown, thus this is kind of frequency filtering.

Figure 7 Spatial filtering

3.4 Smoothing Linear Filters:

The result of a smoothing, linear spatial filter is just pixels’ average contained in the neighbourhood of the filter mask. These filters are at some point known as ‟averaging filters”. They are also termed as low pass filters (Figure 8).

The concept behind the smoothing filters is very simple. In this we replace each pixel value in an image by the average of the gray levels in the neighbourhood [17]

Their theoretical foundations, however, are very much less secure and they can generate components which are totally spurious. Hence, we must take care while using them. A few of the denoising or filtering methods have been explained below:

Figure 8 Smoothened Image

3.5 Mean filter

As its name suggest is an averaging linear filter. Here, image is divided into smaller area and then, filter computes the average value of the corrupted image and the center pixel intensity value is then replaced by newly obtained average value. This process is repeated for each pixel present in the image.

Figure 9 Mean filter with Salt and Pepper Noise

Figure 10 Mean filter with Gaussian Noise

Figure 11 Mean filter with Speckle Noise

The above Figure 9-Figure 11 shows the effect of use of mean filter on different types of noise.

3.6 Median Filter

Median filter is very much similar to mean filter. Here, image is divided into smaller area and then, filter computes the median value of the corrupted image and the center pixel intensity value is then replaced by newly obtained average value. This process is repeated for each pixel present in the image. Median filter is found to be very effective in images suffered from salt and pepper noise. These filters are widely used in the smoothing of images, as well as in signal processing. Median filter is a non-linear filter. A major advantage of the median filter is that it can suppress the effect of input noise significantly.

Figure 12 Median filter with Salt and Pepper Noise

Figure 13 Median filter with Gaussian Noise

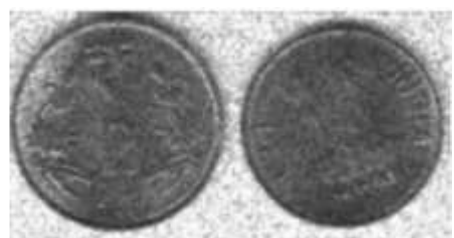

Figure 14 Median filter with Speckle Noise

The main advantage of Median filter is that it maintains the sharpness of the image while noise removal process Figure 12 -Figure 14 shows the effect of median filter on various types of noise.

3.7 Adaptive Filter

These filters change modify their behaviour on the basis of statistical characteristics of the image [31-37]. An adaptive filter perform better of denoising images compared to the averaging filter. The main difference between the mean filter and the adaptive filter is that in the adaptive filter the weight matrix updated in each iteration, which remains constant in the mean filter, irrespective of iterations [31-36].

In some images which are changing with time or non-stationary. As adaptive filters changes their characteristic in each iteration, thus are capable of denoising non-stationary images. In non-stationary images abrupt change in intensity occurs.

As most of the practical images are non-stationary, adaptive filters found to be perform better in comparison to other filters. (Figure 15 -Figure 17 shows the effect of adaptive filter on different types of noise.

Figure 15 Adaptive filter with Salt and Pepper Noise

Figure 16 Adaptive filter with Gaussian Noise

Figure 17 Adaptive filter with Speckle Noise

4. CONCLUSIONS

In this paper different image denoising filters and their merits and demerits are discussed. Various noise models such as Gaussian noise, salt and pepper noise, speckle noise and Brownian noise are detailed. Depending on the type of noise present in an image a particular type of filter need to be selected for better performance.

To summarize, it is concluded in the paper that filters are essential components in image processing. Using filters noise can’t be completely eliminated; they suppress noise and produce a good quality image by removing noises. The type of filter to be used in image depends upon the kind of noise which exists in an image. For example salt and pepper noise, can be efficiently suppressed using the median filter and its performance is better compared to mean filter and adaptive filter.

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