A Review on Noise Types and Image Denoising Techniques

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Abstract— Today, the transmission of information takes place mainly through digital images and videos, but the image obtained after transmission is often corrupted with noise. The received image needs processing before it can be used in applications. Image denoising involves the manipulation of the image data to produce a visually improved quality image. In this paper, a brief study on different noise models is presented. They include Gaussian noise, salt and pepper noise, shot noise, speckle noise and thermal noise. This work reviews the existing denoising algorithms, such as filtering approach and wavelet based approach and performs their comparative study. Selection of the denoising algorithm is application dependent.

Key words: Image Noise, Denoising, Wavelet Domain

I. INTRODUCTION

Images that captured digitally and stored electronically are considered as digital images. The use of these digital images has become so vast with the advancement in technology. Applications now extend from more general documentation of an event & visual communication to more serious surveillance & medical fields. As the application of images increase, the demand of these images has also increased with high visual quality and accuracy. However, during the acquisition or transmission of digital images, they often get corrupted. Due to this corruption, the visual appearance of image may be affected. Image denoising is an important topic in the field of image processing where the main aim is to improve the visual quality of an image by reducing noise from noisy image.

Distortion of images may occur due to various types of noise like Gaussian noise, Salt and Pepper noise, Speckle noise etc. These noises may come from noise sources present in the surrounding of image capturing devices, faulty memory location, inaccuracy in cameras, misaligned lenses, weak focal length, scattering and other adverse conditions may be present in the atmosphere [1].

II. IMAGE NOISE

The actual meaning of noise is unwanted signal. It is a random variation of brightness and color information in images & is usually an aspect of electronic noise. It is an undesirable by-product of image capture that adds spurious and extraneous information [2].

A. Sources & Types of Noises

During image acquisition or transmission, several factors are responsible for introducing noise in the image. The number of pixels corrupted in the image will decide the quantification of the noise. Image noise comes from a variety of sources. It can be produced by the sensor and circuitry of a digital camera or scanner [11]. The sources and types of noise are also depends upon the physical measurement. Noise often comes from a source that is different from to be measured, but sometimes it is due to the measurement process itself. The main sources of noise in the digital image are:

1) Environmental conditions may effects the imaging sensor during image acquisition.
2) Insufficient Light levels and sensor temperature may corrupt the image.
3) Interference in the transmission channel may also introduce noise in the image
4) Dust particles present on the scanner screen, they can also corrupt the image [3].

Image distortion is most pleasance problem in image processing [1]. Distortion of images may take place due to various types of noise like Gaussian noise, Salt and Pepper noise, Shot noise, Speckle noise and many more are fundamental noise types in case of digital images. The most common noises affecting the digital images are described here:

1) Gaussian Noise:

Gaussian noise is also known as electronic noise because it produces in amplifiers or detectors. It is produced by natural sources like thermal vibration of atoms and discrete nature of radiation of warm objects [1]. The images with AWGN are used as the benchmark images for assessing the performance of image denoising algorithms. In case of Gaussian noise, an amount of noise is added to every part of the picture i.e., each pixel in the image will be changed from its original value by a small amount. Gaussian noise is a statistical noise that has a probability density function (pdf) of the normal distribution (also known as Gaussian distribution) [2].

This is defined as:

$$p_G(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{z-\mu}{\sigma}\right)^2} \qquad (2.1)$$

The parameter z is the grey level, μ is the mean or expectation (location of the peak) and σ is known as the standard deviation [2]. The distribution with μ=0 and $\sigma^2 = 1$ is called the standard normal distribution or the unit normal distribution.

2) Salt-and-Pepper Noise:

Fat-tail distributed or "impulsive" noise is sometimes called salt and pepper noise. Any image having salt and pepper noise will have dark pixels in bright regions and bright pixels in dark regions [11]. The corrupted pixels are either set to the maximum value or have single bits flipped over. In some cases single pixels are set alternatively to zero or to the maximum value, giving the image a salt and pepper like appearance [12]. Typical sources include flecks of dust inside the camera, overheated or faulty CCD elements, analog-to-digital converter errors etc [4]. Salt-and-pepper noise may also arise due to errors during transmission of an image like bit errors in transmission. Denoising schemes based on median filtering are usually effective on this kind of noise.

3) Photon Shot Noise:

Poisson or photon shot noise can occur, when number of photons sensed by the sensor is not sufficient to provide detectable statistical information [3]. Shot noise has a root-mean-square value proportional to the square root of the image intensity, and the noises at different pixels are independent of one another. It follows a poisson distribution, which except at very low intensity levels approximates a Gaussian distribution [2].

4) Speckle Noise:

Speckle noise is multiplicative noise. There appearance is seen in coherent imaging system such as laser, radar, acoustic etc [1]. Due to random fluctuations in the return signal from an object in conventional radar that is not big as signal image processing element, speckle noise occur [5].

5) Thermal Noise:

Thermal noise occurs due to the random thermally generated motion of electrons. It occurs in resistive devices and is proportional to the temperature. Thermal noise occurs even in the absence of light and is therefore sometimes referred to as dark-current noise. Thermal noise is an example of noise which can be reduced by modifying the signal acquisition process. One of the most common ways for reducing thermal noise is the cooling of the camera sensor.

6) Quantization Noise:

Quantization noise is also considered as uniform noise. This results when a continuous random variable is converted to a discrete one or when a discrete random variable is converted to one with fewer levels. In images, quantization noise often occurs in the acquisition process. The image may be continuous initially, but to be processed it must be converted to a digital representation [6].

B. Image Denoising

Image denoising is the recovery of a digital image that has been contaminated by noise. It attempts to remove whatever noise is present and retains the significant information, regardless of the frequency contents of the signal [13].

Image denoising is very important task in image processing for the analysis of image. Various image denoising algorithm are available, but the best one should remove the noise completely from the image, while preserving the details [3].

III. DENOISING TECHNIQUES

A. Classification of Image Denoising Algorithms

Generally, image denoising methods have been broadly classified into spatial domain methods & transform domain methods. They are briefly described as:

1) Spatial Domain Method:

The implementation of spatial filters is the conventional method to remove noise from the noisy image. Spatial domain filtering techniques basically take the original noisy image data into consideration & employ a filtering process on this. It is further classified into linear filters and nonlinear filters.

a) Linear Filters:

Linear filters are preferred when only additive noise is present. It includes Mean filter & Wiener filter. Linear filters too tend to blur sharp edges, destroy lines and other fine image details, and perform poorly in the presence of signal dependent noise.

b) Non Linear Filters:

With non linear filters, the noise is reduced without any attempt to explicitly identify it. It removes the noise to very large extent but cost of blurring of images which in turn makes the edges in picture invisible [7]. To overcome the problems arise with linear filters, a number of non linear filters such as median, weighted median, rank conditioned rank selection, & relaxed median have been developed.

2) Transform Domain Method:

The transform domain filtering methods can be sub divided according to the basic functions. The base functions can be further classified as data adaptive and non-data adaptive [7].

a) Data Adaptive Transform

This technique is successfully used for denoising of non Gaussian data [8]. This technique assumes that signal should be non-Gaussian. This assumption helps to understand denoising of images with non-Gaussian along with Gaussian distribution. Independent component analysis (ICA) transformation methods recently gain more importance include key component analysis, factor analysis, and projection detection. One advantage of using ICA is it's assumption of signal to be non-Gaussian which helps denoising of images with non Gaussian as well as Gaussian distribution [14].

b) Non Data Adaptive Transform

The Transform domain filtering techniques that made use of non-data adaptive transform functions were further subcategorized into two domains are spatial- frequency domain & wavelet domain.

(1) Spatial Frequency Domain

In this method low pass filter is used by using Fast Fourier Transform (FFT) [5]. Before application of filtering technique, domain of given noisy image is converted from spatial to frequency domain using Fast Fourier Transform (FFT). However, these techniques are time consuming & depend on the cutoff frequency & the behaviour of filter functionality.

(2) Wavelet Domain

Wavelet provides an appropriate basis for separating noisy signal from image signal. The motivation is that as the wavelet transform is good at energy compaction, small coefficient is more likely due to noise and large coefficient due to important signal features [15]. For denoising in the wavelet domain, several algorithms based on wavelet transform have been proposed and implemented. The focus of researchers was shifted from the spatial & Fourier domain to the wavelet domain. Image signal do not have to be completely transformed into the frequency domain. Some transformations only partially convert an image into the frequency domain. A major advantage of wavelet methods is that it provides time and frequency localization simultaneously [5]. Filtering operation in the wavelet domain can be sub categorized into the given techniques:

(a) Linear Filter

Commonly, Wiener filter is used in this category. Weiner filter gives optimal result in wavelet domain. Weiner filter is used where data corruption can be modeled as a Gaussian process and accuracy criterion is mean square error [14].

(b) Non Linear Threshold Filtering

This domain is mostly considered in denoising by using wavelet transform. It basically uses the property of wavelet transform and the fact that wavelet transform maps noise in signal domain to that of noise in transform domain [7]. It includes Adaptive threshold and Non Adaptive threshold.

(c) Wavelet Coefficients Model

A new model is proposed based on the wavelet coefficients by considering the advantages and limitations of statistical model. Wavelet coefficients with large magnitude are representatives of edges or some textures. This method presents effective results but their spatial adaptivity is not well suited near object edges where the variance field is not smoothly varied [9]. It includes deterministic method & statistical method.

IV. CONCLUSION

Image denoising is an important part of image processing; it plays a vital role in modern applications in various fields, like medical imaging and preprocessing for computer vision. Noise that occurs due to various sources effects the visual quality of image and cause the poor vision of image.

In this paper, a brief study on various types of noise is presented. There are different types of noises that may corrupt an image in real life such as, Salt-Pepper noise, Speckle noise, Shot noise, Thermal noise, Gaussian noise etc. In this paper, investigation of several well-known algorithms for image denoising is carried out & their performances with their methodologies are examined. It is essential to know about the noise present in the image so as to select the suitable denoising algorithm.

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