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Study on Noise and Its Removal Techniques

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***Abstract*—** Removal of noise is an essential and challengeable operation in image processing. Before performing any process in the image, it must be first restored. Images may be corrupted by noise during image acquisition and transmission. Nature of the noise removal depends upon the type of the noise corrupting the image. In an image there will be different type of noises like impulse noise, adaptive white Gaussian noise, short noise, quantization noise, film grain, these one or more are coupled together to form a mixed noise. To remove this type of noise there is a novel method comprises two stages: the first stage is to detect the noise in the image. In this stage, based on the intensity, the pixels are roughly divided into "noise-free pixel" and "noisy pixel". Then, in the second stage it is to eliminate the noise from the image. In this, only the "noise-pixels" are processed. The "noise free pixels" are copied directly to the output image. The survey aims to study the different types of noises and noise removal techniques of an image.

***Keywords*—** Noise, Removal techniques, Pixels, Impulse Noise. Gaussian Noise, quantization Noise, Short Noise

I. INTRODUCTION

Images are prone to a various noises, which is the result of errors in the image acquisition process that result in pixel values that do not reflect the true intensities of the real scene. There are several by which noise can be introduced into an image, depending on the image is created.

For example:

1. If the image is scanned from a photograph made on film, the film grain will be the source of noise. Noise result from damage to the film or it can be introduced by the scanner itself.
2. If the image is acquired directly in a digital format, the mechanism for gathering the data (such as a CCD detector) can introduce noise.
3. Electronic transmission of image data can introduce noise. [8]

Noise estimation of an image is a difficult task in which: we need to find out whether local image variations are due to color, appearance, or brightness from an image itself, or due to noise. A fundamental problem is to effectively remove noise from an image while keeping its fundamental structure constituting of edges, corners, etc., intact or retaining as much as possible the important signal features. This method is called Image Denoising [9]. Noise can be systematically familiarized into images throughout acquisition and transmission.

During image acquisition or transmission, several factors introduce noises in image. Depending upon the type of disturbance, the noise can affect the image to various extents [2]. Generally we focus in remove certain kind of noise from a particular image separating or not interacting with other noise in the same image and also there are mechanisms to remove mixed noise from image detecting single noises as well as simultaneously removing without detecting. So we identify the type of noise and apply algorithms accordingly to remove the noise. Image noise is classified into Impulse noise (Salt-and-pepper noise), Amplifier noise (Gaussian noise), Shot noise, Quantization noise (uniform noise), Film grain, on-isotropic noise, Multiplicative noise (Speckle noise) and Periodic noise [10].

Image denoising is the necessary and foremost step for image analysis. Denoising remain one of the most challenging research area in image processing, due to image denoising techniques not only poised some technical difficulties, but also it will result into the interpretation of the image(i.e. making it blur) if not effectively and adequately applied to image[11]. So, it is necessary to depute some effective image denoising techniques to prevent this type of corruption from digital images. In selecting a noise reduction algorithm, one must look into several factors:

- The available computer power and time available: a digital camera must apply noise removal in a fraction of a second, while a desktop computer will have much more power and time
- Is sacrificing some real detail is acceptable if it allows more noise to be removed (how aggressively to decide whether variations in the image are noise or not)
- The properties of the noise and the detail in the image, to make better decisions.[12]

The noise removal algorithms reduce or take away the visibility of noise by smoothing the entire image leaving areas near contrast boundaries [2]. Many researchers have achieved a mile stone to develop algorithms to remove/reduce noises [13]. We are having mainly three types of images according to applications of images, to device used to capture/store and to most widely used images: sensor, medical and gray scale images and most frequently occurred noises in these images are: Impulse, Speckle and Gaussian noises. So, we are classifying noise removal algorithms into three types according to these three different noises and images [13]. This paper provides different methodologies for noise reduction. It also gives us knowledge about various noises and also which method will provide the consistent and approximate estimate of original image from given its degraded version.

II TYPES OF NOISE

Depending on the type of disruption, the noise can affect the image to various extents. There are various types of noise which affect the properties of the image.

A Impulse Noise

Fat-tail distributed or "impulsive" noise is sometimes called salt-and-pepper noise or spike noise that is usually caused by faulty memory locations, malfunctioning pixel elements in the camera, or can be timing errors in the process of digitization. . An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions [2]. 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 is 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. This can be eliminated in large part by using dark/bright pixels.

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.

B Gaussian Noise

Principal source of Gaussian noise in digital images arise during accession e.g. sensor noise caused by defective illumination and/or excessive temperature, and/or transmission e.g. electronic circuit noise. Gaussian noise is evenly distributed over the signal. Each pixel in noisy image is the sum of true pixel value and a random Gaussian distributed noise value. This noise has a probability density function of the normal distribution. It is also known as Gaussian distribution [3]. It is a major part of the read noise of an image sensor that is of the constant level of noise in the dark areas of the image. In digital image processing Gaussian noise can be reduced using a spatial filter, though when smoothing an image, an unacceptable outcome may be result in the blurring of fine-scaled image edges and details because they also correspond to blocked excessive frequencies. Normal spatial filtering techniques for noise removal include: mean (convolution) filtering, Gaussian smoothing and median filtering.

C Poisson Noise

Poisson or shot photon noise is the noise which will cause, when number of photons sensed by the sensor is not sufficient to provide detectable statistical information. Shot noise has a root-mean-square value proportional to the square root of the image unconventional, and the noises at different pixels are independent of one another. It follows a Poisson distribution, which is not very different from Gaussian [1]. In addition to photon shot noise, there can be extra shot noise from the dark leakage current in the image sensor; this noise is sometimes known as "dark shot noise" or "dark-current shot noise". Dark current is greatest at "hot pixels" within the image sensor. The changeable dark charge of normal and hot pixels can be subtracted off (using "dark frame subtraction"), withdrawing only the Poisson noise, or unarranged component, of the leakage.

D Speckle Noise

Speckle is a granular 'noise' that inherently exists in and degrades the quality of the active radar, synthetic aperture radar (SAR), and medical ultrasound images. In the major part of surfaces, synthetic or natural, are extremely rough on the scale of the wavelength. Images acquired from these surfaces by logical and consistent imaging systems like laser, SAR, and ultrasound suffer from a similar phenomena is called speckle. Speckle, in both instances, is firstly due to the interference of the returning wave at the transducer opening [2]. The starting of this noise is seen if we model our reflectivity function as an array of scatterers. Because of the limited resolution, at any time we are accepting from a distribution of scatterers within the resolution cell. Scattered signals add coherently; they add constructively and destructively depending on the relative phases of each scattered waveform. Speckle noise which results from these patterns of constructive and destructive interference shown as bright and dark dots in the image. Speckle noise in conventional radar results from random fluctuations in the return signal from an object that is no bigger than a single image-processing component. It increases the grey level of a local area. Speckle noise in SAR is normally serious, causing difficulties for image exposition. It is can be due to coherent processing of backscattered signals from multiple distributed targets[6].

E Flim Grain

Film grain or granularity is the random optical texture of processed photographic film due to the presence of small particles of a metallic silver, or dye clouds, developed from silver halide that have received enough photons. The grain of photographic film is a signal-dependent noise, with similar statistical distribution to shot noise. If film grains are uniformly distributed (equal number per area), and if each grain has an equal and independent probability of developing to a dark silver grain after absorbing photons, then the number of such dark grains in an area will be random with a binomial distribution. In areas where the probability is low, this distribution will be close to the classic Poisson distribution of shot noise[3]. A simple Gaussian distribution is often used as an adequately accurate model. Film grain is usually regarded as a nearly isotropic (non-oriented) noise source. Its effect is made worse by the distribution of silver halide grains in the film also being random[1].

F Quantization Noise

The noise caused by quantizing the pixels of a sensed image to a number of discrete levels is known as quantization noise; it has an approximately uniform distribution, and can be signal dependent, though it will be signal independent if other noise sources are big enough to cause dithering, or if dithering is explicitly applied. This error is either due to rounding or truncation[1].The error signal is sometimes considered as an additional random signal called quantization noise because of its stochastic behaviour.

G Anisotropic Noise

Some noise sources show up with significant bearings in images. For eg, image sensors are sometimes subject to row noise or column noise. Anisotropic noise textures are interesting for many visualization and graphics [1]. The spot samples can be used as input for texture generation, e.g., Line Integral Convolution (LIC), but can also be used directly for visualization by itself. They are especially acceptable for the visualization of tensor fields that can be used to define a metric for the anisotropic density field. We present a new method for making stochastic samples to create anisotropic noise textures consisting of non-overlaying ellipses, whose size and density suit a given metric. Our method grounds an mechanized packing of the elliptical samples resulting in textures similar to those generated by anisotropic reaction-diffusion [6].

III METHODS OF DENOISING

There are basically two approaches for image denosing – spatial filtering method and transform domain filtering method.

A Spatial Filtering Method

Spatial filtering is the method of choice in situations when only additive noise is present. It can be further classified into 2 categories: Linear filters and Non Linear Filters.

1) Linear Filters

A mean filter is the optimal linear for Gaussian noise in the sense of mean square error. It blurs sharp edges; destroy lines and other fine feature of image. It includes Mean filter and Wiener filter.

a. Mean filter: This filter provides smoothness in an image by reducing the intensity variations between the adjacent pixels. Mean filter is essentially an averaging filter. Here the filter calculates the average value of the image with noise in a predefined area and the centre pixel intensity value is then changed by average value of pixels in the neighborhood [5]. This process is repeated for all pixel values in the entire image. The main disadvantage is that edge preserving criteria is poor in Mean filter.

b. Wiener Filter: The most important technique for removal of blur in images due to linear motion or unfocussed optics is the Wiener filter [5]. From a signal processing point of view, softening due to linear motion in a photograph is the result of poor sampling. Every pixel in a digital representation of the photograph should represent the intensity of a single stationary point in front of camera. Unluckily, if the shutter speed is slow and the camera is in motion, a given pixel will be having an amalgram of intensities from points along the line of the camera's motion.

2) Non-Linear Filters

In recent years, a variety of non-linear median type filters such as rank conditioned, relaxed median, weighted median and rank selection have been developed to overcome the shortcoming of linear filter. With the non-linear filter, noise is removed without any attempts to explicitly identify it. It is the method of choice in situations when multiplicative and function based noise is present. In this case, the median of the neighborhood pixels determine the value of an output pixel.

a. Median Filters : Median filter belongs to the class of non linear filter . Median filtering is done by, firstly finding the median value by across the window, and then replacing each entry in the window with the pixel's median value. Median filter is a best order static, non- linear filter, whose reply is based on the positioning of pixel values on basis of rank contained under the filter region [5].

Median filter yield good result for salt and pepper noise. These filters are primilarly smoothers for image processing, as well as in signal processing. The benefit of the median filter over linear filters is that the median filter can remove the effect of input noise values with huge magnitudes.

B Transform Domain Filtering

The transform domain parsing can be divided according to choice of basic functions as Non adaptive transform and adaptive transform.

1) Non Adaptive Transform

This is divided into wavelength domain and spatial frequency domain.

a. Wavelength Domain: Filtering operations in the wavelet domain can be subdivided into linear and nonlinear methods.

i. Linear Filter: Linear filters such as Wiener filter in the wavelet domain yield optimal results when the signal corruption can be modeled as a Gaussian process and the accuracy criterion is the mean square error (MSE). However, designing a filter based on this assumption frequently results in a parsed image that is more visually displeasing than the original noisy signal, even though the parsing operation successfully lessens the MSE. In a wavelet-domain spatially adaptive FIR Wiener filtering for image denoising is proposed where wiener filtering is performed only within each scale and intrascale filtering is not allowed [6].

ii. Non Linear Threshold Filtering: The most investigated domain in denoising using Wavelet Transform is the non-linear coefficient thresholding based methods. The methods exploit sparsity property of the wavelet transform and the fact that the Wavelet Transform maps white noise in the signal domain to white noise in the transform domain. Thus, while signal energy becomes more intensive into fewer coefficients in the transform domain, noise energy does not. It is thus important principle that enables the separation of signal from noise[6].

iii. Non-orthogonal Wavelet Transforms: Undecimated Wavelet Transform (UDWT) has also been used for decomposing the signal to provide visually better answer. Since UDWT is shift invariant it keeps away the visual artifacts such as pseudo-Gibbs occurrence. However the improvement in results is much higher, use of UDWT adds a large aloft of computations thus making it less feasible. In normal hard/soft thresholding was extended to Shift Invariant Discrete Wavelet Transform.[6]

iv. Wavelet Coefficient Model: This approach focuses on exploiting the multi resolution properties of Wavelet Transform. This skill identifies close connection of signal at different resolutions by observing the signal across multiple resolutions. This procedure produces excellent output but is computationally much more complex and costly. The modeling of the wavelet coefficients can either be deterministic or statistical [3]. In deterministic method of modeling involves creating tree structure of wavelet coefficients with every level in the tree representing each scale of transformation and nodes representing the wavelet coefficients. In statistical approach focuses on some more interesting and appealing properties of the Wavelet Transform such as multiscale correlation between the wavelet coefficients, local connection between neighborhood coefficients etc.

b. Spatial-Frequency Filtering: Spatial-frequency filtering refers use of low pass filters using Fast Fourier Transform (FFT) In frequency smoothing methods the removal of the noise is achieved by designing a frequency domain filter and adapting a cut-off frequency when the noise components are decorrelated from the useful signal in the frequency domain. These procedures are time consuming and depend on the cut-off frequency and the filter function behavior. Moreover, they may produce artificial frequencies in the processed image[3].

2) Data Adaptive Transform

The behavior of adaptive filters changes depending on the characteristics of the image inside the filter region. Recently a new method called Independent Component Analysis (ICA) has gained wide spread attention. The ICA procedure was successfully implemented in denoising Non-Gaussian data. One extraordinary merit of using ICA is it's assumption of signal to be Non-Gaussian which helps to denoise images with Non-Gaussian as well as Gaussian distribution. Disadvantages of ICA based methods as compared to wavelet based methods are the computational cost because it uses a sliding window and it requires sample of noise free data or at least two image frames of the same scene [6].

Types of noise removing algorithm	**Description**	**Benefits with methods**
Spatial Filtering	- Spatial filters are direct and high speed processing tools of images - traditional way to remove the noise from the digital images to employ the spatial filters - further classified into linear filters and non-linear filters	- filter provides smoothness in an image - removal of blur in images due to linear motion - smoothers for image processing, as well as in signal processing
Transfer domain Filtering	- The transform domain parsing can be divided according to choice of basic functions as Non adaptive transform and adaptive transform - Transform domain mainly includes wavelet based filtering techniques	- helps to denoise images with Non-Gaussian as well as Gaussian distribution - keeps away the visual artifacts such as pseudo-Gibbs occurrence - exploiting the multi resolution properties of Wavelet Transform

Table 1: Summary Of Denoising Algorithm

IV OTHER FORM OF NOISE

One form of noise is mixed noise in which more than one noise is coupled together to form disturbance in the image which is a challenging task since the noise distribution usually does not have a parametric model and has a heavy tail. One kind of mixed noise is additive white Gaussian noise (AWGN) coupled with impulse noise (IN). Many mixed noise removal methods are detection based procedures. They first observe the locations of IN pixels and then remove the mixed noise. The mixture of IN and AWGN, however, makes the denoising problem much more difficult because of the very different properties of the two types of noises. A few methods have been developed to remove the mixed IN and AWGN noise like median-based signal-dependent rank ordered mean (SDROM) filter which can be used for IN removal as well as mixed noise removal, trilateral filter incorporates the rank-order absolute difference (ROAD) statistics into the BF framework for IN detection, HDIR filter removes mixed noise by kernel regression with Bayesian classification of the input pixels, FIRDM filter contains two separate steps: an IN detection step and a noise reduction step that preserves edge sharpness. It can effectively remove SPIN, but its performance in removing RVIN is not satisfactory because RVIN may not produce large gradient values and weighted sparse encoding technique there is no explicit impulse pixel detection in WESNR, and we encode each noise-corrupted patch over a pre-learned dictionary to remove the IN and AWGN simultaneously in a soft impulse pixel detection manner [7]. In this we can say that with all the mixed noise removal technique weighted encoding is far better than others.

V CONCLUSION

As image is important in our day to day life, denoising image is also an important task where image which we use will be free from all types of noise. Here we have brought in to consideration some types of noises that affect the image and disturb the image. And also paper shows some basic forms of denoising techniques using which we can reduce the noise from the image. Noises will not only appear individually they will couple together to attack our image so there are some mixed noise removing technique which is also mentioned in this paper. Therefore this survey aims to bring the important type of noise as well as their technique along with one form noise called mixed noise. Mixed noise is difficult to remove since the noise coupled in image will not have same proportion. Study concludes by indicating the importance of mixed noise removal and the best technique to reduce is weighted encoding.

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