Image Noise Reduction Using Linear and Nonlinear Filtering Techniques

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Abstract— Noise is always presents in digital images during image capturing, coding, transmission, and processing steps. The performance of imaging sensors is affected by a variety of factors, such as environmental conditions during image capturing, and by the quality of the sensing elements themselves. For instance, in capturing images with a CCD camera, light levels and sensor temperature are major factors affecting the amount of noise in the resulting image. Images are corrupted during transmission principally due to interference in the channel used for transmission. Noise is very difficult to remove it from the digital images without the prior knowledge of noise model. That is why, review of noise models are essential in the study of image noise-reduction techniques. In this paper, we express a brief overview of various noise models. These noise models can be selected by analysis of their origin. In this paper we present results for different filtering techniques and we compare the results for these techniques. Noise removal is an important task in image processing. In general the results of the noise removal have a strong influence on the quality of the image processing techniques.
The nature of the noise removal problem depends on the type of the noise corrupting the image.

Index Terms— Noise model, PDF(Probability Density Function), filtering techniques, Linear smoothing filter, non-linear median filter, wiener filter, adaptive filter and Gaussian filter .

1 INTRODUCTION

NOISE is a random variation of image intensity and visible as a part of grains in the image. It may cause to arise in the image as effects of basic physics-like photon nature of light or thermal energy of heat inside the image sensors. It may produce at the time of capturing or image transmission. Noise means, the pixels in the image show different intensity values instead of true pixel values that are obtained from image.

Noise removal algorithm is the process of removing or reducing the noise from the image. The noise removal algorithms reduce or remove the visibility of noise by smoothing the entire image leaving areas near contrast boundaries. But these methods can obscure fine, low contrast details. Many techniques, of considerable interest in the field of image denoising, need continuous and uniform review of relevant noise theory. Different noises have their own characteristics which make them distinguishable from others. Image noise can also originated in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is an undesirable by-product of image captured.

In this paper, the literature survey is based on statistical concepts of noise theory. We start with noise and the roll of noise in image distortion. Noise is random variation of image intensity. It is used to destroy most of the part of image information. Image distortion is most pleasance problems in image processing. Image distorted due to various types of noise such as Gaussian noise, Poisson noise, Speckle noise, Salt and Pepper noise and many more are fundamental noise types in case of digital images. These noises may be came from a noise sources present in the vicinity of image capturing devices, faulty memory location or may be introduced due to imperfection/inaccuracy in the image capturing devices like cameras, misaligned lenses, weak focal length, scattering and other adverse conditions may be present in the atmosphere. This makes careful and in-depth study of noise and noise models are essential ingredient in image denoising. This leads to selection of proper noise model for image denoising systemsIJSER staff will edit and complete the final formatting of your paper.

2. Noise Models

The principal sources of noise in the digital image are: i) The imaging sensor may be affected by environmental conditions during image acquisition. ii)Insufficient Light levels and sensor temperature may introduce the noise in the image. iii) Interference in the transmission channel may also corrupt the image. iv) If dust particles are present on the scanner screen, they can also introduce noise in the image.

Nowadays, with advances in sensor design, the signal is relatively clean for digital SLRs at low sensitivities, but it remains noisy for consumer-grade and mobilephone cameras at high sensitivities (low-light and/or high-speed conditions). Adding to the demands of consumer and professional photography those of astronomy, biology, and medical imaging, it is thus clear that image restoration is still of acute and in fact growing importance. Working with noisy images recorded by digital cameras is difficult because different devices produce different kinds of noise, and introduce different types of artifacts and spatial correlations in the noise as a result of internal post-processing.

Noise to be any degradation in the image signal caused by external disturbance .If an image is being sent electronically from one place to another via satellite or wireless transmission or through networked cables, we may expect errors to occur in the image signal. These errors will appear on the image output in different ways depending on the type of disturbance in the signal. Usually we know what type of errors to expect and the type of noise on the image; hence we examine some of the standard noise for eliminating or reducing noise in color image. Image Noise is classified as Amplifier noise (Gaussian noise), Salt-and-pepper noise (Impulse noise), Shot noise, Quantization noise (uniform noise), Film grain, on-isotropic noise, Speckle noise (Multiplicative noise) and Periodic noise.

2.1 **Gaussian noise**

Because of its mathematical tractability in both the spatial and frequency domains, Gaussian (also called *normal, amplifier*) noise models are used frequently in practice. In fact, this tractability is so convenient that it often results in Gaussian models being used in situations in which they are marginally applicable at best. In Gaussian noise, each pixel in the image will be changed from its original value by a (usually) small amount . A histogram, a plot of the amount of distortion of a pixel value against the frequency with which it occurs, shows a normal distribution of noise.

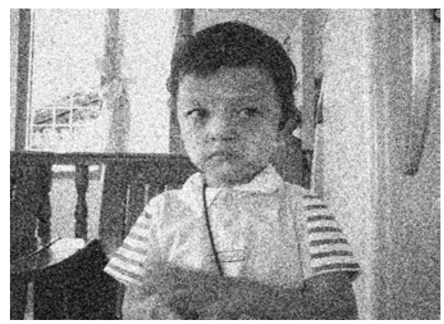
The PDF of a Gaussian random variable, is given by

$$p(z) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(z-\bar{z})^2/2\sigma^2}$$

where z represents intensity, $\bar{z}$ is the mean (average) value of *z*, and σ is its standard deviation. The standard deviation squared,σ^2 is called the *variance* of *z*. A special case is white Gaussian noise, in which the values at any pair of times are identically distributed and statistically independently (and hence uncorrelated).In communication channel testing and modeling , Gaussian noise is used as additive white noise to generate additive white Gaussian noise.

Example of gaussian noise ;

Original Image



Noisy Image

```
Ariel=imread('Ariel.jpg');
AG=rgb2gray(Ariel);
imshow(AG);
N1=imnoise(AG,'gaussian',0,0.05);
figure,imshow(N1);
```

2.2 **Impulse (salt-and-pepper) noise**

Salt and pepper noise is sometimes called impulse noise or spike noise or random noise or independent noise. In salt and pepper noise (sparse light and dark disturbances), pixels in the image are very different in color or intensity unlike their surrounding pixels. Salt and pepper degradation can be caused by sharp and sudden disturbance in the image signal. Generally this type of noise will only affect a small number of image pixels. When viewed, the image contains dark and white dots, hence the term salt and pepper noise.

The PDF of (*bipolar*) *impulse* noise is given by

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

If b > a intensity *b* will appear as a light dot in the image. Conversely, level *a* will appear like a dark dot. If either P_a or P_b is zero, the impulse noise is called *unipolar*. For this reason, bipolar impulse noise also is called *saltand-pepper* noise. *Data-drop-out* and *spike* noise also are terms used to refer to this type of noise.We use the terms *impulse* or *salt-and-pepper* noise interchangeably.

Example of salt and pepper noise ;

Original Image

Noisy Image

```
Ariel=imread('Ariel.jpg');
AG=rgb2gray(Ariel);
imshow(AG);
N1=imnoise(AG,'salt & pepper',.5);
figure,imshow(N1);
```

2.3 Speckle noise

Whereas Gaussian noise can be modelled by random values added to an image; speckle noise (or more simply just speckle) can be modelled by random values multiplied by pixel values, hence it is also called multiplicative noise. Speckle noise is a major problem in some radar applications. Although Gaussian noise and speckle noise appear superficially similar, they are formed by two totally different methods, and, as we shall see, require different approaches for their removal. The PDF Speckle noise is given by

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

Example of Speckle noise ;

Original Image

Noisy Image

```
Ariel=imread('Ariel.jpg');
AG=rgb2gray(Ariel);
imshow(AG);
N1=imnoise(AG,'speckle',.5);
figure,imshow(N1);
```

3. Removing Noise from Images by Filtering

It turns out that filters offer a natural mechanism for finding simple patterns because filters respond most strongly to pattern elements that look like the filter. For example, smoothed derivative filters are intended to give a strong response at a point where the derivative is large. At these points, the kernel of the filter looks like the effect it is intended to detect. Smoothing filters are used for blurring and for noise reduction. Blurring is used in preprocessing tasks, such as removal of small details from an image prior to (large) object extraction, and bridging of small gaps in lines or curves. Noise reduction can be accomplished by blurring with a linear filter and also by nonlinear filtering.

3.1 Smoothing Filter (Linear Filter)

The output (response) of a smoothing, linear spatial filter is simply the average of the pixels contained in the neighborhood of the filter mask. These filters sometimes are called *averaging filters*. As mentioned in the previous section, they also are referred to a *low-pass filters*.The idea behind smoothing filters is straightforward. By replacing the value of every pixel in an image by the average of the intensity levels in the neighborhood defined by the filter mask, this process results in an image with reduced “sharp” transitions in intensities. Because random noise typically consists of sharp transitions in intensity levels, the most obvious application of smoothing is noise reduction. Linear filters also tend to blur sharp edges, destroy lines and other fine image details, and perform poorly in the presence of signal-dependent noise.

3.2 Order-statistic Filters (Nonlinear Filters)

Order-statistic filters are nonlinear spatial filters whose response is based on ordering
(ranking) the pixels contained in the image area encompassed by the filter, and then replacing the value of the center pixel with the value determined by the ranking result. The best-known filter in this category is the *median filter*, which, as its name implies, replaces the value of a pixel by the median of the intensity values in the neighborhood of that pixel (the original value of the pixel is included in the computation of the median). Median filters are quite popular because, for certain types of random noise, they provide excellent noise-reduction capabilities, with considerably less blurring than linear smoothing filters of similar size. Median filters are particularly effective in the presence of *impulse noise*, also called *salt-and-pepper noise* because of its appearance as white and black dots superimposed on an image.

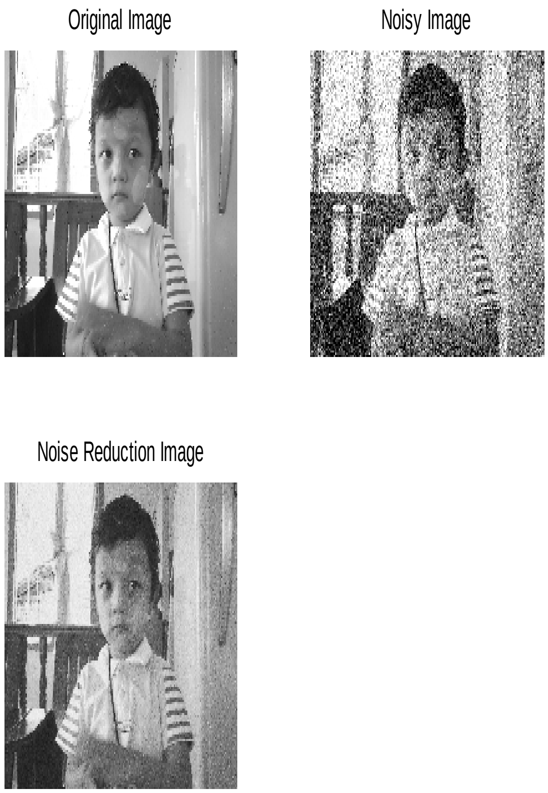
For example, suppose that a neighborhood has values (10, 20, 20, 20, 15, 20, 20, 25, 100).These values are sorted as (10, 15, 20, 20, 20, 20, 20, 25, 100), which results in a median of 20. Thus, the principal function of median filters is to force points with distinct intensity levels to be more like their neighbors. In fact, isolated clusters of pixels that are light or dark with respect to their neighbors, and whose area is less than (onehalf the filter area), are eliminated by an median filter. In this case “eliminated” means forced to the median intensity of the neighbors. Larger clusters are affected considerably less.

4. Noise Reduction from image using Filters

4.1 Using Adaptive filter to remove Gaussian noise

Adaptive filters are a class of filters which change their characteristics according to the values of the greyscales under the mask; they may act more like median filters, or more like average filters, depending on their position within the image. Such a filter can be used to clean Gaussian noise by using local statistical properties of the values under the mask.

Suppose we take the noisy image shown in figure and attempt to clean this image with adaptive filtering. We will use the wiener2 function, which can take an optional parameter indicating the size of the mask to be used. The default size is 7 x 7. Being a low pass filter, adaptive filtering does tend to blur edges and high frequency components of the image. But it does a far better job than using a low pass blurring filter. We can achieve very good results for noise where the variance is not as high as that in our current image. The image and its appearance after adaptive filtering are as shown in figure. The result is a great improvement over the original noisy image.



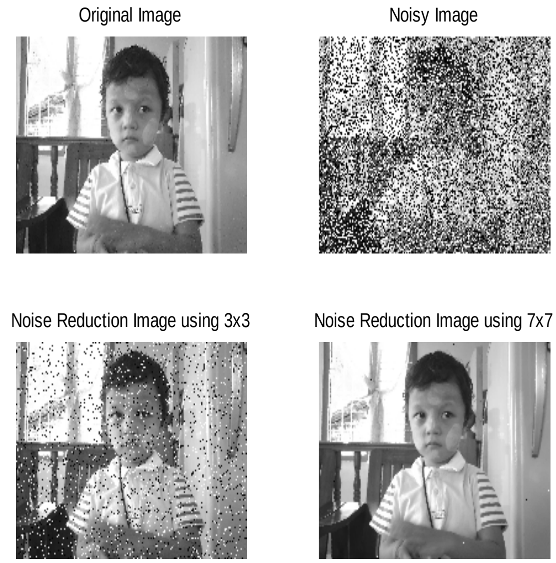
4.2 Using Median filter to remove salt and pepper noise

Median filtering seems almost tailor-made for removal of salt and pepper noise. Recall that the median of a set is the middle value when they are sorted. If there are an even number of values, the median is the mean of the middle two. A median filter is an example of a non-linear spatial filter; using a 3 x 3 mask, the output value is the median of the values in the mask. For example:

50	65	52
63	255	58
61	60	57

$\longrightarrow$ 50 52 57 58 [60] 61 63 65 255 $\longrightarrow$ 60

The operation of obtaining the median means that very large or very small values _noisy values_ will end up at the top or bottom of the sorted list. Thus the median will in general replace a noisy value with one closer to its surroundings. To remove noise completely, we can either try a second application of the 3 x 3 median filter, the result of which is shown in following figure or try a 7 x 7 median filter on the original noisy image:




```
Ariel=imread('Ariel.jpg');
AG=rgb2gray(Ariel);
subplot(2,2,1);
imshow(AG); title('Original Image');
N1=imnoise(AG,'salt & pepper',0.5);
subplot(2,2,2);
imshow(N1); title('Noisy Image');
N2=medfilt2(N1,[3,3]);
subplot(2,2,3);
imshow(N2); title('Noise Reduction Image us-
ing 3x3');
N3=medfilt2(N1,[7,7]);

subplot(2,2,4);
imshow(N3); title('Noise Reduction Image us-
ing 7x7');
```

5. Conclusion

During image acquisition and transmission, noise is seen in images. This is characterized by noise model. So study of noise model is very important part in image processing. On the other hand, image denoising is necessary action in image processing operation. Without the prior knowledge of noise model we cannot elaborate and perform denoising actions.

Hence, here we have reviewed and presented various noise models. In this paper, we discussed different filtering techniques for removing noises in gray level image. Furthermore, we presented and compared results linear and nonlinear filtering techniques. The results obtained using median filter technique ensures noise free and quality of the image as well. The main advantages of this median filter are the denoising capability of the destroyed color component differences. Hence the method can be suitable for other filters available at present. But this technique increases the computational complexity. Our future research will be focused on the construction of other Median filtering methods for color images to suppress other types of noises.

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