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REVIEW OF IMAGE DEGRADATION AND RESTORATION PROCESS

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ABSTRACT

Image restoration is the process of recovering an image that has been degraded by noise, blur, or other distortions. It is a crucial step in many image processing applications, such as medical imaging, remote sensing, security, and digital forensics. However, choosing the appropriate image restoration technique for different applications and domains is not a trivial task. It depends on several factors, such as the type and level of degradation, the prior knowledge about the image, the desired output quality, and the computational resources available. In this article, we will explore some of the common image restoration techniques and how to select them based on these factors. As in image enhancement, the principal goal of restoration techniques is to improve an image in some predefined sense. Although there are areas of overlap, image enhancement is largely a subjective process, while image restoration is for the most part an objective process. Restoration attempts to recover an image that has been degraded by using a priori knowledge of the degradation phenomenon. Thus restoration techniques are oriented toward modelling the degradation and applying the inverse process in order to recover the original image. This approach usually involves formulating a criterion of goodness that will yield an optimal estimate of the desired result. By contrast, enhancement techniques basically are heuristic procedures designed to manipulate an image in order to take advantage of the psychophysical aspects of the human visual system. For example, contrast stretching is considered an enhancement technique because it is based primarily on the pleasing aspects it might present to the viewer, whereas removal of image blur by applying a deblurring function is considered a restoration technique.

Keywords: Analysis, investigation, research, Image processing, restoration, degradation, noise

1. INTRODUCTION

We consider the restoration problem only from the point where a degraded, digital image is given; thus, we consider topics dealing with sensor, digitizer, and display degradations only superficially. These subjects, although of importance in the overall treatment of image restoration applications, are beyond the scope of the present discussion.

The degradation process is modelled as a degradation function that, together with an additive noise term, operates on an input image f(x, y) to produce a degraded image g(x, y). Given g(x,y), some knowledge about the degradation function H, and some knowledge about the additive noise term $\eta\ (x, y)$ the objective of restoration is to obtain an estimate $\hat{f}$ (x,y) of the original image. We want the estimate to be as close as possible to the original input image and, in general, the more we know about H and $\eta\ (x, y)$ the closer will be to f(x, y). The restoration approach used throughout most of this chapter is based on various types of image restoration filters.

If H is a linear, position-invariant process, then the degraded image is given in the spatial domain by

$$g(x,y) = h(x,y) \otimes f(x,y) + h(x,y)$$

Where $h(x, y)$ is the spatial representation of the degradation function and, the symbol $\otimes$ indicates convolution. This is demonstrated in the Figure 1 below.

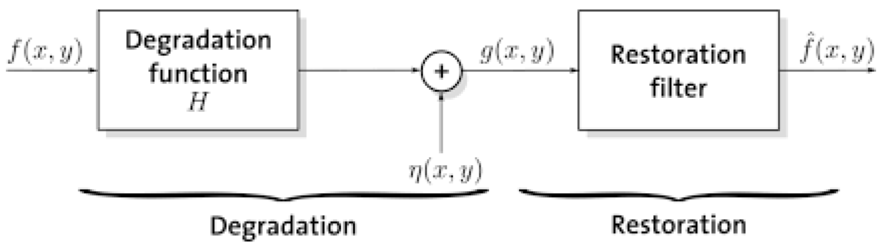


Figure 1: Image Degradation – Restoration Model

1.1 Reasons for Image Degradation:

There are many reasons available for degradation such as sensor noise, camera-misfocus, relative object-camera motion, random atmospheric turbulence. random variation of brightness or color information in the image is called noise it can be produced by sensor and circuitry of a scanner or digital camera. While object moves to the camera or vice versa, motion blur can be caused. While the object is out of focus of the camera during exposure, the object region in the image is also blurred. This kind of blur is called defocus blur imaging system is affected by atmospheric turbulence by virtue of wave propagation through a medium with nonuniform index of refraction. The situation in which degradation occurs is image acquisition and transmission of the image. Types of distortions are space variant and space invariant where all pixels are suffered from the same distortion problem is space invariant degradation and the distortion suffered by pixels in the image are depending upon their location called space invariant. Space invariant occurred due to camera motion or global lack of focus. Space-variant distortion is complex as it depends on their location with compare to space invariant.

2. NOISE MODELS

The principal source of noise in digital images arises during image acquisition and transmission. The performance of imaging sensors is affected by a variety of environmental and mechanical factors of the instrument, resulting in the addition of undesirable noise in the image. Images are also corrupted during the transmission process due to non-ideal channel characteristics.

2.1 Gaussian Noise:

Because of its mathematical simplicity, the Gaussian noise model is often used in practice and even in situations where they are marginally applicable at best. Here, m is the mean and σ2 is the variance. Gaussian noise arises in an image due to factors such as electronic circuit noise and sensor noise due to poor illumination or high temperature.

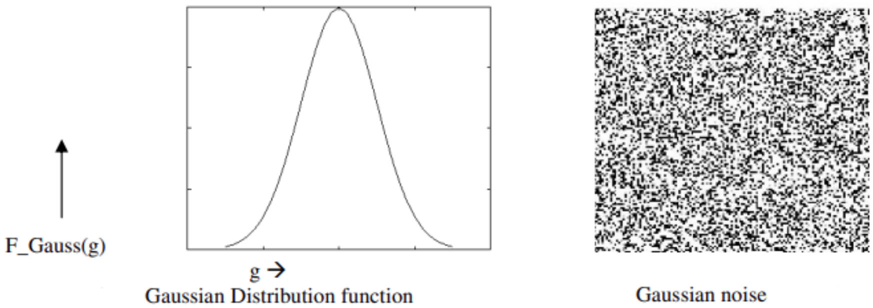


Figure 2.1: Gaussian Noise

2.2 Salt and Pepper Noise

A type of noise commonly seen in photographs is salt and pepper noise. It manifests as white and black pixels that appear at random intervals. Errors in data transfer cause this form of noise to appear. The values a and b in salt pepper noise are different. Each has a probability of less than 0.1 on average. The corrupted pixels are alternately set to the minimum and highest value, giving the image a "salt and pepper" appearance. The distribution and pixel representation of this noise is shown below. The use of a median filter, morphological filter, or contra harmonic mean filter is an effective noise eradication strategy for this type of noise. In situations when quick transients, such as improper switching, occur, salt and pepper noise creeps into images.

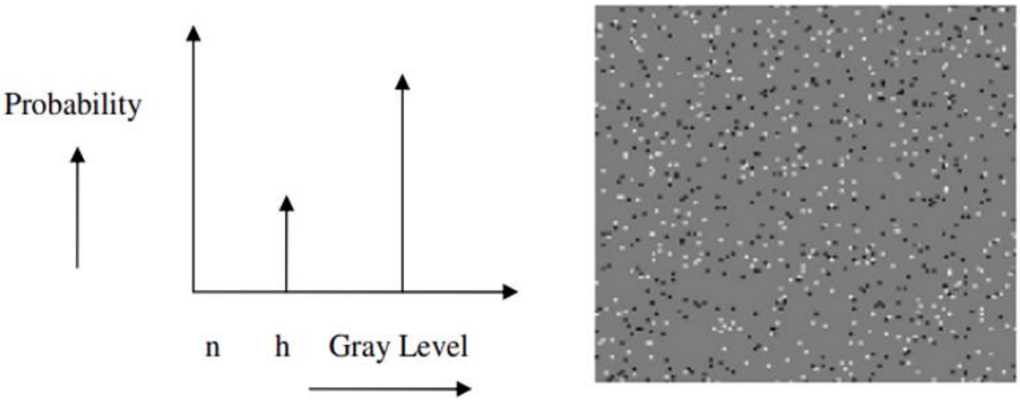


Figure 2.2: Salt and Pepper Noise

2.3 Speckle Noise

Unlike Gaussian or Salt and Pepper noise, speckle noise is multiplicative noise. In diagnostic examinations, this reduces image quality by giving images a backscattered wave appearance caused by many microscopic, dispersed reflections flowing through internal organs. This makes it more difficult for the observer to distinguish fine details This type of noise can be found in a wide range of systems, including synthetic aperture radar (SAR) images, ultrasound imaging, and many more.

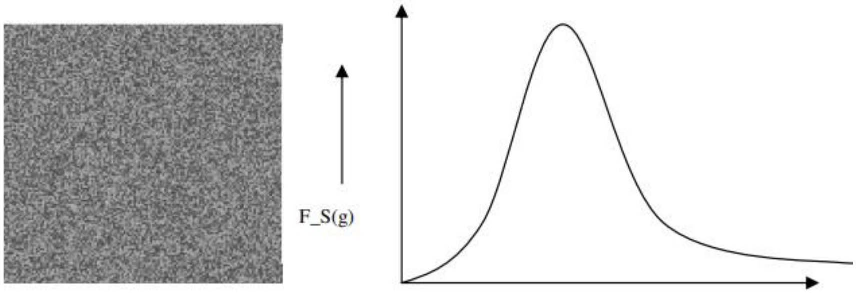
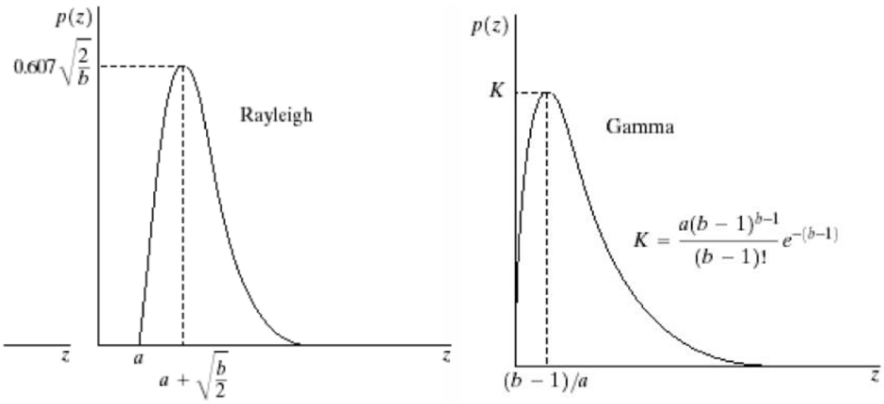


Figure 2.3: Speckle Noise

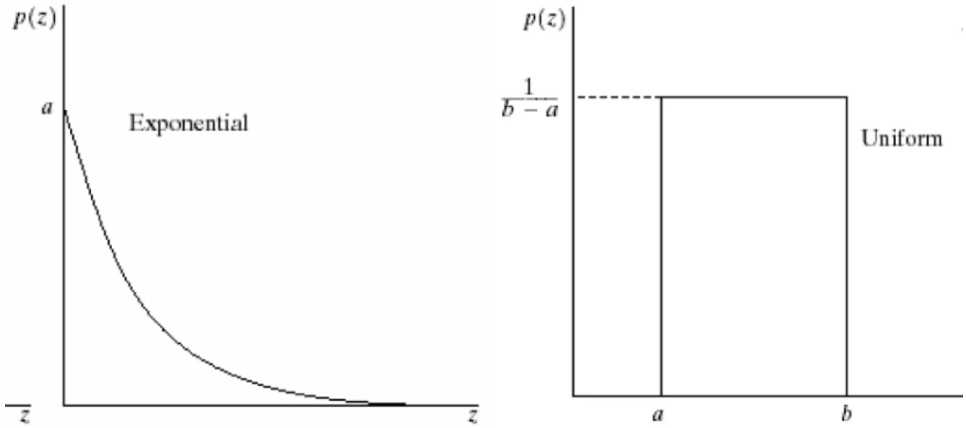
2.3 Other Noise Models

Other Noise Models include Rayleigh Noise which can be used to approximate skewed histograms, Erlang (Gamma Noise), Exponential Noise and Uniform Noise. These are demonstrated in the Figure 2.4.

Rayleigh noise is usually used to characterize noise phenomena in range imaging. Gamma noise density finds application in laser imaging. Exponential noise is also commonly present in cases of laser imaging. Uniform noise is not practically present but is often used in numerical simulations to analyze systems.



(a) Rayleigh Noise (b) Erlang (Gamma) Noise



(c) Exponential Noise (d) Uniform Noise

Figure 2.4 Various Noise Model Graphs

3. RESTORATION TECHNIQUES

There are various restoration techniques as well as spatial domain filter for noise removal. In spatial domain methods, the technique operates directly on the pixels of an image. The spatial domain methods are used for removing additive noise only. Sometimes blur helps to increase photo's expressiveness, but it decreases the quality of image unintentionally. In image restoration, the improvement in the quality of the restored image over the recorded blurred one is measured by the signal-to-noise ratio improvement. Image restoration techniques are used to make the corrupted image as similar as that of the original image. Figure.3 shows classification of restoration techniques. Basically, restoration techniques are classified into blind restoration techniques and nonblind restoration techniques. Non-blind restoration techniques are further divided into linear restoration methods and non-linear restoration method.

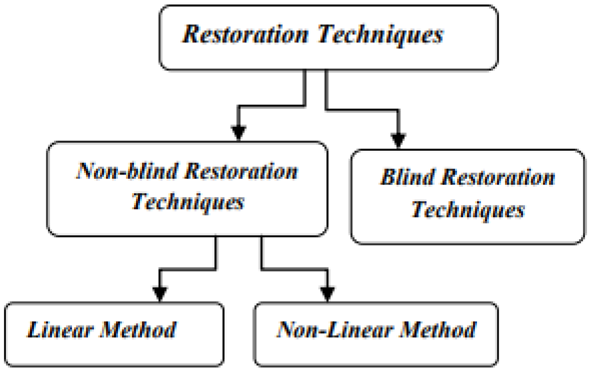


Figure 3: Classification of Image Restoration Techniques.

3.1 Non-blind restoration techniques

A non-blind technique depends on the estimation of PSF which should be priorly known. Based on PSF estimation it restores the input image. As mentioned above other two types of non-blind techniques are linear restoration methods such as Weiner filter, Inverse filter, and Constrained Least square filter. Lucy-Richardson algorithm is a Non-linear type of restoration method.

3.2 Weiner Filter

Wiener filter includes both the degradation function and statistical characteristics of noise into the restoration process. The main objective of the method is to find an estimated value of the uncorrupted image value such that the mean square value between them is minimized. The drawback of inverse and pseudo inverse filtering is that they are noise sensitive. But wiener filtering is not noise sensitive .so this is the advantage of the wiener filtering. Its response is better in presence of noise.

$$f = g \times (f + n)$$

3.3 Direct Inverse Filtering

The blurring function of the corrupted image is known or can be developed then it has been proved as quickest and easiest way to restore the distorted image. Blurring can be considered as low pass filtering in inverse filtering approach and use high pass filtering action to reconstruct the blurred image without much effort. Suppose first that the additive noise is negligible. A problem arises if it becomes very small or zero for some point or for a whole region in the plane then in that region inverse filtering cannot be applied.

$$F(x,y) = \frac{G(u,v)}{H(u,v)}$$

3.4 Constraint Least-Square Filter

Regularized filtering is used in a better way when constraints like smoothness are applied on the recovered image and very less information is known about the additive noise. The blurred and noisy image is regained by a constrained least square restoration algorithm that uses a regularized filter. Regularized restoration provides almost similar results as the wiener filtering but viewpoint of both the filtering techniques are different. In regularized filtering less previous information is required to apply restoration. The regularization filter is frequently chosen to be a discrete Laplacian. This filter can be understood as an approximation of a Weiner filter.

$$g = Hf + \eta$$

3.4 Mean Filters

3.4.1 Arithmetic Mean Filters

The Arithmetic mean filter is also called Linear Filter. It averages all the values of pixels within the window. The arithmetic filter is the simplest form of the mean filter. This filter helps in smoothing the variations in an image and it blurs the image. It normally blurs the edges. This may be a problem if sharp edges are required in the desired output.

3.4.2 Geometric mean filter

Same as an arithmetic mean filter but it loses less image detail when processing the image. Filter size is large so it is giving blurring effect.

3.4.3 Harmonic mean filter

It is used in a situation in which data values are so high. It cannot denoise the pepper noise. This is the best filter for gaussian noise and salt noise.

3.4.4 Contra harmonic mean filter

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This filter is best for eliminating salt and pepper noise. It can't remove both the noises at the same time. If choose wrong values, then the filter can behave as a dragon. The filter removes pepper noise and for its negative value, it destroys salt noise. If choose a wrong value, then filter gives the worst results.

3.5 Order Statistic Filter

In these type of filters, the values of the pixels of an image are ranked in order. Only those pixel values are ranked whose area or region is enclosed in the filter.

3.5.1 Median Filter

This filter first calculates the median of the intensity levels of the pixels Suppose the pixel values are from 1-9, so the median will be 5, that is, the midpoint of the pixel values. Then after calculating the median, it replaces the corrupted pixel value with the new value (median value). This filter is more robust because single pixel in the neighborhood never affects median value. It is much better at preserving sharp edges than another filter. But it is more expensive and complex to execute. It is taking much time to calculate a median value for each window.

3.5.2 Max and Min Filter

These filters are used to find the brightest and darkest points in the image. The Max filter replaces the pixel value with the brightest point and the Min filter replaces the pixel with the darkest point. Max filter helps to find light colored pixels in an image while Min filter helps to find dark points in the image.

3.5.3 Midpoint Filter

The Midpoint filter computes the midpoint between the maximum and minimum values of the image. The midpoint filter is widely used for noises like Gaussian noise and uniform noise. but it works well only for randomly distributed noise.

3.5.4 Alpha-trimmed Mean Filter

As the name implies, this filter trims the d/2 highest and d/2 lowest intensity values of the corrupted image in Sxy. Let gr(s,t) represents remaining mn-d pixels. Then the alphatrimmed mean filter averages the value of these remaining pixels. The value of d ranges from 0 to mn-1. When d=0, then alpha-trimmed filter becomes arithmetic mean filter. If d=mn-1 then, the filter ecomes a median filter. It is useful in a situation such as multiple types of noise, Gaussian noise, and the combination of salt and pepper noise.

3.6 Adaptive Mean Filter

This filter is the third type of spatial domain filters. In Adaptive median filters, the size of the filter can be change. The other filters discussed above can only be used for the images where the density of the noise is less. But this filter is used especially to remove high-density noise from corrupted images.

4. RESULTS AND DISCUSSION

With the explosion in the number of digital images taken every day, the demand for more accurate and visually pleasing images is increasing. However, the images captured by modern cameras are inevitably degraded by noise, which leads to deteriorated visual image quality. Therefore, work is required to reduce noise without losing image features (edges, corners, and other sharp structures). Each method has its own advantages and disadvantages. Table below demonstrates the suitability of each technique with respect to the type of noise found in images.

Table 1. Comparison table of restoration methods

Techniques	Salt-pepper noise	Gaussian noise	Uniform noise	Motion blur	Defocus blur	Gaussian blur
Direct Inverse Filter	No	No	No	Yes	Yes	Yes
Wiener Filter	Yes	Yes	Yes	Yes	Yes	Yes
Constrained least-square Filter	-	-	-	Yes	Yes	Yes
Arithmetic Mean Filter	No	Yes	Yes	No	No	No
Geometric Mean Filter	Yes	Yes	No	No	No	No
Harmonic Mean Filter	Salt-Yes, Pepper-No	Yes	No	No	No	No
Contra-harmonic Mean Filter	Yes	No	No	-	-	-
Median Filter	Yes	Yes	No	Yes	Yes	No

Max and Min Filter	Yes	No	No	No	No	No
Midpoint Filter	No	Yes	Yes	No	No	No
Adaptive Mean Filter	Yes	No	No	No	No	No

5. CONCLUSION

In image processing image restoration is widely used techniques which is very useful for removing noise and blurs from image which is formed during the process of acquisition and transmission. With the addition of these impurities in image it degrades the performance of image. In this paper we presents the literature study about the image restoration and also discusses some techniques of it. After study it is found that the some techniques are removing noises and some are removing blurs so in future work need to design such technique which is suitable for removing both efficiently and consumes less time during processing

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