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A Comparative Review Paper for Noise Models and Image Restoration Techniques

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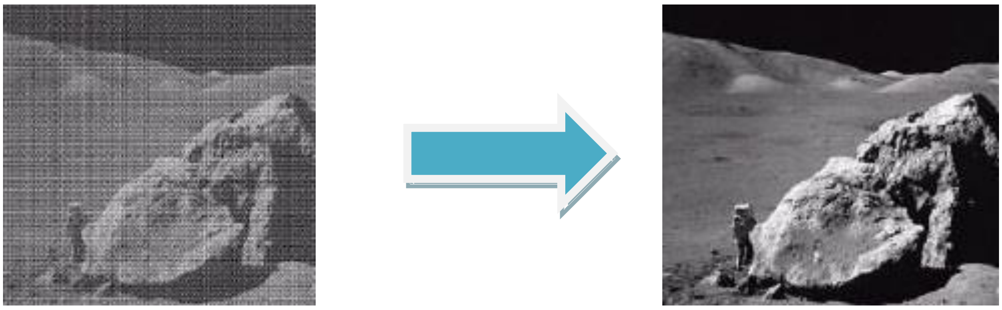
ABSTRACT : ***The process of image restoration involves recovering the original image by eliminating noise and blur from image, since image blur is very difficult to avoid in certain situations such as in photography, radar imaging to remove the effect of image system response etc. Noise is an unwanted signal which occurs in image during image acquisition. This noise can be in the form of thermal or electrical signal. In this regard we will examine and discuss different noise models and restoration methods.***

Keywords - Filters, Image restoration, Noise Models, Noise removal techniques

I. INTRODUCTION

An image worth thousands of words and atmospheric-turbulence affects the image quality so it is necessary to restore that degraded images. Generally, main causes of degradation are a blur, noise, and motion. Restoration of the image is a very big challenge in the field of image processing. To restore the image there must have knowledge of degradation. Restoration process improves the appearance of the image. Reconstruction of the image can be performed using two types of model (a) Degradation Model (b) Restoration Model.



(a) **(b)**

Figure 1(a) Degraded image 1(b) Restored image

In Fig (1) there are two images shown. Fig 1(a) is imperfect due to various reasons described in this paper. Fig1 (b) shows the clear image which is obtained by different types of restoration techniques. Generally, image acquisition and transformation from one device to another device are main causes of image degradation.

g(x, y) = h(x,y) * f(x,y) + n(x,y)……..(1)

In Equation (1) f(x, y) is an original image which is degraded by PSF (Point Spread Function) H. And once the image is degraded we need to restore it by adding noise n(x, y) and convolving restoration function. Finally, restored image f^(x, y) is obtained. The Mathematical Equation (1) is represented as follows, where h(x, y) is distortion. The symbol * represents convolution [1].

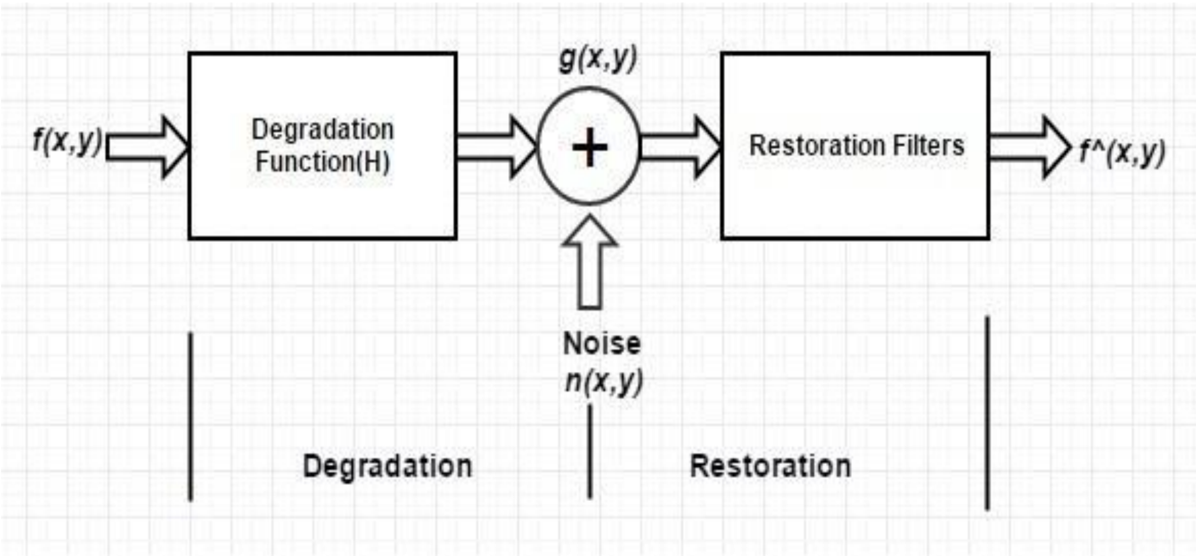


Figure 2 degradation-restoration Model

Restore the image using Non-blind restoration techniques and blind restoration techniques. Non-blind techniques further classified into linear restoration as well as Non-linear restoration techniques [2].

2. NOISE MODEL:-Noise is the unwanted element produced in the image. During image acquisition or transmission, several factors are responsible for generating noise in the image [3]. Depending on the type of disturbance, the noise can affect the image to a different extent. Generally researchers aim to remove certain kind of noise. Therefore researchers identify certain kind of noise and apply different algorithms accordingly to eliminate the noise. Image noise can be categorised as Impulse noise (Salt-and-pepper noise), Amplifier noise (Gaussian noise), Shot noise, Multiplicative noise (Speckle noise), Quantization noise (uniform noise), and Periodic noise [3].

2.1. Impulse noise (Salt-and-pepper noise): This type of noise appears as black and white dots on the entire image. This type of noise is also called by the terms spike noise, random noise or independent noise, data drop noise. This noise is also referred as salt and pepper noise but the image is not wholly corrupted by salt and pepper noise instead some of the pixel values are altered in the image. Although in noisy image, there is a possibility that some of the neighbours does not change.

$$P(z) = \begin{cases} P_a & \text{if } z=a, \\ P_b & \text{if } z=b, \\ 0 & \text{Otherwise.} \end{cases}$$

Where intensity of ‘b’ is white dot (means salt), and intensity of ‘a’ is black dots (means pepper).

2.2Amplifier noise: This type of noise also known as normal noise, has a random distribution of amplitude over time and occurs frequently. The Probability density function of Gaussian noise is:

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

Where $\boldsymbol{\sigma}$ is a standard deviation and z is intensity value.

2.3. Shot noise: This type of noise is also known as Photon noise or Poisson noise. This noise is caused due to statistical nature of electromagnetic waves such as x-rays, visible lights and gamma rays [4]. Sources of x-rays and gamma rays emit number of photons per unit time. In x-ray and gamma ray imaging, the photon rays are injected in patient's body from sources which have random fluctuations. This noise obeys Poisson distribution which is given as:

$$\mathrm{P\ (f(pi))\ =\ k)} = \frac{\lambda^k \iota^{e^{-\lambda}}}{\mathrm{k!}}$$

2.4. Speckle noise: Multiplicative noise is another name of speckle noise. The appearance of speckle noise is seen in coherent imaging system such as radar, laser and acoustics etc. Probability density function of speckle noise is as:

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

2.5. Quantization noise: Quantization noise is also called as uniform noise. This type of noise appearance is inherent in amplitude quantization process [4]. This type of noise is caused due to conversion of analog data into digital data. In quantization model, signal to noise ratio (SNR) is limited by minimum and maximum pixel value, p_{min} and p_{max} respectively. Its probability density function is given as:

$$\mathrm{P\ (g)} = \begin{cases} \frac{1}{b-a} & \text{If } a \leq g \leq b \\ 0 & \text{Otherwise.} \end{cases}$$

2.6. Periodic noise: This type of noise cannot be eliminated in spatial domain. Due to electrical and electro mechanical interface during acquisition, images are usually corrupted due to periodic noise. Spatial domain masks cannot be used to remove periodic noise fully. This type of noise can only be eliminated by studying their response in frequency domain [5]

3. IMAGE RESTORATION TECHNIQUES:-Fig 2 depicts the various restoration techniques as well as spatial domain filters used for noise removal:

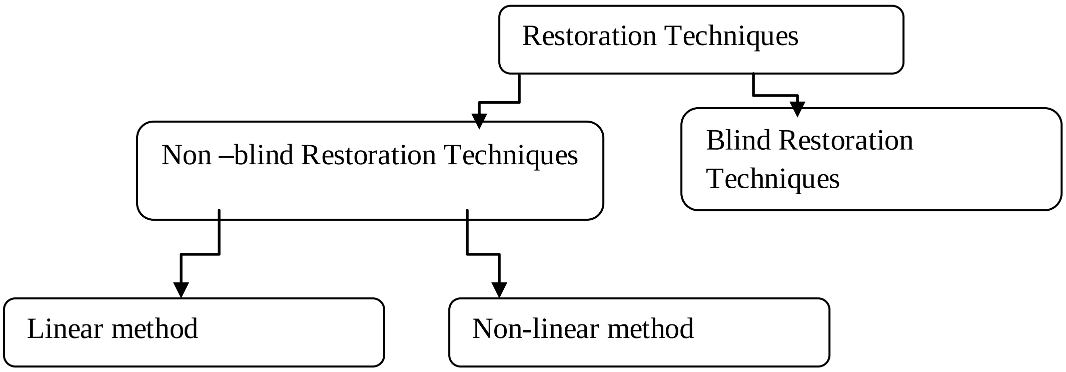


Figure 2.Restoration techniques

Non-blind restoration techniques are further divided into linear and non-linear restoration methods. Linear restoration method includes Weiner filter, inverse filter, and constrained least square filter where as non-linear type of restoration method includes Lucy-Richardson algorithm [6].

3.1**. Direct Inverse Filtering:**

The blurring function of corrupted image can be either known or it can be developed which proves a quickest and easiest way to restore distorted image. Blurring is considered as low pass filtering i9n this approach and it uses a high pass filtering action to reconstruct this blurred image without much effort.

3.2. **Weiner Filter:**

This image restoration technique is a standard approach that has been proposed by N.Weiner, which incorporates both the degradation function and statistical characteristic of noise into the restoration function. It is considered as one of the best deblurring linear methods by which image can be reconstructed from degraded one, by using known PSF. It works with both high and low pass filter to perform deconvolution tom remove noise with compression operation.

$$f = g \times (f + n)\ldots\ldots\ldots\ldots\ldots (2)$$

The output image is obtained by above equation (2) where additive noise and frequency characteristics are known [7].

3.3**. Lucy – Richardson Algorithm Technique:**

The Lucy-Richardson deconvolution algorithm has been popularly used in medical imaging and in the field of astronomy. It is a non-linear iterative method, here the number of iterations is manually determined for each image as per PSF size. It is used for recovering an image that has been blurred by known PSF. PSF(Point Spread function) is the extent to which an optical source blurs (spreads a point of light). It is the inverse Fourier transform of optical transfer function (OTF) in the frequency domain.

3.4. **Constraint Least-Square Filter:**

Filtering is used in a better way when some constraints such as smoothness are applied on the recovered image at the time when very less information is known about the additive noise. Constrained least square restoration algorithm is used to gain a blurred and noisy image and uses regular as a filter. This type provides the same result as Weiner filtering but both the techniques obey different viewpoints.

Spatial domain filters can be categorised as mean filters, order statistic filter and adaptive filter.

3.5**. Neural Network Approach:**

Neural network is a multiprocessor computer system with processing elements and interconnected node groups [9]. These interconnected node groups are called neurons which sends messages to each other. ANN is used as a robust tool for approximating a target function by giving a set of input output example and for reconstructing function from a class image. Two algorithms such as Back propagation and the Perception use gradient-decent techniques are used to tune the network parameters so that they best fit to a training set of input output examples. [10]

3.6**. Mean Filters:**

3.6.1 **Arithmetic Mean Filters:**

This type of filter is also called linear filter which averages all the pixel values within the window and helps in smoothing the variations and blurs present in image.

3.6.2. **Geometric Mean Filter:**

This type is same as arithmetic mean filter which loses less image details while processing the image.

3.6.3. **Harmonic Mean filter:**

This type of filter is used in situations in which the data values are so high, however it cannot denoise the pepper noise and is best for Gaussian noise and salt noise.

3.6.4. **Contra harmonic mean filter:**

This type of filter is used for eliminating salt and pepper noise but it cannot remove both of these noises at the same time. If sometimes wrong values are chosen then it behaves as a dragon. This filter removes pepper noise and for a negative value it destroys salt noise.

3.7. Order Statistic filter:

In order statistic filters, the values of pixels in an image are orderedly ranked and only those pixels are ranked whose region (area) is enclosed within a filter.

3.7.1**. Median Filter:**

This type of filter calculates the median of the intensity values of the pixels that is midpoint of the pixel values is calculated, after calculating the median it replaces the corrupted pixel value with a new median value. This filter is considered as more robust because a single pixel in the neighbourhood never affects median value.

3.7.2**. Max and Min Filter:**

This type of filter finds the brightest and darkest points in the image. The Max filter always replaces the pixel value with the brightest point and in contrast to this the min filter replaces the pixel value with the darkest point.

3.7.3. **Midpoint Filter:**

This type of filter computes midpoint between max and min values of the image.

3.7.4. **Alpha–trimmed Mean Filter:**

This type of filter trims the d/2 highest and d/2 lowest intensity values of corrupted image in $S_{xy.}$ it is used in a situation when there exists multiple types of noise , Gaussian noise and both salt and pepper noise.

3.8. Adaptive Mean Filter:

This filter is one of the type of spatial domain filters, where the size of filter can change. This type of filter is used especially for eliminating high density noise from the corrupted image.

4. Application:

Digital image restoration technique finds its application in the engineering community in the area of astronomy. Restoration technique is being used for mammograms, for filtering of camera shutter speeds which are relative to a rapid space craft motion [8]. It has also been used for terrestrial observation of earth and in magnetic resonance imaging.

5. CONCLUSION:

After conducting literature survey of various image restoration techniques proposed by different researchers, we can conclude that deblurring blur from images is a problem that is difficult to resolve, however to some extent the above techniques such as Lucy and Weiner Filter give better results. We also tried to apply neural networks on these techniques. In this paper, noise model, blurring and deblurring techniques are elaborated and their merits and demerits are explored.

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