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Noise Types and Various Removal Techniques

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***Abstract*— To send visual digital images are a major issue in the modern data communication network. The images sent from sender end may not be the same at the receiving end. The image obtained after transmission is often corrupted with noise. A noise is introduced in the transmission medium due to a noisy channel, errors during the measurement process and during quantization of the data for digital storage. The image received at the receiving end needs processing before it can be used for further applications. To restore the original image at the receiver end is the challenging task for the researchers. Noise can degrade the images at the time of capturing or transmission of the image. Before applying image processing tools to an image, noise removal from images is done at highest priority. This paper discussed various noises like Salt and Pepper, Poisson noise etc and various filtering techniques available for denoising the images.**

***Index Terms*- Denoising, filtering, Gaussian noise, Median filter, Mean filter.**

I. INTRODUCTION

Noise represents unwanted information which deteriorates image quality. Noise is a random variation of image intensity and visible as grains in the image [2]. Noise means, pixels within the picture present different intensity values rather than correct pixel values.. Noise originates from the physical nature of detection processes and has many specific forms and causes, Noise is defined as a process (n) which affects the acquired image (f) and is not part of the scene (initial signal-s), and so the noise model can be written as

$$f(i, j) = s(i, j) + n(i, j).$$

Digital image noise may come from various sources. The acquisition process for digital images converts optical signals into electrical signals and then into digital signals and is one processes by which the noise is introduced in digital images. Each step in the conversion process experiences fluctuations, caused by natural phenomena, and each of these steps adds a random value to the resulting intensity of a given pixel. **Sources of Noise**:

The principal sources of noise in digital images are:

I. if the image is scanned from a photograph made on film, the film grain is the source of noise. Noise can also be the result of the damage to the film, or be introduced by the scanner itself.
II. The imaging senor may be affected by environmental conditions during image acquisition.
III. If the image is acquired directly in a digital format, the mechanism for gathering the data can introduce noise.
IV. Insufficient light levels and senor temperature may introduce the noise in the image.
V. Electronic transmission of image data can introduce noise.
VI. Interference in the transmission channel may also corrupt the image.
VII. If dust particles are present on the scanner screen, they can also introduce noise in the image.

I. TYPES OF NOISE

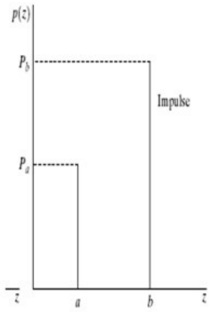
During image acquisition or transmission, several factors are responsible for introducing noise in the image. Depending on the types of disturbance, the noise can affect the image to different extent. Our main concern is to remove certain kind of noise. So we have to first identify certain type of noise and apply different algorithms to remove the noise. The common types of are:

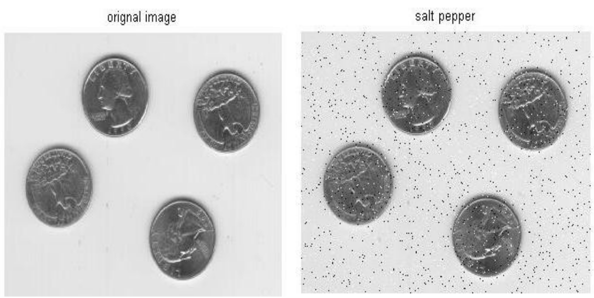
II.1: Salt Pepper Noise:

Salt and pepper noise is an impulse type of noise. It is actually the intensity spikes. This type of noise is coming due to errors in data transmission. This noise occurs in the image because of sharp and sudden changes of image signal. For images corrupted by salt and pepper noise the noisy pixels can take only the maximum and the minimum values in the dynamic range. It is found that an 8- bit image, the typical value for pepper noise is 0 and for salt noise it is 255. The salt and pepper noise is generally caused by malfunctioning of pixel elements in the camera sensors, faulty memory locations or timing errors in the digitization process.

Impulse noise:

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





I.2: Poisson Noise:

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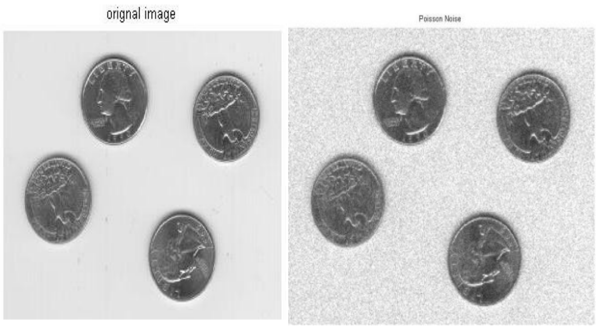
Poisson or shot photon noise is the noise that is caused when number of photons sensed by the senor is not sufficient to provide detectable statistical information. Shot noise exists because a phenomenon such as light and electric current consists of the movement of discrete packets. Shot noise may be dominated when the finite number of particles that carry energy is sufficiently small so that uncertainties due to the Poisson distribution, which describe the occurrence of independent random events, are of significance. Magnitude of this noise increase with the average magnitude of the current or intensity of the light.

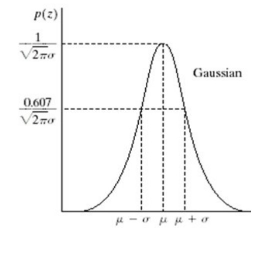


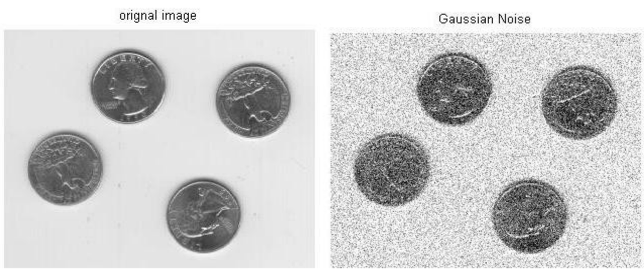
II.3: Gaussian Noise:

Gaussian noise is evenly distributed over signal. This means that each pixel in the noisy image is the sum of the true pixel value and a random Gaussian distributed noise value. The noise is independent of intensity of pixel value at each point. A special case is white Gaussian noise, in which the values at any pair of times are identically distributed and statistically independent. White noise draws its name from white light. Principal sources of Gaussian noise in digital images arise during acquisition, for example sensor noise caused by poor illumination or high temperature or transmission.

Gaussian noise:

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





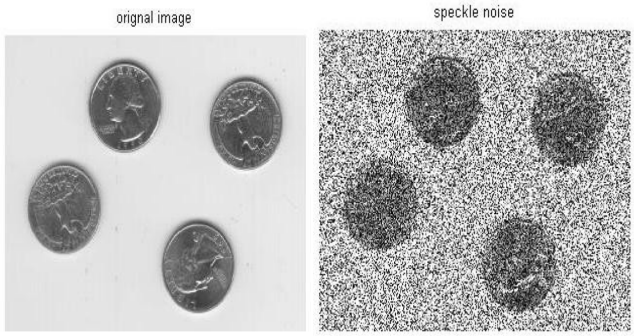
II.4: Speckle Noise:

Speckle noise is multiplicative noise unlike the Gaussian and salt pepper noise. This noise can be modeled by random vale multiplications with pixel values of the image and can be expressed as

$$P = I + n * I$$

Where P is the speckle noise distribution image, I is the input image and n is the uniform noise image by mean o and variance v.

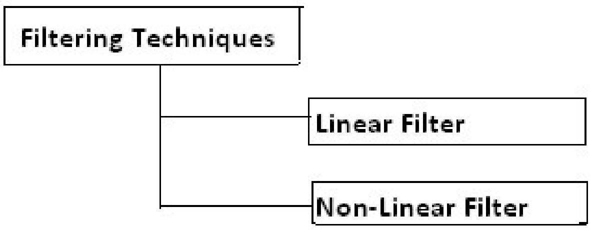
Speckle noise is commonly observed in radar sensing system, although it may appear in any type of remotely sensed image utilizing coherent radiation. Like the light from a laser, the waves emitted by active sensors travel in phase and interact minimally on their way to the target area. Reducing the effect of speckle noise permits both better discrimination of scene targets and easier automatic image segmentation.



II. NOISE REMOVAL TECHNIQUES

Image de-noising is very important task in image processing for the analysis of images. One goal in image restoration is to remove the noise from the image in such a way that the original image is discernible. In modern digital image processing data de-noising is a well- known problem and it is the concern of diverse application areas. Image de-noising is often used in the field of photography or publishing where image was somehow degraded but needs to be improved before it can be printed. When we have a model for the degradation process, the inverse process can be applied to the image to restore it back to the original form.

There are two types of noise removal approaches (i) linear filtering (ii) nonlinear filtering.



Linear Filtering: Linear filters are used to remove certain types of noise. These filters remove noise by convolving the original image with a mask that represents a low-pass filter or smoothing operation. The output of a linear operation due to the sum of two inputs is the same as performing the operation on the inputs individually and then summing the results. These filters also tend to blur the sharp edges, destroy the lines and other fine details of the image. Linear methods are fast but they do not preserve the details of the image.

Non-Linear Filtering: Non- linear filter is a filter whose output is not a linear function of its inputs**.** Non-linear filters preserve the details of the image. Non-linear filters have many applications, especially removal of certain types of noise that

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are not additive. Non-linear filters are considerably harder to use and design than linear ones.

Different types of linear and non-linear filters:

Mean Filter: The mean filter is a simple spatial filter. Mean filter acts on an image by smoothing it. The mean filter is a simple sliding window spatial filter that replaces the center value in the window with the average of all the neighboring pixel values including itself. This process is repeated for all pixel values in the image. By doing this, it replaces pixels that are unrepresentative of their surroundings. The window is usually square but it can be of any shape.

8	4	7
2	1	9
5	3	6

This provides a calculated value of 5. The center value is 1, in the pixel matrix and it is replaced with this calculated value 5.

Median Filter: Median filter is a simple and powerful non-linear filter which is based on order statics, whose response is based on the ranking of pixel values contained in the filter region. It is easy to implement method of smoothing images. The median filter also follows the moving window principle similar to the mean filter. A 3*3, 5*5, or 7*7 kernel of the pixels is scanned over pixel matrix of the entire image. In this filter, we do not replace the pixel value of the image with the mean of all neighboring pixel values; we replace it with the median value. Median filtering is done by, first sorting all the pixel values from the surrounds neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value.

124	125	127	131	141
123	125	127	128	136
119	121	**154**	126	135
120	116	120	124	134

[Here neighborhood values are 116 120 121 124 125 126 127 128 154 and median value= 125]

Adaptive Filter: Adaptive filter is performed on the degraded image that contains original image and noise. The mean and variance are the two statistical measures that a local adaptive filter depends with a defined mxn window region. The adaptive filter is more selective than a comparable linear filter, preserving edges and other high-frequency parts of an image. The `wiener2` function applies a Wiener filter (a type of linear filter) to an image adaptively, tailoring itself to the local image variance. Where the variance is large, `wiener2` performs little smoothing. Where the variance is small, `wiener2` performs more smoothing. Another method for removing noise is to evolve the image under a smoothing partial differential equation similar to the heat equation which is called anisotropic diffusion.

Wiener Filter: The main aim of this technique is to filter out noise that has corrupted the signal. It is kind of statistical approach. For the designing of this filter one should know the spectral properties of the original signal ,the noise and linear time-variant filter whose output should be as close as to the original as possible. The Wiener filter minimizes the mean square error between the estimated random process and the desired process.

Weiner filter are characterized by following:

1. Assumption: Signal and additive noise are stationary linear with known spectral characteristics or known autocorrelation and cross-correlation.
2. Requirement: the filter must be physically realizable.
3. Performance criterion: minimum mean –square error. The orthogonality principle implies that the Wiener filter in Fourier domain can be written as follows:

$$W(f_1, f_2) = \frac{H^*(f_1, f_2)S_{xx}(f_1, f_2)}{|H(f_1, f_2)|^2 S_{xx}(f_1, f_2) + S_{\eta\eta}(f_1, f_2)},$$

Max and Min Filter: Minimum and maximum filters, also known as erosion and dilation filters, respectively, are morphological filters that work by considering a neighborhood around each pixel. From the list of neighbor pixels, the minimum or maximum value is found and stored as the corresponding resulting value. Finally, each pixel in the image is replaced by the resulting value generated for its associated neighborhood. If we apply max and min filters alternately they can remove certain kind of noise, such as salt-and-pepper noise very efficiently.

Midpoint Filter: The midpoint filter simply computes the midpoint between the maximum and minimum values in the area encompassed by the filter.

Alpha- trimmed mean Filter: Alpha-trimmed mean filter is windowed filter of nonlinear class, its nature is hybrid of the mean and median filters. The basic idea behind filter is for any element of the signal (image) look at its neighborhood, discard the most atypical elements and calculate mean value using the rest of them. Alpha you can see in the name of the filter is indeed parameter responsible for the number of trimmed elements.

Alpha-trimmed mean filter algorithm:

a) Place a window over element.
b) Pick up elements.
c) Order elements.
d) Discard elements at the beginning and at the end of the got ordered set.
e) Take an average — sum up the remaining elements and divide the sum by their number.

III. PERFORMANCE PARAMETERS

Signal to Noise Ratio: SNR compares the level of desired signal to the level of background noise. The higher the

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ratio, the less obtrusive the background noise is.

SNR= P_{signal} / P_{noise}

Mean Square Error: The MSE symbolizes your cumulative squared mistake relating to the compacted along with the unique image.

$$MSE = \frac{1}{mn}\sum_{0}^{m-1}\sum_{0}^{n-1}\|f(i,j) - g(i,j)\|^2$$

Where f represents the matrix data of our original image, g represents the matrix data of our degraded image, m represents the numbers of rows of pixels of the image and i represent the index of that row, n represents the number of columns of the pixels of the image and j represents the index of that column.

Root mean square error: Root mean square error is square root value of mean square error.

RMSE= √MSE

Peak signal-to-noise ratio: The Peak Signal to Noise Ratio (PSNR) is the value of the noisy image with respect to that of the original image. This ratio is often used as a quality measurement between the original and a compressed image. The higher the PSNR, the better the quality of the compressed or reconstructed image.

$$PSNR = 20\log_{10}\left(\frac{MAX_f}{\sqrt{MSE}}\right)$$

Here MAX_f is the maximum signal value that exists in our original image.

Structural Similarity Index: The structural similarity (SSIM) index is a method for measuring the similarity between two images. SSIM considers image degradation as perceived change in structural information. Structural information is the idea that the pixels have strong inter-dependencies especially when they are spatially close. The SSIM metric is calculated on various windows of an image. The measure between two windows x and y of common size *N*×*N* is

$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

Where μ_x is the average of x, μ_y is the average of y, σ_x^2 the variance of x, σ_y^2 the variance of y , σ_{xy} the covariance of x and y, $c_1 = (k_1 L)^2$, $c_2 = (k_2 L)^2$ two variables to stabilize the division with weak denominator, L the dynamic range of the pixel- value and $k_1 = 0.01$ and $k_2 = 0.03$ by default.

CONCLUSION

In this paper, we have discussed what noise is and how it creeps into images when we acquire them or send them using any transmission medium. In the second section various types of noise models are discussed. In the third section we present the different filtering techniques that can be used to de-noise the images. In next section various performance parameters are discussed which are used to compare the effectiveness of filtering techniques. Mostly Peak signal-to-noise ratio parameter is used for measuring the effectiveness of ay filter. Each filter work differently on different types of noises. Median filter works well for Salt and Pepper noise where as wiener filter works well for removing Poisson and speckle noise and the Mean filter works well as compared to Max and Min filter.

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