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A Comparative Study of Various Types of Image Noise and Efficient Noise Removal Techniques

Mr. Rohit Verma
School of Information Technology
APJIMTC, Jalandhar, India

Dr. Jahid Ali
SSCIMT, Badhani, Pathankot, India

Abstract--- Getting an efficient method of removing noise from the images, before processing them for further analysis is a great challenge for the researchers. Noise can degrade the image at the time of capturing or transmission of the image. Before applying image processing tools to an image, noise removal from the images is done at highest priority. Ample algorithms are available, but they have their own assumptions, merits and demerits. The kind of the noise removal algorithms to remove the noise depends on the type of noise present in the image. Best results are obtained if testing image model follows the assumptions and fail otherwise. In this paper, light is thrown on some important type of noise and a comparative analysis of noise removal techniques is done. This paper presents the results of applying different noise types to an image model and investigates the results of applying various noise reduction techniques.

Keywords---Median filter, mean filter, adaptive filter, salt & pepper noise, Gaussian noise.

I. INTRODUCTION

Noise is a random variation of image Intensity and visible as grains in the image. It may 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. 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. The common types of noise that arises in the image are a) Impulse noise, b) Additive noise [1], c) Multiplicative noise. Different noises have their own characteristics which make them distinguishable from others.

II. VARIOUS SORCES OF NOISE IN IMAGES

Noise is introduced in the image at the time of image acquisition or transmission. Different factors may be responsible for introduction of noise in the image. The number of pixels corrupted in the image will decide the quantification of the noise. The principal sources of noise in the digital image are:

a) The imaging sensor may be affected by environmental conditions during image acquisition.
b) Insufficient Light levels and sensor temperature may introduce the noise in the image.
c) Interference in the transmission channel may also corrupt the image.
d) If dust particles are present on the scanner screen, they can also introduce noise in the image.

III. DIFFERENT NOISE TYPES

Noise is the undesirable effects produced in the image. During image acquisition or transmission, several factors are responsible for introducing noise in the image. Depending on the type of disturbance, the noise can affect the image to different extent. Generally our focus is to remove certain kind of noise. So we identify certain kind of noise and apply different algorithms to remove the noise. Image noise can be classified as 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.

A. Impulse Noise (Salt and Pepper Noise)

The term impulse noise is also used for this type of noise [2]. Other terms are spike noise, random noise or independent noise. Black and white dots appear in the image [5] as a result of this noise and hence salt and pepper noise. This noise arises in the image because of sharp and sudden changes of image signal. Dust particles in the image acquisition source or over heated faulty components can cause this type of noise. Image is corrupted to a small extent due to noise. Fig 2. Show the effect of this noise on the original image (Fig 1).

Fig 1. Original image without noise

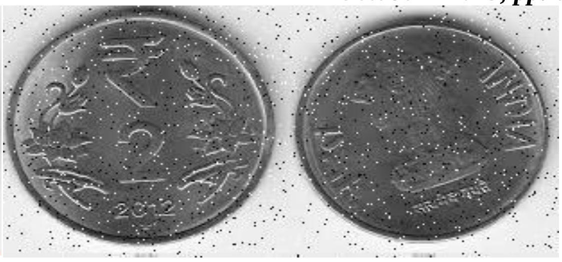

Fig 2, Image with 30% salt & pepper noise

B. Gaussian Noise (Amplifier Noise)

The term normal noise model is the synonym of Gaussian noise.
This noise model is additive in nature [4] and follow Gaussian distribution. Meaning 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. The PDF of Gaussian random variable is given by:

$$P(x) = 1/(\sigma\sqrt{2\pi}) * e^{(x-\mu)2 / 2\sigma^{2}} \quad -\infty < 0 < \infty$$

Where: *P(x)* is the Gaussian distribution noise in image; μ and σ is the mean and standard deviation respectively.
Figure 3, shows the effect of adding Gaussian noise to Figure 1, with zero mean

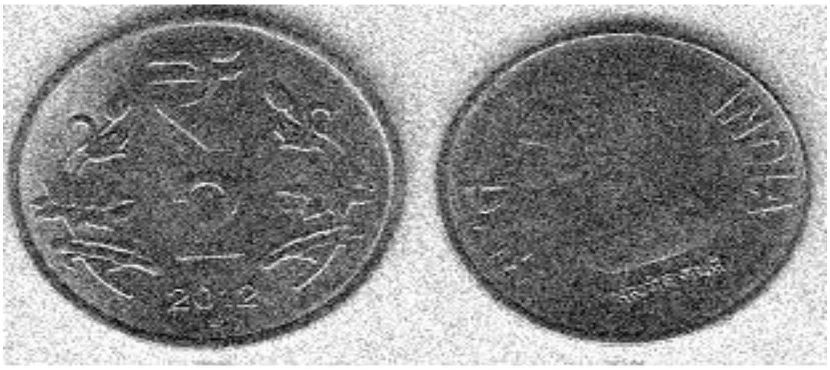

Fig 3, Gaussian noise with zero mean

C. Poisson Noise (Photon Noise)

Poisson or shot photon noise is the noise that can cause, when number of photons sensed by the sensor is not sufficient to provide detectable statistical information [4]. This noise has root mean square value proportional to square root intensity of the image. Different pixels are suffered by independent noise values. At practical grounds the photon noise and other sensor based noise corrupt the signal at different proportions [3]. Figure 4 shows the result of adding Poisson noise.

Fig 4. Image with Poisson noise

D. Speckle Noise

This noise can be modeled by random value multiplications with pixel values of the image and can be expressed as

$$J = I + n*I$$

Where, J is the speckle noise distribution image, I is the input image and *n* is the uniform noise image by mean *o* and variance *v*. This noise deteriorates the quality of active radar and Synthetic aperture radar (SAR) [4] images. This noise is originated because of coherent processing of back scattered signals from multiple distributed points. In conventional radar system this type of noise is noticed when the returned signal from the object having size less than or equal to a single image processing unit, shows sudden fluctuations. Mean filters are good for Gaussian noise and uniform noise. Fig 5(a), shows the effect of adding speckle noise

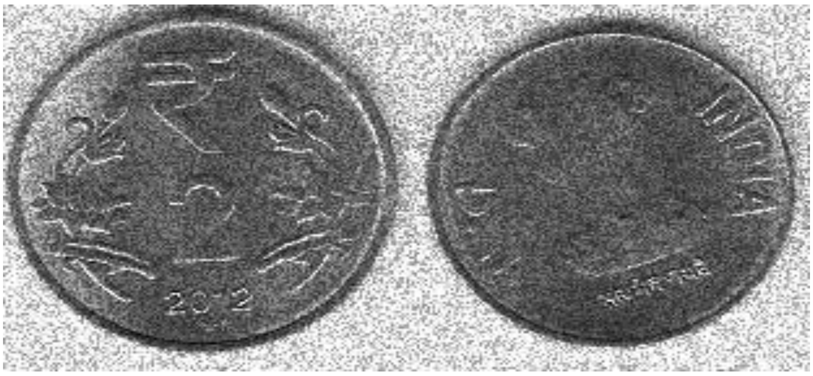

Fig 5(a), Image with speckle noise

IV IMAGE DE-NOISING

Image de-noising is very important task in image processing for the analysis of images. Ample image de-noising algorithms are available, but the best one should remove the noise completely from the image, while preserving the details. De-noising methods can be linear as well as non-linear. Where linear methods are fast enough, but they do not preserve the details of the images, whereas the non- linear methods preserve the details of the images. Broadly speaking, De-noising filters can be categorized in the following categories:

- Averaging filter
- Order Statistics filter
- Adaptive filter

A. Mean filter

Mean filter is an averaging linear filter [6]. Here the filter computes the average value of the corrupted image in a pre-decided area. Then the center pixel intensity value is replaced by that average value. This process is repeated for all pixel values in the image. Fig 5-Fig 8, show the effect of using mean filter of size 5X5 on different types of noise.

Fig 5 Mean filter used on Salt pepper noise

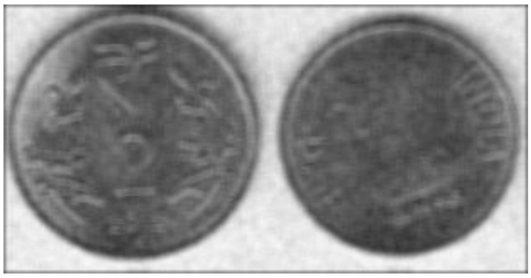

Fig 6 Mean filter used on Gaussian noise

Fig 7 Mean filter used on Poisson noise

Fig 8 Mean filter used for Speckle noise

B. Median Filter

Median filter is a best order static, non- linear filter, whose response is based on the ranking of pixel values contained in the filter region. Median filter is quite popular for reducing certain types of noise. Here the center value of the pixel is replaced by the median of the pixel values under the filter region [9] [10]. Fig 9-Fig 12 show the effect of median filter on different types of noise.

Fig 9 Median filter used for Salt and pepper noise

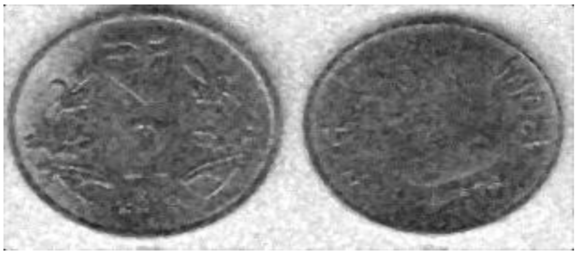

Fig 10 Median filter used for Gaussian noise

Fig 11 Median filter used for Poisson noise

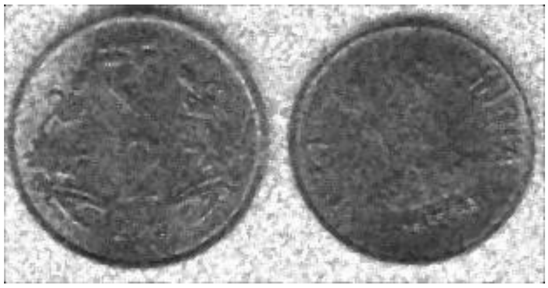

Fig 12 Median filter used for Speckle noise

Median filter is good for salt and pepper noise. These filters are widely used as smoothers for image processing, as well as in signal processing. A major advantage of the median filter over linear filters is that the median filter can eliminate the effect of input noise values with extremely large magnitudes.

C. Order Statistics Filter

Order-Statistics filters are non-linear filters whose response depends on the ordering of pixels encompassed by the filter area. When the center value of the pixel in the image area is replaced by 100^{th} percentile, the filter is called max-filter. On the other hand, if the same pixel value is replaced by 0^{th} percentile, the filter is termed as minimum filter. Fig. 13-Fig 16 will present the result of using minimum order static filter

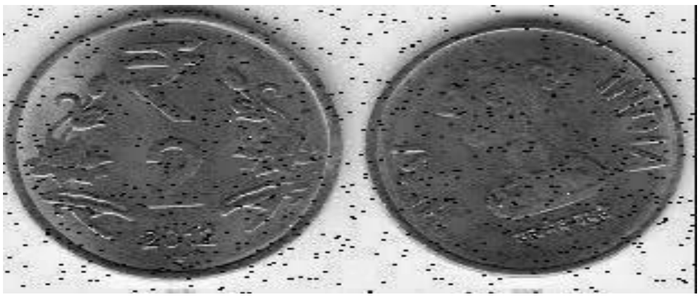

Fig 13 Order Static (minimum) filter used for Salt and pepper noise

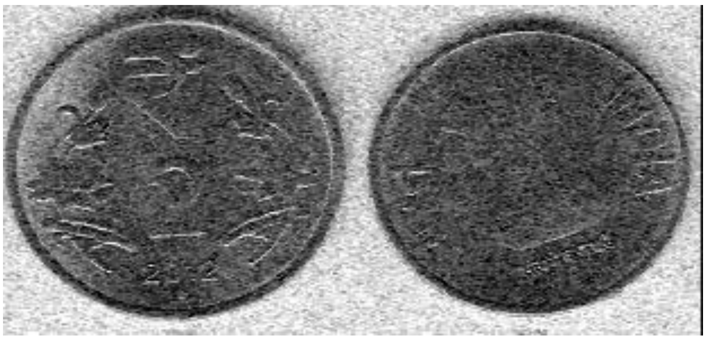

Fig 14 Order Static (minimum) filter used for Gaussian noise

Fig 15 Order Static (minimum) filter used for Poisson noise

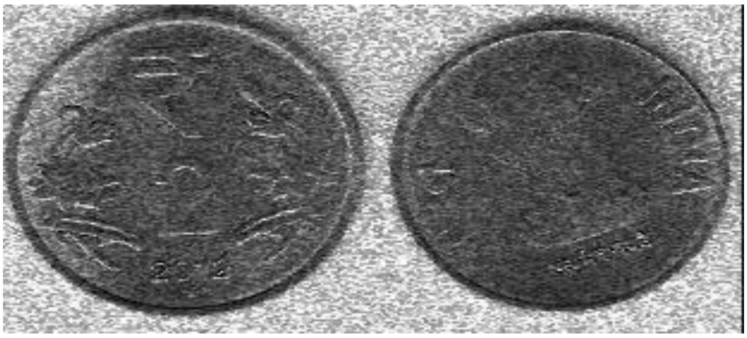

Fig 16 Order Static (minimum) filter used for Speckle noise

D. Adaptive Filter

These filters change their behavior on the basis of statistical characteristics of the image region, encompassed by the filter region.BM3D is an adaptive filter. It is a nonlocal image modeling technique based on adaptive, high order group-wise models.

This de-noising algorithm can be divided in three steps [7-8]:

1. *Analysis*. Firstly similar image blocks are collected in groups. Blocks in each group are stacked together to form 3-D data arrays, which are de-correlated using an invertible 3D transform.
2. *Processing*. The obtained 3-D group spectra are filtered by hard thresholding.
3. *Synthesis.* The filtered spectra are inverted, providing estimates for each block in the group. These block-wise estimates are returned to their original positions and the final image reconstruction is calculated as a weighted average of all the obtained block-wise estimates.

The results of applying BM3D algorithm is presented in the Fig 17-Fig 20

Fig 17 BM3D filter used for Salt and pepper noise

Fig 18 BM3D filter used for Gaussian noise

Fig 19 BM3D filter used for Poisson noise

Fig 20 BM3D filter used for Speckle noise

V RESULTS

TABLE 1. PSNR in dB

	Salt &pepper	Gaussian	Poisson	Speckle
Mean	30.19	28.30	29.92	28.11
Median	30.19	28.98	30.99	28.96
Order Static	29.09	27.23	28.98	27.41
BM3D	31.15	28.68	30.74	28.50

TABLE 2 MSE of different noises

	Salt & pepper	Gaussian	Poisson	Speckle
Mean	62.17	96.05	66.19	100.34
Median	62.17	82.33	51.65	82.52
Order Static	80.10	122.80	82.22	117.83
BM3D	49.79	87.97	54.75	91.68

VI CONCLUSION

In this paper, we have discussed different types of noise that creep in images during image acquisition or transmission. Light is also thrown on the causes of these noises and their major sources. In the second section we present the various filtering techniques that can be applied to de-noise the images. Experimental results presented, insists us to conclude that BM3D and median filters performed well. Whereas averaging and minimum filters performed worst. BM3D is the best choice of removing the Salt and pepper noise. Whereas in other cases median filter is more suitable.

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