GAUSSIAN NOISE ESTIMATION TECHNIQUE FOR GRAY SCALE IMAGES USING MEAN VALUE

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ABSTRACT

The usage of digital image becomes ubiquitous. Also, the digital images are processed using digital devices. There are many mathematical techniques available to estimate the Gaussian noise of reproduced digital image. Assessing quantity of the Gaussian noise in a digital image is a difficult task. There are few factors affecting the process of digitizing images. The electronic devices used for acquiring images are the cause of the Gaussian noise. In this paper, a mathematical technique is proposed to estimate the Gaussian noise in the reproduced digital image. The proposed technique estimates quantity of the Gaussian noise in the reproduced image in a better way. The proposed technique is compared with Root Mean Square Error (RMSE), Peak Signal to Noise Ratio (PSNR), and Structural Similarity Index value (SSIM). This experiment shows that the proposed technique is suitable for estimating the exact amount of Gaussian noise in the reproduced image than the other mentioned techniques.

Keywords: *Quality of Images, RMSE, PSNR, SSIM, and Mean Metric.*

1. INTRODUCTION

The digital image usage becomes increasing and applied in almost all the applications and electronic devices. The image can express the idea in short amount of time than the text information. Further, the illiterate people can understand the message made of image very well without others help. A simple example for this, is the sign board placed on the sides on the highways. Moreover, the reader shows interest to a greater extent to read an article which comprises of images than the plain text one. The above reasons are evident of increase in the usage of digital images in all fields.

The electronic devices used to acquire the image, observe the scenario and represent the view in the digital form as an image. The regenerated digital image has different type of noises, which are introduced by the electronic devices because of the environmental factors. One of the common noise introduced into the image is the Gaussian noise. There are many mathematical techniques available to estimate different noises. But they are highly suitable for certain type of images [1].

The three common error metrics used for estimating noise on images are RMSE, PSNR, and SSIM. While applying these techniques on different gray scale images, we observed that these techniques failed to estimate the amount of noise for certain types of images where the reproduced image mean value is greater than the source image mean value. The above said techniques work well for the cases where the reproduced image mean value is lesser than the source image mean value.

2. ERROR METRICS

The RMSE, PSNR, and SSIM are well known error metrics used to estimate the noise in the reproduced images. The RMSE can be defined as follows:

$$\text{Error} = \left[\frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \left[s_i - r_j \right]^2 \right]^{\frac{1}{2}} \qquad (1)$$

Where i, j are the positions of pixels in the image, $s_{i,j}$ refers to the i^{th} row and j^{th} column pixel value of the source image and $r_{i,j}$ refers to the i^{th} row and j^{th} column pixel value of the reproduced image. The RMSE failed in the following two scenarios. The first scenario is, the source image pixels were added with a constant value but the signs of the values are random, either positive or negative. This makes the contrast of the image increase. The RMSE value will be the same for both the images: source image and contrast increased image. The second one is, adding an independent white Gaussian noise to the original texture image. Again the RMSE values remain same for both the images: the source image and the reproduced image with the Gaussian noise [2].

The PSNR can be defined as

$$\text{PSNR} = 10 \times \log_{10} \times (\text{MAX} / \text{RMSE}) \qquad (2)$$

where, MAX is the maximum pixel value of the image. In the case of 8 bits gray scale images the MAX value will be 255.

For the above two cases where RMSE failed to calculate the error, SSIM estimates the error [3]-[7]. The SSIM can be defined as the collection of three important properties of an image. They are Luminance measurement l(x, y), Contrast measurement c(x, y), and Structure measurement s(x, y) of the image.

$$\text{SSIM}(x, y) = f(l(x, y), c(x, y), s(x, y)) \qquad (3)$$

that is,

$$\text{SSIM}(x,y)=\frac{(2\mu_x\mu_y + C1)(2\sigma_{xy} + C2)}{(\mu_x^2 + \mu_y^2 + C1)(\sigma_x^2 + \sigma_y^2 + C2)} \qquad (4)$$

Where, μ_x, μ_y, are the mean intensity, σ_x, σ_y, are the estimate of the signal contrast.

3. MEAN METRIC TECHNIQUE

In order to precede the experiment, where the source image mean value is lesser than the reproduced image and the source image mean value is greater than the reproduced image mean value, two images were created. One is full of black in color and another is full of white in color. The black image z1.tif will have values for all the pixels the lowest possible value 1 and the white image z2.tif will have values for all the pixels the highest value 255.

The source images z1.tif and z2.tif considered for the experiment are as shown below. The z2.tif is complete white in colour and not visible because the colour of the paper is also white, thus a border in black colour is added.

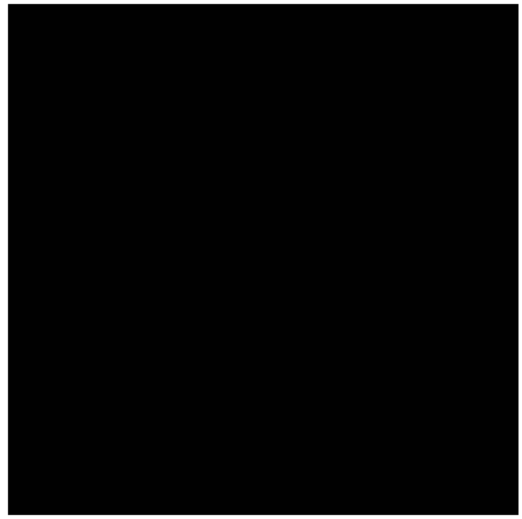


Figure 1 z1.tif

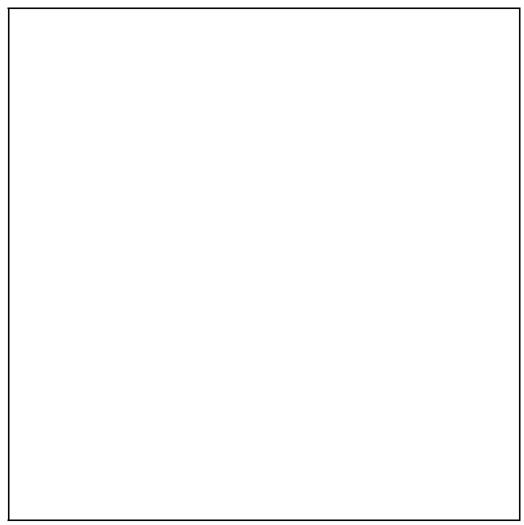


Figure 2 z2.tif

The two source images were introduced with 10% Gaussian noise and the RMSE, PSNR, SSIM and our proposed error metric Mean Metric (MM) are calculated. Further, 10% is added and continued up to 100% and then during each step the reproduced image's RMSE, PSNR, SSIM and MM are calculated. The values are tabulated and comparison study was done.

It is observed that if the mean value of the source image is lesser than the mean value of the reproduced image the NMSE, PSNR and SSIM metrics failed to measure the quantity of the Gaussian noise. In order to handle these types of images, a simple mathematical based calculation is proposed. This technique makes use of the mean value of the source image and mean value of the reproduced image, then calculates the Mean Metric. This technique measures the Gaussian noise of the reproduced image in a better way than the other techniques mentioned. The mathematical formula for Mean Metric is as shown below,

```
if (mr > ms) then
    mm = mr / ms
else
    mm = ms / mr
```

where, *mr* is the mean value of the reproduced image with Gaussian noise and *ms* is the mean value of the source image. The ratio of the mean value is calculated between the source image and the reproduced image and named Mean Metric.

The following table-1 lists the experiment results for the increasing mean value of the reproduced images using the image z1.tif. The mean value of the pixels of z1.tif picture is 1. The Gaussian noise introduced into the source image starts from 10% to 100% with the interval of 10%. At each step, the Mean, RMSE, PSNR, SSIM and Mean Metric of the reproduced image are calculated.

Table 1 Increasing Mean Value

Mean	RMSE	PSNR	SSIM	MM
1	0	Infinite	1.0000	1.0000
32.77	10.7214	13.8021	0.0024	0.0305
45.49	10.8466	13.8021	0.0009	0.0220
54.80	10.9907	13.6173	0.0005	0.0182
61.10	11.0042	13.6173	0.0004	0.0164
66.62	11.0773	13.6173	0.0003	0.0150
70.21	11.0568	13.6173	0.0003	0.0142
73.56	11.0761	13.6173	0.0002	0.0136
75.73	11.0456	13.6173	0.0002	0.0132
78.29	11.0606	13.6173	0.0002	0.0128
80.33	11.0881	13.6173	0.0002	0.0124

In the above table-1, the RMSE values, there are increase and decrease in between fifth iteration to tenth iteration. PSNR values are same for four decimal places from third iteration to tenth iteration. SSIM values are same in fifth iteration and sixth iteration up to four decimal places. Similarly, seventh to tenth iteration SSIM values are same up to four decimal places. The Mean Metric value has clear distinction in each step. The above table makes clear that when the reproduced image has higher Mean value than the source image, the RMSE, SSIM, and PSNR failed to find exact quantity of the Gaussian noise of the reproduced image.

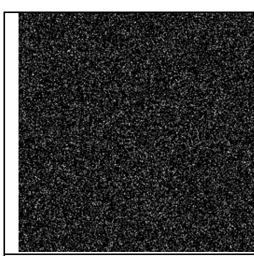
The following table-2 lists the experiment results for the decreasing Mean value of the reproduced images using the image z2.tif. The Gaussian noise introduced into the source image starts from 0% to 100% with the interval of 10%. At each step, the Mean, RMSE, PSNR, SSIM and MM of the reproduced image are calculated.

Table 2 Decreasing Mean Value

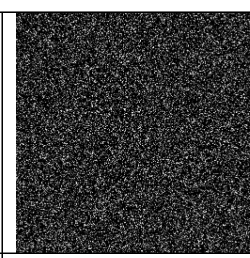
Mean	RMSE	PSNR	SSIM	MM
0	0	Infinite	1.0000	1.0000
223.07	0	24.0654	0.0307	0.8748
210.01	0	24.0654	0.0159	0.8236
200.61	0	24.0654	0.0111	0.7867
195.20	0	24.0654	0.0093	0.7655
189.57	0	24.0654	0.0080	0.7434
184.97	0	24.0654	0.0072	0.7254
182.07	0	24.0654	0.0066	0.7140
179.03	0	24.0654	0.0062	0.7021
176.39	0	24.0654	0.0059	0.6918
173.83	0	24.0654	0.0056	0.6817

It is observed from table-2 that when the reproduced image has lower mean value than the source image, the RMSE and SSIM are able to give quantity of noise of the reproduced image. But, PSNR fails in this case. For both the cases the MM works well without any difficulty.

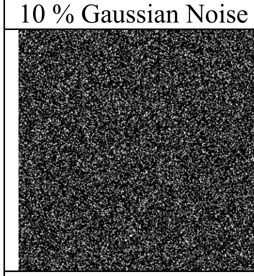
The z1.tif source image modified with 10% Gaussian noise at each step is shown below.



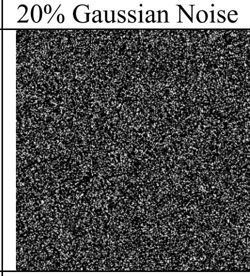
10 % Gaussian Noise



20% Gaussian Noise



30% Gaussian Noise



40% Gaussian Noise

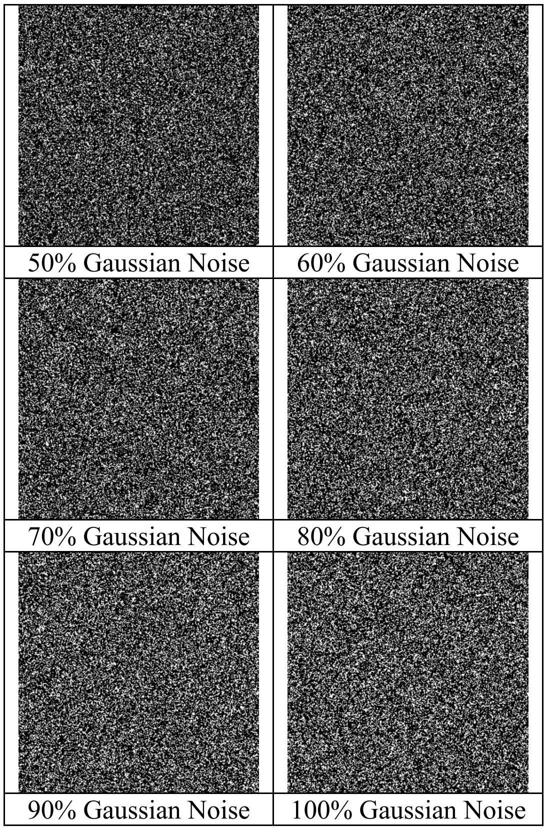
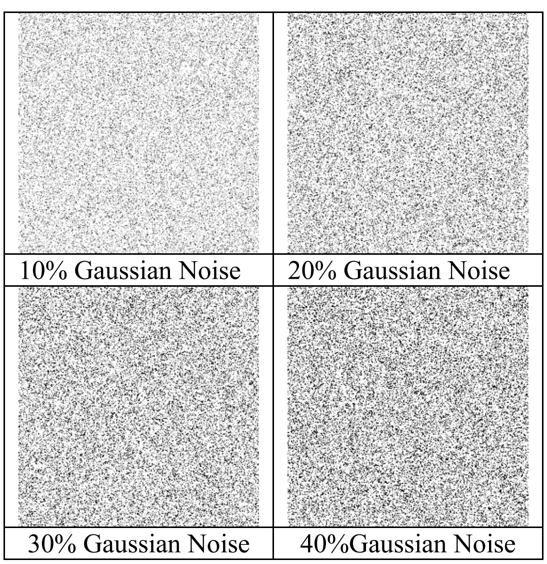


Figure 3 Gaussian noise images of z1.tif

The z2.tif is added with 10% Gaussian noise at each step and the images are with Gaussian noise at each step as shown below.



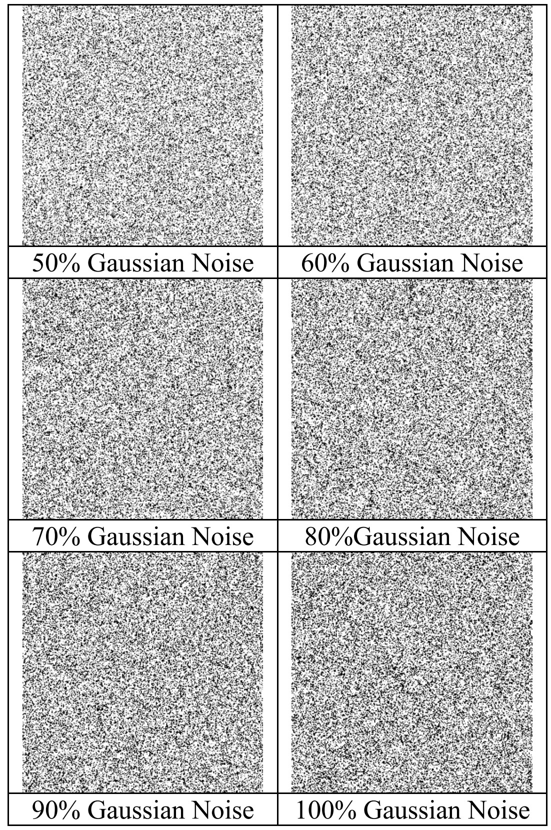


Figure 4 Gaussian noise images of z2.tif

Further, the following three gray scale images *plant.tif, chart.tif* , and *clock.tif* are considered for experiment. The *plant.tif* image has lesser mean value than the reproduced image mean value. The other *chart.tif* and *clock.tif* images have higher mean value than the reproduced images mean values.

At each step, 10% Gaussian noise was added to these images and error values calculated individually. The following table-3, table-4 and table-5 list the results of these experiments.

Figure 5 plant.tif

The *plant.tif* image is shown in figure-4 and the experiment results are shown in Table-3.

Table 3 Results of the image plant.tif

Mean	RMSE	PSNR	SSIM	MM
0	0	Infinite	1.0000	1.0000
108.13	10.6589	13.8021	0.1259	0.1259
111.53	10.8348	13.8021	0.0799	0.9367
113.82	10.9325	13.6173	0.0615	0.9178
114.63	10.9514	13.6173	0.0532	0.9114
116.12	11.0093	13.6173	0.0430	0.8997
116.69	11.0167	13.6173	0.0399	0.8952
117.80	11.0398	13.6173	0.0372	0.8868
118.19	11.0580	13.6173	0.0331	0.8839
118.33	11.0522	13.6173	0.0308	0.8828
118.74	11.0752	13.6173	0.0299	0.8798

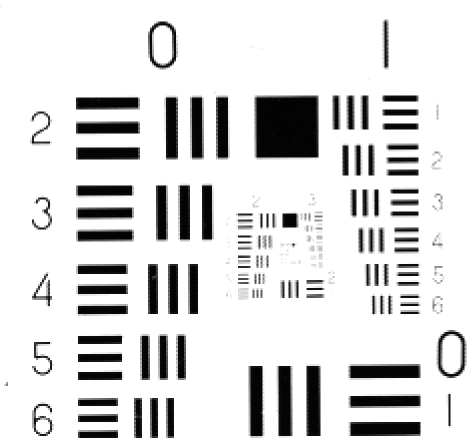


Figure 6 chart.tif

The *chart.tif* image is shown in Figure-5 and the experiment results corresponding to this image are listed in Table-4.

Table 4 Results of the image chart.tif

Mean	RMSE	PSNR	SSIM	MM
0	0	Infinite	1.0000	1.0000
200.93	4.1489	17.8533	0.2920	0.8894
191.50	4.2216	17.7815	0.2157	0.8477
184.29	4.2089	17.8533	0.1799	0.8158
179.00	4.2600	17.7815	0.1529	0.7924
175.08	4.2497	17.7815	0.1361	0.7750
172.48	4.2650	17.7815	0.1247	0.7635
169.44	4.2830	17.7815	0.1114	0.7501
168.67	4.2839	17.7815	0.1088	0.7466
165.68	4.2953	17.7085	0.1001	0.7334
163.66	4.2970	17.7085	0.0921	0.7245

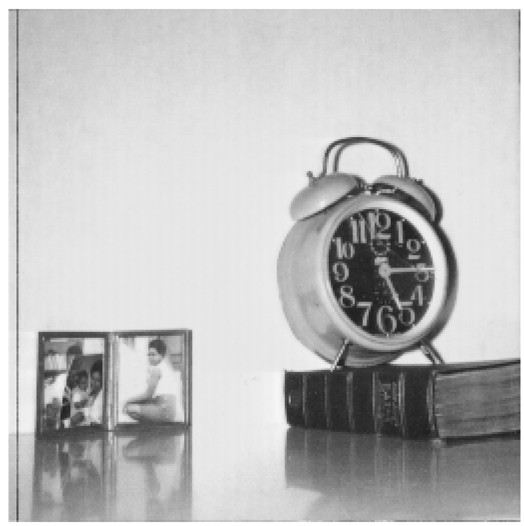


Figure 7 clock.tif

The *clock.tif* image is shown in Figure-6 and the experiment results corresponding to this image are listed in Table-5.

Table 5 Results of the image clock.tif

Mean	RMSE	PSNR	SSIM	MM
0	0	Infinite	1.0000	1.0000
174.48	10.6868	13.8021	0.0989	0.9382
167.17	10.8532	13.6173	0.0644	0.8989
162.63	10.9262	13.6173	0.0496	0.8745
159.50	10.9819	13.6173	0.0405	0.8577
156.04	10.9940	13.6173	0.0388	0.8390
155.27	11.0685	13.6173	0.0337	0.8349

152.24	11.0157	13.6173	0.0282	0.8186
151.78	11.0831	13.6173	0.0259	0.8161
150.85	11.1147	13.6173	0.0264	0.8112
148.75	11.0654	13.6173	0.0250	0.7998

4. CONCLUSION

The proposed mathematical formula estimates the Gaussian noise in a better way when compared to RMSE, PSNR, and SSIM techniques where the mean value of the reproduced image is greater than the mean value of the source image. This presented formula uses the mean value of the source image and mean value of the reproduced image to compute the mean metric. The computation involves subtraction, division and multiplication. These simple arithmetic operations makes the computation faster and simpler. The Mean Metric values are zero if there is no error in the reproduced image, and for other cases it is a positive integer number. These shows that the Mean Metric is more preferable than the other mentioned techniques for estimating the Gaussian Noise.

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