# Study on Different Image Quality Assessment Techniques for Gray Scale Images

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***Abstract -- Quality is a very important parameter for all objects and their functionalities. For authentic quality evaluation ground truth is required. But in practice, it is very difficult to find the ground truth. Usually, image quality is being assessed by MSE (Mean Square Error) and PSNR (Peak Signal to Noise Ratio). In contrast to MSE and PSNR, recently, SSIM (Structured Similarity Indexing Method) is proposed which compares the structural measure between obtained and original images. This paper is mainly stressed on SSIM and compares the finding with MSE and PSNR. To measure the image quality we have done a simulation work by adding noise to bench-marked original images and then calculated MSE, PSNR and SSIM of the corresponding image. We have found the superiority of the SSIM in comparison to MSE and PSNR.***

***Indexed Terms: Image Quality, Computer Simulation, Salt & Pepper noise, Gaussian noise***

## I. INTRODUCTION

Image Quality Assessment (IQA) is considered as a characteristic property of an image. Degradation of perceived images is measured by image quality assessment. Usually, degradation is calculated compared to an ideal image.

Image quality can be described technically as well as can also be determined by objectives to indicate the deviations from the ideal or perfect models. It also relates to the subjective perception or prediction of an image. Example: an image of a human look [1], [2].

The reduction of the quality of an image is affected by the noise. This noise depends on how it correlates with the information the viewer seeks in the image.

There are several techniques and metrics available to be used for image quality assessment. These techniques are grouped into three categories based on the availability of a reference image [3].The categories are:

Full-Reference (FR) approaches –The FR approaches focus on the assessment of the quality of a test image in comparison with a reference image. This reference image is considered as the perfect quality image. Example: original image compared to the JPEG-compressed image.

Reduced-Reference (RR) approaches – The RR approaches focus on the assessment of the quality of a test and the reference image. The comparison between the test and reference image depends on the features extracted from the both images.

No-Reference (NR) approach – The NR metrics focus on the assessment of the quality of a test image only. No reference image is used in this method.

Image quality metrics are also categorized to measure a specific type of degradation such as blurring, blocking, ringing, or all possible distortions of signals.

A full-Reference (FR) image quality measurement technique SSIM which calculates the mean SSIM value and compares to the MSE and PSNR figures are focused in this paper.

The mean squared error (MSE) is the most widely used and also the simplest full reference metric which is calculated by the squared intensity differences of distorted and reference image pixels and averaging them with the peak signal-to-noise ratio (PSNR) of the related quantity.

Image quality assessment metrics such as MSE, PSNR are mostly applicable as they are simple to calculate, clear in physical meanings, and also convenient to implement mathematically in the optimization context. But they are sometimes very mismatched to perceive visual quality. In that case we have taken into account the most effective method structured similarity indexing method which gives us the minimum mean value between the two experimental images where the mean squared error is very high and the PSNR value is rather countable comparing to MSE.

In this paper, we will compare the SSIM, MSE and PSNR values between the two images (an original and a recovered image) on the basis of the minimum error rate.

## II. OBJECTIVES OF QUALITY ASSESSMENT OF IMAGES

Image quality assessment technique is used to measure the degradation of the recovered image compares to its primary version. Practically there are two kinds of evaluation: subjective and objective [4]. Subjective evaluation is not convenient, time-consuming and also expensive to implement. Afterwards the objective image quality metrics are developed on the basis of different aspects. The most commonly used objective image quality measures are MSE, PSNR, and SSIM. In this paper, our main focus is on full reference objective quality metrics.

## III. QUALITY MEASUREMENT TECHNIQUES

There are so many image quality techniques largely used to evaluate and assess the quality of images such as MSE (Mean Square Error), UIQI (Universal Image Quality Index), PSNR (Peak Signal to Noise Ratio), SSIM (Structured Similarity Index Method), HVS (Human Vision System), FSIM (Feature Similarity Index Method), etc. In this paper we have worked on SSIM, MSE and PSNR methods.

## IV. MSE (MEAN SQUARED ERROR)

MSE is the most common estimator of image quality measurement metric. It is a full reference metric and the values closer to zero are the better.

It is the second moment of the error. The variance of the estimator and its bias are both incorporated with mean squared error. The MSE is the variance of the estimator in case of unbiased estimator. It has the same units of measurement as the square of the quantity being calculated like as variance. The MSE introduces the Root-Mean-Square Error (RMSE) or Root-Mean-Square Deviation (RMSD) and often referred to as standard deviation of the variance.

The MSE can also be said the Mean Squared Deviation (MSD) of an estimator. Estimator is referred as the procedure for measuring an unobserved quantity of image. The MSE or MSD measures the average of the square of the errors. The error is the difference between the estimator and estimated outcome. It is a function of risk, considering the expected value of the squared error loss or quadratic loss [4].

Mean Squared Error (MSE) between two images such as g(x,y) and g῀(x,y) is defined as

$$e_{\text{mse}} = \frac{1}{MN}\sum_{n=0}^{M}\sum_{m=1}^{N}[\hat{g}(n,m)-g(n,m)]^2$$

Mean squared error depends on the image scaling intensity. We can express it in dB scale as 10log10 [$e_{mse}$].

## V. PSNR (PEAK SIGNAL-TO-NOISE RATIO)

PSNR is used to calculate the ratio between the maximum possible signal power and the power of the distorting noise which affects the quality of its representation. This ratio between two images is computed in decibel form. The PSNR is usually calculated as the logarithm term of decibel scale because of the signals having a very wide dynamic rang. This dynamic range varies between the largest and the smallest possible values which are changeable by their quality.

The Peak signal-to-noise ratio is the most commonly used quality assessment technique to measure the quality of reconstruction of lossy compression codecs such as image compression. The signal is considered as the original data and the noise is the error yielded by the compression or distortion. The PSNR is the approximate estimation to human perception of reconstruction quality compared to the compression codecs [5].

In quality degradation image and video compression, the PSNR value varies from 30 to 50 dB for 8-bit data representation and from 60 to 80 dB for 16-bit data [6], [7]. In wireless transmission, accepted range of quality loss is approximately 20-25 dB [8], [9].

PSNR is expressed as:

$$PSNR = 10\log_{10}\left(\left(peakval^{2}\right)/MSE\right)$$

## VI. STRUCTURAL SIMILARITY INDEX METHOD (SSIM)

Structural Similarity Index Method is a perception based model. In this method, image degradation is considered as the change of perception in structural information. It also includes some other important perception based fact such as luminance masking, contrast masking, etc. The term structural information emphasizes about the strongly inter-dependent pixels or spatially closed pixels. This strongly inter-dependents pixel refers some more important information about the visual objects in image domain. Luminance masking is a term where the distortion part of an image is less visible in the edges of an image. On the other hand contrast masking is a term where distortions are also less visible in the texture of an image.

SSIM estimates the perceived quality of images and videos. It measures the similarity between two images - the original and the recovered. This method is applied as a full reference metric. The term full reference means the prediction of image quality depends on distortion free image which is used as reference image to assess quality.

### A. MS-SSIM (Multi Scale SSIM):

There is an advanced version of SSIM called Multi Scale Structural Similarity Index Method (MS-SSIM) that evaluates various structural similarity images at different image scale. In MS-SSIM, two images are compared to the scale of same size and resolutions. As Like as SSIM, change in luminance, contrast and structure are considered to calculate multi scale structural similarity between two images. Sometimes it gives better performance over SSIM on different subjective image and video databases [10], [11], [12].

### B. 3–SSIM (Three Components SSIM):

Another version of SSIM, called a three-component SSIM (3-SSIM) that corresponds to the fact ¬- human visual system observes the differences more accurately in textured regions than the smooth regions. SSIM has three categories of regions such as textures, edges and smoothness of an image. The resulting metric is calculated as a weighted average of structural similarity for these three categories. The proposed weight measuring estimations are 0.5 for edges, 0.25 for texture and 0.25 for smooth regions. It can also be mentioned that a 1/0/0 weight measurement influences the results to be closer to the subjective ratings. This can be implied that, no textures or smooth regions rather edge regions play a dominant role in perception of image quality [13].

### C. DSSIM (Structural Dissimilarity):

There is another distance metric referred as Structural Dissimilarity (DSSIM) deduced from the Structural Similarity (SSIM) can be expressed as:

$$DSSIM_{(x,y)} = \frac{1 - ssim(x,y)}{2}$$

The SSIM index method, a quality measurement metric is calculated based on the computation of three major aspects termed as luminance, contrast and structural or correlation term. This index is a combination of multiplication of these three aspects [12].

Structural Similarity index method can be expressed through these three terms as:

$$SSIM(x,y) = [l(x,y)]^{\alpha} \cdot [c(x,y)]^{\beta} \cdot [s(x,y)]^{\gamma}$$

Here, l is the luminance (used to compare the brightness between two images), c is the contrast (used to differ the ranges between the brightest and darkest region of two images) and s is the structure (used to compare the local luminance pattern between two images to find the similarity and dissimilarity of the images) and α, β and γ are the positive constants [14].

Again luminance, contrast and structure of an image can be expressed separately as:

$$l(x, y) = \frac{2\mu_x \mu_y + C_1}{\mu_x^2 + \mu_y^2 + C_1}$$

$$c(x, y) = \frac{2\sigma_x \sigma_y + C_2}{\sigma_x^2 + \sigma_y^2 + C_2}$$

$$s(x, y) = \frac{\sigma_{xy} + C_3}{\sigma_x \sigma_y + C_3}$$

Where $\mu_x$ and $\mu_y$ are the local means, $\sigma_x$ and $\sigma_y$ are the standard deviations and $\sigma_{xy}$ is the cross-covariance for images x and y sequentially. If $\alpha=\beta=\gamma=1$, then the index is simplified as the following form:

$$SSIM(x, y) = \frac{(2\mu_x \mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

We can express it in dB scale as $10\log_{10}$ [SSIM(x,y)].

## VII. IMPLEMENTATION

Implementation of SSIM, PSNR and MSE on some images is shown from Fig. 1 to Fig. 3.

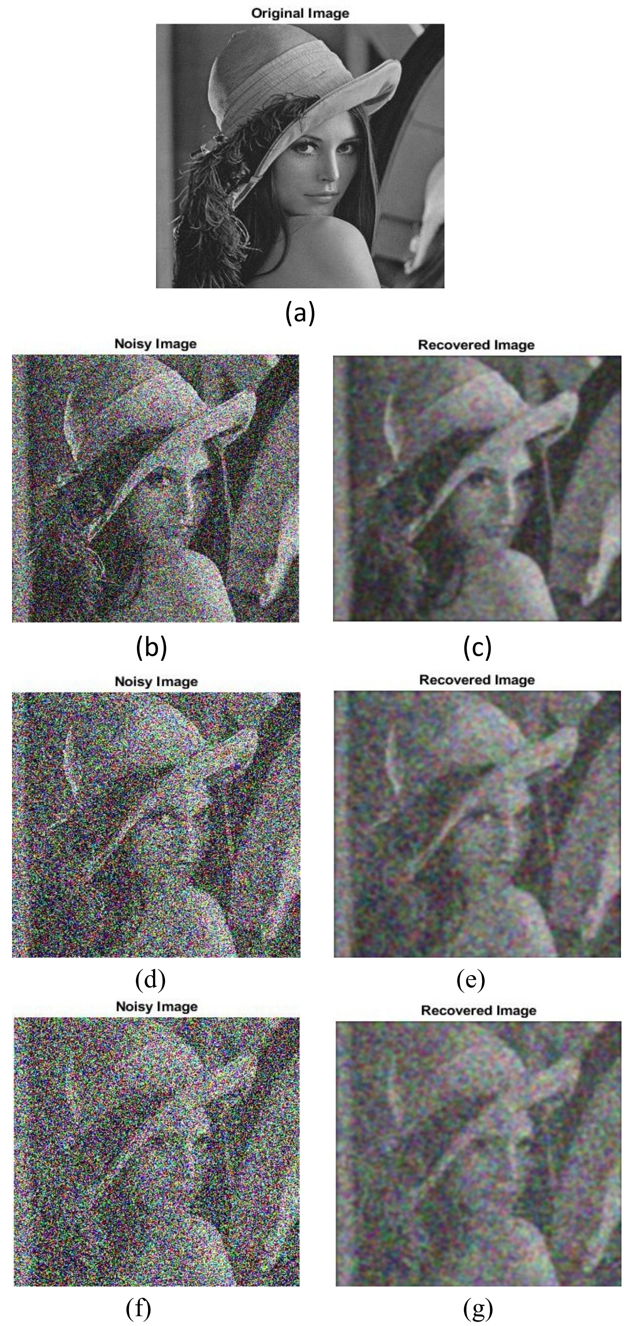


Fig. 1

Here, we have used Gaussian noise to the images and filtered by Gaussian Filter. Noise levels are 0.1, 0.3 and 0.5 sequentially. The MSE, PSNR and SSIM value of two images (the original and the recovered image) are listed in the table below.

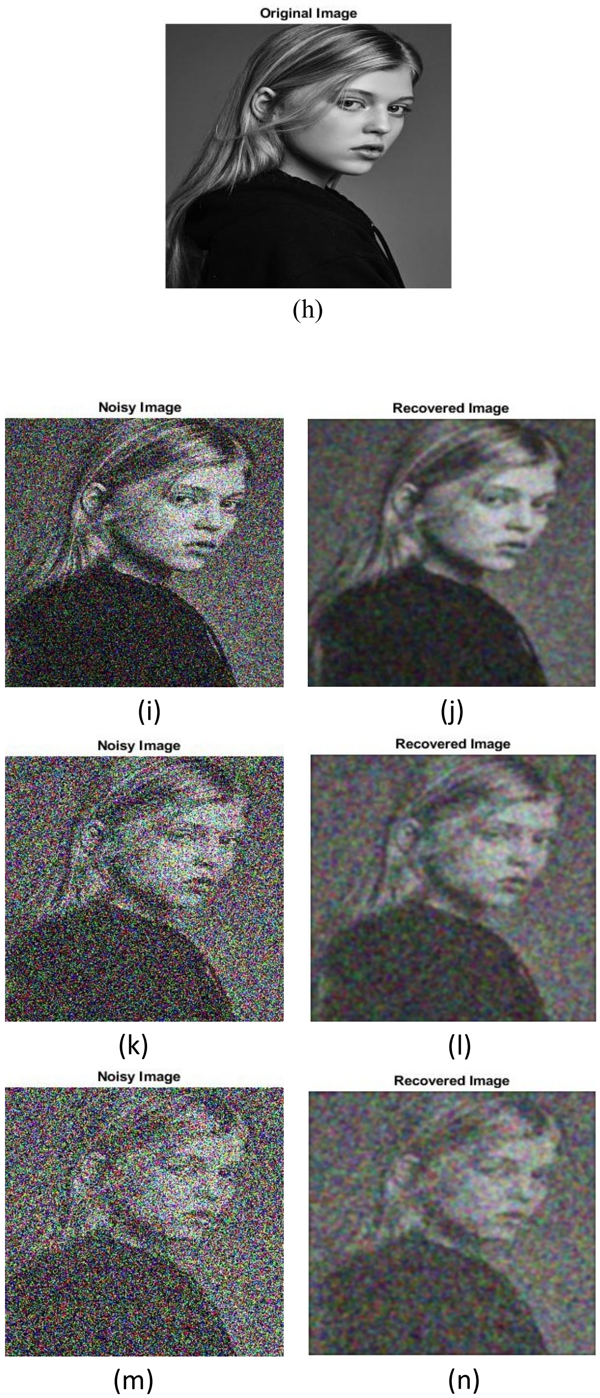


Fig. 2

Here, we have used Gaussian noise to the images and filtered by Gaussian Filter. Noise levels are 0.1, 0.3 and 0.5 sequentially. The MSE, PSNR and SSIM value of two images (the original and the recovered image) are listed in the table below.

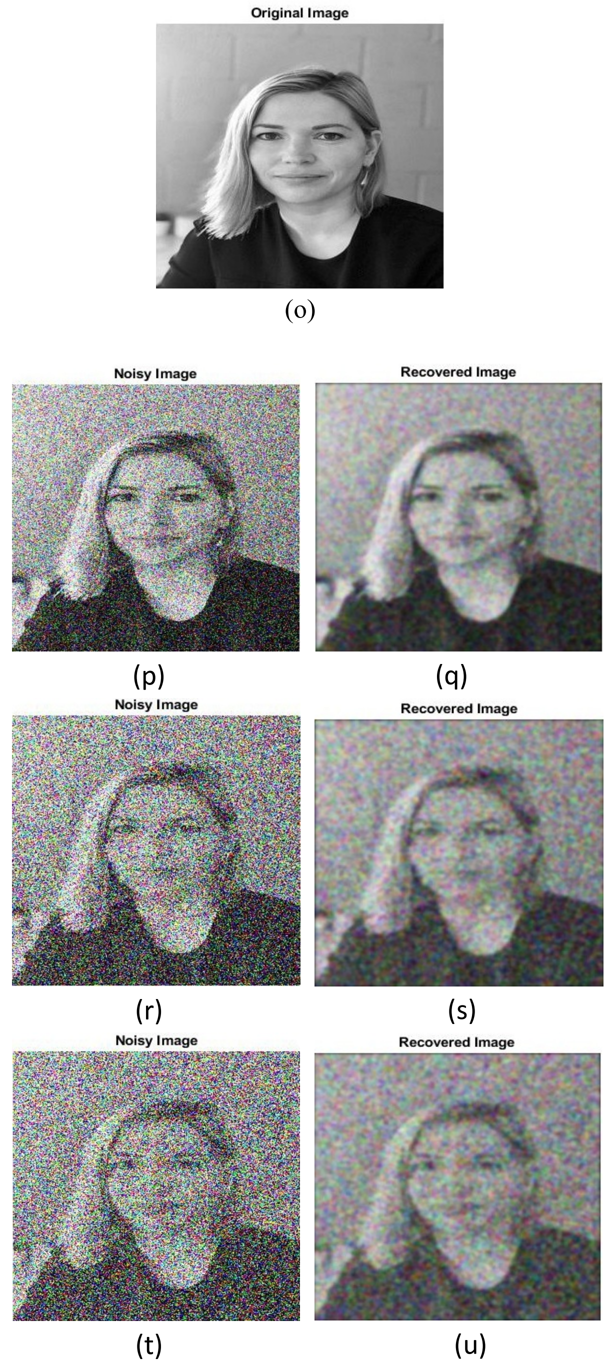


Fig. 3

Here, we have used Gaussian noise to the images and filtered by Gaussian Filter. Noise levels are 0.1, 0.3 and 0.5 sequentially. The MSE, PSNR and SSIM value of two images (the original and the recovered image) are listed in the table below.

## VIII. RESULT AND DISCUSSION

| Images | Noise and Filtering Technique | Quality Assessment Techniques | Noise Level | | |
|---|---|---|---|---|---|
| | | | 0.1 | 0.3 | 0.5 |
| Image1 | Gaussian Noise and Gaussian Filter | MSE | 27.83 | 25.66 | 24.61 |
| | | PSNR | 27.92 | 25.63 | 24.70 |
| | | SSIM | **0.73** | **0.67** | **0.65** |
| Image2 | | MSE | 27.38 | 24.41 | 23.01 |
| | | PSNR | 27.43 | 24.34 | 23.02 |
| | | SSIM | **0.73** | **0.66** | **0.64** |
| Image3 | | MSE | 27.72 | 24.86 | 23.63 |
| | | PSNR | 27.81 | 24.98 | 23.66 |
| | | SSIM | **0.75** | **0.68** | **0.65** |

## IX. CONCLUSION

Image Quality Assessment plays a very significant role in digital image processing applications.The three metrics (MSE, PSNR and SSIM) are applied in this paper to get the best quality metric. We have done simulating experiments using Impulse and Gaussian noises through different filtering techniques. The obtained image quality is judged on applying the above metrics. From the results we find that SSIM's performance is the best as it is consistent than the others (MSE, PSNR).

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