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Quality Measurement for Reconstructed RGB Image via Noisy Environments

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ABSTRACT

Image compression and decompression process could be quite affected by noisy environment during transmitting/receiving medium. This paper develops a procedure which finds the effect of noisy environments on the reconstructed RGB images. The image has been degraded by three kinds of noises then; noisy image planes are transformed into new domain of four bands by applying the first level 2D DWT. The inverse 2D DWT is applied on the noisy RGB planes to reconstruct; concatenate; and restore the original transmitted image. The quality of re-stored images is measured by applying SNR/PSNR with respect to the noise variances. The SNR/PSNR dB curves are used for comparing different noisy environment effects on the quality of reconstructed RGB images. The paper provides basic procedure for calculating scale factors used for reconstructing images directly in SNR/PSNR units. The SNR/PSNR dB curves for Gray images satisfied better result than RGB for all testing conditions, while speckle noise was relatively the most stable degrading noise that had maximum dB values over wide noise variance. Salt & pepper noise had the worst dB curves among Gaussian and speckle. The intersection points of the dB curves at 0.5 density noise is discussed and concluded to find out the SNR/PSNR behavior at this degradation value.

Keywords: DWT, IDWT, RGB, SNR, PSNR, noise

1. INTRODUCTION

The RGB color system represents the most commonly used in computer fields, although there are an infinite number of color spaces. Most of those color systems are derived from the RGB color space by applying linear transforming function of R, G, and B. Image compression is a one area that Discrete Wavelet Transform (DWT) has proven its applicability in reconstruct the compressed image efficiently, even better than Discrete Cosine Transform (DCT) method. To compress the RGB image, it is recommended to apply one of compression algorithms; likes DCT or DWT. The three RGB planes should be first separated and processed as a 2D gray image. The compressed image can be transmitted quicker and then decompressed faster by the receiver [1,2]. A compression algorithm object is to remove the redundancy in image data by exploiting

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these redundancies in a way that makes the reconstruction is possible. The entropy (H_e) finds the minimum limit representation of grey bit that value should not be exceeded during compression. For example, an image has M grey levels and P(k) probability for level k, the entropy formula is [3,4]:

$$H_e = -\sum_{i=1}^{M} P(k) log_2 \ [P(k)] \qquad (1)$$

The compressed gray level would be encoded within this boundary: $H_e \le L_{comp} \le L_{(fixed)}$

Where:

$L_{(fixed)}$: 2^n fixed length code

L_{comp} : The new compressed code

This paper develops a proposed testing system that applies an evaluation procedure to measure the reconstructed noisy RGB image quality using Signal to Noise Ratio (SNR) and Peak Signal to Noise Ratio (PSNR). The transformed RGB image was injected by wide scale of noise variance of noisy environments, so quality measurement of the reconstructed and de-noised RGB image is calculated to study the decibel curves behaviour with respect to the noise variances. The PSNR is the most commonly used as quality measurement of the reconstructed lossy compressed images. It is the ratio between the max ***possible*** signal power to the power of the corrupted noise. It is derived by setting the mean squared error (MSE) in relation to the maximum possible value of the luminance (for a typical 8-bit value this is -1 = 255) as follows [5, 6, 7]:

$$PSNR = 20. log_{10} \left[\frac{255}{\sqrt{MSE}}\right] \qquad (2)$$

Where (MSE) is the mean squared error between the origin and destination image,

$$MSE = \frac{\sum_i^M \sum_j^N [\, f(\,i,j\,) - g(i,j)\,]^2}{M.N} \qquad (3)$$

The SNR is defined as the power ratio between the original signal and the unwanted background noise:

$$SNR = 10. log_{10} \left[\frac{\sum_i^M \sum_j^N [\, f(\,i,j\,)\,]^2}{\sum_i^M \sum_j^N [\, f(\,i,j\,) - g(i,j)\,]^2}\right] \qquad (4)$$

Where:

$f(\,i,j\,)$: *is the original image*

$g(i,j)$: is the destination or degraded image

2. EVALUATION PROCEDURE

The general block diagram of the proposed testing system that runs the evaluating procedure as stages is explained in figure 1. Mainly it includes:

- Noise(s) injection and RGB planes separated
- Analysis / synthesis of noisy RGB planes
- De-noising and image planes concatenated
- Quality measurement using SNR/PSNR

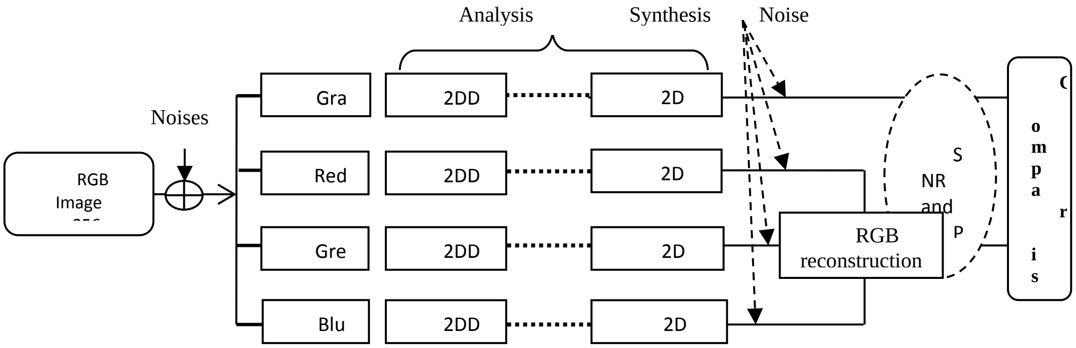

Figure 1 General block diagram of evaluation system.

2.1 Noise(s) injection and RGB planes separated

The proposed noisy environment contains three kinds of noises. These noises are injected to the RGB image sequentially (separately) or simultaneously (mixed). These noises are:

- Salt and pepper: also called shot, impulse, or binary noise and it is happened because of sharp, sudden, and random change in the image signal.
- Gaussian noise: also called additive noise, it is the idealized form of white noise; it is caused by random fluctuations in the image signal. If I represents the image signal, and N_g is the Gaussian noise, then:

$$I' = I + N_g \qquad (5)$$

- To remove the degradation of this kind of noise, a mean filter is applied as explained in equation (6).

$$I' = \frac{1}{100} \sum_{i=1}^{100} (I + N_g) \qquad (6)$$

- Speckle noise: also called multiplicative noise; it is the major problem in some radar and medical applications. Median or mean filter are the more suitable filters for denoising image that degraded with this kind of disturbance.

$$I' = I(1 + N_{sk}) \qquad (7)$$

The degradation procedure is implemented using one of two methods:

First method: Noises are injected in the original RGB image then SNR/PSNR evaluation is calculated for each red, green, and blue matrix separately

Second method: Noises are injected on each red, green, and blue plane separately then SNR/PSNR is calculated for their Gray and RGB equivalent. The two methods are qualified and compared using the PSNR dB curves in figures 2 and 3. The decibel curves are very similar and relatively keep the same curve shape over wide variant noise values, except the Gray image of figure 2 which has maximum dB values comparing with other curves. So, decision is taken to consider the first method regarding noise injection procedure. These noises are injected using two modes: separately/sequentially or simultaneously/mixed to meet all probabilities of testing condition.

2.2 Analysis/Synthesis of noisy RGB planes

The DWT analysis is used to divide the information of image into approximation and detail subsignals. The approximation band represents the general shape of pixel values, while the other bands describe the horizontal, vertical, and diagonal details inside image. A simple formula is estimated from Wavelet transformation is:

$$\text{Number of Bands} = (\text{No. of levels} \times 3) + 1 \qquad (8)$$

The degraded RGB image is separated into three corresponding planes (red, green, and blue) as well as its equivalent noisy gray one. The next step is to apply the 2D DWT on the four noisy gray images. That means, the total number of transformed noisy images would be:

$$4_{(no.of\ noisy\ images)} \times 4_{(no.of\ bands)} = 16_{(4\ approx.band\ +\ 12\ detail\ bands)}.$$

Those bands are currently ready for compressing and re-constructing. The current stage is completed by finding the IDWT for those $16_{(128\times128))}$ bands, which means the four noisy images are composed again, they are; $red_{(256\times256)}$, $green_{(256\times256)}$, $blue_{(256\times256)}$, $gray_{(256\times256)}$

2.3 De-noising, concatenated, and quality measurement

This stage runs three processes, first one is to remove or decrease the amount of noise(s) in the reconstructed images using suitable filter, secondly is to concatenate and restore the original Gray and RGB image. The third process is to qualify the resulted images to find and discuss the factor which relates between the amount of injected noise(s) and the accepted SNR/PSNR dB unit. The noise scale is 23 values ranging from 0.01 to 1. Figures 4 and 5 represent the PSNR/SNR dB curves for mixed noise injection mode. The SNR/PSNR of" peppers.png" image for sequential noise injection regarding Gray and RGB images are explained in figure 6, 7, 8, and 9 respectively.

3. RESULT AND DISCUSSIONS

Degradation Procedure: figure 2 and 3 represent the results of the two degradation procedures. Procedure one degrades the RGB image then separates the individual planes while, the 2nd procedure separates the individual planes before making the degradation. The PSNR dB curves for two procedures are so closed except the gray image of procedure one which is satisfied max. PSNR (28.13 dB) comparing with (24.77 dB) for gray image in procedure two. So, the proposed evaluation procedure would consider the 1st procedure in the degradation method.

PSNR/SNR Qualification: figure 4 is the PSNR for mixed noises regarding Gray and RGB images. The max. PSNR value (29.91 dB) is satisfied with Gray image, while (26.87 dB) was the value of RGB image. The max. SNR value is satisfied with Gray image (21.24 dB), while (18.89 dB) was the max. value for RGB image as shown in figure 5. Figure 6 and 7 represent the SNR/PSNR qualification curves for Gray image. The maximum SNR/PSNR values are satisfied with speckle noise (25.32 dB) and (31.21 dB) respectively, while the Gaussian noise was the min. one with (20.12 dB) and (28.78 dB) respectively for noise density 10%. The reconstructed RGB images are qualified in figure 8 and 9. The speckle noise has max SNR/PSNR values with (24.82 dB) and (34.04 dB), while Gaussian noise has the min. SNR/PSNR value with (20.46 dB) and (28.40 dB) respectively.

Crossing Values: the decibel curves for Gaussian and Salt& pepper noise have a noticeable feature that they always crossing when the noise density is approximately 0.5. This means, the two noises have the same effectiveness at this value, so one of them could be substituted by another one. Example of these features are tabulated in table 1.

Table 1 Matching features for sequential noise injection with density equals 50%

SNR Qualification (dB)				PSNR Qualification (dB)			
Gray		RGB		Gray		RGB	
gaussian	*salt*	*gaussian*	*salt*	*gaussian*	*salt*	*gaussian*	*salt*
6.22	6.26	6.18	6.09	14.87	14.94	14.14	14.09

4. CONCLUSION

The evaluation procedures is proposed and implemented as quality measurement using SNR/PSNR. The RGB image is supposed to be transmitting via multi noisy environments so it is degraded with three kinds of noises. Then, the degraded RGB image is separated and transformed into 16 subbands using 2D DWT. The degraded and transformed sub-images are reconstructed by applying the inverse DWT. The RGB planes are re-concatenated again to measure and evaluate the SNR/PSNR for wide noise variance. At 0.5 density noise, the decibel curves of Gaussian and salt& pepper noise are approximately same; also the Gray dBs and RGB dBs are approximately same. Also, the SNR/PSNR curves satisfied maximum dB values when the degradation is speckle noise, and minimum dB values are obtained from salt& pepper noise degradation. In SNR/PSNR units, the image is still usable when it's degraded with ≤ 0.5 mixed noises.

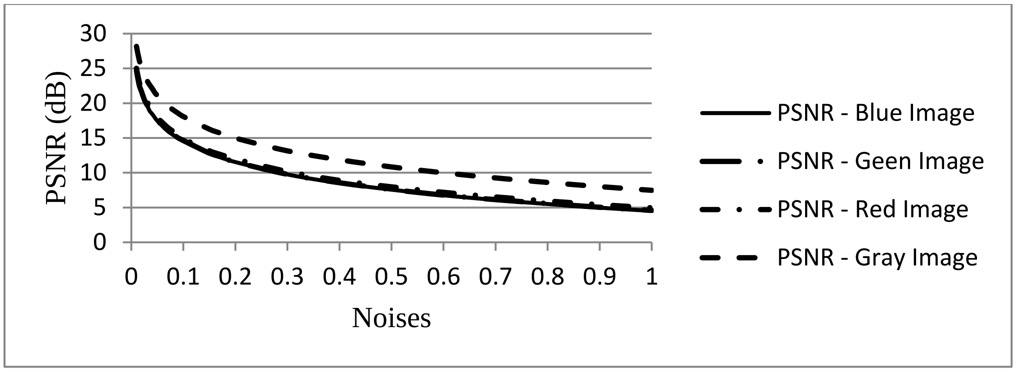

Figure 2. Quality mesurment using method 1 degradation

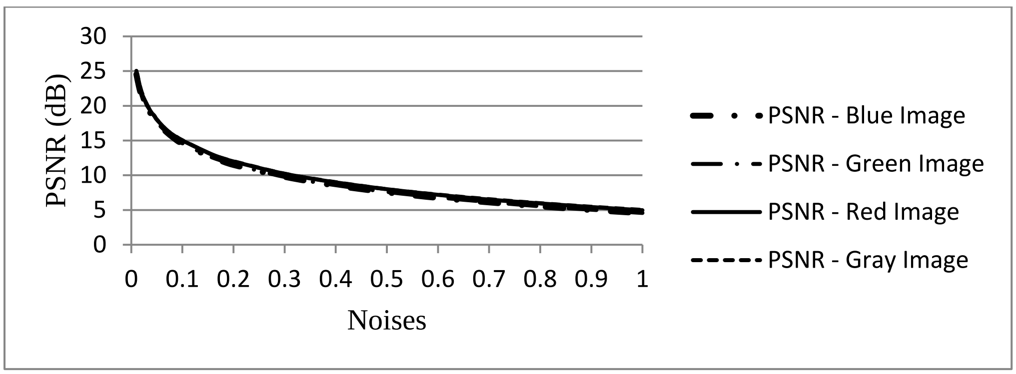

Figure 3. Quality mesurment using method 2 degradation

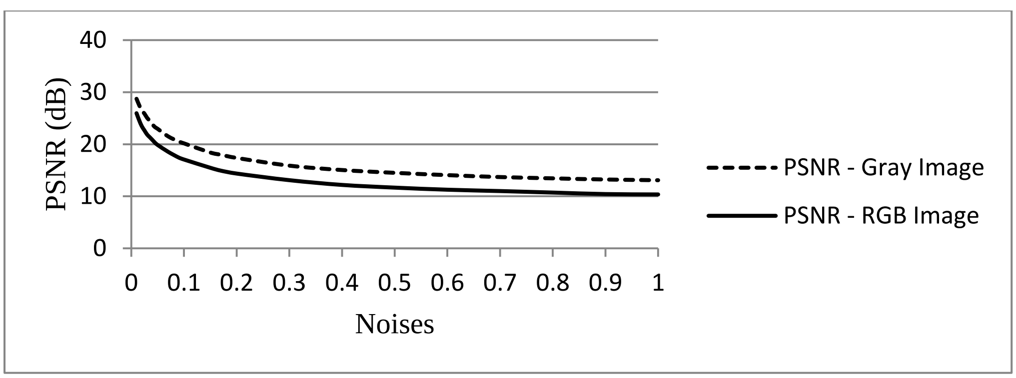

Figure 4 PSNR qualification for mixed degradation

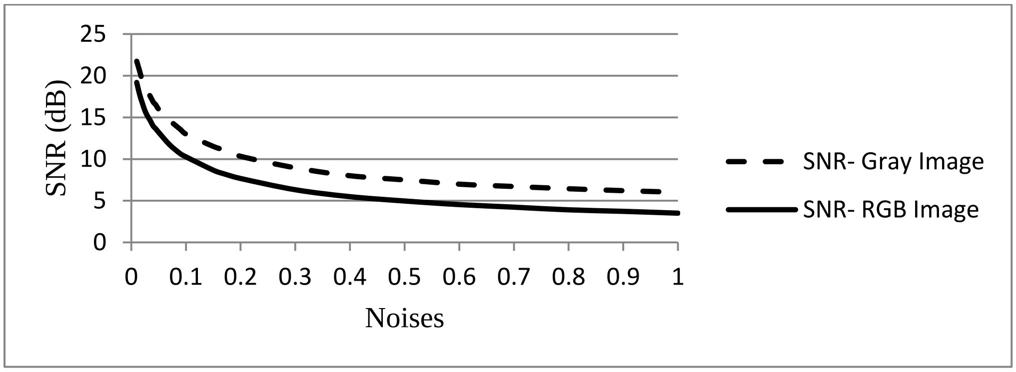

Figure 5. SNR qualification for mixed degradation

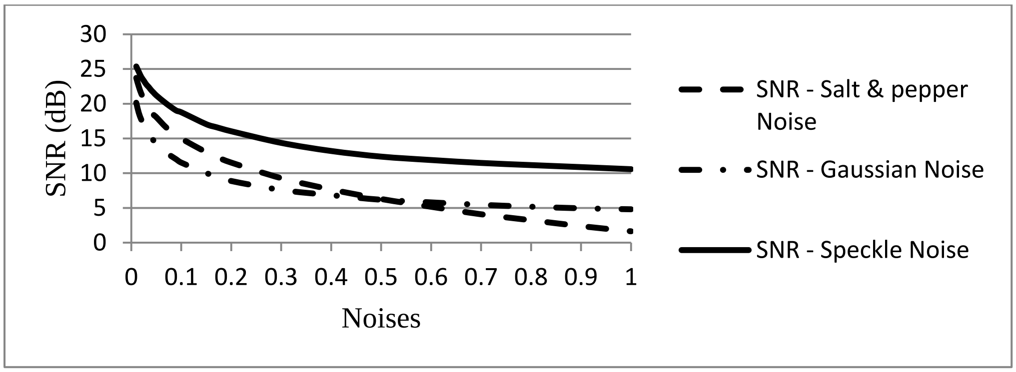

Figure 6. SNR qualification for sequential injection of Gray image

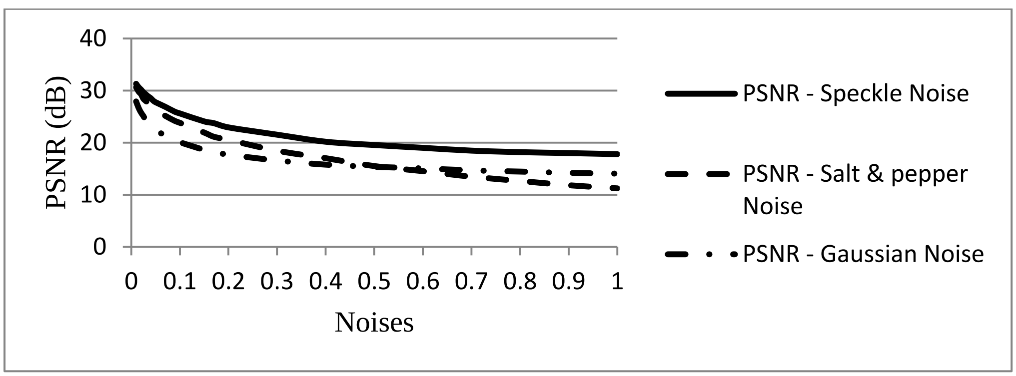

Figure 7. PSNR qualification for sequential injection of Gray image

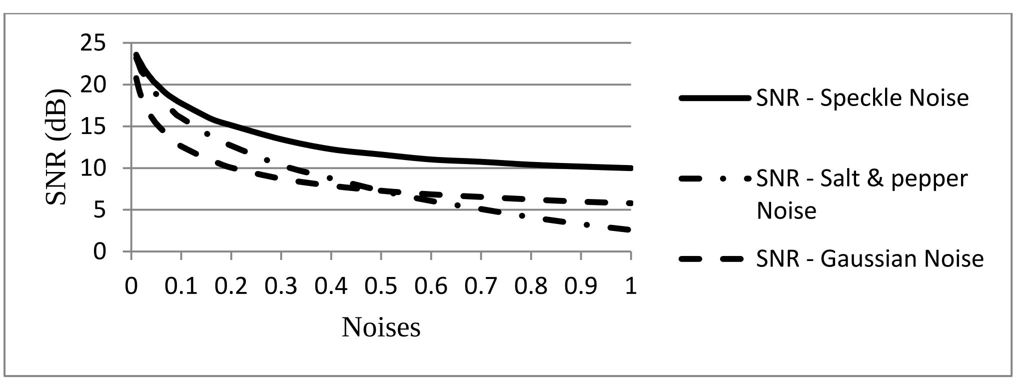

Figure 8. SNR qualification for sequential injection of RGB image

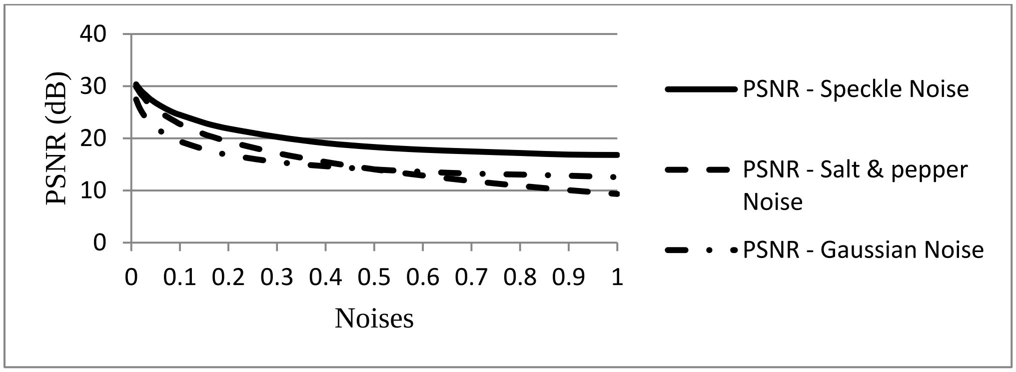

Figure 9. PSNR qualification for sequential injection of RGB image

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