Evaluation of SPIHT Compression Scheme for Satellite Imageries Based on Statistical Parameters

Nagamani .K, A. G. Ananth

Abstract:- Non reversible and lossy image compression techniques is known to be computationally more complex as they grow more efficient, confirming the constraints of source coding theorems in information theory that a code for a (stationary) source approaches optimality the limit of infinite computation (source length). It has been observed that when a variety of images of different types are compressed using a fixed wavelet filter, the peak signal to noise ratios (PSNR) vary widely from image to image. This variation in PSNR can be attributed to the nature and inherent statistical characteristics of image. To explore the effect of various image features on the coding performance, a set of gray level image statistics have been analyzed by using SPIHT (Set Partitioning In Hierarchical Trees) algorithm. The Mean Square Error (MSE) and Peak Signal to Noise Ratios (PSNR) determined for an image depends on the statistical properties of the image and the compression scheme applied. The efficiency of the compression scheme can be evaluated by examining the statistical parameters of the image. In this paper various statistical parameters associated with the SPIHT compression scheme are derived for three different types of images namely standard Lena, satellite urban and rural imageries based on higher order statistics. The statistical parameters include higher order image statistics like Rate Distortion and Skewness and Kurtosis which describe the shape and symmetry of the image. The statistical parameters derived for a fixed rate and fixed level of decomposition for three types of images have been are used for the explanation of the Compression Ratio and Peak Signal to Noise Ratio (PSNR) achieved for the satellite imageries. The results show that urban images are better suited for SPIHT compression scheme compared to that of satellite rural image. The results of the analysis are presented in the paper.

Key Words:- Compression ratio, EZW, MSE, SPIHT, PSNR.

I. INTRODUCTION

In zero tree based image compression scheme such as EZW and SPIHT, the intent is to use the statistical properties of the trees in order to efficiently code the locations of the significant coefficients. Since most of the coefficients will be zero or close to zero, the spatial locations of the significant coefficients make up a large portion of the total size of a typical compressed image. A coefficient (likewise a tree) is considered significant if its magnitude (or magnitudes of a node and all its descendants in the case of a tree) is above a particular threshold. By starting with a threshold which is close to the maximum coefficient magnitudes and iteratively decreasing the threshold, it is possible to create a compressed representation of an image which progressively adds finer detail. Due to the structure of the trees, it is very likely that if a coefficient in a particular frequency band is insignificant, then all its descendants (the spatially related higher frequency band coefficients) will also be insignificant [1,2,3,4,5,6,7] There are several important features to note. It is possible to stop the compression algorithm at any time and obtain an approximation of the original image, the greater the number of bits received, the better the image. Due to the way in which the compression algorithm is structured as a series of decisions, the same algorithm can be run at the decoder to reconstruct the coefficients, but with the decisions being taken according to the incoming bit stream.

In practical implementations, it would be usual to use an entropy code such as arithmetic code to further improve the performance of the dominant pass. Bits from the subordinate pass are usually random enough that entropy coding provides no further coding gain.

The coding performance of EZW has since been exceeded by SPIHT and its many derivatives.

II. SPIHT ALGORITHM

The SPIHT uses the fundamental idea of zero-tree coding from the EZW but is able to obtain a more efficient and better compression performance in most cases without having to use an arithmetic encoder. The SPIHT algorithm groups the wavelet coefficients and trees into sets based on their significance information. The encoding algorithm consists of two main stages, sorting and refinement.

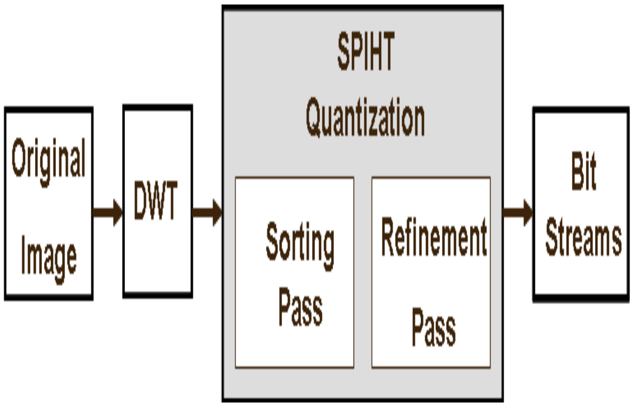

Figure 1Block diagram of SPIHT

In the sorting stage, the threshold for significance is set as 2n, where n is the bit level, and its initial value is determined by the number of bits required to represent the wavelet coefficient with the maximum absolute value.

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Significance for trees is obtained by checking all the member detail coefficients. Approximation coefficients are tested as individual entries.

The initial listing that determines the order in which significance tests are done is predetermined for both the approximation coefficients as well as the trees. The algorithm searches each tree, and partitions the tree into one of three lists:

- The list of significant pixels (LSP) containing the coordinates of pixels found to be significant at the current threshold;
- The list of insignificant pixels (LIP), with pixels that are not significant at the current threshold;
- The list of insignificant sets (LIS), which contain information about trees that have all the constituent entries to be insignificant at the current threshold.

If a coefficient or a tree is found to be insignificant, a “0” bit is sent to the output bit stream and the corresponding coordinates are moved to the LIP or LIS respectively, for subsequent testing at a lower bit level. When a coefficient is found to be significant, a “1” bit and a sign bit are sent out and its coordinate is moved to the LSP.

If an LIS member is found to be significant, a “1” bit is sent out and the tree is partitioned into its offspring and descendants of offspring. The offspring are moved to the end of the LIP and subsequently tested for significance at the same bit level. The offspring are also moved to the LIS as the roots of their corresponding descendant sets that will be subsequently tested for significance at the same bit level. The bit level is successively lowered, and the precision of every member of the LSP found significant at the previous bit level is enhanced by sending the next bit from the binary representation of their values. This operation is called the refinement stage of the algorithm.

The refinement pass allows for successive approximation quantization of the significant coefficients. When the bit level is decremented, the sorting pass is applied in the same manner as before to the remaining LIP and LIS constituents. The encoding process terminates when the desired bit rate or quality level is reached. In the decoder, the output of the significance tests are received, and therefore the same lists (LIP, LIS, and the LSP) can be built, as in the encoder. [1,2,3,4,5,6,7,8,]

III. STATISTICAL PARAMENTERS

Mean Square Error (MSE)

Mean Squared Error is the average cumulative squared error between the compressed and the original image; it is computed pixel-by-pixel by adding up the squared differences of all the pixels and dividing by the total pixel count.

$$MSE = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}\left[I(x,y) - I'(x,y)\right] \qquad (1)$$

Where I(x,y) is the original image, I'(x,y) is the approximated version (which is actually the decompressed image) and M,N are the dimensions of the images. A lower value for MSE means lesser error

The MSE is the **second moment** (about the origin) of the error, and thus incorporates both the variance of the estimator and its bias. For an unbiased estimator, the MSE is the variance.

Peak Signal to Noise Ratio (PSNR)

PSNR is a measure of the peak error. The PSNR is most commonly used as a measure of quality of reconstruction of lossy compression codec’s (e.g., for image compression). The signal in this case is the original data, and the noise is the error introduced by compression

$$PSNR = 20 * Log_{10}\left(\frac{255}{\sqrt{MSE}}\right) \qquad (2)$$

Logically, a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction. Typical values for the PSNR in lossy image are between 30 and 50 dB, where higher is better.

Compression ratio (CR)

Compression Ratio is the ratio of number bits required to represent the data before compression to the number of bits required to represent data after compression. Increase of compression ratio causes more effective compression technique employed and vice versa

Rate Distortion

Rate is defined as the average number of bits used to represent each sample value. Distortion is a measure of difference between original and reconstructed data.

Rate distortion function R(D) specifies the lowest rate at which output of the source can be encoded while keeping the distortion less than or equal to D.

$$R(D) = \frac{1}{2} * Log_{10}\left(\frac{\sigma^2}{MSE}\right) \qquad (3)$$

Where σ^2 is the Variance

Skewness

Skewness is a measure of the asymmetry of the data around the sample mean. If skewness is negative, the data are spread out more to the left of the mean than to the right. If skewness is positive, the data are spread out more to the right. The skewness of the normal distribution (or any perfectly symmetric distribution) is zero. The skewness of a distribution is defined as

$$\gamma = \frac{E(x-\mu)^3}{\sigma^3} \qquad (4)$$

Where μ is the mean of x is the standard deviation of x, and E (t) represents the expected value of the quantity t.

Kurtosis

Kurtosis is a measure of how outlier-prone a distribution is. The kurtosis of the normal distribution is 3. Distributions that are more outlier-prone than the normal distribution have kurtosis greater than 3; distributions that are less outlier-prone have kurtosis less than 3. The kurtosis of a distribution is defined as

$$k = \frac{E(x-\mu)^4}{\sigma^4} \qquad (5)$$

Where μ is the mean of x is the standard deviation of x, and E (t)

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represents the expected value of the quantity t. [1,2,3,4,5,6,7]

IV. RESULTS AND DISCUSSIONS

The images used for compression are all 256 X 256, 8-bit grayscale images in BMP format. It means that the images consist of 256 X 256 = 65,536 pixels, and each pixel is represented by 8 bits or 1 byte. The SPIHT algorithm has been implemented on MATLAB software and various parameters have been determined for three images namely standard Lena image and satellite rural image, satellite urban image, Comparing the reconstructed image and the original images the Compression ratio (CR), PSNR values are estimated. The Various statistical parameters such as Mean Square Error (MSE), Rate Distortion, Skewness, and Kurtosis are found for all the three images for the decomposition level 5 and fixed rate of transmission computed for the three types of images are tabulated and shown in table 1.

Table 1 Comparison of Statistical parameters of three images for Rate=1 and Level =5

STATISTICAL PARAMETERS	LENA IMAGE	SAT URBAN IMAGE	SAT RURAL IMAGE
Compression Ratio	8	8	8
PSNR (dB)	36.26	14.86	12.84
Mean Square Error	11.87	33.27	35.29
Rate Distortion	1.960757	-0.8665	- 1.055464
Skewness	-1.41119	-2.09385	- 2.412692
Kurtosis	3.467426	8.197354	9.538937

It is seen from the Table 1 that for the same compression ratio ~8, the PSNR values for the three types of images for Lena image ~36.26 dB, satellite urban image is ~14.86 dB, and satellite rural image ~12.84 dB indicating that the PSNR values for the satellite images are very much lower than the Lena image. In the same table it can be seen that the MSE measured for the SPIHT compression scheme for the Lena Image ~11.87 , satellite urban image ~33.27 and satellite rural Image ~35.29, indicating the MSE for the satellite imageries are much higher than that of Lena images. Satellite imageries exhibit lower PSNR and higher MSE variations .The lower PSNR values results in lower quality of the reconstructed satellite images due to the higher second order moment (MSE).

Further it may be seen from the table that the satellite urban images shows slightly higher PSNR values ~14 dB compared to rural images ~12 dB. The statistical parameters for the satellite urban image is lesser than the rural image indicating that the SPIHT compression algorithms is better suited for satellite urban image.

The Rate Distortion (RD) values derived for satellite imageries shows that for satellite rural image -1.05 and for satellite urban image -0.86 both negative values compared to Lena image which shows positive value 1.96 indicating that satellite imageries cannot be more efficiently coded than the Lena image. Further it can be seen from the table that all three images are negatively Skewed (CS) but for Lena image is less skewed compared to satellite imageries .The Satellite imageries are more skewed from the mean exhibits higher order image statistics .

Kurtosis (CK) is a measure of outlier-prone distribution. The kurtosis of the normal distribution is 3. Distributions that are more outlier-prone than the normal distribution have kurtosis greater than 3; distributions that are less outlier-prone have kurtosis less than 3. The table shows that the Kurtosis for satellite imageries are very much higher ~9 compared to Lena image which shows the Kurtosis value of ~3 which is closer to normal distribution. The kurtosis measurements clearly indicate that the satellite imageries exhibits large deviations from normal distribution and show higher order image statistics

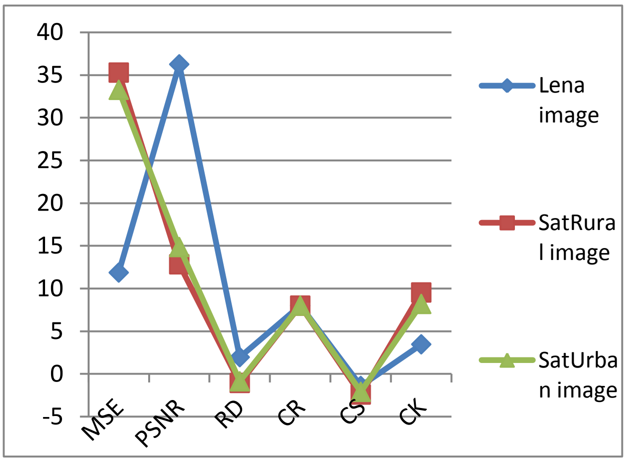

Figure 1 The statistical parameters derived for three images for Rate=1 and Level =5

The statistical parameters derived for the Lena image and satellite imageries are plotted and shown in Figure 2. It is evident in the figure that the statistical parameters MSE, RD, CS and CK shows similar behavior consistently higher values and low PSNR values for both the satellite urban and rural imageries. The Lena image shows low values for the statistical parameters with high PSNR values. These results clearly indicate that the SPIHT compression scheme gives better compression ratio and PSNR values for the satellite imageries compared to EZW scheme., The SPIHT scheme cannot produce high quality reconstructed images due to low PSNR values. which may be attributed to higher order statistical parameters associated with the inherent characteristics of the satellite imageries.

V. CONCLUSIONS

From the analysis of the results carried out in this paper the following conclusions can be drawn

- For satellite imageries the SPIHT algorithm gives high compression ratios ~8 and low PSNR ~ 12 to 14 dB and indicate reduction in the quality of the reconstructed satellite imageries compared to the of Lena image.

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- The statistical parameters derived for the satellite imageries shows higher values compared to the Lena image, indicating the SPIHT compression scheme is sensitive to the higher order statistics and inherent characteristics of the image. .
- The lower statistical variations seen in satellite urban images compared to rural images can be attributed to the features present in the urban scene, which are distributed in orderly fashion astheurban features are mostly man made compared to the natural features occurring in rural scenes.
- The results indicate that urban images are better suited for SPIHT compression scheme compared to that of satellite rural image.

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