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Analyses of Higher Order Metrics for SPIHT Based Image Compression

Richa Jindal
Lecturer,
IT Dept, PEC University of Technology,
Chandigarh

Sonika Jindal
Lecturer,
Shaheed Bhagat Singh College of Engg & Technology,
Ferozepore.

Navdeep Kaur
Lecturer,
IT Dept, PEC University of Technology,
Chandigarh

ABSTRACT
The increasing use of digitized images has led to the need to compress such imagery to allow economical storage and fast data transfer. Despite all the advantages of JPEG compression schemes based on DCT namely simplicity, satisfactory performance, and availability of special purpose hardware for implementation; these are not without their shortcomings. The input image needs to be blocked which results in noticeable and annoying blocking artifacts particularly at low bit rates. So over the past several years, the wavelet transform has gained widespread acceptance in signal processing in general and in image compression research in particular. SPIHT codes the individual bits of the image wavelet transform coefficients following a bit-plane sequence. The evaluation of an image compression system is a difficult problem. While mean square error and peak signal to noise ratios are easily and commonly calculated, they are widely recognized to not to be completely satisfactory. The statistical parameters include high order image statistics like skewness and kurtosis which describe the shape and symmetry of the image. The aim of this paper is to provide a uniform gauge of the performance of data compression processes. In addition, it specifies how the performance of different data compression methods should be ranked so that the best compressor for a specific application can be identified. In the present work, three compression algorithms viz. the JPEG coding, the wavelet transform coding and the SPIHT coding have been discussed and compared.

Categories and Subject Descriptors
Image processing, SPIHT

General Terms
SPIHT, EZW, skewness, kurtosis

Keywords
HSV, MSE, PSNR

1. INTRODUCTION
Generally, images carry three main type of information: redundant, irrelevant, and useful. Redundant information is the deterministic part of the information which can be reproduced, without loss, from other information contained in the image (i.e., inter-pixel redundancy): for example, low-varying background information. Irrelevant information is the part of information that has enormous details which is beyond the limit of perceptual significance (i.e., psycho-visual redundancy). Useful information is the part of information which is neither redundant nor irrelevant. Decompressed images are usually observed by human beings. Therefore, their fidelities are subject to the capabilities and limitations of the human visual system (HSV). A significant property of the HVS is the fact that it recognizes images by their regions and not by intensity value of their pixels. Despite all the advantages of JPEG compression schemes based on DCT namely simplicity, satisfactory performance, and availability of special purpose hardware for implementation; these are not without their shortcomings. Unlike the Discrete Cosine Transformation, the Wavelet transform is capable of providing the time and frequency information simultaneously, hence it gives a time-frequency representation of the signal. According to wavelet transformation, a function, which can represent an image, a curve, signal etc., can be described in terms of a coarse level description in addition to others with details. Set partitioning in hierarchical trees *(SPIHT)*, an example of a progressive image compression algorithm is an extension of Shapiro's embedded zerotree wavelet (EZW) method. These two new algorithms are a significant breakthrough in lossy image compression in that they give substantially higher compression ratios than prior techniques including JPEG, vector quantization, and the discrete wavelet transform combined with quantization. Images from different categories tend to show different spatial domain characteristics. For example, [4] many medical images like MRI or CT scan contain significant low intensity (black) regions along image boundaries. Compound images with significant amount of text are a mixture of binary and continuous tone data. It has been observed that when we compress a variety of images of different types using a fixed wavelet filter, the peak signal to noise ratios vary widely from image to image. This variation in PSNR can only be attributed to the nature and inherent characteristics of image. To explore this problem and to see the effect of various image features on the coding performance, set of gray level image statistics have been analyzed by using different coding algorithms. The evaluation of an image compression system is a difficult problem. While mean square error and peak signal to noise ratios are easily and commonly calculated, they are widely

recognized to not to be completely satisfactory. The statistical parameters include high order image statistics like skewness and kurtosis which describe the shape and symmetry of the image. Pixel level statistics are used like skewness and kurtosis. In addition to this comparative analysis is done on the basis of mean square error (MSE), peak signal to noise ratio (PSNR) and compression ratio achieved by various algorithms. In this paper comparative analysis of image compression techniques is performed based on higher order statistics.

2. METRICS

Metrics are an integral part of any image quality assessment program. The aim of thesis is to provide a uniform gauge of the performance of data compression processes. It provides a uniform, repeatable measurement procedure that leads to a clear description of the effects of data compression on reconstructed images. In addition, it specifies how the performance of different data compression methods should be ranked so that the best compressor for a specific application can be identified. Subjective Image Quality recognizes that a user's view of image utility is based on the type and amount of information that can be extracted from the reconstructed image. The information obtained from an image is related, but not necessarily limited by, the types of distortion introduced by the data compressor/decompressor**.** Quantitative measures designed to determine the information content of an image do not correspond well to qualitative measures. Each compression method produces its own unique type of artifacts and distortion. Mathematically, the effect of the artifacts may be the same. However, the utility of the image may vary with its visual quality. The utility of an image depends on the application. If the application can still be performed with extreme distortion, then the quality of the compression method is acceptable. Judging the relative quality of the image over another depends on many factors such as: image information content, application requirements, and display.

3. ERROR METRICS

Two of the error metrics used to compare the various image compression techniques are:

- Mean Square Error (MSE)
- Peak Signal to Noise Ratio (PSNR).

The MSE is the cumulative squared error between the compressed and the original image, whereas PSNR is a measure of the peak error. The mathematical formulae for the two are

$$\text{MSE} = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y)-I'(x,y)]^2$$

PSNR = 20 * log10 (255 / √MSE)

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, and as seen from the inverse relation between the MSE and PSNR, this translates to a high value of PSNR. 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.

4. HIGHER ORDER METRICS

Combination of two or more statistical features can be used to ensure the robustness of coding techniques. The statistics include first order, secondorder and higher order statistics. These are mean, median, range, standard deviation, coefficient of variation, energy, entropy, skewness and kurtosis. The first order statistics like mean and median mainly extract low spatial frequency features. Second order statistics generally provide a good representation of overall nature of the image such as coarseness. The higher order statistics used are skewness and kurtosis, which describe the shape and symmetry of the histogram. Skewness shows how evenly distributed the data is on either side of mean. Kurtosis shows how peaked the distribution of data is around the mean.

- **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

$$y = \frac{E(x-\mu)^3}{\sigma^3}$$

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

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

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

5. EXPERIMENTAL RESULTS

All the results shown are for different types of images viz Medical Images General Images, and Aerial Images (Noisy). The prime contribution of SPIHT coding technique over the international standard JPEG is that it gives higher compression ratios while maintaining the supreme quality of images.

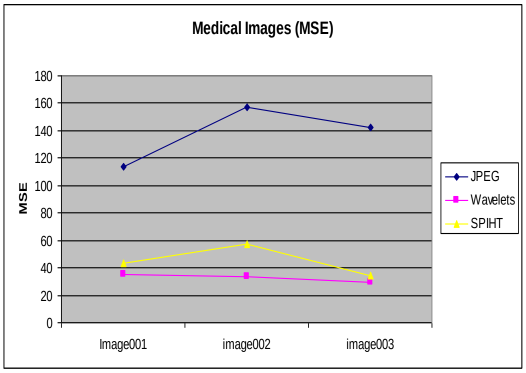

Figure1 Graphical representation of MSE of medical images

Figure 1 shows that JPEG has highest values for mean square error and Wavelet based coding has lowest MSE in all three types of test images taken.

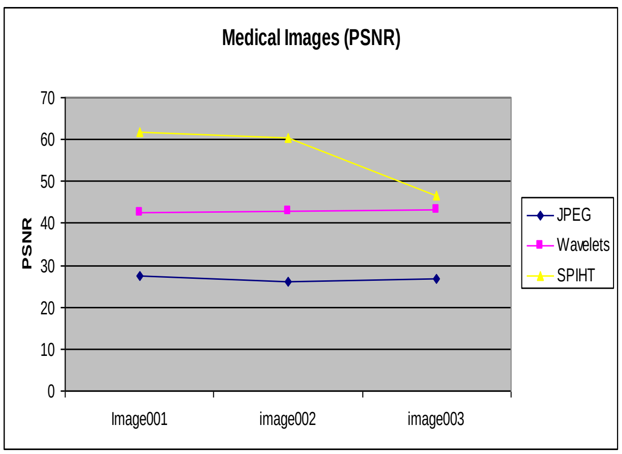

Figure 2 Graphical representation of PSNR of medical images

PSNR is most commonly used as a measure of quality of reconstruction in image compression. Highest values of PSNR can be seen in SPIHT coding, meaning that the quality of reconstructed image in case of SPIHT coding is highest and when we are compressing and reconstructing the same images with JPEG, PSNR is the lowest. Whereas wavelet based coding gives the intermediate values which are more closely related to SPIHT.

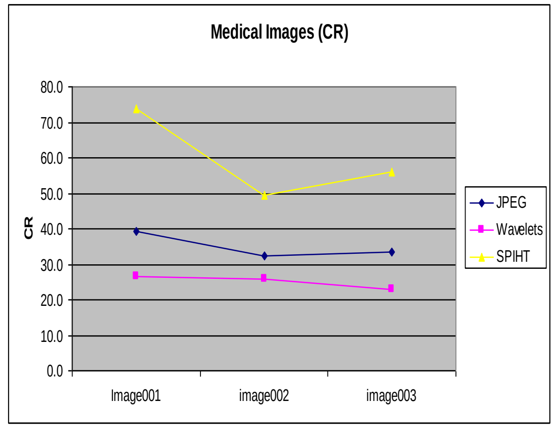

Figure 3 graphical representation of compression ratios of medical images

Compression ratio achieved in case of SPIHT is more than other two methods. . As stated earlier, SPIHT also gives least value of mean square error in medical images. This proves that SPIHT is better technique for compression when it comes to compression of medical images. Still next best compression method is wavelets and JPEG is least commonly used algorithm for medical images.

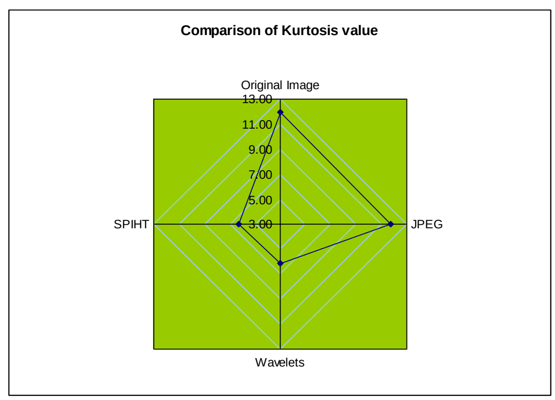

Figure 4 Graphical representation of average kurtosis value of all images by JPEG, Wavelets and SPIHT

Average value of kurtosis value is taken to compare the three algorithms. It is observed that wavelets and SPIHT have comparable value of 6.12 as compared to JPEG which have the average kurtosis value of 11.70. 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. This concludes that JPEG is more outlier prone algorithm. JPEG is more robust than wavelets and SPIHT.

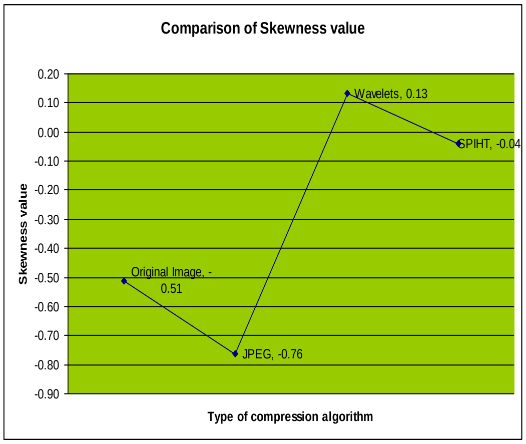

Figure 5 Graphical representation average skewness value of all images by JPEG, Wavelets and SPIHT

Average values of skewness for JPEG, Wavelets and SPIHT are calculated to compare the algorithms. It is observed that skewness value of SPIHT (-0.04) is less than Wavelets (0.13) and JPEG (-0.76). This concludes that the reconstructed image obtained by SPIHT is less skewed than reconstructed image obtained from wavelets which in turn is less skewed than reconstructed image of JPEG.

6. CONCLUSION

As concluded from various values and graphs, SPIHT is best coding technique for all general types of images and for medical images too which have little bit of salt and pepper noise. The results have been shown by all three coding techniques when applied on aerial images which can be taken as noisy images. SPIHT works best in that case also when images are noisy and contain little amount of useful information. JPEG compressed image has highest amount of MSE indicating that JPEG is not much suitable for lower bit rates. The SPIHT coded image has very high MSE at higher bit rates but quite reasonable MSE at lower bit rates. Thus SPIHT compression algorithm performs better at lower bit rates. From the computation of higher order statistic metrics it is concluded that standard JPEG is most robust coding technique as compared to wavelets and SPIHT. Kurtosis value is highest in case of JPEG which proves that JPEG is more outlier prone coding method. The values of skewness obtained in all three coding methods suggest that wavelets and SPIHT are comparable and JPEG lacks the symmetry. SPIHT and wavelets have lover values of skewness approaching towards zero which states that both algorithms are more symmetrical.

7. ACKNOWLEDGMENTS

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