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Image Compression Based on Multilevel Adaptive Thresholding using Meta-Data Heuristics

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Abstract Satellite image processing involves very often the need of compression. The compression of satellite images will reduce storage requirements and conserves transmission bandwidth. In this paper, a lossy image compression method is proposed based on multilevel adaptive thresholding using Meta-Data heuristics to compress the Landsat-8 satellite images. In the proposed method the number of thresholds is fixed in accordance with the bitrate required and the Peak Signal to Noise Ratio (PSNR) is improved by entropy based adaptive thresholding. Test image of Landsat-8, Band 3, 5 is used for performing the compression and the performance metric PSNR is measured for uniform thresholding and the proposed method. The proposed method gives improvement in the PSNR and the method is computationally simulated using Fixed Point Binary scaling.
Keywords *PSNR; BPP; DN (digital numbers); Threshold*

1. Introduction

Satellite image data is very memory thirsty, a typical Lansat-8 image with 11 bands, requires memory in the order of 2.4GB. This drives a search for better image compression algorithms. Wallace (1992) explained JPEG compression standard which ruled the technology for years for performing compression. JPEG standard is based on DCT (Discrete Cosine Transform) and is having advantages of real transform. The JPEG methods have limitations like blocking artifact at low bitrates, Huffman table requirement for low bitrates. The JPEG 2000 (ISO, 2000) method is based on wavelet; this method offers better resolution scalability, better PSNR at low bit rates. This method has limitations like ringing effect.it was explained that the histogram influences threshold selection and the better thresholds will reduce intra and inter class variances (Otsu, 1979). Sahoo (1988) explored different thresholding methods. Sujoys (2014) approach of image compression based on multilevel thresholding and the entropy was maximized using differential evolution. Kapur (1985) worked on gray-level picture thresholding using the entropy of the histogram. Borodkin et al. (2006) explained that Lloyd-Max quantization gives better results in non-uniform quantizers. In the course of time several evolutionary algorithms have originated based on thresholding of images. Landsat images are of sizes 7811 x 7641, 16 bit length with the intensity variation of 0-65535 (Wuldaer, 2014).

In our method we proposed a method to compress Landsat-8 images based on non-uniform thresholding.

2. Uniform Thresholding Method

The Thresholding technique basically makes an approximation of the image histogram by properly choosing the set of thresholds, when the image is thresholded into n+1 levels only; log2(n+1) bits are required to represent the image. In our work we used Band 3 & Band 5 for compression. The thresholds are stored in an array, and used as metadata for decoding. The variable bit rate is obtained by varying the number of bits n.

Geo Tiff Information of Band 5

File Mod Date: '08-Mar-2014 13:42:26'
File Size: 119430538, Format: 'tif',
Height: 7811, Width: 7641, Bit Depth: 16,
Color Type: 'grayscale'
PCS: 'WGS 84 / UTM zone 44N'
Projection: 'UTM zone 44N'
Map Sys: 'UTM_NORTH'
Zone: 44, CT Projection: 'CT_Transverse Mercator'
GCS: 'WGS 84', Datum: 'World Geodetic System 1984'
Ellipsoid: 'WGS 84', Semi Major: 6378137,
SemiMinor: 6.3568e+06, PM: Greenwich', PM Long to Greenwich: 0
UOM Length: 'meter', UOM Length in Meters: 1,
UOM Angle: 'degree'
UOM Angle in Degrees: 1

In Figure 1 the typical histogram of the image Band 5 is shown and Digital Numbers (pixel values) frequency is plotted.

The simple method of uniform thresholding is obtained on the histogram and the image gray value is rounded to the nearest threshold.

Step size = (r-p)/2^n (1)

where p=minimum intensity level, r=maximum intensity level, n=number of bits to address the thresholds.

3. Proposed Method

The typical histogram of band-5 is shown in the Figure 1. The Figure reveals the pixel variation is from p=5744 to r=55417. The probability density plot of Band 5 is shown in the Figure 2. Mostly the Probability density function plot of Landsat 8 images appears to be Laplacian distribution. The distribution is broadly classified in to two categories. The first one which covers the area of probability density functions from μ- σ to μ+ σ. Most of the slope of the curve is obtained in this region. The second region is rest of the region of probability density function.

The threshold assignment of first category is chosen such that the number of step levels n_1 is nearly double to that of uniform step size. This increases the entropy in the granular region. The rest of the thresholds are fixed according to the slopes of the curve of the Probability density function. The thresholds n_2, n_3 are obtained based on equation 4 and the thresholds are fixed with weighted average method as show in equation 5 for obtaining entropy maximization.

The proposed method is simulated in Matlab 2013a, Intel® core™ (i5-4460) using fixed point Binary scaling. The results are shown in the Table 1. The PSNR is calculated from the equation 6. It is seen from the results nearly 3db gain is obtained when compared with the uniform quantizer. The original image of band 5 at 16 bits per pixel is shown in the Figure 4 and the reconstructed image of band 5 at 8 bits per pixel is shown in Figure 5. The average encoding time is nearly 350 seconds and average decoding time requires decoding time is nearly 5 seconds.

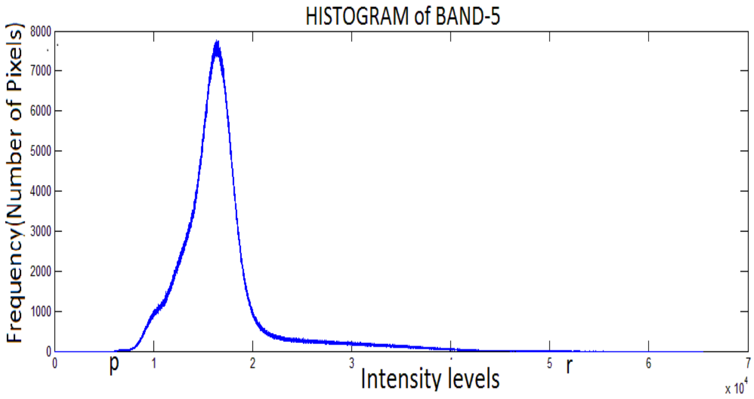

Figure 1: *Histogram of Band-5*

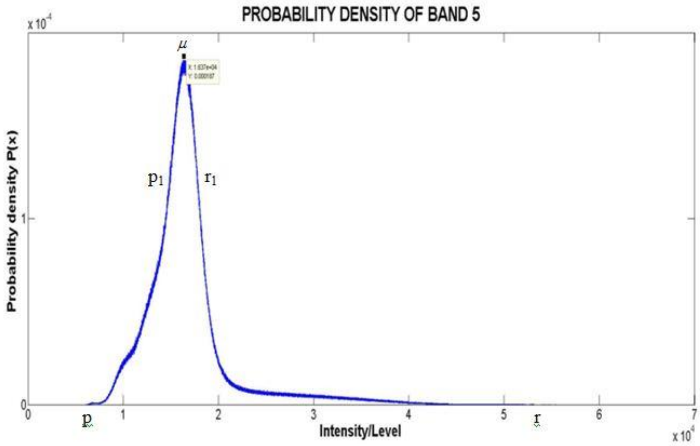

Figure 2: *Probability Density of Band 5*

Laplacian Distribution Equation

$$P(x)=\frac{1}{2b}e^{-|x-\mu|/b} \quad (2)$$

μ =mean, σ=standard deviation =sqrt(2) * b.

$$p1 = \mu - \sigma, \; r1 = \mu + \sigma. \quad (3)$$

$$\frac{n_2}{n_3} = \frac{\sum_{p}^{p_1} p(x)}{\sum_{r_1}^{r} p(x)} \qquad (4)$$

Where n_2 = number of levels from p to p_1.
n_3 = number of levels from r_1 to r.
n_1 = numbers of thresholds in the first region form p_1 to r_1.
nt = total number of thresholds.
Total levels=n_1 +n_2+n_3.

A typical values for n_t =255, n_3=131, n_1=76, n_2=48

$$T = (\sum p(x)*x) / \sum p(x) \qquad (5)$$

$$PSNR = 10\log10(R^2/MSE) \qquad (6)$$

$$MSE = \frac{\sum_{MN}[I(m,n) - C(m,n)]^2}{(M*N)}$$

where M=number of rows, N= number of columns
I= original image, C= reconstructed image
R= 65535.

Table 1: *Calculated PSNR*

Band 3				**Band 5**			
Uniform method		Proposed method		Uniform method		Proposed method	
Bits per pixel	PSNR In db	Bits per pixel	PSNR In db	Bits per pixel	PSNR In db	Bits per pixel	PSNR In db
4	40.1	4	45.5	4	37.8	4	41
5	46.2	5	51.7	5	44.3	5	47.1
6	52.1	6	56.8	6	50.6	6	53.2
7	58.1	7	62.8	7	56.7	7	59.3
8	64.1	8	68.6	8	62.8	8	66.23

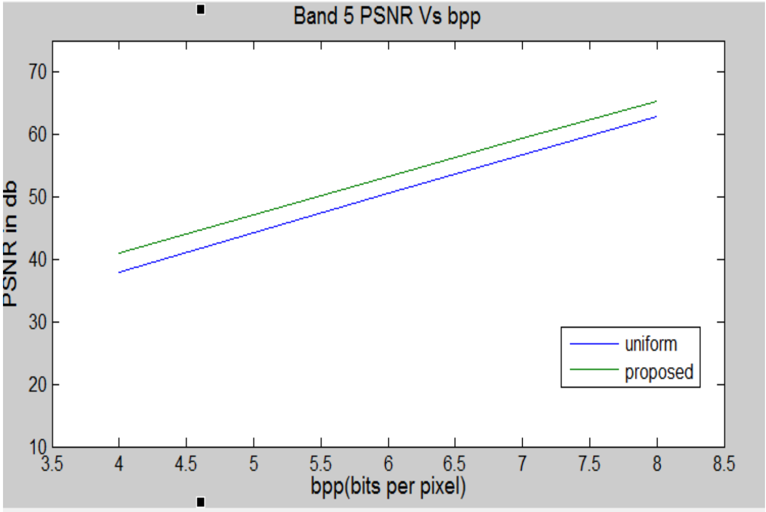

Figure 3: *Band 5 PSNR Vs bpp*

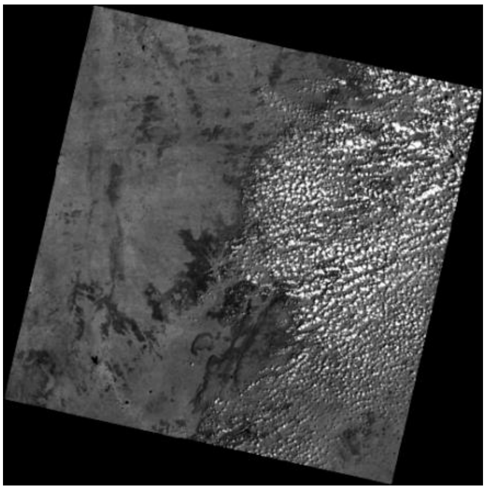

Figure 4: *Original image of band 5 at 16 bits per pixel*

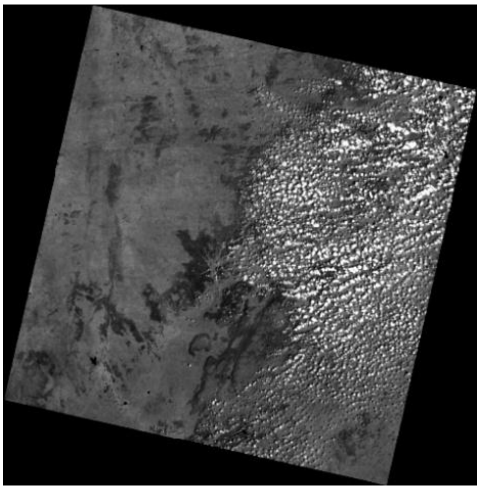

Figure 5: *Reconstructed image of band 5 at 8 bits per pixel*

Discussion

Since satellite images conserves bandwidth and are memory thirsty, the image compression plays a vital role in satellite image processing several things like memory requirements, computational complexity and retrieval time are to be considered for designing of satellite image compression algorithms. In our work we proposed method based on adaptive thresholding method and the method appeals in terms of variable bitrate and less retrieval time.

Conclusion

The proposed method gives better PSNR than the uniform quantization. Hence for Landsat images the proposed method can be applied to improve the PSNR for different bitrates. The proposed method for a compression rate of 8 bits per pixel has advantages like less retrieval time, non-requirement of an exclusive compiler and the PSNR is merely lossless.

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