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Vector Quantization for Satellite Image Compression

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***Abstract*- Image compression is the process of reducing the size of a file without humiliating the quality of the image to an unacceptable level by Human Visual System. The reduction in file size allows to store large amount of data in minimum memory, which can also speed up the transmission process in low bandwidth network, in the case of remote sensing the time consumption of image transmission from satellite to ground station will be reduced. This paper presents a coding scheme for satellite images using Vector Quantization which is a well-known technique for signal compression, and it is also the generalization of the scalar quantization. The given satellite image is compressed using VCDemo software by creating codebooks for vector quantization and the quality of the compressed and original image is compared by the Mean Square Error, Signal to Noise Ratio, Peak Signal to Noise Ratio values.**

Keywords - Satellite Image Compression; Vector Quantization; MSE; SNR; PSNR

I. INTRODUCTION

Image compression plays an important role in Satellite images because it supports in manipulation, storing and transmission of the images [1]. The satellite data is high in rate that easily exceeds the capacity of the downlink channel. In addition, when no ground-station can be reached, the data must be recorded on some mass storage medium, the storage capacity of which can easily be exhausted. The situation has become even more severe in the last few years with the increased requirements of modern satellite systems, including high resolution, and wide swat. Image compression techniques can be broadly classified into two types: lossless and lossy. In lossless scheme exact original data can be recovered while decomposing but in case of lossy method, only the close approximation of the original data can be obtained Various raw data compression algorithms have been proposed in the past few years; these methods can generally be divided into three categories: (1) scalar compression algorithms, (2) vector compression algorithms and (3) transform domain compression algorithms.

Transform domain compression algorithms include FFT-BAQ [2], WHTBAQ [3], DCT-BAQ, wavelet transform (WT) and compressed sensing Scalar compression algorithms include block adaptive quantization (BAQ) [4] block floating point quantization (BFPQ), fuzzy BAQ (FBAQ), entropy-constrained BAQ (ECBAQ) [5], and flexible block adaptive quantization (FBAQ). Vector compression algorithms involve vector quantization (VQ) [6], block adaptive vector quantization (BAVQ), block gain adaptive vector quantization (BGAVQ) [7], and trellis coded vector quantization (TCVQ) [8].

II. PRINCIPLE OF VECTOR QUANTIZATION

Vector quantization (VQ) is a well-known technique for signal compression, and it is also the generalization of the scalar quantization. It fully takes advantages of: (1) the space filling properties, (2) the probability density function shape of the source and (3) both linear and nonlinear dependencies between vector components [7,8]. VQ can be defined as a mapping of k dimensional Euclidean space R into the codebook Y, which can be represented as: $y_i = Q(y)$ for I = 1, 2, ……, N where $Y= \{y^T_{1,} y^T_2 ,…., y^T_N\}$, $X = [x_1, x_2, ………., x_k]^T$, $y_i = [y_{i1}, y_{i2}, ……. y_{ik}]^T$, and N is the length of the codebook [9,10].

III. VC DEMO SOFTWARE

The VcDemo image and video compression learning tool is a fully menu-driven package. It is operated by selecting compression techniques and parameters using buttons. In most cases you should be able to run VcDemo without any further explanations starting from the main application window.

VcDemo is a tool assisting the learning process, but does in itself, not explain the compression techniques. The VcDemo software, including sample images and sequences[11].

IV. IMAGE QUALITY ASSESSMENT

The quality of a compressed image is evaluated in order to measure the degradation in digital images while lossy compression is performed and to find how the image quality is affected by the compression method [12]. The image quality is evaluated by MSE, SNR and PSNR values. MSE is the cumulative square error if the error is minimum, MSE values will be less and it translates to a higher value of PSNR. SNR is the ratio between the meaningful information and the unwanted information, it is a measure of the signal strength related to background noise.

PSNR is a measure of peak error between the compressed image and original image. The PSNR value should be higher for better compression, signal is the original image and noise is the error in the reconstructed image.

The evaluation process is done based on the design of the elements in the input and output matrix. By this method, the quality of the different compression method is performed and also a comparison of the results using different compression ratio is done.

Matrix a is denoted as the input of compression system with elements a_{ij}, with $i\in\{1..M\}$, $j\in\{1..N\}$, where M denotes the number of image elements in vertical path and N denotes the number of image elements in horizontal path. MxN is the total number of image elements [13].

The output matrix created by the compression system is A' with elements a'_{ij}. The error or the loss of image quality is measured by the distance between the elements of matrices A and A'. Normally the error will be larger in higher compression ratios. The compression ratio can be set by the user, which directly influence the data size of the compressed image [11,13].

The total reconstruction error is defined as:

$$E = \sum_{i=0}^{m-1}\sum_{j=0}^{n-1} ||a_{ij} - a'_{ij}||^2$$

The distance between matrices A and A' is frequently calculated using the MSE:

$$MSE = \frac{E}{MN} = \frac{1}{MN}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1} ||a_{ij} - a'_{ij}||^2$$

$$SNR = 20 * \log_{10}\left(\frac{p_{signal}}{p_{noise}}\right)$$

The total number of pixels in an image is MxN, and the sum will be applied to all image elements. The amplitude of image elements is in the range [0, 2n-1], n is the number of bits needed for the binary representation of the amplitude of each element in the original image. MSE considers only the difference between amplitudes, so PSNR is introduced in order to consider amplitudes of image elements.

$$PSNR = 10.\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20.\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right)$$

The MAX_I is the variable which represents maximum amplitude value of image pixel. When the amplitude of the image pixel is represented by B bits, MAX_I is 2B -1.
We can define n = 8 bits/image element by:

$$PSNR = 10.\log_{10}\left(\frac{255^2}{MSE}\right)$$

PSNR values for classic "lossy" compression images will be between 30 to 50 dB.

V. MATERIALS AND METHOD

In this study satellite images taken from [14] serve as the data source. The uncompressed satellite images available in the website is used in this work. These images are in tiff file format with a resolution of 7904 x 8512 and file size of 192 MB. The obtained images are resized into a resolution of 1024 x 1024 and used as the input file for VCDemo v 5.03 [15].

In this paper, we have created three codebooks with different parameters. The first codebook is created by setting the horizontal and vertical size as 2 and the rate per vector min as 1 and max as 8, the maximum number of iterations used is 10 and the convergence threshold is 0.01. By changing the rate per vector and horizontal/vector size, we have generated three codebooks, by using this codebook the satellite image is compressed and the MSE, SNR and PSNR values are calculated. The Table. 1 shows the obtained values and the parameters used.

TALBLE I. VALUES OBTINED BY THE CODE BOOK

Horizontal / Vertical Size		2	4	8
Rate Per Vector	**Min**	1	2	4
	Max	8	9	11
	Bitrate (bpp)	1	0.31	0.1
	MSE	173	290.9	364
	SNR	14.3	12	11
	PSNR	25.7	25.5	23

The codebook design using VCDemo is simple, but it needs some parameters. The Fig.1 shows the codebook design window of VCDemo.

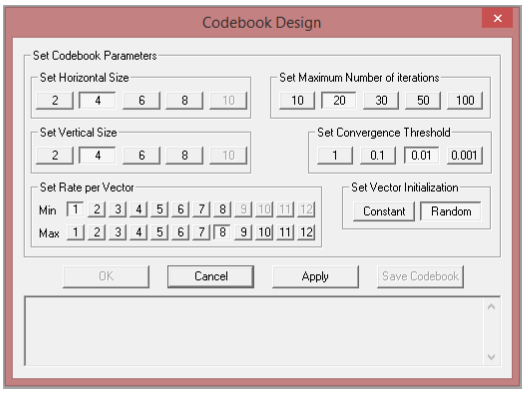

Fig.1. Vector Codebook Design Window of VC Demo Software.

The currently loaded image is considered as training image, and used to design a codebook . This codebook design menu has parameters that can be grouped into two classes:

- *Codebook vector parameters*

Horizontal and vertical dimension of the codebook vectors can be selected independently. The dimensions must be a multiple of the image dimensions.

Minimum and maximum bit rate for which the codebook needs to be designed. Note that the design of a codebook is exponentially increasing with the bit rate. The design of larger codebooks (10-12 bits) may take quite some time – of course memory and CPU-speed dependent – but be prepared to wait and get some coffee! It is generally advisable to start with smaller codebook size. The program will output some information in the text window so you will know it is still alive. Note that the design procedure cannot be interrupted.

- *Initialization and convergence*

The design of a codebook is an iterative procedure. As in any iterative procedure, the iterations must be initialized. The codebook vectors can be initialized using random numbers in the range [0,255] or with constant gray values, uniformly distributed over the codebook vectors in the range [0,255]. The results will be different and convergence speed may be different.

The codebook design iterations have to be truncated after sufficient convergence. Two thresholds are, in effect, namely the difference in MSE in two subsequent iterations (calculated on the current estimate of the codebook and the training vectors) which is called the convergence threshold, and the number of iterations carried out (to prevent infinite computation time). Setting smaller convergence thresholds and/or larger number of iterations yields larger computation times. Different types of codebooks can be created using various parameters and Codebooks that have been designed, can be saved and used immediately.

VI. RESULT AND DISCUSSION

Table. 1 shows the values obtained by the Vector Quantization compression method in satellite image the table shows the parameters given to the software as inputs and the respective values obtained by it.

a)
b)

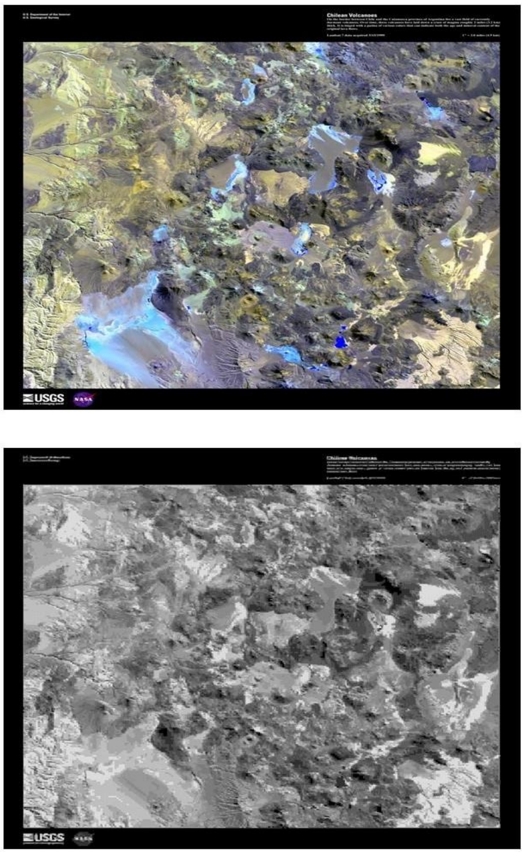

Fig 2. Satellite images a) Original Satellite Image, b) Compressed Satellite Image.

The Fig. 2 (a) shows the original satellite image used in this paper and Fig.2 (b) shows the compressed image, Fig. 3 (a) shows the MSE values obtained by vector Quantization algorithm for the given satellite image for low vector size the MSE value is low and for higher the values obtained is also high. For the 8 x 8 horizontal and vector size the rate per pixel is defined as min 4 and max 11. The MSE value obtained is very high. Similarly, the Fig. 3 (b) and Fig. 3 (c) shows the SNR and PSNR values obtained and plotted in the graph using the bpp values.

A compressed image is a better image if it has lower MSE and higher PSNR. It also seems that for a higher rate of compression the noise in the image increases, i.e. the lower value of SNR and PSNR [16].

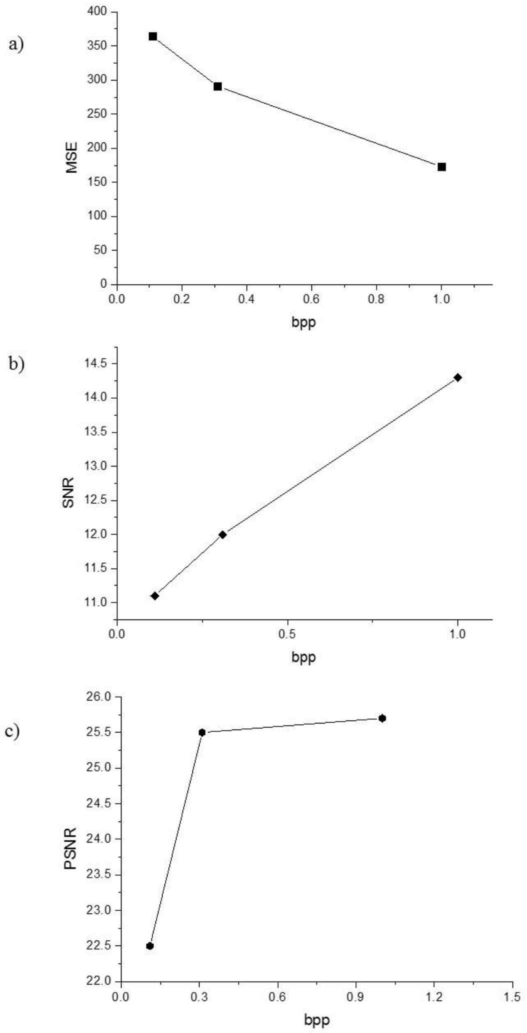

Fig. 3. MSE, SNR and PSNR values Obtained by Vector Quantization Method a) MSE values, b) SNR values and c) PSNR values

VII. CONCLUSION

In this paper the Vector Quantization (VQ) is used to compress the satellite image. MSE, SNR and PSNR values are obtained and verified, according to the obtained MSE, SNR and PSNR values the performance of VQ is somewhat good in satellite image compression. The performance of VQ can be increased by making slight changes, accordingly it can be used for on-board satellite image compression.

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