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COLOR IMAGES COMPRESSION USING VECTOR QUANTIZATION (VQ)TECHNIQUE WITH DIFFERENT MATHEMATICAL TRANSFORMATIONS

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Abstract:

Image data compression is one of the most important techniques in digital image processing that used to reduce the size of image data with taking into account getting good quality of the compressed image, before several decades the researchers produced a lot of coding methods to decrease the image size, these methods include loss data compression and lossless data compression. in this research vector quantization techniques have been used to compress color image, firstly vector quantization has been applied using only cosine transform and then using principle component transform together with cosine transform, secondly vector quantization (VQ) has been achieved using wavelet transform only and then using the same transform with the principle component transform, many statistical properties have been shown and many fidelity criteria have been computed. This manuscript also includes the theory concepts of Vector Quantization, cosine transformation, principle component analysis and wavelet transform.

Keywords: image compression, Vector quantization (VQ), DCT , PCT, wavelet..

Introduction:

Image compression contributes to reducing data size which required to represent a digital image. The main basis of the decreasing process is the removal of redundant data [1,2].

In general Digital images contain a wide range of redundancy "spatial, spectral, or temporal redundancy". Data growing is a central problem in digital image compression or coding. It is not an abstract concept but a measurable mathematical entity. If n1 and n2 denote the number of information data sets that represent oneself information, the ratio data redundancy R_d can be given as [3] [4]:

$$R_{d}= 1 - \frac{1}{C_R} \qquad (1)$$

Where C_R, commonly called the compression ratio, is define as:

$$C_R = \frac{n1}{n2} \qquad (2)$$

Generally, Compression algorithms are designed to taking advantage of reducing the redundancy in an image. The primary types of redundancy can be found in images are;

1. Coding Redundancy: It is occurring when the data used to represent the image are not utilized in an optimum manner; e.g. if we have an 8 bits/pixel image that allow 256 gray-level values, but the actual image contains only 16 levels (i.e. only 4 bits/pixel are actually needed)
2. Inter-pixel Redundancy: it is occurring because adjacent pixels to be highly correlated. This is a result of the fact that in most images the brightness levels do not change rapidly, but change gradually, so the adjacent pixel's values to be close to each other. For video or motion images, this concept can be extended to include inter-frame redundancy; i.e. redundancy between frames of image data.

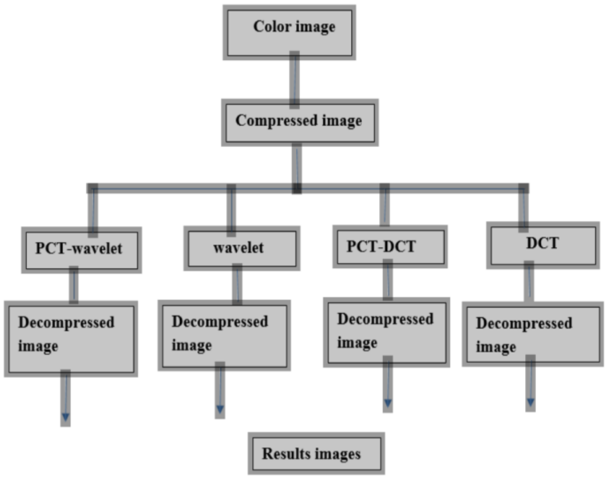
3. Psych visual Redundancy; refers to the fact that some information is more important to the human visual system than other; e.g. we can only perceive spatial frequencies below 50 cycles per degree, so that the higher frequency is of little interest to us [5][2].

Image data compression is possible due to the following basic characteristics [6] :

The next step is to convert the quantized values to entropy. This is shown in Figure (1) [5]

There are two main types of compression; either lossless, where no information is missing and a duplicate of the image is copied, or lossy, where only an approximation of the origin is generated. For important data, including scientific and medical images, lossless is often considered unnecessary. This is because potential future uses of data may be easily unknown and the degree of loss of accuracy may be unacceptable [7][8]. In this research there are many compression methods have been adopted to compressed the color image. These techniques include firstly desecrate cosine transformation and wavelet transform. Secondly apply principle component analysis transform with desecrate cosine transform once and then apply principle component analysis with wavelet . For more information, see the flowchart (1).

Flowchart (1): The main compression methods have applied in the original image.



2. Lossy-coding Methods

Generally, image data-compression techniques can be divided into two major types;

lossy and lossless

Lossless data compression recognizes a certain loss of accuracy in exchange for increased compression, which proves to be effective when applied to graphics and digital audio images. Most of the missing compression techniques can be adjusted to different quality levels, and higher accuracy is obtained against less effective compression [3]. The lossless compression of these secured technologies is made to create an accurate repeat of the input data stream after a compression / expansion cycle. In even a little loss one can cause catastrophic. However, the lossless compression is best, but unfortunately, its compression factor or bit rate is restricted by

Shannon Information Theory, which state that: Whatever the lossless compression coding method is efficient, its bitrates cannot be less than the entropy.

Information Theory uses the term entropy as a measure of how much information is encoded in a message. The word entropy was borrowed from thermodynamics, and it has a similar meaning. The higher the entropy of a message, the more information it contains.

Lossy compression techniques involve some loss of information, and data that have been compressed using lossy techniques generally cannot be recovered or reconstructed exactly. In return for accepting this distortion in the reconstruction, we can generally obtain much higher compression ratios than is possible with lossless compression [11-14]. For more information see figure 2.

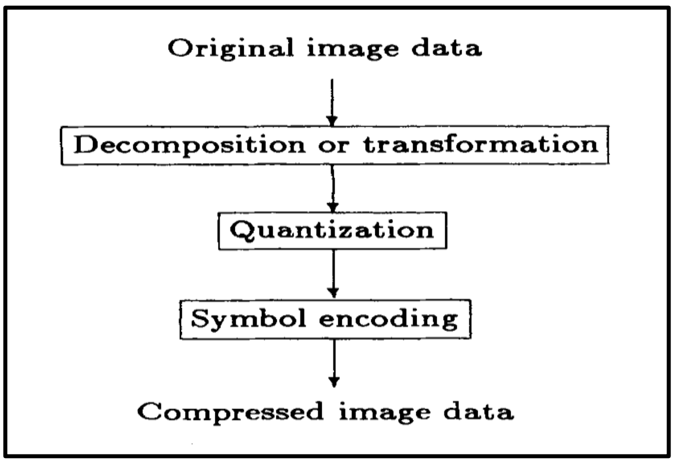


Fig (2) Lossy Compression Scheme

Lossy compression results in a larger reduction of data compared to the lossless case. Of course, when we refer to an image compressed using a lossy compression method, it is implied that the decompressed image is quite useful. Otherwise, one can obtain an unlimited amount of compression at the expense of image quality [15]. fig (3) show an example of lossy image compression using discrete cosine transform:

(a) (b)

fig.(3): (a)Original image and(b) decompressed image using DCT.

Because it is a lossy compression, artifacts are clearly seen in the reconstructed image. If we allow a larger compression the artifacts will be even more visible. Thus, we can trade quality for higher compression when using a lossy compression method.

A lossy compression introduces distortions in the decompressed image, the higher compression ratio that is leads to large distortion [15]. The lossy compression techniques are usually applied to data where high fidelity of reconstructed data is not required for perception by the human perceptual system. Examples of such types of data are image, video, graphics, speech, audio, etc [16].one of the most important lossy compression methods is vector quantization for more details see the next section.

3. Vector Quantization

- Vector quantization is the process of mapping a vector that can have many values to a vector that has a smaller (quantized) number of values.
- The vector quantization deal with a string of values instead of an individual. The image is divided into block.
- The first encountered is consider to represent the first classified vector and inserted in a code book file.
- The other blocks should be compared with those existed in the code book file.
- The minimum distance criterion method usual used to show if the compared block is matched with one existed inside the codebook or note as follow:

- If **b_i** represent the elements of the image block and **c_i** most the element of the classified vectors in the codebook then.

$$minimum\ distance\ d_j = \sum_{i=1}^{n} |b_i - c_i| \tag{3}$$

where

n: The number of elements in the considered block

J: I an index referring to the position of the classified blocks in side code book are transmitted.

the compressed block is considering as to similar to one of those existed inside the codebook or do not depends on a suggest threshold value (th) as follow:

if $|b_i - c_i|$ <= th, then the codebook given the index j.

if $|b_i - c_i|$> th, then the block is considering as to be new class and inserted in the codebook.

4. Vector Quantization Levels Concept

there are three levels of vector quantization "1D, 2D, and 3D" if the source is one-dimension signal, it is grouped into L consecutive samples, if two-dimensional (2D) signal, like an image, it is divided into $n \times n$ samples or blocks of L pixels [5]. While a3D "three dimensional "vector can be resulted from RGB color components of a one pixel [3].

From the block coding point of view, "VQ take advantage the correlation among pixels in a local block, and fractional bits can be allocated to each pixel, leading to an efficient compression technique. Decompression operation of VQ is very simple and fast because no computation is needed except the table look-Up. The two most important components in a vector quantization system: the codebook and the pattern matching block. VQ is a pattern matching technique. For a given input vector, the VQ encoder finds the best matched code word vector and outputs its index. There must be a pattern matching rule. To design a vector, quantize, one needs to consider the following three aspects" [1].

In the second hand, "VQ takes advantage of the link between pixels in the local block, and the fractional bits can be allocated per pixel, resulting in an efficient compression technique. The two most important components of the vector quantization scheme: the code book and the pattern matching block, VQ is a pattern matching technique, there must be a pattern matching rule. "To design a quantum vector, one needs to consider the following three aspects.

1. Select a pattern matching rule,

2. Make a codebook, and possibly

3. Reduce the difficulty of the pattern matching process.

The vector quantization method consists of encryption and decryption. This is just a memory, and a reservation whose volume is the size of the input vector. These encoders decoders make up the codebook, and the vectors stored are called code-vectors the code words are specific or designed to represent input vectors or blocks in an image to be compressed" [5]. For more information, see figure 4.

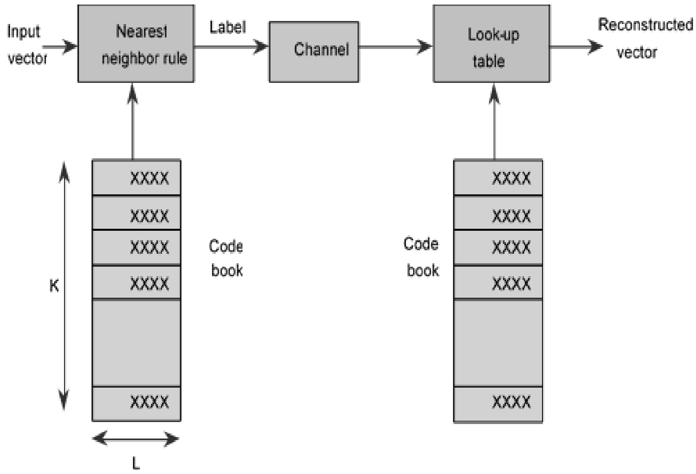
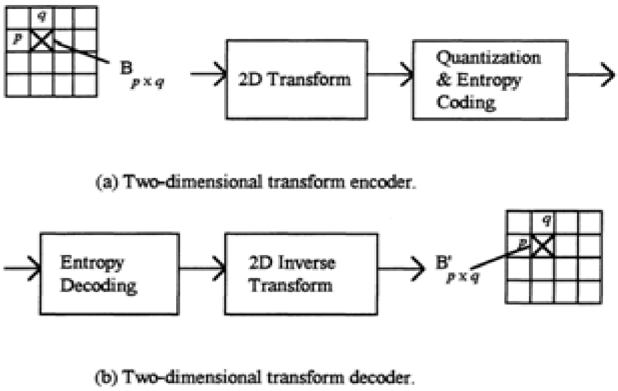


Fig (4). Compression and decompression using vector quantization (VQ).

In vector quantization (VQ), the original image is first decomposed into n-dimensional image vectors. The vectors can be created in many methods. For example, an $n = 1 \times m$ block of pixel values can be ordered to form an n-dimensional vector, or a 3D vector can be formed from the RGB color components of an individual pixel [3].

5. **Transform Coding**

Transform encoding is an effective way to encode a block of pixels by applying a linear transformation on these pixels and encoding the transform coefficients acquired from the transformation. The average concept is that appropriate transformation method a smaller linked transform coefficient than the real pixels, and the information may be concentrated into smaller transform coefficients. Thus, few bits can be used in the encoding process. Another factor that supports encoding transform is that the human visual system has cognitive masking effects so that some frequency components are not sensitive to coding errors like others. By assigning fewer bits to "disguised" frequency factors, transform coding can result in a picture that is perceived to be of high quality.



(a) Two-dimensional transform encoder.

(b) Two-dimensional transform decoder.

fig. (5) Two-dimensional transform coding system for digital images.

Figure 5 shows a 2D encoding system for digital images. The digital image is first divided into a number of small rectangular blocks the size of p x q. After that, these blocks are converted, and the transactions are determined and treated. Through the decoding process, the entropy decoding is computed followed by the inverse transformation of the coefficients to receive the reconstructed image [1].

5.1 **Discrete Cosine Transform**

The mean idea of transform coding is to transform the input into several form, it can then be compressed effectively.

The DCT is consider to be the most important transforms that used for image compression, more so than the discrete Fourier transform (DFT). This is because the DFT suppose periodicity, which is not important true in images.

The DCT does not suppose periodicity and will only require low amplitude high-frequency components. The DCT does not require a phase, which is typically represented using complex numbers in the DFT [17].

Each component in this transformation subdivide the image into blocks of size 8×8 pixels. A 2D DCT is applied to each block of data to get an 8×8 sets of coefficients. If $x[m, n]$ act the image pixel values in a block, then the DCT is computed for each block of the image data as follows:

$$X[u,v] = \frac{C[u]C[v]}{4} \sum_{m=0}^{7} \sum_{n=0}^{7} x[m,n] \cos\frac{(2m+1)u\pi}{16} \cos\frac{(2n+1)v\pi}{16} \quad 0 \le u,v \le 7 \qquad (4)$$

Where

$$C[u]\begin{cases} \frac{1}{\sqrt{2}} & u = 0, \\ 1 & 1 \le u \le 7 \end{cases}$$

The inverse discrete cosine transform (IDCT) can be used to return the original image as follows:

$$x[m,n] = \frac{C[u]C[v]}{4}\sum_{u=0}^{7}\sum_{v=0}^{7} X[u,v]\cos\frac{(2m+1)u\pi}{16}\cos\frac{(2n+1)v\pi}{16} \qquad 0 \le m,n \le 7 \qquad (5)$$

The DCT, consider to be one of sinusoidal transforms groups has received special interesting due to its efficiency in compression of real-world images [9][12].

5.2 **Sub-band Coding and Wavelet Transform**

Wavelet transformation, as shown in Figure 6, which features such as energy pressure and link cancellation is used in image compression, which reduces the impact of artifacts. Wavelets are one of the most important transformations in the field of signal processing and are used in various image processing.

Continuous wavelet transform (CWT) is used for analog signal, and for discrete signals, Discrete transformation is used on a large scale and is easily executed using computers. This switch uses photo compression techniques. Wavelets display high-power compression and unlinking, such as DCT, accordingly, the quantization of wavelet coefficients can be used [9] [10] [5].

The advantage of this analysis is that the local features of the image can be used with few transactions. These parameters can be encoded, and a very good compressed image can be obtained [1]. For more information see figure 6.

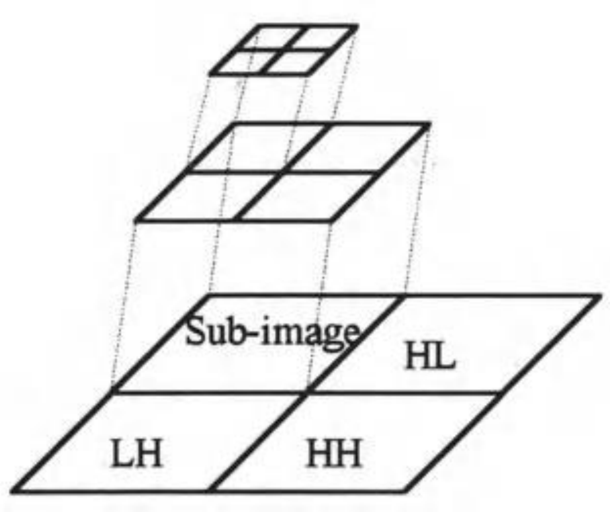


fig. (6) Wavelet transform

The original image is divided into rounded and two-dimensional details, a scanned row and a column. We receive approximately one (LL1) and three details: horizontal (HL1), vertical (LH1), and country (HH1). For the next level decomposition, the rounding is filtered again to divide it into four other ones, thus reaching the seventh level. The decomposition method is shown in Figure (7).

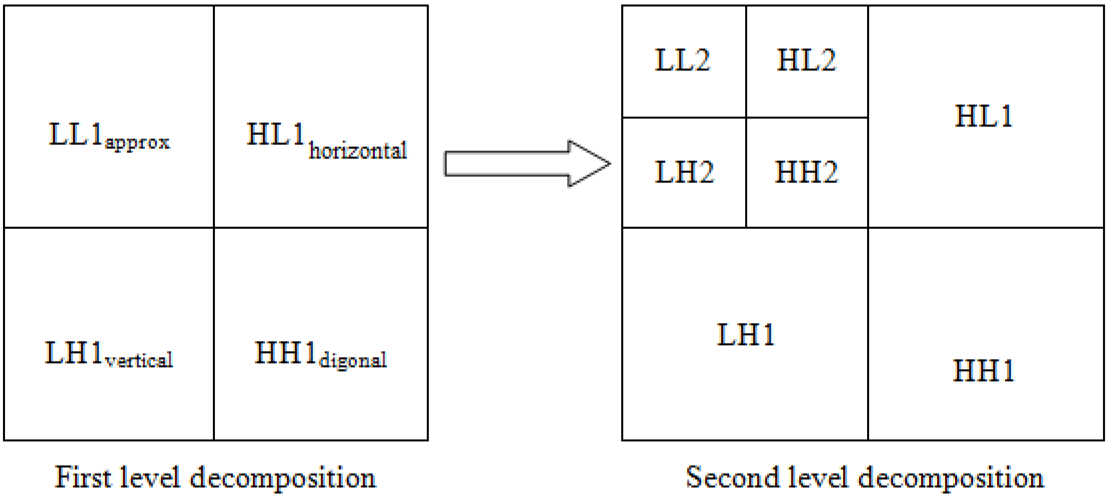


fig. (7): Show the first and second level decomposition

Using the compression method, wavelet conversion coefficients are estimated by the marginal value of wavelet coefficients. Thresholds can be changed for different sub-domains depending on their importance, which depends mainly on the contrast or energy. A large volume of quantization steps can be used to estimate low power sub-bands [5].

The researches now, subdivision coding and discrete wavelet transformations (DWT) have become widespread in image compression and indexing applications. These techniques frequently pass an image through a pair of "low pass and high pass" filters, removing filter outputs (i.e., ignoring each other sample) in order to maintain the same data rate as the input signal [11] [12].

6.Result and Discussion

For any image in a specific format, such as a gray image or a color image, contains a lot of information that requires large storage space, large transport ranges, and long transport times. Therefore, it is necessary to compress the image by storing and handling only the important information needed to reconstruct the image. Image compression field consists of two type of compression techniques the first type reconstruct the information of the image without loss but with low compression factor, and the other type of compression methods reconstruct the original image with amount of loss but with high compression factor, this research follow the second type of compression techniques where the vector quantization method has been applied on color image as show in figure (8) to compressed its size using different transformation models, the first transformation is cosine and the results of applying it on the color image can be shown in figure (9), with the same transform the principle component transform has been used the result showed that the compression factor has been increase and peak signal to noise ratio has been decrease as show in table (4). in the other side the result of applying principle component transform with wavelet transform on the same adopted image the results also show that using PCT with the wavelet increase the compression factor but decrease the peak signal to noise ratio for more information see figure (10). That is mean the function of principle component transform (PCT) with other transforms is increase the compassion ratio and decrease the information in the reconstructed images.

7. Conclusion

The conclusion of the results can be giving a very important benefit help the researchers to select the principle component transform beside the other transformation to increase the compression ratio. spatially when we deal with color and multispectral image because these types of images need a very big size for saving and transforming purpose. But in other side this research don't advice the researchers to use the principle component transform (PCT) with other transforms when we deal with text image and medical image because the higher compression that get it by using (PCT) will decrease the quality of the reconstructed images.

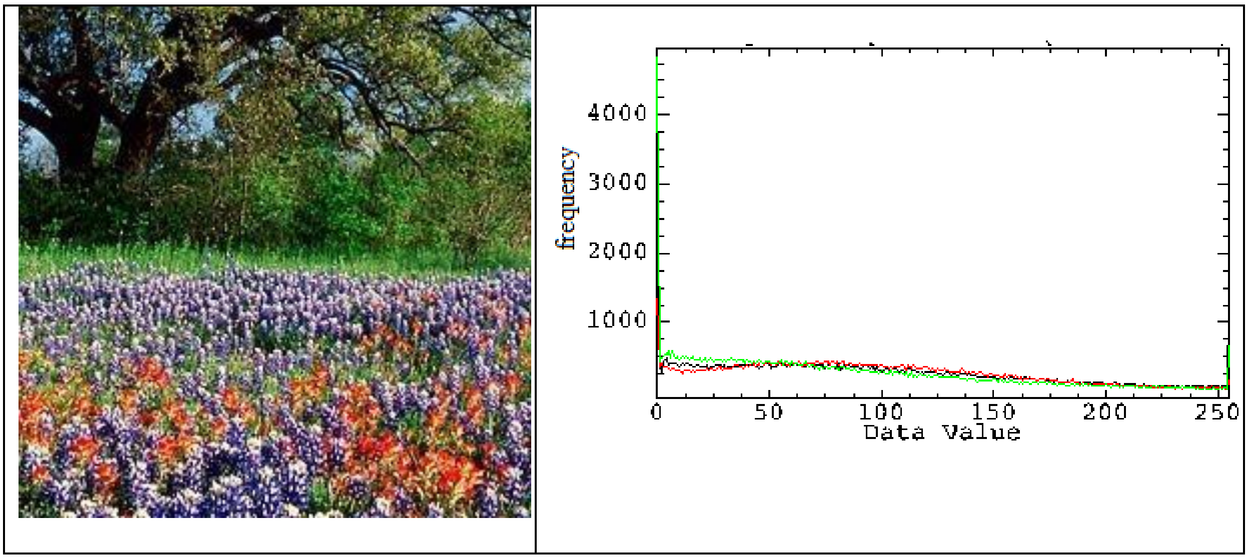
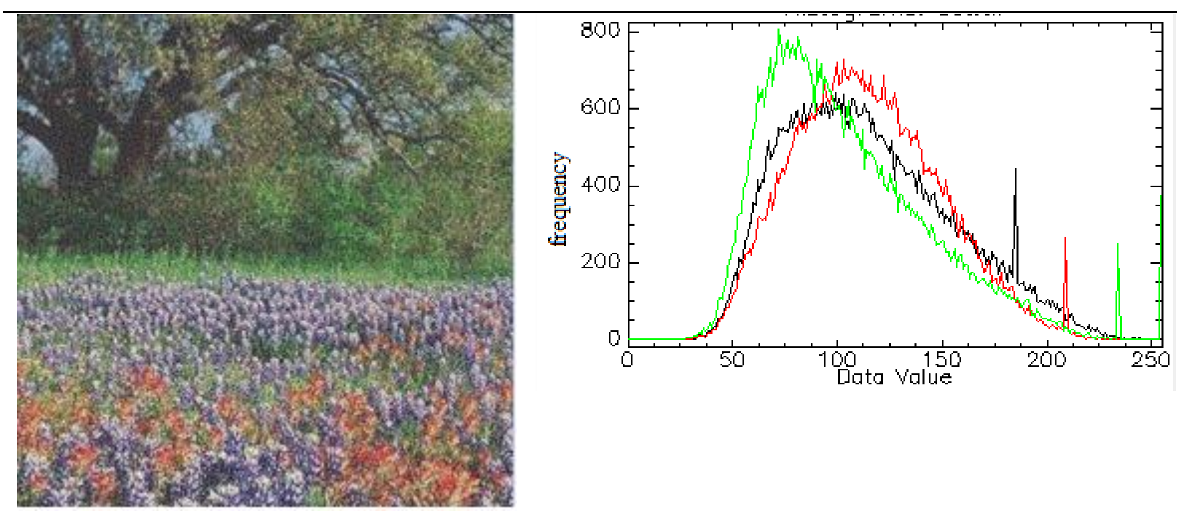
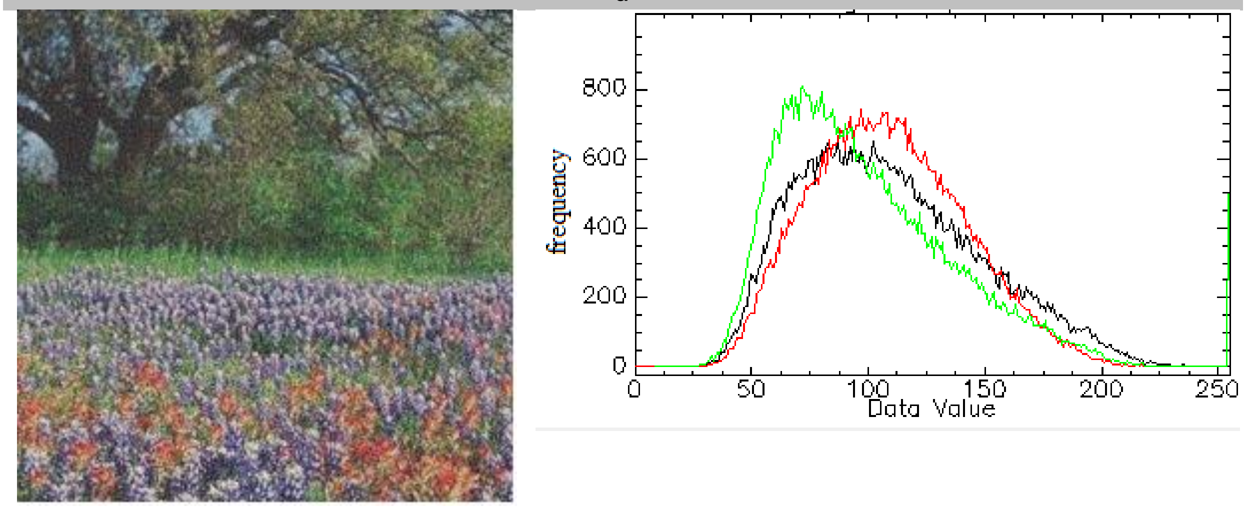


Fig.(8): The original with its histogram.

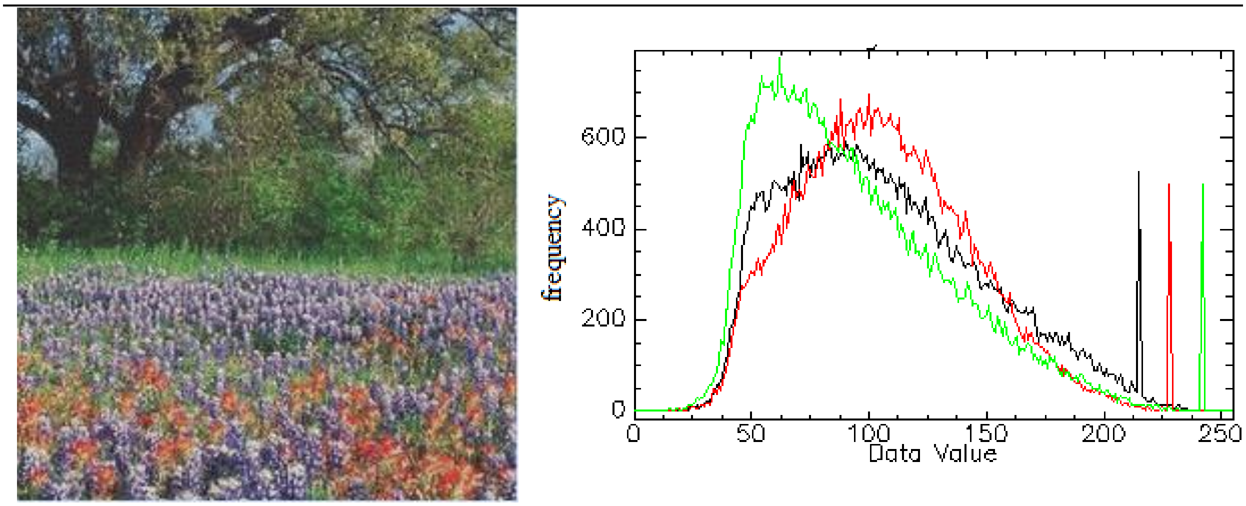


a



b

Fig.(9): The compressed image using vector quantization with a)DCT with its histogram b)PCT-DCT with its histogram.



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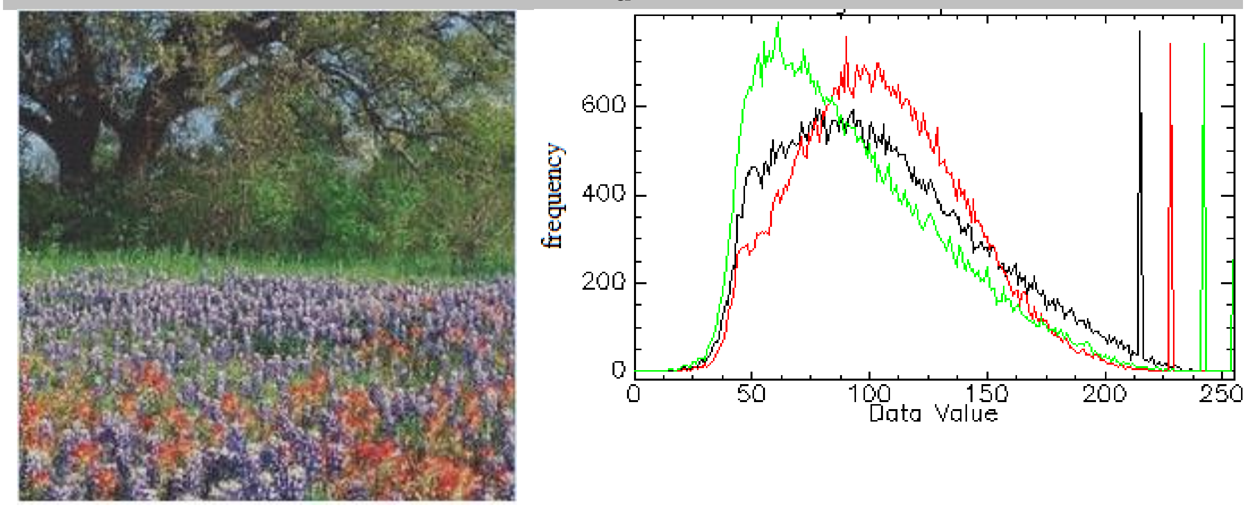

b

Fig. (10): The compressed images using vector quantization with a) wavelet b) PCT-wavelet.

Table 1: The statistical properties of original image.

Band	Mean	S.D.	Skew	Energy	Entropy
0	93.462	67.047	0.611	0.006	7.745
1	92.701	59.994	0.502	0.005	7.758
2	75.888	63.635	0.878	0.010	7.475

Table 2: The statistical properties of the compressed images using VQ with DCT and PCT-DCT transformation .

Compressed image	Band	Mean	S.D.	Skew	Energy	Entropy
DCT	0	114.843	39.117	0.510	0.007	7.257
	1	114.365	34.175	0.310	0.008	7.111
	2	103.821	36.996	0.716	0.008	7.131
PCT-DCT	0	109.308	38.367	0.507	0.007	7.231
	1	108.848	32.608	0.301	0.009	7.044
	2	98.583	35.854	0.710	0.008	7.088

Table 3:The statistical properties of the compressed images using VQ with wavelet and PCT-wavelet transformation.

Compressed images using VQ with	Band	Mean	S.D.	Skew	Energy	Entropy
wavelet	0	104.280	42.423	0.506	0.007	7.361
	1	103.770	37.018	0.344	0.008	7.216
	2	92.276	40.043	0.745	0.008	7.226
PCT-wavelet	0	102.650	41.943	0.515	0.007	7.346
	1	102.154	35.553	0.328	0.008	7.161
	2	90.913	39.105	0.737	0.008	7.194

Table 4: The comparison between the original and compressed image using different methods.

Compressed image using VQ with	**Bands**	**PSNR**	**RMSE**
DCT	Band1 Band2 Band3	16.466 16.826 15.879	38.305 36.749 40.984
PCT-DCT	Band1 Band2 Band3	15.869 16.037 15.127	41.031 40.241 44.690
wavelet	Band1 Band2 Band3	18.419 18.747 17.964	33.321 32.050 35.171
PCT-wavelet	Band1 Band2 Band3	17.121 17.349 16.585	35.522 34.603 37.783

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