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Comparative Study of Various Image Compression Techniques

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Abstract— this paper presents comparative study of various image compression techniques to assess the progress made in the field of image compression effects on different images for different applications. The advancement in the computer vision increases the demand of high data transmission speed as well as need of large storage space. Thus the field of Image compression is now essential for such applications where such high volume data is required to transmit and stored. In this paper, we review about the image compression, need of compression, its principles, and types of compression and different algorithms used for image compression.

Index Terms— Image compression, Redundancy, RLE, DPCM, DCT, Huffman, DWT.

1 Introduction

MULTIMEDIA data such as graphics, audio and video needs considerable amount of storage capacity and requires more transmission bandwidth. Also the increase in the digital imaging techniques in the last few decades has made it possible to capture high resolution images using hand held devices such as digital cameras, mobile phones, ipads etc. As these digital images are usually represented by a very large number of bits, communication of a single image from source to sink node involves the transmission of several data packets. This results in large energy consumption at the source node than nodes collecting and forwarding scalar data [1]. With the help of Image compression, we can able to reduce the amount of data required to represent digital images. The objective of image compression is to reduce the storage requirements per image, while maintaining image quality. Ideally, we would like to maintain the appearance of the image to a human observer. In this paper we present different compression techniques for different types of images. Image compression has proven to increase data transmission speed, bandwidth, and throughput and reduce the memory requirement for the storage of high volume data [2].

2 Compression Principles

Correlation between neighboring pixels and irrelevance data is the common characteristics seen in most of the images which consists of redundant information. Using compression, less correlated representation of the image can be determined. Redundancy and irrelevancy reduction are the two fundamental components of compression [3]. Redundancy reduction is done by discarding similar pixels from the signal source (image/video) while Irrelevancy reduction discards the parts of the signal that will not be noticed by the Human Visual System (HVS). Figure 1 shows the relationship between useful information and redundant data. Thus an image is equal to the actual information plus redundant data.

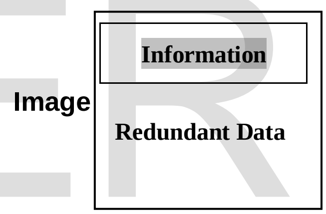

Fig.1: Image with redundant data.

3 Types of Redundancies

Basically there exists, three types of redundancy in an image:

3.1 Coding Redundancy

A code is the combination of symbols like letters, numbers, bits etc. used to represent any type of image information or set of events. Each block of pixels are assigned a sequence of code symbols, called a code word. The length of code word is nothing but number of symbols. In most of the 2-D intensity arrays, it will contain more bits than these are needed to represent the intensities especially in case of 8-bit codes that are used to represent the intensities. This type of coding is always reversible and usually implemented using look-up tables (LUTs). Huffman codes and arithmetic coding techniques are the examples of coding redundancy [4].

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3.2 Interpixel / Spatial Redundancy

An image can contain strongly correlated pixels, in other words, most of the pixels in large regions exhibits the same characteristics. This redundancy can be explored in several ways, one of which is by predicting a pixel value based on the values of its neighbouring pixels. In order to do so, the original 2-D array of pixels is usually mapped into a different format, e.g., an array of differences between adjacent pixels [5]. If the original image pixels can be reconstructed from the transformed data set the mapping is said to be reversible. Examples of compression techniques that explore the interpixel redundancy include Run-Length Encoding (RLE) techniques, and many predictive coding algorithms such as Differential Pulse Code Modulation (DPCM).

3.3 Psychovisual Redundancy

This type of redundancy deals with the persistence of vision of human eye that can tolerate some amount of loss of data after compression. Many experiments have proven that human eye does not respond with equal sensitivity to all incoming visual information; some pieces of information are more important than others. Thus the resulting type of redundancy is called as Psychovisual redundancy. The result of using these techniques is to compressed image file such that whose size and quality are little bit smaller than the original information with acceptable quality for the respective applications.

4 Why Compression?

As we know the amount of data in visual information is very large therefore in order to store such a large amount of data we need to have enormous memory capacity. Table 1 shows the qualitative comparisons for different types of images along with disk space required, bandwidth requirement for data transmission, and transmission time needed to store and transmit such uncompressed data. Thus to reduce memory size for data storage for an image data, image compression is used.

5 Classification Of Image Compression

There exist two types of image compression, Lossless compression and Lossy compression. In Lossless compression technique, coding technique is to compress the data while retaining all information content. However, the result achieved after compression for file size reduction is not sufficient for many applications [6]. While in lossy image compression method, as the name lossy some amount of data will be lost during compression. In this case the file size reduction can be much more significant than obtained with lossless compression. Both the types are waveform based compression techniques. Further Lossless compression techniques are classified into two class i.e. Statistical and Universal approaches. Statistical approach is Huffman's coding, Gilbert transform etc. Ziv-Lempel and Runlength coding are the examples of Universal approach. On the other hand, the lossy method works in both Spatial/Time Domain and Frequency Domain. Delta Modulation, PCM, DPCM and VQ etc. are the examples of Spatial/time domain. Frequency domain is again divided into Filter based and Transform based. Subband encoding and Wavelet based approaches are come under filter based while Fourier Transform (FT) and Discrete Cosine Transform (DCT) are the examples of Transform based compression techniques [7].

5.1 Lossless Image Compression

In lossless compression scheme, after compression the reconstructed image is nearly identical to the original image. Thus it achieve less compression and useful in text transmission.

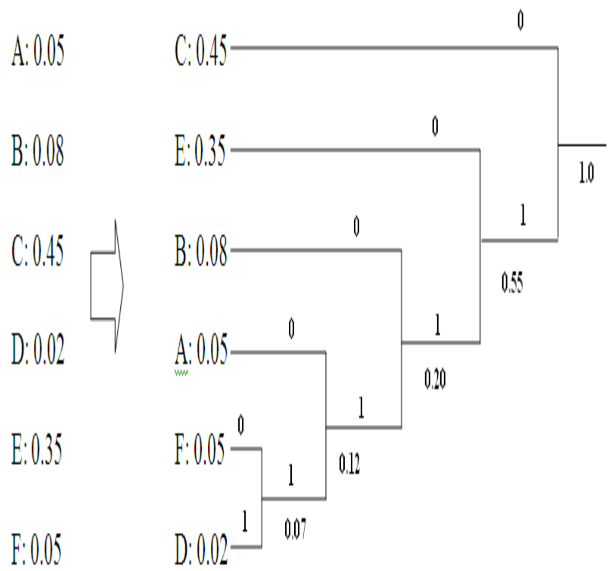
5.1.1 Huffman Coding

This method is works on the concept of frequency of occurrence of pixels in an image, thus it is also called as an entropy coding based method. As per the theory entropy is the average minimum number of bits necessary to describe an aspect of a particular source (i.e., pixel within an image). Entropy is denoted as $H(X)$ and takes into account the probability of occurrence for all items within a source.

$$H(x) = \sum_{i=1}^{N} \mathrm{p}(\mathrm{x_i}) \log_2 \frac{1}{\mathrm{p}(\mathrm{x_i})}$$

Where x is the source and p is the probability

In this method a lower number of bits are used to encode the data with high probabilities and larger number of bits is used with low probabilities. A Huffman code is generated by merging together the two least probable characters, and repeating this process until there is only one character remaining. Using this process a code tree is generated and by labeling this code tree the Huffman code is obtained [8]. The procedure for generating Huffman code is explained below:



In the above example a source generates 6 symbols {A, B, C, D, E, F} with probabilities {0.05; 0.08; 0.45; 0.02; 0.35; 0.05} respectively. Two least probable characters are assigned 0 and 1 and merged. This merged and the third least probable characters are assigned 0 and 1 and merged. The process is then repeated until there is only one character remaining. The Huffman code for a particular character is then simply obtained by reading the tree backwards, from right to left and collecting different bits on different branches. The codes for above example are shown in the table 2 below:

x	Code
A	1110
B	110
C	0
D	11111
E	10
F	11110

Table 2: Code generated for Huffman tree

Steps for encoding the images:

- Divide image into 8 x 8 blocks of pixels.
- Each block is a symbol to be coded
- Compute Huffman codes for set of block
- Encode blocks accordingly

This will compress an image. For retrieval of original image, apply decoding which is the reverse of encoding.

5.1.2 Lempel-Ziv-Welch (LZW) Coding

Lempel Ziv Welch coding is a dictionary based coding which can be static or dynamic. In static LZW coding, dictionary is fixed during the encoding and decoding processes. While the dictionary is updated on fly in dynamic LZW dictionary coding, this type of coding is widely used in computer industries [9]. It is also implemented as compress command on UNIX. LZW works based on the occurrence multiplicity of character sequences in the string to be encoded. Its principle consists in substituting patterns with an index code, by progressively building a dictionary. The dictionary is initialized with the 256 values of the ASCII table. The file to be compressed is split into strings of bytes, each of these strings is compared with the dictionary and is added, if not found there. In encoding process the algorithm goes over the stream of information, coding it; if a string is never smaller than the longest word in the dictionary then it is transmitted. In decoding, the algorithm rebuilds the dictionary in the opposite direction; it thus does not need to be stored.

5.1.3 Run Length Encoding (RLE)

The simple and one of the most popular data compression algorithms is the Run-length encoding (RLE) in which the runs of data i.e. the sequence of similar data elements in the input data stream (repeating string) are replaced by a single data element value or the count. The RLE plays a vital role in cases where the data stream contains many runs. If any files that do not have many runs there is a chance of increase the file size and hence it is not useful [10].Consider a 15-character string with four different characters runs as shown below. This string without the RLE would require 15 bytes to represent the string.

B	**B**	**B**	**B**	**B**	**B**	**B**	**a**	**a**	**a**	**a**	**X**	**X**	**X**	**X**	**y**

However after applying the RLE to the above sequence, there are four runs of seven B's, four a's, three X's and one y. Thus, for the above characters the resulting string would require only eight bytes of data as shown below.

7	**B**	**4**	**a**	**3**	**X**	**1**	**y**

Thus, using this technique, a string of 15-byte would require only eight bytes of data to represent the entire string, instead of original 15 bytes. Thus it results compression of an image up to 54%.
Since Run-length encoding is lossless data compression, it is well suited to bitmap file formats, such as TIFF, BMP, and PCX. Practically run length encoding with Huffman coding are used in Fax machines. It is relatively efficient because the data sent over the fax machine are used mostly white space,

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with occasional interruptions of black. But it does not work well for continuous-tone images such as photographs, although JPEG uses it quite effectively on the coefficients that remain after transforming and quantizing image blocks. It is used as a primary compression technique in the 1-D CCITT Group 3 fax standard and in conjunction with other techniques in the JPEG image compression standard.

5.2 Lossy Image Compression

In lossy image compression scheme as the name some amount of data can be lost which can tolerate our human eye.

5.2.1 Differential Pulse Code Modulation

Differential pulse-code modulation (DPCM) is a signal encoder consisting of pulse-code modulation (PCM) with added functionalities based on the prediction of the samples of the signal. The input to DPCM may be an analog signal or a digital signal. Since DPCM requires discrete time signal as a input, and if the input is a continuous-time analog signal, then it is required to be sampled first so that a discrete-time signal is obtained which is then given to the DPCM encoder. It is an efficient data compression technique, which is useful for reducing transmission rate of digital picture information. The use of DPCM in image coding, however, requires some caution when transmission errors occur, because in the reconstructed DPCM image transmission errors tend to propagate and severely degrade the image quality [11]. Figure 2 shows block diagram of DPCM encoder.

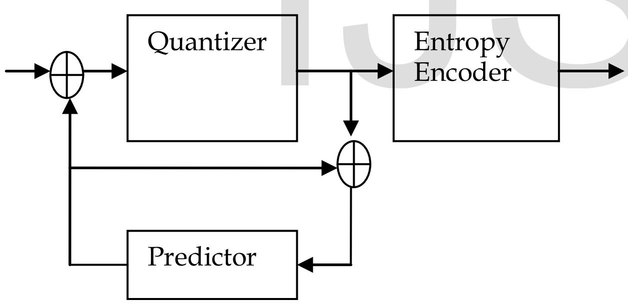

Fig. 2: DPCM encoder

5.2.2 Vector Quantization (VQ)

It extends basic principles of scalar quantization to multiple dimensions. In vector quantization, normally entropy coding is used. It exploits linear and non-linear dependence that exists among the components of a vector. A dictionary of fixed-size vectors, called code vectors can be generated by using this technique. A given image is then partitioned into non-overlapping blocks called image vectors. Then for each image vector, the closest matching vector in the dictionary is determined and its index in the dictionary is used as the encoding of the original image Vector [12,13]. Because of its fast lookup capabilities at the decoder side, VQ-based coding schemes are most widely used in multimedia applications.

5.2.3 Discrete Cosine Transform (DCT)

A discrete cosine transform (DCT) is the sequence of finitely many data points in terms of a sum of cosine functions oscillating at different frequencies. In this a reversible linear transform such as Fourier Transform is used to map the image into a set of transform coefficients, which are then Quantized and encoded. DCT and Fourier transforms convert images into frequency domain from time-domain to de-correlate the pixels in an image [14].

There are two types of DCT as given below.

One-Dimensional DCT

Commonly used discrete cosine transform with 1-D sequence of length N is given by:

$$P(i) = \alpha(i) \sum_{X=0}^{L-1} f(x) \cos\left[\frac{\pi(2x+1)i}{2L}\right] \quad \textbf{(1)}$$

For i = 0, 1, 2… L −1.

and the inverse DCT is defined as

$$f(x) = \sum_{i=0}^{L-1} \alpha(i) P(i) \cos\left[\frac{\pi(2x+1)i}{2L}\right] \quad \textbf{(2)}$$

For x = 0, 1, 2… L −1.

Where α (i) is defined as

$$\alpha(i) = \begin{cases} \sqrt{\frac{1}{L}} & for\ i = 0 \\ \sqrt{\frac{2}{L}} & for\ i \neq 0 \end{cases} \quad (3)$$

From first equation it is clear that for

$$i = 0,\ P(i = 0) = \sqrt{\frac{1}{L}} \sum_{x=0}^{L-1} f(x). \quad \textbf{(4)}$$

Thus, the first transform coefficient is the average value of the sample sequence. The value of each coefficient is referred to as the DC Coefficient. Whereas all other transform coefficients are called the AC Coefficients.

Two-Dimensional DCT

The one of many transforms that takes its input and transforms it into a linear combination of weighted basis functions i.e. the frequency is the Discrete Cosine Transform (DCT). If 1-D DCT applied twice i.e. Once in the x direction, and again in the y direction then the resulting form is the 2-D Discrete Cosine Transform. For large image doing this in-

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creases computational complexity thus, many algorithms, such as the Fast Fourier Transform (FFT), have been develop to speed up the computation. Equation (Eq.5) shows the computation of i, jth entry of the DCT of an image.

$$Q(l,j) = \frac{1}{\sqrt{2L}} P(l)P(j) \sum_{x=0}^{L-1} \sum_{y=0}^{L-1} T(x,y) \cos\left[\frac{(2x+1)l\pi}{2L}\right]$$

$$* \quad \cos\left[\frac{(2y+1)j\pi}{2L}\right] \qquad (5)$$

$$P(i) = \begin{cases} \frac{1}{\sqrt{2}}, & if\ i = 0 \\ 1, & if\ i > 0 \end{cases} \qquad \textbf{(6)}$$

Where T(x, y) represents the xth , yth element of the image represented by the matrix T. L is the block size on which the DCT is applied. The equation calculates one entry (l, jth) of the transformed image from the pixel values of the original image matrix. For 8x8 standard block size that JPEG compression uses, L equals to 8 and x and y range from 0 to 7. Thus Q(l, j) would be given by equation (7).

$$Q(i,j) = \frac{1}{4} P(l)P(j) \sum_{l=0}^{7} \sum_{j=0}^{7} T(x,y) \cos\left[\frac{(2x+1)l\pi}{16}\right] *$$

$$\left[\frac{(2y+1)j\pi}{16}\right] \qquad (7)$$

The resulting matrix depends on the horizontal and vertical frequencies because the DCT uses cosine functions. Therefore an image block with a lot of change in frequency shows very random looking matrix, while an image matrix of just one color, has a resulting matrix of a large value for the first element and zeroes for the other elements. In JPEG compression standard discrete cosine transform is used.

JPEG Process

1. Break the image into 8x8 blocks of pixels.
2. Apply DCT to each block from left to right, top to bottom.
3. Apply Quantization to compress each block.
4. The array of compressed blocks that constitute the image is stored in a drastically reduced amount of space.
5. Decompression using Inverse Discrete Cosine Transform (IDCT).

5.2.4 Wavelet Transform

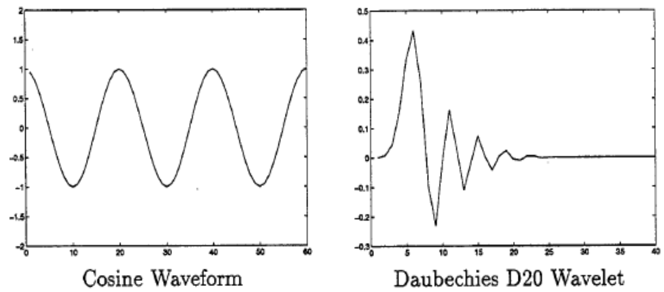

Fig.3: Cosine and Daubechies Wavelet

It is similar to that of the DCT, where image pixels are transformed to spatial frequency coefficients. Wavelet based image compression scheme differs in two different aspects. The first aspect is the basis function used for compression. The basis function in DCT is the cosine waveform. On the other hand wavelets can have one of many basis functions that meet certain criteria. The other aspect is in DCT image compression the image is divided into 8x8 sub images before transformation but for the wavelets transform, the whole image is used as a single input [15]. A wavelet is a waveform of effectively limited duration "localized in time," localized in frequency and has an average value of zero. Wavelets are the irregular and asymmetric waveforms as shown in figure 3.

The basic idea of the wavelet transform is to represent any arbitrary function (p) as a superposition of a set of such wavelets or basis functions. These basis functions or baby wavelets are obtained from a single prototype wavelet called the mother wavelet, by dilations or contractions (scaling) and translations (shifts). Figure 4 shows the block diagram of wavelet based image compression scheme.

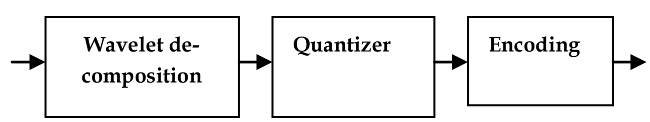

Fig. 4: Wavelet compression

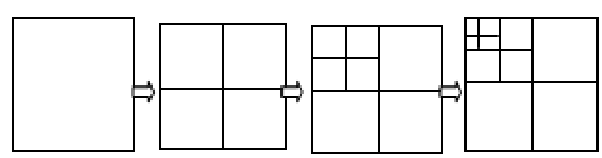

Fig.5: Original image 1st level 2nd level 3rd level

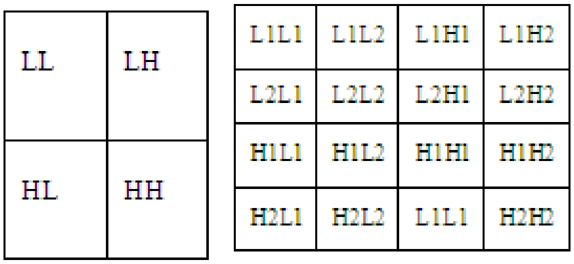

Fig.6: (a) Scalar wavelet (b) Multiwavelet decomposition

In many applications wavelet-based schemes (also referred as sub band coding) outperform other coding schemes like the one based on DCT. Since there is no need to block the input image and its basis functions have variable length, wavelet coding schemes at higher compression avoid blocking artifacts. Wavelet-based coding is more robust under transmission and decoding errors, and also facilitates progressive transmission of images. In addition, they are better matched to the HVS characteristics. Because of their inherent multi-resolution nature [16], wavelet coding schemes are especially suitable for applications where scalability and tolerable degradation are important. JPEG 2000 is based on DWT.

6 Conclusion

Thus we have carried out comparative study of image compression, different image compression schemes and their principle of working. From this survey it is seen that wide research has been taking place in this area in last decade. Depending on the types of application and storage required we can choose the suitable method for better compression of digital image. Again from this survey following observations can be notified:

• For text matters, FAX images, images generated using computer where we need nearly exact replica of original image, Lossless compression scheme such as Huffman's, LZW or RLE compression can be used.

The selection of suitable algorithm is based on the following criteria:

• The quality of the image required.
• The amount of compression required.
• Compression speed.

The quality of image depends on whether we use Lossless or Lossy compression technique. The amount of compression is depends on the type of compression scheme used and content to be discarding during compression. Factor such as nature of file, hardware used and type of compression algorithm used decides the speed of compression.

Through this survey we briefly introduce the techniques that utilize the statistical characteristics for image compression.

It is clear from this survey that the DCT-based image compression (JPEG) compress an image very well at moderate bit rates; however, at higher compression ratio, because of the artifacts resulting from the block-based DCT scheme the quality of the image degrades. Advantage of JPEG is that this is the current compression standard used in most of the applications such as MP3, Compact disk etc but its major disadvantage is quantization and bit allocation for each block.

In Wavelet-based coding(JPEG2000) because of overlapping basis functions and better energy compaction property of wavelet transforms, Substantial improvement will be seen in picture quality at low bit rates. Because of the inherent multi-resolution nature, wavelet-based coders facilitate progressive transmission of images thereby allowing variable bit rates. Wavelet based approach is state of art and achieve high compression ratio.

Keeping in view the ever increasing need for low bit rate compression methods and also the storage required for various types of data, scope exists for developing new methods as well as evolving more efficient algorithms in the existing methods. The review makes clear that, the field will continue to interest of researchers in the days to come.

The various issues like retrieval of accurate images, optimal representations for such images, and rapidly computing such optimal representations are the major challenges facing by the researchers of data compression. Image coding based on human perception, scalability, robustness, error resilience, and complexity are a few of the many challenges in image coding to be fully resolved and may affect image data compression performance in the years to come.

Table 1 shows the comparative analysis for various images for different parameters.

7 References

[1] I.F.Akyildiz, W.Su, Y.Sankarasubramaniam and E.Cayirci, "Wireless Sensor Networks: A Survey", Computer Networks 38(4)(2002) 393–422.

[2] Subramanya A. "Image Compression Technique," potentials IEEE, Vol. 20, issue 1, pp19-23, Feb-March 2001.

[3] Zhao W., Chellappa R., Rosenfeld A., Phillips P.J., Face Recognition: A Literature Survey, ACM Computing Surveys, Vol. 35, Issue 4, December 2003, pp. 399-458

[4] R. C. Gonzalez and R. E. Woods, "Digital Image Processing", 2nd Ed., Prentice Hall, 2004.

[5] Se-Kee Kil, Jong-Shill Lee, Dong-Fan Shen, Je-Goon Ryu, Dept. of Electronic Eng., Inha University, Korea, "Lossless Medical Image Compression using Redundancy Analysis", International Journal of Computer Science and 50 Network Security, VOL.6 No.1A, January 2006

[6] Z. Wang, A. C. Bovik, H. R. Sheikh and E. P. Simoncelli, "Image quality assessment: From error visibility to structural similarity," IEEE Transactions on Image Processing, Vol. 13, no. 4, 2004.

[7] Z. Wang, et al., —A Universal Image Quality Index, IEEE Proc, Vol.9, No.3, pp.81-84, 2002.

[8] Wang, E.-h. Y. 2009. Joint Optimisation Run-Length Coding, Huffman Coding, and Quantization Table with Complete Baseline JPEG Decoder Compatibility. IEEE Transactions on Image Processing , Volume No. 18, No.1, January.

[9] Ismail Avcibas, Nasir Memon, Bulent Sankur, Khalid Sayood, "A Progressive Lossless / Near Lossless Image Compression Algorithm,"IEEE Signal Processing Letters, vol. 9, No. 10, pp 312-314, October 2002.

[10] U. S. Mohammed and W. M. Abd-elhafiez, "Image coding scheme based on object extraction and hybrid transformation technique," Int. Journal of Engineering Science and Technology, vol.2, no. 5, pp. 1375–1383, 2010.

[11] Ranbeer Tyagi, D. K. Sharma, Bhopal (M.P.) India," Digital Image Compression Comparisons using DPCM and DPCM with LMS Algorithm", International Journal of Computer Applications & Information Technology Vol. I, Issue II, September 2012 (ISSN: 2278-7720)

[12] Y. Linde, A. Buzo and R.M.Gray, —An algorithm for vector quantizer design, IEEE Trans. Commun., vol.28, pp.84-95, Jan.2003

[13] A classical tutorial on vector quantization Vector quantization, R.M. Gray, IEEE ASSP Mag., vol.1, pp. 4-29, April 2004.

[14] Wallace, G. K. "The JPEG Still Picture Compression Standard", Comm. ACM, vol. 34, no. 4, April 1991, pp. 30- 44.

[15] N. Gupta, M. N. S. Swamy, and E. I. Plotkin, "Wavelet domain-based video noise reduction using temporal discrete cosine transform and hierarchically adapted thresholding," IET Image Process., vol. 1, no. 1,pp. 2–12, Mar. 2007.

[16] B. Goossens, A. Pizurica, and W. Philips, "Removal of correlated noise by modeling the signal of interest in the wavelet domain," IEEE Trans.Image Process., vol. 18, no. 6, pp. 1153–1165, Jun. 2009.

Image Type	Image Size	Bits/Pixel	Uncompressed Size (Kbytes)	Transmission Bandwidth(Megabits)	Time required
Text matter	11" x 8.5"	Variable	5Kbytes Approx.	32-64 Kbits/page	1.2 – 2.5 Sec
Grayscale Image	512 x 512	8 bpp	262 KB	2.1 Mb/Image	73Sec
Color Image	512 x 512	24 bpp	786 KB	6.29 Mb/Image	219 Sec
Medical Image	2048 x 1680	12 bpp	5.16 MB	41.3 Mb/Image	1434 Sec
SHD Image	2048 x 2048	24 bpp	12.58 MB	100 Mb/Image	3495 Sec

Table 1: Parameters for different images.