Progressive Image Compression Analysis Using Wavelet Transform

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ABSTRACT

With the use of digital cameras, requirements for storage, manipulation, and transfer of digital images has grown explosively. These images can be very large in size and can occupy a lot of memory, so compression of images is required for efficient transmission and storage of images. Image data comprise of a significant portion of the multimedia data and they occupy the major portion of the channel bandwidth for multimedia communication. Therefore development of efficient techniques for image compression has become quite necessary. The design of data compression schemes involves trade-offs among various factors, including the degree of compression, the amount of distortion introduced (if using a lossy compression scheme) and the computational resources required for compressing and decompressing of images. Wavelet based compression methods, when combined with SPIHT (Set Partitioning in Hierarchical Trees) algorithm gives high compression ratio along with appreciable image quality (like lossless). SPIHT belongs to the next generation of wavelet encoders, employing more sophisticated coding. In fact, SPIHT exploits the properties of the wavelet-transformed images to increase its efficiency. Progressive image compression methods are more efficient than conventional wavelet based compression methods it gives the facility to user choose the best compressed image which does not have recognizable quality loss.

Keywords- Compression, SPIHT, PSNR, MSE, Wavelet.

I. INTRODUCTION

Image compression is minimizing the size in bytes of a graphics file without degrading the quality of the image to an unacceptable level. The reduction in file size allows more images to be stored in a given amount of disk or memory space. Demand for communication of multimedia data through the telecommunications network and accessing the multimedia data through Internet is growing explosively with the use of digital cameras, requirements for storage, manipulation & transfer of digital images. These images files can be very large and can occupy a lot of memory. A gray scale image that is 256 X 256 pixels has 65,536 elements to store, and a typical 640 x 480 color image has nearly a million. Downloading of these files from internet can be very time consuming task, so image compression is necessary at this stage.

II. TYPES OF COMPRESSION

Lossless versus Lossy compression: In lossless compression schemes, the reconstructed image, after compression, is numerically identical to the original image [5]. However lossless compression can only achieve a modest amount of compression. Lossless compression is preferred for archival purposes and often medical imaging, technical drawings, clip art or comics. But lossy schemes are capable of achieving much higher compression this is because lossy compression methods, especially used at low bit rates[4],[17].An image reconstructed following lossy compression contains degradation relative to the original. Lossless methods concentrate on compacting the binary data using encoding algorithms - the most commonly used example is WinZip. To achieve higher levels of compression there are Lossy encoding techniques. Lossy encoding methods (such as JPEG) are varied but tend to work on the principle of reducing the total amount of information in the image in ways that the human eye will not detect.

III. WHY WAVELET BASED COMPRESSION

The power of Wavelet comes from the use of multi-resolution. Rather than examining entire signals through the same window, different parts of the waves are viewed through different size windows (or resolutions)[2],[8]. Wavelets are functions defined over a finite interval and having an average value of zero. The basic idea of the wavelet transform is to represent any arbitrary function (t) as a superposition of a set of such wavelets or basic
functions [3],[8]. These basic functions or baby wavelets are

obtained from a single prototype wavelet called the mother wavelet, by dilations or contractions (scaling) and translations (shifts).

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi(\frac{t-b}{a}) \qquad (1)$$

where a is the scaling parameter and b is the shifting parameter.

Another advantage of wavelet is thresholding [7]. Thresholding is a simple non-linear technique, which operates on one wavelet coefficient at a time. In its most basic form, each coefficient is thresholded by comparing against threshold, if the coefficient is smaller than threshold, set to zero; otherwise it is kept or modified. In wavelet transform the image is divided in low and high frequency portion, and these low and high frequency portion is further divided, after a threshold is applied to all the portion except LL portion because it is nature of the information to reside in low frequency portion of signal and less affected by noise [2][7].

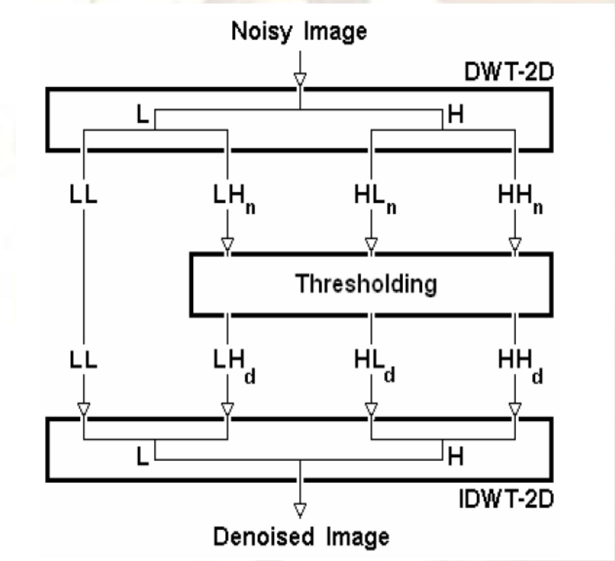


Fig.1: Thresholding of an image

V. PROGRESSIVE APPROACH OF COMPRESSION USING SPIHT

One of the most efficient algorithms in the area of image compression is the Set Partitioning In Hierarchical Trees (SPIHT). In essence it uses a sub-band coder, to produce a pyramid structure where an image is decomposed sequentially by applying power complementary low pass and high pass filters and then decimating the resulting images [1]. These are one-dimensional filters that are applied in cascade (row then column) to an image whereby creating a four-way decomposition: LL (low-pass then another low pass), LH (low pass then high pass), HL (high and low pass) and finally HH (high pass then another high pass)[1],[2]. The resulting LL version is again four-way decomposed, this process is repeated until the top of the pyramid is reached.

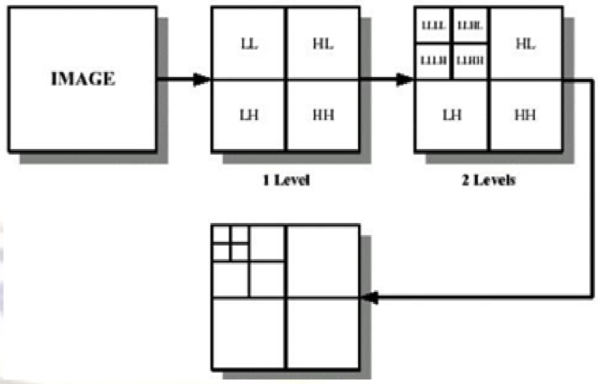


Fig.2: Decimation of an image in low & high frequency portion

Progressive methods convert the original image in to intermediate format then it is converted in to appropriate format. In fact, SPIHT exploits the properties of the wavelet-transformed images to increase its efficiency. SPIHT based method provide following advantages.

1. Encoding/Decoding Speed

The SPIHT algorithm is nearly symmetric, i.e., the time to encode is nearly equal to the time to decode. (Complex compression algorithms tend to have encoding times much larger than the decoding times). The SPIHT process represents a very effective form of entropy-coding. Binary-encoded (extremely simple) and context-based adaptive arithmetic coded (sophisticated). Surprisingly, the difference in compression is small, showing that it is not necessary to use slow methods [5]. A fast version using Huffman codes are used in this method [4]. a straightforward consequence of the compression simplicity is the greater coding/decoding speed.

2. Optimized Embedded Coding

SPIHT is an embedded coding technique. In embedded coding algorithms, encoding of the same signal at lower bit rate is embedded at the beginning of the bit stream for the target bit rate [5], [12]. Effectively, bits are ordered in importance. This type of coding is especially useful for progressive transmission using an embedded code; where an encoder can terminate the encoding process at any point [5].

3. Uniform Scalar Quantization

For image coding using very sophisticated vector quantization, SPIHT achieved superior results using the simplest method: uniform scalar quantization [20].

4. Image Quality

SPIHT based methods gives very good quality images At first it was shown that even simple coding methods produced good results when combined with wavelets. SPIHT belongs to the next generation of wavelet encoders, employing more sophisticated coding. In fact, SPIHT exploits the properties of the wavelet-transformed images to increase its efficiency [1],[21]. The SPIHT advantage is even more pronounced in encoding color images.

5. Progressive Image Transmission

In some systems with progressive image transmission (like www browsers) the quality of the displayed images follows the sequence: (a) weird abstract (b) you begin to believe that it is an image of something; (c) CGA-like quality; (d) lossless recovery. With very fast links the transition from (a) to (d) can be so fast that you will never notice. Considering that it may be possible to recover an excellent-quality image using 10-20 times less bits, it is easy to see the inefficiency. Furthermore, the mentioned systems are not efficient even for lossless transmission. If an image were transferred over a slow network like the Internet, it would be nice if the computer could show what the incoming picture looks like before it has the entire file. This feature is often referred to as progressive encoding [21].

IV. COMPRESSION QUALITY EVALUATION

Performance analysis of a compressed image is judged by three parameters.

1. Compression ratio:

The data compression ratio is analogous to the physical compression ratio used to measure physical compression of substances, and is defined in the same way, as the ratio between the compressed size image to the original size:

CR = Compressed Size/ Original Size (2)

2. Mean Square Error:

Two commonly used measures for quantifying the error between images are Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR)[12]. The MSE between two images I and k is defined by

$$MSE = \frac{1}{MN}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left\| I(i,j) - K(i,j) \right\|^2 \qquad (3)$$

where the sum over j; k denotes the sum over all pixels in the images, and N is the number of pixels in each image [7].

3. Peak Signal to Noise Ratio:

PSNR tends to be cited more often, since it is a logarithmic measure, and our brains seem to respond logarithmically to intensity [12]. Increasing PSNR represents increasing fidelity of compression

$$PSNR = 20\log_{10}\left(\frac{MAX_1}{\sqrt{MSE}}\right) \qquad (4)$$

Here, MAX_i is the maximum possible pixel value of the image.

V. ANALYSIS OF VARIOUS IMAGE PROCESSING PARAMETER USING HAAR WAVELET (SPIHT)

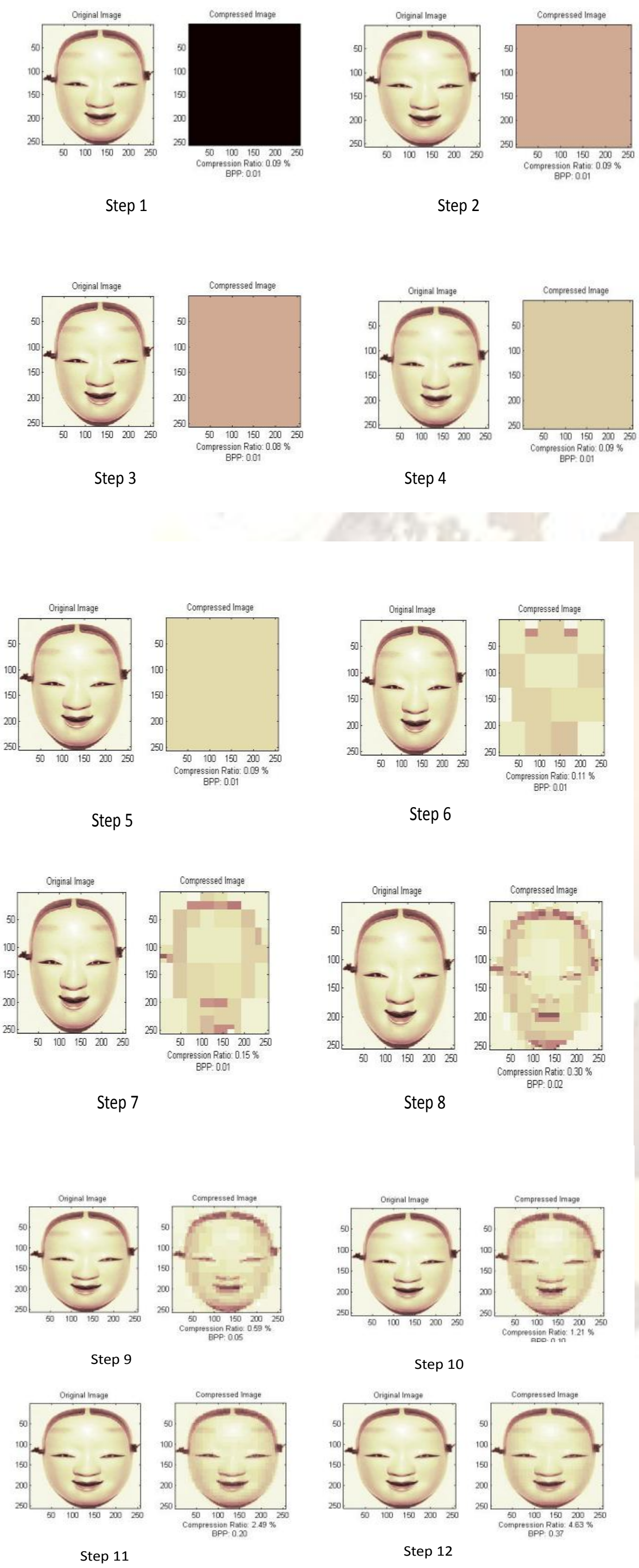
The Haar transform is the simplest of the wavelet transforms. This transform cross-multiplies a function against the Haar wavelet with various shifts and stretches, like the Fourier transform cross-multiplies a function against a sine wave with two phases and many stretches. The Haar wavelet is a certain sequence of rescaled "square-shaped" functions which together form a wavelet family or basis. Wavelet analysis is similar to Fourier analysis in that it allows a target function over an interval to be represented in terms of an orthonormal function basis.

Table 1: Result of different parameter using SPIHT based method with haar wavelet transform

STEPS	CR	BPP	MSE	PSNR
1	0.09	0.01	6.3739e+004	2.37
2	0.09	0.01	6.3739e+004	10.08
3	0.09	0.01	6.3739e+004	10.08
4	0.09	0.01	3.6824e+003	12.46
5	0.09	0.01	3.1046e+003	13.21
6	0.11	0.01	2.3597e+003	14.40
7	0.15	0.01	1.6745e+003	15.89
8	0.30	0.02	997.23	18.23
9	0.59	0.05	501.25	21.13
10	1.21	0.10	242.77	24.27
11	2.49	0.20	105.27	27.89
12	4.63	0.37	41.72	31.92
13	7.51	0.60	17.03	35.81
14	11.81	0.94	7.09	39.62
15	18.62	1.49	3.23	43.03
16	29.79	2.38	1.68	45.86
17	44.80	3.58	1.17	47.43
18	44.80	3.58	1.17	47.43
19	44.80	3.58	1.17	47.43
20	44.80	3.58	1.17	47.43

VI.RESULTS AND DISCUSSIONS

Progressive methods starting with the well known SPIHT algorithm using the Haar wavelet. The key parameter is the no. of steps. Increasing it leads to better recovery of MSE and PSNR value but worse compression ratio as we going through the table we find that step 12,13,14 gives satisfactory results. The compression ratio CR means that the compressed image is stored using only CR% of the initial storage size.The Bit-Per-Pixel(BPP) gives the no. of bits use to store one pixel of the image.



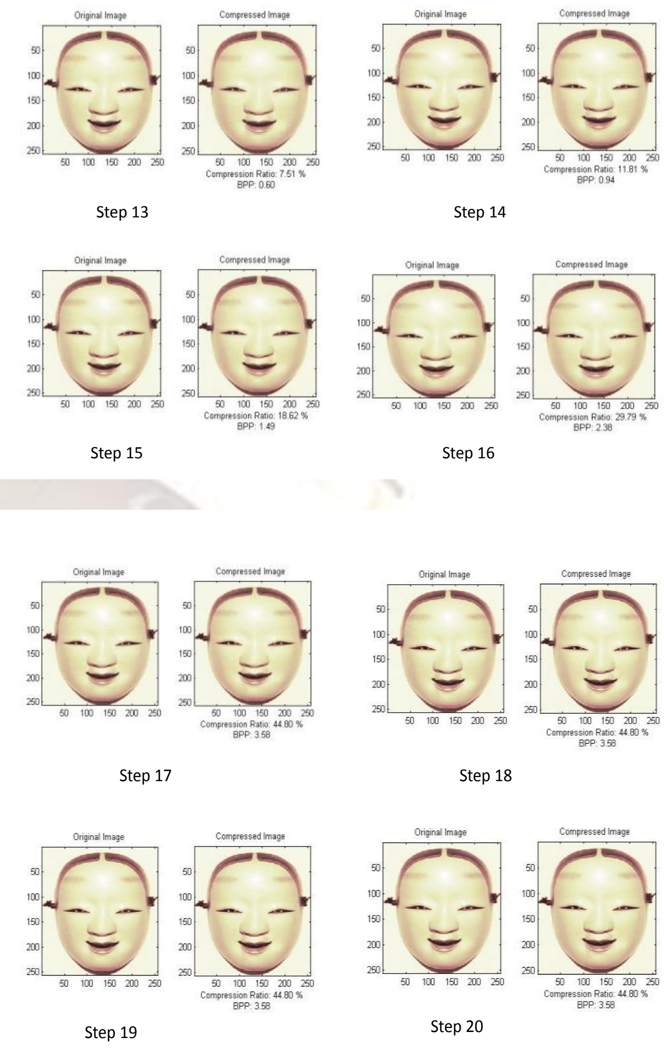
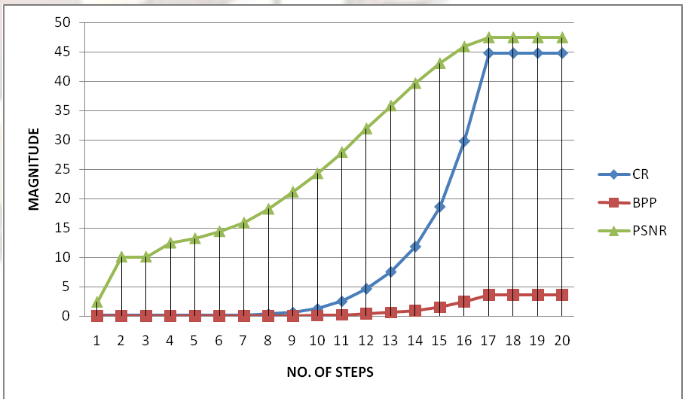


Fig.2: Results of various compressed image



the user to achieve appropriate compression ratio, PSNR and MSE, means by choosing various steps he decide which step is suitable for compression. this method is different from other wavelet compression methods because in conventional method wavelets compress maximum level and not give the facility to choose user from a set of compressed image but in SPIHT algorithm progressive compression ratio gives this facility to which compressed image user want to be send on transmission channel. In the above graph CR for step 1-5 is fixed (no changes) further it increases and going constant after step 17 which shows further compression of image is not possible.

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