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Implementation of the Wavelet Transformation for Image Compression System

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***Abstract*— Image compression can be used to reduce the size of the image before transmission it. The compressed image retains many of the original image's features but requires less bandwidth. This paper proposes to show how to compress and uncompress a true-color image. The goal of the true compression is to minimize the length of the sequence of bits needed to represent the image, while preserving information of acceptable quality. Wavelet contributes to effective solutions for this problem. The complete chain of compression includes phases of quantization, coding and decoding in addition of the wavelet processing itself. A synthesis performance of the compression is given by the compression ratio and the Bit-Per-Pixel ratio which are equivalent. The challenge of compression methods is to find the best compromise between a weak compression ratio and a good perceptual result. The work presented in this paper involved developing an image compression system based on the wavelet transforming using Set Partitioning In Hierarchical Trees (SPIHT) coding in the MATLAB environment.**

***Keywords*—Coding Scheme, Image Compression, True-color Images, Wavelet, Compression Methods.**

I. INTRODUCTION

When the image compression is studied, there are generally two different solutions, the lossless and lossy concepts of operation. Lossless compression techniques are essential in archival and communication of medical images. True-color images can be compressed along the same scheme as the grayscale images by applying the same strategies to each of the three color components. It can be said that one image contains thousands of pixels. For example, the 512×512 pixels image contains total 262,144 pixels which represent features of this entire image. If the resolution for each pixel is 8 bits, the format requires 256KB of memory per image. Even now, after the rapid development in computer engineering, it is necessary to study an efficient image compression technology when large image data are an important issue in many scientific and engineering applications. Recently, image compression is an important methodology to reduce the large amounts of handling image data; such technology can improve the working speed in the transmission and storage of the popular multimedia, video, medical diagnosis and interpretation systems [1]. A good image compression skill is not only achieving the highest compression rate but also assuring the good quality of the compressed image. The design of the wavelet based image compression system can be considered as two dimensional pixel array I with N rows and N columns. One component of image compression is transform coding whereby the image is transformed into another domain, such as DWT domain. The purpose of this transformation is to take advantage of some characteristics of the image so that the energy of the transformed image is localized into a small number of pixels.

As can be seen in Fig. 1, image compression systems are composed of two distinct blocks: an encoder and a decoder. Image f(x, y) is fed into the encoder, which creates a set of data symbols from the input data and uses them to represent the image. Let n_1 and n_2 denote the number of bits in the original and encoded images, respectively, the compression that is achieved can be quantified numerically via the compression ratio:

$$C_R = \frac{n_1}{n_2} \qquad (1)$$

A compression ratio like 10 (or 10:1) indicates that the original image has 10 information carrying units (e.g. bits) for every 1 unit in the compressed data set.

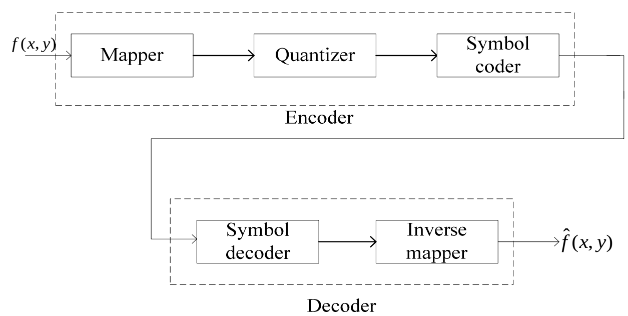

Fig. 1 Block diagram of a general image compression system [2]

In the first stage of the encoding process, the mapper transforms the input image into a format designed to reduce the interpixel redundancies. The second stage, or quantizer block, reduces the accuracy of the mapper's output in accordance with a predefined fidelity criterion- attempting to eliminate only psychovisually redundant data. This operation is irreversible and must be omitted when error-free compression is desired. In the third stage, or final stage of this process, the symbol coder creates a code for the quantizer output and maps the output in accordance with the code.

The decoder in Fig. 1 contains only two components: a symbol decoder and an inverse mapper. These blocks perform, in reverse order, the inverse operations of the encoder's symbol coder and mapper blocks. For measuring the difference between two signals, there is a compromise between visual perception and easiness of computation [2].

Two quantitative measures giving equivalent information are commonly used as a performance indicator for the compression:

- The compression ratio CR, which means that the compressed image is stored using only CR% of the initial storage size.
- The Bit-Per-Pixel ratio BPP, which gives the number of bits required to store one pixel of the image.

Two measures are commonly used to evaluate the perceptual quality:

- The Mean Square Error MSE, which represents the mean squared error between the compressed image and the original image and is given by:

$$MSE(x,y)=\frac{1}{n}\sum_{i=0}^{n-1}(x_i-y_i)^2 \quad (2)$$

The lower the value of MSE, the lower the error.

- The Peal Signal to Noise Ratio (PSNR), which represents a measure of the peak error and is expressed in decibels. It is defined by:

$$PSNR=10\log_{10}\frac{255}{MSE(x,y)} \quad (3)$$

The higher the PSNR, the better the quality of the compressed or reconstructed image.

In this work, Progressive Coefficients Significance Methods (PCSM) is used to compress the true-color image. The simulation results give the difference between haar and biorthogonal (4, 4) wavelets in the MATLAB environment.

II. Discrete Wavelet Transform

When digital images are to be viewed or processed at the multiple resolutions, the Discrete Wavelet Transform (DWT) is the mathematical tool of choice. In addition to being an efficient, highly intuitive framework for the representation and storage of multiresolution images, the DWT provides powerful insight into an image's spatial and frequency characteristics. The Fourier Transform, on the other hand, reveals only an image's frequency attributes. The choice of wavelet functions as primitives promises to be good, because natural signal x like audio streams or images consist of same structures at different scales and different positions. Wavelets correspond to multiresolution analysis due to reversibility and the efficient computation of the appropriate transform [3].

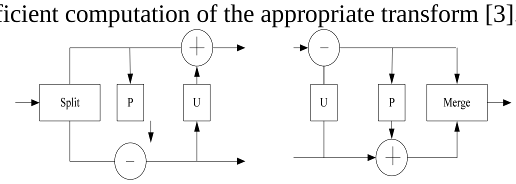

Fig. 2 Lifting scheme [3]

There exist two ways to implement the computation of the discrete wavelet transform. The first approach uses filtering with appropriate boundary handling; the second is a fast lifting approach. Lifting scheme is derived from a polyphase matrix representation of the wavelet filters, a representation that is distinguishing between even and odd samples. Using the algorithm of filter factoring, the original filter can be split into a series of shorter filters. Those filters are designed as lifting steps. Lifting scheme has one disadvantage-the filter has to be factorized before starting the computation. Computational savings of the scheme are gained from the length of the filter. In this paper haar and biorthogonal (4,4) wavelets are used for the image compression. The scaling and wavelet functions for decomposition and reconstruction are symmetric. Symmetry is a very important property if the image compression is considered, because in the absence of symmetry artifacts are introduced around edges.

III. SPIHT Coding Scheme

Said and Pearlman have significantly improved the codec of Shapiro. The main idea is based on partitioning of sets, which consists of coefficients or representatives of whole sub-trees [4]. SPIHT assumes that the decomposition structure is the octave-band structure and then uses the fact that sub-bands at different levels but of the same orientation display similar characteristics. SPIHT defines spatial parent-children relationships in the decomposition structure and describes this collocation with one to four parent-children relationships,

$$Parent=(x,y) \quad (4)$$

$$Children=[(2x,2y), (2x+1,2y), (2x,2y+1), (2x+1,2y+1)] \quad (5)$$

where the parent is in a sub-band of the same orientation as the children but at a smaller scale. If the data is ordered as previously described and every level of decomposition produces sub-bands of exactly half the size of the previous sub-bands, then the parent-children relationships in two dimensions become.

Working of SPIHT consists of two passes, the ordering pass and the refinement pass. In the ordering pass SPIHT attempts to order the coefficients according to their magnitude. In the refinement pass the quantization of coefficients is refined. The ordering and refining is made relative to a threshold. The threshold is appropriately initialized and then continuously made smaller with each round of the algorithm. SPIHT makes use of three lists-the List of Significant Pixels (LSP), List of Insignificant Pixels (LIP) and List of Insignificant Sets (LIS). These are coefficient location lists that contain their coordinates [5].

The algorithm has several advantages. The first one is an intensive progressive capability- we can interpret the decoding at any time. This is desirable when transmitting files over the internet, since users with slower connection speeds can download only a small part of the file, obtaining much more useful results when compared to other codec such as progressive JPEG. Second advantage is a very compact output bitstream with large bit variability.

But SPIHT is very vulnerable to bit corruption. A single bit error can introduce significant image distortion depending on its location. For SPIHT to be employed in real-time applications, interleaving and multiple channel codes are used for error protection of different portions of the SPIHT stream. The progressive properties of SPIHT come with the property of graceful degradation at low bit rates in the sub-band coding scheme. This graceful degradation makes intermediate low bit rate results meaningful not just noise-like. In this paper we can see better results due to SPIHT coding scheme.

IV. Image Compression

The purpose of image compression is to reduce the amount of data required to represent a digital image. Compression is achieved by the removal of one or more of three basic data redundancies:(1) coding redundancy, which is present when less than optimal (i.e. the smallest length) code words are used; (2) inter-pixel redundancy, which results from correlations between the pixels of the image; and (3) psychovisual redundancy, which is due to data that is ignored by the human visual system. The two types of image compression method are lossless and lossy compression. In lossless compression, the image can be recovered without any degradation of the image. There is no loss of information at all.

Image data can be either indexed or true-color. An indexed images stores colors as an array of indices into the figure colormap. A true-color image does not use a colormap; instead, the color values for each pixel are stored directly as RGB triplets. The property of true-color image is a three dimensional array (m-by-n-by-3). This array consists of three m-by-n matrices (representing the red, green and blue color planes) concatenated along the third dimension. In a true color image of class double, the data values are floating-point numbers in the range [0, 1]. In a true-color image of class unit8, the data values are integers in the range [0,255], and for true-colour image of class unit16 the data values are integers in the range [0, 65535].

In this paper Progressive Coefficients Significance Methods (PCSM) are used to compress true-color image. These methods are:

- Embedded Zerotree Wavelet (EZW)
- Set Partitioning In Hierarchical Trees (SPIHT)
- Spatial-orientation Tree Wavelet (STW)
- Wavelet Difference Reduction (WDR)
- Adaptively Scanned Wavelet Difference Reduction (ASWDR).

V. Simulation Results

The software simulation results give the effects of wavelet based image compression. Especially, size and dimensions are important to implement this simulation. Digital colour image (Peppers) is used to obtain the results. In the MATLAB environment, the wcompress command compresses the image X using the compression method COMP_METHOD. And then compression ratio (CR), bits per pixel (BPP), mean square error (MSE) and peak signal to noise ratio (PSNR) are calculated to compare the differences between the original and the compressed images. In this paper haar and bi-orthogonal (4, 4) wavelets are used to test the various compression methods. Among these methods, SPIHT gives the best results for both wavelets. The users can choose the compression steps as required. In this work the compression step can be set as 12 because of its compression ratio, which indicates the compressed image is stored using CR% of the initial storage size.

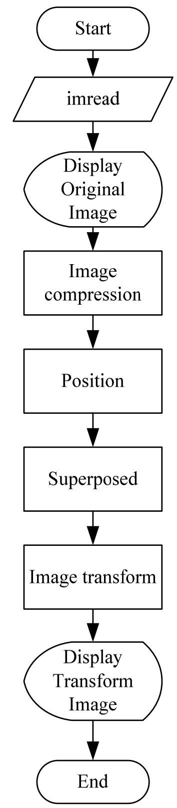

Fig. 3 Flow chart of image compression system

TABLE I
COMPRESSION RESULTS FOR HAAR WAVELET USING PCSM

Method	Bits Per Pixel (BPP)	Compression Ratio (CR)	Mean Square Error (MSE)	Peak Signal to Noise Ratio (PSNR)
EZW	1.7929	7.4703	14.0943	36.6404
SPIHT	0.6107	2.5444	36.1885	32.5451
STW	0.8690	3.6209	30.0003	33.3596
WDR	2.0853	8.6889	14.0943	36.6404
ASWDR	1.9682	8.2010	14.0943	36.6404

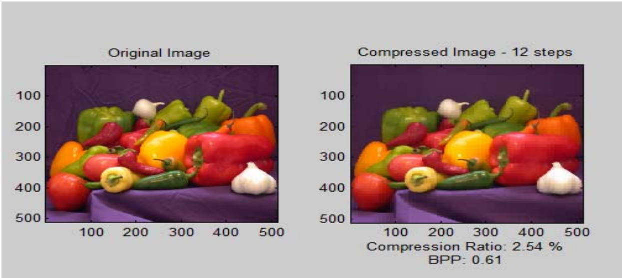

Fig. 4 Peppers image compression result for haar wavelet using SPIHT method

This simulation revealed a fact that SPIHT is the most efficient method. It is also important to understand how image size affects the compression. It is obvious that higher image resolution leads to better quality result as shown in Fig. 3.

In Fig. 4, image compression is implemented by using biorthogonal (4,4) wavelet. As can be seen, biorthogonal (4,4) wavelet gives better results than haar wavelet. Moreover, in Table 2 the various compression methods are used to compare the results. In fact, both the wavelets give symmetry. This work results in the compressed image with small distortion error. Especially, step 12 is good to achieve the compressed image similar to the original image because of its compression ratio.

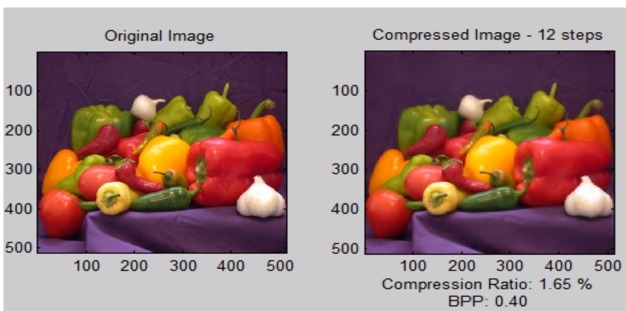

Fig. 5 Peppers image compression result for bior4.4 wavelet using SPIHT method

TABLE II
COMPRESSION RESULTS FOR BIORTHOGONAL (4, 4) WAVELET USING PCSM

Method	Bits Per Pixel (BPP)	Compression Ratio (CR)	Mean Square Error (MSE)	Peak Signal to Noise Ratio (PSNR)
EZW	1.1807	4.9196	10.3825	37.9678
SPIHT	0.3966	1.6527	26.7808	33.8526
STW	0.8690	3.6209	30.0003	33.3596
WDR	1.3055	5.4394	10.3825	37.9678
ASWDR	1.2635	5.2644	10.3825	37.9678

VI. Conclusions

The outstanding efficiency of the DWT-SPIHT image compression has been demonstrated. SPIHT coding results are very unpredictable in that sense. In the future much more effort must be emerged in order to make the codec more resilient against bit or synchronization errors, which should be quite challenging task in order to keep the embedded character of the bit stream together with the progressive behaviour.

This is important due to the fact that a square of fixed size is usually used as a processing segment for compression of this type, so the quality and size of the image should be carefully decided. The subjective quality of reconstructed image is very good even though compression ratio is set noticeably high. This fact confirms the exceptional SPIHT efficiency.

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