www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 3 Issue 6 June, 2014 Page No. 6538-6543

SPIHT ALGORITHM BASED COLOR IMAGE COMPRESSION

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Abstract— Embedded zero tree wavelet(EZW) coding is a very effective and computationally simple technique for image compression. Here we present a new and different implementation based on set partitioning in hierarchical trees(SPIHT).It is based on the principles of partial ordering by magnitude with a set partitioning sorting algorithm, ordered bit plane transmission and exploitation of self similarity across different scales of an image wavelet transform. The image coding results calculated from actual file sizes and images reconstructed by the decoding algorithm are either comparable to or surpass previous results obtained through much more sophisticated and computationally complex methods. In addition, the new coding and decoding procedures are extremely fast, and they can be made even faster, with only small loss in performance, by omitting entropy coding of the bit stream by arithmetic coding. It can be used for future still and moving image coding systems. Additional features required for this include fidelity and resolution scalability, region of interest enhancement, random access decoding, resilience to errors due to channel noise or packet loss, fast encoding and/or decoding speed and low computational and hardware complexity.

***Index Terms*—color, image,pixel,PSNR,HVS**
(key words)

I. INTRODUCTION

Compression of images saves storage capacity, channel bandwidth, and transmission time. Image compression techniques, especially non-reversible or lossy ones have been known to grow computationally more complex as they grow more efficient. Digital image compression is a very popular research topic in the field of multimedia processing. The major focus of research is to develop different compression schemes/algorithms in order to provide good visual quality and fewer bits to represent an image in digital format. These compression schemes are either implemented in software using higher-level languages such as C or Java or in hardware using application specific integrated circuit (ASIC). Data compaction, or lossless coding, is a reversible processing in which the original data can always be recovered from the encoded data without any loss of information, since lossless coding exploits only the statistical redundancy of the image, the compression ratio achieved rarely exceeds 2 : 1, A much better performance is guaranteed by data compression, or lossy coding, which easily achieves compression ratios of 10 : 1 and more. A number of techniques have been proposed. To obtain a good encoding performance with limited complexity, many researchers rely on transform coding techniquesEffective and computationally simple techniques of transform-based image coding is Set Partition in Hierarchical Tree algorithm, introduced by Said and Pearlman in their successful effort to extend and improve Shapiro‟s EZW (Embedded Zerotree Wavelet) algorithm.The SPIHT algorithm has since become a standard benchmark in image compression.The SPIHT scheme employs an iterative partitioning or splitting of sets or groups of pixels (or transform coefficients), in which the tested set is divided when the maximum magnitude within it exceeds a certain threshold. When the set passes the test and is hence divided, it is said to be significant. Otherwise it is said to be insignificant. Insignificant sets are repeatedly tested at successively lowered thresholds until isolated significant pixels are identified. This procedure sorts sets and pixels by the level of their threshold of significance. The results of these so-called significance tests describe the path taken by the coder to code the source samples. Since the binary outcomes of these tests are put into the bit stream as a 1 or 0 the decoder at the destination can duplicate the execution path of the encoder.The principle of set partitioning and sorting by significance is the key to excellent coding performance with very low computational complexity. An important characteristic is the capability of progressive transmission and embededness. Progressive transmission refers to the transmission of information in decreasing order of its information content. In other words, the coefficients with the highest magnitudes are transmitted first. Since these coding schemes transmit value information in decreasing order of significance, this ensures that the transmission is progressive. Schemes like EZW, SPIHT maintain a list of significant pixels, so that their bits can be sent in decreasing bit plane order. Such a transmission scheme makes it possible for the bit-stream to be embedded, i.e., a single coded file can used to decode the image at almost any rate less than or equal to the coded rate, to give the best reconstruction possible with the particular coding scheme.

In order to compress a binary file, some prior information must be known about the properties and structure of the file in order to exploit the abnormalities and assume the consistencies. The information that we know about the image file that is produced from wavelet transformation is that it can be represented in a binary tree format with the root of the tree having a much larger probably of containing a greater pixel magnitude level than that of the branches of the root. The algorithm that takes advantage of this information is the Set Partition in Hierarchical Tree (SPHT) algorithm.

WHAT IS COMPRESSION

During compression, data that is duplicated or that has no value is eliminated or saved in a shorter form, greatly reducing a file‟s size. For example, if large areas of the sky are the same shade of blue, only the value for one pixel needs to be saved along with the locations of the other pixels with the same color. When the image is then edited or displayed, the compression process is reversed. There are two forms of compression—**lossless and lossy.**

Lossless : In lossless compression schemes, the reconstructed image, after compression, is numerically identical to the original image. However lossless compression can only achieve a modest amount of compression.

Lossy: An image reconstructed following lossy compression contains degradation relative to the original. Often this is because the compression scheme completely discards redundant information. However, lossy schemes are capable of achieving much higher compression. Under normal viewing conditions, no visible loss is perceived (visually lossless).

TYPES OF DIGITAL IMAGES:

There are four types of image representations namely

1. Binary images
2. RGB images

1. **BINARY IMAGES:**In a binary image, each pixel assumes one of only two Discrete values. Essentially, these two values correspond to on and off. A binary image is stored as a logical array of 0's

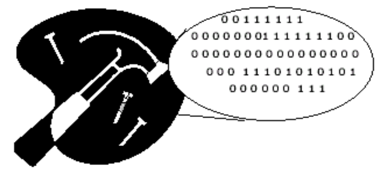

Fig. 1. Binary Image

2. **RGB IMAGES:**

An **RGB** image, sometimes referred to as a **true color** image, is stored in MATLAB as an **m-by-n-by-3** data array that defines **red**, **green**, and **blue** color components for each individual pixel. The color of each pixel is determined by the combination of the red, green, and blue intensities stored in each color plane at the pixel's location.

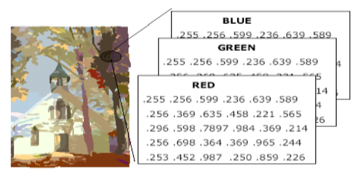

Fig. 2 RGB image

II. COMPRESSION BY SPIHT METHOD :

This method provides the following features good image quality, high PSNR, especially for color images;
it is optimized for progressive image transmission; produces a fully embedded coded file; simple quantization algorithm; fast coding/decoding (nearly symmetric); has wide applications, completely adaptive; can be used for lossless compression.
can code to exact bit rate or distortion; efficient combination with error protection.

III. THE USUAL STEPS INVOLVED IN COMPRESSING AN IMAGE ARE

1. Specifying the Rate (bits available) and Distortion (tolerable error) parameters for the target image.

2. Dividing the image data into various classes, based on their importance.

3. Dividing the available bit budget among these classes, such that the distortion is a minimum.

4. Quantize each class separately using the bit allocation information derived in step 3.

5. Encode each class separately using an entropy coder and write to the file.

IV. RECONSTRUCTING THE IMAGE FROM THE COMPRESSED DATA

1. Read in the quantized data from the file, using an entropy decoder. (reverse of step5).

2. Dequantize the data. (reverse of step 4).

3. Rebuild the image. (reverse of step 2).

V. PROGRESSIVE IMAGE TRANSMISSION

The original image is defined by a set of pixel values Pi,j ,where (i,j) is the pixel coordinate. The coding is done to the two dimensional arrays.

$$\mathbf{C = \Omega(P),}$$

Where Ω(.) represents a unitary hierarchical subband transformation. The two dimensional array C has the same dimensions of P, and each element Ci,j is called transform coefficient at coordinate (i,j). For the purpose of coding we assume that each ci,j is represented with a fixed point binary format, with a small number of bits. Typically 16 or less and can be treated as an integer.

In a progressive transmission scheme, the decoder initially sets the reconstruction vector ĉ to zero and updates its components according to the coded message .After receiving the value(approximate or exact) of some coefficients, the decoder can obtain a reconstructed image

A major objective in a progressive transmission scheme is to select the most important information-which yields the largest distortion reduction-to be transmitted first, For this selection we use the mean squared-error (MSE) distortion measure,

$$D_{mse}(\mathbf{p}-\hat{\mathbf{p}}) = \frac{\|\mathbf{p}-\hat{\mathbf{p}}\|^2}{N} = \frac{1}{N}\sum_i\sum_j (p_{i,j}-\hat{p}_{i,j})^2.$$

Where N is the number of image pixels. The coefficients with larger magnitude should be transmitted first because they have a larger content of information. The information in the value of |ci_j | can also be ranked according to its binary representation, and the most significant bits should be transmitted first.

VI. TRANSMISSION OF THE COEFFICIENT VALUES

Let us assume that the coefficients are ordered according to the minimum number of bit s "required for its magnitude binary representation, that is, ordered according to a one-to-one mapping $\eta : I \rightarrow I^2$, such that

$$\lfloor \log_2 |c_{\eta(k)}| \rfloor \geq \lfloor \log_2 |c_{\eta(k+1)}| \rfloor, \quad k = 1, \ldots, N.$$

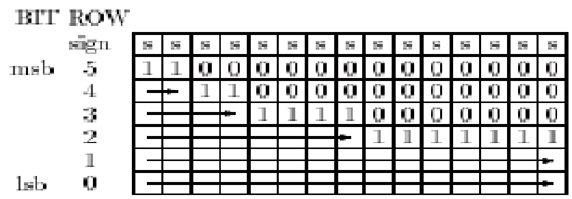

Figure3: Binary Representation of the magnitude- ordered coefficients.

Fig.1 shows the schematic binary representation of a list of magnitude-ordered coefficients. Each column k in Fig. 1 contains the bits of c_η (k). The bits in the top row indicate the sign of the coefficient. The rows are numbered from the bottom up, and the bits in the lowest row are the least significant. Now, let us assume that, besides the ordering information, the decoder also receives the numbers μ_n corresponding to the number of coefficients such that $2^n <= |Ci,j| < 2^{n+1}$.The most effective order for progressive transmission is to sequentially send the bits in each row, as indicated by the arrows in Fig. 1.Because the coefficients are in decreasing order of magnitude, the leading "0" bits and the first "1" of any column do not need to be transmitted, since they can be inferred from μ_n and the ordering.

VII. SET PARTITIONING SORTING ALGORITHM

One of the main features of the proposed coding method is that the ordering data is not explicitly transmitted. Instead, it is based on the fact that the execution path of any algorithm is defined by the results of the comparisons on its branching points. So, if the encoder and decoder have the same sorting algorithm, then the decoder can duplicate the encoder's execution path if it receives the results of the magnitude comparisons, and the ordering information can be recovered from the execution path.One important fact used in the design of the sorting algorithm is that we do not need to sort all coefficients. Actually, we need an algorithm that simply selects the coefficients such that $2^n <= |Ci,j| < 2^{n+1,}$ with n decremented in each pass. Given n, if $|ci\_j| >= 2^n$ then we say that a coefficient is significant, otherwise it is called insignificant.The sorting algorithm divides the set of pixels into partitioning subsets Tm and performs the magnitude test

$$\max_{(i,j)\in T_m} \{|c_{i,j}|\} \geq 2^n \ ?$$

If the decoder receives a “no” to that answer (the subset is insignificant), then it knows that all coefficients in Tm are insignificant. If the answer is “yes”(the subset is significant),then a certain rule shared by the encoder and the decoder is used to partition Tm into new subsets Tm,l, and the significance test is then applied to the new subsets. This set division process continues until the magnitude test is done to all single coordinate significant subsets in order to identify each significant coefficient. To reduce the number of magnitude comparisons (message bits) we define a set partitioning rule that uses an expected ordering in the hierarchy defined by the sub band pyramid. The objective is to create new partitions such that subsets expected to be insignificant contain a large number of elements, and subsets expected to be significant contain only one element. To make clear the relationship between magnitude comparisons and message bits, we use the function

$$S_n(T) = \begin{cases} 1, & \max_{(i,j)\in T} \{|c_{i,j}|\} \geq 2^n, \\ 0, & \text{otherwise}, \end{cases}$$

to indicate the significance of a set of coordinates T. To simplify the notation of single pixel sets, we write

$$S_n(\{(i,j)\}) \text{ as } S_n(i,j).$$

VIII. SPATIAL ORIENTATION TREE

Most of an image’s energy is concentrated in the low frequency components. Consequently, the variance decreases as we move from the highest to the lowest levels of the subband pyramid. Furthermore, it has been observed that there is a spatial self-similarity between subbands, and the coefficients are expected to be better magnitude-ordered if we move downward in the pyramid following the same spatial orientation. in For instance, large low-activity areas are expected to be identified in the highest levels of the pyramid, and they are replicated in the lower levels at the same spatial locations.

A tree structure, called spatial orientation tree, naturally defines the spatial relationship on the hierarchical pyramid.Fig.2 shows how our spatial orientation tree is defined in a pyramid constructed with recursive four sub band splitting. Each node of the tree corresponds to a pixel, and is identified by the pixel coordinate. Its direct descendants (offspring)correspond to the pixels of the same spatial orientation in the next finer level of the pyramid. The tree is defined in such a way that each node has either no offspring (the leaves)or four offspring, which always form a group of 2 * 2 adjacent pixels. In Fig.4 the arrows are oriented from the parent node to its four offspring. The pixels in the highest level of the pyramid are the tree roots and are also grouped in 2*2 adjacent pixels. However, their offspring branching rule is different, and in each group one of them (indicated by the star in Fig. 4) has no descendants.

The following sets of coordinates are used to present the new coding method.

LIS List of insignificant sets: contains sets of wavelet coefficients which are defined by tree structures, and which had been found to have magnitude smaller than a threshold (are insignificant). The sets exclude the coefficient corresponding to the tree or all sub tree roots, and have at least four elements.

LIP List of insignificant pixels: contains individual coefficients that have magnitude smaller than the threshold.

LSP List of significant pixels: pixels found to have magnitude larger that the threshold (are significant).

***O*(*i, j*)** : in the tree structures, the set of offspring (direct descendants) of a tree node defined by pixel location (i, j).

***D*(*i, j*)** : set of descendants of node defined by pixel location (i, j).

***L*(*i, j*)** : set defined by $L(i, j) = D(i, j)-O(i, j)$.

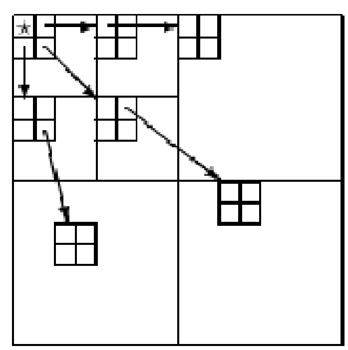

Figure 4. Examples of parent-offspring dependencies in the spatial-orientation tree.

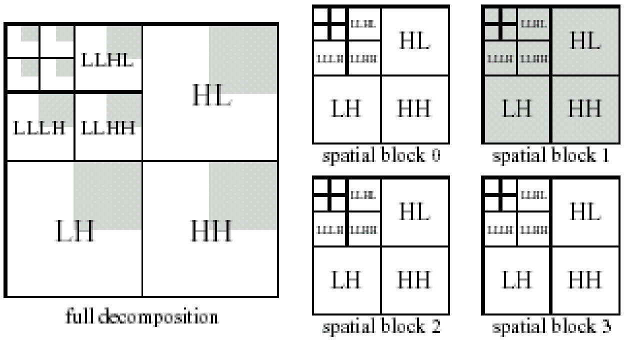

Figure 4.1. Grouping the spatial orientation trees of the Wavelet transform. The shaded sub bands belong to group or spatial block "1".

For instance, except at the highest and lowest pyramid levels, we have
O(i, j)={(2i,2j),(2i,2i+1),(2i+1,2j),(2i+1,2j+1)}
We use parts of the spatial orientation trees as the partitioning subsets in the sorting

Algorithm. The set partitioning rules are simply:

1.The initial partition is formed with the sets {(I,j)}and D(i ,j) for all (i ,j) ϵ H;
2. If D(I,j) is significant then it is partitioned into L(I,j) plus the four single-element sets with (k, l) (O(I, j).
3. if L(I, j) is significant then it is partitioned into the four sets D(k, l) with (k,l) ϵ O(i, j).
σ_q

IX. CODING ALGORITHM

1. **Initialization**: output η= | $\log_2$ (max $_{(i,j)}$ {|ci,j|}|;

set the **LSP** as an empty list, and add the coordinates (I,j) ϵ H to the LIP,and only those with descendants also to the **LIS** , as type A entries.

2. **Sorting pass:**

2.1. for each entry (I,j) in the **LIP** do:

2.1.1 output Sn(I,j);

2.1.2 if Sn(I,j)=1 then move to the LSP and output the sign of ci,j;

2.2. for each entry (I,j) in the LIS do

2.2.1. if the entry is of type A then • output(Sn(D(I,j));

- if Sn(D(i,j)) = 1 then * for each (k,l) ϵ o(I,j) do: output Sn(k,l);
- if Sn(k,l)=0 then add (k,l) to the LSP and output the sign of Ck,l;
- if Sn(k,l)=0 then add (k,l) to the end of the LIP;

*if L(I,j) ≠ ø then move (I,j) to the end of the LIS , as an entry of type B, and go to step 2.2.2; else ,remove entry (I,j) from the LIS;

2.2.2. if the entry is of type B then •

output Sn(L(I,j));

- if Sn(L(I,j))=1 then* add each (k,l) ϵ o(I,j) to the end of the LIS as an entry of type A;
- remove (I,j) from the LIS.

3. **Refinement pass**: for each entry (I,j) in the **LSP**, except those included in the last sorting pass (i.e., with same n)output the n-th most significant bit of |ci,j |.

4.Qua**ntization-step update:** decrement n by 1 and go to Step 2.

X. **Quality Measures in Image Coding**

In order to measure the quality of the image or video data at the output of the decoder, mean square error (MSE) and peak to signal to noise ratio (PSNR) ratio are often used. The MSE is often called ***quantization error variance***

3. The MSE between the original image ***f*** and the reconstructed image ***g*** at decoder is defined as:

MSE =
$$= \sigma_q^2 = \frac{1}{N}\sum_{j,k}(f[j,k]-g[j,k])^2$$

Where the sum over j, k denotes the sum over all pixels in the image and N is the number of pixels in each image. The PSNR between two images having 8 bits per pixel or sample in terms of decibels (dBs) is given by: **PSNR**
$$10\log_{10}\left(\frac{255^2}{MSE}\right)$$

Signal to noise ratio (SNR) is also a measure, but it is mostly used in telecommunications. However, one can calculate SNR for an image in terms of decibels (dBs) as:

PSNR = 10 $\log_{10}$ <u>Encoder input image energy or variance</u>
Noise energy or variance

In compression systems, the term ‘compression ratio’ is used to characterize the compression capability of the system.

Compression ratio = <u>Source coder input data size</u>

Source coder output data size

XI.Overall result

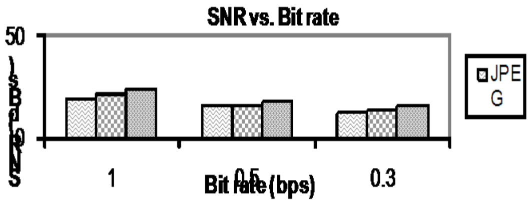

Figure 5 Comparison between JPEG, EZW and SPIHT in terms of SNR of the reconstructed images

Looking at Figures it is clear that performance of SPHIT is better than JPEG and EZW. Both EZW and SPHIT use arithmetic entropy coding and the threshold for quantization is not fixed as in case of JPEG.

XII. CONCLUSIONS

The performance of DWT based algorithms, i.e., EZW and SHPIT is quite better than the others in terms of SNR,

PSNR and visual quality of the reconstructed images. SPHIT in particular, has outperformed every Where .

standard/algorithm we have used and has given excellent results at low bit rates especially in terms of visual quality.

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