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Analysis and Comparison of Digital Image Compression Algorithms Combined with Huffman Encoding

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Abstract
SPIHT (Set Partitioning In Hierarchical Tree) has become the most effective image compression tool computationally in no time among all the other algorithms, because it boosts the operating potency, reduces its complexness, gets implemented in code and hardware simply. In this paper, a special approach to the initial SPIHT algorithm that relies on Set Partitioning in Row/Column-wise (SPIR) rule has been proposed and compared to EZW method. This rule is well implementable compared to the BP-SPIHT (Block-based pass parallel SPIHT algorithm) and alternative compression techniques. This algorithm applies on wavelet decomposed image, followed by verification of the row/column wise constituent values. Output bit stream of SPIR encoding rule, combined with Huffman encoding, presents a simple and effective methodology.

Keywords: *SPIHT, algorithms, encoding, EZW, wavelet*

INTRODUCTION

Image compression is the method ofdecreasingthe quantity of information needed to represent an image; it is often one amongst the most helpful and commercially sellable technologies within the field of digital image processing. Compression of pictures ordata helps in higher storage capacity and for faster transmission. In recent years, wavelet transforms as branch of mathematics developed very fast, which is famous for exhibition of a decent localization property concerning the main points of any scale and any frequency [1–5]. So, wavelet is relatively superior to Fourier transform and DCT (discrete cosine transform) in compression applications. EZW stands for Embedded Zero-tree Wavelet and is an easy, efficient, effectiveand versatileimage compression toolfor low bit rate image coding. The properties of EZW permits to code and compress the information blocks on an individual basis and conjointly compress it at any bit rate. Therefore, based on progressive coding a block will be compressed into a bit stream with increasing accuracy. This ruledoes not need learning and pre-stored code book. More enhancements over EZW can be achieved bySPIHT, by Ameer and William Pearlman, in 1996 article, "Set Partitioning In hierarchic Trees", this method is wavelet–based image compression coder. It initially converts the image into its wavelet transform and then transmits information regarding the wavelet coefficients. The decoding algorithm makes use of the received signal to reconstruct the wavelet and performs an inverse transform to reconstruct the image. SPIHT is comprehensive in comparison to its predecessor EZW for its vector quantization. And additionally SPIHT displays exceptional characteristics over manyimage compression tools in terms of a number of metrics such as good image qualitywith a high peak signal/noise (PSNR), fastdecoding, and a totally progressive bit-stream, can be applied for lossless compression, could also be combined with error protection, ability to code for precise bit rate or PSNR [6–8]. Thus, SPIHT can be thought of as wide used compression algorithmic program for wavelet-transform based pictures. A major drawback of this algorithm can be its slow processing speed because of its dynamic processing order which depends on the image contents. To beat this downside, an altered version of SPIHT algorithmic program referred to as block-based pass-parallel SPIHT (BPS-block-based pass-parallel SPIHT algorithm) and Improved SPIHT algorithmic program was recently revealed [9, 10]. In this paper, we present an algorithmic program SPIR (Set Partitioning in Row-wise) that is easy, efficient, less complicated and simple to implement compared to SPIHT. This algorithmic program is combined with Huffman coding for increased compression. In SPIR algorithmic program, at the start all the wavelet coefficients need to be checkedin row/column wise. In SPIR algorithm, if there is a maximum value in a row that is crossing threshold, then thefirst half columns is checked followed by the half columns. If the significance value is higher than all max value found in either of the halves then that halfis transferred to a different matrix. Thus, by this means each row is checked with the same threshold for that exact pass. Threshold is halved for every next pass. This algorithmic program is incredibly easy to grasp and enhances the operating efficiency for higher implementation. Followed by wavelet decomposition, some images have vital valuesin grand grand children's locations in hierarchy. In that case, application of SPIHT algorithmic program will not code those significant pixels and thus cannot get those original pixel values even in spite of any number of passes the image is passed through. However, by using this algorithm the initial values will be reconstructed after all passes. The MATLAB code implementation is simplefor each encoding and decoding process. In this paper, to attain higher compression the output bit stream of SPIR algorithm is further combined with Huffman encoding. Number of experimental results was carried out to show that this algorithm saves plenty of bits in transmission [11, 12].

EXISTING CODING ALGORITHMS

SPIHT ALGORITHM:

First of all the image is wavelet decomposed. For a four-band two-dimensional wavelet transform, the LL band consists of the low pass coefficients and exemplifies a soft approximation to the image. The HL, LH and HH bands represent the vertical, horizontal, and diagonal features of the image. These bands store the maximum details of the image [13, 14].

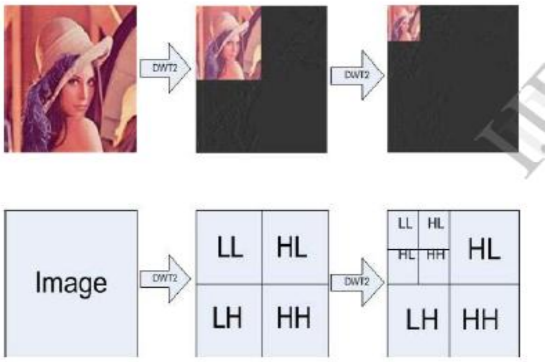

Fig. 1: *2-Level 2D Wavelets Transform.*

Then within the wavelet decomposition method the coefficients are dispersed into a structured tree. This data structure is named spatial orientation tree shown in Figure 1. 4-level wavelet decomposition of the spatial orientation trees structure is shown in Figure 2 below. The combination of coordinates of coefficients is used for representation of set partitioning technique in SPIHT algorithm. The coordinate of coefficient is denoted by (i, j), where i and j denote the indices of row and column, respectively. $O\ (i,\ j)$: Collection of offspring of the coefficient (i, j),

$$O(i,j) = \{(2i,2j),(2i,2j+1),(2i+1,2j),(2i+1,2j+1)\}$$

Journal of VLSI Design and Signal Processing
Volume 2 Issue 2

D (*i*, *j*): Collection of all descendants of the coefficient (*i*,j)

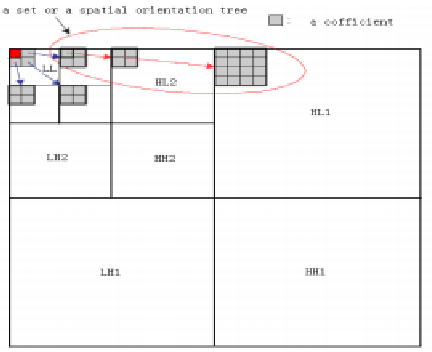

Fig. 2: *Parent-Child Relationship in SPIHT.*

Three ordered lists List ofInsignificant Sets (LIS), List of Insignificant Pixels (LIP), and at last List of serious Pixels (LSP) will be used to store the important information throughout set partitioning procedure. Four passes are required to contrive the SPIHT algorithm. A major function $S_n(\tau)$ that decides the importance of the set of coordinates,τ in relation to the threshold 2^n is defined by:

$$Sn(\tau) = \begin{cases} 1, \text{ If } \max|c(i,j)|)>=2^n \\ 0 \text{ else} \end{cases}$$

Where c (i, j) is the wavelet coefficients.

Initializations Pass

In this pass, we calculate $n = \lfloor log2(\max |c(i,j)| \rfloor$ here $\lfloor \ \rfloor$ represents the highest integer less than |c (i, j) |. This resets the values of n for testing significance of pixels and creating the significance map. The LSP is emptied and the LIS initially stores all the pixels inside the low-pass sub-band that have offspring and as a result act as roots abstraction trees. All the pixels in LIS are assigned to be of a specific class A. All pixels within the low-pass sub band are initially stored in LIP.

Sorting Pass

In this pass, at first for every entry of the LIP is tested for significance with regard to n (as donepreviously). If it has high significance1 is transmitted along with a sign bit indicating the sign of that pixel, and the pixel coordinates are transferred to LSP. If it is has no descendent with a high significance value then a 0 is transmitted. In this way the significance map is being transmitted. Following which, everyelement of the LIS is checked for the presence of descendants with high significance value. If not a single descendant is found, then a 0 is transmitted. If the element has a minimum of one important descendent then a 1 is transmitted and all the immediate descendants are tested for significance. If again a high significance descendant is found, a 1 and a sign bit are transmitted and also the pixel coordinates are added to the LSP. If no descendant with high significance value is found, a 0 is transmitted and also the pixel coordinates are added to the LIP. Hence significant maps of the immediate descendants are sent. If the pixel has more descendants (that is, grandchildren and more), then it is transferred to theend of the LIS as an entry of a new class B. If an element in the LIS is of class B, then its descendants-grandchildren onward- are tested for significance. If a minimum of one descendant is found with high significance value, then this element is eliminated from the list and its immediate descendants are added to the top of the list as entries of class A. During this pass we first check the LIP list values followed by testing of the LIS list elements, whether these elements are in class A.

Refinement Pass

The nth MSB of the magnitude of every element of the LSP, excluding those which were added in the previous sortingpass, is sent.

Quantization Step Pass

'n' is decremented and the process is repeated from the sorting pass.

BP-SPIHT ALGORITHM

BP-SPIHT (a block based pass parallel SPIHT algorithm) is a modified of SPIHT algorithm. BPS applied on wavelet decompose image data into 4 x 4block simultaneously encodes all the bits in a bit plane of a 4 × 4 block. To take advantage of parallelism, BPS restructures the three passes of the original SPIHTalgorithm after which the BPS encodes/decodes the restructured three passes in a parallel and pipelined way. In this algorithm, three lists are used from the Sorting pass (SP), Refinement pass (RP), First refinement pass (FRP). First given wavelet coefficients are divided into 4 blocks, i.e., H1, H2, H3, and H4.

Check the H1values if in this any value is maximum or equal to significance value then transmits the SP is 1 otherwise 0. If 1 is transmitted then check the each 2 x 2 block, there pixel is maximum then transmit the1 in SP and check each bit in the 2 x 2 blockotherwise 0 is transmitted. If 1 is transmitted then check each value, if it is maximum then transmit 1else 0 in FRP pass. If 2x2 blocks is already checked in last pass then the bits transmitted in RP. Sign bits are transmitted after the all pass bits transmitted. In the first pass no refinement pass. In the quantization step n is decremented by 1 and the procedure repeated.

IMPROVED SPIHT ALGORITHM

Description of the algorithm

In improved SPIHT image coding algorithm, first sort descending coefficient matrix, then original coordinates of sorted coefficients in the array are then successively added in one-dimensional array, and corresponding wavelet coefficients stored into a vector. The major disadvantage is that sorted list is to be taken into consideration while decoding, i.e., to transfer the same values to decoding time. So, that it gives more bits output.

PROPOSED CODING ALGORITHM: SPIR ALGORITHM

Description of the Algorithm

The HL, LH and HH bands store the details of the image. First, the wavelet decomposed data is fixed. Then, the maximum value which is the threshold value is found out of the wavelet coefficients.

$$n = \lfloor \log_2(\max\{|c(i,j)|\}) \rfloor$$

Where c (i, j) are wavelet coefficients. Two orderedlists LIP and LPS comprise the significance information during set partitioning. In SPIR algorithm, the values are checked row wise. If in the first row, any pixelvalue is greater than or equal to 2^n then1 is transmitted else 0 is transmitted. If transmit bit is 0, then the second row is tested for significance. But if the transmit bit is 1, and then the first half of the row elements is checked. If absolute maximum value of these pixels is greater than or equal to the 2^n then 1 is sent else 0 is sent. If the transmit bit is 0, then this half of the row pixels is transferred to a new matrix. But if transmit bitis 1, and then each pixel value is tested for significance. If the pixel value is found to be significant then 1 is sent followed by a sign bit (1 for negative and 0 for positive) and the index is moved to LSP but if it is found to be insignificant then 0 is transmitted and the index is shifted to LIP. After this same significance test is done for the second half of the row pixels. This procedure is followed for all the rows till the end. This completes the first sorting pass. Next the second sorting pass is executed. In this pass threshold is decreased by half, i.e., n= n-1. With this threshold first LIP pixels are checked for significance, if significant then 1is transmitted followed by sign bit and the index is shifted to LSP else 0 is sent. Then the new matrix is checked (which was created during the previous sorting pass with insignificant half rows) for significance. If it is significant then 1 is sent else 0 is sent. If it is significant then all the pixels are checked for significance.

Again, if these pixels are significant 1 is sent followed by sign bit and the pixel index is shifted to LSP bit if they are insignificant then their index is shifted to LIP. Now, the left over rows ofthe original matrix is tested whose significant rows during previous pass were moved to a new matrix or LIS or LSP. After second sorting pass follows the refinement pass.

Refinement Pas

The nth MSB of the magnitude of every element of the LSP, excluding the ones added in the current sorting pass, is sent. At the end of the first sorting pass, no bits would be transmitted as a part of the refinement pass because the LSP contain no pixel prior to the current sorting pass as in SPIHT.

DATA COMPRESSION: HUFFMAN ENCODING

For the output bit stream of SPIR encoding with a large number of seriate "0" situation, we obtain a conclusion by a lot of statistical analysis: “0000” appears with the greatest probability value, usually, will be about 1/4. Therefore, divide the binary output stream of SPIR every 4 bits as a group, every group recorded as a symbol, a total of sixteen kinds of symbols, probability that they appear, and then encoded using variable-length encoding naturally. In this paper, the encoding method being used is Huffman encoding. Using the output bit stream of above example to introduce the new encoding method process. In decoding the code word is used with comparison table. Then, the original bit stream of algorithm is obtained. Then, SPIR decoding is appliedon bit stream it is very easy to decode (Decoding isinverse process of the above-mentioned process).

RESULTS

The Figure shows the result with SPIHT and EZW coding.

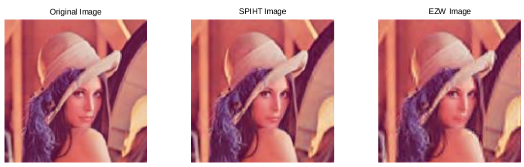

Fig. 3: *SPIHT and EZW Coding.*

Table 1: *Comparison of Parameters.*

Image Parameter	**Lena**	**Baboon**
MSE	26.9051	136.42
PSNR	34.0242	26.9732
Computational Time	6.05	11.74
Compression Ratio	0.375	0.5

The two algorithms have been compared in terms of some performance parameters.

CONCLUSION

This proposed algorithm is simpler and effective method combined with Huffman encoding for further compression saves a lot of bits in the image data transmission and gives the best performance for attaining high PSNR. The quantitative PSNR values in case of the SPIR algorithm are better for taken images. The algorithm is easy to understand and to implement also. Bits are nearly same as SPIHT algorithm encoding bits. This shows that the proposed algorithm is more suitable for the robust storage of data.

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