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SPHIT Algorithm combined with Variable length encoder to enhance the performance of the image compression technique

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Abstract—SPIHT is computationally very fast and among the best image compression algorithms known today. According to statistic analysis of the output binary stream of SPIHT encoding, propose a simple and effective method combined with variable length encoder (Huffman encoder) for further compression. A large number of experimental results are shown that this method saves a lot of bits in transmission, further enhanced the compression performance.

Keywords- Encoding; DWT; SPIHT; Huffman

I. INTRODUCTION

In recent years, wavelet transform [1] [2] as a branch of mathematics developed rapidly, which has a good localization property[3] in the time domain and frequency domain, can analyze the details of any scale and frequency. so, it superior to Fourier and DCT. It has been widely applied and developed in image processing and compression. EZW stands for 'Embedded Zero tree Wavelet', which is abbreviated from the title of Jerome Shapiro's 1993 article[4], "Embedded Image Coding Using Zero trees of Wavelet Coefficients". EZW is a simple and effective image compression algorithm, its output bit-stream ordered by importance of encoding was able to end at any location, so it allowed to achieve accurate rate or distortion. This algorithm does not need to train and require pre-stored codebook. In a word, it does not require any prior knowledge of original image. More improvements over EZW are achieved by SPIHT, by Amir Said and William Pearlman, in 1996 article, "Set Partitioning In Hierarchical Trees" [5]. In this method, more (wide-sense) zero trees are efficiently found and represented by separating the tree root from the tree, so, making compression more efficient. Experiments are shown that the image through the wavelet transform, the wavelet coefficient's value in high frequency region are generally small [6], so it will appear seriate "0" situation in quantify. SPIHT does not adopt a special method to treat with it, but direct output. In this paper, focus on this point, propose a simple and effective method combined with Huffman encode for further compression. A large number of experimental results are shown that this method saves a lot of bits in transmission, further enhanced the compression performance.

II. SPIHT ALGORITHM

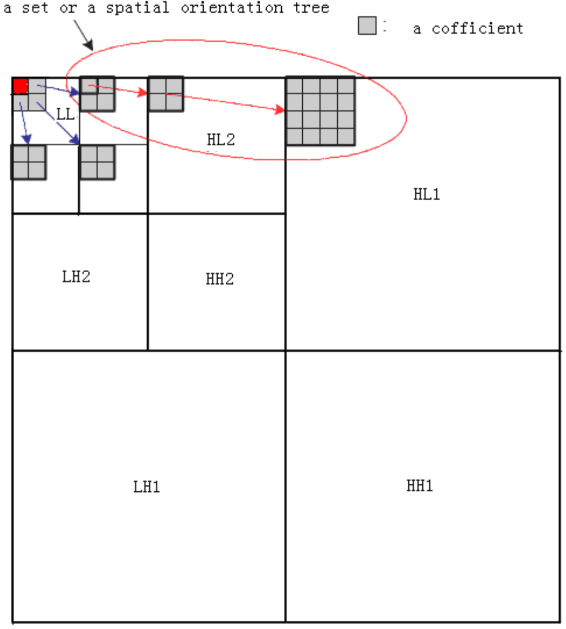
A. *Description of the algorithm*

Image data through the wavelet decomposition the coefficient of the distribution turn into a tree. According to this feature, defining a data structure spatial orientation tree. 4- level wavelet decomposition of the spatial orientation trees structure are shown in Figure1.We can see that each coefficient has four children except the 'red' marked coefficients in the LL subband and the coefficients in the highest sub bands ($HL1;LH1; HH1$).

The following sets of coordinates of coefficients are used to represent set partitioning method in SPIHT algorithm. The location of coefficient is notated by(i,j),where i and $j$indicate row and column indices,
respectively.

H : Roots of the all spatial orientation trees
$O(i, j)$:Set of offspring of the coefficient (i, j), $O(i, j) = \{(2i, 2j), (2i, 2j + 1),(2i + 1, 2j), (2i + 1, 2j + 1)\}$, except (i, j) is in LL; When (i,j) is in LL subband, $O(i; j)$ is defined as:
$O(i, j) = \{(i, j + wLL), (i + hLL, j), (i + hLL, j + wLL)\}$, where
wLL and hLL is the width and height of the LL sub band, respectively.
$D(i, j)$:Set of all descendants of the coefficient (i, j),
$L(i, j)$:$D(i, j)$ -$O(i, j)$

A significance function $Sn(\Gamma)$ which decides the significance of the set of coordinates, Γ, with respect to the threshold is 2^n .In the algorithm, three ordered lists are used to store the significance information during set partitioning. List of insignificant sets (*LIS*), list of insignificant pixels (*LIP*), and list of significant pixels (*LSP*) are those three lists. Note that the term 'pixel' is actually indicating wavelet coefficient if the set partitioning algorithm is applied to a wavelet transformed image.



Algorithm : SPIHT

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1) Initialization:
1. output [log max{ ( , )}] 2 n = c i j ;
2. set LSP =⎞ ;
3. set LIP = (i, j) ε H;
4. set LIS = (i, j) ε H, where D(i; j) ⎞and set each
entry in LIS as type A ;
2) Sorting Pass:
1. for each(i, j) ε LIP do:
    (a) output $S_n$(i ,j )
    (b) if$S_n$(i ,j ) = 1 then move (i, j) to LSP and output
    Sign C( i, j )
2. for each (i, j) ε LIS do:
    (a) if (i, j) is type A then
        i. output Sn(D(i, j))
        ii. if Sn(D(i; j)) = 1 then
            A. for each (k, l) ε O(i, j)
                . output Sn(k; l)
                . if Sn(k, l) = 1 then append (k, l) to LSP, output
                sign(ck,l),and ck,l = ck,l- 2n . sign(ck,l)
                . else append (k; l) to LIP
            B. move (i, j) to the end of LIS as type B
    (b) if (i, j) is type B then
        i. output Sn(L(i, j))
        ii. if Sn(L(i, j)) = 1 then
            . append each (k, l) ε O(i, j) to the end of LIS as
            type A
            . remove (i, j)from LSP
3) Refinement Pass:
1. for each (i, j) in LSP, except those included in
the last sorting pass
    . output the n-th MSB ofC(i,j);
4) Quantization Pass:
1. decrement n by 1
2. goto step 2)
```

B. Analyse of SPIHT algorithm

Here a concrete example to analyze the output binary stream of SPIHT encoding. The following is 3-level wavelet decomposition coefficients of SPIHT encoding:

	0	1	2	3	4	5	6	7
0	63	−34	49	10	7	13	−12	7
1	−31	23	14	−13	3	4	6	−1
2	15	14	3	−12	5	−7	3	9
3	−9	−7	−14	8	4	−2	3	2
4	−5	9	−1	47	4	6	−2	2
5	3	0	−3	2	3	−2	0	4
6	2	−3	6	−4	3	6	3	6
7	5	11	5	6	0	3	−4	4

n = [log max{|C (i, j)}|] =5, so, The initial threshold value:T0=2^5, for T0, the output binary stream: 11100011100010000001010110000, 29 bits in all. By the SPIHT encoding results,we can see that the output bit stream with a large number of seriate "0" situation, and along with the gradual deepening of quantification, the situation will become much more severity, so there will have a great of redundancy when we direct output.

C. Modified SPIHT Algorithm

For the output bit stream of SPIHT encoding with a large number of seriate "0" situation ,we obtain a conclusion by a lot of statistical analysis: ‘000’ appears with the greatest probability value , usually will be about 1/4.Therefore, divide the binary output stream of SPIHT every 3 bits as a group, every group recorded as a symbol, a total of eight kinds of symbols, statistical probability that they appear, and then encoded using variable-length encoding naturally reached the further compressed, in this paper, variable length encoding is Huffman encoding. Using the output bit stream of above example to introduce the new encoding method process .

1) First, divide the binary output stream every 3 bits as a group: 111 000 111 000 100 000 010 101 100 00. In this process, there will be remain 0,1,2 bits can not participate. So, in order to unity, in the head of the output bit stream of Huffman encoding cost two bits to record the number of bits that do not participate in group and those remainder bits direct output in end.

Number of remain bits	Bit stream	remain bits

Figure 2 is shown the output bit stream structure of Huffman encoding. Figure2 the bit stream structure of Huffman encoding

2) The emergence of statistical probability of each symbol grouping results are as follows:

P(‘000’)= 0.3333 P(‘001’)= 0

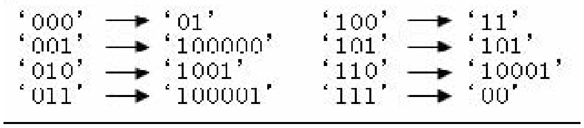
P(‘010’)= 0.1111 P(‘011’)= 0

P(‘100’)= 0.2222 P(‘101’)= 0.1111

P(‘110’)= 0 P(‘111’)= 0.2222

3) According to the probability of the above results, using Huffman encoding , then obtain code word book, as follow table1.

Table 1 Code word comparison table



‘000’ → ‘01’ ‘100’ → ‘11’
‘001’ → ‘100000’ ‘101’ → ‘101’
‘010’ → ‘1001’ ‘110’ → ‘10001’
‘011’ → ‘100001’ ‘111’ → ‘00’

Through the above code book we can get the corresponding output stream: 10 00 01 00 01 11 01 1001101 11 00, a total of 25 bits, The ‘10’ in the head is binary of remainder bits number , The last two bits ‘00’ are the result of directly outputting remainder bits. Compared with the original bit stream save four bits. Decoding is inverse process of the above-mentioned process.

III. ANALYSIS OF EXPERIMENTAL RESULTS

In order to verify the validity of this algorithm, images usually using all are analyzed, we use 5-level pyramids constructed with the 9/7-tap filters.Table2 is shown the experiment results of two standard 512×512 grayscale image Lena, Goldhill at different rate. Average code length which is calculated as follows:

$$L = \Sigma p(i) L_i$$

Where p is the probability of symbols appeared, $L_i$is the length of word code .

From the experimental results ,we can see that values of L are less than 3, so we can achieve the compression effect. For each image in the same rate always the probability of each symbol appear flat, and only small fluctuations, so saving the number of bits are also pretty much the same thing. With the rate increase word code length in average (L) will be an increasing trend, but after the rate greater than 0.3bpp the trending will be become very slow , and more value of rate more bits will be save.

IV. CONCLUSION

Proposing a simple and effective method combined with Huffman encoding for further compression in this paper that saves a lot of bits in the image data transmission. There is very wide range of practical value for today that have a large number of image data to be transmitted.

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