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## THE IMPLEMENTATION OF A SPIHT WAVELET CODEC and blood

## Ovidiu COSMA Some Line Hill and Sunnaharpare

Abstract. Finding an efficient way to encode the subband coefficients is essential for revealing the potential of the wavelet transform. Saphiro's paper [1] introduces the zerotrees, as an instrument for taking advantage of the correlation between the coefficients in several subbands. The SPIHT codec presented in [2] is also based on zerotrees, but achieves better compression. In this paper are presented the results of implementing a Java codec based on the SPIHT algorithm, with little optimisations.

MSC: 68P30 Keywords: image compression

## 1. Zerotrees

A zerotree is a quad-tree in which all the nodes are smaller or equal with the root. Such a tree can be coded with a single symbol and reconstructed by the decoder as a quad-tree filled with zeros.

The coefficients obtained by applying the nonstandard wavelet transform [3] to an image can be represented with trees, because of the subsampling that is performed in the transform. Each coefficient in a low subband has four descendents in the next higher subband, and every descendent has four other descendents in the next higher subband.

Natural images usually have a low pass spectrum. The energy in the subbands decreases as the scale decreases, so the wavelet coefficients will be smaller in the higher subbands than in the lower subbands [4], [5]. Fig. 1 presents the first 16 x 16 wavelet coefficients, (the first four subbands) for the Lena portrait, generated with the Villasenor 18/10 filter [6].

## adl 2. The SPIHT Codecate and analysis at absolute as ablorion and balances and strangification

The SPIHT encoder exploits the zerotrees, based on the property that the wavelet coefficients usually decrease with scale, and there is a good probability that all the coefficients in a quad-tree will be smaller than a certain treshold, if the root is smaller than this treshold. If the image is scanned going from the lowest subband to higher subbands, many positions can be coded efficiently with zerotrees symbols.

algorithm builds the following data structures: The List of Insignificant Sets LIS that contains the roots of the zerotrees, and two lists that hold the coefficients extracted from the transformed image: the List Insignificant Pixels LIP, and the List of 2000 Hib Significant Pixels LSP. The LIP keeps the coefficients, that are lower than a certain treshold, and the LSP holds the coefficients that are bigger than the treshold [2] adT admediate largers (1 strong)?

of bottomer The confollowing nonsets to of odes coordinates are used for presenting the SPIHT algorithm:

- D(i,j) = all the descendents of the node (i,j) in the quad-tree
- O(i,j)=((2i,2j),(2i,2j+1),(2i+1,2j

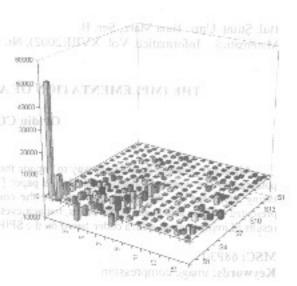


Figure 1

L(i,j)=D(i,j)-O(i,j)-O(i,j) and yet between the ludmys elignis a fline behave of an expectation of the captures of the wavelet transform. 1, if  $\max_{i,j} |c_{i,j}| \ge n$ 

transform, her a coefficient in a low subband has four descendents in the next higher subhand, The LIS contains elements (i,j) of type A that represent D(t,j), and elements of type B. Natural totages usually have a low pass spectrum. The energy(Li) A trassrept that decreases as the scale decreases, so the way let enefficients will be smaller in the higher talev2.1. The encoding algorithm and last fill fill should be a sweet and a supply the street of the control of

The image has lx l pixels, and l is a power of 21 (should be nucl tail of the street of the line of th  $c_{i,l}$ ,  $0 \le i \le l$ ,  $0 \le j \le l$ , are the wavelet transform coefficients.

The LIP contains the coefficients city that are below the treshold n, and LSP the coefficients that exceeded the treshold, in absolute value. The elements of the LIS have the following structure: (i,j,type).

The SPHT encoder exploits the zerotrees, based on the property that the wavelet coefficients usually decrease with scale, and there is a good probled by and good act and in a quad-tree will be smaller than a certain treshold, if the root is smaller than this reshold. If and output  $n=2\ell_{\rm th} d$  and the overall average  $c_{\rm th} d$  as several and more going frames, as again and initialize LSP as an empty list

add the coefficients  $c_{i,j}$  in the lowest subband to the LIP add the coordinates (i,j) in the lowest subband to the LIS, as type A entries

for each coefficient c, in the LIP do:

```
The elements of the LSP have the structure which at the \frac{n}{\ln c} \le \frac{1}{\ln c}
       add the value |c_{+}|-n to the LSP
        output the sign of the coefficient c_r
       remove the coefficient c, from the LIP I based as a word on to sometimes and blos
                                   add the clements (i.i) to the lowest subband to the ia till
    else output 0
  for each entry (i,j) in the LIS do:
        read the next bit of the coefficient co. The coefficients are read the next bit of the coefficient co.
     if the entry is of type A, then
         i(S_n(D(i,i)) = 1, then
            for each (k,l) \in O(i,j) do:
               if |c_{k,l}| \ge n, then
                   output 1
                   add the value |c_{k,l}| - n to the LSP no SLI odd on V_k(t) towards does not add the value |c_{k,l}| - n to the LSP no V_k(t) and V_k(t) to so V_k(t) to so V_k(t).
                   output the sign of the coefficient c_{k1}
                else
                   add the coefficient cky to the EIPon and to not axed and been
             if L(i,j) \neq \phi, then
                set the type B for the element (i,j) in the LIS and the set
                encode_type_B_element(i,j) n = ____ 2, 133 terminals off blue
                remove the element (i,j) from the LIS.
          encode type B element(i,j)
3. for each element c_v in the LSP, excepting the ones included in the last pass, do:
      if c_x \ge n, then:
          output 1, |c_x| = c_x - n 21 f adi moni (i,j) mamala adi avvannat
       else output 0
4. n = n/2, go to step 2.
         The condition for ending the process, can be related to the reach of a certain value for
the current treshold n, or to the length in bits of the resulting code.
encode type_B element(t,j): tooo oult in note out et . v. orostw., tt.:
output S_{*}(L(l,j))
if S_n(L(i,j)) = 1, then
    add each element (k,l) \in O(i,j) to the end of LIS, as a type A element.
    remove the element (i,j) from the LIS
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The elements of the LSP have the structure: (i,j,c1), those of the LIP have the
    structure: (i,j), and those of the LIS have the structure: (i,j, type).
    1. read n, l and the overall average c_{\alpha\beta}
           add the coordinates of the lowest subband to the LIS, as elements of the form (i,j,A)
           add the elements (i,j) in the lowest subband to the la LIP
           initialize the LSP, as an empty list
   for each element (i,j) in the LIP do:
                  read the next bit of the coefficient c_{ar}. The coefficients are read starting with the MSB.
                   if the read bit - 1, then
                          read the sign s_{i,i} of the coefficient c_{i,i}
                          add the element (i,j,s_{i,j} \cdot n) to the LSP
                         remove the element (i,j) from the LIP
           for each element (i,j) in the LIS do: \{i,j\} and or i,j \in \{i,j\} and i,j \in \{i,j\}
                  if the element (i, j) is of type A, then
                          read S_n(D(i,j))
                          if S_n(D(i,j)) = 1, then
                                  for each (k,l) \in O(i,j) do:
                                         read the next bit of the coefficient cky indications out blue
                                         if the read bit - 1, then
                                                read the sign s_{kl} of the coefficient c_{kl} of and H sore or line
                                                add the element (k,l,\ s_{k,l}\cdot n) to the LSP n -apply allowed
                                         else
                                                add the element (k, l) to the LIP 1 (1,1) intenses out avomes
                                 if L(i,j) \neq \phi, then
                                 set the type B for the element (i,j) in the LIS and in the the set of the sector of th
                                        decode type B element(i,j)
                                else
                                         remove the element (i,j) from the LIS
                 else
                         decode type B element(i,j)
       3. for each element (i,j, c,j) in the LSP, excepting the ones added in the last pass, do:
The condition for ending the process, can be trained and to tid tran add the received for
                 the read bit =1, then so correct treshold a, or to the length in bits of the resulting code and it is the read bit =1.
                         c_{i,j} = c_{i,j} + s_{i,j} \cdot n , where s_{i,j} is the sign of the coefficient c_{i,j} is A and A
 4. n - n/2, go to step 2.
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2.2. The decoding algorithm

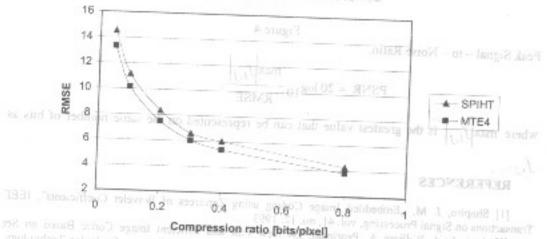
The process can continue until it is reached a certain treshold n, or a certain compression ratio, or to the end of the input data. In the end of the algorithm, the reconstructed coefficients are in the LSP, in the form of  $(i,j,c_{i,j})$  elements. decode\_type\_B\_clement(i,j): read  $S_e(L(i,j))$ 

if  $S_o(L(i,j)) = 1$ , then

add each element (k,l) in O(i,j) to the LIS, as a type A element remove (i,j) from the LIS

3. Implementation results

My implementation follows the SPIHT algorithm, with a few optimisations. The next two images present the performance of the original SPIHT algorithm, compared to my implementation (MTE4). Compression ratio [bits pixel]



[2] Amir Sard, William A Pearin [lexiq\ziid] oltar nolzzerqmoOmi image Codze Based on Scr. Partitioning in Hierarchical Trees", IEEE Transactions on Circuits and Systems for Video Technology.

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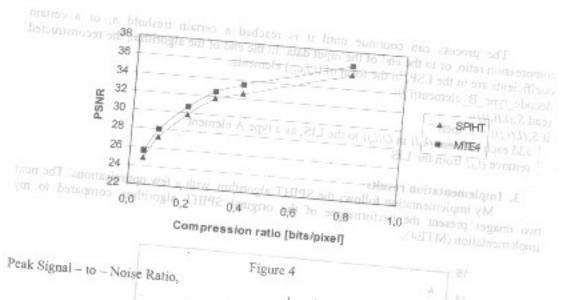
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[5] Oxidia Cosma, Optionsong the culor space engagement for 
$$\frac{1+\log 4}{2}$$
 and  $\frac{1}{2}$  and  $\frac{1}{2}$ .

Mare for B, Minematica - Informatics, Vol. 3/12  $(2/2, 1 - 1/2)$   $(1/2, 1$ 

Darsachons un finage Pracessing, vol. 2. Aug. 1905 where  $f_{i,j}$  and  $\tilde{f}_{i,j}$  are the pixels of the original, and those of the reconstructed image.

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is the greatest value that can be represented on the same number of bits as fin. REFERENCES

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Department of Mathematics and Computer Science Faculty of Sciences, North University of Baia Mare E-mail: cosma@alphanet.ro