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MEDICAL IMAGE COMPRESSION USING SPIHT COMBINED WITH ARITHMETIC CODING

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ABSTRACT

This paper deals with the basic requirements like data rate and storage capacity of a system while converting analog data to digital data. These requirements can be achieved by compressing the data. There are number of image compression techniques, but this paper concentrates on Set Partitioning in Hierarchical Trees (SPIHT), which is a wavelet based compression algorithm that offers good compression ratios, fully progressive bit-stream and good image quality. This paper presents the results of adding arithmetic compression to the SPIHT images in the hopes of further reducing the image size with better data rates and image quality.

KEYWORDS: Image Compression, SPIHT, Arithmetic Coding, Compression Ratio, PSNR

INTRODUCTION

Sequence of images tends to demand enormous memory and storage capacities. For example, consider the data sets from the field of Medicine. It consists of images taken at one-third mm intervals resulting a data set in Giga Bytes. Access and transport of these data sets will stress existing processing, storage and transmission capabilities. Therefore, the efficient compression should be applied to those data sets before storage and transmission.

Many image compression algorithms based on wavelet-transform (WT) [1], [2] and [3] are proposed recently because of its good localization property [4]. There are simple, efficient and are widely used in many applications. Examples include the EZW (Embedded Zero tree Wavelet) algorithm [5], SPIHT (Set Partition in Hierarchical Trees) algorithm, and the improved EZW algorithm of Said and Pearlman [6], which offers comparable results to SPIHT with lower complexity.

Huffman coding algorithm can be refined to generate a new effective compression algorithm. SPIHT, as the state–of–the–art encoder, has many attractive properties. It is an efficient embedded technique. SPIHT has been proved as a powerful tool to compress image sequences, if it is combined with an entropy encoding. SPIHT is combined with Huffman Encoding technique [7] to reduce redundancies. But, Arithmetic coding has its advantages in reducing the size of the sequence. In this paper, [7] is considered as Existing Algorithm and SPIHT combined with Arithmetic coding is considered as Proposed Algorithm. This paper is organized as following: the proposed algorithm will be described in Section II. Section III presents experimental results and Section IV concludes the paper.

PROPOSED ALGORITHM

SPIHT combined with Huffman Encoding (SPIHT-HC) technique to reduce redundancies [7] has lower compression ratios and takes much time for encoding and decoding process. Since, Huffman encoder encodes each symbol in the sequence individually. So, there is a need to improve these parameters for efficient compression and transmission of data. We have presented medical image compression algorithm by combining SHIPT with arithmetic coding. The block diagram for proposed algorithm i.e. medical image compression is shown below in figure 1.

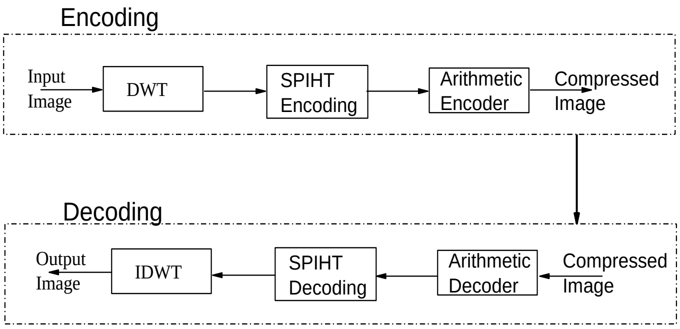

Figure 1: Block Diagram for Image Compression Using Proposed Algorithm

Set Partitioning in Hierarchical Trees- Description

SPIHT is an embedded coding technique, where embedded coding algorithms, encoding of the signal at lower bit rate is embedded at the beginning of bit stream for the target bit rate. Image data through the wavelet decomposition, the coefficient of the distribution turn into a tree. According to this feature, a spatial orientation tree would be formed by defining a data structure. 4-level wavelet decomposition of the spatial orientation tree's structure are shown in Figure 2.We can see that each coefficient has four children except the 'red' marked coefficients in the *LL* sub-band and the coefficients in the highest sub-bands (*HL*1;*LH*1; *HH*1).

The following sets of coordinates 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* sub-band, $O(i; j)$ is defined as: $O(i, j) = \{(i, j + w_{LL}), (i + h_{LL}, j), (i + h_{LL}, j + w_{LL})\}$, where w_{LL} *and* h_{LL} is the width and height of the *LL* sub-band, respectively.

$D(i, j)$: Set of all descendants of the coefficient (i, j),

$L(i, j)$: $D(i, j) - O(i, j)$

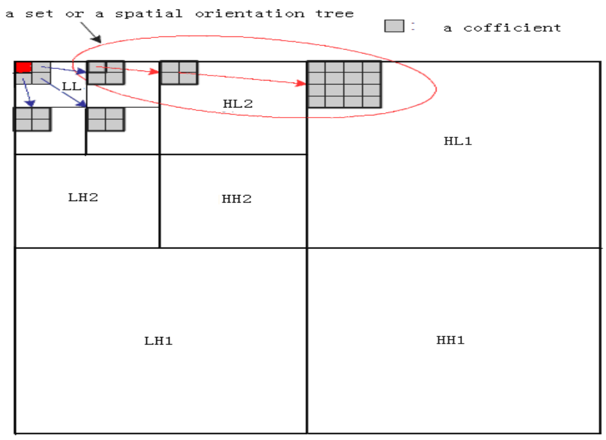

Figure 2: Parent-Child Relationship in SPIHT

A significant function $S_n(\tau)$ which decides the Significance of the set of coordinates, τ, with respect to the threshold 2^n is defined as:

$$S_n(\tau) = \begin{cases} 1, if\ max_{(i,j)\epsilon\tau}\{|C_{i,j}|\} \geq 2^n \\ 0, else \end{cases}$$

Where $c_{i,j}$ is the wavelet coefficient.

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

Step 1: Initialization

- Output n= [$\log_2$ max {| ($c_{i,j}$)|}]
- Set *LSP* =$\emptyset$;
- Set *LIP* = (i,j) $\in$ H;
- Set *LIS* = (i,j) $\in$ H, where *D*(*i; j*) ≠ $\emptyset$ and set each entry in *LIS* as type A entry;

Step 2: Sorting Pass

- For each entry (*i, j*) $\in$ *LIP* do:
  - output $S_n(i,j)$
  - if $S_n(i,j)$ = 1 then move (*i, j*) to *LSP* and output Sign ($c_{i,j}$)
- For each (*i, j*) ∈ *LIS* do:
  - if (*i, j*) is type A then
    - output $S_n(D(i,j))$
    - if then$S_n(D(i,j))$ = 1 then
- for each (*k, l*) $\in$ *O*(*i, j*)

  output $S_n(k,l)$

  if $S_n(k,l)$ = 1 then append (*k, l*) to *LSP*, output Sign($c_{k,l}$),and $c_{k,l} = c_{k,l} - 2^n$ sign($c_{k,l}$)

  else append (*k; l*) to *LIP*
- move (*i, j*) to the end of *LIS* as type B
  - (b) if (*i, j*) is type B then
    - output $S_n(L(i,j))$
    - if $S_n(L(i,j))$ = 1 then

- append each $(k, l) \in O(i, j)$ to the end of *LIS* as type A

remove (i,j) from *LSP*

Step 3: (Refinement Pass)

- for each entry (i,j) in the LSP, except those included in the last sorting pass

  output the *n*-th MSB of $|c_{i,j}|$

Step 4: Quantization Pass

- decrement *n* by 1
- goto step 2)

Set Partitioning of Hierarchical Trees with Arithmetic Coding (SPIHT-AC)

For the output bit stream, 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 entropy coding naturally reached the further compressed in proposed system. (Arithmetic coding is used as an entropy coding). Arithmetic coding is a well-known method for lossless data compression [8, 9]. The idea can be traced back to the work of Shannon [10], but it was first explicitly described by Elias and described as a footnote in reference [11].

Arithmetic coding is a compression technique that can give compression levels at (or) near entropy. What it means is that if we have a message composed of symbols over some finite alphabet, we can generate the exact number of bits that corresponds to a symbol (e.g. 1.6 bits/symbol).

This is opposed in Huffman encoding which must output an integer number of bits per symbol (e.g. 2 bits/symbol). Arithmetic coding achieves entropy (or very near it) by grouping symbols together until an integer value of bits can be an output for a sequence of symbols (e.g. ABC may correspond to 1011).

Arithmetic coding works by using a probability interval defined with variables L and R, which are initially set to 0 and 1 respectively. The value of L represents the smallest binary value consistent with a code representing the symbols processed so far. The value of R represents the product of the probabilities of those symbols. To encode the next symbol, which is the j^{th} of the alphabet, both L and R must be recomputed. L and R get the following values:

$$L = L + R * \sum_{i=1}^{j-1} P_i$$

$$R = R * P_i$$

This preserves the relationship between L, R, and the symbols that have been previously processed. At the end of the message, any binary value between L and L + R will unambiguously specify the input message. The interval will continue to be redefined until an end-of-sequence marker is coded.

EXPERIMENTAL RESULTS

The performance of SPIHT-HC on medical images i.e. (CT, MRI, Ultra-Sound and Iris) are tabulated in table 1 and proposed method (SPIHT-AC) performance are shown in table 2. Figures 3 and 4 show the PSNR, CR, Encoding time and decoding time for SPIHT-HC and proposed algorithm SPIHT-AC for medical images. The results show that the proposed algorithm can improve compression ratio (CR) and peak signal to noise ratio (PSNR).

Table 1: Comparison of CR and PSNR Using SPIHT with Huffman Coding

Images	SPIHT with Huffman Coding			
	CR	PSNR	Encoding Time	Decoding Time
MRI	10.0514	62.7854	18.433	45.039
CT	7.7772	59.2370	18.554	44.731
Ultra Sound	7.9857	60.2318	17.476	45.149
IRIS	6.2635	58.4824	21.358	45.609

Table 2: Comparison of CR and PSNR Using SPIHT with Arithmetic Coding

Images	SPIHT with Arithmetic Coding			
	CR	PSNR	Encoding Time (s)	Decoding Time (s)
MRI	22.4965	83.8575	14.558	25.692
CT	17.3357	80.3091	19.328	33.886
Ultra Sound	17.8036	81.3039	19.101	33.455
IRIS	13.9764	79.5545	17.622	32.409

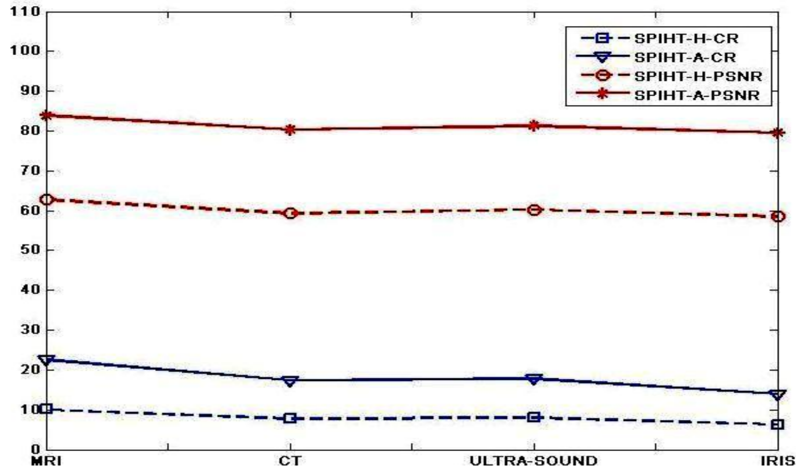

Figure 3: Comparison of PSNR and CR between Existing and Proposed Algorithms. (Dotted Lines Existing Algorithm; Solid Line Proposed Algorithm)

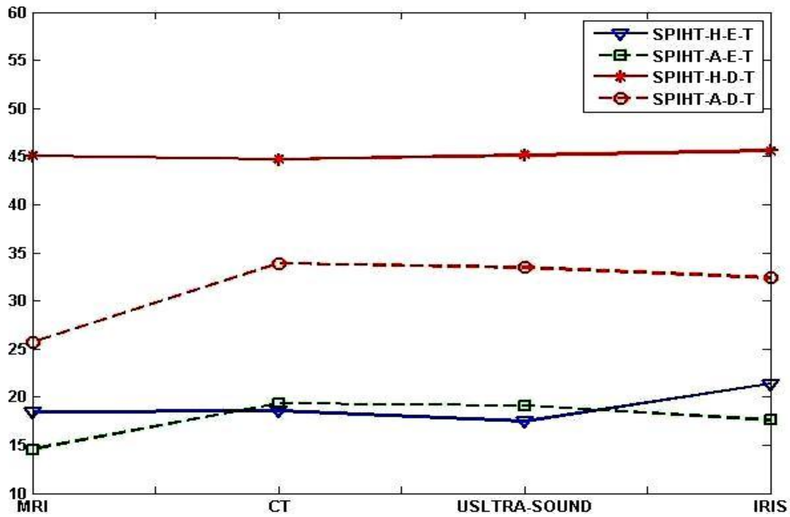

Figure 4: Comparison of Encoding and Decoding Times between Existing and Proposed Algorithms. (Dotted Lines-Proposed Algorithm; Solid Lines-Existing Algorithm)

CONCLUSIONS

Two different entropy coding approaches have been presented for image compression using SPIHT. It is observed that the added compression of SPIHT encoded images using arithmetic compression is better compared to modified SPIHT algorithm i.e. SPIHT combined with Huffman coding. Simulation results also show that the compression ratio (CR) and peak signal to noise ratio (PSNR) are better in proposed algorithm compared to the existing one. Existing algorithm takes less time for encoding purpose but requires much to decode the compressed image. Whereas the proposed algorithm can perform both the operations in less time. The results of proposed algorithm have been validated using medical images. The evaluation parameters like CR and PSNR are indicating that the performance of proposed algorithm is better than that of the existing algorithm.

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