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Improving Quality of Medical Image Reconstruction Using Wavelet Based Modified SPIHT Coding Technique

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Abstract : *In this paper, we present an improved technique to the Set Partitioning in Hierarchical Trees (SPIHT) based image compression. These modification and the preprocessing techniques provide significantly better quality reconstruction at the decoder with little additional computational complexity. Firstly, we proposed a pre-processing scheme, by 2-D arrangement for wavelet coefficients. Secondly, rearranging the order of the encoded output bit stream by memory optimization at the algorithmic three continuosly growing linked lists levels and a low bit rate image coder. As far as objective quality assessment of the reconstructed image is concerned, we have compared our proposed results with popular Average Difference (AD), Structural Similarity (SSIM) Index in Image Space, Peak Signal to Noise Ratio (PSNR) and Compression Ratio (CR). These metrics show that our proposed work is an improvement over the original one.*
Keywords: *SPIHT, Lifting Wavelet Transform, wavelet coefficients, quality assessment.*

I. Introduction

Telemedicine [1, 7] is the provision of health care services via interactive audio visual and data communications. It is a digitized and computerized process incorporating many technologies like communications, databases, user-interfaces and medical science while the foundation of it is communication. As the medical images may be very big, the transmission and storage of the medical image often cause difficulties [3].

For example, a single 2048x2048 X-ray image may use 4 megabytes, and transmitting it over a telephone line operating at 9600 bits per second (bps) may take one hour, which would be very inefficient. So, if we want to get better performance, we'll have to either increase the bandwidth of the communication channel or apply some compression during transmission.

Furthermore, the situation of narrow-band communication can't be totally eliminated in the near future. In many remote countryside places, wide-band communication service may be unavailable; in moving vehicles, ships or planes, it is hard to achieve wide-band communication because of the nature of the channel (e.g. fading).So a compression ratio of at least 10:1 is highly required, and better could reach 30:1.Then for the previous example, it means that the image could be transmitted in only a few minutes.

There already have been many very successful works on image compression [11, 14], and a large variety of algorithms have been proposed. A standard compression algorithm, JPEG, is available which will get good results on most images except when the compression ratio is high. Recently, the wavelet transform was proposed and it can achieve a better compression ratio without increasing computational complexity.

When using wavelet algorithms [5, 9, 10] to compress an image with a ratio of 10:1 or even 30:1, down to below one bpp, the decompressed image's quality is enough for most uses. But for medical usage there are still some problems. First, as the medical image's quality may influence the diagnosis result, lossy compression has not yet been completely accepted for use in diagnostic usage. Second, unlike ordinary usage, which is mainly concerned with the overall impression of the image, medical imaging may be very concerned about the detail at some region (e.g. a pathologically important region), so the deviation caused by a 30:1 or 10:1 compression at that region may be unacceptable.

By considering the strict requirement of medical imaging and the fact of low-band communication in the future decade, the current image compression technology is still not adequate for the task. Some new technology is required.

We had taken these patients MR image [2, 13] and analyzed these images with previously proposed methods and compared with our proposed algorithm of improved SPIHT algorithm.

Our proposed algorithm with comparative results, CR and PSNR had shown better results than the proposed algorithms [6, 8]. In our proposed algorithm we are using resolution method to improve the compression rate of 20: 1 value and reconstruction accuracy of 82 % with PSNR of 52.97 which shows a reliable transmission of MR image through a communication link in the vicinity of patient's location. Based on our proposed algorithm, MR image can be encoded using a MR image encoder [4, 12] which provides a loss less reconstruction of the original image.

Our proposed algorithm had shown better results compared to previously proposed algorithms.

The remaining part of the paper is organized as follows. In section II, we describe SPIHT algorithm. Proposed Improved SPIHT Coding Technique has been presented in section III. In section IV, we have discussed comparative results. Finally, paper is concluded with highlighting the need of reliable application of MRI images.

II. RELATED WORK : SPIHT

Most definitions of the lists and symbols are $MaxLIP$, $MaxLIS$ and $MaxLSP$, are increased. They are as follows:

- $O(i)$: Set of coordinates of all offspring of node i.
- $D(i)$: Set of coordinates of all descendants of node i.
- H: Set of coordinates of all spatial orientation treeroots.
- $L(i)$:$D(i) - O(i)$.
- c_i : The magnitude of the coefficient of node i.
- $MaxLIP$: The maximal address of all nodes in the LIP list.
- $MaxLIS$: The maximal address of all nodes in the LIS list
- $MaxLSP$: The maximal address of all nodes in the LSP list.
- T: All nodes in the image.
- N: The address of the last node in the image.
- A set $L(i)$ or $D(i)$ is said to be significant if any coefficient in the set has a magnitude greater than the threshold.

Similar to the SPIHT algorithm, four encoding steps, initialization, sorting pass, refinement pass and quantization pass, are performed and three linked lists, LIS, LSP and LIP, are used in the proposed SPIHT. Its pseudo-code is de- scribed as follows.

1. Initialization step:
   - Output $n = \log_2 (max\{|c_i|\})$, $0 \le i \le N$;
   - Set $LSP(i) = 0, 0 \le i \le N$;
   - Set $LIP(i) = 1, \forall i \in H$, otherwise set to 0;
   - Set $LIS(i) = A, \forall i \in H$ with descendants, otherwise set to 0;
   - Set $MaxLIP = max(H)$, $MaxLIS = max(H)$,$MaxLSP = 0$;
2. Refinement pass:
   - For $0 \le i \le MaxLSP$
     - If $LSP(i) = 1$ then Output the $(n+1)$ th most significant bit of $|c_i|$;
     - Else if $LSP(i) = 2$ then Set $LSP(i) = 1$;
3. Sorting pass:
   - For $0 \le i \le MaxLIP$
     - If $LIP(i) = 1$ then
       - * Output $S_n((i+1))$,
       - * If $S_n((i+1)) = 1$, then
         - Output sign of c_{i+1}
         - Set $LSP(i) = 2$,
         - $MaxLSP = max(i, MaxLSP)$
         - Set $LIP(i) = 0$
   - For $0 \le i \le MaxLIS$
     - If $LIS(i) = A$ then
       - * Output $S_n(D(i+1))$
       - * If $S_n(D(i+1)) = 1$ then
         - For $(i \times 4) \le j \le (i \times 4 + 3)$
           - Output $S_n((j+1))$
           - If $S_n((j+1)) = 1$ then
             - Set $LSP(j) = 2$,
             - $MaxLSP = max(i+1, MaxLSP)$

Output the sign of c_j

Else

Set $LIP(j)$ = 1,

$MaxLIP = max(i+1, MaxLIP)$

If $(i \times 16) < N$ then

Set $LIS(i) = B$,

$MaxLIS = max(i+1, MaxLIS)$

Else

If $LIS(i) = B$ then

* Output $S_n(L(i+1))$

* If $S_n(L(i+1)) = 1$, then

For $(i \times 4) \leq j \leq (i \times 4 + 3)$

Set $LIS(j) = A$

Set $LIS(i) = 0$

4. Quantization-step update pass:

• Decrement n by one and go to refinement pass.

III. Progressive Approach To Our Proposed Improved SPIHT Coding Technique

Compression of medical MR images is typical tasks. Compression techniques like EZW and SPIHT will give poor image quality metrics. They lack with the reconstruction of medical images. We are proposing an improved SPIHT algorithm to improve the reconstruction accuracy of compressed MR images. Our comparative result clearly shows these limitations. Improved SPIHT enhances the reconstructed image with high resolution and high quality in image recovery.

In this paper, an improved SPIHT algorithm is presented. The modifications includes

1. Simplifications of coefficient scanning process by 2-D arrangement for wavelet coefficients.
2. Fixed memory allocations for the data lists instead of a dynamic allocation required in original SPIHT.
3. Wavelet packet transform, while the original is wavelet transform and Wavelet packet zero tree is defined, while in original spatial orientation tree is used.
4. Memory optimization at the algorithmic three continuosly growing linked lists levels and a low bit rate image coder.

Our proposed improved SPIHT algorithm is analyzed in three different ways. They are:

1. High resolution wavelet based SPIHT method (HRW-SPIHT).
2. Multi wavelet based SPIHT method (MW-SPIHT)
3. High quality image reconstruction based SPIHT method (HQ-SPIHT)

We compared the above three modified SPIHT algorithms and analyzed HQ-SPIHT as an improved SPIHT version of traditional SPIHT. HQ-SPIHT process is proposed in to two approaches, firstly a pre-processing scheme by the simplifications of coefficient scanning process by 2-D arrangement for wavelet coefficients and secondly rearranging the order of the encoded output bit stream by memory optimization at the algorithmic three continuosly growing linked lists levels and a low bit rate image coder. These modifications are listed below in encoding procedure. These modifications proved better quality results than original SPIHT.

Above modifications are listed in the following improved SPIHT encoding procedure:

1) Initialization:

Obtain the target bit-rate and Output n;

Set the LSP as an empty list, and add the coor-dinates $(i, j) \in H$. Add only the coordinates with de-scendants also to the LIS as type A entries.

2)Sorting Pass:

2.1) for each entry (i, j) in the LIP: 2.1.1) output $S_n(i, j)$;
2.1.2) if $S_n(i, j) = 1$ by (6), then output the
sign and $c_{i,j}(N_{db})$ and delete (i, j) node.

2.2) for each entry (i, j) in the LIS: 2.2.1) if the entry is of type A then

• output $S_n(D(i, j))$;

• if $S_n(D(i, j)) = 1$ then ♦ for each $(k, l) \in O(i, j)$:

• compute $S_n(k, l)$ by (6);

- if $S_n(k, l) = 1$, then output the sign and $c_{k,\,l}(N_{db})$ and delete (i, j) node;

- if $S_n(k, l) = 0$, then add (k, l) to the end of the LIP;

♦ if $L(i, j) \neq \varphi$, then move (i, j) to the end of the LIS as an entry of type B; go to Step 2.2.2; otherwise, remove entry (i, j) from the LIS.

2.2.2) if the entry is of type B, then

- output $S_n(L(i, j))$;

- If $S_n(L(i, j)) = 1$ then

♦ add each $(k, l) \in O(i, j)$ to the end of the LIS as an entry of type A;

♦ remove (i, j) from the LIS.

2.3) Threshold Update: decrease n by 1;

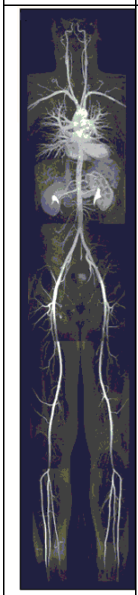
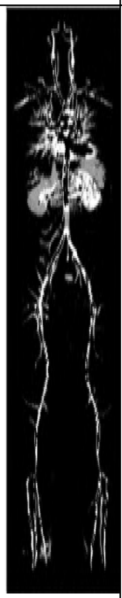
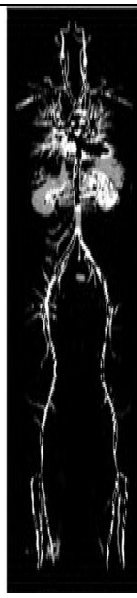
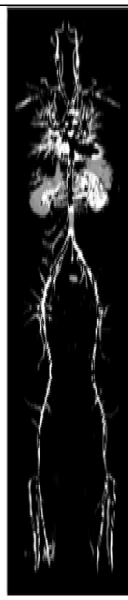
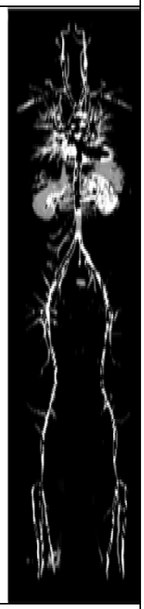
2.4) go to step 2.

IV. COMPARATIVE RESULTS AND DISCUSSIONS

In our experiments, we had taken three patients scan reports as test image of 256×256 mri image as shown in Table 1, 2and 3 and Quality of image reconstruction, compression time CR, PSNR, and SSIM values from different wavelets [5] are noted. For different wavelets the given input MRI image is analyzed. And their respective PSNR and CR values are plotted in comparison with the other compression techniques are shown in Figure 1 & 2, and Table 4 & 5.

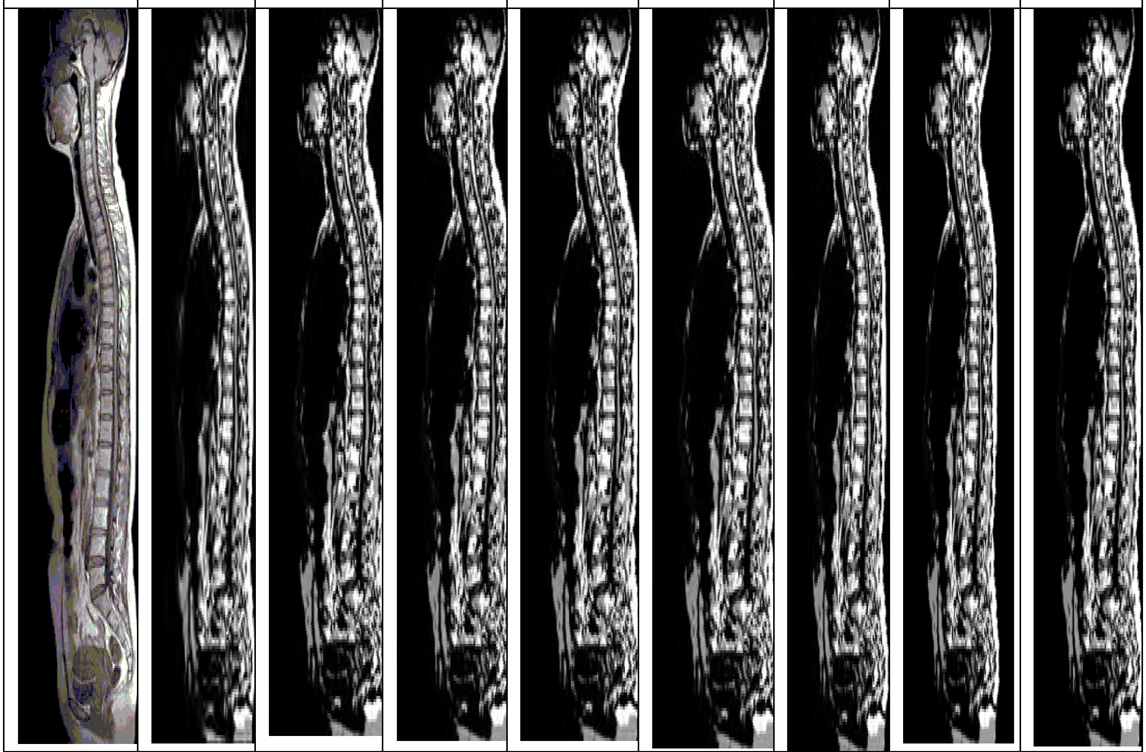
We have analyzed Human Vessels, Human Spinal and Human Body of three patients MR scan images. These scanned images are having entropy of 5 with bit depth of 8. Our proposed SPIHT method is compared with original SPIHT method, wavelet based method and multi wavelet based method. Comparative CR and PSNR values clearly show that the reconstruction accuracy and time is improved over the original SPIHT. SSIM values proved compressed image is reconstructed without any loss of image data.

Table 1: Comparative Results: 3DMR_Human_Vessels.

								
	SPIHT Method	HRW-SPIHT (Proposed)					MW-SPIHT (Proposed)	HQ-SPIHT (Proposed)
Image Input mri human vessels		Sym8 Wavelet image	Rbio 6.8 Wavelet image	Bior 4.4 Wavelet image	Coif5 Wavelet image	Dmey Wavelet image		
Current Image Size (KB) 91	66.21	41.98	39.52	41.20	44.24	43.10	40.25	36.52
Quality	0.025	0.01	0.01	0.01	0.01	0.01	0.01	0.15
CT	1.79	2.99	3.01	3.04	2.98	3.35	4.97	22.66

De CT	1.13	2.16	1.24	1.22	2.19	1.74	3.64	17.01
CR	1.37	2.16	2.30	2.20	2.05	2.11	2.26	2.49
PSNR	26.31	39.36	38.54	39.14	38.89	38.54	49.83	52.97
SSIM	0.68	0.83	0.84	0.88	0.84	0.79	0.97	0.98
AD	1.08	0.04	0.05	0.14	0.01	0.13	0.30	0.30

Table 2: Comparative Results: 3DMR_Human_Spinal.



	SPIHT Method	HRW-SPIHT (Proposed)					MW-SPIHT (Proposed)	HQ-SPIHT (Proposed)
Image Input mri human spinal		Sym8 Wavelet image	Rbio 6.8 Wavelet image	Bior 4.4 Wavelet image	Coif5 Wavelet image	Dmey Wavelet image		
Current Image Size (KB) 52	42.21	30.51	29.21	32.45	33.15	31.25	31.15	20.52
Quality	0.025	0.01	0.01	0.01	0.01	0.01	0.01	0.15
CT (sec)	1.71	3.21	3.30	3.24	3.22	3.43	5.47	20.73
DCT(sec)	1.02	1.58	1.77	1.63	1.64	1.97	3.45	16.05
CR	1.23	1.70	1.78	1.78	1.56	1.66	1.66	2.53
PSNR	22.87	34.15	33.32	34.25	34.08	34.35	44.93	51.64
SSIM	0.76	0.86	0.85	0.88	0.86	0.83	0.96	0.98
AD	0.16	0.99	0.12	0.21	0.13	0.04	0.39	0.41

Table 3: Comparative Results: 3DMR_Human_Body.

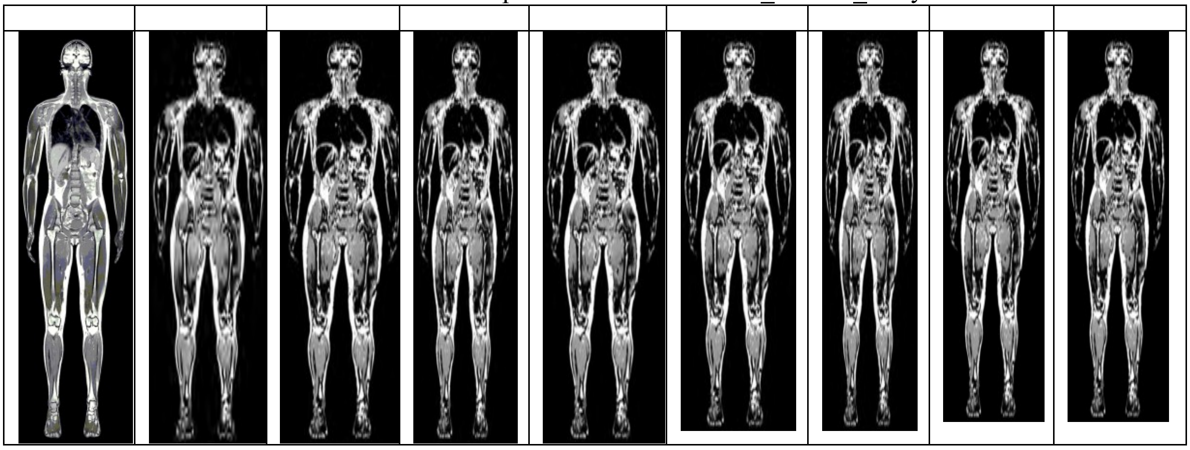


Image Input mri human body	SPIHT Method	HRW-SPIHT (Proposed)					MW-SPIHT (Proposed)	HQ-SPIHT (Proposed)
		Sym8 Wavelet image	Rbio 6.8 Wavelet image	Bior 4.4 Wavelet image	Coif5 Wavelet image	Dmey Wavelet image		
Current Image Size (KB) 52	41.26	31.26	31.26	30.26	34.26	30.81	30.89	22.43
Quality	0.0025	0.01	0.01	0.01	0.01	0.01	0.02	0.15
CT (sec)	1.87	3.21	3.19	3.33	3.29	3.46	5.69	22.83
DCT(sec)	1.29	1.69	1.66	1.71	1.74	2.02	4.09	18.77
CR	1.26	1.66	1.66	1.71	1.51	1.68	1.68	2.31
PSNR	22.39	32.19	31.84	32.40	32.18	32.30	42.71	51.56
SSIM	0.74	0.85	0.84	0.87	0.84	0.82	0.95	0.99
AD	0.73	0.06	0.02	0.13	0.03	0.06	0.36	0.42

Table 4: PSNR Comparative Results.

		HRW-SPIHT (Proposed)					MW-SPIHT (Proposed)	HQ-SPIHT (Proposed)
	SPIHT	Sym8	Rbio6.8	Bior4.4	Coif5	Dmey		
Human Vessels	26.31	39.36	38.54	39.14	38.89	38.54	49.83	52.97
Human Spinal	22.87	34.15	33.32	34.25	34.08	34.35	44.93	51.64
Human Body	22.39	32.19	31.84	32.4	32.18	32.3	42.71	51.56

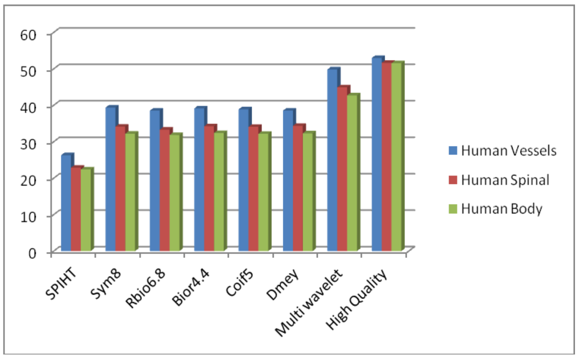


Figure: 1 Comparative results of Table 4.

Table 5: CR Comparative Results.

		HRW-SPIHT (Proposed)					MW-SPIHT (Proposed)	HQ-SPIHT (Proposed)
	SPIHT	Sym8	Rbio6.8	Bior4.4	Coif5	Dmey		
Human Vessels	1.37	2.16	2.3	2.2	2.05	2.11	2.26	2.49
Human Spinal	1.23	1.7	1.78	1.78	1.56	1.66	1.66	2.53
Human Body	1.26	1.66	1.66	1.71	1.51	1.68	1.68	2.31

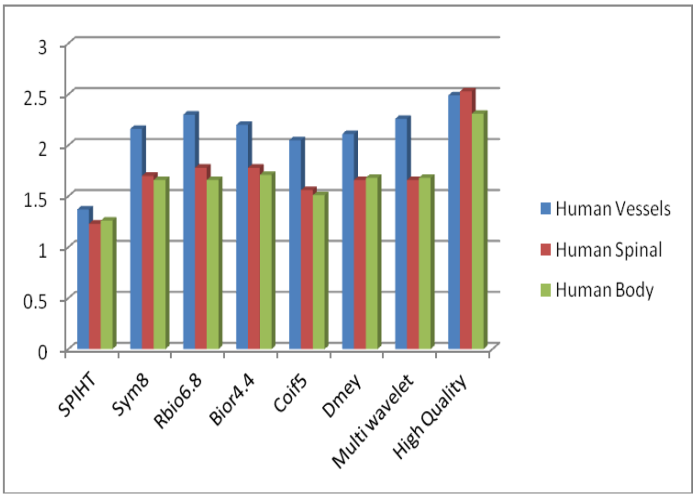


Figure:2 Comparative results of Table 5.

V. CONCLUSIONS

In this paper, we have developed an image compression algorithm based on the improved method as Set Partitioning In Hierarchical Tree algorithm. This algorithm is able to improve the performance of the SPIHT algorithm because it optimizes quality without increasing computation time of encoding and decoding. In addition, this algorithm performed comparatively better with the wavelet based image compression techniques, which could be very interesting for the field of medical image compression.

VI. FUTURE RESEARCH

Our proposed algorithm can be further extended to hierarchical coding of DICOM images where fast and scalable multi wavelet of image decomposition is necessary. Further our algorithm can be applicable to fast bit rate image coder for image transmission over telephone cables.

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