Available online at www.sciencedirect.com
ScienceDirect
Procedia Computer Science 46 (2015) 1732 – 1738
Procedia Computer Science

International Conference on Information and Communication Technologies (ICICT 2014)

Image compression using SPIHT with modified spatial orientation trees

Rema N.R[a],*, Binu Ani Oommen[a], Mythili P[a]

[a]*Division of Electronics Engineering, School of Engineering, CUSAT,Kochi-682022,India.*

Abstract

A new way of reordering spatial orientation tree of SPIHT for improving compression efficiencies for monochrome and color images has been proposed. Reordering ensures that SPIHT algorithm codes more significant information in the initial bits. List of insignificant pixels and sets are initialized with fewer number of coefficients compared to conventional SPIHT for monochrome images. For color images an altered parent offspring relationship and an extra level of wavelet decomposition on chrominance planes were performed. PSNR improvement of 32.06% was achieved at 0.01 bpp for monochrome images and 19.76% for color images at 0.05 bpp compared to conventional schemes.

Peer-review under responsibility of organizing committee of the International Conference on Information and Communication Technologies (ICICT 2014)

Keywords: SPIHT;spatial orientation tree;discrete wavelet transform;color image coding.

---

1. Introduction

Transmission of uncompressed images over Internet requires large bandwidth. Slower connections take more time for receiving such image. Image compression is an efficient method for reducing transmission time. It also reduces the amount of memory required to store the image. Wavelet based compression algorithms provide good compression efficiency. When images are wavelet transformed, information is organized in different frequency bands. This can be effectively utilized for progressive transmission. The 9/7-biorthogonal wavelet has the best energy compaction property. Correlations exist within and between wavelet transformed frequency sub bands. Wavelet based compression algorithms are operated by exploiting these correlations. Wavelet coefficients

---

* Corresponding author. Tel.: +91-999-569-0086
E-mail address: remasyama@gmail.com

Peer-review under responsibility of organizing committee of the International Conference on Information and Communication Technologies (ICICT 2014)
doi:10.1016/j.procs.2015.02.121

corresponding to the same spatial location and orientation are grouped to form a spatial orientation tree (SOT). A tree with no significant coefficient with respect to the given threshold is known as a zero tree. Embedded Zero tree Wavelet (EZW) image compression was introduced by Shapiro[2]. Said and Pearlman proposed an improved scheme[3], called Set Partitioning In Hierarchical Trees (SPIHT). SPIHT algorithm generates an embedded bit stream of wavelet coefficients with respect to decreasing thresholds. When more number of bits in the encoded bit stream indicate insignificance, it results in very poor image quality. If the bits in the encoded bit stream are reordered with priority given to significant information, an improved reconstructed image quality is confirmed. This leads to better exploitation of the energy compaction of the wavelet coefficients. A modified SOT structure has been implemented[4] to increase significant information in the initial bits of the encoded bit stream with a listless structure.

Compression of color images is done by extending gray level image compression algorithm using SPIHT to three planes of color image[5]. For color image compression, the image is transformed to luminance-chrominance color planes (YCbCr). Each color plane is coded independently and resultant bit streams are transmitted one after other. Pixels from the lowest frequency sub band of luminance and the two chrominance planes are used to initialize LIP and LIS. Due to this efficiency is reduced at lower bit rates. This is known as direct coding. Several efficient color image compression algorithms using SPIHT have been proposed[6, 7]. In color SPIHT[6] (CSPIHT) only pixels from the lowest frequency sub band of luminance plane is used to initialize lists and hence better efficiency at lower bit rate is achieved. A modified complicated SOT[7] based on EZW algorithm was proposed in 1999. Two SPIHT-based methods for coding color images[8] are introduced in which color components are efficiently linked with the luminance component by composite spatial orientation trees. For color images, large number of chrominance plane coefficients is insignificant during initial positions of the bit stream. For better exploitation of chrominance plane coefficients, these planes are wavelet transformed with an additional level of decomposition in this paper.

This paper is organized as follows: Section 2 describes the proposed modifications in SPIHT for monochrome and color image coding. In section 3 simulation results and comparison with the conventional SPIHT scheme is presented. Section 4 concludes the paper.

2. Proposed modifications in SPIHT

2.1 Conventional SPIHT algorithm

Conventional SPIHT algorithm[3] consists of three stages: initialization, sorting pass and refinement pass. SPIHT algorithm contain three lists: list of insignificant sets LIS, list of insignificant pixels LIP and list of significant pixels LSP. LIP is initialized with all nodes of the lowest frequency sub band. These nodes are grouped in 2 x 2 adjacent pixels. In each group, the upper left corner node has no descendants. The remaining nodes in lowest frequency band have descendants as shown in Fig. 1. LIS is initialized with all nodes of the lowest frequency sub band that have descendants. For the nodes in higher frequency bands if (x, y) is the position of the root node, descendants are given by (2x, 2y), (2x, 2y+1), (2x+1, 2y) and (2x+1, 2y+1). LSP is initially an empty list. During initialization the SPIHT algorithm defines a threshold based on the maximum value in the wavelet coefficients. In the sorting pass, the algorithm check the significance of elements in the LIP and then in the LIS. In LIP each pixel is compared with the current threshold and a bit is generated (0 or 1) to indicate whether it is significant or not. If the coefficient is significant, a sign bit is generated and the pixel is moved to the LSP. During the sorting pass of LIS, the SPIHT algorithm check the significance of each set in the LIS and output the significance information (0 or 1). If a set is significant, it is partitioned into its offspring and descendants. Each offspring is tested for significance. If a coefficient in the offspring set is significant it is moved to LSP and if it is insignificant moved to LIP and the corresponding bits are generated. If these offspring have descendants, then the offspring are taken as new sets in LIS and check for significance in the same pass itself. If there are no descendants for offspring, the set is removed from the list. In the refinement pass, refinement bits are generated for those coefficients which are found to be significant during previous passes. After refinement pass, the threshold is divided by 2 and the nodes in the lists are processed in the same way as above for the new threshold. The sorting and refinement stages are continued until the target bit rate is achieved.

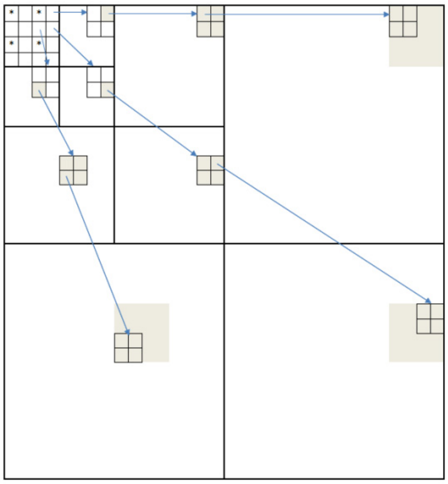

Fig. 1. Parent offspring relationship in conventional SPIHT across bands

2.2 Modifications in SPIHT for monochrome images

At low bit rates a small percentage of bits is used to code significant information, hence poor quality of images is obtained. When the bit stream consists of more significant bits, the image quality improves. The modified algorithm is similar to conventional SPIHT except at initialisation. In the proposed method only the nodes that had no descendants in conventional SPIHT (marked with *), form the roots of the modified tree and LIP and LIS are initialised with these nodes. These nodes have three offspring in the same band as specified by the modified parent children relationship shown in Fig. 2. If (x, y) is the position of the root node, offspring positions are at (x, y+1), (x+1, y) and (x+1, y+1). In successive passes, the other coefficients will accumulate the lists through the SOT relationship across several bands as in conventional SPIHT. With this modification the percentage of significant information has increased in the bit stream, thus improving the coding efficiency.

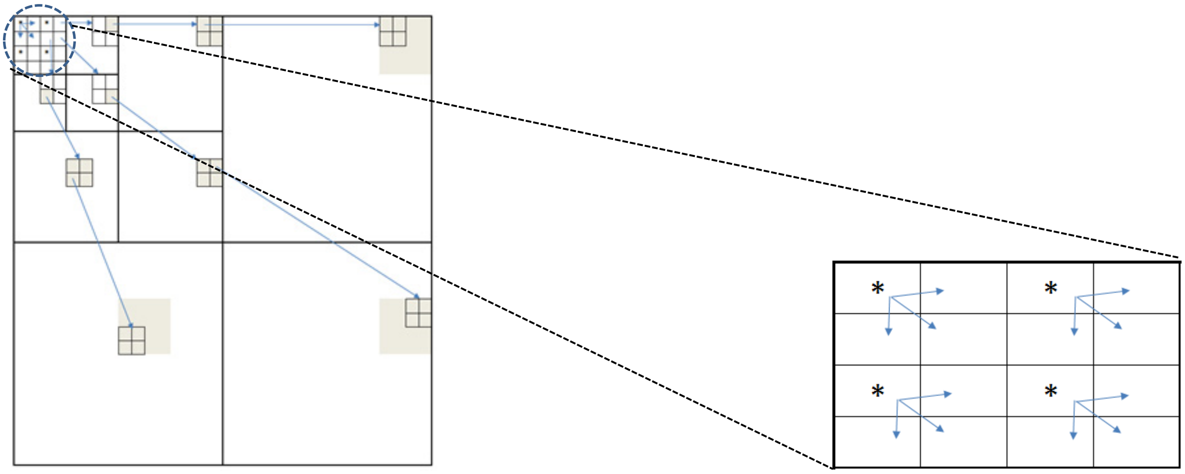

Fig. 2. Proposed parent offspring relationship in modified SPIHT across bands with an inset indicating the parent offspring relationship in lowest frequency sub band

2.3 Modifications in SPIHT for color images

Color image is first converted to the luminance chrominance (YCbCr) colorspace. Then color images in YCbCr form are wavelet transformed with chrominance planes undergo an additional level of decomposition. In conventional SPIHT for a 2 x 2 group in the lowest frequency sub band (LL band), upper right pixel will have descendants in horizontal details, lower left pixel will have descendants in vertical details and lower right pixel will have descendants in diagonal details in the same decomposition level. In the proposed technique parent child relationship is altered. The pixels in first quadrant of the LL band in luminance plane are taken as the parent of corresponding pixels in chrominance planes. In the luminance plane, the pixels in second quadrant of LL band have descendants in horizontal details, third quadrant pixels have descendants in vertical details and fourth quadrant pixels have descendants in diagonal details in the same decomposition level. In LL band of chrominance planes, the first quadrant pixels have no descendants and the pixels in the remaining quadrants have descendants in the chrominance plane at the same level of decomposition as shown in Fig. 3. Threshold selection during initialization, sorting pass and refinement pass are same as that of conventional SPIHT.

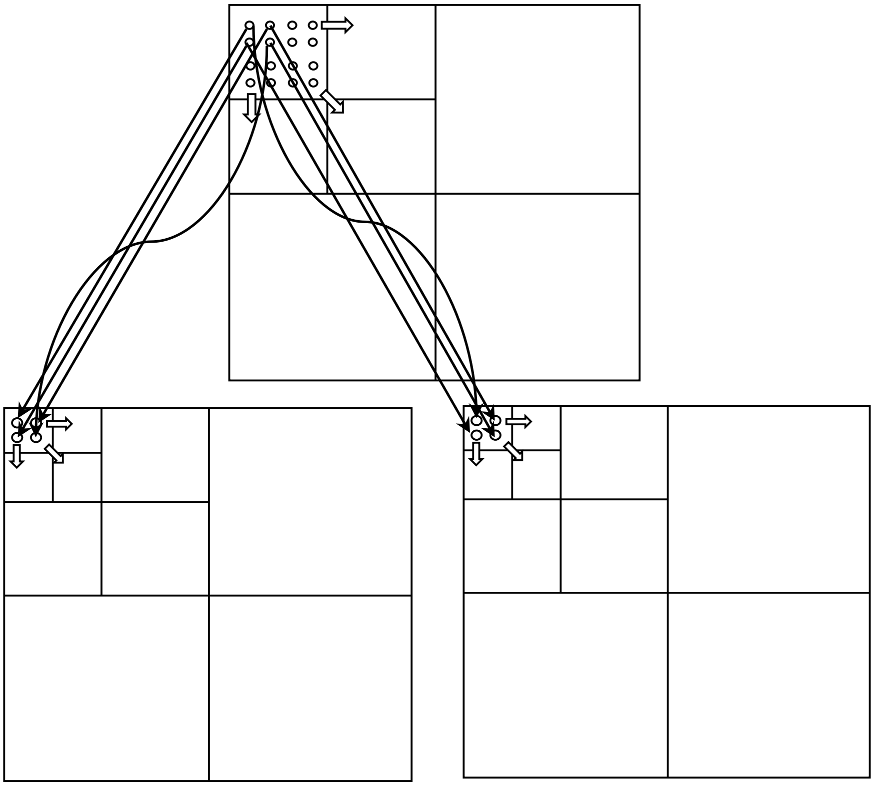

Fig. 3. Modified spatial orientation tree for color images

In the proposed technique luminance plane pixels are used to initialize lists. LIP and LIS are initialized with pixels in lowest frequency band of luminance plane. Chrominance plane pixels are added to the list through their luminance parents when found to be significant. First quadrant pixels of LL band in luminance plane have descendants in chrominance plane in the corresponding positions. For remaining pixels in LL band if (x, y) is the position of the root node, offspring positions are given by (2x, 2y), (2x, 2y+1), (2x+1, 2y) and (2x+1, 2y+1). In the chrominance plane parent child relation except in first quadrant of LL band is same as that of luminance plane. First quadrant pixels in chrominance plane have no descendants. The remaining coefficients in luminance and chrominance planes have descendants in the higher frequency bands as in conventional SPIHT.

3. Simulation results

3.1 For monochrome images

The number of significant bits in the encoded bit stream at various bit rates from 0.01 to 0.5 bits per pixel (bpp) for Lena, Goldhill, Clock, Moon and Barbara images[9] is shown in Table 1. This compares the progressive transmission performance of the proposed modified SPIHT (MSPIHT) and conventional SPIHT coder. The 9/7-biorthogonal-filter bank is used for 2-D wavelet decomposition with four levels of decomposition. From the table it can be seen that at low bitrates, the number of significant bits in the encoded bit stream is considerably higher compared to conventional SPIHT. As the rate increases, difference between the percentages of significant bits between both coders reduces as more wavelet coefficients are included by both coders. Simulations were done in MATLAB for various images. The results of five such images are shown here.

Table 1. Rate in bpp versus percentage of significant bits.

	Percentage of significant bits									
Rate	Lena 512 x 512		Clock 256 x 256		Moon 256 x 256		Goldhill 512 x 512		Barbara 512 x 512	
(bpp)	SPIHT	MSPIHT	SPIHT	MSPIHT	SPIHT	MSPIHT	SPIHT	MSPIHT	SPIHT	MSPIHT
0.01	49.87%	77.20%	65.24%	84.83%	52.74%	81.18%	41.80%	76.32%	46.15%	74.87%
0.03	49.35%	70.97%	55.87%	67.85%	53.28%	71.23%	46.22%	69.54%	48.60%	69.82%
0.05	51.50%	61.79%	55.05%	64.30%	54.55%	64.46%	49.71%	63.38%	51.15%	59.52%
0.1	51.47%	55.43%	52.80%	58.03%	50.56%	55.42%	51.20%	56.05%	50.28%	56.78%
0.2	51.10%	53.26%	53.42%	56.22%	45.66%	47.89%	51.61%	54.34%	52.21%	55.89%
0.5	55.25%	56.33%	53.19%	54.16%	46.51%	47.50%	52.58%	53.72%	55.79%	57.02%

The quality of the reproduced image is measured by peak signal to noise ratio (PSNR).

$$PSNR = 10\ log_{10} \frac{255^2}{mse} \tag{1}$$

where mse is the mean square error between original and reconstructed image. The PSNR results of SPIHT and modified SPIHT are shown in Table 2.

Table 2. Comparative PSNR evaluation of SPIHT coding.

Rate (bpp)	PSNR (db)														
	Lena 512 x 512			Clock 256 x 256			Moon 256 x 256			Goldhill 512 x 512			Barbara 512 x 512		
	SPIHT	MSPIHT	% Imp.	SPIHT	MSPIHT	% Imp.	SPIHT	MSPIHT	% Imp.	SPIHT	MSPIHT	% Imp.	SPIHT	MSPIHT	%Imp.
0.01	11.88	15.31	28.87	13.05	15.79	21.00	10.49	14.06	34.03	11.32	16.32	44.17	11.56	15.29	32.27
0.03	22.31	23.69	6.19	20.12	20.87	3.73	24.14	25.32	4.89	21.99	23.07	4.91	20.34	21.15	3.98
0.05	25.03	25.70	2.68	22.57	23.04	2.08	26.59	26.90	1.17	24.17	24.66	2.03	21.92	22.18	1.19
0.1	28.44	28.68	0.84	25.44	25.69	0.98	28.23	28.38	0.53	26.30	26.51	0.80	23.39	23.55	0.68
0.2	31.74	31.88	0.44	28.74	28.84	0.35	29.50	29.57	0.24	28.40	28.50	0.35	25.64	25.83	0.74
0.5	36.46	36.52	0.16	35.29	35.41	0.34	31.59	31.64	0.16	31.47	31.52	0.16	30.38	30.46	0.26

From the table it can be seen that modified SPIHT algorithm perform better than conventional SPIHT at all bit rates for monochrome images. Since the PSNR values are dependent on images, the average of PSNR improvement for all images under consideration is taken into account as the overall PSNR improvement. PSNR improvement of 32.06% is achieved at 0.01 bits per pixel compared to conventional SPIHT for monochrome images. The average PSNR improvement increases drastically as the rate reduces for monochrome images.

3.2 For color images

The PSNR results of the proposed modified CSPIHT (MCSPIHT) is compared with CSPIHT[6] at various bit rates from 0.05 to 0.7 bits per pixel (bpp) for Lena, Sailboat, Mandrill, Pepper and Airplane images[9] as shown in Table 3.The input image is first converted into luminance chrominance color space format and transformed by the biorthogonal 9/7 wavelet. The luminance plane goes through 4 levels of decomposition and the chrominance planes undergo an additional level of decomposition compared to the available techniques in the literature. These transform coefficients are linked with a composite SOT shown in Fig. 3. When chrominance plane coefficients are wavelet transformed with an additional level, a large number of insignificant coefficients appear in chrominance planes compared to luminance plane. Hence during initial passes, insignificant pixels can be represented as insignificant set. As a result improvement in performance is observed at lower bit rates. As bit rate increases these pixels become significant and sets are split into pixels. Simulations are done in MATLAB for various color images. The results of five such images are shown here. The overall PSNR of the three color components is calculated as

$$PSNR = 10\,log_{10}\frac{255^2}{(mse(y)+mse\,(cb)+mse(cr))/3} \qquad (2)$$

where *mse (y)* is the mean square error for the luminance component Y, *mse (cb)* is the mean square error for the chrominance component Cb and *mse(cr)* is the mean square error for the chrominance component Cr. The PSNR values of CSPIHT and modified CSPIHT are shown in Table 3.

Table 3. Comparative PSNR evaluation of SPIHT color coding.

Rate (bpp)	PSNR (db)														
	Lena 512 x 512			Sailboat 512 x 512			Mandrill 512 x 512			Pepper 512 x 512			Airplane 512 x 512		
	CSP	MCSP	% Imp.	CSP	MCSP	% Imp.	CSP	MCSP	% Imp.	CSP	MCSP	% Imp.	CSP	MCSP	%Imp.
0.05	22.35	26.36	17.94	19.98	24.02	20.22	20.09	23.32	16.08	22.23	24.97	12.33	19.13	25.3	32.25
0.1	29.42	30.90	5.03	26	27.10	4.23	24.45	24.99	2.21	27.86	28.85	3.55	27.76	29.5	6.27
0.2	33.47	33.93	1.37	28.69	29.05	1.25	25.85	26.05	0.77	31.28	31.73	1.43	31.66	32.46	2.53
0.3	35.36	35.69	0.93	30.21	30.40	0.63	26.74	26.94	0.75	32.98	33.29	0.95	33.61	34.34	2.17
0.4	36.47	36.67	0.55	31.10	31.31	0.68	27.47	27.58	0.40	34.62	34.75	0.37	35.63	35.99	1.01
0.5	37.35	37.50	0.40	31.89	32.11	0.69	28	28.12	0.43	35.38	35.46	0.23	36.68	36.90	0.60
0.6	38.09	38.22	0.34	32.6	32.69	0.28	28.52	28.62	0.35	36.05	36.15	0.28	37.69	38	0.82
0.7	38.64	38.73	0.23	33.03	33.11	0.24	28.99	29.09	0.34	36.60	36.74	0.38	38.70	38.90	0.52

An improved coding performance of MCSPIHT compared to CSPIHT is observed in the table at all bit rates. In addition considerable gain in PSNR is achieved by MCSPIHT over CSPIHT at lower bit rates. As rate increases the PSNR gap between CSPIHT and MCSPIHT reduces, with MCSPIHT having a slight advantage. Since the PSNR values exhibit variation with images at the same bit rate, the average of PSNR improvement for all images under consideration is taken into account as the overall PSNR improvement. PSNR improvement of 19.76% is obtained at 0.05 bits per pixel compared to CSPIHT for color images. The average PSNR improvement increases as the rate reduces in color images.

4. Conclusions

Modifications on the conventional SPIHT for monochrome and color images have been proposed and successfully verified with improved PSNR performance. A reordering in spatial orientation tree of SPIHT algorithm ensures that it codes more significant information in the initial bits of the encoded bit stream leading to better performance at very low bit rates. Thus it can be used in small mobile devices having limited memory and processing capability when they are compressing an image for transmission over any network. For color images an additional DWT decomposition level and an altered composite SOT results in an improved PSNR performance at lower bit rates.

References

1. M Antonini, MM Barlaud, P Mathieu, I Daubechies. Image coding using wavelet transform. *IEEE Trans. on Image Processing*. 1992;**1**:p. 205–220.
2. JM Shapiro. Embedded image coding using zero trees of wavelet coefficients. *IEEE Trans. Signal Processing*. 1993;**41**:p.3445-3462.
3. A Said, WA Pearlman. A new fast and efficient image codec based on set partitioning in hierarchical trees. *IEEE Trans. on Circuits and Systems for Video Technology*. 1996; **6**:p.243-250.
4. Hong Pan, WC Siu, NF Law. Efficient and low-complexity image coding with the lifting scheme and modified SPIHT. *International Joint Conference on Neural Network 2008.*
5. BJ Kim, Z Xiong, WA Pearlman. Low Bit Rate Scalable Video Coding With 3D Set Partitioning in Hierarchical Trees (3D SPIHT). *IEEE Trans. Circuits and Systems for Video Technology*. 2000;**10**:p.1374-1387.
6. AA Kassim, WS Lee. Embedded color image coding using SPIHT with partially linked spatial orientation trees. IEEE *Trans. Circuits Sys. Video Tech*. 2003;**13**:p.203-206.
7. Ke Shen, EJ Delp. Wavelet based rate scalable video compression. *IEEE Trans. Circuits Syst. Video Technol.* 1999. p.109-122.
8. E Khan, M Ghanbari. Efficient SPIHT-based embedded color image coding techniques. *IEEE Electronics letters.* 2001;**37**:p.951-952.
9. University of Southern California, USC image database at http://sipi.usc.edu/services/database.