World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:1, No:12, 2007

Efficient Secured Lossless Coding of Medical Images – Using Modified Runlength Coding for Character Representation

S. Annadurai, and P. Geetha

Open Science Index, Computer and Information Engineering Vol:1, No:12, 2007 publications.waset.org/9700.pdf

Abstract**—**Lossless compression schemes with secure transmission play a key role in telemedicine applications that helps in accurate diagnosis and research. Traditional cryptographic algorithms for data security are not fast enough to process vast amount of data. Hence a novel Secured lossless compression approach proposed in this paper is based on reversible integer wavelet transform, EZW algorithm, new modified runlength coding for character representation and selective bit scrambling. The use of the lifting scheme allows generating truly lossless integer-to-integer wavelet transforms. Images are compressed/decompressed by well-known EZW algorithm. The proposed modified runlength coding greatly improves the compression performance and also increases the security level. This work employs scrambling method which is fast, simple to implement and it provides security. Lossless compression ratios and distortion performance of this proposed method are found to be better than other lossless techniques.

Keywords**—**EZW algorithm, lifting scheme, lossless compression, reversible integer wavelet transform, secure transmission, selective bit scrambling, modified runlength coding .

I. INTRODUCTION

CLINICAL picture archiving and communication systems (PACS), and telemedicine networks require the storage and transmission of a large amount of medical image data, and efficient compression of these data is crucial. Applying Image compression reduces the storage requirements, reduces network traffic, and therefore improves efficiency. Several techniques have been proposed for image compression [16]. These can be classified into lossy and lossless techniques. Lossless compression techniques allow exact reconstruction of the original, but the achievable compression ratios are only of the order approximately 2:1. This paper addresses the following combined problem: (1) obtaining high compression ratio for the lossless coding of images, comparable to other methods [12],[13],[17] (2) achieving this in an embedded fashion, i.e. in such a way that all lower rate codes of an image are embedded at the beginning of the bitstream generated for the lossless coding, and (3) secured transmission of the embedded bitstream. Solving this problem is important for many application domains.

In medical area one cannot afford information loss due to compact coding, because lossy compression may destroy some of the information required during processing, or add artifacts that lead to erroneous interpretations. Lossless compression has been widely preferred by medical professionals [16], because it facilitates accurate diagnosis.

The standard wavelet compression techniques, even if loss-less in principle, do not reconstruct exactly the original image because of the rounding of the floating-point wavelet coefficients to integers. The use of the lifting scheme allows generating truly loss-less integer-to-integer wavelet transforms. In recent years, new reversible integer wavelet transforms [2],[6],[10] can be developed using lifting scheme, have grown in popularity for lossless image compression. These compression systems [2],[6],[10], comprising a wavelet transform followed by Shapiro's EZW(embedded zero trees of wavelet coefficient) algorithm, have proven to be a successful method in the field of image compression. In this paper zero tree coding scheme together with new modified runlength coding is used to encode the subband coefficients. Modified runlength coding (MRLE) increases the compression ratios of the proposed approach and it also increase the security level.

Lossless image compression coder, such as context based predictive coding (CALIC) [17] and universal context modeling based coding [14], the lack of a progressive transmission capability makes them unsuitable for interactive applications like telematics over large networks. Embedded coding permits the progressive transmission of the compressed data, starting with an economical initial transmission of a rough image followed by gradual transmission of the refinement details, needed for the final reconstruction. Embedded progressive coding becomes quite important in terms of compressing medical images, because an image may be stored without any loss.

In addition to compression, secured transmission helps in accurate diagnosis and medical research. Changes in data bits by the intruder make accurate diagnosis a difficult task. Medical researchers will be reluctant to provide their valuable contents if they are not assured that their contents are securely protected. Hence several technologies have been developed for information protection [7]. One is through encryption. Traditional cryptographic algorithms such as Digital Encryption Standard (DES) [3] are not fast enough to meet the real- time delivery requirement [8], because they usually add a large amount of processing overhead. Because of this the compression ratio achieved is also limited to 1.5 to 2.

Manuscript received March 4, 2005 .

S. Annadurai is with the Government college of Engineering, Tirunelveli (phone: 0462 2552448; e-mail anna_prof @yahoo.co.in)

P. Geetha is with Government college of Technology, Coimbatore (phone: 0422 2437210; e-mail: geetha_akp@yahoo.co.in).

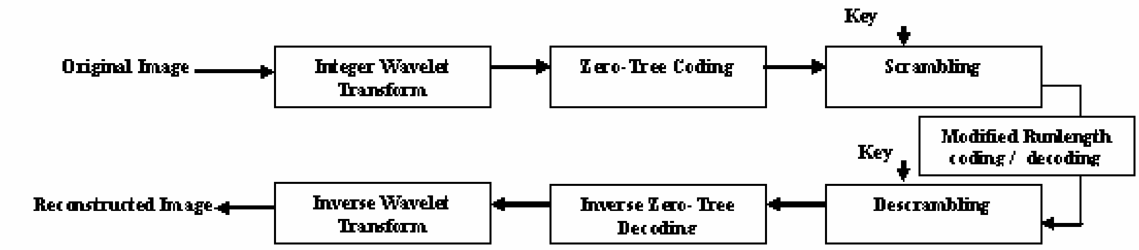

Fig. 1. Block diagram of the proposed compression Techniques.

To reduce the amount of processing overhead in this paper selective bit scrambling method is applied. In addition to this in the proposed approach to make the computation easier integer wavelet transform is used. The digital image will be scrambled before it is distributed and only authorized users who have the proper key for decryption can access the clear content. This technique does not introduce additional bits which in turn reduce the compression ratio.

Hence in this paper, a secured lossless image compression framework is proposed in which image data are scrambled without significantly affecting the compression efficiency. The rest of paper is organized as follows. Overview of the proposed framework is discussed in section II, Experiments and Results are presented in section III, the paper is concluded in section IV.

II. OVERVIEW OF THE PROPOSED FRAMEWORK

Secured Lossless Image Compression can be obtained by Integer wavelet transform followed by EZW algorithm and selective bit scrambling. Scrambling is a disordered mixture of data. A digital image scrambling scheme should have a relatively simple implementation, low-cost and low-delay operation for real-time interactive applications. It should have a minimum adverse impact on the compressibility of the image. The digital image scrambling method aims to meet the objectives outlined earlier. Fig. 1 shows a general architecture of the proposed system. The proposed Secured image compression and reconstruction architecture addressed in this paper involves the following steps.

Step 1: The given image is decomposed using Integer wavelet transform. Integer wavelet transform can be developed using lifting scheme.
Step 2: Zero tree coding technique is applied to the data obtained in the previous step, which provides a compact multiresolution representation of significance map indicating the positions of the significant coefficients. To encode a coefficients of significant map four symbols are used 1) Zerotree root, 2) Isolated zero, 3) Positive significant, 4) Negative significant.
Step 3: The four symbols used in zero tree coding are encoded by distinct binary values for efficient transmission.
Step 4: Scramble the encoded bits based on the key to encrypt an image data.
Step 5: Modified runlength coding (MRLE) of the scrambled coefficients. Transmit the output via transmission line. Receiver applied the reverse procedure, obtained a sequence of bits.
Step 6:The encoded coefficients are reformed by descrambling the bits using the same key .
Step 7: In decoding operation, the symbols are decoded from the coefficients obtained in step 6.
Step 8: The Inverse zerotree decoding method is applied to find the positions of the decoded symbols and decompress the wavelet coefficients of the significant map. Go to step 2, run the algorithm sequentially and stops whenever a target rate is met exactly.
Step 9: Inverse Integer wavelet transform is applied to the decompressed data obtained in the previous step to reconstruct the original image.

The above said steps are explained in the forthcoming sections.

A. Lifting and Reversible Integer Wavelet Transforms

In most cases, the wavelet transform produces floating-point coefficients and although this allows perfect reconstruction of the original image in theory, the use of finite-precision arithmetic, together with quantization, results in a lossy scheme. Recently, new Integer wavelet transform, i.e. wavelet transforms that transform integer to integer have been introduced [1],[2],[10]. In [2], it was shown that an integer version of every wavelet transform with finite filters can be obtained using the lifting scheme of[11]. Lifting allows a wavelet transform to be computed quickly through a series of individual lifting steps and fully in place calculation. In this work, the following reversible integer wavelet transforms of[2] based on the lifting scheme have been used with the notation (M,N) where M and N represent the number of vanishing moments of the analysis and synthesis high pass filters, respectively .

a . The (2,2) Transform *b . The (4,2) Transform*
c. The (2,4) Transform *d . The (6,2) Transform*
e . The (2+2,2) Transform *f. The S Transform*

The image is compressed using EZW algorithm; compression of significant map using zerotree coding is discussed in the next step.

B. EZW Compression/ Decompression Algorithm

The embedded zero tree wavelet algorithm (EZW) as a simple and remarkably effective image compression algorithm, having the property that the bit stream are generated in order of importance, yielding a fully embedded code. In addition to producing a fully embedded bit stream, EZW consistently produces compression results that are competitive with other compression algorithms on standard test images. Zerotrees allow the successful prediction of insignificant coefficients across scales to be efficiently represented as part of exponentially growing trees. In a hierarchical subband system, every coefficient at a given scale can be related to a set of coefficients at the next finer scale of similar orientation. The coefficients at the coarse scale are called the parent, and all coefficients corresponding to the same spatial location at the next finer scale of similar orientation are called children. Parent child relation and scanning order for subband encoding are given in [9].

Four symbols are used to encode the significant map. They are

a) Zerotree root - A coefficient x is said to be an element of a zerotree for a given threshold T if itself and all of its descendents are insignificant with respect to T.
b) Isolated zero- Which means that the coefficient is insignificant but has some significant descendant.
c) Positive significant- The coefficient value is greater than the threshold T.
d) Negative significant- The magnitude of the coefficient value is greater than the threshold

Two passes are needed to encode the coefficients of significant map: Dominant and Subordinate pass (refinement pass) are explained in [9]. The procedure for encoding the symbols is given in section C.

C. Encoding Dominant and Subordinate Pass Symbols

Encoded dominant pass symbols are effectively represented for efficient transmission and to reduce the storage requirement. Most of symbols are zero tree root (ZTR) in the dominant pass, so in this paper, ZTR is represented by a single bit i.e., Z=0. To uniquely identify the symbols from embedded bit stream the symbols are effectively represented as Positive P=10, Isolated zero I=110, Negative N=111. Subordinate pass symbols are represented by either ‘0’ or ‘1’ based on the uncertainty interval. Scrambling of the encoded bits to ensure security is discussed in the next step.

D. Selective Bit Scrambling of Encoded Coefficients

Several scrambling systems [5],[18] rely on methods of directly distorting the visual image data such that, without descrambling, the image appears unintelligible to the viewer. The proposed approach, Scramble the encoded bits based on the key to encrypt an image. To increase the level of security block shuffling and block rotation is used, discussed in [15]. For the encryption of the bits, if a codebreaker is to recover the encoded bits, an exhaustive search is required. Selective bit scrambling approach scrambles selected bits of encoded coefficient obtained in the previous step to encrypt an image data. Applying new modified coding improves the compression performance and also it increases the security level, is explained in the next step.

E. A Modified Runlength Coding and Decoding

Modified runlength coding (MRLE) algorithm has the following form.

Algorithm 1

```
0) Read the output file of EZW algorithm 8 bits at a time and
   convert it into character and store the character in result
   file.
1) Compute threshold values. (given below)
2) Choose a separator character such that it is not present in
   the result file.
3) Scan the characters of the result file one by one and count
   the repeated occurrence of the same character.
   i)  if count < threshold , print character in the output
       file
   ii) if count >= threshold , print the separator followed
       by count and that character.
```

MRLE representation takes 4 bytes (separator (S)-1byte, Number of characters (Count)-2, Character-1).

Threshold = S+ Count+ Character

So more than four consecutive occurrence of the same character is replaced by 4 bytes representation of MRLE. If the number of consecutive occurrence is less than 4, MRLE is not applied and each character occupies just a byte. Whereas in RLE [19] even a single occurrence of a character is replaced by 3 byte (count, char) representation which is not efficient for a file having more none repeated character.

When the result of the dominant pass is checked most of the symbols are found to be zerotree root. So, if MRLE is applied it gives better results. In decoding, the symbols are decoded sequentially by applying the reverse procedure. The receiver with a proper key can descramble the bits is given in the next step.

F. Descrambling the Encoded Coefficients

The encoded coefficients can be descrambled by the user with the same key. Without this key, it is difficult to reconstruct the decoded symbols and also it is hard to find the position of the decoded symbols.

G. Decoding Dominant and Subordinate Pass Symbols

In the decoding operation, each decoded symbol, both during a dominant and a subordinate pass are obtained using the reverse procedure of encoding. Predicting the position of decoded symbols is discussed in the next step.

H. Inverse Zerotree Decoding Method

Inverse zerotree decoding method finds the co-ordinates of the decoded symbols based on the scanning order is given in [9]. In the zerotree decoding operation, each decoded symbol, both during a dominant and a subordinate pass are refines and reduces the width of the uncertainty interval in which the true value of the coefficient may occur Decompressed data are obtained from the reconstructed values of dominant and subordinate pass symbols. The procedure to obtain the original image is explained in the next step.

I. Inverse Integer Wavelet Transform

Lifting allows simple inverse transform, of the same complexity as the forward one - Reversible integer wavelet transform being composed of the elementary operations of the forward one, taken in reversed order. Inverse integer wavelet transform is applied to the decompressed data to get the integer data of the image. Experimental results are given in the next section.

III. EXPERIMENTS AND RESULTS

The proposed secured Lossless Compression algorithm is applied to a WILLIS image of size 128 × 128 which is digitized to 8 bits/pixel is shown in Fig.2(a). Fig 2(b)and 2(c) are decomposed and reconstructed images. This algorithm is tested for various images and the CR (Compression Ratios) are compared with other lossless compression techniques: lossless JPEG (LJPEG) [12], Low complexity, content based lossless compression (LOCO-I) [13], Context based adaptive lossless image codec (CALIC) [17], EZW and arithmetic coding is shown in Table I. From the Table I results, the proposed algorithm offers excellent compression ratio and also the computational speed is high. The average PSNR (peak signal to noise ratio) for this, is roughly 3dB and 4dB better than other lossless techniques. CALIC [17], the lack of a progressive transmission capability makes them unsuitable for interactive applications expanded over large networks. There was no single transform that performed best over the entire data set. Compare to arithmetic coding this gives better results for most of the images with similar pattern.

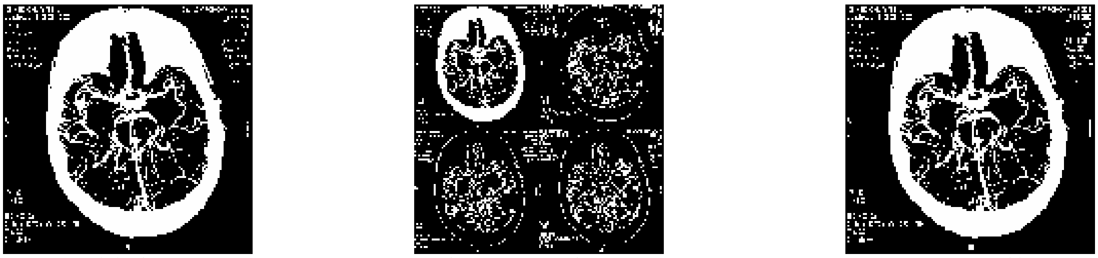
(a) Original Image (b) Decomposed Image (c) Reconstructed image

Fig. 2 Scrambled Lossless compression and Reconstruction of WILLIS Image result of (2,4) transform CR=8.33

TABLE I
COMPARISON ON CR OF DIFFERENT INTEGER WAVELET TRANSFORM OF THE PROPOSED APPROACH WITH OTHER METHODS

Image(256 X256)	LOCO-I [13]	CALIC [17]	EZW(2,4) Arith.code	**Proposed approach**					
				(2,2)	(2,4)	(4,2)	(6,2)	(2+2,2)	S
XRAY	2.52	2.61	6.59	6.29	**7.01**	6.77	6.70	6.45	6.29
Blood cell	3.10	3.51	5.02	6.18	**6.28**	6.08	6.05	6.21	3.40
CT_skull	2.25	2.35	4.24	4.35	4.45	**4.46**	4.39	4.46	4.23
CT_wrist	4.80	4.79	**5.88**	5.78	5.82	5.70	5.71	5.70	5.52
MR_liver	2.53	2.73	4.74	4.73	4.81	4.79	4.85	**4.91**	4.70
Spinal	2.42	2.49	5.21	6.33	7.86	**7.86**	6.08	7.26	6.21
Willis	2.32	2.64	8.21	8.01	**8.39**	8.20	8.18	8.24	7.89

IV. CONCLUSIONS

Medical imaging generate vast amount of data. To preserve these data lossless compression is widely preferred, because it allows the exact reconstruction of the original image. The secured transmission helps in accurate diagnosis and research. The proposed secured lossless compression is based on joint encryption and lossless compression. Use of MRLE increases the compression performance. An excellent compression ratio is achieved and also the quality of the image is found to be good. This is particularly useful for the fast consultation and transmission of losslessly archived large medical images.

REFERENCES

[1] Amir said and William A. Pearlman," An Image multiresolution representation for lossy and lossless compression," IEEE Transactions on Image processing, vol.5, pp.1303-1310, Sept.1996.

[2] R.Calderbank, I.Daubechies, W.Sweldens, and B-L.Yeo, " *Wavelet transforms that map integers to integers*," submitted to Journal of Applied and Computational Harmonic Analysis.

[3] Data Encryption standard, FIPS PUB 46, Jan. 1977.

[4] I.Daubechies and W.Sweldens, "*Factoring wavelet transforms into lifting steps*," preprint, Bell Laboratories, Lucent Technologies, 1996.

[5] G.L.Hobbs, "Video *Scrambling*", U.S.Patent 5815 572, Sep. 29, 1998.

[6] Jun Wang, H.K.Haung, "Medical Image Compression by Using Three-Dimensional Wavelet Transformation", *IEEE Transactions on Medical Imaging*,vol. 15, pp.547-554, Aug.1996.

[7] B.Macq and J.Quisquater," Cryptology for digital TV broadcasting", *Proc. IEEE*, vol.83, pp.944-957, June 1995.

[8] J.Meyer and F.Gadegast, "Security Mechanisms for Multimedia Data with the Example MPEG-1 Video," , http://www.cs.tuberlin.de/phade/phade/secm-peg.html,1995.

[9] J.Shapiro, "Embedded Image coding using zerotrees of wavelet coefficients", *IEEE Transactions on Signal Processing*, vol.41, pp. 3445- 3462, Dec.1993.

[10] Steven Dewritte, Jan Cornelis, Member, "Lossless Integer Wavelet Transform", *IEEE Signal Processing Letters*, vol.4.pp.158-160, June 1997.

[11] W.Sweldens, "The Lifting scheme: A custom-design construction of biorthogonal wavelets," *Journal of Applied and Computational Harmonic Analysis*,vol. 3 (2),pp.186-200,1996.

[12] G.K.Wallace," The JPEG still picture compression standard," *Comm.ACM*,34, 1991, 30-44.

[13] M.J.Weinberger, G.seroussi, and G.Shapiro,"LOCO-I:Alow complexity, context-based lossless image compression algorithm," *in Proc.of 1996 Data Compression Conference*,1996,pp.140-149.

[14] M.J.Weinberger, J.J.Rissanen and R.B.Arps,"Applications of universal context modeling to lossless compression of gray-scale images," *IEEE Trans. Image Processing*,5, 1996, 575-586.

[15] Wenjun Zeng,Shawmin Lei, "Efficient Frequency Domain Selective Scrambling of Digital Video*", IEEE Transaction on multimedia*,vol. 5, March 2003.

[16] S.Wong, L.Zaremba,D.Gooden, and H.K.Huang, "Radiologic image compression –A review," *Proc.of the IEEE*, vol.83, pp.194-219,Feb.1995.

[17] X.Wu and N.Menon,"CALIC-A context based adaptive lossless image codec,*" in Proc.of 1996 International Conference on Acoustics,Speech,and Signal Processing*, 1996,pp.1890-1893.

[18] D.Zeidler and J.Griffin, "*Method and Apparatus for Television Signal Scrambling using Block Shuffling*," U.S. Patent 5 321 748, June 14, 1994.

[19] Rafael C.Gonzalez, "Digital Image Processing," 2nded. pp. 343-362, 1992.

Annadurai. S (S'94-M'97) was born in Tamilnadu, India on May 2, 1954. He received B.E. degree in Electronics and communication, M.E. degree in Computer science and engineering from Government College of technology in 1975, 1990 respectively. He also received Ph.D. degree in computer science from Anna University in 1997.

From 1975 to 1992, he was a lecturer and during 1992-2003 he became a HOD in computer science and Engineering, Govt.college of technology. Since 2004, he has been a principal of Govt.college of Engineering Tirunelveli. His current research interest include signal and image processing, artificial neural network implementation of image processing algorithm, computer vision, network security, multitasking, face recognition.

Geetha. P was born in tamilnadu, India on Feb 20,1978. She received B.E. degree in Computer science and Engineering from Anna university.M.E. degree in Computer science &Engineering from Govt. college of Engineering in 2002.

Since 2002, she has been a Research scholar in computer science department, Govt college of Technology. Her current research interest includes signal and image processing, processing of moving images, computer vision.