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An efficient block based lossless compression of medical images

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ABSTRACT

Medical images play a significant role in diagnosis of diseases and require a simple and efficient compression technique. This paper proposes a block based lossless image compression algorithm using Hadamard transform and Huffman encoding which is a simple algorithm with less complexity. Initially input image is decomposed by Integer wavelet transform (IWT) and LL sub band is transformed by lossless Hadamard transformation (LHT) to eliminate the correlation inside the block. Further DC prediction (DCP) is used to remove correlation between adjacent blocks. The non-LL sub bands are validated for Non-transformed block (NTB) based on threshold. The main significance of this method is it proposes simple DCP, effective NTB validation and truncation. Based on the result of NTB, encoding is done either directly or after transformation by LHT and truncated. Finally all coefficients are encoded using Huffman encoder to compress. From the simulation results, it is observed that the proposed algorithm yields better results in terms of compression ratio when compared with existing lossless compression algorithms such as JPEG 2000. Most importantly the algorithm is tested with standard non medical images and set of medical images and provides optimum values of compression ratio and is quite efficient.

1. Introduction

Diagnosis of diseases with the aid of medical images and their storage finds much important place but consumes more bandwidth. For telemedicine applications, these medical images need to be transmitted to different destinations. Medical images such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (US), Electrocardiogram (ECG) and Positron Emission Tomography (PET) need to be stored and sent for checking by another medical expert if necessary. These vast amounts of data cause a large amount of memory occupation and increase the time and traffic during transmission. Hence, medical image compression is essential in order to reduce the storage and bandwidth requirements.

Many advanced image compression methods have been proposed in response to the increasing demands for medical images. JPEG 2000 is a high performance image compression algorithm [2]. SPHIT is good compression algorithm, but it requires image-level access and cannot eliminate the correlation inside the sub bands [3]. Most importantly, these are lossy schemes and cannot be efficient for medical images. 1D modified Hadamard transformation based on JPEG 2000 is proposed but it is suitable for the LL- sub band [4]. A lossless algorithm method introduced in [5] based on hierarchical prediction and significant Bit Truncation (SBT) method occupies huge amount of memory to buffer the sub bands coefficients. A lossless algorithm is proposed in [6–8] by sub band decomposition with 1-D MHT. 1-D MHT could perform a vector decorrelation, but for vectors between two adjacent rows, it cannot able to further improve the CP.

The objective of this work is to achieve an improved compression ratio for medical images. Here decomposition is done through IWT and LHT, DCP are performed to remove the correlation inside the block and the correlation between adjacent blocks respectively. But second and third stages of transformations are done for only for LL sub band and non-LL sub bands are validated for further truncation or direct encoding. After validation, the non truncated non-LL bands are encoded directly. LL and validated non-LL bands are truncated and encoded using lossless Huffman encoder to compress.

The remaining part of the paper is organized as follows: In Section 2, the technical phenomena related to this work are explained in detail. Section 3 describes the proposed compression method based on LHT & Huffman encoding with the detailed workflow and with necessary representations and equations. The stage by stage progress is also presented. In Section 4, the performance is evaluated and the paper is concluded in Section 5.

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0030-4026/

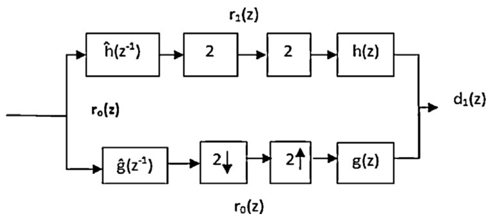

Fig. 1. Basic filter bank for biorthogonal wavelet transform.

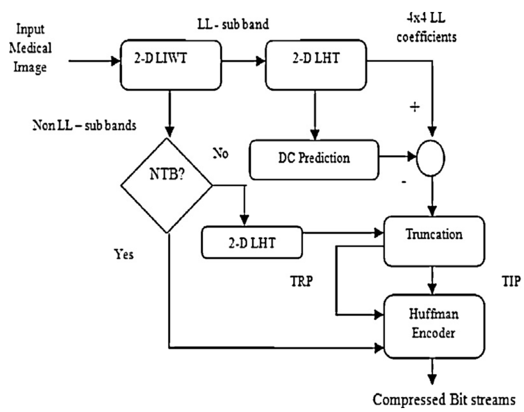

Fig. 2. Interpretation of the proposed algorithm.

2. Technical background

2.1. Integer wavelet transform for decomposition

3D integer Wavelet Transform is proposed and the CR of 3.27 was achieved for MRI image and CR of 4.13 was achieved for CT image [19]. Integer version of every wavelet transform employing finite filters can be built with a finite number of lifting steps in [18]. A new set of decomposition bases was presented and Lanczos filter is used in the lifting scheme in [17]. The CR was increased to about 10% for noisy images and about 30% for the MRI images. Integer Wavelet Transform (IWT) is a lossless encoding, but also simple to implement in practice [15]. The standard lifting scheme (LS) can achieve an invertible lossless integer transformation [13] and it can be easily implemented since it involves simple arithmetic operations [14].

In most of the cases, in wavelet transform the output coefficients of the filter are in floating point representation. Since, the input images are represented as matrices and it consists of integer values, but the filtered output no longer consists of integers and will result in quantization loss. For lossless coding it is required to make an invertible mapping from an integer image input to an integer wavelet representation.

The wavelet transform can be considered as a sub band transform and implemented with a filter bank. Fig. 1 describes the general block scheme of a one-dimensional biorthogonal wavelet transform.

5/3 LWT is utilized in this work and its prediction, update equations are

$$Y(2n+1)^{\text{prediction}} = \begin{cases} X(2n+1) - \dfrac{X(2n)+X(2n+2)}{2} & \text{Normal} \\ X(2n+1) - X(2n) & \text{odd end} \end{cases} \quad (1)$$

$$Y(2n)^{\text{update}} = \begin{cases} X(2n) + \dfrac{Y(2n+2)}{2} & \text{Normal} \\ X(2n) + \dfrac{Y(2n-2)+Y(2n+2)+2}{2} & \text{even end} \end{cases} \quad (2)$$

where Y is the one dimensional transformation of X which is the periodic extension of the prediction and update separately, the "odd-end" and "even-end" represent the embedded extensions for the problem of boundary extension [12]. When updating the first data of the image, the "even-begin" in (2) is transformed into

$$Y(0) = X(0) + \frac{Y(1)+1}{2} \quad (3)$$

$Y(1)$ can be calculated by the "normal" in (1)

$$Y(1) = X(1) - \frac{X(0)+X(2)}{2} \quad (4)$$

Table 2
Adjusted TIP and TRPARR.

TIP (8-bit)	TRPARR (2-bit)	TIP (8-bit)	TRPARR (3-bit)
10011011	11	10011011	011
11111010	01	11111011	101
11100010	10	11100011	110
11101110	00	11101111	100
11111101	00	11111110	100
11111001	10	11111010	110
00001000	00	00001000	000
00000001	00	00000001	000
11101101	10	11101110	110
00000101	00	00000101	000
00001000	00	00001000	000
11111111	10	00000000	110
11100101	00	11100110	100
00000011	00	00000011	000
00000111	11	00000111	011
00001100	01	00001100	001

Table 1
Stage wise results.

LL coeff. (8-bit)	2-D LHT coeff. (16-bit)	TIP (8-bit)	TRP (4-bit)	TRPARR (2-bit)
01011101	0000100110111110	10011011	1110	11
01110010	1111111110100100	11111010	0100	01
01110000	1111111000101000	11100010	1000	10
01101111	1111111011100010	11101110	0010	00
01110000	1111111111010000	11111101	0000	00
11110100	1111111110011010	11111001	1010	10
11100011	0000000010000010	00001000	0010	00
11010010	0000000000010000	00000001	0000	00
01101001	1111111011011000	11101101	1000	10
11000001	0000000001010010	00000101	0010	00
10111000	0000000010000010	00001000	0010	00
01111000	1111111111111000	11111111	1000	10
01100101	1111111001010010	11100101	0010	00
11101111	0000000000110000	00000011	0000	00
10101010	0000000001111100	00000111	1100	11
10011111	0000000011000110	00001100	0110	01