High quality and Efficient Image Compression used for Wireless Capsule Endoscopy

N. Jarray[1] and A. Ben Hmida[2]
Electronics and Microelectronics Laboratory
Faculty of Sciences, university Monastir
Tunisia

M. Elhajji[3] and A. Zitouni[4]
[3]College of Science, university of Hafr Al Batin,
[4]College of Education in Jubail, university of Damman
Saudi Arabia

Abstract:
Image compression is very significant for a lot of applications that involve an enormous amount data storage, transmission, and retrieval such as for endoscopic imaging. To save the wireless transmission power and bandwidth, image compression is very important. Several transformations are used for data compression. The two most commonly techniques used to achieve an efficient compression are the DCT and the DWT algorithms. When using the DWT lifting algorithm, a higher level of DWT lifting decomposition stages needs to be considered to achieve a higher compression. Moreover, this will increase computational complexity and degrade the image quality. Additionally, utilizing CORDIC-Loeffler-based DCT, a higher number of blocks image is needed to be processed, due to smaller size data block used. Hence, the idea is to explore the advantages of both algorithms DWT lifting and CORDIC-Loeffler-based DCT to achieve a higher compression ratio with an acceptable image quality. Also, we introduce a lossless context adaptive variable-length-coding (CAVLC) compression technique to encode the compressed bit streams at compression stage. The CAVLC produces coding with higher efficiency than the conventional VLC coding. Therefore, an efficient hybrid DWT lifting based on CORDIC-Loeffler-based DCT and the CAVLC algorithm is suggested in this paper. Simulation has been conducted on several endoscopic images. The experimental results demonstrate that our suggested hybrid algorithm achieves a higher compression ratio while preserving the visual image quality. Hence, based on experimentally obtained results, the proposed hybrid DWT lifting-CORDIC-Loeffler-based DCT and CAVLC algorithm performs much better than DWT lifting and CORDIC-Loeffler-based DCT algorithms in terms of PSNR.

Key words:
Wireless capsule endoscopy; Compression; Hybrid; DWT; DCT; CAVLC

1. Introduction

A Wireless Capsule Endoscopy (WCE) is a state of the art technology to receive an image of human intestines for medical diagnosis. The WCE is swallowed by the patient and then travels through the Gastro-Intestinal (GI). It captures images and sends them wirelessly to an outside data recorder. Next, the images are downloaded into a workstation. The capsule runs on button batteries that need to supply power for about 8 to 10h [1]. The captured endoscopic image demands a large volume of storage, as well as bandwidth for data transmission, which increases the cost and transmission time. The transmission of image data consumes about 90% of the total power in the battery. Therefore, to spare the battery life, it is important to have an efficient compression algorithm that is capable of attaining a higher compression ratio while preserving an acceptable quality image.

A lot of research work has been conducted to improve the performance of the WCE. In [2], the authors proposed an efficient data encoder based on the Lempel-Ziv-Welch technique for the WCE. In [3], [4], a Discrete Cosine Transform (DCT) was used. In [5], the authors suggested a 2D-DCT image compression algorithm, which exploited the Huffman encoding method for WCE. On the other hand, the Discrete Wavelet Transform (DWT) has appeared as an efficient method for medical image compression [6], [7], thanks to its ability to display images at a different resolution. Therefore, it offers a higher compression ratio. Availed from the respective powerful point of popular coding schemes, a new method known as a hybrid algorithm has been developed where two transform technique are implemented together. In [8], [9], [10], [11], the authors presented a hybrid algorithm that performed DCT on the DCT coefficient and found that this scheme had a better performance than other methods. In [12],[13], a new hybrid image compression method was presented, which was a combination of DCT, DWT and Huffman coding to minimize the blocking artifacts and false contouring that would happen during the DCT based techniques. In this paper, we present a hybrid 2D-DWT lifting algorithm followed by an 8x8 2D-DCT Cordic Loeffler algorithm. The 2D-DWT is applied on a 16x16 data block of an image. In this paper, we made a comparative analysis of three transform coding techniques, viz. DWT lifting, CORDIC-Loeffler-based DCT and hybrid DWT-DCT-CAVLC based on different performance measure such as Peak Signal to Noise Ratio (PSNR), Compression Ratio (CR). This paper is organized as follows. Section 2 presents the transform technique for image compression. Section 3 provides the proposed

Manuscript received July 5, 2017
Manuscript revised July 20, 2017

hybrid DWT lifting/DCT-cordic-loeffler and CAVLC algorithm. The experimental results and comparison are given in section 4. Section 5 concludes the paper.

2. Transform technique for image compression

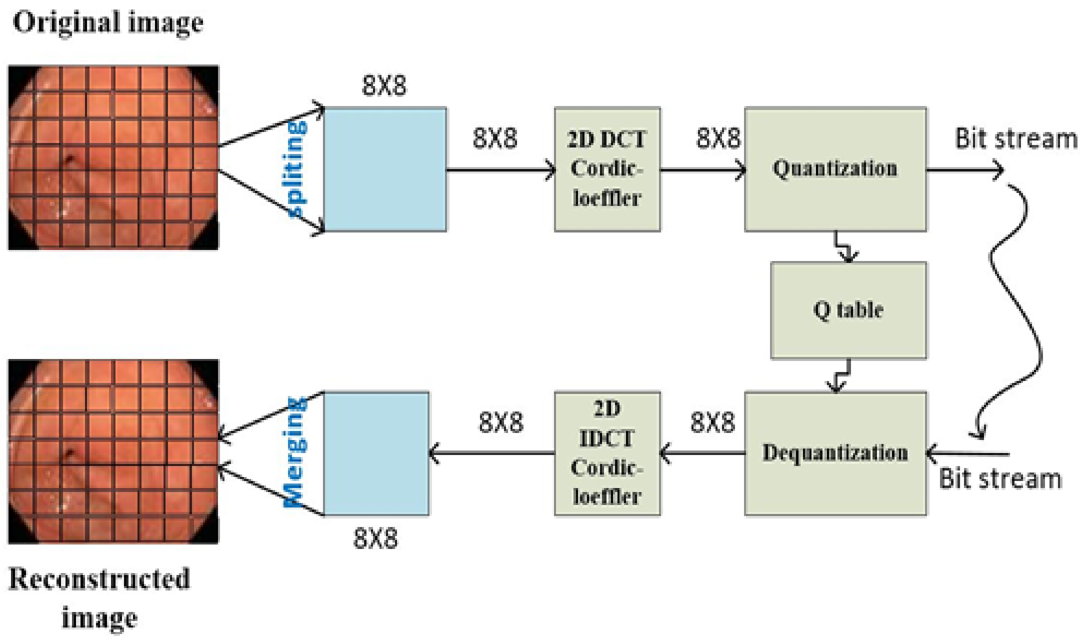
The various techniques of transformation are utilized for image compression as follows:

2.1 CORDIC- Loeffler-based DCT algorithm

The DCT process is applied to each 8x8 blocks of the image to convert the spatial domain gray level of pixels into coefficients in the frequency domain. There are a lot of techniques used to compute the DCT coefficients. In this paper, we use the Cordic-Loeffler-based DCT algorithm proposed in [14], which has low-complexity and high-quality images. After the computation of the DCT coefficients, a quantization table is applied. The quantization is achieved by dividing each element of the transform data matrix by a corresponding element in the quantization matrix Q and round to the nearest value as shown in (1):

$$Q_{quant}(i,j) = round\left(\frac{D_{dct}(i,j)}{Q(i,j)}\right) \quad (1)$$

The de-quantization is performed to reconstruct the data.The de-quantized matrix is then transformed back using the inverse CORDIC-Loeffler-based DCT algorithm, as represented in Fig.1:



2D-DCT Cordic-Loeffler algorithm compression and decompression

2.1 5/3 DWT lifting algorithm

The DWT process is a multi-resolution transform, mostly utilized for image compression to achieve a higher compression ratio. In this work a lifting scheme scheme 5/3 based forward DWT is used. The lifting scheme consists of the following three steps to decompose the samples [20], as depicted in Fig.2.

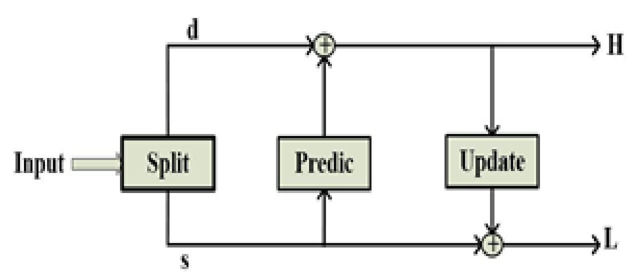


Fig. 1. Block diagram of lifting scheme

Split step: The input samples are split into even samples (s) and odd ones (d).

$$d(i)=x(2i+1)$$

$$s(i)=x(2i) \quad (2)$$

Predict step: The even samples are multiplied by the predicted factor, and then the results are added to the odd samples to generate the detailed coefficients (H).

$$H(i)=d(i)+\alpha(s(i)+s(i+1)) \quad (3)$$

Update step: The detailed coefficients computed by the predicting step are multiplied by the update factors, and then the results are added to the even samples to get the coarse coefficients (L).

$$L(i)=s(i)+\beta(H(i-1)+H(i)) \quad (4)$$

where α and β are the filter coefficient, with α=-0.5 and β=0.25.

A 2D-DWT can be implemented by applying a 1D transform twice: one row wise and one column wise. After one level 2D-DWT, four sub-images are formed namely LL which represent the low frequency details, and LH which is the vertical detail image as it contains vertical details of the input image, an HL sub-image which carries the horizontal details of the input image, and an HH one which carries the diagonal details, as illustrated in Fig.3.

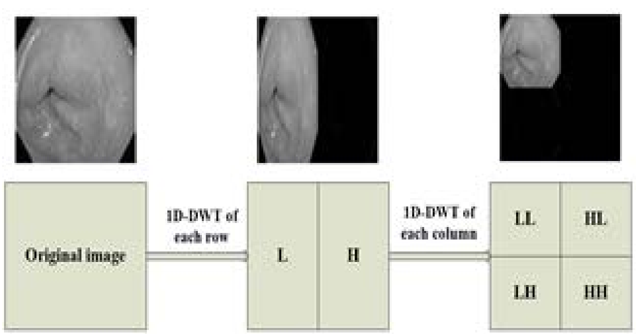


Fig. 2. Principle of one-level 2D-DWT lifting

2.2 CAVLC encoding

Context-adaptive variable-length coding (CAVLC) is a form of entropy coding that used for coding the transform coefficients. It is applied after a quantization step. As known that after quantization, most non-zero coefficients are centered in low frequency whereas the most zero coefficients and other non-zero coefficients are -1 or +1 mostly are centred in high frequency. Therefore, the CAVLC encoding uses these characteristics to compress the data and increases the coding efficiency. The coding process of CAVLC is as follows [19]:

- Scanning the quantized DCT coefficients in zigzag order;
- Encoding the number of non-zero coefficients and the number of trailing coefficients (which value is -1 or +1), adaptively selecting the coding table according to the number of non-zero coefficients of left and upper blocks;
- Encoding the sign of trailing coefficients;
- Encoding the level information for other non-zero coefficients;
- Encoding the run information before each nonzero coefficient.

3. Proposed Hybrid DWT-DCT-CAVLC technique

The goal of image compression is to reduce the storage size with high compression and less-loss of information. In section 2 we presented two different ways of achieving the goals of image compression, which have some advantages and disadvantages, in this section, we are suggesting a hybrid transform technique that will exploit the benefits of both DWT and DCT, to get the compressed image. Hybrid DWT-DCT transformation gives more compression ratio compared to JPEG and JPEG2000, preserving most of the image information and create a good quality of the reconstructed image. Hybrid DWT-DCT transform reduces blocking artifacts, false contouring and ringing effect [15].

3.1 Compression procedure

The input image is first converted to the gray image from the color image. Then the whole image is divided into the size of 16x16 pixels blocks. Then one-level DWT lifting applied on each block of 16x16 block, by using 2 D-DWT lifting, four details are produced. After getting four blocks of size 8x8, the high-frequency LH, HL and HH coefficients are discarded while we use the approximated details LL for computation of CORDIC-Loeffler-based DCT coefficients. These coefficients are then quantized and send to the CAVLC encoder step. The compression steps of the hybrid algorithms are depicted in Fig.4

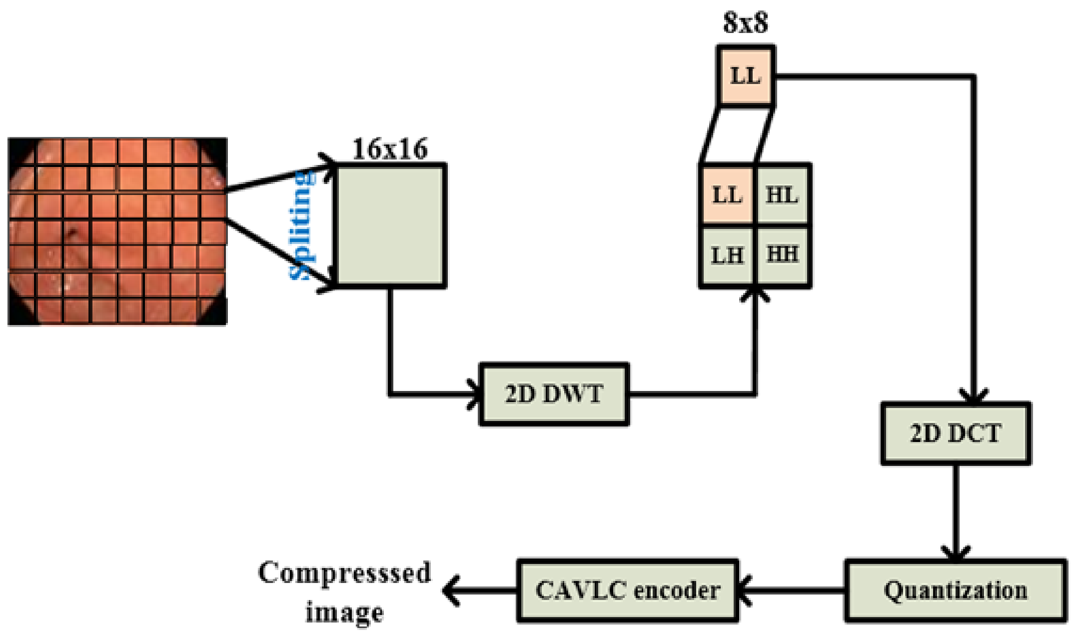


Fig. 3. Compression technique using Hybrid transform

3.2 Decompression procedure

After compression, the image is reconstructed following the inverse procedure. Firstly, the compressed image passed through the CAVLC decoder. Then decode the quantized DCT coefficients and compute the inverse two-dimensional DCT (IDCT) of each block. Then block is de-quantized.

Further, we take inverse wavelet transform of the de-quantized block. Since the level of decomposition, we take inverse wavelet transform to get the same block size i.e. 16x16. This procedure followed for each block received. When all received blocks are converted to 16x16 by following decompression procedure, explained above. We arrange all blocks to get reconstructed image. The complete decoding process is explained in Fig.5.

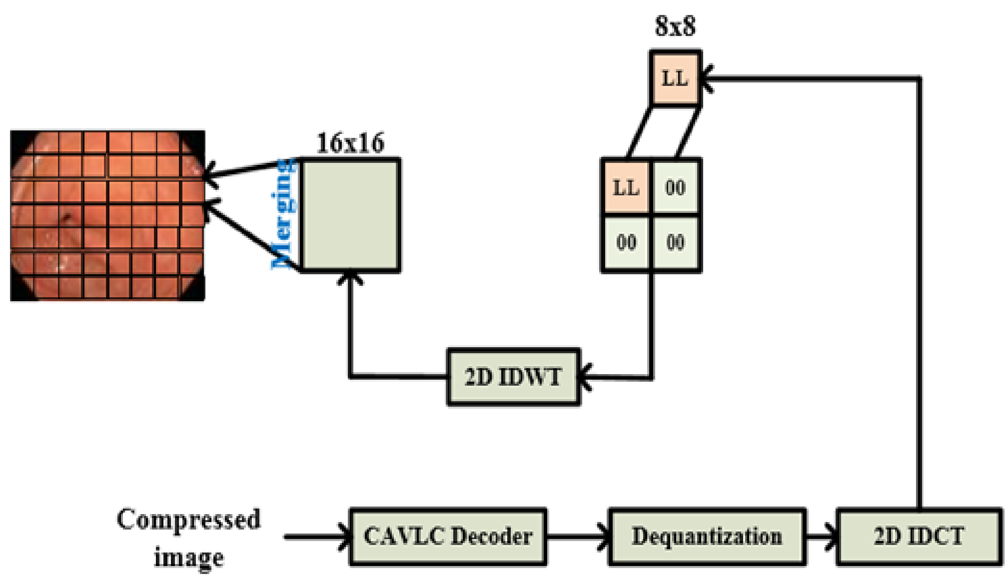


Fig. 4. Decompression technique using hybrid transform

4. Experimental results and comparison

After the using the techniques of the image compression, some amount of distortion is introduced in the reconstructed image. Therefore, it is important to evaluate the image quality. Hence, the quality of reconstructed images can be evaluated regarding the following parameters.

- The Peak Signal to Noise Ratio (PSNR) is defined as the following formula:

$$PSNR = 20\log(10)\frac{255}{\sqrt{\left(\frac{1}{MN}\right)\sum_{n=1}^{n}\sum_{m=1}^{m}\left(x_{m,n}-x'_{m,n}\right)^{2}}} \quad (5)$$

Where M and N are the image width and height, and x and x' are the original and reconstructed component values, respectively.

- The Compression Ratio (CR) can be expressed as:

CR = Discarded data/Original data (6)

In this section several endoscopic images are used to evaluate the performance of the suggested hybrid model (DWT lifting, CORDIC-Loeffler-based DCT and CAVLC). Then, to verify the efficiency of proposed hybrid model, it is compared DWT lifting, CORDIC-Loeffler-based DCT algorithms. The following figures show the result of image compression by DCT, DWT and Hybrid DCT-DWT-CAVLC respectively. The Fig.6 and Fig.7 depict the results in terms of PSNR and CR respectively for the various endoscopic images using the proposed method hybrid model (DWT lifting, CORDIC-Loeffler-based DCT and CAVLC) as well as the DWT lifting and CORDIC-Loeffler-based DCT algorithms. Therefore, based on the comprehensive simulation results, We can notice from Fig.6 that for CR=90%, the proposed hybrid algorithm has a higher PSNR value equal to 36 dB and performed better than the other two algorithms DWT lifting and CORDIC-Loeffler-based DCT. Moreover, the algorithm which has a lower PSNR value is the DWT lifting algorithm. The average PSNR value for DWT lifting is around 33dB. Hence, the CR is performed at the average PSNR value for DWT lifting. The Fig.7 illustrates the CR of different algorithms for a fixed PSNR for 33dB. It can be seen that the CR obtained by the suggested hybrid algorithm is higher compared to other algorithms.

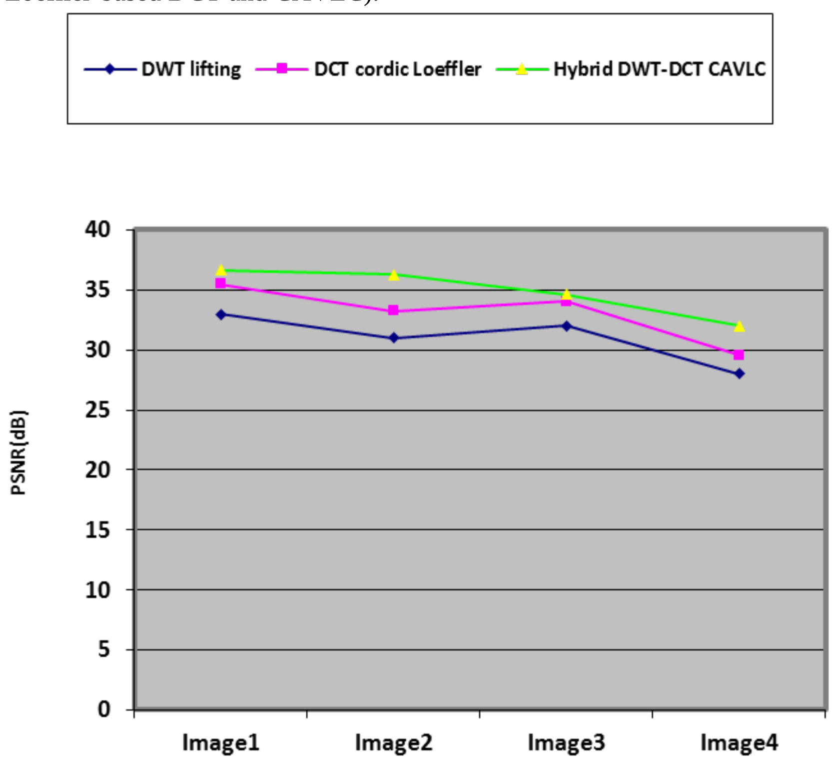


Fig. 5. PSNR graph at CR=90%

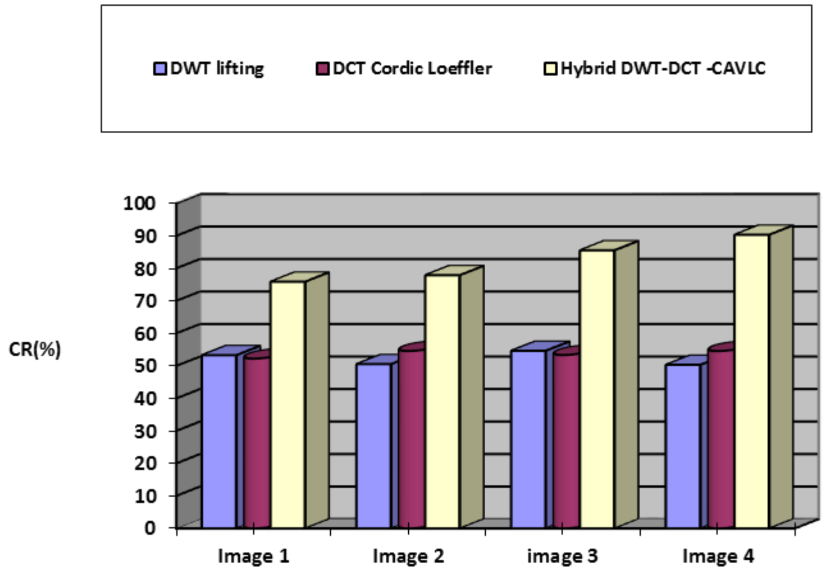


Fig. 6. CR graph at PSNR 33dB

Yet, to improve the effectiveness of our hybrid algorithm, it is compared with some existing hybrid methods. Table I and provide a simple comparison between other transforms in terms of reconstructed image quality. The proposed technique is compared with [18] using medical images and endoscopic video clips. Note that the algorithm is applied to a spatial domain only, and the video is treated as series of frames.

TABLE I. Result comparasion

	PSNR (dB)	
	[18]	***Proposed***
Frame of endoscopic video	***28.98***	***31.34***
Medical image	***36***	***36***

5. Conclusion

A new hybrid algorithm composed of DWT lifting, CORDIC-Loeffler-based DCT and CAVLC algorithms suggested in this paper. This proposed algorithm enables to produce an efficient image compressor needed to save the limitation condition of wireless capsule endoscopic (transmission power, retaining reconstruction quality for an accurate diagnosis). The suggested algorithm performs the CORDIC-Loeffler-based DCT on the DWT lifting coefficients and then the CAVLC coding is used to encode the compressed bit streams at compression stage. To evaluate the performance of the proposed algorithm, several endoscopic image are used. The experimental results have demonstrated that our algorithm produces a high degree of compression while preserving critical image/video information. Consequently, the suggested hybrid model (DWT lifting, CORDIC-Loeffler-based DCT and CAVLC) performed better in terms of PSNR and compression ratio than standalone CORDIC-Loeffler-based DCT and DWT lifting algorithm.

References

[1] D. Faigel and D. Cave, “Capsule endoscopy,” in Saunders Elsevier, 2008 .
[2] R. Tajallipour and K. Wahid, “Efficient data encoder for low-power capsule endoscopy application,” in 10th International Conference on Information Science, Signal Processing and their Applications (ISSPA 2010), 2010, pp. 512–515.
[3] K. Wahid, S.-B. Ko, and D. Teng, “Efficient hardware implementation of an image compressor for wireless capsule endoscopy applications,” in 2008 IEEE International Joint Conference on Neural Networks (IEEE World Congress on Computational Intelligence, 2008, pp. 2761–2765.
[4] L.-R. D. Lin, Meng-Chun and P.-K. Weng, “An ultra-low-power image compressor for capsule endoscope,” BioMedical Engineering OnLine, 2006.
[5] P. Turcza and M. Duplaga, “Low-power image compression for wireless capsule endoscopy,” in 2007 IEEE International Workshop on Imaging Systems and Techniques, 2007, pp. 1–4.
[6] L. Chen, VLSI design of wavelet transform: analysis, architecture and design examples. Imperial College Press, 2007.

[7] R. A. DeVore, B. Jawerth, and B. J. Lucier, “Image compression through wavelet transform coding,” IEEE Transactions on Information Theory, vol. 38, no. 2, pp. 719–746, 1992.
[8] E. Ramandeep, K. Grewal, M. Tech, and N. Randhawa, “Image compression using discrete cosine transform & discrete wavelet transform, 2012.
[9] T. SRIRAM.B, “Hybrid transformation technique for image compression,” in Journal of Theoretical and Applied Information Technology, 2012.
[10] J. A. Mohammed, Aree Ali; Hussein, “Efficient hybrid transform scheme for medical image compression,” Mohammed, Aree Ali; Hussein, Jamal Ali, 2011.
[11] D. Mohamad et al., “Image compression using hybrid technique,” The International Institute for Science, Technology and Education (IISTE),
[12] 2012.
[13] S. S. Harjeetpal singh, “Hybrid image compression using dwt, dct & huffman encoding techniques,” International Journal of EmergingTechnology and Advanced Engineering, 2012.

[14] K. K.N. Bharath, G. Padmajadevi, “Hybrid compression using DWT-DCT and huffman encoding techniques for biomedical image and video applications,” International Journal of Computer Science and Mobile Computing, 2013.
[15] N. Jarray, M. Elhaji, and A. Zitouni, “Low complexity and efficient architecture of 1D-DCT based cordic-loeffler for wireless endoscopy capsule,” in Systems, Signals & Devices (SSD), 2015 12th International Multi-Conference on. I, 2015, pp. 1–5.
[16] Sriram.B,Thiyagarajans.S, “Hybrid Transformation technique for image compression ”,Journal of theoretical and applied information technology, 31st July 2012 Vol. 41 No.2
[17] Gastrolab [Online] (2016): Available at: http://www.gastrolab.net.
[18] U. S. Mohammed, “Highly scalable hybrid image coding scheme,” Digital Signal Processing, vol. 18, pp. 364–374, 2008.
[19] S. Shrestha et al., “A sub-sample based hybrid dwt-dct algorithm for medical imaging applications,” Citeseer, 2010.
[20] Asma Ben Hmida, Salah Dhahri, Abdelkrim Zitouni, “A High Performance Architecture Design of CAVLC Coding Suitable for Real-Time Applications”, Association of Computer Electronics and Electrical Engineers, 2013.
[21] D. Darji, A. N. Chandorkar, and S. N. Merchant. “Memory efficient and low power VLSI architecture for 2-D lifting based DWT with dual data scan technique”, In Proceedings of the 5th WSEAS international conference on Circuits, systems and signals (CSS'11), pp: 62-67, 2011.