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RGB Medical Video Compression Using Geometric Wavelet and SPIHT Coding

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ABSTRACT

The compression of medical video represents a big challenge. It gets indispensable solution in field of storage and transmission of medical data. This paper introduces an algorithm for color medical video compression based on geometrical wavelet coupled with SPIHT coding algorithm. In order to prove the efficiency of our algorithm, comparative study is made between other classical transforms. The peak signal- noise Rate (PSNR), it used as an objective parameter to measure the quality of recovred frames. The experimental results show that the proposed algorithm for low bit rate is superior to traditional methods; this is justified with a high valus of PSNR parameter.

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1. INTRODUCTION

With the important increasing volumes of data in the field of medical imaging, compression is the major challenges in healthcare services. In telehealth, Magnetic Resonance Imaging (MRI), Ultrasound (US), Computed Tomography (CT), etc need to be transmitted to another medical expert. These huge data cause a high time transmission and storage cost. The problem becomes even more critical with the generalisation of 3D sequence. So it is necessary to use compression in order to reduce the amount of medical data to be stored and transmitted. In the literature many compression schemes by transformation have been proposed, we can cite the standards MPEG for compressing video. All of these standards are based on the discrete cosine transform (DCT) [1].

Over the past ten years, the wavelets (DWT) compression has significantly better performance in terms of objective and subjective parameters at low bit rate. To improve the coding efficiency, this transform is suitable to horizontal vertical and diagonal directions. These characteristics permit a higher coding efficiency in isotropic regularity along various curves. Unfortunately, these separately basis present discontinuities in all recovered frames. In fact, the degradation of quality visual increases tremendously. Several rigorous transforms have been developed and exploit to encapsulate anisotropic regularity in frames. In [2] CANDES and DONOHO introduced ridgelet transform as multidimensional extension of the wavelet transform. In1999, CANDES and DONOHO introduced curvelet transform [3]. In [4] and [5] DO and VETTER have proposed contourlet transform. All these representations are used to exploit the geometric regularity but do not allow to exploit completely. To overcome these limitations, PENNEC and MALLAT introduced geometric wavelet to represent differentes regularity [6] and [7].

To improve the quality of frames in video at high compression rate, several coders have been proposed and reported in the literature. The effectiveness of coding was first demonstrated by Shapiro's Embedded Zerotree Wavelet (EZW) [8]. Later, research by Said and Pearlman on Set Partitioning in Hierarchical Trees encoder (SPIHT) [9]. SPIHT applied successfully to both lossy and lossless compression of image and improved upon EZW. This paper is organized as follows: Section 2 describes the geometric wavelet. SPIHT coder is discussed in section 3. Section 4 describes steps of proposed algorithm. The performance and the experimental results are shown in section 5. Finally, a conclusion sums up the findings of paper.

2. GEOMETRIC WAVELET

Over the past decades, there has been abundant interest on X_Lets family for the compression of image. Pennec and Mallat have proven that geometric wavelet has non separable basis, unlike the wavelet transform, this advantage is very important in many domains. The wavelet bases generates a redundancy, this is translated in the presence of high-magnitude coefficients in the singularities of the image [10]. To maintain the regularity of the frame, each frame is decomposed through wavelet transform. After decomposition we obtain four spatial frequency subbands. The subbands are given as:

$$\begin{aligned} a_j(x,y) &= \left\langle f(x,y), \phi_j(x)\phi_j(y) \right\rangle \\ d_j^H(x,y) &= \left\langle f(x,y), \psi_j(x)\phi_j(y) \right\rangle \\ d_j^V(x,y) &= \left\langle f(x,y), \phi_j(x)\psi_j(y) \right\rangle \\ d_j^D(x,y) &= \left\langle f(x,y), \psi_j(x)\psi_j(y) \right\rangle \end{aligned} \qquad (1)$$

where

j :represent the scale factor.

$\phi_j(x,y)$:scaling function.

$\psi_j(x,y)$:wavelet function.

Due to the redundancy of transform, we can partition each subbands into several blocks with different size to take a best segmentation of each scale. We present the support of the blocks as S , and it is divided into small several sub-regions.Such segmentation is represented as quad-tree. The local directions in which frames have regular variations are shown by geometric flow. The relationship between the geometric flow and curve in each region of blocks can be gotten by Equation 2 [11].

$$\tau(x) = \frac{1}{\sqrt{1+|c'(x)|^2}} \begin{pmatrix} 1 \\ c'(x) \end{pmatrix} \qquad (2)$$

$c'(x)$: Slope of optical flow.

The optimal geometric flows of each block are determined by minimizing a Lagrange cost

$$L(f,R) = \|f - f_R\|^2 + \frac{3}{28} Q^2 \sum_j \left(R_{sj} + R_{Gj} + R_{Bj} \right) \qquad (3)$$

To optimize algorithm of quad-tree segmentation, Peyre and Mallat proposed to build the best quad-tree segmentation, this corresponding to minimize the Lagrangian cost of combing the four children together. For a LxL block S , denote its four children as (s_1, s_2, s_3, s_4), the Lagrange cost of combing the four children together is:

$$\tilde{L}(s) = L_0(s_1) + L_0(s_2) + L_0(s_3) + L_0(s_4) + L_0(s) + \frac{3}{28} Q^2 \qquad (4)$$

If there is no geometric flow in that macro-block, it means that the macro-block is regular uniformly so we can use wavelet basis. Otherwise, the sub-block must be processed by geometric wavelet basis by applying the warp operation, which is defined in [12].

Each image of sequence is compressed by coding of segmentation of image and a geometric flow in each region of the segmentation. After quantization, the coefficients are coded. The total number of bits R is decomposed into

$$R = R_j = \sum \left(R_{js} + R_{jG} + R_{jB} \right),$$

where

R_s is the number of bits to code the dyadic square segmentation.

R_G is the number of bits to code the direction in each square region

R_B is the number of bits to code the quantized geometric wavelet coefficients.

The wavelet coefficients are products between function $f\left(x,y\right)$ and basis of discrete separable wavelet.

$$\begin{Bmatrix} \phi_{j,n_1}(x)\psi_{j,n_2}(y), \\ \psi_{j,n_1}(x)\phi_{j,n_2}(y), \\ \psi_{j,n_1}(x)\psi_{j,n_2}(y) \end{Bmatrix} \qquad (5)$$

Separable wavelets are warped with an operator W along flow lines, defined as $W\left(f\left(x,y\right)\right) = f\left(x, y - c\left(x\right)\right)$ for the vertical parallel flow. The W is an orthogonal operator, its adjoint is equal to its inverse, $W * f\left(x,y\right) = W^{-1} f\left(x,y\right) f\left(x, y - c\left(x\right)\right)$. The warped wavelet basis is obtained by W^{-1} to each separable wavelet basis.

$$\begin{pmatrix} \phi_{j,n}(x)\psi_{j,n_2}(y-c(x)) \\ \psi_{j,n}(x)\phi_{j,n_2}(y-c(x)) \\ \psi_{j,n}(x)\psi_{j,n_2}(y-c(x)) \end{pmatrix} = \begin{Bmatrix} \psi^H_{j,n} \\ \psi^V_{j,n} \\ \psi^D_{j,n} \end{Bmatrix} \qquad (6)$$

After W operation of wavelet basis, the next step is a bandeletization to construct geometric wavelet. The $\psi\left(x,y\right)$ consists of high-pass filters and has vanishing moments at lower resolutions, this is valid for $\psi^V_{j,n}$ and $\psi^D_{j,n}$, but not for $\psi^H_{j,n}$. Problem of regularity along the flow line is due to the scaling function $\phi\left(x,y\right)$ where it consists of low-pass filters and does not have vanishing moment at lower resolutions. To take advantage of regularity along the flow lines for $\psi^H_{j,n}$, the deformed wavelet basis is bandeletization by replacing the horizontal wavelet $\psi^H_{j,n}$ with new functions

$$\psi_{j,n}(x)\psi_{j,n}(y-c(x)) \qquad (7)$$

The orthonormal basis of geometric wavelet of field warping is defined by:

$$\begin{pmatrix} \psi_{j,n}(x)\psi_{j,n}(y-c(x)) \\ \psi_{j,n}(x)\phi_{j,n}(y-c(x)) \\ \psi_{j,n}(x)\psi_{j,n}(y-c(x)) \end{pmatrix} = \begin{Bmatrix} \psi^H_{j,n} \\ \psi^V_{j,n} \\ \psi^D_{j,n} \end{Bmatrix} \qquad (8)$$

After warping, the warped region is regular along the vertical or horizontal (same previous operations) direction. The bandeletization removes the correlation that exists between wavelet coefficients near the singularity. Lastly, the resulting of geometric wavelet coefficients are computed from warped wavelets with 1D discrete wavelet transform than are encoded using subband coder. The full detailed descriptions of the geometric wavelet are shown in Figure 1.

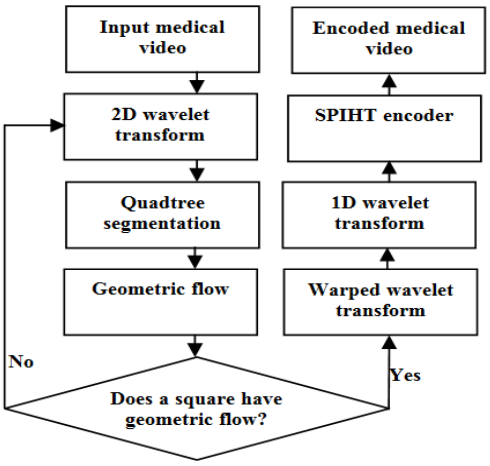


Figure 1. Block diagram of geometric wavelet for medical video encoding

3. REVIEW OF SET PARTITIONING IN HIERARCHICAL TREES

SPIHT [13] is considered to be one of the most popular wavelet image compression algorithms. The success of SPIHT is due to the organisation of wavelet coefficients into the spatial orientation trees. Three types of trees: $D(i,j)$, $O(i,j)$ and $L(i,j)$, with root at coordinate (i,j), are used to hold wavelet coefficients as sets: $O(i,j)$ is a special case of $D(i,j)$, and $L(i,j)=D(i,j)-O(i,j)$. All coefficients are organised in three lists:

LIP (List of insignificant Pixels).
LIS (List of Insignificant Sets).
LSP (List of Significant Pixels).

During initialisation, the coefficients in high frequency subband are put on the $D(i,j)$ types of trees in LIS, with roots (i,j) at the coarsest subband and leaves on the finest subband; other coefficients are out in the LIP; the initial LSP is empty. Then bit plane coding is transmitted by sorting and refinement passes. In sorting pass, the coefficients in LIP are scanned and coded individually, and significant coefficients are moved to LSP; the trees in LIS are scanned and coded, and significant trees are partitioned in subtrees and / or individual coefficients, which are put to LIS, LIP and LSP respectively. In refinement pass, coefficients in LSP are scanned and coded.

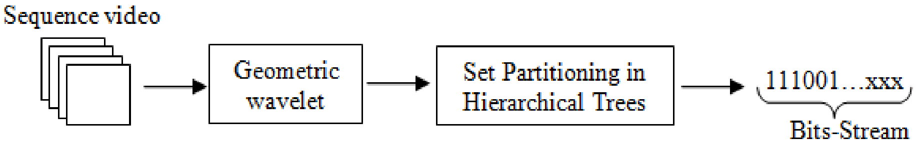


Figure 2. Block diagram of generic binary of SPIHT encoder

4. PROPOSED ALGORITHM

The proposed algorithm to encode medical frames developed as follows:

- **Step 1:** Input the color medical sequences of size 512x512.
- **Step 2:** Decompose the each input Y, Cb and Cr frame through 2D DWT.
- **Step 3:** The Y, Cb and Cr of each frame of sequences are recursively segmented into dyadic squares.
- **Step 4:** Geometric flow is constructed in square for each Y, Cb and Cr.
- **Step 5:** The wavelets basis is warped along geometric flow.
- **Step 6:** The bandeletization operation is applicated to the warped wavelet basis.
- **Step 7:** The SPIHT coder is used to encode geometric wavelet coefficients.
- **Step 8:** Collect all layers in one matrix Ycbcr.
- **Step 9:** The resulting sequence qualities are measured in terms of PSNR (dB) parameter.

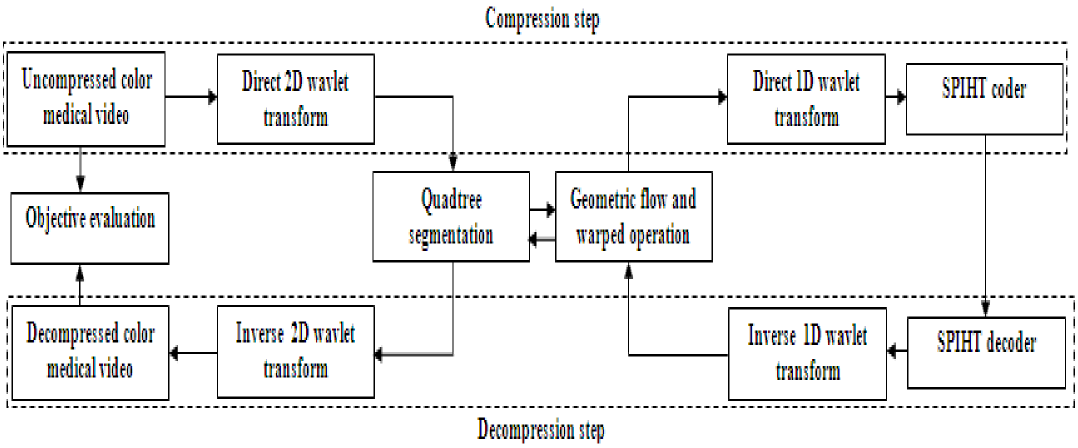


Figure 3. Proposed block diagram for color medical video compression

5. RESULTS AND ANALYSIS

In this paper, we are interested in lossy compression methods based on geometrical wavelet because their importantes role in capturing anisotropic regularity along various curves. The proposed algorithm was applied to encode test natural sequences (FOREMAN, AKIYO) and medical sequences (ENDOSCOPY, BACTERIA-GROWTH) of size 512x512, these natural and medical video are taken from database [14] and [15]. For the purpose of evaluation, the classical methods (discret wavelet transform (DWT) [16] and discret curvelet transform (DCuT)) [17] has been used. The importance of our work lies in the possibility of reducing the bit-rates for which the video quality remains acceptable. The efficiency of the proposed algorithm is evaluated according to the objective parameters. In general, a higher Peak-Signal-to-Noise-Ratio (PSNR) value should correlate to a higher quality frame.

$$PSNR = 10\log_{10}\left(\frac{255^2}{\frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}\left(C_{ij}-R_{ij}\right)^2}\right) \qquad (9)$$

Where:

N : Size parameter.
i, j : Position information.
C_{ij} : Current frame.
R_{ij} : Reference frame.

Figure 4 shown below illustrates the compressed results for different bit-rate values. To show the performance of the proposed method (geometric wavelet coupled with SPIHT coder), we suggest to applicated to a set of natural and medical video. We note that our algorithm is adapted for the medical video compression. Also, we can observe that compression degrades for low compression bit-rate. However, for high compression bitrate, our algorithm achive a high valus of PSNR (dB).

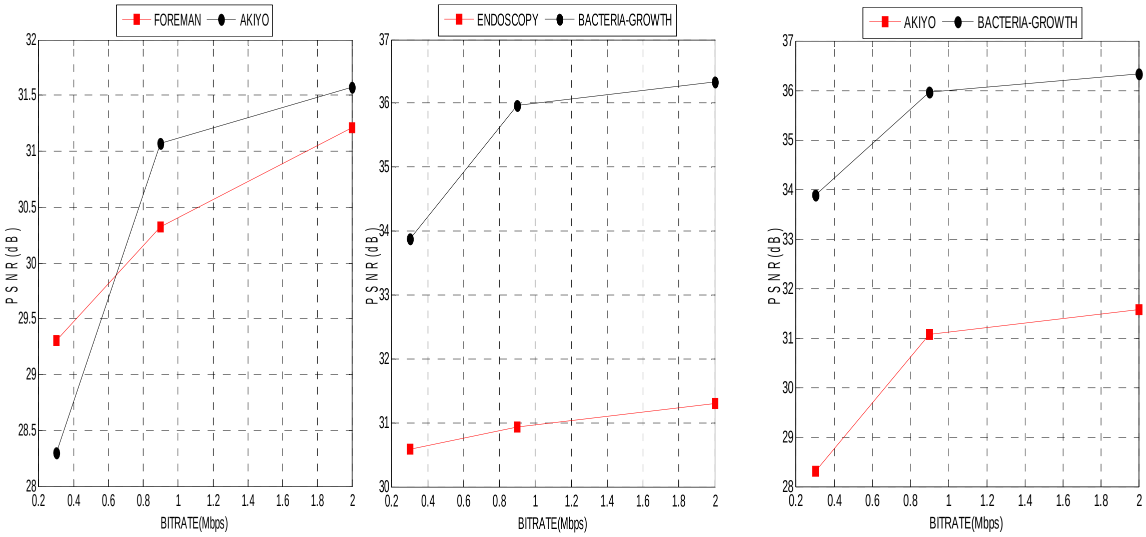


Figure 4. PSNR (dB) values achieved for natural and medical test frames using the proposed methods

To show the performance of the proposed method, we make a comparison between different types of transform DWT, DCuT and GEOMETRIC WAVELET (GW) coupled with the SPIHT. For each application we vary the bit-rate frome (0.3, 0.9 and 2Mbps), and we calculate the PSNR (dB) parameter. The results obtained are given in Table 1. According to the PSNR (dB) values, we note that video reconstruction becomes almost perfect with proposed algorithm for all bitrate values. Also from this results, our experimental results show that the proposed algorithm for low bit rate (0.3Mbps) is able to reduce up to 37.19% and 28.20% of the complex geometrics detection compared to the DWT+SPIHT and DCuT+SPIHT algorithm. The quality visual degradation of frames is less in low bit rate than in high bit rate. Also, we can see that the PSNR (dB) value depend on the decomposition thresholds (T) as it shown in F

Figure 5. The quality visual of decompressed frames (for first, tenth, twentieth and thirtieth frame) using algoritm of GEOMETRIC WAVELET-SPIHT at 2Mbps are shown in Figure 6.

Table 1. The PSNR (dB) values of reconstructed BACTERIA GROWTH sequence for various bitrate values using WAVELET-SPIHT, CURVELET-SPIHT and GEOMETRIC WAVELET-SPIHT

BITRATE (Mbps)	WAVELET-SPIHT	CURVELET-SPIHT	PROPOSED ALGORITHM
0.3	24.6947	26.4254	33.8799
0.9	24.5830	26.7219	35.9627
2	30. 4890	30. 9402	36.3323

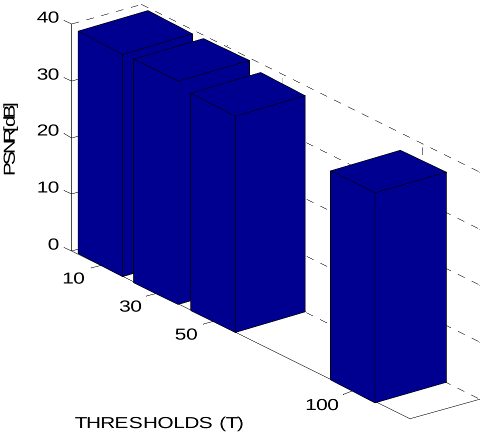


Figure 5. PSNR (dB) values of reconstructed BACTERIA GROWTH sequence vs thresholds (T=10, 30, 50 and 100) using proposed method

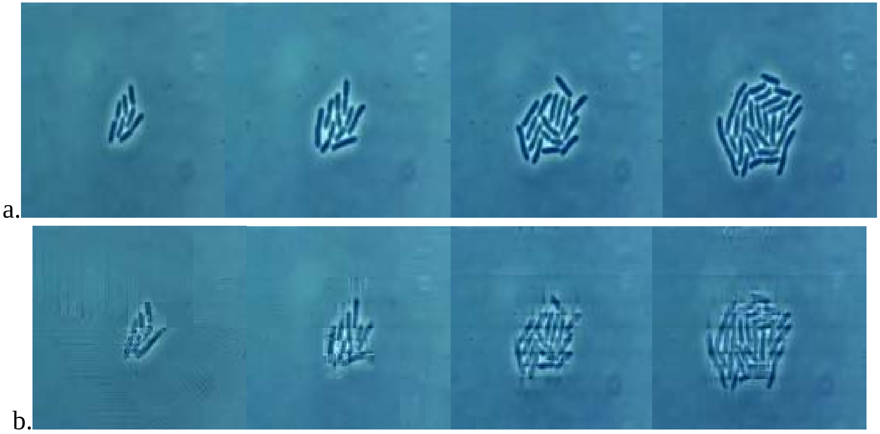


Figure 6. Visual quality of decompressed BACTERIA GROWTH frames using GEOMETRIC WAVELET-SPIHT at 2Mbps for first, tenth, twentieth and thirtieth frame: (a).Original frames; (b).Decompressed frames

Before applying proposed algorithm on the color video, the RGB color frames are converts into YCbCr form, and then applying proposed algorithm on each layer independently, this means each layer from YCbCr are compressed as a grayscale frame. YCbCr refers to the color resolution of digital component video signals, which is based on sampling rates. This process is repeated for every frame and resolution in the case of level 5 decompositions. RGB color and YCbCr form of recovred frames including natural and medical frames by the proposed method are presented in Figure 8. Recovered BACTERIA GROWTH sequences yielded by the using GEOMETRIC WAVELET+SPIHT, DCuT+SPIHT and DWT+SPIHT are shwons in Figure 9.

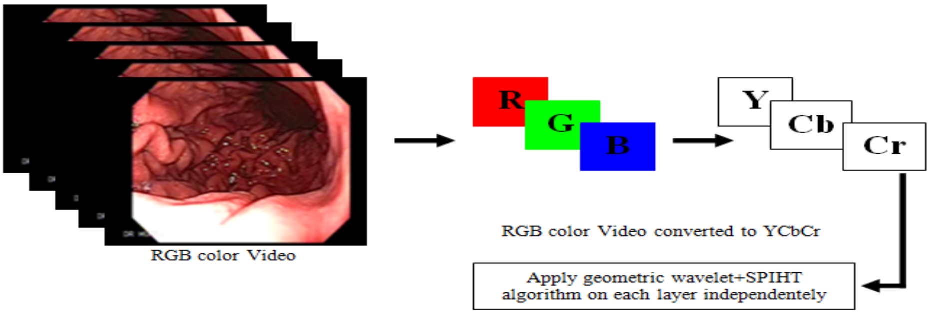
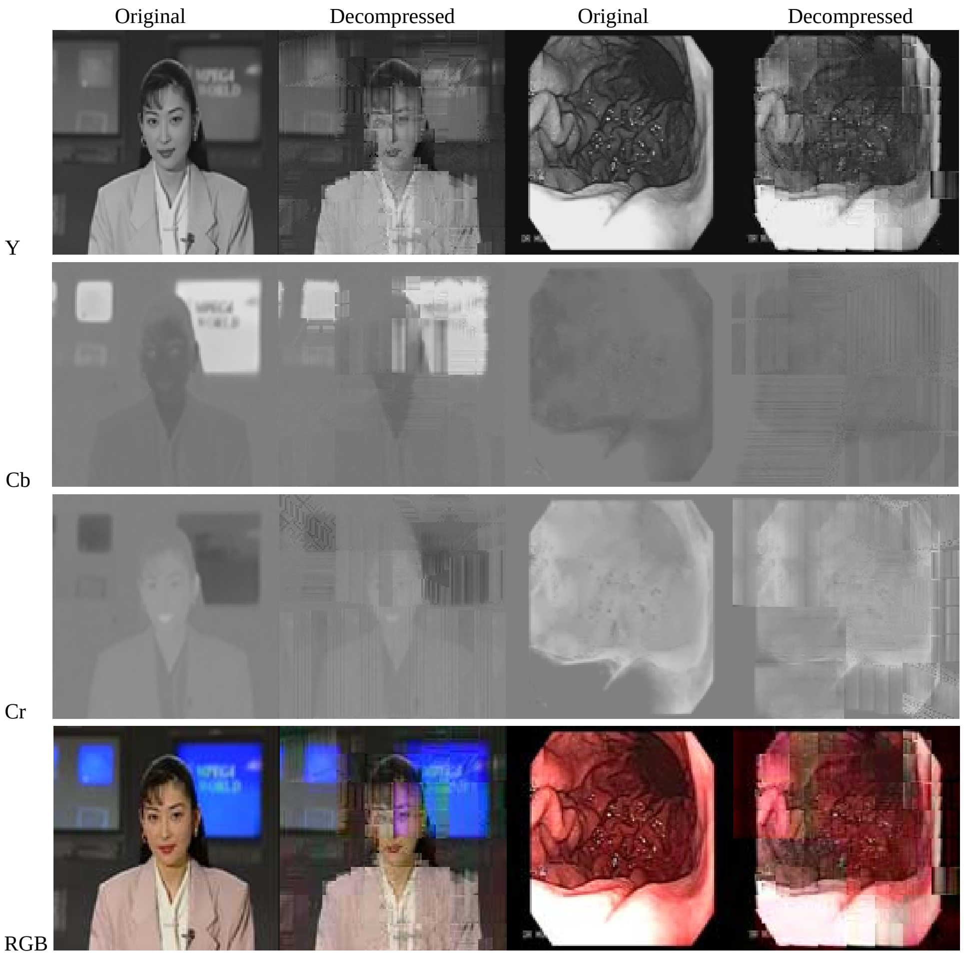


Figure 7. Video compression steps using Geometric Wavelet transform coupled with SPIHT



(a). AKIYO (b). ENDOSCOPY

Figure 8. Recovered color frames using proposed algorithm at 0.9Mbps

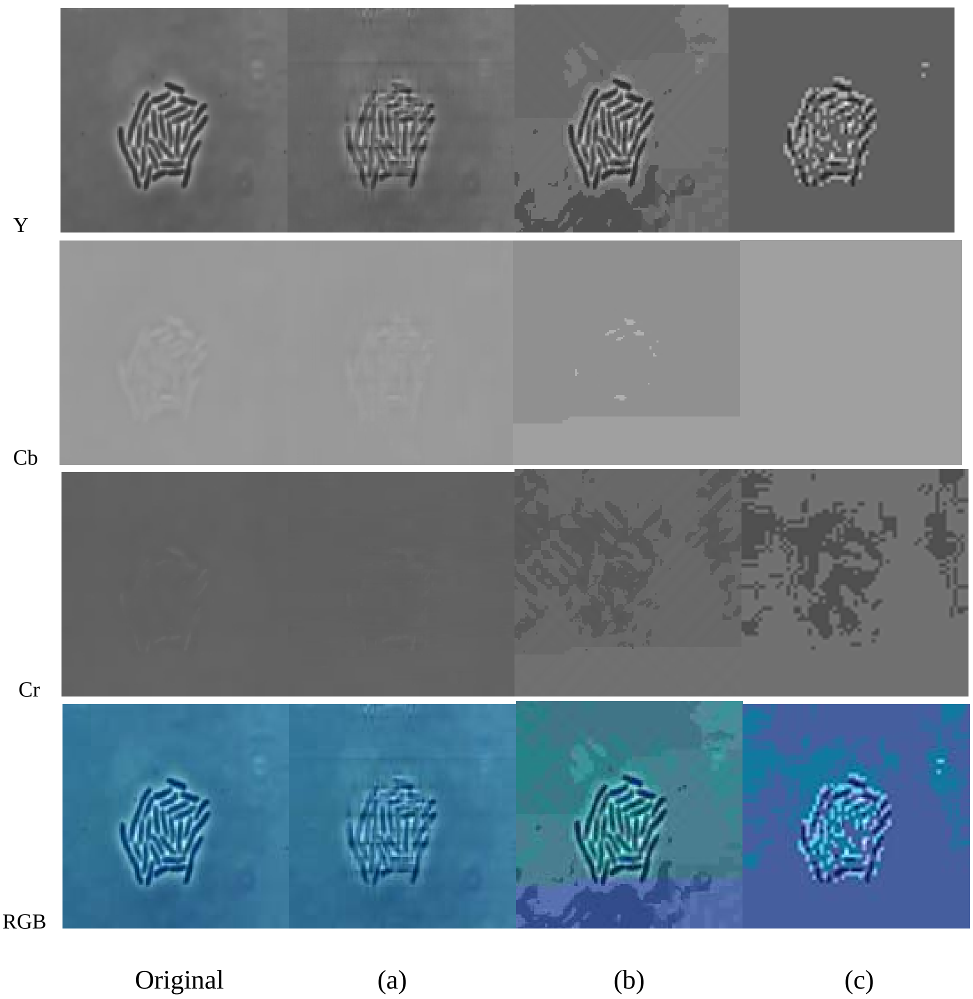


Figure 9. Recovered BACTERIA GROWTH sequence using: (a). GEOMETRIC WAVELET+SPIHT, (b). DCuT+SPIHT and (c). DWT+SPIHT at 0.9Mbps

6. CONCLUSION

The objective of this paper is to improve the enhancement of color medical video quality after the application of the proposed algorithm to aid diagnosis (storage or transmission) in medical imaging. We used the geometric wavelet coupled with SPIHT coding. After several applications, we found that this algorithm gives better results than the other traditional algorithms. To develop our algorithm, we have applied this technique on different types of color video. We have noticed that for low bit-rate, the proposed algorithm provides very important PSNR (dB) values for color medical video and it is more suitable for BACTERIA-GROWTH video. In perspective, we aspire to apply our algorithm to compress video sequences with another efficient transforms and coders.

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