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Effect of Scene Changing on Image Sequences Compression Using Zero Tree Coding

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Abstract**—**We study in this paper the effect of the scene changing on image sequences coding system using Embedded Zerotree Wavelet (EZW). The scene changing considered here is the full motion which may occurs. A special image sequence is generated where the scene changing occurs randomly. Two scenarios are considered: In the first scenario, the system must provide the reconstruction quality as best as possible by the management of the bit rate (BR) while the scene changing occurs. In the second scenario, the system must keep the bit rate as constant as possible by the management of the reconstruction quality. The first scenario may be motivated by the availability of a large band pass transmission channel where an increase of the bit rate may be possible to keep the reconstruction quality up to a given threshold. The second scenario may be concerned by the narrow band pass transmission channel where an increase of the bit rate is not possible. In this last case, applications for which the reconstruction quality is not a constraint may be considered. The simulations are performed with five scales wavelet decomposition using the 9/7-tap filter bank biorthogonal wavelet. The entropy coding is performed using a specific defined binary code book and EZW algorithm. Experimental results are presented and compared to LEAD H263 EVAL. It is shown that if the reconstruction quality is the constraint, the system increases the bit rate to obtain the required quality. In the case where the bit rate must be constant, the system is unable to provide the required quality if the scene change occurs; however, the system is able to improve the quality while the scene changing disappears.

Keywords**—**Image Sequence Compression, Wavelet Transform, Scene Changing, Zero Tree, Bit Rate, Quality.

I. INTRODUCTION

IMAGE sequences are characterized by both the spatial and temporal redundancies. For the limited bandwidth communication services such as internet, videophone, videoconference, etc, spatial resolution of a frame is reduced to minimize the bit rate. If a high spatial resolution is required, then the compression ratio must be high to satisfy the channel constraints. In this case, the image quality will be poor. For the industrial networks which have a large band pass channel, the bit rate may be increased to obtain the good reconstruction quality. The typical situation may be concerned by the transmission of medical image sequences where the reconstruction quality is a fundamental requirement. In general, it is difficult to achieve a high compression ratio and keep a high reconstruction quality in the case of the full motion in image sequences.

However, the characteristics of image sequences in videophone or videoconference services are quite different. They are characterized by slow shoulder and head motions in the field of the camera. Furthermore, the spatial resolution and frame rate are small. According to these considerations, it is possible to compress image sequences in the above applications at low bit rate and obtain a good reconstruction quality. H263, H263+ [1] are the standards that encode image sequences at low bit rate using Discrete Cosine Transform (DCT) as key technology despite his blocking artifacts and H.264 [2-3] using separable integer transform. The wavelet transform is the emerging technology used for image compression. Shapiro proposed Embedded Zerotree Wavelet algorithm (EZW) [4] for image still compression which is based on wavelet transform [5]. Since, many developments in image compression using wavelet transform are performed [6-11]. Improvements have been obtained by modification of EZW [10-11]. These different developments have contributed to the realization of the new still image coding JPEG'2000 standard [19-21]. In video compression, some developments are done [12, 14, 15, 24, 26, 27, 28] even if there is not yet a standard for video coding based only on wavelet transform.

In this paper, we study the impact of the scene changing on reconstruction quality and on bit rate in image sequences coding using EZW based system. A special image sequence is generated in which the scene changing occurs randomly. Our goal is to analyse how the encoder will response while the scene changing occurs. In one hand, the encoder must keep the reconstruction quality as constant as possible by varying the bit rate. In the other hand, the encoder must keep the bit rate as constant as possible even if the reconstruction quality is poor. The remaining of the paper is organized as follows: section 2 presents some basics of wavelet transform theory and the choice of wavelet basis for image processing. A short description of EZW is presented in section 3; section 4 presents the proposed coding system. Section 5 presents the simulation results and discussions. Finally, section 6 presents conclusion and the future work.

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II. BASICS OF WAVELET TRANSFORM

Subband based coding systems has been receiving increased interest as an alternative to DCT block based coding, as they overcome the blocking effect problem and produce images of superior subjective quality. Subband schemes in particular that implement the Discrete Wavelet Transform (DWT) have been receiving significant attention in the field of image compression. The basic idea behind the DWT is to represent any arbitrary function f as a weighted sum of a set of basis functions which are scaled and shifted version of a single mother wavelet ψ. The wavelet decomposition is defined by equation 1:

$$f(t)=\sum_{a}\sum_{b}C(a,b)\psi_{a,b}(t) \tag{1}$$

where $\psi_{a,b}(t)=\frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right)$

There exist special choices of ψ such that the set $\{\psi_{a,b}\}$ form an orthogonal basis of $L^2(R)$. In that case:

$$C(a,b)=\langle\psi_{a,b}\rangle=\int\psi_{a,b}(t)f(t)dt \tag{2}$$

The DWT can be computed via an octave band subband decomposition, where the filter coefficients are derived from the wavelet ψ and satisfy some regularity requirements. The figures 1 and 2 show one scale of 2D-DWT decomposition and reconstruction schemes respectively where HPF and LPF are the High Pass Filter and the Low Pass Filter respectively.

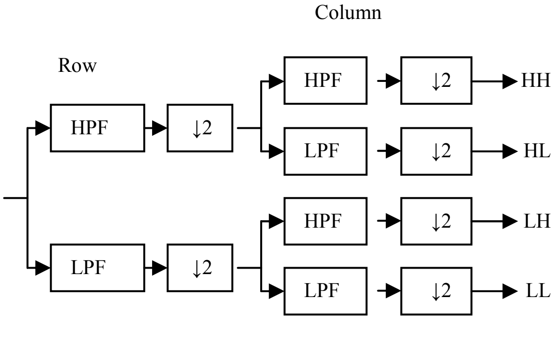


Fig. 1 One scale 2D-DWT decomposition scheme

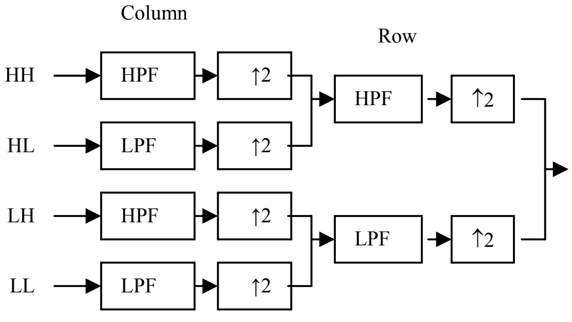


Fig. 2 One scale 2D-DWT reconstruction scheme

However, orthogonal wavelet filters cannot have linear phase, which is desirable in image processing applications. Therefore, biorthogonal wavelet basis [18] is more suitable for image processing applications. In that case, the reconstruction formula is defined by the equation 3:

$$f(t)=\sum_{a}\sum_{b}C(a,b)\tilde{\psi}_{a,b}(t) \tag{3}$$

where ψ et $\tilde{\psi}$ are orthogonal to each other. While a set of biorthogonal wavelet filters creates a subband coding scheme with perfect reconstruction in the presence of quantization noise, the choice of the filters can play an important role in the performance of system. A comparative study to determine the role of various characteristics of the wavelet filters such as regularity, filter length have been done by several authors and especially in [22] and in [23].

III. EMBEDDED ZEROTREE WAVELET CODEC

The EZW encoder encodes images in embedded fashion from their dyadic wavelet representations. The goal of embedded coding is to generate a single encoded bit stream that allows achieving any desired bit rate while giving the best reconstructed quality at this rate. In wavelet domain, image is represented by approximation subband (called DC or LL subband) and detail subbands (called AC or HL_i, LH_i, and HH_i, subbands at scale i.) as illustrated in the figure 3 (for two scales). The EZW encoder encodes wavelet coefficients by using a sequence of thresholds T. The initial value of threshold T_0 is defined such that $T_0 \succ \frac{C}{2}$ where C is the maximum wavelet coefficient. A coefficient X_i is considered as significant if $|X_i| \geq T$. Significance map, which consists of scanning the wavelet coefficient array to decide if a wavelet coefficient is significant, is generated at each bit plane. Two passes are performed for each threshold value: the dominant pass and the subordinate pass. All significant coefficients found in dominant pass are encoded by four symbols. The tree is structured according to a rule such that a parent coefficient in AC subband is linked with four children in the next finer subband. Only the parent coefficient in DC subband is linked with three children, one in each of the three coarse AC subbands (see figure 3). The four symbols used for encoding the coefficients are ZTR (ZeroTree Root.), IZ (Isolated Zero.), POS (significant positive.) and NEG (significant negative.). ZTR symbol is generated for an insignificant coefficient, which has no significant child. IZ symbol is generated for an insignificant coefficient, which has at least one significant child. POS and NEG are generated for significant coefficients which are positive and negative respectively. In finer AC subbands (HL_1, LH_1 and HH_1.) where the coefficients have no child, the IZ and ZTR symbols are merged to form the Z (zero.) symbol. The subordinate pass refines the quantized coefficients to obtain the best approximation of original wavelet coefficients. The particularity of embedded coding is that it can terminate the encoding at any point and thereby allowing a target rate or target distortion metric to be met exactly. This is interesting for rate and quality scalability applications.

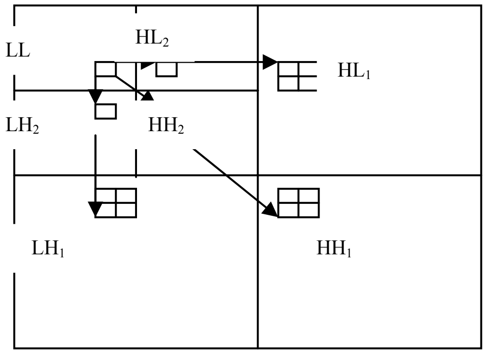
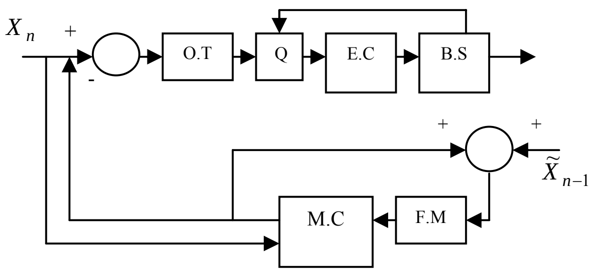


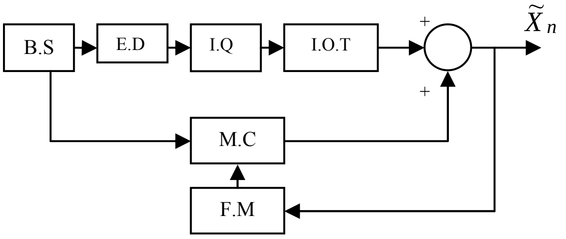
Fig. 3 Wavelet coefficients representation in EZW

IV. CODING OF IMAGE SEQUENCES

A general structure of image sequences coding system is composed by encoder and decoder such as shown in the figure 4. We shortly describe this system, referring to the MPEG2 standard in which the orthogonal transform is the DCT and the entropy coding is the variable length coding (VLC.). In the encoder, blocks of the first image in the sequence are encoded in intra-mode without any reference. DCT is applied in blocks of 8 x 8 pixels. The quantized coefficients are then encoded using VLC coding to produce the bit stream. The subsequent images are encoded by prediction from the previous images using motion estimation and compensation technique. The motion estimation process tries to detect the displaced blocks between the current image and the previous image. These blocks are then encoded to predict the current image. Of course, for constant bit rate applications, bit rate control algorithm is used to prevent the underflow or overflow. However, MPEG does not specify the way to search the displaced blocks; this is the detail that the system designer can choose to implement in one or many possible ways. It is also the case of bit rate control algorithm where complexity versus quality issues needs not to be addressed relative to individual application. The decoder performs the inverse operations accomplished by the encoder.



a



b

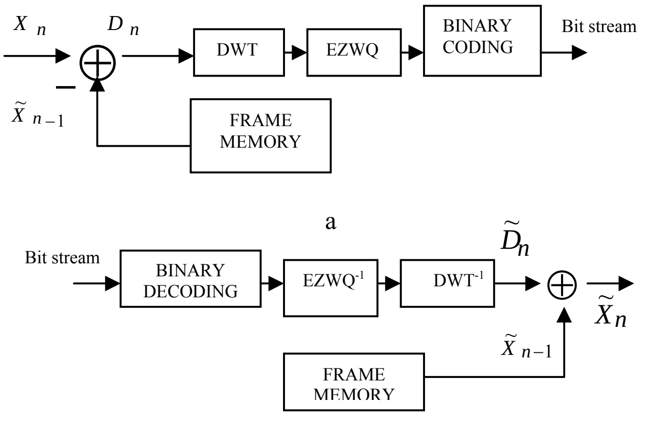
Fig. 4 General structure of image sequences coding system: a) Encoder, b) Decoder

In the figures 4.a and 4.b, O.T is the Orthogonal Transform, Q is the Quantizer, E.C is the entropy Coding, B.S is the Bit Stream, M.C is the Motion Compensation, F.M is the Frame Memory, E.D is the Entropy Decoding, I.Q is the Inverse Quantizer, I.O.T is the Inverse Orthogonal Transform. X_n, $\tilde{X}_{n-1}$ and $\tilde{X}_n$ are the current frame candidate to encoding, the previous encoded frame and the current encoded frame respectively.

Our approach is based on wavelet transform and figure 5 shows the scheme of the image sequences coding system proposed. The encoder contains three components: the first component is the Discrete Wavelet Transform (DWT.). The second component is the Embedded Zerotree Wavelet Quantization (EZWQ.) which quantizes the wavelet coefficients in embedded fashion and produces the EZW symbols. The third component is the binary coding which encodes the EZW symbols by specific defined binary codes [13]. The decoder performs the inverse of the encoder operations. In [13], we have studied the distribution of the EZW symbols (ZTR, IZ, POS, NEG and Z) for the still images. This study provides us the binary code book which we have called CB1. It contains the code word for each of the above EZW symbols in each wavelet subband, presented in table 1. The coding results using CB1 outperform the Flexible Wavelet Coder (FZW.) [11] as well in bit rate as in PSNR. Due to this success, we have extended the study of EZW symbol distribution to image sequences. A set of image sequences are decomposed in wavelet domain. The differences between the successive images in the sequence are generated and the residual images produced are decomposed in wavelet domain [14-15]. In [14 -15]. We have analysed the distribution of the residual EZW symbols (ΔZTR, ΔIZ, ΔPOS, ΔNEG and ΔZ) for the image sequences. This study provides us the binary code book which we have called CB2. It contains the code word for each of the above residual EZW symbols in each wavelet subband, presented in table 2.

These two code books (in table 1 for still image or for the first image in an image sequence) and (in table 2 for the subsequent images in image sequences) are used to encode the image sequences. The experimental results obtained [14] show that our coding approach provides comparable reconstruction quality, compared to H.263 codec.

In the figure 5, the first image in the sequence is decomposed in wavelet domain and encoded using the binary codebook CB1. The subsequent images in the sequence are encoded as residual images D_n (obtained by the difference between the current image X_n and the reconstructed previous image $\tilde{X}_{n-1}$ in the decoder). This is the particularity of our coding system because the previous image (used to reduce the temporal redundancy) is in the decoder. Our approach may be justified by the fact that in the real transmission situations, the previous image is in the decoder and not in the encoder. So, a local decoder is used for the decoding of the previous frame. The frame memory showed in figure 5a and 5b is the decoder frame memory. Since the previous image is in the decoder frame memory, it will be probably affected by the source coding noise or by the channel coding noise or by the both; so, the encoder must take this event into account in the encoding process. The current image X_n is reconstructed by using the previous reconstructed image $\tilde{X}_{n-1}$ in the decoder and the residual decoded image $\tilde{D}_n$.



a

b

Fig. 5 Proposed system for image sequence coding a) Encoder, b) Decoder

The encoding process is performed in the following steps:

1. The first image X_0 in the sequence is decomposed in wavelet domain and encoded in intra-mode by using EZW algorithm and CB1. The produced bit stream is the main bit stream;
2. The difference between the current image X_n and the previous image $\tilde{X}_{n-1}$ in the frame memory is calculated to remove temporal redundancies.
3. The obtained residual image D_n is decomposed in wavelet domain and encoded in prediction mode by using EZW algorithm and CB2. The bit stream produced in this case is the residual bit stream;
4. The current image is reconstructed by adding the residual image $\tilde{D}_n$ and the previous image $\tilde{X}_{n-1}$ in the decoder.

The equations 4 et 5 describe image difference calculating, and reconstruction process:

$$D_n = X_n - \tilde{X}_{n-1} \tag{4}$$

$$\tilde{X}_n = \tilde{X}_{n-1} + \tilde{D}_n \tag{5}$$

The equation 4 provides the difference D_n between the current image X_n and the previous image $\tilde{X}_{n-1}$ and the equation 5 gives the reconstruction of the current image $\tilde{X}_n$ from the residual image $\tilde{D}_n$ and the reconstructed previous image $\tilde{X}_{n-1}$. This process may be considered as motion estimation operated on full resolution and not on blocks such as the case of MPEG or H.263 standards.

The bit rate and the quality are managed by the simplified algorithm illustrated in the figure 6. Once the image sequence is loaded, the system wait for the choice of the requirement. If the response is **no**, the system performs the constant bit rate compression. However, if the response is **yes**, the system performs the compression with a constant quality (at least equal to a given signal to noise ratio PSNR). In fact, the user have to enter either the Target Signal to Noise Ratio (TSNR) for constant quality compression or the Target Bit Rate (TBR) for constant bit rate compression. In the particular case where the requirement is the quality, the increase of bit rate is operated in one hand, by the refinement of the early quantized wavelet coefficient (by adding next bit in the representation of significance map) and in the other hand, by the quantization of the new significant coefficients due to the progressive characteristic of the system.

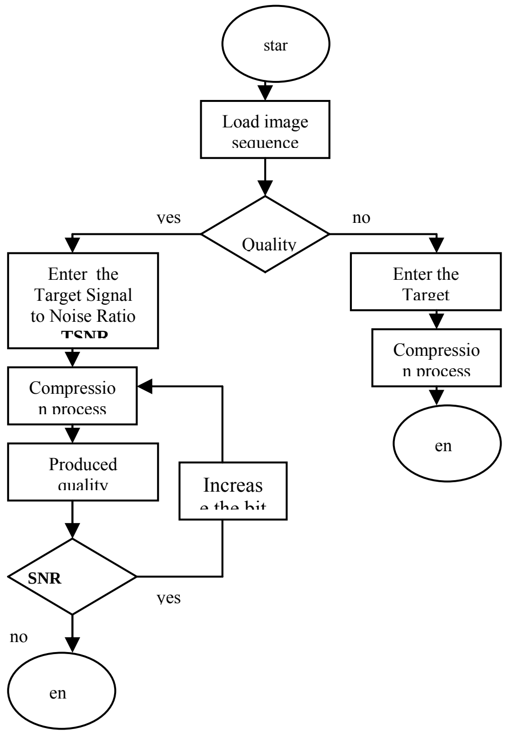


Fig. 6 Simplified algorithm for scene changing coding

TABLE I
BINARY CODES FOR STILL IMAGE (CB1)

	ZTR	IZ	POS	NEG	Z
LL5	11	10	0	-	-
HL5	10	11	0	-	-
LH5	1	-	0	-	-
HH5	1	-	0	-	-
HL4	0	10	110	111	-
LH4	0	10	111	110	
HH4	0	10	110	111	-
HL3	0	10	110	111	-
LH3	0	10	111	110	-
HH3	0	10	111	110	-
HL2	0	10	110	111	-
LH2	0	10	110	111	-
HH2	0	10	110	111	-
HL1	-	-	11	10	0
LH1	-	-	11	10	0
HH1	-	-	10	11	0

TABLE II
BINARY CODES FOR IMAGE SEQUENCES (CB2)

	ΔZTR	ΔIZ	ΔPOS	ΔNEG	ΔZ
LL5	10	0	111	110	-
HL5	0	10	110	111	-
LH5	10	0	111	110	-
HH5	10	0	111	110	-
HL4	10	0	111	110	-
LH4	10	0	111	110	-
HH4	0	10	111	110	-
HL3	0	10	110	111	-
LH3	10	0	110	111	-
HH3	0	10	111	110	-
HL2	0	10	110	111	-
LH2	0	10	110	111	-
HH2	0	10	111	110	-
HL1	-	-	10	11	0
LH1	-	-	10	11	0
HH1	-	-	10	11	0

V. EXPERIMENTAL RESULTS AND DISCUSSIONS

Simulations are performed on Claire sequence as a low motion sequence and on a special sequence obtained by alternation between Claire and Alexis image sequences, both in CIF format (288 x 352 pixels by frame). This special sequence contains 25 images composed respectively by 8 successive images of Claire, 8 successive images of Alexis and 9 successive images of Claire. All simulations are performed with five scales wavelet decomposition [17]. The 9/7-tap filter bank biorthogonal wavelet [18] is chosen in our work due to its well known success in image coding. Figure 7 and figure 8 show bit rate versus frame number for a given reconstruction quality. Figure 9 and figure 10 show PSNR versus frame number for a given bit rate.

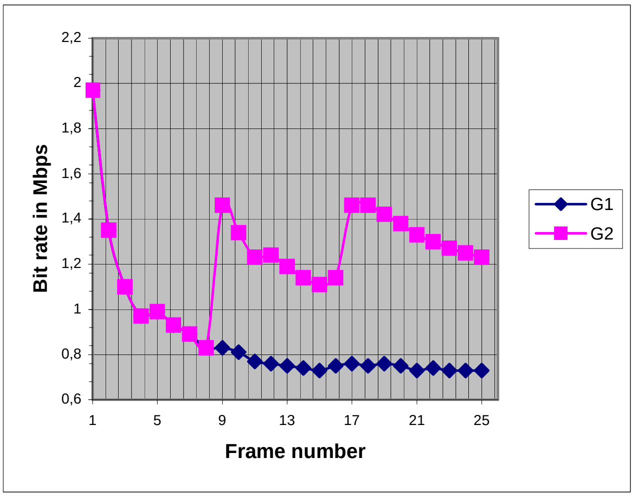


Fig. 7 Bit rate versus frame number for PSNR = 41.10 dB
G1: Claire, G2: scene changing

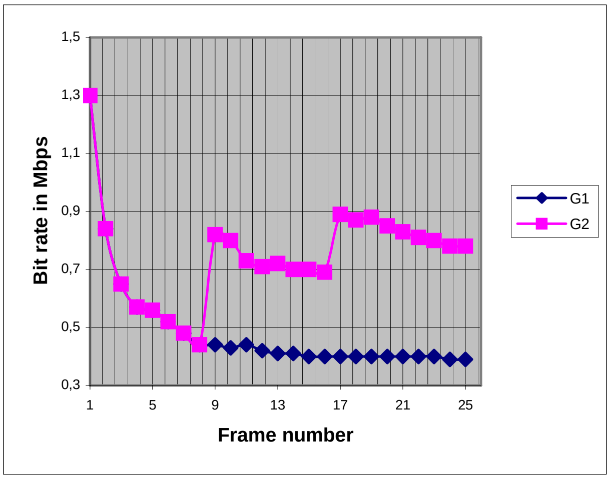


Fig. 8 Bit rate versus frame number for PSNR = 38.56 dB
G1: Clair, G2: scene changing

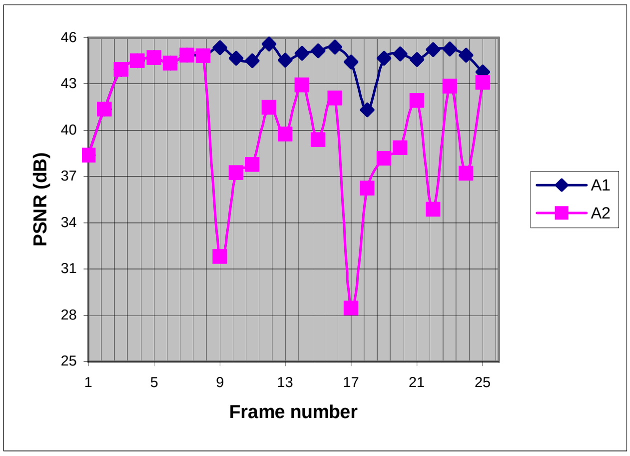


Fig. 9 PSNR versus frame number for BR = 1.31 Mbps
A1: Claire, A2: scene changing

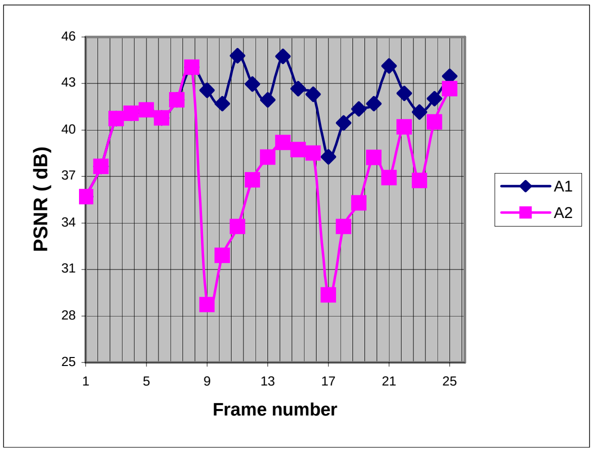


Fig. 10 PSNR versus frame number for BR = 0.80 Mbps
A1: Claire, A2: scene changing

In the case of Claire sequence (low motion), we observe in figure 7 and figure 8 that for a given reconstruction quality, the bit rate which is maximal at the beginning of encoding process, decreases as the compression progress and converges to a minimum bit rate. More precisely, for a PSNR of 41.10dB (figure 7), the bit rate decreases from 1.97 to 0.73 Mbps and for a PSNR of 38.56 dB (figure 8), it decreases from 1.30 to 0.39 Mbps. In figure 9 and figure 10, we observe that for a given bit rate, the reconstruction quality increases. More precisely, a PSNR of 44.81 dB is obtained for a constant bit rate of 1.31 Mbps in figure 9. In figure 10, we observe that a PSNR of 44.65 dB is obtained for a constant bit rate of 0.80 Mbps.

In the case of special sequence (scene changing), figure 7 and figure 8 show that to keep the reconstruction quality up to a required level, the bit rate must be increased. This increase in bit rate is precisely observed where scene changing occurs. So, for a PSNR of 41.10 dB (figure 7), the bit rate must be increased from 0.8 to 1.46 Mbps for the first scene changing and from 1.14 to 1.46 Mbps for the second scene changing. For a PSNR of 38.56 dB (figure 8), the bit rate must be increased from 0.44 to 0.82 Mbps for the first scene changing and from 0.69 to 0.89 Mbps for the second scene changing. We also observe in these two cases that the bit rate decreases when the scene changing disappears.

The figures 9 and 10 show that the reconstruction quality decreases while the scene changing occurs: it is due to the fact that the bit is constant. However, this degradation of the quality is quickly overcome and the best quality is progressively obtained after the scene changing.

The figures from 11 to 14 compare the results obtained by our system and the results obtained by LEAD H263 EVAL (which is the evaluation version of the H263 standard), in terms of PSNR for a constant bit rate). We observed that our codec outperforms the LEAD H263 EVAL. So, the gains of 0.46 dB and 0.50 dB are obtained in the figure 11 and in the figure 12 for a constant bit rate of 1.31 Mbps and 0.80 Mbps respectively for Claire sequence. The gains of 0.42 dB and 0.49 dB are obtained in the figure 13 and in the figure 14 for a constant bit rate of 1.31 Mbps and 0.80 Mbps respectively for scene changing.

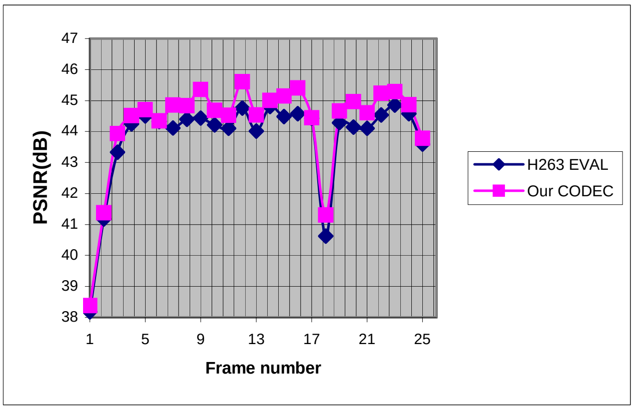


Fig. 11 PSNR versus frame number for BR = 1.31 Mbps for Claire
Average PSNR = 43.79 dB for H263 EVAL
Average PSNR = 44.25 dB for our codec

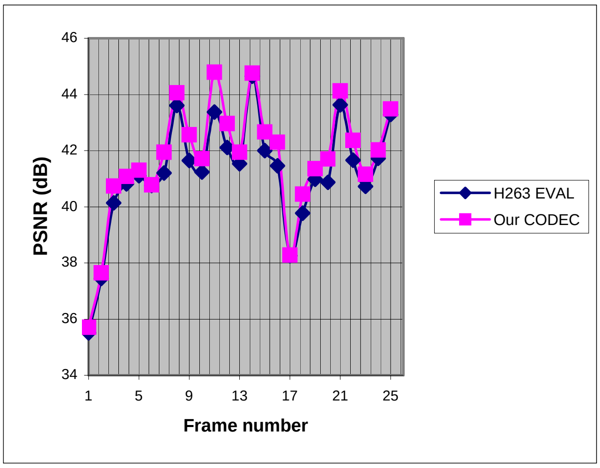


Fig. 12 PSNR versus image number for BR = 0.80 Mbps for Claire
Average PSNR = 41.18 dB for H263 EVAL
Average PSNR = 41.68 dB for our codec

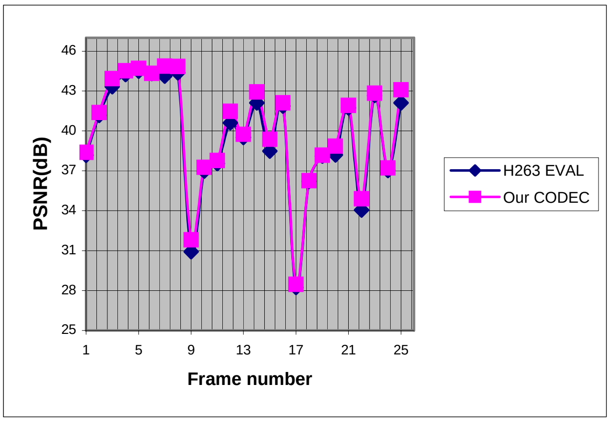


Fig. 13 PSNR versus frame number for BR = 1.31 Mbps for scene changing
Average PSNR = 39.63 dB for H263 EVAL
Average PSNR = 40.05 dB for our codec

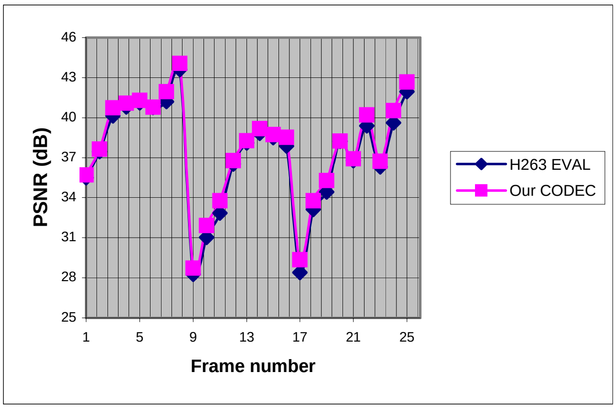


Fig. 14 PSNR versus frame number for BR = 0.80 Mbps for scene changing
Average PSNR = 37.23 dB for H263 EVAL
Average PSNR = 37.72 dB for our codec

VI CONCLUSION AND PERSPECTIVES

In this paper, we have presented a study of the effect of the scene changing on image sequences coding using an EZW based system. Image sequences are decomposed in the wavelet domain. To exploit the redundancy in temporal domain, difference between the reconstructed previous image in the decoder and the current image in the encoder is performed. The obtained residual image is decomposed in wavelet domain and encoded by a specific binary code book. Experimental results show that when the scene changing occurs, the system increases the bit rate to keep the reconstruction quality greater or equal to a required quality. This is managed by the refinement of the early quantized wavelet coefficient by adding a next bit in the representation of significance map and by the quantization of the new significant coefficients, due to the progressive transmission property of the system. Also, the results show that if the requirement is the constant bit rate, the reconstruction quality is affected by the degradation when the scene changing occurs. Compared to LEAD H263 EVAL standard, it is shown that our system outperforms the LEAD H263 EVAL and an average gain of 0.50 dB may be obtained.

We think that some points must be analysed in our approach to improve this work. First, the difference between the current frame and the previous frame is decomposed in wavelet domain and the coding is operated on all subbands trough all different scales. This is a major disadvantage since some subbands contain little or no energy and their contribution to reconstruction quality is insignificant. Some criterion may be defined for the selection of the subbands candidate for coding: only subbands which verify the selection criterion will be encoded and all the subbands which don't verify the selection criterion will be rejected. Second, a pre-processing of residual frame in spatial domain may be operated before its decomposition in wavelet domain; so, some statistic characteristics such as mean or standard deviation may be used in pre-processing for the selection of the residual pixels which can give a significant contribution in the reconstruction quality. Third, it is possible to adapt our recent development [29] to improve the results.

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