Novel Video Coder Using Multiwavelets

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1. Introduction

Information has become one of the most valuable assets in the modern era. Recent technology has introduced the paradigm of digital information and its associated benefits and drawbacks. A thousand pictures require a very large amount of storage. While the advancement of computer storage technology continues at a rapid pace a means of reducing the storage requirements of an image and video is still needed in most situations. Thus, the science of digital image and video compression has emerged. For example, one of the formats defined for High Definition Television (HDTV) (Ben Waggoner 2002) broadcasting is 1920 pixels horizontally by 1080 lines vertically, at 30 frames per second. If these numbers are multiplied together with 8 bits for each of the three primary colors, the total data rate required would be 1.5 GB/sec approximately. So compression is highly necessary. This storage capacity seems to be more impressive when it is realized that the intent is to deliver very high quality video to the end user with as few visible artifacts as possible. Current methods of video compression such as Moving Pictures Experts Group (MPEG) standard (Peter Symes 2000, Keith Jack 1996) can provide good performance in terms of retaining video quality while reducing the storage requirements. But even the popular standards like MPEG have limitations.

Research in new and better methods of image and video compression is ongoing, and recent results suggest that some newer techniques may provide much greater performance. This motivates to go for video compression. An extension of image compression algorithms based on multiwavelets and making them suitable for video (as video contains sequence of still pictures) is essential. This chapter gives a summary of the new multiwavelet decomposition algorithm along with quantization techniques and illustrates their potential for inclusion in new video compression applications and standards (Sudhakar et al., 2009, Sudhakar & Jayaraman 2007, Sudhakar & Jayaraman 2008). Video coding for telecommunication applications has evolved through the development of the ISO/IEC MPEG-1, MPEG-2 and ITU-T H.261, H.262 and H.263 video coding standards (and later enhancements of H.263 known as H.263+ and H.263++), (Iain E.G. Richardson 2002) and has diversified from ISDN and T1/E1 service to embrace PSTN, mobile wireless networks, and LAN/Internet network delivery.

2. Significance of the present work

Multiwavelets (Cheung, K.W & Po L.M, 1997.; Chui, C.K. & Lian J., 1996) are beginning only now to approach the maturity of development of their scalar counterparts Wavelets and DCT (Xiong et al., 1999.; Devore et al 1992; Gilbert Strang & Truong Nguyen 1996) A few papers that have tested the image compression properties of multiwavelets suggest that multiwavelets (Cotronei et al 2000; Shen 1997; Strela et al 1999; Gilbert Strang & Strela 1994; Michael & Amy E. Bell 2001 and Michael, B.M 1999) can sometimes perform as well as or better than scalar wavelets and DCT. But to date, no researchers have pursued this more thoroughly with the intention of determining whether multiwavelets might be a better choice for video compression than scalar wavelets and DCT. In this chapter, evaluations of the performance of state-of-the-art multiwavelet methods for compression of general classes of videos have been presented. The videos taken for comparison include 'Football', 'Dancer', 'Claire', 'Foreman', 'Trevor' and 'Miss America'. This chapter presents the following new results:

- An efficient algorithm is presented for motion estimation with half pixel accuracy using fast approach algorithms. A comparison between the popularly used block matching algorithm (Diamond search algorithm) (Shan Zhu & Kai-Kuang Ma 2000) and the new Kite cross diamond algorithm (Chi-Wai Lam et al 2004) is provided.
- A comparison between the best known multiwavelets and the best known scalar wavelets is made. Both quantitative and qualitative measures of performance are examined for several videos.
- A novel video encoder combining the advantages of multiwavelets, Kite Cross Diamond Search algorithm and the novel scheme is also provided.

3. Proposed video coder

This section deals with proposed video coder and the new concepts which matches with the existing standards. The proposed novel encoder is shown in Figure 1. The new schemes used in this video coder are highlighted first and are explained in the subsequent sections.

- In Intra frame coding the following new schemes are introduced.
  - Multiwavelet transform is used for coding the frames (I-frames)
  - 'SPIHT', 'SPECK', 'Novel scheme' is used for coding of multiwavelet coefficients
- In Inter frame coding the following new schemes are introduced.
  - Fast algorithms for motion estimation
  - Half pixel accuracy motion estimation
  - Predictive coding of motion vectors
  - Multiple reference frame motion compensation

3.1 Intra frame coding

Removing the spatial redundancy within a frame is called as intraframe coding. Normally I-frames are coded in this way. This is achieved using transform. There are many transforms like 'DCT', 'DWT', and Multiwavelet transform. As it is obvious that 'DCT' introduces blocking artifacts, normally 'DWT' is used in JPEG 2000 (Skodras, A.N et al 2000). As demonstrated in the papers (Sudhakar et al., 2009; Sudhakar & Jayaraman 2007; Sudhakar & Jayaraman 2008), that multiwavelet transform supersedes wavelets in still image compression, in this proposed coder multiwavelet based transform is extended for video

also. The simple reason is that video is a set of still frames arranged in a regular order. Before applying the multiwavelet transform to the input images or residuals, the image is to be preprocessed. The prefilter (Strela, V., 1996; Strela, V., 1998) is chosen corresponding to the filters chosen for applying multiwavelet transforms (Strela, V & Walden A.T., 1998; Strela V et al., 1999). Similarly, the post processing is to be done at the receiver side.
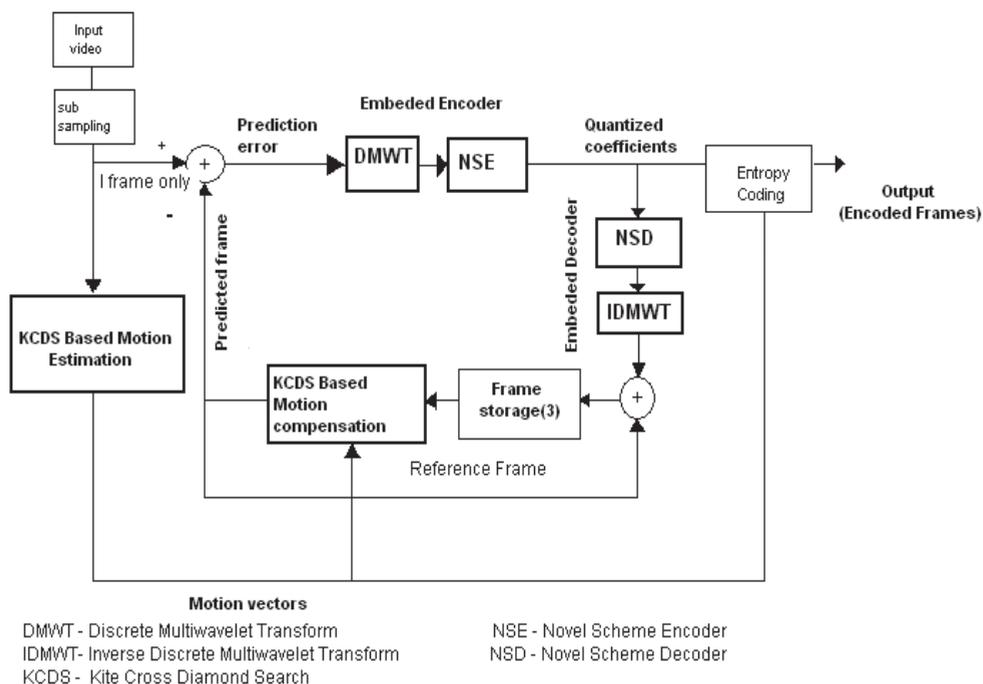

Fig. 1. Block diagram of the Proposed Novel encoder

3.1.1 Coding of multiwavelet coefficients

The coding and quantization of the multiwavelet coefficients could be done by SPIHT or SPECK algorithm. The coding of the multiwavelet coefficients using SPIHT and SPECK (Said A & Pearlman 1996; Pearlman et al. 2004) are explained and completely available in the papers (Sudhakar et al., 2009; Sudhakar & Jayaraman 2007; Sudhakar & Jayaraman 2008). Compression is the result of quantization. In this work different multiwavelets (Sudhakar, R.; & Jayaraman, S., 2008) are used and their performances are studied. SPIHT performs better for high bit rate but produces poor quality at low bit rates. SPECK performs well at low bit rates but results in poor compression. So a novel scheme is introduced. In this coder the 'Y' and 'U' components are coded using 'SPIHT' and the 'V' component is coded using 'SPECK' at 75% of the rates used in 'SPIHT'. The very first frame or every twelfth frame of video sequences is coded as I-frame. Every other frame is coded as P-frame. If the mean square error between the predicted frame and the actual frame is greater than the threshold then the current frame is coded as the I-frame. The 'bpp' settings of SPIHT encoder for residual are set to very less rate compared to the I-frame rate.

3.1.2 Entropy coding

The purpose of the entropy coding algorithm (Lei and Sun 1991), is to represent frequently occurring (run, level) pairs with a short code and less frequently occurring pairs with a longer code. In this way, the run-level data may be compressed into a small number of bits. Huffman coding and arithmetic coding are used widely for entropy coding of image and video data. In this chapter Huffman coding is used as the entropy coding.

3.2 Inter frame coding

The temporal redundancy between the successive frames is removed by interframe prediction. This is achieved by Motion estimation and compensation. An efficient fast motion estimation algorithm to predict the current frame from the previous reference frames is used. Here the motion estimation is done up to half pixel accuracy. The detailed explanations are given in the subsequent sections

3.2.1 Fast motion estimation algortihm

Full search (FS) block motion estimation matches all possible points within a search area in the reference (target) frame to find the block with the minimum block distortion measure (BDM). Thus this algorithm gives the best possible results. However, a full search algorithm accounts for about two-thirds of the total computational power and it is very intensive computationally. Due to the high requirement of intensive computation for the full search algorithm many fast motion algorithms (Peter Symes 2000) have been proposed over the last two decades to give a faster estimation with similar block distortion compared to the full search method. The most well known fast Block Motion Algorithms (BMA) are the three-step search (TSS) (Li et al 1994; Koga et al 1981), the new three-step search (NTSS), the four-step search (4SS) (Po Ma 1996) and the diamond search (DS) (Shan Zhu and Kai-Kuang Ma 2000). Diamond search is more popular among the existing standards. The main aim of these fast search algorithms is to reduce the number of search points in the search window and hence the computations. This is completely evident from the Table. 1. The motion field for a block of a real world image sequence is gentle, smooth usually and varies slowly. One of the most important assumptions of all fast motion estimation algorithm is 'error surface is monotonic' i.e. BDM is the least at the center or the global minima of the search area and it increases monotonically as the checking point moves away from the global minima.

Video	FS	TSS	NTSS	4SS	DS	KCDS
Trevor	202.1	23.2	20.67	18.65	16.25	12.67
Dancer	202.1	23.24	21.38	18.80	16.84	12.89
Foot ball	202.1	23.06	17.65	16.69	13.67	7.73
Miss America	202.1	23.46	19.99	18.319	16.36	9.54
Claire	202.1	23.22	15.924	16.19	12.4	5.23

Table 1. Average Searching Points for different fast searching Algorithms

Many fast motion estimation algorithms is based on the centre biased motion vector distribution. But this assumption may not hold for videos with very fast motions. Kite Cross Diamond Search (KCDS) algorithm (Chi-Wai Lam et al 2004) which is based on the cross centre biased distribution characteristics is employed in this chapter.

3.2.2 Half pixel accuracy motion estimation

Fractional pixel motion estimation is employed in modern coding standards in which the displacement of an object between two frames in videos is not an integer no of pixels. Here motion vectors are used. These vectors point to candidate blocks that are placed at half pixel locations. It is advantageous to place a candidate block at fractional location. This gives better matching properties than at an integer location. Further it helps to reduce the degree of error between origilnal and predicted image. Interpolating linearly or bilinearly the nearest pixels at integer locations, it is possible to obtain the pixel values in the fractional locations. But the demerit here is that the computational overhead increases.

Hence it becomes necessary to save the computation overhead. Conventional encoders can be used for this purpose. The process of motion estimation in this conventional encoder is dealt in two steps.

1. Criteria minimum is found at integer location.
2. Interpolation of candidate block correponding to the eight nearest half pixel displacement motion vectors as shown in fig. 2

Interpolation is done to the best integer and motion vector is refined into sbupixel by computing the criterain between the current block and its eight half pixel candidate block. Real time encoder finds this process too difficult to be implemented because of its complexity in computation, hence much faster methods have been investigated in the literature (Lee and Chen 1997).
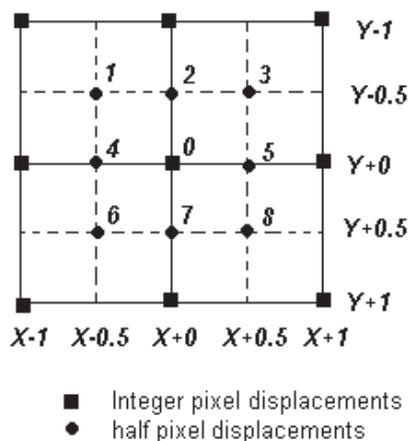

Fig. 2. Integer and half pixel displacements

3.2.3 Predictive coding of motion vectors

The motion vectors are predicted from the previously coded motion vectors (Lee et al 2000) so as to reduce the number of bits required to code them. Variable bit rate coding is used to encode the difference. Based on the previously found motion vectors, a predicted vector MVp is formed, which depends on the motion compensation partition size and its availability of nearby vectors. The Motion Vector Difference (MVD) between current and predicted vector is encoded and transmitted. Variable bit length coding is used for encoding the difference. Short codes are used code the most frequently occuring motion vector. Figure 3 shows the actual motion vectors and the difference between the predicted one and the actual motion vectors.

1.5	1.0	-0.5	-1.5
1.0	1.5	2.0	1.5
0.5	-0.5	-0.5	-1.0
-0.5	-0.5	-1.0	-1.5

1.5	0.5	1.5	1.0
0.5	-0.5	-0.5	0.5
0.5	1.0	0.0	0.5
1.0	0.0	0.5	0.5

(a)   (b)
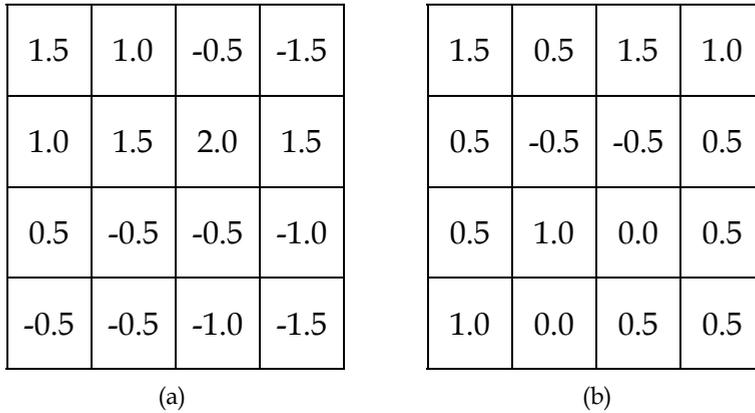
Fig. 3. (a) Actual motion vectors (b) Difference between the predicted and actual motion vectors

Now the difference is encoded as:
- First bit represents the sign of the difference; negative difference is represented by 1 and positive as 0.
- Next to the sign bit is M ones followed by one zero; M is the absolute value of difference.
- Last bit represent the decimal value; 0.5 is represented as 1 and 0.0 is represented as 0

For example, -1.0 and 0.5 are coded as

$$-1.0 \rightarrow 1100$$
$$0.5 \rightarrow 001$$

4. Block diagram of the proposed decoder system

The block diagram of the proposed decoder is shown in the figure 4. Here every step is a reverse process to the encoder except the motion prediction. By using the reference frames and the decoded motion vectors a new frame is reconstructed by motion compensation method.


NSD Novel Scheme Decoder
IDMWT Inverse Discrete Multiwavelet Transform
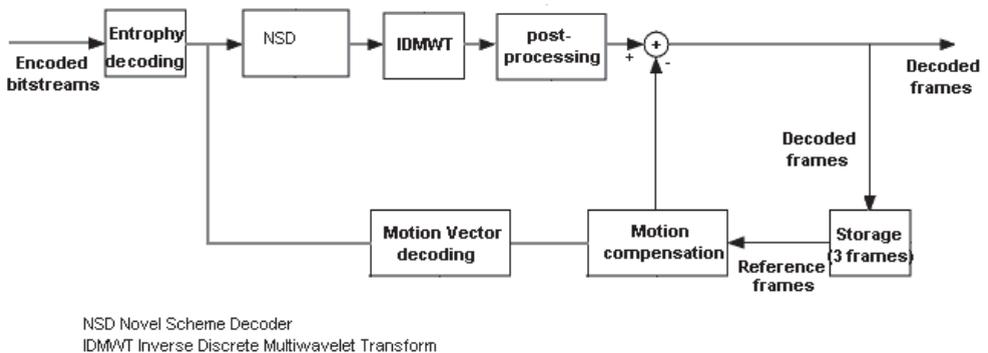
Fig. 4. Block diagram of the proposed decoder system

5. Results and discussion

This section has four sub sections. Section 5.1 deals with "SPIHT results" and it gives the information about the performance of SPIHT due to the variation of I rate and P rate. Several comparisons are made here like comparison between 'DS' and 'KCDS' and also between Wavelet and Multiwavelet. Section 5.2 discusses the results between 'SPECK' and 'Novel scheme'. This section also features the performance of 'SPECK' for different videos and the comparison among SPIHT, SPECK and Novel scheme. Novel scheme is one in which the 'Y' and 'U' components are coded with 'SPIHT' but 'V' component is coded using SPECK at 75% of rate used in 'SPIHT'. Summary of the results is provided in section 5.3. Section 5.4 deals with reconstructed frames illustrating the Comparison of 'SPIHT', 'SPECK' and 'Novel scheme'. In this work, two sets of video sequences are used. First set is CIF (352×288) which includes "Dancer", "Football" video sequences. The other set is QCIF (176×144) with the video sequences, "Claire", "Foreman", "Trevor" and "Miss America". The videos used are listed in the Table 2 and their visuals are shown in Figure 5, followed by some description about them.

Name	Frame Size
Claire	144×176
Foreman	144×176
Trevor	144×176
Miss America	144×176
Dancer	288×352
Football	288×352

Table 2. List of test videos

The 'Claire' and 'Miss America' videos have very small motions with still background and contain the motion of only one object. The 'foreman' has large motion and variable background due to camera motion. 'Trevor' video has random motions involving different objects. The 'Dancer' video has moving background and contains the slow motions of two objects. The 'football' video has a very large motion without moving background in the opposite direction. It also contains the motion of many objects moving with different velocities.

The parameters used here are PSNR and Compression ratio. The video format used is "YUV". Each component i.e. 'Y', 'U', 'V' are processed separately and hence the peak signal value is 255. The average of these 3 values will give the average PSNR for a particular frame. When many frames are considered the average PSNR for all the frames is used as the performance factor.

The PSNR in dB for an M × N Video frame for each component is calculated as

$$PSNR = 10 \log \left(\frac{255^2}{MSE} \right) dB \tag{1}$$

where the mean square error (MSE) is defined as

$$MSE = \frac{1}{MN} \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} \left| x(m,n) - \hat{x}(m,n) \right|^2 \tag{2}$$

Compression ratio (CR) is calculated as CR = M × N × 3 × 8 × No of Frames / No of bits after coding. M × N is the size of the frame

(a)   (b)   (c)   (d)

(f)   (e)
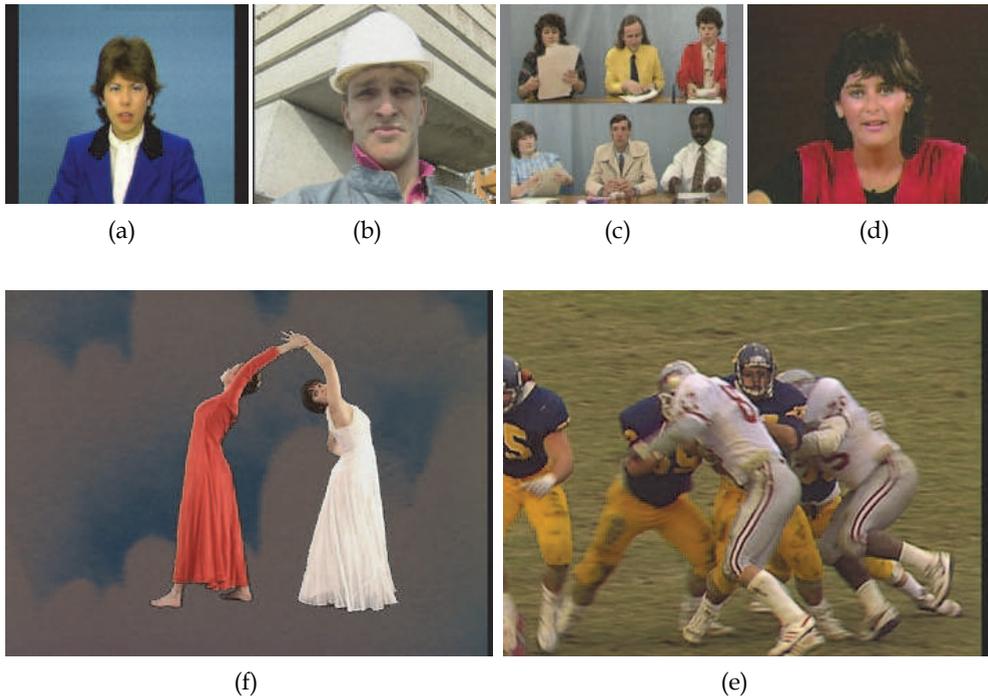
Fig. 5. Test videos (a) 'Claire', (b) 'Foreman', (c)'Trevor', (d) 'Miss America' , (e)'Dancer' and (f)'Football'

The other conventions used are the 'I' rate and 'P' rate. 'I' rate is the rate at which the reference or intra frame is coded and 'P' rate is the rate at which the residue is coded. Residue is the difference between the reference frame and the predicted frame. Both have the unit of bpp (bits per pixel). Similarly, the default search algorithm is 'KCDS', and default transform is Multiwavelet. In the case of discrepancy, these conventions can be assumed as default. The multiwavelet filters (Sudhakar, R.; & Jayaraman, S., 2008) used in this work are symmetric / anti symmetric multifilter ("Sa4"), Chui-Lian orthogonal multifilter ("Cl"), "GHM" pair of multifilters, and Cardinal 2-balanced orthogonal multifilter ("Cardbal2"). The corresponding prefilters used are "Sa4ap", "Clap", "Ghmmap", and "Id" respectively. The scalar wavelet filter taken for comparison are Haar wavelet ("Haar"), Daubechies 4 coefficient scalar filter ("Db4") and Daubechies 8 coefficient scalar filter ("La8").

5.1 'SPIHT' results
The results are observed with 'I' rate = 0.9 and 'P' rate = 0.05.

5.1.1 'Claire' video

Here "Cardbal2" performs well in terms of Average PSNR and "Cl" produces higher compression ratio. In terms of search algorithm, 'KCDS' and 'DS' almost perform equally in terms of average PSNR with 'KCDS' gives better compression ratio.

Wavelet	Average PSNR (dB)	CR
Haar	38.49	73.34
Db4	39.51	72.12
La8	39.7	72.32

Table 3. Comparison of average 'PSNR', 'CR' for different Wavelets in 'Claire' video (84 Frames) using 'KCDS'

Multiwavelet	Average PSNR (dB)		CR	
	KCDS	DS	KCDS	DS
Sa4	38.99	38.98	81.61	78.95
Cl	39.11	39.14	82.47	79.41
GHM	39.21	39.21	72.64	70.56
Cardbal2	39.59	39.58	71.35	69.46

Table 4. Comparison of average 'PSNR', 'CR' for different multiwavelets in 'Claire' video (84 Frames)

5.1.2 'Foreman' video

Here "GHM" multifilter performs better in terms of average PSNR and "Cl" in terms of compression ratio. "Sa4" performs better as well. In all the cases 'KCDS' performs marginally better than 'DS'.

Wavelet	Average PSNR (dB)	CR
Haar	35.87	67.57
Db4	36.1	66.36
La8	36.31	66.19

Table 5. Comparison of average 'PSNR', 'CR' for different Wavelets in 'Foreman' video (84 Frames) using 'KCDS'

Multiwavelet	Average PSNR (dB)		CR	
	KCDS	DS	KCDS	DS
Sa4	35.87	35.85	73.39	69.14
Cl	35.71	35.68	73.71	69.68
GHM	36.21	36.17	65.05	62.21
Cardbal2	36.12	36.08	67.03	63.69

Table 6. Comparison of average 'PSNR', 'CR' for different multiwavelets in 'Foreman' video (84 Frames)

5.1.3 'Dancer' video

Here in terms of multiwavelet "cardbal2" performs better in terms of average PSNR and "Cl" in terms of compression ratio. Here also, "Sa4" performs better. 'DS' performs marginally better than KCDS in terms of average PSNR and 'KCDS' perform better in terms of compression ratio.

Wavelet	Average PSNR (dB)	CR
Haar	38.1	53.69
Db4	38.63	53.27
La8	38.76	52.95

Table 7. Comparison of average 'PSNR', 'CR' for different Wavelets in 'Dancer' video (84 Frames) using 'KCDS'

Multiwavelet	Average PSNR (dB)		CR	
	KCDS	DS	KCDS	DS
Sa4	37.82	37.82	56.27	55.67
Cl	37.65	37.69	56.55	55.86
GHM	37.76	37.84	51.99	51.38
Cardbal2	38.08	38.11	51.56	51.04

Table 8. Comparison of average 'PSNR', 'CR' for different Multiwavelets in 'Dancer' video (84 Frames)

5.1.4 'Football' video

Here in terms of multiwavelet "cardbal2" performs better in terms of average 'PSNR' and "Cl" in terms of compression ratio. But overall "Sa4" performs better. In all the cases KCDS performs marginally better than DS.

Wavelet	Average PSNR (dB)	CR
Haar	32.02	43.29
Db4	32.47	42.94
La8	32.31	44.31

Table 9. Comparison of average 'PSNR', 'CR' for different Wavelets in 'Football' video (84 Frames) using 'KCDS'

Multiwavelet	Average PSNR (dB)		CR	
	KCDS	DS	KCDS	DS
Sa4	32.43	32.41	46.69	46.67
Cl	31.88	30.57	48.32	48.29
GHM	32.49	31.87	42.88	41.98
Cardbal2	32.53	32.50	43.15	43.10

Table 10. Comparison of average 'PSNR', 'CR' for different multiwavelets in 'Football' video (84 Frames)

5.1.5 'Trevor' video

Here "Cardbal2" performs better in terms of average 'PSNR' and "Cl" in terms of compression ratio. But overall "Sa4" performs better. In all the cases 'KCDS' performs marginally better than DS.

Wavelet	Average PSNR (dB)	CR
Haar	34.8	70.2
Db4	35.33	68.48
La8	35.53	68.17

Table 11. Comparison of average 'PSNR', 'CR' for different Wavelets in 'Trevor' video (84 Frames) using 'KCDS'

Multiwavelet	Average PSNR(dB)		CR	
	KCDS	DS	KCDS	DS
Sa4	36.46	36.44	77.02	75.39
Cl	36.08	36.04	78.61	76.71
GHM	36.58	36.55	69.36	68.11
Cardbal2	36.61	36.58	68.96	67.74

Table 12. Comparison of average 'PSNR', 'CR' for different multiwavelets in 'Trevor' video (84 Frames)

5.1.6 'Miss America' video

Here "Cardbal2" performs better in terms of average 'PSNR' and "Sa4" in terms of compression ratio.

Wavelet	Average PSNR (dB)	CR
Haar	39.14	67.82
Db4	39.65	67.53
La8	39.77	67.51

Table 13. Comparison of average PSNR, CR for different Wavelets in 'Miss America' video (84 Frames) using 'KCDS'

Multiwavelet	Average PSNR(dB)		CR	
	KCDS	DS	KCDS	DS
Sa4	38.81	37.44	76.37	75.39
Cl	38.75	37.45	75.21	75.11
GHM	38.36	37.54	70.02	69.01
Cardbal2	39.37	37.62	67.31	66.32

Table 14. Comparison of average 'PSNR', CR for different multiwavelets in a 'Miss America' video (84 Frames)

Video	Wavelet/ Multiwavelet	Average PSNR (dB) for a 'I' rate of			
		0.6	0.8	0.9	1
Miss America	Sa4	35.78	37.96	38.59	39.37
	Cl	35.69	37.88	38.49	39.37
	La8	36.56	38.49	39.44	39.83
Trevor	Sa4	33.18	35.72	36.67	37.39
	Cl	32.88	35.36	36.29	37.1
	La8	33.21	36.31	37.09	37.65

Table 15. Average PSNR values for different 'I' rates with a constant 'P' rate of 0.05 bpp; 96 frames

Video	Wavelet/ Multiwavelet	CR (for a 'I' rate of)			
		0.6	0.8	0.9	1
Miss America	Sa4	96.04	83.01	77.41	71.53
	Cl	96.74	83.02	77.39	71.68
	La8	85.74	73.86	68.24	63.76
Trevor	Sa4	101.71	87.66	80.92	74.84
	Cl	102.35	89.13	82.38	75.98
	La8	91.02	78.35	72.55	67.35

Table 16. CR values for different 'I' rates with a constant 'P' rate of 0.05 bpp; 96 frames

The results available in Tables 15 and 16 show the variation of I rate with constant 'P' rate, for two different videos 'Miss America' (slow motion) and 'Trevor' (Fast and Random motion). Irrespective of the videos, the PSNR values show an improvement as 'I' rate increases, with the reduction of compression ratio. The Compression ratio (roughly 5 to 10) is increased in the case of multiwavelets compared to wavelets, irrespective of the videos.

Video	Wavelet/ Multiwavelet	Average PSNR (For a 'P' rate of)			
		0.01	0.05	0.07	0.1
Miss America	Sa4	38.33	38.59	38.7	38.93
	Cl	38.22	38.49	38.62	38.86
	La8	39.21	39.44	39.6	39.79
Trevor	Sa4	36.4	36.67	36.77	36.96
	Cl	36.04	36.29	36.4	36.57
	La8	36.81	37.08	37.24	37.46

Table 17. Average PSNR values for the variation of 'P' rate with a constant 'I' rate of 0.9 bpp; 96 frames

The results available in tables 17 and 18 show the variation of 'P' rate with constant 'I' rate, for two different videos 'Miss America' (slow motion) and 'Trevor'(Fast and Random motion). The PSNR is increased with the increase in P rate with a little variation, at the same time compression ratio is increased in a larger way.

Video	Wavelet/ Multiwavelet	Compression Ratio (for a 'P' rate of)			
		0.01	0.05	0.07	0.1
Miss America	Sa4	81.42	77.4	74.43	69.81
	Cl	81.23	77.39	74.32	69.59
	La8	71.28	68.24	65.93	60.78
Trevor	Sa4	86.32	80.92	77.48	71.93
	Cl	87.52	82.38	79.02	73.38
	La8	76.49	72.54	69.71	65.39

Table 18. 'CR' values for the variation of 'P' rate with a constant 'I' rate of 0.9 bpp; 96 frames

5.2 'SPECK' and 'Novel scheme' results
5.2.1 'SPECK' results

From the above tables it is evident that "Sa4" multiwavelet performs better. Hence the following results are achieved with "Sa4" as the reference. KCDS is used as a prediction technique. From the results available in Table 19, 'SPECK' performs well for all the videos with less compression ratio compared to 'SPIHT' results shown in the previous section. On comparing the results available in table 20, SPECK performs better than SPIHT for all the videos at low bit rate (0.4 bpp) whereas SPIHT performs better than SPECK at a bit rate of 1.0 bpp.

Videos	Average PSNR (dB)	CR
Claire	40.07	54.48
Trevor	34.79	53.95
Foreman	36.44	53.20
Miss America	39.49	52.79

Table 19. Performance of 'SPECK' for different videos with 'I' rate of 0.9bpp and 'P' rate of 0.07bpp; 84 frames

Videos	Average PSNR for SPECK	Average PSNR for SPIHT
'I' rate=1bpp and 'p' rate=0.01bpp		
Claire	40.56	41.1
Trevor	34.8	36.99
Miss America	41.04	41.29
Foreman	38.67	38.3
Dancer	38.49	44.47
'I' rate=1bpp and 'p' rate=0.01bpp		
Claire	36.13	30.07
Trevor	31.48	26.53
Miss America	36.64	32.03
Foreman	34.54	27.54
Dancer	36.82	29.6

Table 20. Comparison between 'SPIHT' and 'SPECK' for different 'I' rates

5.2.2 'Novel scheme' results

The results of the 'Novel scheme' explained previously are available in table 21. The multiwavelet chosen is "Sa4". It is shown that the novel scheme performs well for all the videos both in terms of 'PSNR' and 'CR'.

Videos	Average PSNR (dB)	CR
Claire	39.67	75.79
Trevor	35.32	72.67
Foreman	36.11	68.82
Miss America	38.72	71.22

Table 21. Performance of 'Novel scheme' for different videos with 'I' rate of 0.9bpp 'P' rate of 0.07bpp; 84 frames

5.3 Summary of results

5.3.1 Comparison between 'DS' and 'KCDS'

As mentioned previously "Sa4" multiwavelet performs well, and all the comparisons are with respect to "Sa4" alone. From the results available in table 22, 'KCDS' performs better than 'DS' both in terms of Average PSNR and compression ratio.

Videos	Average PSNR		CR	
	KCDS	DS	KCDS	DS
Claire	38.99	38.98	81.61	78.95
Trevor	36.46	36.44	77.02	75.39
Foreman	35.87	35.87	73.39	69.14
Dancer	37.82	37.82	56.27	55.67

Table 22. Comparison between 'DS' and 'KCDS using 'SPIHT' for different videos with 'I' rate of 0.9bpp; 'P' rate of 0.05bpp; 84 frames

Videos	Average PSNR(dB)		Compression Ratio		Execution time (Secs)	
	KCDS	DS	KCDS	DS	KCDS	DS
Claire	38.84	38.81	79.07	76.45	189	201
Foreman	35.39	35.39	71.24	67.17	200	211
Trevor	33.53	33.54	75.34	74.14	194	202
Dancer	37.52	37.59	56.27	55.52	2796	2892
Football	32.24	31.62	46.72	49.74	3640	3365

Table 23. Comparison between 'DS' and 'KCDS' in 'Novel scheme' for different videos with 'I' rate of 0.8bpp; 'P' rate of 0.08bpp; 84 frames

From the results shown in table 23, it is completely evident that for all the videos 'KCDS' and 'DS' performs equally in terms of PSNR with 'KCDS' resulting in higher compression ratio. For the same PSNR, 'KCDS' is faster than 'DS'. In Football video 'KCDS' produces better PSNR and hence it takes more time than 'DS'.

Videos	Average PSNR (dB)		CR	
	Sa4	La8	Sa4	La8
Claire	38.99	39.88	81.61	79.5
Trevor	36.46	36.94	77.02	69.4
Foreman	35.87	36.52	73.39	66.86
Dancer	37.82	38.27	56.27	51.36

Table 24. Comparison between wavelet and multiwavelet using 'SPIHT' with 'P' rate of 0.05bpp; 'I' rate of 0.9bpp; 84 frames (KCDS)

Videos	Average PSNR (dB) for SPECK; I-rate:0.8bpp; P-rate:0.08bpp		Average PSNR (dB) for Novel Scheme I-rate:0.8bpp; P-rate:0.08bpp	
	La8	Sa4	La8	Sa4
Claire	37.42	39.95	37.95	38.84
Foreman	32.54	36.18	33.19	35.39
Trevor	29.07	33.34	31.98	33.53
Dancer	34.39	37.22	36.33	37.52
Football	31.85	32.76	31.67	32.24
	CR for SPECK I-rate:0.8bpp; P-rate:0.08bpp		CR for Novel Scheme; I-rate:0.8bpp; P-rate:0.08bpp	
	La8	Sa4	La8	Sa4
Claire	57.29	57.41	73.99	79.07
Foreman	56.72	56.67	67.32	71.24
Trevor	57.53	57.55	71.53	75.34
Dancer	48.45	48.84	54.09	56.27
Football	43.34	43.38	44.63	46.72
	Execution time(Secs) for SPECK I-rate:0.8bpp; P-rate:0.08bpp		Execution time(Secs) for Novel Scheme I-rate:0.8bpp; P-rate:0.08bpp	
	La8	Sa4	La8	Sa4
Claire	441	**185**	443	**189**
Foreman	444	**198**	456	**200**
Trevor	448	**198**	453	**194**
Dancer	3314	**2332**	3838	**2796**
Football	3672	**2735**	4743	**3640**

Table 25. Comparison of wavelet and multiwavelet using 'SPECK' and 'Novel scheme' with respect to average PSNR,CR and execution time; 84 frames

5.3.2 Comparison between wavelet and multiwavelet
The performance of wavelets and multiwavelets using "SPIHT", for different videos are displayed in table 24. Here, 'La8' performs better for all videos in terms of average PSNR

and 'Sa4' in terms of compression ratio. Hence the conclusion is that irrespective of the videos selected, multiwavelet gives good Compression ratio with nearing average PSNR as that of wavelets.

5.3.3 Comparison between wavelet and multiwavelet in 'SPECK' and 'Novel scheme'
From the results available in table 25, multiwavelet performs better than wavelets in both 'SPECK' and 'Novel scheme' for all the videos in terms of PSNR, CR, and Execution time.

5.3.4 Comparison between 'SPIHT', 'SPECK' and 'Novel scheme'
The results available in table 26, are taken with I rate of 0.8 and 'P' rate of 0.08. The first 84 frames are considered for all the videos. In general 'SPECK' performs better in terms of average PSNR and execution time but with poor compression ratio for all the videos. Novel scheme is found to be a close competitor with better compression ratio. 'SPIHT' yields high compression ratio but it is very slow. Novel scheme matches 'SPIHT' closely and it is also faster than 'SPIHT'. In overall comparison, 'Novel Scheme' performs better than 'SPIHT' and 'SPECK'.

Videos	Average PSNR (dB) for SPIHT	Average PSNR (dB) for SPECK	Average PSNR (dB) for Novel Scheme
Claire	37.85	39.95	38.84
Foreman	34.68	36.18	35.39
Trevor	34.12	33.34	33.53
Dancer	37.44	37.22	37.52
Football	31.85	32.76	32.24
	CR for SPIHT	CR for SPECK	CR for Novel Scheme
Claire	85.41	57.41	79.07
Foreman	76.26	56.67	71.24
Trevor	79.83	57.55	75.34
Dancer	59.62	48.84	56.27
Football	49.36	43.38	46.72
Videos	Execution time (Secs) for SPIHT	Execution time (Secs) for SPECK	Execution time (Secs) for Novel Scheme
Claire	205	185	189
Foreman	211	198	200
Trevor	208	198	194
Dancer	3162	2332	2796
Football	4128	2735	3640

Table 26. Comparison of 'SPIHT', 'SPECK' and 'Novel Scheme' for different videos based on average PSNR,CR and execution time; 84 frames

5.4 Reconstructed frames illustrating the comparison of 'SPIHT', 'SPECK' and 'Novel scheme'

The Figures 6(a)-(c) show the reconstructed frames (1, 9 and 13) for 'Miss America' using 'SPIHT'. The Figures 7(a)-(c) show the reconstructed frames (1, 9 and 13) for 'Miss America' using 'SPECK' and Figures 8 (a)-(c) show the reconstructed frames (1, 9 and 13) for the 'Novel Scheme'.


(a)   (b)   (c)
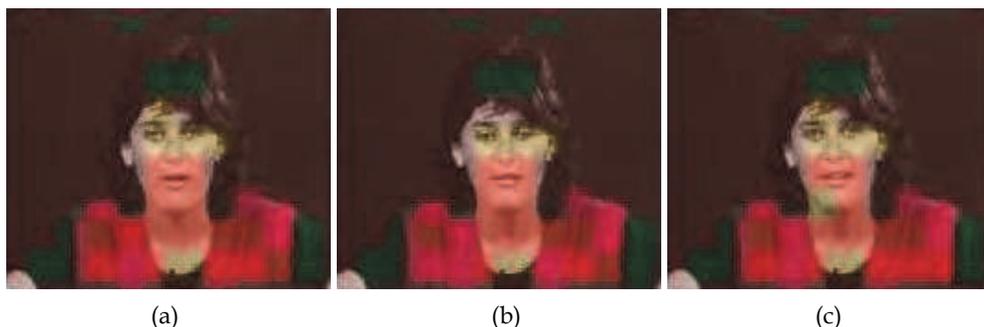
Fig. 6. Reconstructed frames in 'Miss America' using 'SPIHT' at 'I' rate =0.4bpp and 'P' rate of 0.04bpp (a) 1st frame (b) 9th frame (c) 13th frame

(a)   (b)   (c)

Fig. 7. Reconstructed frames in 'Miss America' using 'SPECK' at 'I' rate =0.4bpp and 'P' rate of 0.04bpp (a) 1st frame (b) 9th frame (c) 13th frame

(a)   (b)   (c)

Fig. 8. Reconstructed frames in 'Miss America' using 'Novel Scheme' at 'I' rate =0.4 bpp and 'P' rate of 0.04 bpp (a) 1st frame (b) 9th frame (c) 13th frame

6. Conclusion

The above results lead to the following conclusions based on block matching Algorithms, Transforms, and quantization schemes,as listed below. Based on the block matching algorithm for motion estimation, kite cross diamond search (KCDS) based video compression is faster and gives better quality compared to diamond search (DS).The numerical results elucidate the above fact. The video compression based on wavelets is better for high bit rates (above 0.8 bpp) in terms of average PSNR but it is slow and also results in less compression. But at low bit rate, Multiwavelet performs extremely better than wavelets in terms of average PSNR, compression ratio, and speed. Based on quantization scheme SPIHT based video compression is good for high bit rates but fails for low bit rates where SPECK performs well but with low compression ratio. The proposed novel scheme performs well both at low and high bit rates. Addressing individual multiwavelets, the 'Sa4' and 'Cl' multifilters tend to perform better for all type of videos. Since the Novel scheme employs both SPIHT and SPECK quantization schemes, the merits of both quantization schemes are added to give very good results in terms of PSNR, CR, execution time, and thus, it is found to be a close competitor between the two quantization schemes taken individually. Hence, multiwavelet based coder will give efficient storage space because of higher amount of compression ratio. The lower value in PSNR at high bit rates can be improved by the introduction of better prediction schemes that exploits the statistical nature of every video.

7. Acknowledgment

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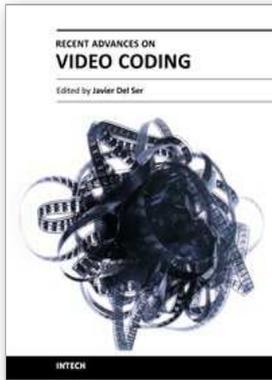
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Edited by Dr. Javier Del Ser Lorente

This book is intended to attract the attention of practitioners and researchers from industry and academia interested in challenging paradigms of multimedia video coding, with an emphasis on recent technical developments, cross-disciplinary tools and implementations. Given its instructional purpose, the book also overviews recently published video coding standards such as H.264/AVC and SVC from a simulational standpoint. Novel rate control schemes and cross-disciplinary tools for the optimization of diverse aspects related to video coding are also addressed in detail, along with implementation architectures specially tailored for video processing and encoding. The book concludes by exposing new advances in semantic video coding. In summary: this book serves as a technically sounding start point for early-stage researchers and developers willing to join leading-edge research on video coding, processing and multimedia transmission.

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