International Journal of Computer Sciences and Engineering Systems
Vol. 12 No.2 (December, 2018)

Hierarchical Based Lossless Intra Coding For H.264/MPEG -4 AVC

N. Krishnan[1], R. K. Selva Kumar[2], P. Vijaya Lakshmi[3] & K. Sankara Subramanian[4]

[1]Senior Member, IEEE, M. S. University, Tirunelveli, Tamil Nadu, India
Email: krishnan@computer.org
[2]Member in IEEE, Kamaraj College of Engineering. and Technology, S. P. G. C. Nagar, Virdhunagar, Tamil Nadu, India
Email: rkselvam@rediffmail.com
[3]Member in IEEE, vijikcet@gmail.com, Kamaraj College of Engineering. and Technology
S. P. G. C. Nagar, Virdhunagar, Tamil Nadu, India
[4]Scientist 'E', Electronics Test & Development Center, Ministry of Communications & Information Technology
Thiruvanmiyur, Chennai-600 041

Manuscript received August 25, 2017, Manuscript revised January 30, 2018

Abstract: *A new hierarchical based lossless intra coding technique fixes the source block and employs sample wise DPCM (Differential pulse code modulation) is presented as an enhancement of H.264/MPEG-4 AVC standard. The current video standard H.264/AVC follows a block design, uses nine prediction modes to leverage the compression ratio. I macro blocks are predicted using Intra prediction from the decoded samples in the current slice. The prediction is formed either for the complete macro block or for each 4x4 block of luma samples in the macro block. The Intra prediction of video frames using 4x4 block luma samples , for every macro block (16x16), one 4x4 block is considered as source block and from that other micro blocks are predicted using nine directional modes. In this paper, we have worked out a technique for Intra coding of video frame by fixing the source block always in the top left corner in the macro block in contrast to a random choice, which enhances the overall performance of the system. From the experiments, it shows that the new hierarchical based lossless intra coding technique improves the compression ratio by 21.04 % more over the current standard of H.264/AVC and 9 % more over modified and state art of technologies.*

Keywords: *H.264 MPEG-4/AVC Standard, Inter Pixel Redundancy, DPCM, Hierarchical Coding, Entropy coding*

1. INTRODUCTION

H.264/AVC adopts a hierarchical coding pattern [1]-[9]. Each frame is divided into 16x16 macro blocks of one Luma array and two Chroma arrays. Every macro block is further partitioned into 8x8, 4x4 micro blocks. By using various techniques, every macro/ micro block is predicted and the respective residual matrix, is encoded either lossy or lossless techniques. The current video standard not using transform coding and quantization process for lossless applications [5]. It employs block prediction and entropy coding to achieve lossless intra coding. In original H.264 standard, used pulse code modulation (PCM) was employed that permitted samples of macro blocks to be coded lossless with little significance to compression ratio. The moving images compression standard H.264/MPEG-4 AVC was developed by ITU-T and ISO/IEC have made the compression ratio to such an extent that the video content can be coded so effectively to suit many lossy applications [4] as compared to the earlier standards either with same or better image performance H.263, H.262/MPEG part 2. To improve the coding efficiency, block prediction is replaced by sample wise DPCM. The draw back of the system is that it demands the construction of the entire block in one shot. Image applications where high fidelity is a prime concern, depends on the lesser number of samples and to perform prediction using sample by sample basis having high cohesion [5] H.264/AVC was aimed for video applications having finite tolerance for losses. However, FRExt design (Fidelity Range Extension) came with the support for lossless applications [8].

1.1 H.264 /AVC Structure

Many standards of H.264 contain different configurations of capabilities based in "profiles" and "levels". A profile is usually a set of algorithmic features, and a level is usually a degree of capability either resolution or speed of decoding. H.264/AVC has three profiles, Baseline profile (lower capability plus error resilience, e.g., videoconferencing, mobile video), Main profile (high compression quality, e.g.,broadcast) and Extended profile(added features)for efficient streaming A coded picture consists of a number of macro blocks, each containing 16x16 luma samples and associated chroma samples (8x8 Cb and 8x8 Cr samples in the current standard). Within each picture, macro blocks are arranged in slices, where a slice is a set of macro blocks in raster scan order. An I slice contain only I macro block types and a P slice may contain P and I macro block types and a B slice may contain B and I macro block types. Each video picture is represented by 3 arrays of samples; the first array is luma array which holds the brightness content of each sample in the image. The second and third arrays are chroma arrays, holding the color difference of samples. To encode the video picture, different sampling structures are used depending on the quality demanded by the end applications. The consumer quality application video uses chroma array which has half the width and half the height of luma array having a structure of 4:2:0. The professional quality application video uses the chroma array having half the width and same height of luma array of size 4:2:2. There are a number of techniques available for predicting each block of samples which is decided by the encoder. The residual transform array is computed by computing the difference between the actual source block picture value and the predicted block. In lossy compression techniques use a block transform and employs quantization and then the transform coefficients are entropy coded and in lossless compression techniques the residuals are entropy coded. The original standard of video compression used the Pulse Code Modulation (PCM), employed macro block coding mode which offered a in efficient compression. The earlier video coding standards MPEG-4, MPEG-2, H.263, and H.262 offered lossy compression of video sequence. The Advanced Video Coding (AVC) which was developed jointly by ITU-T and ISO/IEC offered better performance with lossy encoding capability than its earlier counter parts. The fidelity range extensions standard brought more modifications in the architecture, offered lossless coding and improved the compression ratio greatly.

H.264 uses two different types of block based prediction. The first one is intra prediction, correlation of spatial resolution of the adjacent samples values in the same picture is considered for block prediction, and in the second method the correlation of spatial resolution of sample values in the previously coded picture is considered for block prediction. The video compression standard H.264/AVC employs block based coding style. Here, each picture is segmented into macro blocks of size 16x16luma samples and MxN arrays of chroma samples, where M is 16 for 4:4:4is 8 for 4:2:2, and 4:2:0 and N is16 for 4:4:4 and 4:2:2and is 8 for 4:2:0. Each macro block is then segmented in to micro block of size 4x4. H.264 supports many spatial prediction of block size 16x16, 8x8, 4x4 for luma components and 16x16 (for 4:4:4 video), 16x8 (4:2:2 video), 8x8 (for 4:2:0 video) for chroma components. The prediction of complete block is carried out by the encoder which uses the appropriate directional spatial prediction mode from the Table 1 and uses the values of samples in the adjacent block. Intra prediction of 16x16 block size uses one of four prediction modes, horizontal, vertical, DC and plane modes for luma and chroma components.

Table 1
4 x 4 Luma Prediction Modes

Mode	*Directions*
0	Vertical Extrapolation
1	Horizontal extrapolation
2	DC
3	Diagonal down left
4	Diagonal down right
5	Vertical right
6	Horizontal down
7	Vertical left
8	Horizontal up

Prediction block is created by extrapolating the values of the samples in the adjacent column towards right, is called horizontal prediction and in vertical prediction, Prediction block is obtained by extrapolating the values of the samples in the adjacent row downwards,. In DC prediction, Prediction of block is obtained by average of values of the samples in the adjacent column and row. And in plane prediction, block samples are predicted using mean, horizontal and vertical slope obtained from the adjacent row and column.

2. PROPOSED HIERARCHICAL PREDICTION

Image processing is often difficult because of the large amount of data used to represent an image. So, the Image compression algorithms aim to represent an image using fewer bits, without losing the ability to reconstruct the image. In this paper, we highlight the exclusion of redundant image data present in both Luma and Chromo components of a video frame of H.264/AVC. This new hierarchical based lossless intra coding method is functional for any 4x4, 8x8, and 16x16. The intra prediction is formed either for the complete macro block16x16 or for each 4x4 block of luma samples. In the current standard H.264, the Intra prediction of video frames using 4x4 block luma samples, for every macro block (16x16), one 4x4 block is considered as source block and using that other micro blocks are predicted using the directional modes. Instead of deciding the source block randomly anywhere in the macro block, fixing the source block always in the top left corner (ie: the first block) as shown in the Fig. 1, enhances the overall compression performance of the system. In this paper, we proposed a technique to fix the source block in the macro block, performed the sample wise DPCM and coded hierarchically using entropy coding, which has improved the compression ratio as compared to the Previous standards.

The intention of this paper is to improve the compression ratio and reduction in bit rate for lossless applications, and to optimize the design complexity and without bringing any

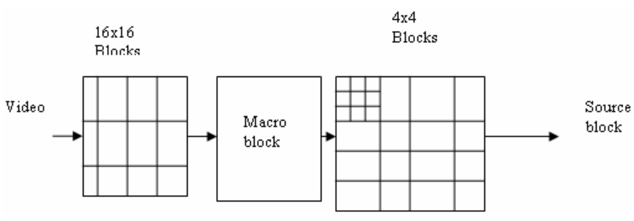

Figure 1: Image Partitioning

variation in the design of H.264/AVC standard. Major applications include still image compression, Messaging Services, Conversational Services and Entertainment Video and Satellite Applications etc. The architecture of proposed work is shown in Fig. 2 . For image of any size, the block based H.264 /AVC Intra coding, in a 4x4 block prediction, one column sample of the bordering block predicts the entire row samples of the prediction block. But, the sample wise DPCM makes better prediction and reduces a lot of inter pixel redundancy, which is a new amendment to be adopted in H.264 standard. The new prediction process launched here always places the first micro block as the source block and prediction proceeds in the left to right and top to bottom fashion using sample wise DPCM. The mathematical model of DPCM used for spatial prediction is shown in the Fig. 3. The concept of predictive techniques is to remove mutual redundancy between successive samples and encode only the new information. Consider a sampled sequence *u (m)*, which has been coded up to m = *n-1*. Let $u'(n-1), u'(n-2), \ldots$ be the reproduced decoded sequence. At *m* = *n*, when *u (n)* arrives, a quantity,

$\bar{u}^{\cdot}(n)$ an estimate of *u*(*n*) is predicted from the decoded symbols, that is

$$\bar{u}(n) = \Psi(u^{\cdot}(n-1), u^{\cdot}(n-2), \ldots) \tag{1}$$

Where ¨ *( )* denotes the prediction rule. To code the prediction error,

$$e(n) \underline{\underline{\Delta}} u(n) - \bar{u}^{\cdot}(n) \tag{2}$$

if $e^{\cdot}(n)$ is the quantized value of $e(n)$, then produced value of $u(n)$ is taken as

$$u^{\cdot}(n) = \bar{u}^{\cdot}(n) + e^{\cdot}(n) \tag{3}$$

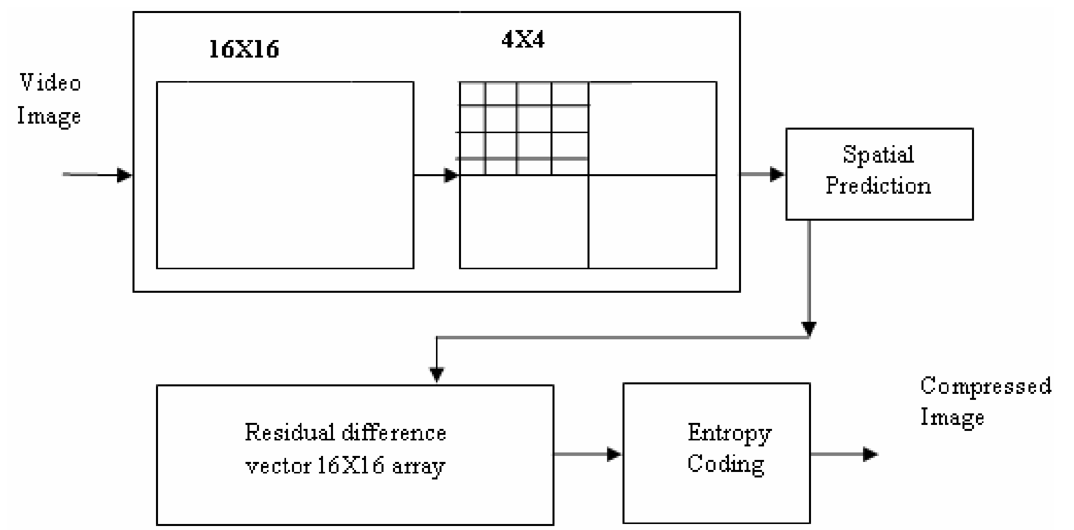

Figure 2: Architecture of Proposed Work

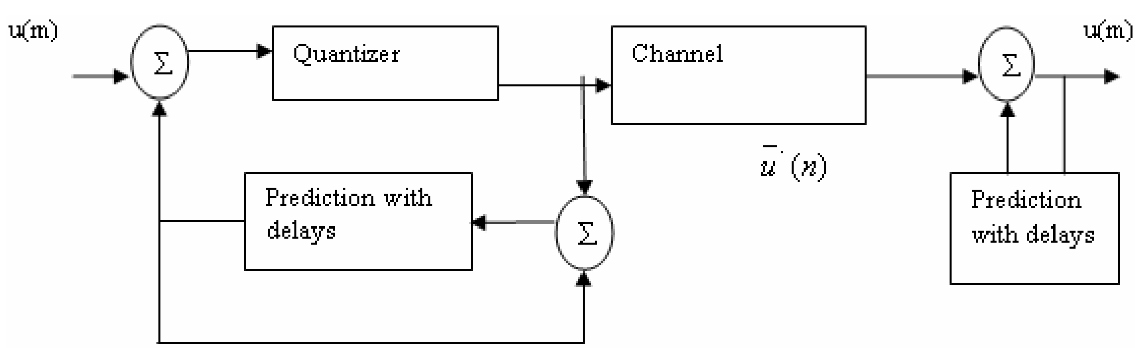

Figure 3: Mathematical Model of DPCM.

In this paper, we highlight the exclusion of inter pixel redundant data present in both luma and chromo components of a video frame by hierarchical coding. The

hierarchical based Intra lossless coding method is functional for any 4x4, 8x8, and 16x16 block size.

3. INTRA PREDICTION

In Intra mode a prediction block P is formed based on previously encoded and reconstructed blocks and is subtracted from the current block prior to encoding. For the luma samples, P is formed for each 4x4 block or for a 16x16 block macro block. There are a total of nine optional prediction modes for each 4x4 luma block, four modes for a 16x16 luma block and four modes for the chroma components.

3.1 Vertical and Horizontal Prediction

The vertical prediction is shown in Figure 4. Here, in the hierarchical coding, spatial prediction of 4x4 micro blocks from top to bottom from the source follows the mode “0”for the vertical prediction. All the samples in the predicted block are deduced using mode ‘0’. In the figure 3.2, both columns 1 and 2 are predicted using mode ‘0’ and residuals transform matrix is calculated. Employing sample based DPCM does not introduce any changes in the existing style of H.264 / AVC, by slightly modifying the algorithm design, we can optimize bit rate more considerably.

S Block

P Block

R1 = S13-P1
R5 = p5- p1
R9 = p9-p5
R13 = p13-p9

P1	P2	P3	P4
P5	P6	P7	P8
P9	P10	P11	P12
P13	P14	P15	P16

R2 = S14-P2
R5 = p6- p2
R9 = p10-p6
R14 = p14-p6

Residual Block

R1	**R2**	R3	R4
R5	**R6**	R7	R8
R9	**R10**	R11	R12
R13	**R14**	R15	R16

Figure 4: Vertical Prediction

Fig. 5, shows horizontal prediction. The prediction of 4x4 micro block from left to right from the source follows directional the mode “1”. All the samples in the predicted block are derived using the same mode. After predicting all micro blocks, residual transform are entropy coded. The encoder sends the source block first along with the residuals of other 15 micro blocks. Then the decoder decodes the residuals and reconstructs the blocks one by one using the source block.

S Block

P Block

P1	P2	P3	P4
P5	P6	P7	P8
P9	P10	P11	P12
P13	P14	P15	P16

R1 = S4-p1
R2 = p2-p1
R3 = p3-p2
R4 = p4-p3

R5 = S8-p5
R6 = p6-p5
R7 = p7-p6
R8 = p8-p7

Residual Block

R1	**R2**	**R3**	**R4**
R5	**R6**	**R7**	**R8**
R9	R10	R11	R12
R13	R14	R15	R16

Figure 5: Horizontal Prediction

4. ANALYSIS OF EXPERIMENTAL RESULTS

Here, a hierarchical lossless intra coding is demonstrated in the perspective of block based H.264 /AVC and the improved lossless intra coding for H.264/AVC[5]. The experiments were conducted on many YUV 4:4:4 and 4:2:2 with QCIF (quadrature common intermediate format), having 100 frames of 30hz frequencies. For the entropy coding, the Huffman algorithm is used. Due to the limitation in the computing power of our computers and non availability of high resolution video frames (image size of 91832400 bits and 364953600 bits), all the experiments are conducted using video image size of 393216 bits. To compare the performance of the new hierarchical lossless method, H.264/ AVC and improved Lossless Intra coding For H.264/AVC [5] are tested using YUV 4:4:4 and 4:2:0 and they are compared. The method is tested to 16x 16, 8x8 and 4x 4 luma blocks, and 8x 8 chromo blocks. The new method in Table 2 used the sample wise horizontal/vertical prediction for 4x4 luma blocks and the sample wise horizontal/vertical predictions and DC and plane prediction modes of the H.264/ AVC lossless intra coding method for the 16 16 luma block and 16x16 chroma block. The new hierarchical method has achieved an average compression ratio of 2.145:1 for various sequences, while the H.264/AVC intra lossless coding standard in Table 2 achieved an average compression ratio of only 1.69:1, also the improved lossless Intra coding for H.264/AVC [5] had achieved a ratio of 1.91:1 (Method 1) and 1.925:1 (Method 2). The new hierarchical method is also tested with video images of size 2027520 bits and the results are tabulated in Table 3.

The result shows that for a larger image size, both the compression ratio and the bit rate increases, it certainly performs still better for the image size, of 91832400 bits and 364953600 bits. The new hierarchical method, compared with JPEG-LS and Motion JPEG2000 [10], [11] state-of-the-art lossless coding techniques, performs better in terms of compression ratio and bit rate. Experimental results state that the new hierarchical method shows good improvement over the other methods without introducing additional capabilities both in the encoder and decoder.

The table confirms that the new hierarchical coding of source block really have an impact in the overall performance of system.

Table 2
Comparison of Compression Ratio of H.264Lossless Intra coding, Improved Lossless H.264 - Method1, Method2 [5] JPEG-LS, M JP2k, Hierarchical (New Method)

Image	*Original Image Size (bits)*	*Method*	*Total Bits*	*Comp-ression Ratio*	*Saving in Bits (%)*
News	91238400	H.264/AVC	49062832	1.859	0
		Improved H.264(1)	42004648	2.172	14.38
		ImprovedH.264(2)	41901888	2.177	14.59
		JPEG-LS	38493000	2.370	21.54
		MJP2k	44094160	2.069	10.12
	393216	Hierarchical (New)	168501	2.380	21.89
Container	91238400	H.264/AVC	47836576	1.907	0
		Improved H.264(1)	42222416	2.160	11.73
		ImprovedH.264(2)	42194984	2.162	11.79
		JPEG-LS	40503200	2.252	15.33
		MJP2k	44423256	2.053	7.13
	393216	Hierarchical (New)	161007	2.442	21.9
Foreman	91238400	H.264/AVC	50418312	1.809	0
		Improved H.264(1)	46101624	1.979	8.56
		ImprovedH.264(2)	45233104	2.017	10.284
		JPEG-LS	43903664	2.078	12.921
		MJP2k	48250840	1.890	4.299
	393216	Hierarchical (New)	165870	2.376	23.86
Silent	91238400	H.264/AVC	54273064	1.681	0
		Improved H.264(1)	48020632	1.899	11.52
		ImprovedH.264(2)	47735224	1.911	12.04
		JPEG-LS	44656200	2.043	17.71
		MJP2k	47552944	1.918	12.38
	393216	Hierarchical (New)	188770	2.083	19.29
Paris	64953600	H.264/AVC	224766912	1.623	0
		Improved H.264(1)	194434228	1.877	13.49
		ImprovedH.264(2)	193983792	1.881	13.69
		JPEG-LS	179265368	2.035	20.24
		MJP2k	196161712	1.860	12.72
	393216	Hierarchical (New)	233845	1.861	12.78
Mobile	364953600	H.264/AVC	285423632	1.278	0
		Improved H.264(1)	258162856	1.413	9.551
		ImprovedH.264(2)	257077240	1.419	9.931
		JPEG-LS	231103384	1.579	19.03
		MJP2k	240223216	1.519	15.83
	393216	Hierarchical (New)	158900	1.74	26.55
Average		H.264/AVC		1.69	0
		Improved H.264(1)		1.91	11.59
		ImprovedH.264(2)		1.925	12.03
		JPEG-LS		2.05	16.07
		MJP2k		1.85	10.48
		Hierarchical(New)		2.145	21.04

Table 3
Experimental Results for Image Size 2027520 bits

Image size 2027520 bits	*Hierarchical (New method) Compression*
Frame 1	3.20
Frame 2	2.896
Frame 3	2.964
Frame 4	2.694
Frame 5	2.687
Frame 6	2.549
Frame 7	2.282

5. CONCLUSION

The new hierarchical based lossless Intra coding method employing sample wise DPCM uses only two prediction modes for predicting each 4 x 4 block of luma samples in the macro block. The experimental result shows that the new method has a compression capability of 21.04% more over the current standard H.264/AVC and 9% more over modified methods [5] and state of art technologies. Also, the new method does not introduce major changes in the design of encoding and decoding process and so the new method can be considered for implementation in the new standards of H.264/AVC. This work can be enhanced by adaptively selecting the source block and applying pixel based prediction instead of block based prediction.

REFERENCES

[1] A. Luthra, G. J. Sullivan, and T. Wiegand, "Introduction to the Special Issue on the H.264/AVC Video Coding Standard", *IEEE, Trans. Circuits Systems. Video Technology*. **13**(7), 557–559, 2003.

[2] T. Wiegand, G. J. Sullivan, G. Bjøntegaard, and A. Luthra, "Overview of the H.264/AVC Video Coding Standard", *IEEE Trans. Circuits Syst. Video Technol.*, **13**(7), 560–576, 2003.

[3] G. J. Sullivan and T. Wiegand, "Video Compression from Concepts to the H.264/AVC Standard," *Proc. IEEE*, 1, 18–31, 2005.

[4] M. J. Weinberger, "The LOCO-I lossless Image Compression Algorithm Principles and Standardization into JPEG-LS," *IEEE Trans. Image Process.*, **9**(8), 1309–1324, 2000.

[5] Yung-Lyul Lee, Ki-Hun Han, and Gary J. Sullivan, *Fellow, IEEE*, Improved Lossless Intra coding for H.264 MPEG-4 AVC, IEEE Transactions on Image Processing, **15**(9), 2006.

[6] H. 264 and MPEG-4 Video Compression, E- Book, www.wiley.com, John Wiley sons Ltd, England, 2003. ISBN 0-470-84837-5.

[7] R. C. Gonzalez, R. E. Woods, *Digital Image Processing*, Prentice Hall, 2nd Ed 2002.

[8] Gary J. Sullivan, Pankaj Topiwala, and Ajay Luthra, The H.264/AVC Advanced Video Coding Standard: Overview and Introduction to the Fidelity Range Extensions, Presented at the SPIE Conference on Applications of Digital ImageProcessing XXVII,Special Session on Advances in the NewEmerging Standard: H.264/AVC,August, 2004.

[9] Thomas Wiegand, Gary J. Sullivan, Gisle Bjontegaard, and Ajay Luthra' Overview of the H.264 / AVC, Video Coding Standard, *IEEE Transaction on Circuits and Systems for Video Technology*, July 2003.

[10] M. J. Weinberger, "The LOCO-I lossless Image Compression Algorithm: Principles and Standardization into JPEG- LS," *IEEE Trans. Image Process.*, **9**(8), 1309–1324, 2000.

[11] Motion JPEG2000 Final Committee Draft, ISO/IEC JTC 1/SC29.