Adaptive Source pixel based Prediction for Lossless Intra Coding of H.264 MPEG-4 /AVC

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Abstract

A new prediction for lossless intra coding technique employs source pixel based prediction in contrast to source block based prediction is presented as an enhancement of H.264/MPEG-4 AVC(Advanced Video Coding) standard. Here, we have worked out technique, to select a significant source block in the macro block adaptively, identified a strong object pixel from that block based on perceptual consideration, which serves as a source pixel to predict the source block and other blocks in the macro block and finally the residuals are entropy coded. The significance of object pixels in the macro block and source block are considered here, to improve the performance of the system. However, the block approach of H.264/AVC is not altered for the transform encoding and decoding process. The experimental result shows that the new method has a compression capability of 28.42% more over the current standard H.264/AVC and 16 % more over modified methods and state of art technologies. This work is aimed to improve the coding efficiency and bit rate for lossless applications. Major applications include still image compression, messaging services, entertainment video and satellite applications etc.

Keywords

Visual Perception, Gradient operators, DPCM, Lossless compression, Intra coding, Entropy coding, H.264/AVC standard and its architecture

1. Introduction

H.264/AVC is a video compression standard. It employs a hierarchical coding pattern [1]-[7]. The current video standard H.264/AVC, is not applying transform coding and quantization process for lossless applications [8]. It employs block prediction and entropy coding to achieve lossless intra coding. The original H.264 standard, used pulse code modulation (PCM) that permitted samples of macro blocks to be coded using lossless method with little significance to compression ratio. The moving image compression standard H.264/MPEG-4 AVC which was developed by ITU-T and ISO/IEC has made the compression ratio to suit the lossy applications [4] as compared to the earlier standards H.263, H.262/MPEG part 2. 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 [6]. To enhance the coding effectiveness, block prediction is replaced by sample wise DPCM (Differential Pulse code modulation) [5],[9]. The draw back of the system is that it demands the construction of the entire block in one shot. The current standard of video compression employs 16 x 16, 8 x 8, and 4 x 4 block size for prediction of Luma and Chromo components. The encoder uses a multi directional mode for the construction of prediction block using the samples in the adjacent block.

1.1 H.264 /AVC Structure:

Many standards of H.264/AVC 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 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.

Table 1.1. 4x4 Luma prediction modes

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

2. Proposed Work

H.264 uses two different types of block based prediction. The first one is intra prediction, where the 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 1.1 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. 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, the 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.

In this paper, we highlight the exclusion of redundant visual data present in both Luma and Chromo components of a video frame of H.264/AVC. In intra prediction of 4x4 block of luma samples , for every macro block 16x16, one micro block 4x4 is coded as a source block . For an image of size 256x256, 256 source blocks are to be coded without prediction. In this paper, we propose a new source pixel based lossless prediction technique that demands only **256 pixels in the place of 256 source blocks**. Here, each macro block is examined to select a source block based on the frequency of object pixels in it. After identifying the source block adaptively, it is scanned for the **strongest object pixel**, which is labeled as "Source Pixel". This source pixel later predicts the source block and other micro blocks in the macro block. Major applications include still image compression, messaging services, entertainment video and satellite applications etc. The architecture of this work is shown in Figure 2.1

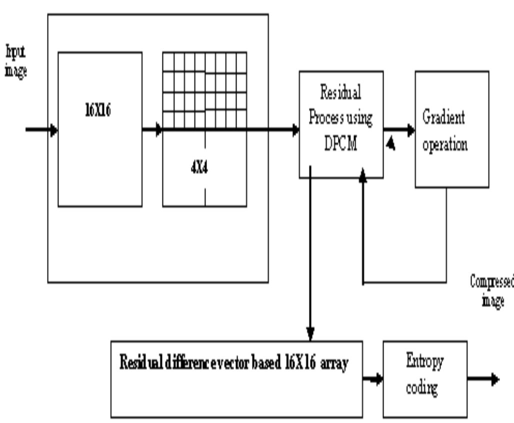

Figure 2.1. Proposed work

2.1 Algorithm for source pixel based prediction:

Step 1: Transform video image f(x y. t) and into YUV model.

I1 = imread('d:\paris .bmp');
Yuvim = rgb2ycbcr(s);

Step 2: Partition the image Y, U, V array into M (16x16) macro block and Mi(4x4) micro block

Step 3: Apply gradient operators for the macro block and select the source block adaptively

BW = edge(s,' Gradient Operator ');

Step 4: Identify a strong Source pixel from the selected source block.

[x,y] = detect(A)

Step 5: Predict the source block first using the source pixel

function [res,a1]=resformat(A)

Step 6: Predict the other micro blocks

Step 7: Entropy code the Residual transforms array
Huffencode=encode1(residual_diff_array,table(1 ,:),code)

Step 8: Output the compressed image

Step 9: At the other end, decode and reconstruct

The philosophy of predictive techniques is to remove inter pixel redundancy between successive pixels and to 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. The block diagram of DPCM is shown in the Figure 2.2.

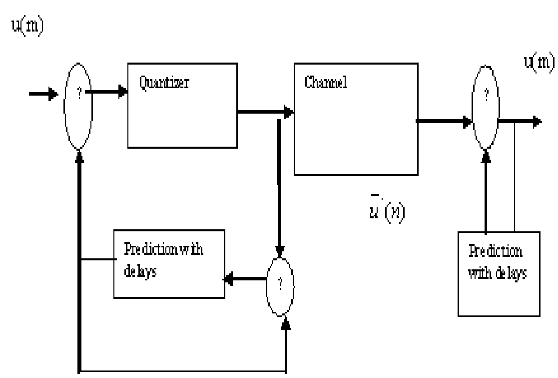

Figure 2.2. Block diagram of DPCM

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

$$\bar{u}(n) = \Psi(u^{\cdot}(n-1), u^{\cdot}(n-2), \ldots) \tag{2.1}$$

where,
$\Psi(.,.,\ldots)$denotes the prediction rule.

To code the prediction error,

$$e(n) \underline{\underline{\Delta}} u(n) - \bar{u}^{\cdot}(n) \tag{2.2}$$

if $e^{\cdot}(n)$ is the quantized value of a $e(n)$,

then produced value of $u(n)$ is taken

$$u^{\cdot}(n) = \bar{u}^{\cdot}(n) + e^{\cdot}(n) \quad (2.3)$$

The Gradient operators are applied over the macro block to investigate the frequency of object pictures present in it. The block diagram of gradient operator is shown in the Figure 2.3.

There is a pair of masks H_1 and H_2, which measure the gradient of the image u(m,n) in two orthogonal directions,

Defining the bidirectional gradients,

$$g_1(m,n) \underline{\Delta} \langle U,H_1\rangle_{(m,n)}, g_2(m,n) \underline{\Delta} \langle U,H_2\rangle_{m,n} \quad (2.4)$$

gradient vector magnitude and direction given by,

$$g(m,n) = \sqrt{g_1^2(m,n) + g_2^2(m,n)} \quad (2.5)$$

$$\Theta_g(m,n) = \tan^{-1}\frac{g_2(m,n)}{g_1(m,n)} \quad (2.6)$$

often the magnitude of gradient is calculated as

$$g(m,n) \stackrel{\Delta}{=} |g_{1(m,n)}| + |g_2(m,n)| \quad (2.7)$$

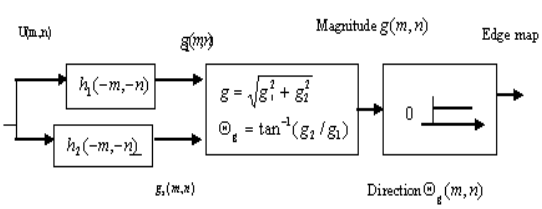

Figure 2.3. Block diagram of Gradient operators

2.2 Horizontal and Vertical Prediction

In H.264/AVC, intra mode of 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.

Here, the intra prediction of 4x4 block of luma samples, a **source block is identified adaptively** from the macro block. Then a strong object pixel is chosen from the source block to serve as a source block. Prediction is first carried out for the source block and subsequently for the other micro blocks using only two directional modes. The Figure-2.4, shows the horizontal prediction of the of the source block using S10 as the source pixel. The pixels S9, S11 and S12 are predicted using mode "1". Similarly, S2, S6 and S14 are predicted using the vertical prediction, mode "0" shown in the Figure 2.5. The other diagonal pixels (located at 45 and 22.5 degree) are predicted using either horizontal or vertical mode based on the SAE (Sum of absolute errors). Here, only **two modes mode "0" and mode "1"are used for prediction of all the pixels**. The same logic is completed for predicting the remaining blocks in that macro block and the residuals are entropy coded. The encoder first sends the 'S10' and its residuals, followed by the residuals for other micro blocks. The decoder at the other end decodes and reconstructs the source block using the source pixel, and then rebuilds the other 15 micro blocks from the respective residuals.

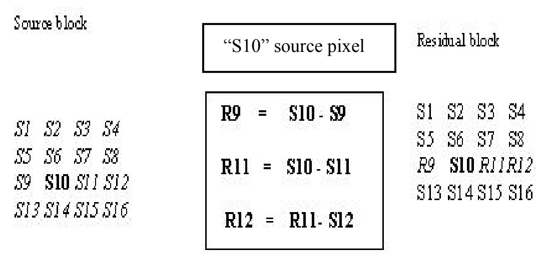

Figure 2.4. Horizontal Prediction of source block

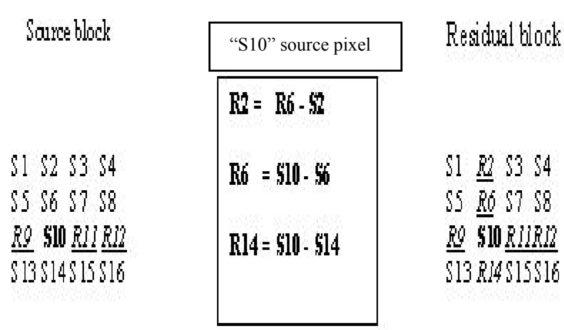

Figure 2.5. Vertical Prediction of source block

3. Entropy Coding

3.1 The Huffman Coding Algorithm

The algorithm gives the Huffman code book for any given set of probabilities. The block diagram of the Coder is shown in the Figure 3.1. Coding and decoding is done by look up values in a table. The code words have variable length and the information is to be transmitted over a constant-rate channel. The size of the code book is L and the longest code word can have as L bits. These parameters become prohibitively large as L increases.

1. Arrange the symbol probabilities p_1 in a decreasing order and consider them as leaf nodes of a tree.
2. While there is more than one node: Merge the two nodes with smallest probability to form a new node whose probability is the sum of the two merged nodes. Arbitrarily assign 1 and 0 to each pair of branches merging in to a node.
3. Read sequentially from the root node to the leaf node where the symbol is located.

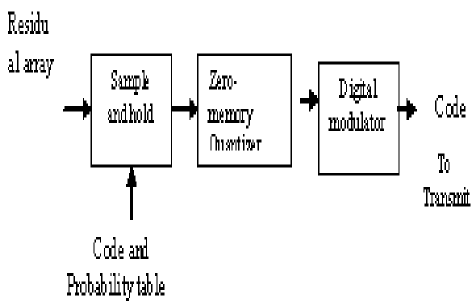

Figure 3.1. Block diagram of Huffman Coding

4. Analysis of Experimental Results

Here, the new adaptive source pixel based prediction for lossless intra coding is demonstrated in the perspective of block based H.264 /AVC and the improved lossless intra coding for H.264/AVC[7].The experiments were conducted on 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 limitations 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 source pixel based prediction of lossless method, H.264/AVC and improved Lossless Intra coding For H.264/AVC [7] using YUV 4:4:4 and 4:2:0 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 4.1 used only the sample

Table 4.1. Comparison of Compression ratio of H.264 Lossless Intra coding, Improved Lossless H.264 - Method1, 2[7], JPEG-LS, M JP2k, and (New method)

Image	Original Image Size(bits)	Method	Total Bits	Compress Ratio	Saving in bits (%)
News	91238400	H.264/AVC	49062832	1.859	0
	91238400	Improved H.264(1	42004648	2.172	14.38
	91238400	ImprovedH.264(2	41901888	2.177	14.59
	91238400	JPEG-LS	38493000	2.370	21.54
	91238400	MJP2k	44094160	2.069	10.12
	393216	(New Method)	148721	2.644	29.58
Container	91238400	H.264/AVC	47836576	1.907	0
	91238400	Improved H.264(1	42222416	2.160	11.73
	91238400	ImprovedH.264(2	42194984	2.162	11.79
	91238400	JPEG-LS	40503200	2.252	15.33
	91238400	MJP2k	44423256	2.053	7.13
	393216	(New Method)	155466	2.529	24.59
Foreman	91238400	H.264/AVC	50418312	1.809	0
	91238400	Improved H.264(1	46101624	1.979	8.56
	91238400	ImprovedH.264(2	45233104	2.017	10.284
	91238400	JPEG-LS	43903664	2.078	12.921
	91238400	MJP2k	48250840	1.890	4.299
	393216	(New Method)	150341	2.615	30.82
Silent	91238400	H.264/AVC	54273064	1.681	0
	91238400	Improved H.264(1	48020632	1.899	11.52
	91238400	ImprovedH.264(2	47735224	1.911	12.04
	91238400	JPEG-LS	44656200	2.043	17.71
	91238400	MJP2k	47552944	1.918	12.38
	393216	(New Method)	165477	2.376	29.25
Paris	364953600	H.264/AVC	224766912	1.623	0
	364953600	Improved H.264(1	194434228	1.877	13.49
	364953600	ImprovedH.264(2	193983792	1.881	13.69
	364953600	JPEG-LS	179265368	2.035	20.24
	364953600	MJP2k	19616171 8	1.860	12.72
	393216	(New)	225409	1.744	07.00
Mobile	364953600	H.264/AVC	285423632	1.278	0
	364953600	Improved H.264(1	258162856	1.413	9.551
	364953600	ImprovedH.264(2	257077240	1.419	9.931
	364953600	JPEG-LS	231103384	1.579	19.03
	364953600	MJP2k	240223216	1.519	15.83
	393216	(New Method)	155905	2.52	49.28
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
		(New Method)		2.404	28.42

wise horizontal/vertical (mode 0,1) prediction modes of the H.264/AVC lossless intra coding method for all pixels in 4x4 luma blocks and the sample wise horizontal/vertical predictions of the H.264/AVC lossless intra coding method for the 16x 16 luma block and 8x8 chroma block. The new adaptive source pixel based method has achieved an average **compression ratio of 2.4:1** and **savings bit rate of 28.42%** for various sequences, while the H.264/AVC intra lossless coding standard in the Table 4.1 achieved an average compression ratio of only 1.69:1 and also the improved lossless Intra coding for H.264/AVC [7] had achieved a compression ratio of 1.91:1 and savings bit rate of 11.59% (Method 1)[7] and a compression ratio of 1.925:1 and savings bit rate of 12.03% (Method 2)[7]. It would certainly perform better for the image size of 91832400 bits and 364953600 bits. The new method, is compared with JPEG-LS and Motion JPEG2000 [1], [2] state-of-the-art lossless coding techniques, the new method performs better in terms of compression ratio and savings in bit rate. Experimental results state that the new adaptive source pixel based method shows good improvement over the other methods without introducing additional complexities both in the encoder and decoder of H.264/AVC.

5. Conclusion

A new prediction for lossless intra coding technique employing source pixel based prediction uses only two prediction modes for predicting all pixel values in each of 4x4 block of luma samples in the macro block. The experimental result shows that the new method has a compression capability of 28.42% more over the current standard H.264/AVC and 16 % more over modified methods [7] and state of art technologies. Also, the new method does not introduce major changes in the design of encoding and decoding process. So, this new adaptive source pixel based prediction for lossless intra coding method can be considered for implementation in the new standards of H.264/AVC

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