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4x4 Luminance Intra Prediction Modes for H.264/AVC

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Abstract — Prediction technique adopted in H.264/AVC is an additional feature which controls the compression ratio, signaling bit rate for decoder. This paper illustrates the implementation of intra prediction for H.264/AVC standard. To implement intra prediction a 4x4_luminance sub block is considered and prediction modes are applied. The matlab based implementation of nine intra prediction modes at 4x4 luma sub block level are analyzed for Peak Signal to Noise Ratio (PSNR) and Sum of Absolute Difference error (SAD) at reconstructed frame and results are tabulated. It is found that from the results analysis, for N x N sized pictures mode 0, mode 2, mode 5, mode 8 gives better prediction gain with faster computations whereas for frames of M x N dimensions mode 1 and mode 8 can be used with moderate computational speed. But, when frames of larger dimension are chosen mode 0 and mode 8 gives the better performance with more computational time expense.

Keywords—Intra Prediction, quantization, transformation, Coder, Decoder, H.264/AVC, compression, signaling bit rate

I. INTRODUCTION

H.264/AVC is a very high compression standard (1) compared with other previous standards. This is because of efficient prediction methods adopted in this standard compared with other previous standards. Here, every macroblock data is predicted using previous coded macroblock data and a residual data of macroblock is created with very little data. A very good compression performance can be obtained when the coding of residual block is done due to the less number of bits utilization.H.264/AVC supports intra and inter prediction to give good compression of picture or video. In intra prediction the data of a macroblock with in current frame (I frame) will be predicted to form residual block where as in inter prediction the previously predicted macroblocks of motion compensated is used to form new current blocks (B-block/P-block). In inter prediction technique different macroblock sizes, multiple reference frames of forward or backward, direct or weighted prediction modes and filter may be applied to reduce artefacts occurs during compression makes the best compression performance. Basically there are three types of sources for macroblock predictions. Firstly, the I - macroblock (I_MB) used in intra prediction which is predicted from neighboring left and above existing predicted macroblock samples in current frame. Secondly P - block (P_MB) prediction is based on previously coded frame blocks which are previous to or subsequent to the present frame and thirdly, B macroblock(i.e., B-MB) prediction is based one or two earlier coded frames blocks. In intra prediction, I MB is predicted without any predicted previous MB outside the current frames. The prediction is must in any frame because there will be a high correlation exists between adjacent MB or between the samples within the MB. In intra prediction samples of adjacent and previously predicted macroblocks are used to predict the current macroblock of a frame. In intra prediction the block sizes varies for Luma component as 16x16, 8x8 and 4x4 where as for chroma components a single macroblock is predicted. Four prediction modes are possible if 16x16 block sizes for luma components is used, nine prediction modes if 8x8 and 4x4 block sizes are chosen. During chrominance components prediction only four prediction modes are applied. The luminance component of a frame is predicted at 4x4 or 8x8 sub block sizes. Here depending on previously predicted samples availability i.e., straight above to the current macroblock, or to the left side predicted samples to current block or above and above right or combination of these, the prediction modes are chosen as illustrated in figure 1.

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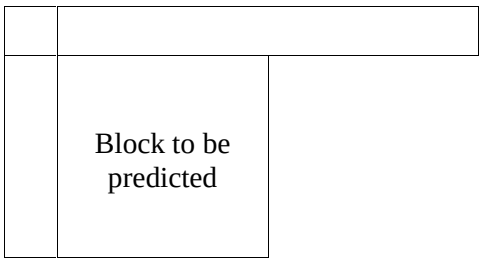

Figure1. 8x8 or 4x4 luma blocks for Intra prediction.

In 16x16 luminance or chrominance components the prediction is created from previously predicted samples availability i.e., above or left of the current macroblock as shown below in figure 2.

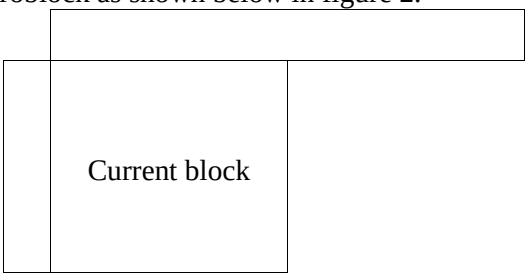

Figure2. Intra prediction used for 16x16 luma blocks

The choice of prediction blocks sizes i.e., 16x16, 8x8 or 4x4 for the luma components depending on prediction efficiency or cost of signaling the prediction mode. If smaller block sizes (4x4) are chosen then it gives a more accurate prediction i.e. a good match of block data and lesser residual data, fewer bits to transform and quantize the residual blocks but the same prediction mode has to be signaled to the decoder which uses more bits. Larger block sizes are less accurate after prediction. Here more bits are required to code residual predicted data with fewer bits used to signal the prediction mode to the decoder to code the prediction choice. Hence the prediction mode selection is based on smaller amount of bits in prediction and residual data can be chosen at the encoder.

II. LITERATURE SURVEY

To reduce spatial redundancy which is available within the macroblocks and frames, Manjanaik N et al (2) proposed 4x4 Intra prediction modes depending on applications, for H.264/AVC. The application of all prediction modes on any application at encoder is time consuming and complex. Here all prediction modes have been applied and suggested mode 0, 1, 2 4 and 6 to use for good compression ratio and lower bit rate. And mode 5, 7 and mode 8 gives lower PSNR, compression ratio and increased bit rate.

Elyousfi, A et al (3) proposed a gradient and quadratic intra prediction algorithm based on the correlation and homogeneity information existing in block sizes. both quadratic and gradient predictions implemented on smaller block sizes whereas gradient prediction has been applied for larger block sizes.it is proved experimentally that the complexity in computational steps have been reduced by retaining the PSNR and slight increase in bit rate.

Ashwini.V et al (4) proposed parallel processing of intra prediction nine modes for luminance components to reduce the latency and computational time. The implementation is done using shift and add method by to avoid multiplication operations which is time consuming and proved the prediction works at faster rate supporting video applications.

Mamatha R.B et al (5) proposed gradient based fast intra prediction modes. Here the blocks of variable sizes are used and depending on gradient direction and cost difference, the intra prediction mode is chosen to optimize rate distortion and sum of Absolute difference.

Soon-kak Kwon et al (6) proposed a method to improve coding efficiency as per coded block characteristics and its usage distributions is analyzed and exclusion modes are applied and proved there is approximately complexity has been reduced by half without degrading the picture quality.

Manjanaik et al (7) proposed horizontal intra prediction modes for H.264 standard using Gaussian pulse multiplication technique. Here Gaussian pulses are multiplied for every transformed coefficients to avoid quantization hits on the samples and proved the increase in coded efficiency and reduced bit rate.

III. PROPOSED WORK

The intra prediction processed here is on 4x4 luma subblock which is a derivative of 16x16 Macroblock and 8x8 subblock . After the intra prediction transformation, quantization and decoding process is done before the deblocking filter. The process of prediction, forward transformation, quantization and inverse of these are illustrated in figure 3. 4x4 intra prediction process is done when neighboring,adjacent 4x4 predicted luma sub blocks are available. Every macroblock of luma consists of 16, 4x4 sub blocks. The order of these sub blocks

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from macroblock in the current frame is scanned from left to right and then next sub block will be from next down left and so on.

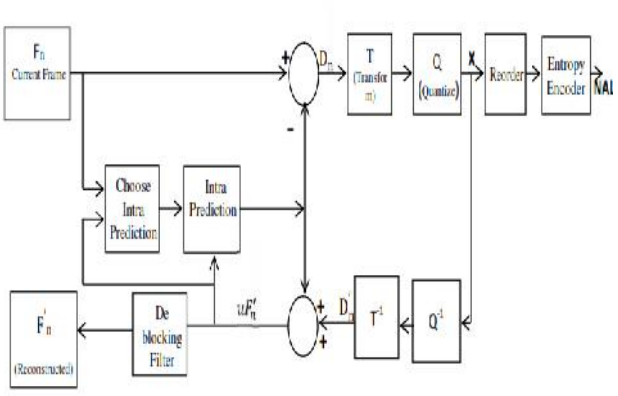


Figure 3: Intra prediction based H.264/AVC Encoder block diagram.

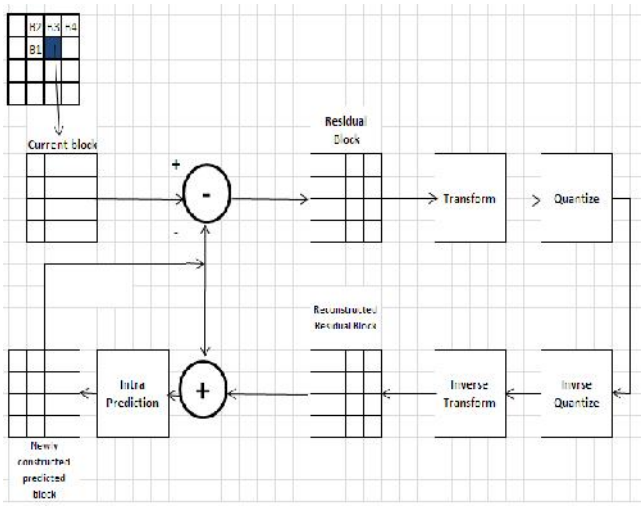


Figure 3: Proposed block diagram o Intra prediction.

From macro block of size 16 x 16, a sub block of size 4x4 luminance is derived to apply the Intra prediction modes which are illustrated in figure 4.

M	A	B	C	D	E	F	G	H
I	a	b	c	d				
J	e	f	g	h				
K	i	j	k	l				
L	m	n	o	p				

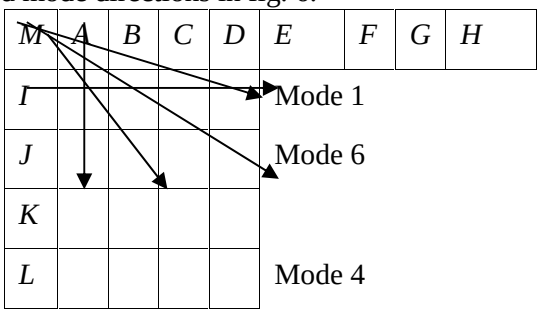
Figure 4: 4x4 luma block for prediction

The samples of previously predicted 4x4 sub blocks are represented through *A-M*. All the samples a-p of current block is predicted using previously predicted samples *A-M*. In the proposed block diagram the intra predicted sub block is generated using nine prediction modes as illustrated below

Table 1: various prediction modes

4x4 Intra prediction mode	Name of 4x4 Intra Prediction
0	4x4 vertical prediction mode
1	4x4 horizontal prediction mode
2	4x4 DC prediction mode
3	4x4Diagonal down left prediction mode
4	4x4 Diagonal downright prediction mode
5	4x4Vertical right prediction mode
6	4x4Horizontal down prediction mode
7	4x4Vertical left prediction mode
8	4x4Horizontal up prediction mode

In modes 0, 1, 4, 5, 6 the upper and left previously predicted block samples are used and in modes 3, 7, 8 the upper right samples are used to extrapolate the current 4x4 sub block samples. The arrows points out the path of prediction for each mode as in figure 5and mode directions in fig. 6.



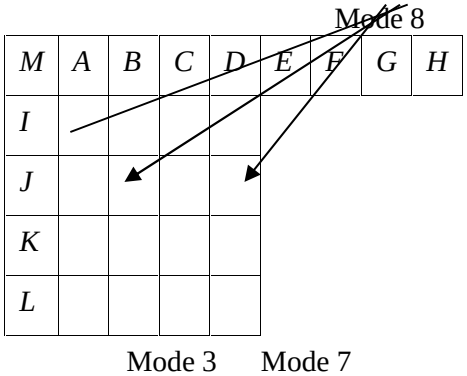


Figure 5: Illustration of nine intra prediction modes

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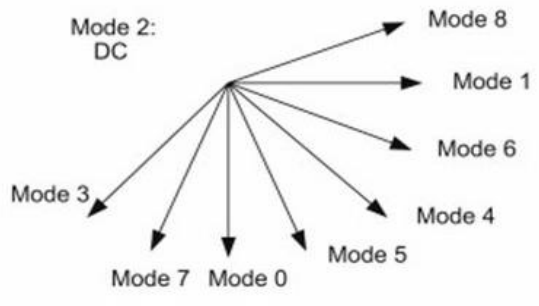

Figure 6: Possible nine 4x4 intra predicted mode directions

Any of the nine prediction modes shall be used during the prediction process for the samples of 4x4 luma current block. The 4x4 Intra vertical mode is applied if the predicted upper sub block samples for the values of v=0, 1, 2, 3 exists.

Then, in 4x4_vertical prediction mode the current block samples are predicted (8) as p (u, v) = p (u, -1), for the values of u & v = 0,1,2,3.

The 4x4 Intra horizontal mode is used if the predicted left sub block samples for the values of u=0, 1, 2, 3 exists. Then, in 4x4_horizontal prediction mode current block samples are predicted as p(u,v)= p(-1, v), for the values of u, v as 0,1,2,3.

Depending on the availability of Upper predicted block and Left predicted block samples, in 4x4 Intra DC prediction mode, the current 4x4 samples predictions are predicted as follows

Case1: If both upper predicted block and left predicted block samples are existing then current block prediction samples are

p (u, v) ={A+B+C+D+I+J+K+L+4} >> 3 with u, v varies as 0,1,2,3.

Case2: If only the upper predicted block of 4x4 samples are exists, then current block samples are

p (u,v)= { A+B+C+D+2} >> 2 for u value 0 to 3.

Case3: If only the left predicted block of 4x4 samples are exists, then current sub block prediction samples are

p (u,v)= {I+J+K+L+2} >> 2 for values of v as 0 to 3.

Case4: If upper and Left predicted 4x4 samples does not exists then current block samples are

p(u,v)= 1<<(N - bits of per sample -1)

In mode 3 the sample are extrapolated at 45° angle between lower left and upper right.

In this mode, if the Upper and Upper right predicted block samples are existing then Prediction of samples for current block for all u,v =0,1,2,3 as

If u=3 and v=3 exists,

then p(u, v)= { p(6, -1)) + 3 * p(7, -1) + 2 } >> 2.

else p(u, v) = { p(u + v, -1) + 2 * p(u + v + 1, -1) + p(u + v + 2, -1) + 2} >> 2

In mode 4, the current sub block prediction samples predicted with 45° angle down and right. In this 4x4 diagonal downright prediction, the predicted samples p(u, -1) with v as 0 to 3 and samples p(-1, v) with v as 1 to 3 exists, then p(u,v) for the values of u & v varying from 0 to 3 are derived under three conditions as

If u > v,then

p(u, v) ={ (p(u - v - 2, -1) + 2 * p(u - v - 1, -1) + p(u - v, -1) + 2)} >> 2

else if

u < v,

p(u,v)= {p (-1, v - u - 2) + 2 * p (-1, v - u - 1) + p (-1, v - u) + 2)} >> 2

else if u is equal to v,

then, p(u, v) ={ (p(0, -1) + 2 * p(-1, -1) + p(-1, 0) + 2)} >> 2.

In 4x4 vertical right prediction modes, the prediction samples are predicted at 26.6° angle to the right of vertical. If the predicted samples p(u, -1) with u varies from 0 to 3 and p(-1, v) with v ranging from -1 to 3 are existing, then current block samples are with variable R_{VR}=2*u – v, then the prediction samples p(u, v), for the values of u, v ranging from 0 to 3 are estimated as

If R_{VR}= 0, 2, 4, or 6,then

p(u, v) = {p(u - (v >> 1) - 1, -1) + p(u - (v >> 1), -1) + 1 } >> 1

else, if R_{VR} = 1, 3, or 5,

then p(u, v) = { p(u - (v >> 1) - 2, -1) + 2 * p(u - (v >> 1) - 1, -1) + p(u - (v >> 1), -1) + 2 } >> 2

else, if R_{VR} = -1,

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then p(u, v) = { p(-1, 0) + 2 * p(-1, -1) + p(0, -1)

+ 2 } >> 2

Else, if R_{VR} =-2 or -3

then, p(u, v) = { p(-1, v - 1) + 2 * p(-1, v - 2) +

p(-1, v - 3) + 2 } >> 2.

In mode 6 the samples are predicted at 26.6° below horizontal. If the samples p(u, -1) for u values 0 to 3 and p(-1, v) with values of v as -1 to 3 are existing then, Letting the variable R_{HD} = 2 * v – u, then p(u, v), for all values of u, v from 0 to 3 are predicted as

If R_{HD}= 0, 2, 4, or 6, then

p (u, v) = { p(-1, v -(u >> 1) - 1) + p(-1, v - (u >> 1)) + 1 } >> 1

else, if R_{HD} = 1, 3, or 5,then

p (u, v) = (p(-1, v - (u >> 1) - 2) + 2 * p(-1, v - (u >> 1) - 1) + p(-1, v - (u >> 1)) + 2 } >> 2,

else, if R_{HD} is equal to -1, then

p(u, v) = { p(-1, 0) + 2 * p(-1, -1) + p(0, -1) + 2 } >> 2

else R_{HD} = -2 or -3,then

p(u, v) = { p(u - 1, -1) + 2 * p(u - 2, -1) + p(u - 3, -1) + 2 } >> 2.

In mode 7 the samples are predicted at 26.6° angle to the left of vertical. when the predicted samples p(u, -1) with u values ranging from 0 to 7 are exists then the prediction samples of p(u, v) is computed with u, v values ranging from 0 to 3 as

If v=0 or 2, then

p(u, v) = { p(u + (v >> 1), -1) + p(u + (v >> 1) + 1, -1) + 1}>> 1

else if, v = 1 or 3, then

p(u, v) = { p(u + (v >> 1), -1) + 2 * p(u + (v >> 1) + 1, -1) + p(u + (v >> 1) + 2, -1) + 2 } >> 2.

In mode 8 the samples are predicted at 26.6° above horizontal.

When the samples p(-1, v) for v values of 0 to 3 are existing with R_{HU}= u + 2 * v, then p(u, v) with u, v = 0 to 3 then,

If R_{HU}= 0, 2, or 4

p(u, v) = { p(-1, v + (u >> 1)) + p(-1, v + (u >> 1) + 1) + 1} >> 1

else, if R_{HU} = 1 or 3

p(u, v) = { p(-1, v + (u >> 1)) + 2 * p(-1, v + (u >> 1) + 1) + p(-1, v + (u >> 1) + 2) + 2 } >> 2

else, if R_{HU}= 5,

p (u, v) = { p(-1, 2) + 3 * p(-1, 3) + 2 } >> 2

else if R_{HU} > 5,

p(u, v) = p(-1, 3).

The proposed intra prediction has been implemented only on luminance components of a frame. All nine modes of intra prediction have been analyzed for PSNR and Sum of absolute Difference in mat lab. The PSNR is calculated using

$$PSNR_{dB} = 20^{\log_{10}\frac{2^n - 1}{MSE}} \quad (1)$$

And the Mean Square error is calculated using

$$MSE = \sqrt{\frac{\sum_{x=0}^{W-1}\sum_{y=0}^{H-1}[g(x,y) - g'(x,y)]^2}{WH}} \quad (2)$$

The Mean Square Error does not reflect the distortion that is perceived by human visual system. Majority of the image compression systems are intended to reduce the MSE and maximize PSNR.

The Sum of Absolute Difference is the prediction error calculated using

$$SAD(dx,dy) = \sum_{(m,n)\in W} |b[m,n,k] - b[m-dy,n-dx,k-1]| \quad (3)$$

IV. IMPLEMENTATION

The proposed work has been implemented using the flow chart as illustrated below

1. Read the Image

2. Convert the image from RGB to YCbCr components.

3. Derive 4x4 luminance sub blocks from 16x16 Macroblocks

of a frame of N x N or NxM dimensioned frames.

4. Apply the intra prediction nine modes algorithm in a

sequential manner and measure the parameters of PSNR by

observing SAD. Lesser the SAD the better prediction

performance.

5. Tabulate the results.

V. EXPERIMENTAL RESULTS

The experimental results obtained were tabulated in table 2.

Table 2: Prediction gain for nine Intra prediction modes.

Images analyzed	Prediction Gain for luminance component for nine Intra prediction modes								
	Mode 0	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 7	Mode 8
Cameraman (256x256)	7.23 dB	5.15 dB	7.41 dB	4.86 dB	5.36 dB	5.01 dB	5.10 dB	6.60 dB	8.79 dB
Lena (512x512)	9.61dB	7.27dB	9.98dB	7.39dB	7.83dB	8.85dB	7.71dB	9.01dB	11.55dB
Autumn (550x525)	8.44dB	14.09dB	10.40dB	8.11dB	8.36dB	8.44dB	5.99dB	8.37dB	12.41dB
Bird (1500x1224)	10.46dB	11.67dB	12.17dB	9.55dB	10.42dB	10.16dB	10.98dB	10.34dB	13.82dB

CONCLUSION AND FUTURE WORK

This paper covers the overview of nine 4x4 luma Intra predictions used in H.264/AVC standard. All the prediction modes are implemented in matlab for 4x4 sub blocks and the various parameters which decide the efficiency of predictionww such as PSNR and Sum of Absolute Difference are measure are analyses for varied sizes of frames. It is found that from the table 2 that for equal sized pictures mode 0, mode 2, mode 5, mode 8 gives better prediction gain with faster computations whereas the frame of different dimensions for which mode 1 and mode 8 can be used with moderate speed, when larger dimensions are used mode 0 and mode 8 gives the better performance but with more computational time expense. Further work to be carried out includes the implementation of four intra prediction modes on chroma components and prediction modes for 8x8 block sizes and 16x16 block sizes.

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