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Pixel Based Intra Prediction Scheme For Video Coding

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Abstract: ***Video compression system are used in many commercial things/products, consumer electronic devices such as mobile phones, digital camcorders to video calling systems. This type of applications make the video compression hardware devices an inevitable part of many commercial products. To improve the performance of the existing applications, many international standard for video compression are existing which uses intra prediction. This new standard improves video compression efficiency based on Intra Prediction. To achieve compression within a frame is the goal behind intra prediction. The neighboring pixels within the picture frame tend to have similar values in order to exploit the spatial redundancy, the prediction is done based on the values of reconstructed pixels of previous sub block. There is total nine modes are known. From them eight modes are directional modes and used to predict structures in a picture such as edges at various angles and textures. In H.264 there are total nine modes which needs to compute for intra prediction, which are very high, to reduce them we proposed new method for mode computation for intra prediction. Implemented an efficient intra prediction scheme and compared to literature the block based Intra prediction techniques. PSNR is increased with 0.5dB and computation complexity reduced by 3.03% and structural similarity index is found out almost 75% which indicated superior video quality.***

Keywords ***intra prediction; pixel based prediction; intra prediction; PSNR; SSIM***

I. INTRODUCTION

Home entertainment and Broadcast television have been revolutionized by the advent of DVD-video and digital TV. These applications and many more were made possible by the of video compression technology standard. The ITU-T VCEG and Joint Video Team (JVT) of ISO/IEC MPEG are finalizing a new standard for the coding (compression) of (natural) video images. The new standard is MPEG-4 Part 10 which is known H.264,"Advanced Video Coding (AVC) H.264 is a video compression standard for an industry, the process of converting digital video into a format that takes up less capacity when it is stored or transmitted. H.264 offers a significant performance improvement over previous video coding standards in terms of better visual quality and peak signal to noise ratio of variable block sizes for multiple reference frames, motion compensation, Integer Transform, Deblocking Filter, and (CAVLC) Context Adaptive Variable Length Coding. The Intra prediction technique is one of the most important features that contribute to the success of H.264/AVC [1, 2]. The H.264 Video coding standard supports intra prediction for various block sizes. For coding the luma signal, one 16x16 macro block may be predicted as a whole or as individual 4x4 sub blocks. There are nine modes of Intra-

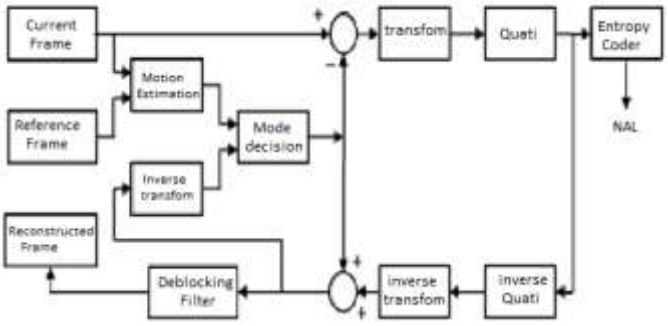

Figure 1. Block Diagram of the H.264 Encoder[1]

Prediction for 4x4 subblocks Figure (1) illustrates the main building blocks of the H.264 encoder. It is clear from the block diagram that the video compression efficiency of the H.264 standard is not a result of single feature but a combination of a number of encoding sub blocks. Intra prediction algorithm is one of the most important factors of the improved compression efficiency of the H.264. An Intra prediction mode is the formation of a predicted block P based on previously encoded and

reconstructed blocks and subtracted from the current block prior encoding. The predicted block P is formed for each 4x4 block or for a 16x16 macroblock (MB). There are nine prediction modes available for 4x4 luma block, 4 modes for a 16x16 luma MB and 4 modes for the Chroma blocks to remove spatial redundancy within a frame. The prediction mode for each block which results in minimum difference between P (predicted macroblock) and the current block is selected. The first three prediction modes (Vertical, Horizontal, and DC) that are used for encoding intra 4x4 block are most commonly used, collectively they cover 85% to 95% of the best modes.

A lot of efforts have been made to improve the intra prediction scheme of H.264. Many research contributions have been done to simplify the intra coding in H.264. Many of researcher are working on block based intra prediction method which has mostly base of (SAD algorithm) Sum of absolute difference and getting good results and good quality of prediction which ended up with visible block distortions. To overcome it, In this paper we are enthusiastic to propose new pixel similarity based technique for reducing the amount of computations performed by H.264 intra prediction algorithm and the power consumption of H.264 intra prediction hardware even further. Technique is applicable to 4x4 luminance, 16x16 luminance and 8x8 chrominance prediction modes. Pixel based intra prediction technique for prediction. The performance is measured in terms of Peak signal to noise ratio (PSNR) and Structure similarity index (SSIM) and compared with another best known intra prediction algorithms. The rest of the paper is as follows: Section II gives the brief theoretical background of intra prediction scheme for H.264 standard. Section III explains pixel based intra prediction in section IV algorithm explained followed by experiment results and conclusion.

II. INTRA PREDICTION

A. Overview of Intra Prediction

Intra prediction algorithm generates a prediction for a Macroblock (MB) based on spatial redundancy. H.264 intra prediction algorithm achieves better coding results than the intra prediction algorithms used in previous video compression standards. However, this coding gain comes with a significant increase in computational complexity. We proposed a pixel equality based technique for reducing the amount of computations performed by H.264 intra prediction algorithm and the power consumption for H.264 intra prediction hardware. To achieve compression within a frame is the goal

Table. 1 4 x4 Intra Prediction Modes[1]

Mode#	Name of Mode	Mode#	Name of Mode
0	Vertical	**5**	Vertical-Right
1	Horizontal	**6**	Horizontal-Down
2	DC	**7**	Vertical-Left
3	Diagonal-Down-Left	**8**	Horizontal-Up
4	Diagonal Down-Right		

behind intra prediction The neighboring pixels within the picture frame tend to have similar values in order to exploit the spatial redundancy, the prediction is done based on the values of reconstructed pixels of previous sub block [1]. For the luminance layer intra frame prediction, there are two possible block sizes (16x16 and 4x4) to encode one MB.

The first is the 16x16MB, with four possible prediction modes applied to the whole 16x16 MB. The second is the 4x4MB, with nine possible prediction modes applied to the sixteen blocks of 4x4 sub blocks which compose the MB. For the chrominance layer there are also four possible modes to predict each 8x8 block (Cr and Cb) in MB. The modes of the 4x4 intra prediction are given in Table 1. The values of each 4x4 block of luma samples are predicted from the neighboring pixels above or left of a 4x4 block. Modes 0, 1, 3, 4, 5, 6, 7, 8 are directional ways of performing the prediction that can be selected by the encoder. However, mode 2 is the DC prediction mode with no direction.

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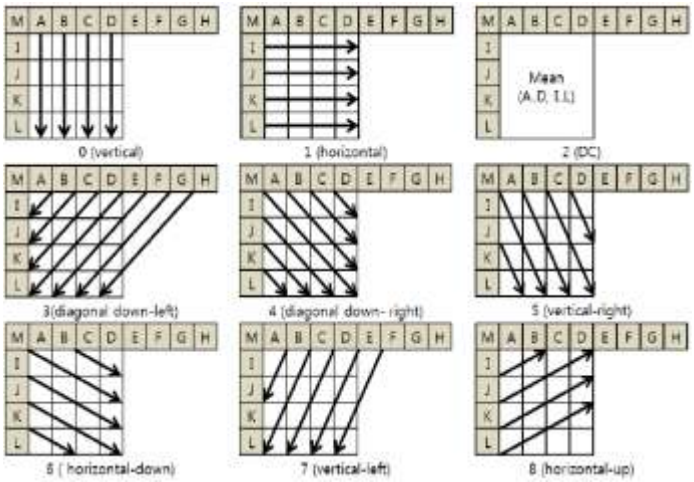

Figure. 2 4x4 Intra Prediction Modes[1]

B. 16 x 16MB Intra Prediction

As an alternative to 4x4 macroblock prediction described above, the entire macroblock may be predicted. This is suited for smooth image areas where a uniform prediction is performed for the whole luma component of an MB. There are only four prediction modes supported,

• Mode 0 is Vertical: extrapolation from upper samples.
• Mode 1 is horizontal: extrapolation from left samples.
• Mode 2 is DC: mean of upper and left-hand samples.

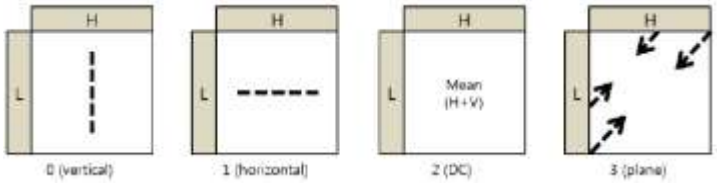

Figure. 3 16x16 Intra Prediction modes[1]

• Mode 4 is Plane: plane prediction based on a linear spatial interpolation by using the left-hand and upper samples of the macroblock.

III. PIXEL BASED INTRA PREDICTION

Pixel based new approach for Intra Prediction for video coding which inspired from block based intra prediction but all together a different approach to find predicted value for that particular pixel using all nine mode. Main advantage for pixel based prediction is it reduces computation remarkably which compare to block based computation. To start intra prediction author had two approach for initial data:

a) Without Prediction
b) With Prediction

Both of the approaches were explained below:

Without prediction means first macroblock (frame is divided in 4x4 or 8x8 or 16x16 block which is called macroblock) column and row are used as it is in predicted frame for the reference pixels (i.e A-M pixels) then using that data author predicted whole frame. In with prediction means to use only first row of pixel of frame is used as a reference pixels prediction can takes place. Both techniques were not so different from each other so author used without prediction method here.

There are total 9 modes which are explained below so one can predict video frame using any of the modes. By using three modes (V, H, DC, M) research was done in[1]. Here we are using all nine modes for prediction and comparing the results with earlier work. Flow chart is given below

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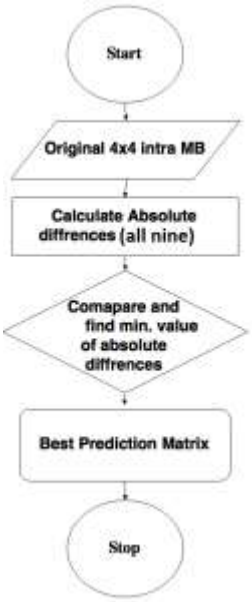

Figure. 4 Flow chart for pixel based intra prediction

Here below figure. 5 is given for three mode pixel based intra prediction which consist one 1x1 matrix for the prediction which is upper-left corner matric (M). Same is applied for the nine modes prediction.

IV. INTRA PREDICTION ALGORITHM

In figure.4 shown the flow chart for the pixel based intra prediction algorithm which elaborates exact flow of prediction. Here author specifically working on 4x4 macroblock which means to process 16 pixel at time. So access first for pixels than make all the mode matrices (c0,c1,c2….c8), where c0 is matrix made by mode 0(vertical) by replicating pixels(A-D) in respective column and same in c1-c8. Then compare all the mode matrices c0-c8 with the original reference matrix which gives absolute difference. dif1, dif2, dif8 which is represented in dotted line box in figure 5 then compare all absolute differences with each other i.e. compare dif1(i),dif2(i),…,dif9(i), where i shows position of the pixel dif-

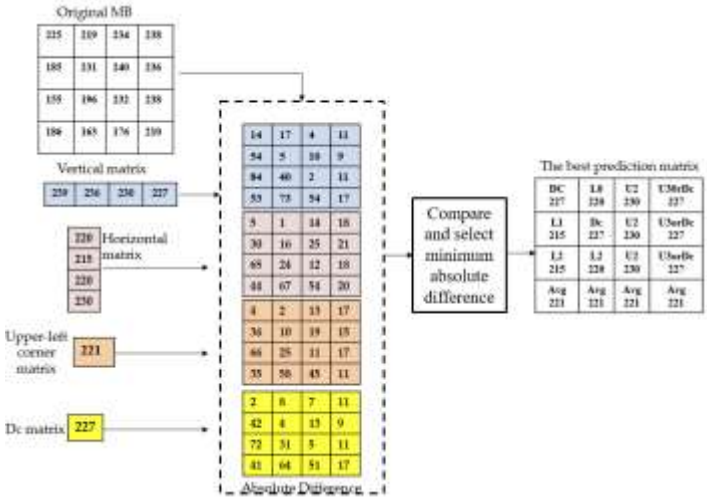

Figure. 5 example for pixel based intra prediction

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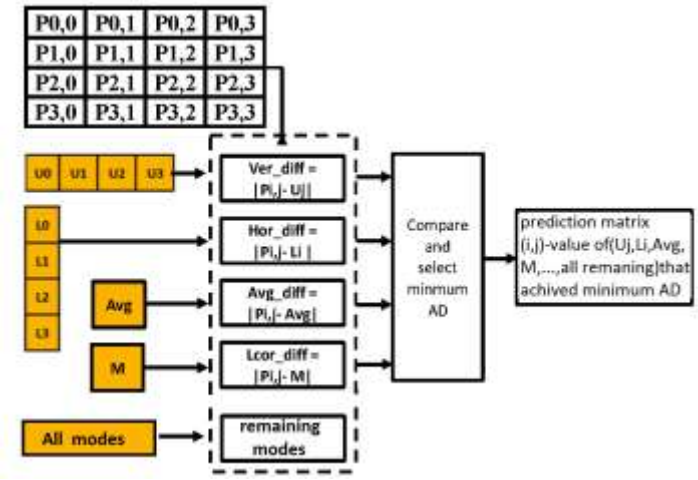

Figure 6 proposed architecture for pixel based intra prediction

Pseudo code for pixel based intra prediction

1: Read original intra 4x4 block;
2: Prepare construction matrices;
3: Compute the absolute difference as follow:
4: **for (**I, j = 0 : 3) **do** step = 1
5: V = $|P_{i,j} – Uj|$; H = |Pi;j - Lij;
6: DC = |Pi,j – Avg|; M = |Pi,j – Mj|; likewise compute for all mode
7: Find the minimum value of the absolute differences;
8: Put the value of one of (Uj, Li, Avg, M,…, all nine) that corre-
9: sponds to this minimum in the prediction matrix (i, j).
10: **end for**
11: Get the best prediction matrix

reference, find out which is lowest among this all then place a pixel values from that c0 to predicted block. Repeat this for all 16 pixels. Comparisons for all that method is given in Table 3 in terms of algorithm, supported video sequences, algorithm complexity and calculation cost.

Table. 2 comparing all algorithms

	SAD Algorithm	**SAD Algorithm**	**BPMM**	**Modified BPMM**
Algorith-m	Block based 3 mode	Block based 9 mode	Pixel based 3 mode	Pixel based 9 mode
Support-ed video sequence	QCIF, CIF, HD, Full HD	QCIF, CIF, HD, Full HD	QCIF, CIF, HD, Full HD	QCIF, CIF, HD, Full HD
Algorith-m compl-exity	Low	Low	Moderate	High
Comput-ation cost	Low	Higher	Lower	High
Advant-age	This method is using only 3 modes so calculations are greatly reduced with lower encoding time with	This method is using all nine modes which greatly increases quality of Prediction	Working on Pixel based Prediction which greatly increases	All the Modes are used prediction which gives superior quality

	lowering bitrate	compared to nine mode prediction with noticeable improvement in PSNR.	Prediction quality of video compared to 3 mode block based Prediction.	prediction video compared to all previous three methods. With lower computation cost.

Intra prediction on one frame. From the table 2 we can clearly conclude that pixel based method for intra prediction demands lower calculations, in pixel based 3 mode algorithm saves 3.03% of resources compare to block based 3 mode method and pixel based 9 mode algorithm saves 3.04% of resource compared to block based 9 mode algorithm.

Two of the error metrics used to compare the various image compression techniques are the Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR). The MSE is the cumulative squared error between the compressed and the original image, whereas PSNR is a measure of the peak error. The mathematical formulae for the two are[1]

$$MSE = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y) - I'(x,y)]^2 \quad (1)$$

$$PSNR = 10\log_{10}\frac{R^2}{MSE} \quad (2)$$

Where.

- I(x, y) is the original image, I'(x, y) is the approximated version (which is actually the decompressed image)
- M, N are the dimensions of the images.

Table. 3 Computation complexity for the one frame (288x355)

	Block based 3 mode	**Pixel based 3 mode**	**Block based 9 mode**	**Pixel based 9 mode**
Addition	6177*16*3	NA	6177*16*9	NA
Sub	6177*16*3	6177*16*3	6177*16*9	6177*16*9
Condition check	6177*3	6177*16*3	6177*9	6177*16*9
Total	**611523**	**592992**	**1834569**	**1778976**
Saving		**18531**		**55593**

V. EXPERIMENTAL RESULTS

The proposed algorithm is implemented on matlab 2013a.in our experiments test platform used is Intel i3 2.48 GHz processor, 3 GB of DDR2 RAM and windows 10 x86 for the experiments.

All the frames are encoded in I frame coding. The performance parameters are the Peak signal to noise ratio(PSNR) and structural similarity index(SSIM).and compared to previous algorithms in literature.300 CIF frames were processed at once in which it runs frames by frame. PSNR measured between predicted image and original image. And SSIM analysis given for Y (luminance), U (Chrominance), V components individually. Which is shown below:

(a) Original frame

(b) 3mode block based

(c) block based 9 modes

(d) pixel based 3 mode

(e) pixel based 9 mode

Figure. 7 Intra predicted frames

Table. 4 PSNR Anlysis

	Foreman	**Container**
Block based 3 mode	32.07857	32.92226
Pixel based 3 mode	32.13246	32.37642
Block based 9 mode	38.59048	37.97396
Pixel based 9 mode	38.62065	38.41653

Table. 5 SSIM Anlysis

	Foreman	**Container**
Block based 3 mode	0.5150(Y) 0.5038(U) 0.4781(V)	0.5370(Y) 0.5462(U) 0.5282(V)
Pixel based 3 mode	0.5490(Y) 0.5364(U) 0.5096(V)	0.5917(Y) 0.5944(U) 0.5871(V)
Block based 9 mode	0.5943(Y) 0.6035(U) 0.5929(V)	0.5585(Y) 0.5752(U) 0.5584(V
Pixel based 9 mode	0.7267(Y) 0.7374(U) 0.6966(V)	0.7372(Y) 0.7608(U) 0.7429(V)

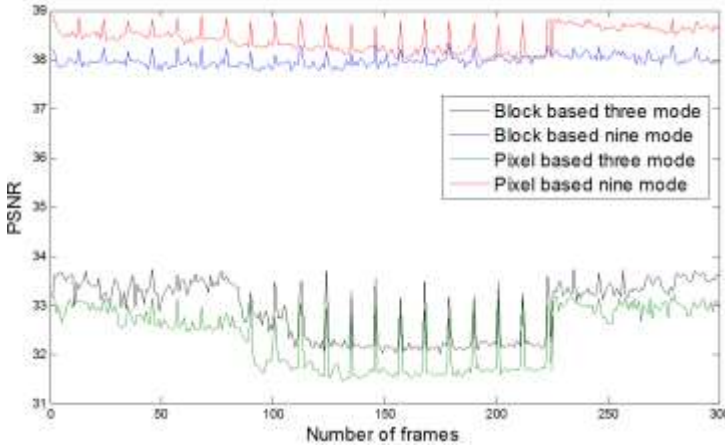

Figure. 9 PSNR comparison for container sequence

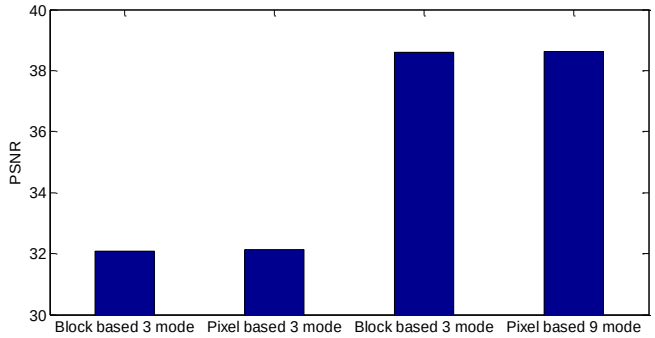

Figure. 10 PSNR comparison for container sequence

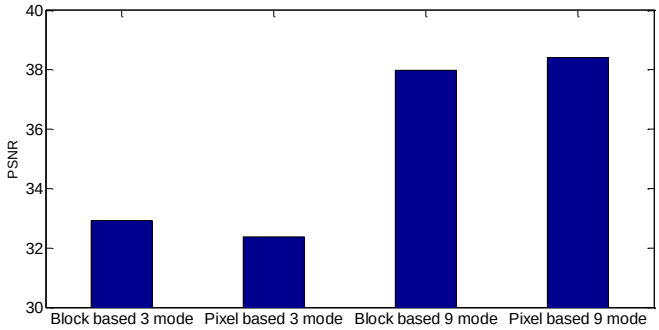

Figure. 11 PSNR comparison for foreman sequence

VI. CONCLUSION

Using Sum of absolute difference(block based) prediction method and Pixel based method measure peak signal noise ratio and SSIM in different modes sets it found that in pixel based nine modes method is superior than all other three methods which gives average 0.5db of PSNR increase while performing on CIF video sequence containing 300 frames. Video sequences are container, mother-daughter and foreman.

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