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Intra mode Decision Algorithm for H.264 Video Coding using Histogram

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***Abstract*— H.264 or MPEG 4 part 10 advanced video encoding is a video compression standard, which employs many techniques to achieve compression efficiency with low bit rate. To choose optimal intra prediction mode H.264 uses RDO technique and full checking strategy which increases complexity computation. In this project, to increase the efficiency of coding, a fast mode decision algorithm is proposed. In this algorithm, histogram of each prediction mode is based on the relationship between the pixels and coding modes. The most possible coding modes are chosen from all prediction modes by using histogram compared with full search algorithm**

***Index Terms*— H.264, Macroblocks, Prediction mode, Pixels**

I. Introduction

Intra prediction is the key technique of block-based video coding standard, such as MPEG4, H.263 and H.264. It aims to remove spatial redundancy between adjacent blocks in the given frame by using neighboring decoded pixels to predict pixels of coding block. In the latest video coding standard H.264, 16x16 and 4x4 block types are employed to encode luma component of video sequence when intra prediction is performed. According to the direction of prediction, 16x16block has 4 prediction modes and 4x4block has 9 prediction modes. For chroma intra prediction, the modes of chroma 8x8 block are similar to luma 16x16block. In order to achieve best quality and lowest bit-rates, H.264 encoder exhaustively checks all these possible block types and prediction modes to select an optimal mode for a coding block which has a minimum rate-distortion cost (RDO). However, this exhaustive checking strategy also increase the complexity and computation load. So it is necessary to develop fast intra prediction mode decision algorithm for some real-time applications. Through using these fast algorithms, the unlikely prediction modes are rejected and only several most possible prediction modes are checked.

II. PROBLEM STATEMENT

In video compression, quality assessment is the major task. To achieve this, many techniques are developed. H.264 AVC has much higher coding efficiency than other standards. Even though these techniques gives efficient results, it introduces computational overhead in maintaining the quality assessment. To reduce coding time and maintaining the quality of video is a challenging issue.

III. EXISTING SYSTEM

The existing fast intra prediction mode decision algorithm for the H.264 can be classified into four classes: spatial-temporal predicting-based class, threshold-based class, simple cost measure-based class and edge direction-based class. In the spatial-temporal predicting-based class, the correlation character of the current block and its adjacent blocks is used to predict the likely candidate modes of current block, such as [1] and [2]. In the threshold-based class, at threshold based on statistic experiments is predefined to early terminate the unlikely prediction mode, such as [3] and [4].Edge direction-based class is the most common fast algorithm, which selects the dominant edge direction of a block as the candidate mode by estimating the edge direction inside the block, such as [5] and [6]. In simple cost measure-based class, the simple cost measurement is developed to instead the RDO function in H.264, and the candidate modes are determined by this simple measurement, such as simple cost based on the symmetric character of predicted block in [7], and fast mode decision algorithm based on SATD in [8].

IV. PROPOSED SOLUTION

In this proposed work, analyzing weighted coefficient of neighboring pixels in the predicted block of each mode, a novel fast intra prediction mode decision algorithm based on the distribution of current pixels and prediction modes is proposed to improve the speed of intra prediction coding. In this scheme, only 3 or lesser modes are selected to replace 9 modes of luma 4x4 block. The prediction modes of luma 16x16 and chroma 8x8 also can be reduced from 4 to 2 or lesser. Simulation results show that the proposed algorithm can save about 77% coding time on average with slightly loss of the coding quality and increment of the bit-rate.

A. Introduction to video coding

Video is nothing but the visual or pictorial information which includes both still and time varying images. It is also called as image sequence and it is represented by time sequence of still-frame images. The video need to be translated in the form of digital by using different encoding and decoding techniques, so that it can be recorded, stored and transmitted. The main building blocks of the video coding system are as shown in fig 1.

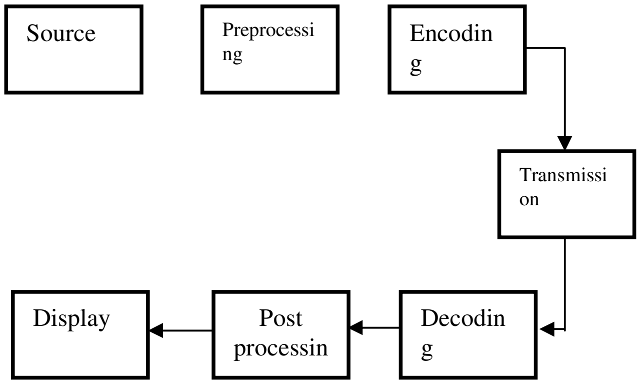

Fig 4.1: Building blocks of video Coding

- Video Acquisition—Source of the video sequence which is output in a digital form. The acquisition process may be temporally and locally decoupled from the following processing steps.
- Pre-Processing—Operations on the raw uncompressed video source material, such as trimming, color format conversion, color correction, or de-noising.
- Encoding—Transformation of the input video sequence into a coded bit-stream. The aim of encoding is to generate a compact representation of the input video sequence which is suitable for the transmission method in the given application scenario.
- Transmission—Packaging the bit-stream into an appropriate format and transmission over the channel. Transmission includes sending and delivery of the video data to the receiver side, as well as potential methods for loss protection and loss recovery. In some scenarios, like in conversational applications with real-time requirements, feedback from the receiver side to the sender side is available and can be used to control the encoder configuration. Such feedback can further be used e.g. to request re-transmission in case of lost information.
- Decoding—Transformation of the received bit stream into a reconstructed video sequence. Since video encoding usually requires lossy compression to achieve the target transmission bitrate constraints, the decoded video constitutes an approximation of the original source video. If unrecoverable transmission losses have occurred, the decoder applies concealment strategies to recover the corrupted video sequence as much as possible.
- Post-Processing—Operations on the reconstructed video sequence for enhancement or for adaptation of the sequence for display. These operations can e.g. include color correction, trimming, or re-sampling. Also special effects may be applied as determined by the application.
- Display—Presentation of the video sequence for viewing. The video sequence needs to be transferred into the appropriate color format for display. The output timing of the pictures of the video sequence is an important aspect to achieve the intended visual impression.

B. *Video Formats*

A variety of video standards are there which define the resolution and colors for display. For a PC, both the monitor and the video adapter determine the support for a graphics standard. The monitor must be capable of displaying the resolution and the colors defined by the standard whereas the video adapter needs to transmit the appropriate signals to the monitor. Some of the popular video standards along with their respective parameters are listed here in tabular forms.

Table 3.1 displays the uncompressed bit rates of some video formats. It can be clearly observed that even QCIF at 15 fps (i.e., relatively low quality video suitable for video telephony) requires 4.6 Mbps for storage or transmission.

Video Format	QCIF	CIF	ITU-R 601
Colour Resolution	88 x 72	176 x 144	429 x 525
Intensity Resolution	176 x 144	352 x 288	858 x 525
Bitsper second (uncompressed)	4.6 Mbps	36.5 Mbps	216 Mbps
Frames per Second	15	30	30

TABLE 4.1 UNCOMPRESSED BIT RATE

C. *Video Coding Standards*

Basically there are two families of standards:

1) ISO/IEC (International Standards Organization and International Electro- Technical Commission)

2) ITU (International Telecommunications Union)

ISO/ IEC produced the MPEG standards which are the standard formats for video compression.

ITU-T developed several recommendations for video coding such as H.261, H.263 starting from 1984 till it was approved in 1990.

In video coding, the video is converted into individual frames and then coding techniques are applied on the images to compress the given file. The compressed images are decompressed and again a video could be created from those so that the compressed video is obtained. Following are the video coding standards:

- H.261/H.263
- MPEG-1

- MPEG-2
- MPEG-4
- H.264

1. H.261/H.263 Standard: These are not the international standards but the recommendations by the ITU. They can be considered as the simplified versions of the MPEG techniques. Since they were actually developed for low bandwidth i.e., for applications like video conferencing; they cannot provide the efficient usage of the bandwidth as some of the most advanced MPEG techniques are not included in these techniques. Hence it can be conclude that H.261 and H.263 are generally not used for video compression.

2. MPEG-1: This was the basic compression standard developed by the ISO/IEC family in the year 1993. The idea is to store the video files in a format suited to CDROMs. Using this standard, video is encoded at a data rate of less than 1.4 Mbps. This standard introduced the mp3 audio format which is the most popular today.

3. MPEG-2: This is an extended version of MPEG-1 which uses higher bandwidth to achieve higher quality and to cover bigger images. These compression techniques are used for the television and telecommunication standards. These techniques are also used in compressing the DVD movies. Higher resolution and a higher transmission rate of 10 Mbps can be observed in this compression technique.

4. MPEG-4: This technique was developed intending to interactive multimedia, video telephony. The transmission of full-motion video at a low bit-rate of only 9-40 kbps is done with this technique. "The classic MPEG-4 video streaming standard is called the MPEG-4 Visual".

5. H.264: The latest standard developed for the video compression is the H.264 standard. It should provide a better video quality at the same bit rate. In this technique as the more applications are possible, all of these have to be implemented without much increase in the complexity of the system. This technique also provides the flexibility to perform a vast range of operations. Some of the important applications to be done using H.264 are:

a) Cable TV, broadcasting, satellite etc.
b) Streaming services
c) Telecom services

Also, the H.264 encodes the HD-DVD and Blu-ray support movies.

D. Constraints

Quality: While performing compression operations, the quality of the compressed video should be taken into account and the compressed video should not lose its quality beyond a certain acceptable level.

Complexity: While executing the different algorithms to obtain compression, the complexity of the algorithm is an important factor. It should not be too complex.

Delay: The execution time should be optimum while running a compression algorithm on a given video. While applying complex algorithms, it usually takes time to implement but the delay should not be very large.

Compression ratio: The ratio of the original file size to the compressed file size is called compression ratio. To obtain better compression ratios, the quality of the video has to be forfeited.

V. REQUIREMENT SPECIFICATION

A. Minimum Hardware Requirement specification:

Processor:Intel Pentium IV Processor

Hard disk capacity:40 GB HDD

Cache memory:4 GB RAM

B. Minimum Software Requirement Specification:

Operating System: Windows XP SP-3, Windows 7

MATLAB R2011a Simulink for design.

VI. HIGH LEVEL DESIGN

A software product is a complex entity. Its development usually follows what is known as Software Development Life Cycle (SDLC). The second stage in the SDLC is the Design stage. The objective of the design stage is to produce the overall design of the software. The design stage involves two sub-stages namely:

- High-Level Design
- Detailed-Level Design

In the High-Level Design, the proposed functional and non-functional requirements of the software are studied. Overall solution architecture of the solution is developed which can handle those needs.

A. RDO and INTRA estimation

H.264/AVC adopts rate-distortion optimization (RDO) technique to obtain the best intra- and inter-prediction, while maximizing visual quality and minimizing the required bit rate. However, full RD cost calculation for all intra-prediction modes and exhaustive searches for optimal motion vectors for all block sizes increase computational complexity considerably with the number of prediction modes allowed. In order to reduce the complexity, we propose an enhanced fast intra-prediction mode selection strategy. Among many new features, the intra- and inter-prediction techniques are recognized to be the main factors that contribute to the success of H.264/AVC.

To reduce the computational complexity, many algorithms (such as fast motion estimation, fast inter-mode prediction, and fast intra-prediction) have been proposed. For fast intra prediction, since it is a new topic in H.264/AVC coding with respect to other standards such as MPEG-1/2/4 and H.261/H.263 and so far no previous work exists for that. Fast intra-mode decision algorithms using edge detection histogram and local edge detection are proposed. However, their pre-processing stages still consume a coding time to detect the edge direction and to classify it into a limited direction. proposed fast algorithms to select the optimal intra-prediction mode using simple 9 prediction modes saves time of 70%. A new fast intra-prediction algorithm is proposed based on macroblock properties .the proposed method reduces the encoding time up to 60~75% with loss in PSNR and negligible increase of required bitrate.

B. Proposed Algorithm

In the latest video coding standard H.264, 16x16 and 4x4 block types are employed to encode luma component of video sequence when intra prediction is performed. According to the direction of prediction, 16x16 block has 4 prediction modes and 4x4 block has 9 prediction modes. For chroma intra prediction, the modes of chroma 8x8 block are similar to luma 16x16 block.

In order to achieve best quality and lowest bit-rates, H.264 encoder checks all these possible block types and prediction modes to select an optimal mode for a coding block which has a minimum rate-distortion cost (RDO). However, this exhaustive checking strategy also increase the complexity and computation load. So it is necessary to develop fast intra prediction mode decision algorithm for some real-time applications. Through using these fast algorithms, the unlikely prediction modes are rejected and only several most possible prediction modes are checked.

Intra-prediction is based on the observation that adjacent macroblocks tend to have similar properties. Therefore, as a first step in the encoding process for a given macroblock, one may predict the macroblock of interest from the surrounding macroblocks. The difference between the actual macroblock and its prediction is then coded; which results in fewer bits to represent the macroblock of interest. Prediction may be formed for each 4x4 luma block (I4MB), 16x16 luma MB (I16MB), and 8x8 chroma block. For prediction of 4x4 luminance blocks, the 9 directional modes consist of a DC prediction (Mode 2) and 8 directional modes; labelled 0, 1, 3, 4, 5, 6, 7, and 8 as shown in Fig 6.1. In Fig 6.1(b), the block (values of pixels "a" to "p") is to be predicted using A to Q. Note that pixels "A" to "Q" from neighboring blocks have already been encoded and may be used for prediction.

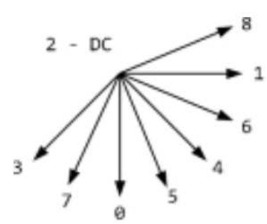

Fig 6.1: (a) Intra-prediction modes for 4x4 luminance blocks. (b) Labeling of prediction samples.

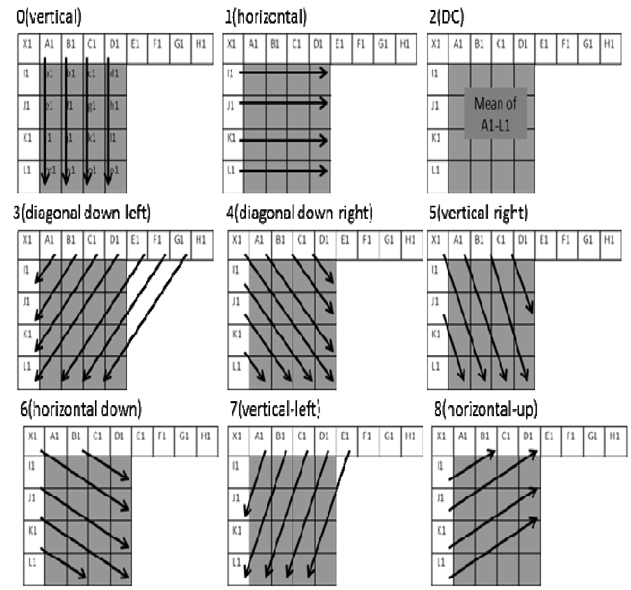

Fig 6.2 Prediction blocks P

VII. DETAILED DESIGN

A. ALGORITHM FOR LUMA 4X4

As specified in the H.264 coding standard, the pixels of the 4x4 block can be generated by calculating the sum of weighted neighboring pixels, which can be expressed by:

$$y = (Q1 \times P1 + Q2 \times P2 + Q3 \times Q3 + Q4)/Q5 \qquad (1)$$

Where PI to P3 denote the neighboring pixels which labelled with A to M in Fig 7.1 (a), and Ql to Q5 are the weighted coefficients. In each prediction mode, the pixels of predicted block are calculated according to (1), and neighboring pixels and corresponding weighted coefficients are selected base on prediction modes and location of pixels in block. The weighted value of each neighboring pixels in whole predicted block can be achieved by accumulating all the pixels in predicted block. The accumulated value of each mode can be expressed as formula (2) to (10):

$$Sum_{M0} = 4A1 + 4B1 + 4C1 + 4D1 \qquad (2)$$

X1	A1	B1	C1	D1	E1	F1	G1	H1
I1	a1	b1	c1	d1				
J1	e1	f1	g1	h1				
K1	i1	j1	k1	l1				
L1	m1	n1	o1	p1				

$$Sum_{M1} = 4I1 + 4J1 + 4K1 + 4L1 \qquad (3)$$

$$Sum_{M2} = 2(A1 + B1 + C1 + D1 + I1 + J1 + K1 + L1) \qquad (4)$$

$$Sum_{M3} = \frac{1}{4}A1 + B1 + \frac{7}{4}C1 + 3D1 + \frac{14}{4}E1 + 3F1 + \frac{7}{4}G1 + H1 \qquad (5)$$

$$Sum_{M4=} 3A1 + \frac{7}{4}B1 + C1 + \frac{1}{4}D1 + 3I1 + 2J1 + K1 + \frac{1}{4}L1 + \frac{14}{4}X1 \quad (6)$$

$$Sum_{M5=} \frac{14}{4}A1 + \frac{15}{4}B1 + 3C1 + \frac{3}{4}D1 + \frac{5}{4}I1 + J1 + \frac{1}{4}K1 + \frac{11}{4}X1 \quad (7)$$

$$Sum_{M6=} \frac{5}{4}A1 + \frac{3}{4}B1 + \frac{1}{4}C1 + 4I1 + \frac{15}{4}J1 + \frac{14}{4}K1 + \frac{3}{4}L1 + \frac{9}{4}X1 \quad (8)$$

$$Sum_{M7=} \frac{3}{4}A1 + \frac{11}{4}B1 + \frac{15}{4}C1 + \frac{16}{4}D1 + \frac{12}{4}E1 + \frac{6}{4}F1 + \frac{1}{4}G1 \quad (9)$$

$$Sum_{M8=} \frac{3}{4}L1 + 4J1 + \frac{15}{4}K1 + \frac{34}{4}I1 \quad (10)$$

Where subscripts in the Sum_{MO} to Sum_{M8} represent the prediction mode, and the neighboring pixels are denoted by A to X. In order to describe it clearly, we multiply each formula from (2) to (10) by 4, then these weighted values are listed in Table 7.1

Based on analyzing the weighted values of pixels in Table 7.1, we can find that the neighboring pixels have different weighted value in each mode, and each accumulated sum of 4x4 block is always determined by some pixels with larger weighted value. For example, in the mode 6, the weighted coefficients of pixels X1, I1, J1 and K1 in Table 7.1 are much larger than that of pixels A1, B1, C1 and L1, so the predicted pixels of prediction mode 6 is mainly determined by the value of pixels X1, I1, J1 and K1. In order to simplify the algorithm, the pixel X1, I1, J1 and K1 in the example can be replaced by the average of two adjacent pixels (1+ X1)/2 and (J1+K1)/2. We define the (I1+X1)/2 and (J1+K1)/2 as the significant value of the mode 6. Therefore, if the mode 6 is selected as the best prediction mode, the values of the pixels in the current block must distribute around these significant values. The significant values of other modes are shown in Table 7.2.

PIXEL	PREDICTION MODE								
	M0	M1	M2	M3	M4	M5	M6	M7	M8
A1	16	0	8	1	12	14	5	3	0
B1	16	0	8	4	7	15	3	11	0
C1	16	0	8	7	4	12	1	15	0
D1	16	0	8	12	1	3	0	16	0
E1	0	0	0	14	0	0	0	12	0
F1	0	0	0	12	0	0	0	6	0
G1	0	0	0	7	0	0	0	1	0
H1	0	0	0	4	0	0	0	0	0
I1	0	16	8	0	12	5	16	0	3
J1	0	16	8	0	8	4	15	0	16
K1	0	16	8	0	4	1	14	0	15
L1	0	16	8	0	1	0	3	0	34
X1	0	0	0	0	14	11	9	0	0

TABLE 7.1.THE WEIGHTED VALUES OF PIXELS IN 9 PREDICTION MODES

Prediction Mode	Significant Values
M0	A1, B1, C1, D1
M1	I1, J1, K1, L1
M2	(A1+B1+C1+D1+I1+J1+K1+L1)/8
M3	(C1+D1)/2, (E1+F1)/2
M4	(X1+A1)/2, (I1+J1)/2
M5	(A1+X1)/2, (B1+C1)/2
M6	(I1+X1)/2, (J1+K1)/2
M7	(B1+C1)/2, (D1+E1)/2
M8	(J1+K1)/2, L1

TABLE 7.2 SIGNIFICANT VALUES OF EACH MODE

To describe the distribution characteristic of pixels and prediction modes, the histogram of pixels in coding block is calculated by counting the number of pixels which has the similar values to the significant values. For each prediction mode, let histogram(Mi) is the histogram of mode Mi. Then, the histogram is constructed as follow:

For (j=0; j<=15; j++) {
If ($|pixel_j$- significant $values_{Mi}| \leq 12$)
histogram(Mi) =histogram(Mi) +1 ;} (11)

Where Mi is the prediction mode, the $Pixel_j$ is jth pixel of the block. Fig 7.3 shows histogram of prediction modes for4x4 block. It shows the most pixels in this block are around the significant values of the mode M1 and M8. So the mode Ml and M8 can be chosen as the likely candidate mode, and the other modes are skipped.

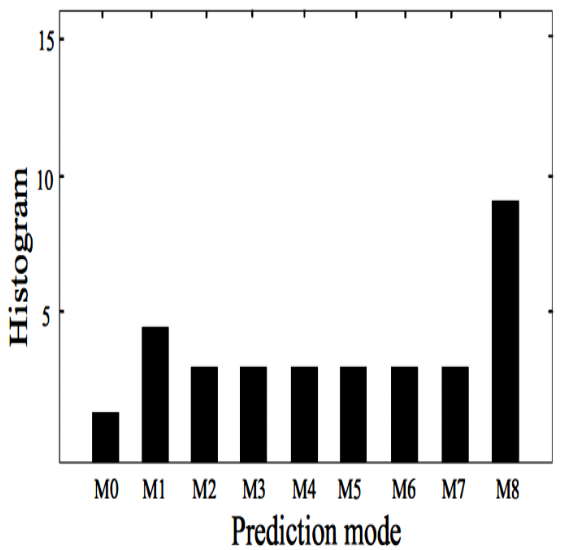

Fig 7.1 The histogram of prediction modes of 4x4 block

According to above analysis, a summary of the proposed algorithm is provided as follows:

Step1: Compute the significant values and histograms for each prediction mode according to Table 2 and formula (11), respectively.

Step2: In the worst case, if amplitudes in histogram are smaller than threshold value 2, it indicates the candidate modes cannot be selected by the proposed fast algorithm in this paper, so original full search method ofH.264 is adopted. Otherwise, go to step 3.

Step3: Three prediction modes Mx, My and Mz with maximum amplitude in histogram are selected. Their amplitudes are labels as hist_ Mx, hist_ My and hist_ Mz, respectively.

Step4: If the difference of hist_ Mx and hist_ My is larger than threshold 6, it shows that the prediction mode with amplitude hist_ Mx is obvious dominant than other modes, so only prediction mode Mx is chosen as candidate mode to encode this block. Otherwise go to Step 5.

Step5: If the difference of hist_My and hist_Mz is larger than 6, it indicates that the mode Mx and My are obvious dominant than other modes, so the Mx and My are selected. Otherwise mode Mx, My and Mz are chosen.

B. ALGORITHM FOR LUMA 16X16 AND CHROMA 8X8

In H.264 coding standard, the luma 16x16 prediction only includes four modes DC, horizontal, vertical and plan. The prediction modes of chroma 8x8 are same to intra 16x16 luma. So the proposed algorithm for them is almost similar. In order to further improve the coding efficiency, we sub-sample the chroma 8x8 and luma 16xl 6 block respectively before intra mode decision. After sub-sampling, the chroma 8x8 block is changed to 4x4 block, and luma 16x16 block is changed to 8x8 block.

The method of histograms for DC, horizontal and vertical prediction mode are similar to luma 4x4. So the proposed algorithm for luma 16x16 and chroma 8x8 is briefly summarized as follow:

Step 1: Calculate significant values and histograms for DC, horizontal and vertical mode.

Step 2: Select prediction mode with maximum amplitude from above three histograms. Then, the mode decision can be done as: If this prediction mode is DC, only the DC mode is chosen as candidate mode; else if the maximum amplitude is less than 3, only the plan prediction plus DC mode are selected; else the prediction mode with maximum amplitude plus DC mode are chosen to perform RDO calculation.

For regions with less spatial details *(i.e.,* flat regions), H.264/AVC supports 16x16 intra-coding; in which one of four prediction modes (DC, vertical, horizontal and planar) is chosen for the prediction of the entire luminance component of the macroblock as shown in Fig 7.4.

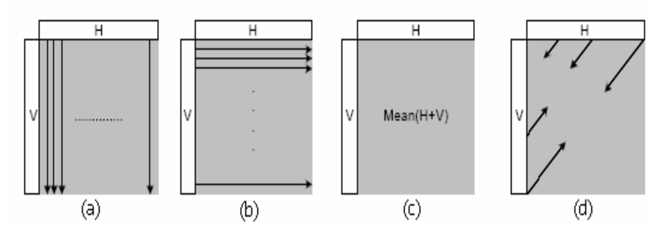

Fig 7.2: Intra 16x16 prediction modes: (a) Mode 0 (vertical). (b) Mode 1 (horizontal). (c) Mode 2 (DC). (d) Mode 3 (plane)

H.264/AVC supports four chroma prediction modes for 8x8 chrominance blocks, similar to that of the I16MB prediction, except that the order of mode numbers is different: DC (Mode 0), horizontal (Mode 1), vertical (Mode 2), and plane (Mode 3). The same prediction mode is always applied to both chroma blocks. The chroma prediction is independent from luma prediction.

C. RESULTS

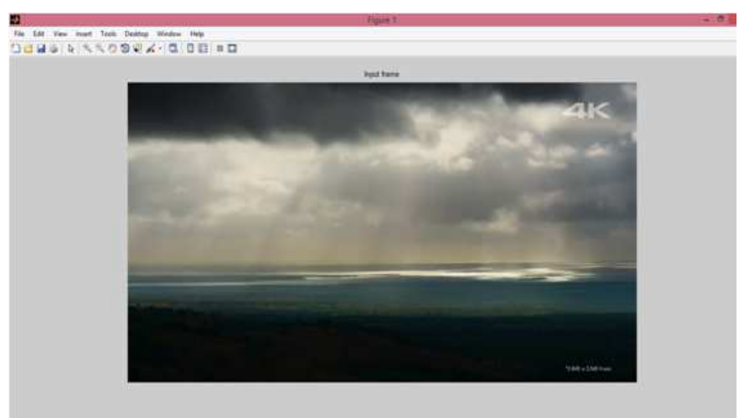

Fig 7.3 Input Frame

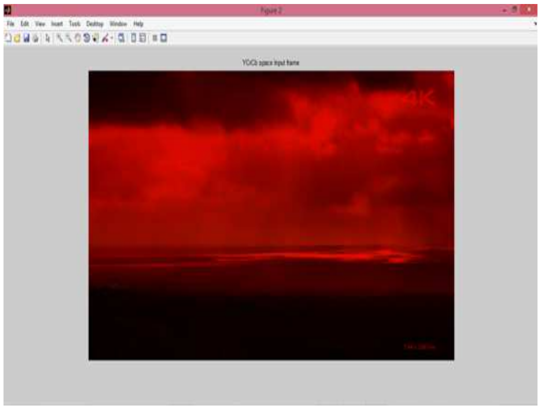

Fig 7.4: YCbCr Input Frame

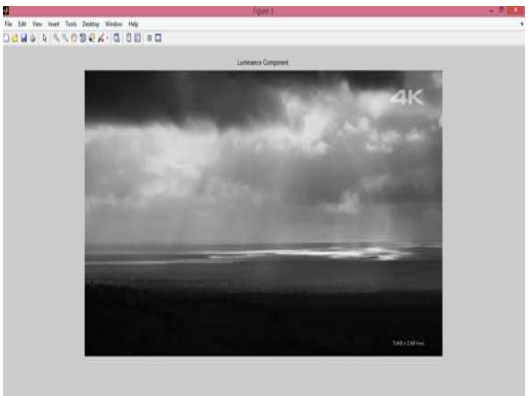

Fig 7.5: Luminance Component

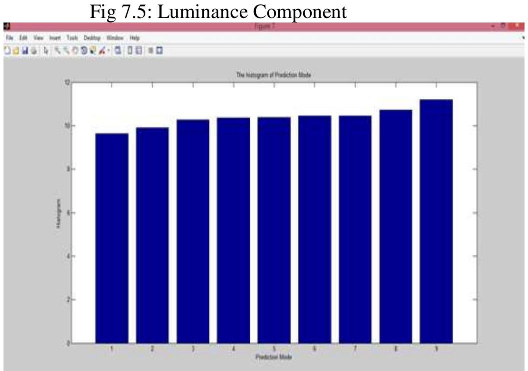

Fig 7.6: Histogram of Prediction modes

VIII. CONCLUSION

The proposed algorithm is used to improve coding efficiency of H.264. In this algorithm, by analyzing weighted value of pixel in predicted block, the significant values of each mode are known, which describe the relationship between the pixels and the prediction mode. Then, by using histogram only some modes are selected as candidate modes. It can also reduce the processing time so that can be used in real time applications. The performance of the standard can be improved. Compared to all existing algorithms it offers significant bit rate and good quality.

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