Fast Mode Decision Algorithm for Intra prediction in H.264/AVC Video Coding

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Summary
The new video coding standard, H.264/MPEG-4 AV C, uses an intra prediction mode with 4x4 blocks and 16x16 blocks sizes for luma component and 8x8 blocks size for chroma component. This new feature of H.264/AVC offers a considerably higher improvement in coding efficiency compared to other compression standards. In order to achieve this, a robust Rate-distortion optimization (RDO) technique is employed to select the best coding mode for each block sizes. However, the computational complexity of H.264 encoder is drastically increased due to the various intra prediction modes. In this paper, we propose a fast mode decision algorithm for intra prediction to reduce the complexity of H.264 video coding. The proposed algorithm based the fact that the dominating direction of a smaller block is similar to that of bigger block, the directional correlation of each block is consistent with directions of the edges, and the prediction modes of each block are also correlated with those of neighboring modes. The experimental results show that the fast intra mode decision algorithm is able to reduce on the average 84.68% encoding time, with a negligible peak signal-to noise ratio loss of 0.19dB or, equivalently, a bit rate increment of 1.88%.

Key words:
Intra prediction, H.264/AVC, video, coding, encoder complexity

1. Introduction

The H.264/AVC is newest video coding standard of the ITU- T Video Coding Experts Group and the ISO/IEC Moving Picture Experts Group [1,2,3,4]. Compared to the previous video coding standards, H.264/AVC has significantly better performance in terms of better peak signal-to-noise ratio (PSNR) and visual quality at the same bit rate [5]. This is accomplished mainly due to the consideration of variable block sizes for motion compensation, multiple reference frames, integer transform [an approximation to discrete cosine transform (DCT)], in-loop deblocking filter, context-based adaptive binary arithmetic coding (CABAC), but also due to better exploitation of the spatial correlation that may exist between adjacent Macroblocks, with the multiple intra-mode prediction in intra (P) slices.

The Intra prediction is a necessary part for any video coding
Standard Including MPEG-1, MPEG-2, H.261, H.263, MPEG-4 part 2 and H.264/AVC. But the intra prediction in H.264/AVC is different from the one in the other standards. In the previous standards, the intra prediction is used in the transform domain [6,7,8]. For example, in MPEG-1, MPEG-2 and H.261 the intra prediction is DC prediction and in MPEG-4 and H.263, additional AC prediction is used. However, in H.264/AVC, the intra prediction is conducted by using spatially neighboring samples of a given block, which are already transmitted and decoded.

The H.264 video coding standard supports intra prediction for various block sizes. For coding the luma signal, one 16x16 macroblock may be predicted as a whole using Intra-16x16 modes, or the macroblock can be predicted as individual 4x4 blocks using nine Intra-4x4 modes. In the profiles that support Fidelity Range Extension (FRExt) tools, a macroblock may also be predicted as individual 8x8 blocks using nine intra-8x8 modes[9]. Intra prediction for the chroma signal uses similar techniques as those for luma Intra-16x 16 predictions. H.264/AVC uses rate-distortion optimization (RDO) [10] technique to obtain the best result maximizing visual quality and minimizing bitrates. To choose the best macroblock mode, H.264 encoder calculates the RDcost (Rate distortion cost) of every possible mode and chooses the mode having the minimum value. Therefore, the computational complexity is extremely increased compared with previous standards, so it makes H.264/AVC difficult for applications with low computational capability, such as mobile devices.

To reduce the complexity of H.264/AVC, various researches are currently being made to develop fast algorithms in motion estimation, intra mode prediction and inter mode prediction for H.264/AVC video coding [11,12]. In this paper, we propose a novel fast intra prediction mode decision algorithm to reducing the computational complexity. The proposed algorithm is able to reduce the number of candidates to achieve fast intra prediction based

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on pre-analysis [13,14,15]. The rest of this paper is organized as follows: Section 2 describes the intra mode decision in H.264/AVC. In Section 3, we propose a fast intra prediction algorithm in detail. Section 4 gives the Experimental results to show the performance of the proposed algorithm. Finally, the paper is concluded in section 5.

2. H.264/AVC INTRA MODE DECISION

The H.264 standard exploits the spatial correlation between adjacent macroblocks/blocks for Intra prediction. In JV T, the current macroblock is predicted by adjacent pixels in the upper and the left macroblocks that are decoded earlier. For the luma prediction samples, the prediction block may be formed for each 4x4 subblock, each 8x8 block, or for a 16x16 macroblock. One case is selected from a total of 9 prediction modes for each 4x4 and 8x8 luma blocks; 4 modes for 16x16 luma block; and 4 modes for each chroma blocks. To take the full advantage of these modes, the H.264 encoder can select the best mode using the rate distortion optimization (RDO).

2.1 4x4 luma intra prediction modes

In 4x4 Intra prediction modes, the values of each 4x4 block of luma samples are predicted from the neighboring pixels above or left of a 4x4 block, and nine different directional ways of performing the prediction can be selected by the encoder as illustrated in Fig. 1 and Table.1 (and including a DC prediction type numbered as mode 2, which is not shown in the figure). Each prediction direction corresponds to a particular set of spatially-dependent linear combinations of previously decoded samples for use as the prediction of each input sample. For the purpose of illustration, Fig. 2 shows a 4x4 block of pixels a, b, c ...p, belonging to a macroblock to be coded. Pixels A, B, C ...H, and I, J, K, L, M are already decoded neighboring pixels used in computation of prediction of pixels of current 4x4 block. Fig. 3, shows of the nine 4 £ 4 Intra prediction modes. For mode 2 (DC), all pixels (labeled a to p) are predicted by (A+B+C+D+I+J+K+L)/8. The mode 0 specifies the vertical prediction mode in which pixels (labeled a, e, i and m) are predicted from A, and the pixels (labeled b, f, j and n) are predicted from B, and so on. If Horizontal prediction is employed (mode 1), a, b, c, d are predicted by E, e, f, g, h by F etc. For mode 3 (diagonal down left), mode 4 (diagonal down right), mode 5 (vertical right), mode 6 (horizontal down), mode 7 (vertical left), and mode 8 (horizontal up), the predicted samples are formed from a weighted average of the prediction samples A-M. For example, samples a and d are respectively predicted by round (I 4 + M 2 + A 4) and round (B 4 + C 2 + D 4) in mode 4, also by round (I 2 + J 2) and round (J 4 + K 2 + L 4) in mode 8. The best prediction mode is selected for each block by minimizing the residual between the encoded block and its prediction.

Table 1: Intra 4x4 prediction modes

Num	Intra 4x4 prediction Mode
0	vertical
1	horizental
2	DC
3	Diagonal-down-left
4	Diagonal-down-right
5	Vertical-Right
6	Horizontal-down
7	Vertical-left
8	Horizontal-up

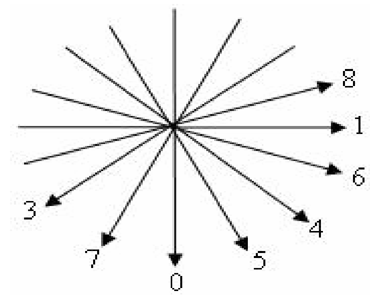

Fig..1 Prediction directions

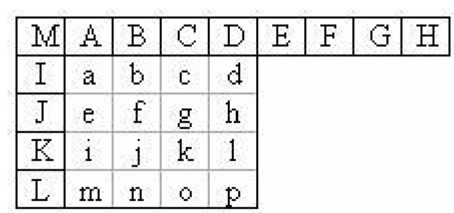

Fig. 2. Block prediction process.

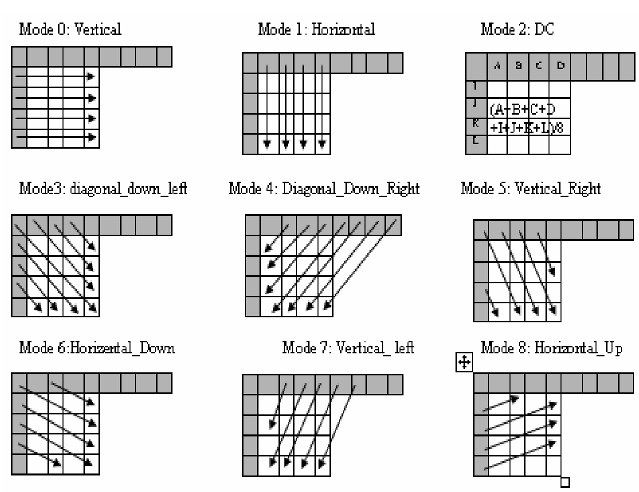

Fig. 3. Nine modes of 4x4 intra prediction in H.264/AVC.

In July, 2004, a new profile was added to H.264 video coding standard, called the Fidelity Range Extensions (FRExt, Amendment 1), which demonstrates even further coding efficiency against MPEG ¡ 2, potentially by as much as 3:1 for some key applications [9]. In the FRExt amendment, an additional intermediate prediction block size of 8x8 was introduced for spatial luma prediction by extending the concepts of 4x4 intra prediction in an effort to improve coding efficiency. For the 8x8 luma intra prediction, 9 prediction modes are used which are the same as that of 4x4 intra prediction. However, the computational complexity of the H.264 encoder is dramatically increased according to this feature of the new extended profile.

2.2 16x16 luma and 8x8 chroma intra prediction modes

The 16x16 luma intra prediction modes are selected in relatively homogeneous area; four prediction modes are supported as listed in Table.2 comprising of the dc, vertical, horizontal and plane prediction. These modes are specified similar to modes in Intra-4x 4 predictions except the plane prediction. In vertical prediction, each of the 16 columns (of 16 pixels each) of current macroblock are predicted using only 1 past decoded pixel each, similar to the case of prediction of 4 pixels of column by a single decoded pixel in the case of 4x4 intra prediction. The horizontal prediction predicts an entire row of 16 pixels by a past decoded neighboring pixel; the process is repeated for each of the 16 rows. The dc prediction uses an average of past decoded row and column of pixels to predict all pixels of the 16x16 block. The planar prediction uses weighted combination of horizontal and vertical adjacent pixels. The neighboring pixels used for prediction of 16x16 luminance component of current macroblock belong to neighboring decoded macroblock. For the chrominance (chroma) components, there are 4 prediction modes that are applied to the two 8x8 chroma blocks (U and V), which are very similar to the 16x16 luma prediction modes such as DC (Mode 0), horizontal (Mode 1), vertical (Mode 2), and plane (Mode 3). To take the full advantage of these modes, the H.264 encoder selects the best mode using the rate distortion optimization (RDO) technique.

Table. 2. Intra 16x16 prediction modes

Num	Intra 16x16 prediction mode
0	Vertical
1	Horizental
2	DC
3	Plan

H.264/AVC encodes the MB by iterating all the luma intra decisions for each possible chroma intra prediction mode for the best coding efficiency. Therefore, the number of mode combinations for luma and chroma components in an MB is N8-chr*(N4*16 +N8*4+N16), where N8-chr, N8, N4, and N16 represent the number of modes for 8x8 chroma blocks, 8x8, 4x4 and 16x16 luma blocks, respectively. It means that, for an MB, it has to perform 4*(9*16 +9*4+ 4) = 736 different RDO calculations before a best RDO mode is determined. As a result, the complexity of the encoder is extremely high. To reduce the encoding complexity with little RD performance degradation, a fast intra-mode decision method is proposed in the next section.

3. Proposed Fast Intra Mode Decision

H.264/AVC standard checks all possible intra prediction modes of every block which belongs to P-frame as well as I-frame in order to achieve optimal coding efficiency. The Rate Distortion optimization (RDO) method used for mode decision in h.264 can achieve higher compression efficiency, but it also brings a bout a large computation complexity due to the transform and entropy coding for each mode. To reduce this complexity, few approaches have been proposed on fast intra prediction algorithm. In (Pan et al., 2003), it is based on the local edge information, and thus adopts the edge direction to predict the possible mode. In (Jongho Kim* and Jechang Jeong, 2005), the directional masks and mode information of neighboring blocks used to select the probable modes. In (Jun Sung Park, and Hyo Jung Song, 2006), it is based on the idea that direction of a bigger block is similar to that of smaller block, the effects of fast mode decision is reduced. Therefore, as an alternative method, we propose a fast intramode decision method based a fort correlation of adjacent direction and the direction of a smaller block is similar to that of bigger block.

3.1 intra-modes decision for 4x4 luma blocks

In order to achieve RDO, conventional transform domain intra prediction mode decision method, uses full search (FS) method to evaluate the Lagrange cost of all nine 4x4 intra prediction modes and select the prediction mode that yields the minimum cost. Therefore, the computation of rate-distortion optimized intra prediction mode decision is computationally expensive. Our proposed method pre-selects a candidate set of most probable 4x4 intra prediction modes in transform domain such that fewer intra prediction modes are examined for RDO. The key idea of our schemes stems from the fact that the prediction modes of each block are correlated with those of neighboring modes prediction and the directional correlation of each block is consistent with directions of the edges. From this idea, for each 4x4 luma blocks, we obtain a candidate mode using simple directional masks from the horizontal edge, the vertical edges, the diagonal down right and the diagonal down left as shown in figure 4.

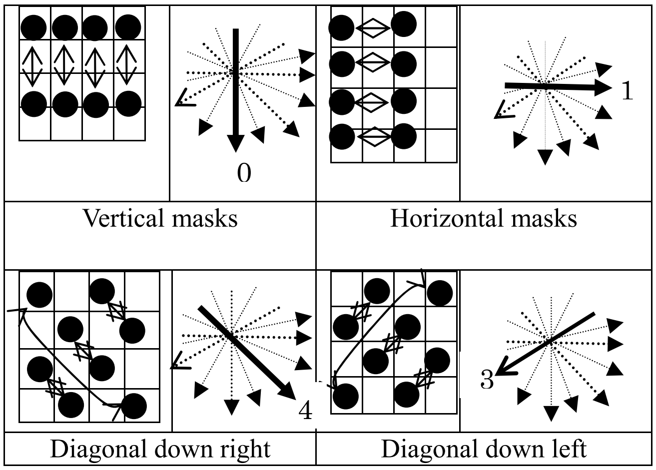

Fig. 4. The proposed directional masks for 4x4 luma blocks

In Figure 4, the block dots and arrows represent the pixels to be examined and directions of correlation, respectively. Since with our algorithm, we reduce the number of direction of the 4x4 intra predictions from nine directions to a four direction. We selected two candidates with minimum and second minimum cost from this four proposed edge direction.
The cost criterion is described in Table 3.

Table. 3. Equations to select a candidate mode using directional masks

Num	Mode name	Equations for cost
0	vertical	Cost=|a-i|+|b-j| +|c-k|+|d-l|
1	Horizontal	Cost=|a-c|+|e-f| +|i-k|+|m-o|
3	Diagonal-down-left	Cost=|b-e|+|g-j| +|l-o|+|d-m|
4	Diagonal-down-right	Cost=|c-h|+|f-k| +|i-n|+|a-p|

In Table 3, the letters used in equations indicate pixel positions in Figure 1, and Cost means SAD (Sum of Absolute Difference) for choosing a candidate mode. Since we regard that a direction with the minimum Cost is consistent with a direction of an edge or maximum correlation, we select the mode with the minimum Cost by the equations in Table 3, as a candidate mode. The candidate set of most probable 4x4 intra prediction modes to examined with RDO are selected with the two modes of prediction already determined and the notion of fort correlation between adjacent mode, Is described as fellow:

(i) If a mode vertical (mode 0) is a minimum cost and mode diagonal down right (mode 4) is the second minimum, candidate mode of the 4x4 block are mode vertical (mode 0) and mode vertical left (mode 7). Else, if a mode diagonal down right (mode 4) is a minimum cost and mode vertical (mode 0) is the second minimum, candidate mode of the 4x4 block are mode diagonal down right (mode 4) and mode horizontal down (mode 6).

(ii) If a mode diagonal down right (mode 4) is a minimum cost and mode horizontal (mode 1) is the second minimum, candidate mode of the 4x4 block are mode diagonal down right (mode 4) and mode vertical right (mode 5). Else, if a mode horizontal (mode 1) is a minimum cost and mode diagonal down right (mode 4) is the second minimum, candidate mode of the 4x4 block are mode horizontal (mode 1) and mode horizontal up (mode 8).

(iii) If a mode vertical (mode 0) is a minimum cost and mode diagonal down left (mode 3) is the second minimum, candidate mode of the 4x4 block are mode vertical (mode 0) and mode vertical right (mode 5). Else, if a mode diagonal down left (mode 3) is a minimum cost and mode vertical (mode 0) is the second minimum, candidate mode of the 4x4 block are mode diagonal down left (mode 3) and mode vertical left (mode 7).

(iv) If a mode diagonal down left (mode 3) is a minimum cost and mode horizontal (mode 1) is the second minimum, candidate mode of the 4 £ 4 block are mode diagonal down left (mode 3) and mode vertical left (mode 7). Else, if a mode horizontal (mode 1) is a minimum cost and mode diagonal down left (mode 3) is the second minimum, candidate mode of the 4x4 block are mode horizontal (mode 1) and mode horizontal down (mode 6).

(v) If a mode horizontal (mode 1) is a minimum cost and mode vertical (mode 0) is the second minimum, candidate mode of the 4x4 block are mode horizontal (mode 1) and mode horizontal up (mode 8). Else, if a mode vertical (mode 0) is a minimum cost and mode horizontal (mode 1) is the second minimum, candidate mode of the 4x4 block are mode vertical (mode 0) and mode vertical left (mode 7).

(vi) Else, the candidate mode of the block is mode 2 (DC) and mode with minimum cost.

According to the criteria described above, we can determine the candidate groups as shown in Table 4.

Table. 4. Candidate modes for 4x4 intra prediction

Minimum cost modes	Second Minimum cost modes	Candidate modes
Modes 0	Modes 4	Modes 0, 7
Modes 4	Modes 0	Modes 4, 6
Modes 0	Modes 3	Modes 0, 5
Modes 3	Modes 0	Modes 3, 7
Modes 1	Modes 4	Modes 1, 8
Modes 4	Modes 1	Modes 4, 5
Modes 3	Modes 1	Modes 3, 7
Modes 1	Modes 3	Modes 1, 6
Modes 0	Modes 1	Modes 0, 7
Modes 1	Modes 0	Modes 1, 8

3.2 Intra-modes decision for 8x8 luma blocks

The FRExt amendment initiative was motivated by the rapidly growing demand for coding of higher-fidelity video material, especially in application areas like professional film production, video post production, or high-definition TV/DVD. In this amendment, an intermediate prediction block size of 8x8 was introduced for spatial luma prediction by extending the concepts for 4x4 intra prediction, but with a prediction block size that is 8x8 rather than 4x4 and with low-pass filtering of the predictor to improve prediction performance. The RD optimization process of 8x8 intra modes is quite complex. To solve this problem, we can reduce the computational complexity by cutting down the number of candidates for the best intra prediction mode. In our experiments, we observe that the dominating direction of a smaller block is similar to that of bigger block. As in Fig. 5, the best prediction mode of 4x4 luma block within 8x8 blocks has the same direction as that of 8x8 luma block. From these observations, for each 8x8 luma block, the resultant modes selected with the four 4x4 luma blocks constructed these 8x8 luma blocks, are the candidate modes of the 8x8 luma intra prediction mode. Thus, for each 8x8 luma block, the number of candidate modes can be reduced from nine to a number between four and one. Fig.6. Illustrates the flow chart of the proposed 8x8 intra prediction mode decision method.

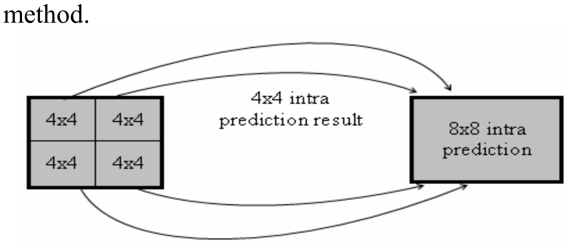

Fig. 5. The scheme of applying 4x4 intra prediction modes result

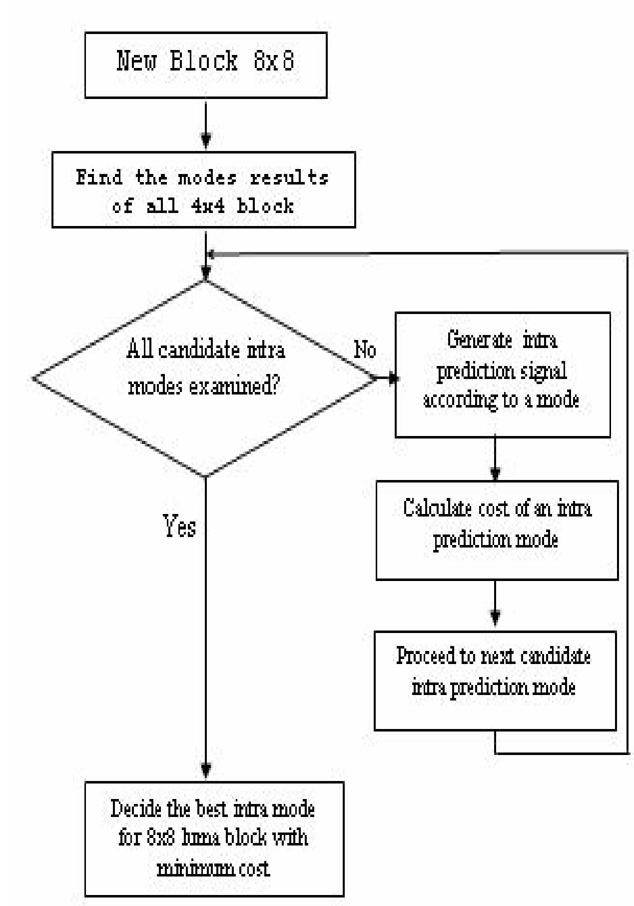

Fig. 6. Flow chart of proposed 8x8 intra prediction mode decision method

3.3 Intra-mode decision for 16x16 luma macroblocks

In H.264/AVC standard video coding, the 16x16 luma intra prediction modes are selected in relatively homogeneous region. Therefore, for 16x16 luma macroblocks, there are only 4 directional modes, different from the case of 4x4 luma blocks, such as horizontal, vertical, DC and plane mode. So for fast intra prediction mode decision, We have implemented the fast 16x16 intra-mode prediction algorithm based on modes of 8x8 luma blocks make this macroblock. This algorithm is composed of two steps as shown below.

(i) Step 1: for each 16x16 luma macroblock, obtain the modes of each 8x8 luma block constructed this macroblock.

(ii) Step 2: in this case, with modes result of 8x8 luma block already selected in step 1, the candidate set of most probable 16x16 intra prediction modes is selected that results are summarized in Table 5.

Table .5 Candidates 16x16 modes according to 8x8 mode

8x8 modes	Candidate 16x16 modes
Modes 7, 0, 5, 2	Modes 0 (vertical)
Modes 8, 1, 6, 2	Modes 1 (horizontal)
Modes 0, 1, 3, 4, 2	Modes 2 (DC).
Modes 0, 1, 3, 2	Modes 3 (plane).

3.4 8x 8 Chroma Intra Prediction Modes

The chroma intra prediction mode of H.264 consists of four modes: DC, horizontal, vertical, and plane mode. These modes are the same as for the luma component in Intra 16x16 macroblocks. we can reduce the number of RDO computations for 8x8 chroma blocks from 4 modes to a number between 1 and 2 modes, according to the best prediction mode of the 16x16 luma blocks, the DC chroma intra prediction is always selected and the second candidate mode of chroma prediction is set to the best mode of 16x16 luma intra prediction. If the best mode of 16x16 luma predictions is DC, then the candidate mode is DC mode only.

3.5 Analysis of Computational Complexity

Table 6 compares the number of candidate modes selected for RDO calculation. As can be seen from Table V, the encoder with the fast mode decision algorithm would need to perform only 1*(1*16 + 1) =17 if the 8x8 intra prediction mode not used. In case that the 8x8 luma block for H.264/AVC FRExt is applied, the mode combination complexity is reduced to a number 1*(1*16+1*4+1) = 21 with our algorithm. Thus our proposed algorithm reduces number of RDO calculation significantly compared to the 1*(4*16 + 4*8 + 4) = 100, 2*(4*16 + 9*8 + 2) = 440 and 4*(9*16 + 9*4 + 4) = 880 modes that are used in the current RDO calculation in H.264/AVC FRExt video coding with (J. S. Park and H. J. Song 2006), (F. Pan, X. Lin,..2005) and Full search method of H.264 respectively

Table 6. Comparison of the number of the candidate modes

block type	Full mode	Pans method	Park method	Jongho method	proposed method
4x4 (Y)	9	4	4 to 7	4	1 to 2
8x8(Y)	9	9	4 to 7	9	1 to 4
16x16(Y)	4	2	4	2	1 to 4
8x8(U,V)	4	2 to 3	1 to 2	2	1 to 2

4. Experimental Results

To evaluate the performance of the proposed method, our proposed method was implemented into H.264/AVC reference software JM10.1 [17] and tested with various Quantization Parameters QP. The system platform is the Intel Pentium 4 Processor of speed 1.8GHz, 512MB DDR RAM, and Microsoft Windows XP. The test conditions are as follows:
(1) MV search range is 16 pixels for QCIF, CIF; (2) RD optimization is enabled; (3) Reference frame number equals to 5; (4) CABAC is enabled; (5) GOP structure is IPPPP or I-frame only; (6) the number of frames in a sequence is 100. Comparisons with the case of exhaustive search were performed with respect to the change of average PSNR (4PSNR), the change of average data bits (4Bit), and the change of average encoding time (4Time), respectively. In order to evaluate the timesaving of the fast intra mode decision algorithm, the following calculation is defined to find the time differences. Let TJM denote the coding time used by JM10.1 encoder and TFI be the time taken by the fast intra mode decision algorithm, and is defined as:

$$\Delta Time = {T_{FI} - T_{JM}} / {T_{JM}} * 100\%$$

Table 7 shows the simulation results of the proposed algorithm with JM10.1 for various sequences with IPPP type. The quantization parameter set was chosen to be [10, 14, 18,...42,46]. It can be seen that the proposed algorithm achieves very high encoding time saving (up to about 82.05%) with a little loss of PSNR and increment of bitrates. Tables 8 and 9 show the tabulated performance comparison of our proposed with the full search method for different image sequences described below. Note that in the tables, positive values mean increments and negative values mean decrements. Experimental results of the proposed method show a significant reduction of computation in between 70.68%, and 84.68%, a slight increase in bit rate in between 1.5% and 3.93%, and similar PSNR in comparison with full search method.

Table 7. Simulation results for IPPP sequences.

sequences	Y-PSNR(dB)	UV-PSNR(dB)	Bitrate (%)	Time(%)
mobile	-0,312	-0,047	+2,54	-82,05
news	-0,352	-0,097	+4,72	-76,77
silent	-0,313	-0,042	-0,02	-78,11
salesman	-0,378	-0,093	+0,99	-78,43
Claire	-0,434	-0,214	+2,37	-76,13
grandma	-0,311	-0,080	-0,30	-75,06
Mthrdotr	-0,399	-0,134	+0,17	-76,78

Fig. 7, 8, 9 shows the RD performance and the computation time for the sequences "silent". It can be seen from these figures that the two RD curves, one from the original full search and the other from the proposed algorithm, are almost overlapping each other. It means that the performance of the proposed algorithm is almost similar to that of the original full-search. From Fig. 9 we can observe that the encoding time with fast intra modes decision is distinctly less than that of without full search under the same test conditions.

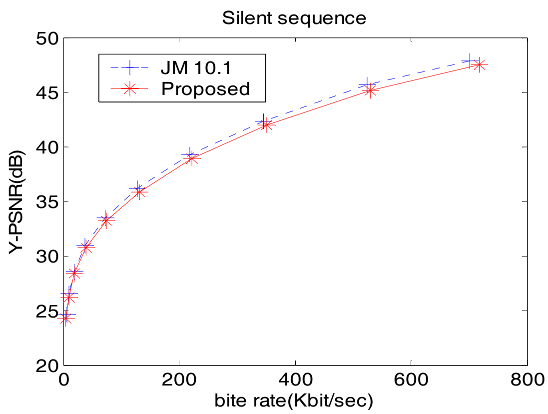

Fig. 7. Comparison of PSNR-Y and bit-rate for the Silent sequences

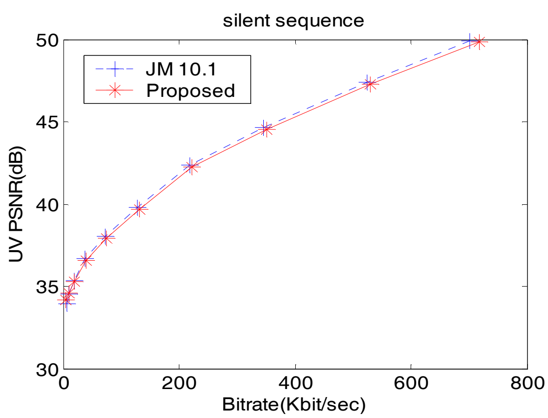

Fig. 8. Comparison of PSNR-UV and bit-rate for the silent sequences

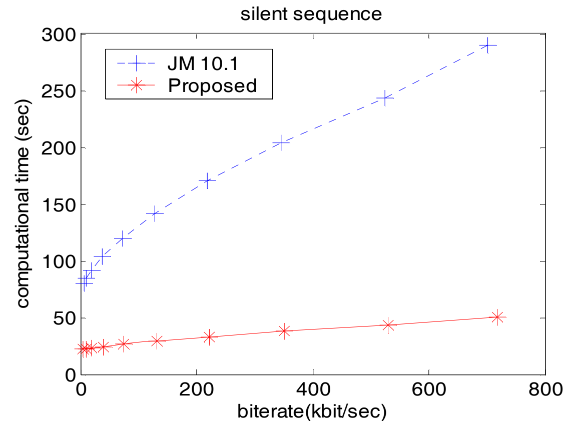

Fig. 9. The computational time comparison of silent sequence

5. Conclusion

In this paper, a fast intra prediction mode decision method for H.264 video coding is proposed based on the directional information and the observation that the dominating direction of a smaller block is similar to that of bigger block. With our method, the number of mode combinations for luma and chroma blocks in an MB that takes part in RDO calculation has been reduced significantly from 880 to as low as 69. From the experimental results, we can see that the proposed method can achieve a considerable reduction of computation complexity while maintaining similar bit rate and PSNR.

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Table 8. Resultants on QCIF test sequence "Grandma".

PQ	Method	Y-PSNR(dB)	U-PSNR(dB)	V-PSNR(dB)	Bitrates(Kbit/sec)	Complexity
10	FS	47,68	48	48,84	633,26	262,468
	Proposed	47,33	47,94	48,76	643,76	51,046
	Δ Improved	-0,35	-0,06	-0,08	+1,66%	-80,55%
18	FS	42,7	44,3	44,87	278,29	180,669
	Proposed	42,25	44,22	44,74	282,47	38,048
	Δ Improved	-0,45	-0,08	-0,13	+1,50%	-78,94%
26	FS	36,67	39,99	40,43	83,72	125,285
	Proposed	36,34	39,99	40,31	83,96	30,999
	Δ Improved	-0,33	-0	-0,12	+0,29%	-75,26%
34	FS	31,79	36,36	37	17,67	94,826
	Proposed	31,55	36,3	37,1	17,09	26,188
	Δ Improved	-0,24	-0,06	-0,1	-3,28%	-72,38%
42	FS	28,22	33,88	34,99	4,1	83,278
	Proposed	27,98	33,85	34,77	3,97	24,421
	Δ Improved	-0,24	-0,03	-0,22	-3,17%	-70,68%

Table 9. Resultants on QCIF test sequence "Mobile".

PQ	Method	Y-PSNR(dB)	U-PSNR(dB)	V-PSNR(dB)	Bitrates(Kbit/sec)	Complexity
10	FS	49.54	49,7	49,63	3987,39	445,608
	Proposed	49.1	49,63	49,57	4062,48	68,27
	Δ Improved	-0.44	-0,07	-0,06	+1,88%	-84,68%
18	FS	42,15	42,4	42,33	2287,06	336,327
	Proposed	41,76	42,33	42,25	2345,1	52,158
	Δ Improved	-0,39	-0,07	-0,08	+2,54%	-84,49%
26	FS	34,63	35,47	35,28	1343,21	238,099
	Proposed	34,31	35,38	35,21	1363,37	39,941
	Δ Improved	-0,32	-0,09	-0,07	+1,50%	-83,23%
34	FS	27,79	29,96	30,1	710,77	168,688
	Proposed	27,59	29,9	30,07	732,09	31,092
	Δ Improved	-0,2	-0,06	-0,03	+3,00%	-81,57%
42	FS	21,83	26,42	26,1	291,87	119,27
	Proposed	21,61	26,39	26,14	303,33	25,393
	Δ Improved	-0,22	-0,03	-0,04	+3,93%	-78,71%