Research on Adjacent Blocks Prediction Mode Selection Algorithm Applied in Video Coding

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Abstract: For high computation complexity of H.264 video coding rate distortion optimization process, this thesis puts forward the adjacent block prediction mode selection algorithm. Using direction gradient to detect texture direction and edge strength of the current block and its neighborhood, screening out the prediction mode with larger direction gradient prior to the R - D cost calculation, the algorithm can reduce the complexity of the rate distortion optimization. Experimental results indicate that, compared with other algorithms using block texture detection, this algorithm maintains the coding performance and decreases encoding time by 50%.

Keywords: Chrominance Components; Distortion; Coding Complexity; Node

1. Introduction

H. 264 is a new generation of digital video compression format co-put forwarded by the International Organization for Standardization (ISO) and International Telecommunication Union (ITU) after MPEG4. H. 264 is one of the video codec technology standard named by the ITU - T according to H.26x series. The H.264 codec is not only designed to meet the demands of application with high compression ratio movement image compression, such as video conference, digital storage media, television broadcast, network streaming media and communication applications, but also a flexible way of encoding data representation for the application of different network environment. On one hand, it makes motion video can works as a kind of computer data to be processed and be stored in a variety of media; on the other hand, eventually it can both transmit and receive on current and future network, and be allocated on the present and future broadcast channel. In order to achieve higher compression efficiency, H.264 employed some new technologies, such as intra-frame coding space prediction, inter-frame coding adaptive block size, multiple reference pictures, 4*4 integer transform, binary arithmetic coding (CABAC) and rate distortion optimization (RDO) based on the context. Test results show that H. 264 has been greatly beyond the existing video coding standard in peak signal-to-noise ratio (PSNR) and video compression ratio.

In recent years people have conducted a lot of research on intra-frame prediction algorithm and put forward lots of fast algorithm for reducing the computation complexity. They can be divided into two types: one is to narrow the range options of prediction mode based on the correlation of current block and adjacent pixels; another is to utilize the related function of RD performance as the basis of mode selection, so as to simplify the cost function. Intra-frame and inter-frame prediction mode selection based on H.264 usually adopt Rate Distortion Optimization (RDO technology) to select the optimal prediction mode. As a result, although lowering output Rate, it greatly increases the coding time, which is unable to meet the requirements of real-time video communication, so H. 264 encoder computation complexity must be reduced. In fact, many fast algorithms are created to reduce the video encoding time and improve the coding efficiency.

Intra-frame prediction coding is an important part of the H. 264. The fast frame prediction algorithm proposed by Feng, a fast frame prediction algorithm based on boundary direction histogram, can preclude some prediction direction with small possibility, only 3 ~ 4 the predicting direction computed one time; Liu Pengyu put forward one prediction algorithm, which uses the gray histogram macro blocks in intra 16*16 and intra 4*4 mode selection, as well as referring to the features of 4*4 block; Zoran Milicevic optimized algorithm based on both the correlation of 16*16 macro block and 4*4 block and inter-frame prediction optimization algorithm, so as to simplified frame and inter-frame prediction mode, shorten the encoding time, but get a great loss on SNR(Signal to Noise Ratio); Chen Hao put forward a scheme, based on the template and the double threshold to predict fast algorithm which did a negative effect on the flatness of the 16*16 judgment and frame coding time on threshold value.

In order to further verify the correctness and validity of the proposed mode selection algorithm based on prediction of adjacent block, simulation experiment was conducted. As a consequence, the basic algorithm and improved algorithm, whose encoding time are reduced more than 50%, compared with JM18.0 full search method on luminance component frame prediction mode selection, having well maintained the coding performance at the same time. On 10 standard series tests, the luminance component kept same as the JM18.0 full search, the bit rate of basic algorithm rise by 2.361%, improved algorithm rate rise by1.477% on average. Experimental results show that in this paper, the basic algorithm and coding complexity are basically same, which achieved a significant lower level compared with full search way, maintained the coding performance well. Besides, the coding performance of improved algorithm is obviously superior to the classic algorithms.

2. Intra-Frame Prediction

Intra-frame coding mode is an important part of video coding, which is mainly used in the following situations: (1) The first frame of the video sequence. Because the first frame of the video has no good encoded frame as the reference frame, intra-frame coding used as a solution. (2) The frame I coding method. (3) Some macro blocks of frame P and frame B. H.264 employs a macro block coding way, which will divide video into macro block and select the optimal prediction model according to the RDO value of macro block, therefore the macro block of frame P or B is likely to be chosen as intra-frame prediction model of encoding. (4) Error recovery. While by using inter-frame coding, errors appear in the process of transmission channel, the decoding end cannot get the information of reference block or get false information, so that the current macro block at the decoding end cannot correct decoding. However, in such cases the intra-frame coding approach can be adopted. H.264 frame prediction coding divided the predicted brightness into16*16 block and 4*4 blocks: 16*16 macro blocks prediction model is suitable for those with gentle change; 4*4 macro blocks applied to those containing many details; also the 8*8 block chromaticity prediction included. Furthermore, on brightness prediction model there are 9 kinds of to 4*4 blocks and 4 kinds to16*16 blocks. On prediction model of chromaticity, there are 4 kinds to 8*8 blocks. Figure 1 (a) the capital letters in A ~ M are the complied codes on the above and left of the 4*4 brightness blocks and the reconstruction of the pixel can be predicting reference pixel.

In H.264 standard, in order to get the optimal intra-frame prediction mode, RDO technique is often used, selecting minimum prediction model of the RDO calculation cost function as the prediction model of the current block. RDO function is below:

$$RDO_{\cos t} = SSD + \lambda_{\mathrm{mod}\, e} \times Rate \tag{1}$$

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

Figure 1. (A) Location of 4*4 block and its adjacent pixels

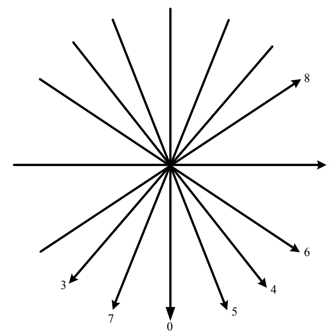


Figure 2. (B)Prediction direction of 4*4 block

Among them, the SSD represents the sum of difference of squares for the primitive and reconstruction blocks pixels; λmode is for Lagrange Multiplier, which is related to Quantization Step QP and the frame type; Rate represents the number of bits used in the forecasting modes.

RDO technology of H.264 standard will iterate over all prediction modes to get the optimal one That is to say, after forecasting, transforming, quantization, coding with every mode, coding bit number (Rate) can be obtained. Then images are reconstructed by inverse quantification and inverse transformation, so as to get distortion degree (SSD) of the original and reconstructed blocks. Therefore, RDO calculation is complicated and time-consuming. In reference procedures JM, the number of RDO calculation to each macro block is C8*(L416+L16), in which C8 represents chromaticity number of 8*8 blocks mode, L4 is the number of brightness in 4*4 blocks prediction mode, L16 represents the brightness number of 16*16 blocs prediction mode. In conclusion, getting a macro block needs compute 4*(9*16+4) = 592 times to obtain the optimal prediction mode, so mode selection algorithm of the H.264 standard is of very high complexity.

3. Mode Selection Algorithm Based on Prediction of Adjacent Blocks

3.1. Mode Selection Model

In order to reduce the encoding complexity, it intends to construct an encoding performance estimation model of low complexity based on intra-frame mode selection algorithm of filtering, screening out coding modes with poor performance prior to RDO, so as to reduce the R - D cost calculation and lower the encoding complexity. This paper adopts direction gradient as the direction of the prediction mode coding performance estimation model to conduct mode selection. The direction gradient of direction prediction model is defined as the mean absolute deviation between current block pixels and its maximum weighted reference pixel in the predicted direction.

$$G(dir) = \frac{1}{n} \sum_{x \in R, x \in C, Xx//dir} | P_X - Ix | \quad (2)$$

dir is the prediction direction; R and C are respectively reference pixel and the sampling subset of current block pixel; Xx / /dir represents consensus of lining between the sampling reference pixel X and the current block pixel X and that in forecasted direction; n is the number of sampling pixels; Px and Ix are respectively the reconstruction value of the reference pixel X value and the original value of the current block pixel X. In function (2), G (dir) is reference pixel in prediction direction and direction gradient of the current block, whose value refers to the edge strength in orthogonal direction of predicted one. Meanwhile, G (dir) is also approximation of prediction residual mean absolute value of the current block in predicted direction, prediction residual energy information included. Therefore, combination of texture direction of image with context the in direction gradient defined by function (2) and the current block prediction residual, indicates the good estimation on coding performance of prediction mode.

3.2. Gradient Computation

In order to simplify the calculation, only give direction gradient with a few typical prediction pixel and reference pixel computational prediction model. The paper sample the number of pixels in power of 2 as the direction of gradient, transforming the division as operation shift to speed up calculation, with I4MB sampling of four pixels, I8MB sampling eight pixels, I16MB sampling 16.

Figure 2 (a) ~ (d) sample the gradient direction calculation method of I4MB in four direction prediction modes, among which dark pixels said of reference pixels and the current block pixels involved in calculation.

As the figure 2 (a) shows, in the vertical prediction mode of I4MB, the current block is forecast by reference block pixel A ~ D, and gradient direction was calculated by the function (3) as below:

$$\begin{cases} G(A) = | P_A - I_c | + | P_A - I_m | \\ G(C) = | P_C - I_g | + | P_C - I_o | \\ G(ver) = (G(A) + G(C)) \ ? \ 2 \end{cases} \quad (3)$$

PA, PC, respectively, are on behalf of the reconstruction value of the reference pixel of A and C; Ie, Im, Ig, Io are respectively the original value of the current block pixels m e, g, o; G (A) and G (C) are gradient of reference pixel A and C to the current block; G (ver) is the direction gradient of the vertical prediction mode (mode 0).

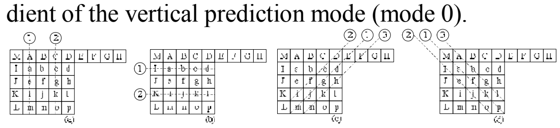


Figure 3. Direction Gradient Calculation of I4MB Prediction Mode

In the 4MB horizontal forecast mode, the predicted value of each line's pixel of current block is equal to its reconstruction value of the reference pixel I ~ L, which is shown in figure 2 (b), and the direction gradient calculated by function (4):

$$\begin{cases} G(I) = | P_I - I_b | + | P_I - I_d | \\ G(K) = | P_K - I_i | + | P_K - I_l | \\ G(hor) = (G(I) + G(K)) \ ? \ 2 \end{cases} \quad (4)$$

3.3. Mode Selection Algorithm

Direction gradient of prediction mode contains texture direction, edge strength and residual energy information between reference pixel and the current block, and can be used as mode estimation on coding performance before simplifying mode. However, the direction gradient can not demonstrate modes' coding performance completely accurately. Mode with minimum gradient is the much better prediction mode, not the best during the actual coding process. At the same time, in the H.264 mode DC is taken as boundary prediction, which is of superior performance in plain area. Therefore, the prediction model is not directly the mode of smallest gradient direction but the mode DC and those with smaller direction gradient as candidates for rate distortion optimization.

As Table 1 shown, in the sequences Foreman. qcif and Tempete. cif, all100 frames use I4MB mode, selecting the mode DC and the minimum direction gradient in 1 ~ 7 kinds direction prediction mode for luminance component prediction to have RDO performance test. Results showed that the mode number more, the performance of coding better; select mode DC and direction mode with three gradient modes can be well achieved encoding time and the balance with coding performance. Other sequence and experiment using I8MB gained similar consequence.. Based on this observation, for the I4MB and I8MB, we have chosen three direction mode with minimum gradient direction and mode DC as a candidate for RDO, taking mode of minimum R - D cost as the optimal prediction mod 4*4 sub-block and 8*8 sub-block l. Whereas for I16MB choose the smallest one among the only three direction modes, selecting direction mode of smallest direction gradient and mode DC as a candidate for RDO, taking the prediction mode with less R - D cost as its optimal one. Then, accumulate of R - D price of in the optimal prediction mode, 4*4 sub-block of I4MB, all 8*8 blocks of I8MB to calculate out R - D cost of macro blocks for I4MB, I8MB and I16MB macro block, which are the best prediction mode's R - D price respectively. Finally, among these three modes by three ways, choose R - D minimum cost of macro blocks as the optimal to predict, and adopt the best method of each sub-block in the optimal prediction mode to do intra-frame prediction. Therefore, under such an advanced grade the times of calculating of luminance component with each macro block is 4 * 4 * 4 + 4 * 2 * 2 + 2 = 82. R - D cost calculation, without chrominance component mode, times of R - D cost calculation of macro block is reduced to 4*82 = 382.

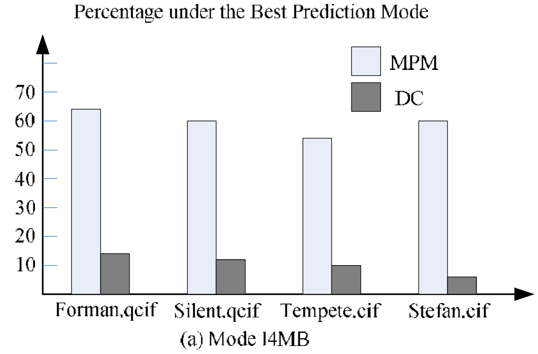
3.4. Algorithm Improvement

Image's spatial correlation not only exists between brightness and chromic value of adjacent pixel, but also manifest in its texture structure. Many areas in natural images between adjacent blocks owns similar edge characteristics and same texture direction, and the best prediction mode of these neighboring blocks tend to be the same, which means there also exists certain spatial correlation between adjacent block's prediction mode. Taking advantage of this feature, using the mode MPM as a candidate of RDO mode can effectively improve coding performance of mode selection algorithm.

The most possible mode MPM of I4MB and I8MB in H.264 is defined as the minimum number of prediction mode of the current block on the left and upper adjacent blocks, and those not on the left and upper take mode DC as the MPM. I16MB has no definition on MPM. Figure 3 manifests the percentage between the block of the best prediction model of MPM under the multiple sequence search mode and mode DC with all blocks, figure 3 (a) and (b) respectively account for I4MB and I8MB mode. Obviously, frequency of both I4MB and I8MB under MPM as the best mode is much higher than that of mode DC. So we improved the basic algorithm that adopting I4MB and I8MB mode in MPM to replace DC mode as the default candidate. Under I4MB and I8MB candidate mode selection, calculating the direction gradient for each block in the direction mode, choose three kinds of modes with smallest direction gradient under I4MB and I8MB as a candidate. If MPM mode gathers the candidates, those in DC mode also join the MPM to candidate mode. I16MB candidate mode selection and the basic algorithm are in the same. Due to the same number of RDO with candidate in the mode, so the complexity of basic algorithm and the improved algorithm are basically the same.

Table 1. Performance Comparison of I4MB by Different Modes (Full Frame I Coding).

Number of Direction modes	Tested Performance of Sequence Foreman. qcif			Tested Performance of Sequence Tempete. cif		
	⊿PSNR/dB	⊿BR/%	⊿Time/%	⊿PSNR/dB	⊿BR/%	⊿Time/%
1	-0.716	10.445	-72.53	-0.601	8.194	-73.87
2	-0.344	4.860	-62.27	-0.368	4.948	-61.84
3	-0.250	3.502	-51.65	-0.237	3.173	-50.90
4	-0.178	2.490	-41.76	-0.161	2.148	-39.09
5	-0.117	1.624	-31.14	-0.096	1.257	-27.21
6	-0.047	0.645	-20.15	-0.051	0.666	-15.33
7	-0.032	0.446	-6.96	-0.017	0.220	-3.67



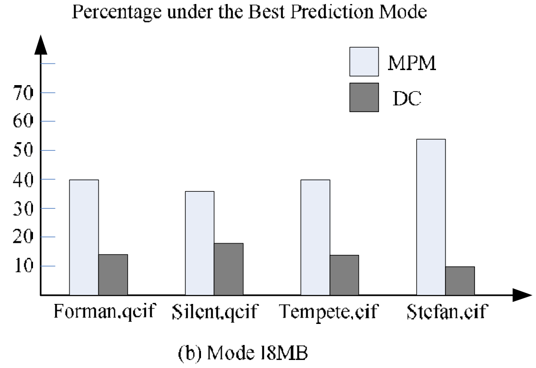


Figure 4. Comparison of MPM as Best Prediction Mode with Mode DC

4. Experimental Simulation and Analysis

4.1. Experimental Comparison Algorithm

After compared with the performance of algorithm proposed in the paper, in the best current algorithm DES and SDD use block segmentation to detect texture strength, which did not provide the brightness component I8MB mode selection method. However, we set the size of the 2*2 sub-block as 4*4 and then referring to I4MB mode to extend the two algorithms. In addition, DES algorithm provides an option of exiting, which is when all the direction gradient values are greater than a threshold, perform full search. But considering the validity of the experiment method, this option is cancelled. In the book "A fast mode decision algorithm and its VLSI design for H.264 intra – prediction ", while algorithms detect edge information without the direction, a full search is also performed. It is a selection branch of algorithm. In order to keep the integrity of algorithm, the implementation is maintained. Algorithm the paper researched does not perform full search in all conditions. At the same time, for the chrominance components of prediction is relatively simple, all comparative experiments don't conduct UV component prediction mode selection algorithm.

4.2. Coding Parameters and Evaluation Index

Experiments evaluate methods performance based on JM18.0 full search strategy. Evaluation indexes include the luminance component PSNR of coding performance index, losses Δ PSNR (dB) of bit rate (BR), and reduced percentage Δ Time relative to JM18.0 encoding time. Δ PSNR (dB) and Δ BR (%) are respectively coding performance loss of fast algorithm relative to JM18.0 under mode PSNR (no loss rate) and code rate mode (no loss of PSNR). Bjontegaard method is under the four quantitative parameters to convert the PSNR verse bit rate and the average fitting. Test sequence includes five standard 4:2: 0 sequences of qcif, cif. Each sequence is encoded with100 frames and other key parameter settings are below:

Quantization parameter (QP) are 28, 32, 36 and 40;
Frame frequency is 30.0;
All frames adopt frame prediction;
Utilize distortion optimization (RDO);
Entropy code with CABAC;
Encode advanced level (high profile).

4.3. Performance Comparison

Figure 3 and figure 4 compares the Paris, cif sequence JM18.0 and the R - D curve and encoding time of fast mode selection algorithm. Figure 3 shows that the improved algorithm R - D curve in this paper is much closer to the JM18.0 full search curve. The performance points of the quantitative parameters are in the top left of the algorithm, and reconstructed video quality and compression performance are better than comparison algorithm. Although algorithm's coding performance in the document [12] is similar to basic algorithm in this paper, its encoding time is significantly higher than the basic algorithm and improved algorithm in this paper as shown in figure 5. Figure 5 shows, frame coding time in the document [11, 13] is close to the algorithm in the paper, but obvious gap of coding performance can be seen from the figure 4 with two algorithms in this paper.

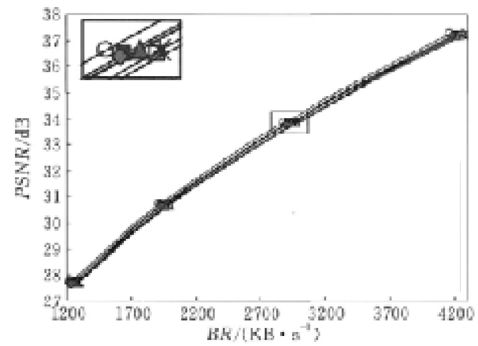


Figure 5. R - D Curve Comparison of Paris, cif Sequence.

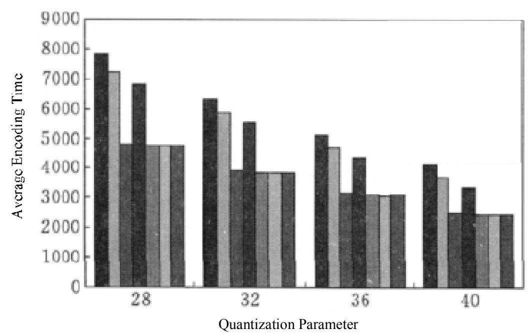


Figure 6. Encoding Time of Paris. Cif Sequence.

Table 2 compares the average coding performance gains and losses of various algorithms in details four quantitative parameters out of 10 test sequences. Compared with JM18.0, the average loss of the basic algorithm in this paper is 0.163 dB PSNR or can reduces the encoding time by about 52% while increasing the encoding rate of 2.361%. The improved algorithm reduces the encoding performance loss fatherly. Compared with JM18.0, it losses 0.101 dB PSNR on average, bit rate is increased by 1.477%, and the encoding time is the same as basic algorithm. (A few sequences like Silent. qcif contain a large number of random textures; the correlation of the current block pixels and neighborhood pixels is low. Document [10] algorithm detects no direction edge information degradation and escapes as the full search method, whose coding performance is close to basic algorithm in this paper. For most sequences, pixels spatial correlation is larger, the current block pixels and neighborhood pixels are in high correlation, but in this paper, the basic algorithm coding performance loss is smaller).

The document [11, 13] algorithms like this paper adopt the same model of a fixed number of candidates to participate in the RDO, so their coding complexity is stable. As sequences' encoding time is same with approach in the paper, but that they all only use block texture feature selection model, which limits the accuracy of model selection and coding performance. Algorithm in document [12] improved algorithm in document [10] from two aspects. On one hand, screening out a kind of coding way based on the macro block of variance in advance reduced the encoding complexity; on the other hand replacing mode DC with MPM improved the coding performance. Though coding performance is better than that in this paper, it is still lower than the improved algorithm of this paper. Meanwhile, like the algorithm of document [10], the algorithms of document [12] detect the edge information without no direction and exit to full search method, but its coding complexity is not stable. The average encoding time has been improved much greatly than that of document [10], but the two algorithms proposed in the paper are still higher about 15%.

Table 3 is the detailed performance comparison of algorithm News. Qcif with quantitative parameter valued as 28 and 32 (the line 2 of table 2). I16MB, I8MB, I4MB columns respectively use I16MB, I8MB, I4MB mode coding. For example, if QP = 28, in JM 18.0, 990 macro blocks use I16MB, 2326 macro blocks use I8MB, and 6584 macro blocks use I4MB mode to predict. The basic algorithm and the improved algorithm in this paper, predict macro blocks in I16MB, I8MB and I4MB, which respectively are1063, 2246, 6591 and 1001, 2139, 6760. Block scheme are better and closer to JM full search method than other algorithms, including the algorithm in document[12] . Same phenomenon exists in other quantitative parameters and other sequence. All algorithms are chosen the optimal partitioning strategy by RDO, which means method based on the direction gradient estimating on the R-D cost is more accurate than the block texture detection method.

Table 2. Integrated Performance Comparison of Frame Mode Selection Algorithm (Full I Frame Coding).

Sequence	⊿PSNR/dB					
	Document [10]	Document [10]	Document [10]	Document [10]	Basic Algorithm	Improved Algorithm
Forman.qcif	-0.159	-0.194	-0.121	-0.232	-0.123	-0.081
News.qcif	-0.291	-0.384	-0.189	-0.316	-0.229	-0.132
Coastguard.qcif	-0.189	-0.312	-0.134	-0.197	-0.163	-0.064
Container.qcif	-0.268	-0.226	-0.046	-0.328	-0.199	-0.116
Silent.qcif	-0.130	-0.184	-0.097	-0.175	-0.147	-0.118
Tempete.cif	-0.161	-0.210	-0.107	-0.210	-0.128	-0.095
Bus.cif	-0.238	-0.235	-0.109	-0.193	-0.119	-0.080
Paris.cif	-0.251	-0.314	-0.136	-0.288	-0.203	-0.112
Mobile.cif	-0.184	-0.258	-0.127	-0.267	-0.153	-0.102
Stefan.cif	-0.186	-0.266	-0.133	-0.241	-0.169	-0.111
Average	-0.206	-0.258	-0.120	-0.245	-0.163	-0.101
Sequence	⊿BR/%					
	Document [10]	Document [10]	Document [10]	Document [10]	Basic Algorithm	Improved Algorithm
Forman.qcif	2.677	3.268	2.036	3.887	2.062	1.357
News.qcif	3.672	4.886	2.362	4.008	2.853	1.627
Coastguard.qcif	3.663	4.550	1.958	3.857	3.157	0.933
Container.qcif	3.892	4.412	0.880	4.783	2.887	2.223
Silent.qcif	2.372	3.332	1.793	3.151	2.645	2.140
Tempete.cif	2.325	3.047	1.546	3.047	1.845	1.369
Bus.cif	3.672	3.624	1.674	2.983	1.837	1.229
Paris.cif	3.248	4.092	1.766	3.745	2.621	1.452
Mobile.cif	2.030	2.853	1.408	2.955	1.694	1.124
Stefan.cif	2.209	3.180	1.575	2.877	2.011	1.313
Average	2.976	3.724	1.700	3.529	2.361	1.477
Sequence	⊿Time/%					
	Document [10]	Document [10]	Document [10]	Document [10]	Basic Algorithm	Improved Algorithm
Forman.qcif	31.74	50.13	42.86	50.82	50.26	51.11
News.qcif	35.06	50.42	45.17	51.29	51.66	51.49
Coastguard.qcif	33.19	49.28	47.14	50.20	50.53	50.60
Container.qcif	35.17	50.38	51.49	51.34	51.21	51.06

Silent.qcif	33.70	50.68	46.98	51.51	51.69	51.44
Tempete.cif	33.86	51.85	42.39	52.65	52.80	52.62
Bus.cif	35.89	51.64	48.52	52.50	52.64	52.62
Paris.cif	35.45	51.46	44.60	52.32	52.45	52.32
Mobile.cif	28.95	52.15	33.60	52.77	53.07	52.83
Stefan.cif	33.01	51.19	41.03	52.10	51.99	51.79
Average	33.60	50.92	44.38	51.75	51.83	51.79

Table 3. Comparison between Coding Performance and Partitioned Pattern of News.

Quantization Parameter	Method	BR/(KB·S-1)	PSNR/dB	Average Encoding Time (ms·frame-1)	116MB	18MB	14MB
QP=28	JM18.0	831.902	38.275	2916	990	2326	6584
	Document [10]	855.917	38.247	1066	1262	2456	6182
	Document [11]	858.156	38.202	805	1363	2301	6236
	Document [12]	845.506	38.185	917	1070	3019	5811
	Document [13]	853.966	38.211	793	1262	2456	6182
	Basic Algorithm	843.358	38.234	785	1063	2246	6591
	Improved Algorithm	834.624	38.194	788	1001	2139	6760
QP=32	JM18.0	473.136	34.147	1081	1291	3051	5558
	Document [10]	605.902	34.871	879	1579	3338	4983
	Document [11]	607.656	34.809	670	1486	3519	4895
	Document [12]	595.231	34.828	747	854	3998	5048
	Document [13]	603.761	34.822	658	1588	3396	4916
	Basic Algorithm	598.956	34.872	653	1342	3103	5455
	Improved Algorithm	590.753	34.846	656	1093	2844	5963

5. Conclusion

For high computation complexity of H.264 video coding rate distortion optimization process, the paper puts forward the adjacent block prediction mode selection algorithm. Using direction gradient to detect texture direction and edge strength of the current block and its neighborhood, screening out the prediction mode with larger direction gradient in advance, the thesis puts forward the mode selection algorithm based on prediction of adjacent block, fully utilizing the spatial correlation of adjacent block prediction mode, replacing mode DC with the mode MPM as the default candidate mode, the basic algorithm greatly improved.

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