Context-Adaptive Fast Motion Estimation of HEVC

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***Abstract*—High Efficient Video Coding (HEVC) is the latest coding standard with superior compression efficiency while its encoding complexity is much higher compared with H.264/AVC. Motion estimation is one of the most time-consuming parts in video coding. In the reference software of HEVC, TZ (Test Zone) search method is adopted as the fast motion estimation method. However, its complexity is still high. There are many other fast motion estimation methods, for example, the hexagon search method, but their performance loss is larger than TZ search. In order to balance coding speed and performance, a new context-adaptive fast motion estimation algorithm is proposed in this paper. In this the proposed, motion intensity is defined in block-level, motion vectors and motion vector differences of neighbor blocks are utilized to measure the motion intensity. When motion intensity is large, TZ search method is used; otherwise, hexagon search method is used. Experimental results show that the proposed method can save 39% ~ 60% of motion estimation time with average 0.5% of BD-rate loss.**

Keywords—HEVC, motion estimation, TZ search, Hexagon search, context-adaptive

I. INTRODUCTION

With the increasing demand for high and ultra-high definition video contents, the compression ratio of H.264/AVC is not enough. The ITU-T VCEG and ISO/IEC MPEG standardization organizations, working together in a partnership known as the Joint Collaborative Team on Video Coding (JCT-VC) recently developed the next generation video coding standard, called High Efficiency Video Coding (HEVC) [1]. Many new coding tools are integrated in the latest coding standard. It doubles the video compression ratio compared with H.264/AVC at the same level of video quality with the coding complexity increasing 2-10 times. Therefore, how to reduce the coding complexity is extremely important for HEVC's application.

TZ search method is adopted as fast motion estimation algorithm in HM (HEVC Test Model). It performs well by combining diamond or square search pattern and raster search method. Further acceleration of TZ is still demanded. In [2], hexagon search method is used to replace TZ search method. It speeds up TZ search three times. However, the performance loss of hexagon search is large.

To make use of the advantage of TZ and hexagon search methods, a new context-adaptive fast motion estimation algorithm is proposed in this paper. It switches locally between TZ and hexagon search methods according to the motion context of neighbor. Meanwhile, some improvements are made on TZ search to accelerate it. Experimental results on HEVC platform indicate that the proposed scheme can save 39%-60% of motion estimation time with average 0.5% of BD-rate loss.

The TZ search method in HM is introduced in Section 2. Section 3 describes our proposed fast motion estimation scheme. The simulation results are given in Section 4 followed by conclusion in Section 5.

II. TZ SEARCH PROCESS

The TZ search method in HM is a hybrid fast search algorithm. The flowchart of TZ search is shown in Fig. 1.It consists the following steps [3][4]:

1. Initial search center. At the beginning, a set of initial search centers are established, including motion vector (MV) from median prediction, MV from the left, the upper and the upper right position and MV at (0,0) position. The one with minimum block distortion (called MBD point) is chosen as the initial search center.

2. Initial search process. The 8-point diamond or square search pattern with different stride lengths is performed around the start search center. The stride length increases from 1 to the search range, in multiples of 2. If the MBD point is found at the start search center, the search stops. If the distance between the MBD point and the initial search center (called best distance) is 1, since most MBD points are near the center, 2-point search process is performed to compensate the two missing points around the center.

3. Raster search. If the best distance is not larger than the value of iRaster(a predefined threshold), star refinement is activated; otherwise, raster search is performed with iRater being used as the stride length within the search window. Then the MBD point is set as the new search center and raster refinement process is performed.

4. Star/Raster refinement. 8-point diamond or square search pattern is used in raster search. The stride length is half of the best distance. The search center and stride length are updated in each round. Star refinement is similar to initial search process and updates the starting point in each round. Both of the two refinement processes stop until the best distance is not larger than 1.

III. PROPOSED SCHEME

Hexagon search method is known for its high efficiency. It consists of two hexagonal patterns: small hexagonal pattern and large hexagonal pattern. In order to quickly find the MBD point,

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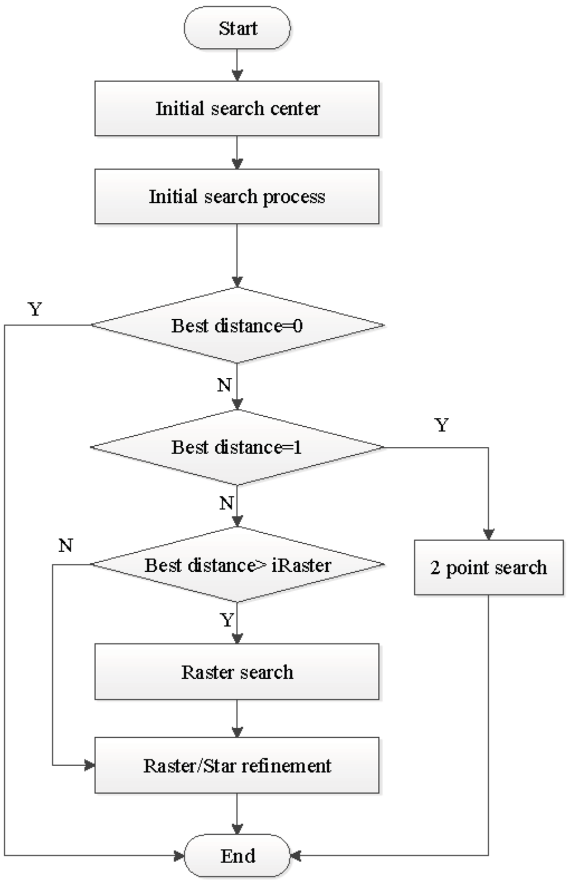

Fig. 1. Flowchart of TZ search method in HM

we set the initial search center as TZ search method does. In the first round, large hexagonal pattern with six candidate points is used, as shown in Fig. 2. If the MBD point is not at the center of hexagon, the MBD point is set as the new search center and the same large hexagonal pattern is used. There are only three non-overlapped candidate points in this round. The search process updates the search center and continues to search with large hexagonal pattern until the MBD point is at the current search center. Then we switch to use the small hexagonal pattern. It includes four points around the search center with stride length being 1[5]. Small hexagonal pattern can't find the possible MBD point at four corners, so we adopt the 8-point square pattern to replace it to compensate for the defect [6].

It is apparent that computation complexity of hexagon search method is much lower than TZ search method. In TZ, initial search process and refinement process use diamond or square search pattern and 8 points are evaluated in each round, while there are only 3 candidate points in hexagonal pattern (except that there 6 points in the first round and 8 points in the last round). Usually, large hexagonal pattern is performed no more than 9 rounds. This means at most 38 points are searched. For TZ search method, in the 8 point diamond search process, if searchrange is 64, at least 52 points are searched. Besides, raster search step is similar to full search method. Therefore, the calculation amount of TZ search method is large [2]. Statistical results in Table II indicate that time performance of hexagon

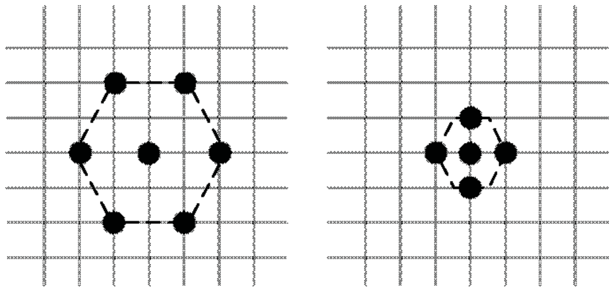

Fig. 2. Hexagon search method, (a) Large hexagonal pattern (b) Small hexagonal search pattern

search method is high, but its coding performance loss is too large compared with TZ search method on some test sequences.

We find that the sequences with large performance loss have a common feature—they are all high motion sequences. What's more, the more the motion intensity is, the larger coding performance loss. On the sequences with few motions, the performance loss is acceptable. Therefore, we propose an alternative locally adaptive search algorithm. To predict the motion intensity of local block. If motion of local block is slow, hexagon search method is used; otherwise, TZ search method is adopted.

Usually, the real motion information of local block has to be obtained after motion estimation, so motion intensity of current block is not available and has to be predicted. To improve the efficiency of motion estimation, predictive motion vector (PMV) is put forward. It may reflect the motion intensity to some extent. If PMV of current block is not zero, the block is identified as high motion intensity one, and TZ search method is used; otherwise, hexagon search method is selected. Besides, the motion information of encoded neighbor blocks is available, and motion vector difference (MVD) can reflect the motion complexity. So motion intensity is predicted based on PMV of current block and MVD of adjacent blocks in our method. Here we choose the upper, left and upper-right blocks as the adjacent blocks. Because they are the closest ones of the coded blocks round the current block and their movements are close to current block, as shown in Fig. 3.

Furtherly, original TZ search method can be improved by early terminating the initial search process. Raster search is available when the best distance obtained from initial search process is larger than iRaster. So the initial search can be terminated once the best distance is greater than iRaster. For example, if iRaster is set to 3, the search process goes to raster search directly when the best distance turns out to be 4 in initial search process.

What's more, the termination operation has no effect on the coding performance. Because no matter what the best distance is, the raster search is always used. Redundant initial search process is removed with early termination and the search can be accelerated [4].

IV. EXPERIMENTAL RESULTS

We choose three classes of high resolution sequences as

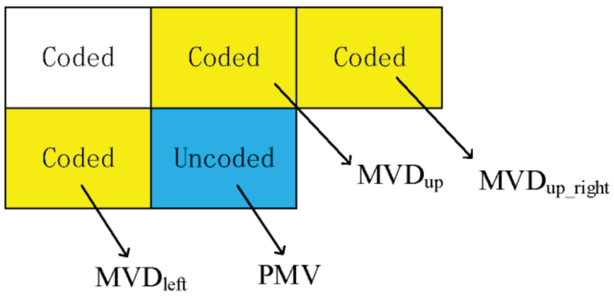

Fig. 3. An example of chosen indicators of motion intensity, the blue block means current block.

shown in Table I with random access configuration to verify the effectiveness of proposed scheme. HM10.0 is used as the test platform. The simulations are carried on Window Server 2012 R2 OS platform with Intel E5-2670 0@2.60 GHz CPU and 4GB RAM. All the sequences are encoded under four QPs (27, 32, 38 and 45). Here we choose SAD (Sum of Absolute Difference) as the measurement of block distortion.

TABLE I. EXPERIMENTAL SEQUENCES

Format	Sequence	Frame rate	Frame number
1080p	Kimono	24	240
	PartyScene	24	240
720p	FourPeople	60	600
	Johnny	60	600
	KristenAndSara	60	600
WVGA	BasketballDrill	50	500
	BQMall	60	600
	PartyScene	50	500
	RaceHorses	30	300

Table III provides the results of the proportion of blocks that TZ search finds better MBD points than hexagon search and they are shown in the 'PB' column. We can see that the proportion is no more than 40%, this means that hexagon search method works well in more cases.

In our scheme, the following condition is defined based on the threshold of average MVD of adjacent blocks:

$$\sum\left(MVD_x^{2}+MVD_y^{2}\right)/N > \text{Threshold} \qquad (1)$$

Where x and y denote the horizontal and vertical components of MVD respectively. N is the number of neighbor blocks.

Our method defaults to use hexagon search and only when the average MVD of adjacent blocks satisfies (1) and PMV of current block is not 0, TZ search method is used. Table IV provides the results of hexagon search method and our scheme with the threshold being set to 10, 25 and 100, and the original TZ search method is the anchor. BD-rate(Y) means the Bjontegaard Distortion-rate of luminance component and the positive value means loss and the negative value means gain. TS means the time saved relative to TZ search method. From the table, it can be observed that the time performance is really good for hexagon search method. But the average BD-rate loss is up to 2.2%. When our scheme is carried out, when the threshold is 25 or 100, the BD-rate is similar to that of hexagon search method. However, when the threshold is set to 10, the performance improvement becomes obvious and the average BD-rate loss is reduced down to 0.5% with half of search time being saved. Especially for Sequence Kimono, BasketballDrill and RaceHorses, the BD-rate losses are decreased down to 0.4%, 0.7% and 1.8% from 2.3%, 3.2% and 8.6% respectively. So the threshold of our method is set as 10.

Besides, the context-adaptive scheme using only PMV or average MVD the alternative condition is also tested. The results show in table II. The BD-rate losses are 0.8% and 1.2% respectively. Therefore, in our method, the two conditions are used jointly to get the optimal performance.

TABLE II. RESULTS OF USING PMV OR MVD ONLY

Sequence	TZ vs Only PMV		TZ vs Only MVD	
	BD-rate(Y)	*TS*	*BD-rate(Y)*	*TS*
Kimono	0.7%	68%	1.1%	67%
PartyScene	0.6%	71%	1.1%	64%
FourPeople	0.1%	50%	0.3%	60%
Johnny	0.1%	55%	0.1%	55%
KristenAndSara	0.1%	57%	0.2%	59%
BasketballDrill	0.9%	55%	2.5%	70%
BQMall	0.8%	69%	1.0%	65%
PartyScene	0.8%	63%	0.9%	63%
RaceHorses	2.8%	69%	3.7%	62%
Average	0.8%	62%	1.2%	63%

V. CONCLUSION

In this paper, we proposed a context-adaptive fast motion estimation scheme by using motion information of current block and adjacent ones. It combined TZ search method and hexagon search method adaptively by predicting the motion intensity of local block based on the above context information. Experimental results showed that the proposed scheme doubled the search speed of the original fast motion estimation algorithm in HM with negligible performance loss.

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TABLE III. THE PROPORTION OF BLOCKS THAT USING TZ SEARCH METHOD IS BETTER THAN HEXAGON SEARCH METHOD

Sequence	QP	PB	Sequence	QP	PB	Sequence	QP	PB
Kimono	27	35%	Johnny	27	19%	BQMall	27	27%
	32	33%		32	17%		32	26%
	38	29%		38	13%		38	24%
	45	21%		45	8%		45	19%
PartyScene	27	21%	KristenAndSara	27	24%	PartyScene	27	20%
	32	22%		32	22%		32	20%
	38	20%		38	18%		38	19%
	45	15%		45	12%		45	16%
FourPeople	27	27%	BasketballDrill	27	28%	RaceHorses	27	39%
	32	26%		32	27%		32	35%
	38	24%		38	24%		38	30%
	45	21%		45	19%		45	25%

TABLE IV. THE COMPARSION RESULTS OF TZ SEARCH METHOD, HEXAGON SEARCH METHOD AND OUR SCHEME

Sequence	TZ vs HEX		Threshold=10		Threshold=25		Threshold=100	
	BD-rate(Y)	*TS*	*BD-rate(Y)*	*TS*	*BD-rate(Y)*	*TS*	*BD-rate(Y)*	*TS*
Kimono	2.3%	88%	0.4%	52%	1.7%	84%	1.8%	84%
PartyScene	1.8%	81%	0.6%	60%	1.4%	78%	1.5%	79%
FourPeople	0.4%	79%	0.1%	39%	0.4%	74%	0.4%	74%
Johnny	0.1%	69%	0.0%	47%	0.2%	67%	0.2%	68%
KristenAndSara	0.2%	79%	0.0%	41%	0.3%	75%	0.2%	76%
BasketballDrill	3.2%	87%	0.7%	44%	2.9%	82%	3.0%	83%
BQMall	1.6%	84%	0.4%	55%	1.5%	81%	1.4%	81%
PartyScene	1.2%	82%	0.8%	52%	1.2%	78%	1.2%	78%
RaceHorses	8.6%	89%	1.8%	51%	6.4%	85%	6.4%	85%
Average	2.2%	82%	0.5%	49%	1.8	78%	1.8%	79%

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