New Two-step Motion Estimation using Adjustable Partial Distortion Search

Advanced Selected Search Point and Early Termination for Two Step Motion Search

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Abstract: In this paper, we proposed an advanced two-step motion estimation using adjustable partial distortion for fast motion estimation. We improve the two-step search by using relationship between neighboring and current block. The proposed algorithm is 187 times faster than FS and 2.7 times faster than TS-EPDS without negligible PSNR degradation. Therefore, it is suitable for real-time video implementation.

1 INTRODUCTION

Motion estimation is a commonly used technique in video compression, because it can reduce temporal redundancy between neighboring frames. All the video standards, including H.263/H.264 and MPEG-1/2/3 have used motion estimation. Full search (FS) is considered as optimal block matching algorithm (BMA), but it has computational complexity problem which limits practical usage. To reduce the computational burden, various methods have been proposed to estimate motion vectors faster while maintaining the accuracy.

Firstly, many algorithm trying to reduce the number of search point, such as diamond search (DS), four-step search (4SS) algorithms, Hexagon-based search (HEXBS), and Enhanced hexagonal search (EHS) algorithm.

Secondly, some algorithms aims at reducing the sum of absolute difference (SAD) computation for each candidate block by testing only part of pixels in the block at the cost of coding quality such as normalized partial distortion search (NPDS), and Cheung and Po extended the NPDS to an adjustable PDS (APDS).

Recently, hybrid algorithms have been proposed, such as dual-halfway stop normalized PDS (DHS-NPDS), fast motion estimation based on search range adjustment, two-step edge based PDS (TS-EPDS), and Adaptive two-step edge based PDS (ATS-EPDS). These algorithms attempt to combine search point reduction (or search range adjustment) with enhanced PDS algorithm. ATS-EPDS shows best performance on both PSNR and speed among four algorithms, but two-step based search method has a problem that causes video quality degradation on specific sequences.

In this paper, new two-step motion estimation is proposed not only to solve quality degradation in TS and ATS methods but also achieve further reduction of complexity adaptive. It reduces the complexity by control the search point and enhanced PDS algorithm.

2 CONVENTIONAL ALGORITHMS

The most common BMA method for matching two blocks use the SAD, which gives similar performance of using mean square error (MSE), but less computational burden. The SAD of N×N is defined as:

$$SAD(x,y,mx,my) = \sum_{i=1}^{N}\sum_{j=1}^{N}\left|I_n(x+i,y+j)-I_{n-1}(x+i+mx,y+j+my)\right|, \quad (1)$$

where and represent the pixel value in the current and previous frame, respectively, while (x,y) represents the coordinates of the upper left corner

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pixel of the current block, and (mx,my) is the horizontal and vertical candidate component of the motion vector.

Table 1: Offset from the upper left corner pixel of a block.

P	(S_p, T_p)	P	(S_p, T_p)
1	(0,0)	9	(1,0)
2	(2,2)	10	(3,2)
3	(2,0)	11	(0,1)
4	(0,2)	12	(2,3)
5	(1,1)	13	(3,0)
6	(3,3)	14	(1,2)
7	(3,1)	15	(2,1)
8	(1,3)	16	(0,3)

2.1 APDS

The partial distortion search algorithm is terminated early when the partial distortion is bigger than minimum SAD, and the *p*th partial distortion D_p of M×M sub-block is defined as follow:

$$D_p(x,y,mx,my) = \sum_{i=1}^{M}\sum_{j=1}^{M}\left|I_n(x+i+s_p, y+j+t_p) - I_{n-1}(x+i+mx+t_p, y+j+my+s_p)\right|, \quad (2)$$

where (s_p, t_p) denotes the pixel coordinates of the upper left corner pixel of a block.

Table 1 represents the offset of the p*th* partial distortion from the upper left corner pixels of a block. The NPDS divide 16×16 block into 4×4 sub-blocks, but the APDS has one more step. To find impossible candidate early, it divides only the first 4×4 sub-block into four 2×2 block. After every partial distortion is calculated, it is compared with minimum SAD value which is calculated during search process.

$$\alpha = (1-\varepsilon)\cdot n + \varepsilon \cdot N^2 , \quad (3)$$

$$N^2 \cdot D_p > \alpha \cdot SAD_{\min} . \quad (4)$$

The APDS algorithm has adjustable control parameter α, where N is block size and n is the number of calculated pixels in the current block. If the ε=0, then α=n and APDS gives the same performance as NPDS. In other case k=1, then $\alpha=N^2$ and APDS works like PDS. Accordingly, if k is decreased, then APDS is faster, but there is quality degradation. In this paper, α is defined as 0.4, which shows best performance on both speed and quality.

2.2 Adaptive Two-step Search

To find best motion vector quickly, selected search pattern is used. Adaptive two-step search consist of two steps; First rough search, and second concentrated search. figure 1 shows the selected search pattern for first step, and it has dense center area and sparse outside area. In case of search range ±16, center area is same, but outside area pattern is just repeated. Two best motion vectors candidates, best motion vector which has minimum SAD and second best motion vector which has second minimum SAD, is obtained from first step. In second step, we use search range adjustment (SRA), and adaptive search range D is defined as:

$$D = \begin{cases} 1 & if\ MVS < 2 \\ 2 & otherwise \end{cases} , \quad (5)$$

Where motion vector similarity (MVS) is defined as:

$$MVS = MAX(|cur\_mv - up\_mv|, |cur\_mv - left\_mv|) . \quad (6)$$

MVS compares the best motion vector from first step with motion vector of neighboring blocks. If motion vectors of neighboring blocks are similar to current best motion vector, then search range around the best motion vector is decreased and second motion vector candidate is ignored.

3 PROPOSED ALGORITHM

3.1 Advanced Selected Search Pattern (ASSP)

In case of search range ±16, selected search point in first step has 161 point, and we add two points, which is motion vector of upper and left block, and the number of maximum search point is 163, and figure 1 represents the advance selected pattern. The additional points are calculated right after (0,0) and then, rest of points are calculated. This algorithm increases the quality, in terms of PSNR, and reduces the average complexity.

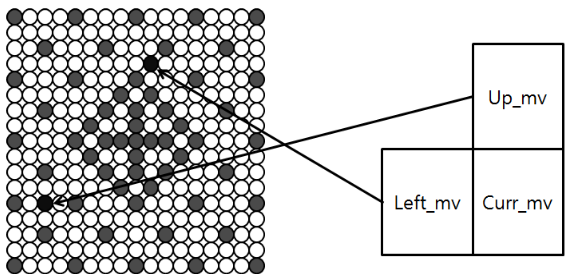

Figure 1: Selected search pattern and additive search points.

3.2 Early Termination

To reduce complexity, we use early termination in first step. The early termination threshold T is defined as follow:

$$T = \begin{cases} (SAD\_\min_{pred})/8 & if\ MVM > 4 \\ (SAD\_\min_{pred})/4 & if\ MVM > 2 \\ (SAD\_\min_{pred})/2 & otherwise \end{cases}, \quad (7)$$

$$MVM = MAX(|up\_mvx| + |up\_mvy|, |left\_mvx| + |left\_mvy|), \quad (8)$$

$$SAD\_\min_{pred} = (SAD\_\min_{up} + SAD\_\min_{left}). \quad (9)$$

It makes first step more quickly without quality degradation.

3.3 Overall Algorithm

New two-step adjustable partial distortion search (NTS-APDS) has two part of search step: first rough search and second concentrated search. Each step is summarized as follows:

Step 1:
Find the two best motion vectors candidate, with a minimum SAD and a second minimum SAD, Using advanced selected search pattern in figure 1 and APDS. If current SAD_min is less than T, ignore the rest search point and go to step 2.

Step 2:
If D is 1 then do (a), otherwise do (a) and (b).
(a) Select the best motion vector point as the search center. Search the points, which are not searched for in Step 1, within a ±D search area via APDS.
(b) Select the second best motion vector point as the search center. Search the points, which are not searched for in Step 1, within a ±D search area via APDS.

4 EXPERIMENTAL RESULTS

We simulated proposed algorithm using the luminance component of various CIF (352×288) sequences. Akiyo, News, Mother&Daughter, and Hall monitor have small motions compared with other sequences whereas Coast guard, Mobil, and Foreman have intermediate motions, and rest of the sequences (Bus, Football, Stefan) have relatively high motions. The spiral scanning is used as searching method, and the search range is ±16 for 16×16 block size.

We have compared performance of our proposed method with FS, APDS, TS-EPDS, and ATS-EPDS. In order to compare the objective performances, the PSNR, speed-up, and operation times are used. Speed-up is defined as operations_of_FS divided by operations_of_BMA. The total number of operations is the sum of addition/subtraction, comparison, absolution, and 8 time of multiplication/division. The reason that multiplication has weight is it requires more computations than others, and shift operation has same weight as addition.

Figure 2 shows the performance of the speed-up factor over various algorithms and figure 3 shows the Encoding times of total frames of each sequence. The proposed algorithm achieves highest speed-up and encoding time reduction. From the Figure 2 and Figure 3, we can see the number of operation and the encoding time are closely related.

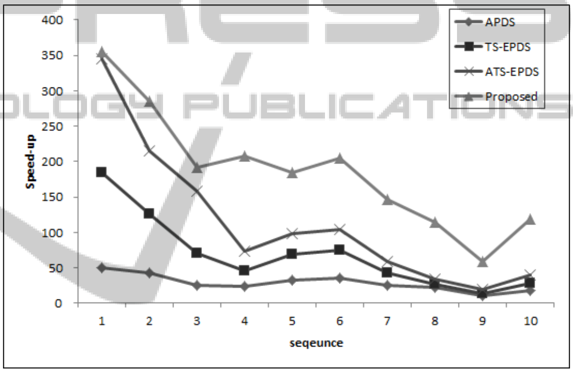

Figure 2: The Speed-up results of the APDS, the TS-EPDS, the ATS-EPDS, and the proposed method, respectively.

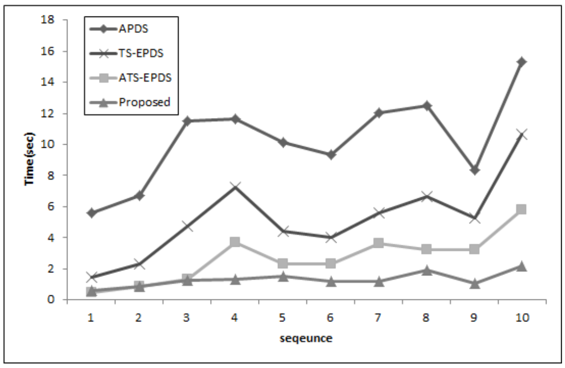

Figure 3: The Speed-up results of the APDS, the TS-EPDS, the ATS-EPDS, and the proposed method, respectively.

Table 2 represents the PSNR performance of four algorithms. The PSNR performance of APDS and proposed algorithm show almost same with FS,

Table 2: Experimental result of PSNR performance.

Sequence (frames)	PSNR (difference with FS) [dB]				
	FS	APDS	TS-EPDS	ATS-EPDS	Proposed
1.Akiyo (300)	42.95	42.93 (-0.02)	42.93 (-0.02)	42.92 (-0.03)	42.93 (-0.02)
2.News (300)	36.91	36.87 (-0.04)	36.83 (-0.08)	36.83 (-0.08)	36.81 (-0.10)
3.Mother&daughter (300)	40.54	40.48 (-0.06)	40.51 (-0.02)	40.50 (-0.03)	40.47 (-0.07)
4.Hall monitor (300)	34.83	34.78 (-0.05)	34.78 (-0.05)	34.79 (-0.04)	34.76 (-0.07)
5.Coastguard (300)	30.68	30.68 (0.00)	30.67 (-0.01)	30.70 (0.02)	30.66 (-0.02)
6.Mobile (300)	25.18	25.16 (-0.02)	25.13 (-0.05)	25.13 (-0.05)	25.13 (-0.05)
7.Foreman (300)	32.33	32.34 (0.01)	32.29 (-0.05)	32.31 (-0.02)	32.35 (0.03)
8.Bus (300)	25.65	25.64 (-0.01)	24.93 (-0.72)	24.78 (-0.87)	25.36 (-0.29)
9.Football (150)	27.73	27.70 (-0.03)	27.74 (0.01)	27.83 (0.09)	28.13 (0.40)
10.Stefan (90)	24.92	24.92 (0.00)	24.73 (-0.19)	24.91 (-0.01)	25.34 (0.42)
average	32.17	32.15 (-0.02)	32.05 (-0.12)	32.07 (-0.10)	32.19 (0.02)

but TS-EPDS and ATS-EPDS have some significant PSNR drop on Bus and Stefan sequences. The proposed algorithm makes up for weak points, and it show better quality on most sequences. This PSNR improvement is from the ASSP by adding two predicted point to original selected search pattern.

5 CONCLUSIONS

In this paper, we present an new two-step adjustable partial distortion (NTS-APDS) for fast motion estimation. By modifying the selected search pattern and using early termination on two-step motion estimation, we can extremely accelerate the convergence speed to the best motion vector. The experimental results show that the proposed algorithm complements weak point of original two-step search, and achieve better performance on both computation reduction and encoding time than other algorithms. The proposed algorithm is 187 times faster than FS and 2.7 times faster than TS-EPDS on average without video quality degradation. Therefore, it is suitable for real-time implementation for high quality digital video applications.

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