A FAST PARTIAL DISTORTION ELIMINATION ALGORITHM USING IMPROVED SUB-BLOCK MATCHING SCAN

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ABSTRACT

In this paper, we propose a fast partial distortion algorithm using normalized dithering matching scan to get uniform distribution of partial distortion which can reduce only unnecessary computation significantly. Our algorithm is based on normalized dithering order matching scan and calibration of threshold error using LOG value for each sub-block continuously for efficient elimination of unlike candidate blocks while keeping the same prediction quality compared with the full search algorithm. Our algorithm reduces about 60% of computations for block matching error compared with conventional PDE (partial distortion elimination) algorithm without any prediction quality, and our algorithm will be useful to real-time video coding applications using MPEG-4 AVC or MPEG-2.

Keywords: computational complexity, image matching, partial distortion elimination, motion estimation

1. INTRODUCTION

In MPEG-2 and MPEG-4 video compression, full search (FS) algorithm based on block matching algorithm (BMA) finds them optimal motion vectors which minimize the matching difference between reference block and candidate block. It has been widely used in video coding applications because of its simple and easy hardware implementation. However, heavy computational load of the full search with very large search range can be a significant problem in real-time video coding application. Many fast motion estimation algorithms to reduce the computational load of the full search have been studied in the last decades.

We classify these fast motion estimation methods into two main groups. One is lossy group of algorithms includes TSS (three-step search), DS (diamond search), HEXBS (hexagon based search), and others. The latter as fast full search technique contains following several algorithms: successive elimination algorithm (SEA) and its modified algorithms, partial distortion elimination (PDE) method and its modified algorithms [1]-[5], and so on. In lossless motion estimation algorithms, PDE is very efficient algorithm to reduce unnecessary computation for matching error calculation. To further reduce unnecessary computation in calculating matching error, J.N. Kim and et al. proposed fast PDE algorithms based on adaptive matching scan, which requires additional computation to get matching scan order [1]-[2]. But the additional computation for the matching scan order can be burden when cascading other fast motion estimation algorithm such as SEA.

In this paper, we propose a fast motion estimation algorithm to reduce computational load of the FS algorithm. We reduced only unnecessary computations which doesn't affect predicted images from the motion vector. To do that, we use normalized dithering matching scan to get uniform distribution of partial distortion which can reduce only unnecessary computation significantly. Additionally, we remove unlike candidate vectors faster by using multiply of LOG value to threshold of matching error. Our algorithm reduces about 60% of computations for block matching error compared with the conventional PDE algorithm without any degradation of prediction quality.

2. CONVENTIONAL WORK

As the manuscript that you prepare will be printed as it is received, we encourage you to be as neat as possible. PDE algorithm uses the partial sum of matching distortion to eliminate impossible candidates before completing calculation of matching distortion in a matching block. That is, if an intermediate sum of matching error is larger than the minimum value of matching error at that time, the remaining computations for matching errors is abandoned. The kth partial sum of absolute differences (SAD) can be expressed by the Eq. (1),

$$\sum_{i=1}^{k}\sum_{j=1}^{N}\left| f_t(i,j) - f_{t-1}(i+x, j+y)\right| \qquad k = 1,2,\ldots,N \qquad (1)$$

Where N represents matching block size. The term, $f_{t+1}(i,j)$, means image intensity at the position (i,j) of the $(t+1)$th frame. The variables x and y are the pixel coordinate of a candidate vector. If the partial sum of matching distortion exceeds the current minimum matching error at k, then we can abandon the remaining calculation of matching error ($k+1$ to Nth rows) by assuring that the checking point is an impossible candidate for the optimal motion vector. Kim et al. [4] calculated block matching errors to reduce unnecessary calculations with the four-directional scan order based on the gradient magnitude of images instead of the conventional top-to-bottom matching scan order. Block matching errors are calculated to further reduce unnecessary computations with adaptive matching scan. While these approaches could reduce unnecessary computations for getting block matching errors, they need additional computations to determine the matching scan order.

Another modified PDE algorithm is NPDS (normalized partial distortion Search) [3]. This algorithm adapted instead of calculating the total distortion consisting of all pixels of a 16×16 MB at one time, a grouping method is applied to divide pixels in one MB into 16 groups with evenly distributed patterns as shown in Fig. 1. As result the sum of absolute differences (SAD) between current MB and a candidate MB is subdivided into 16 partial distortions , where the pth partial distortion is given as

$$d_p = \sum_{k=1}^{3}\sum_{l=1}^{3}\left| \begin{array}{l} f_t(i+4k+s_p, j+4l+t_p) \\ - f_{t-1}(i+4k+s_p+x, j+4l+t_p+y) \end{array} \right| \quad (2)$$

Where $1 \le p \le 16$, and the pth accumulated partial distortion SAD_p is defined as

$$SAD_p \ge \sum_{i}^{p} d_i \quad (3)$$

Note that, in the above equations, $f_t(x,y)$ and $f_{t-1}(x,y)$ denote the pixel values in the current frame and reference frame, respectively. (x,y) denotes the candidate motion vector, and (s_p,t_p) indicates the offsets of the upper left corner point of the pth partial distortion from the upper left corner of the MB. The order of calculation of the 16 partial distortions is illustrated as in the upper left part of Fig. 1. The pth partial SAD to check during the matching is as follows.

$$SAD_p \ge p \cdot \frac{1}{N} SAD_{min} \quad (4)$$

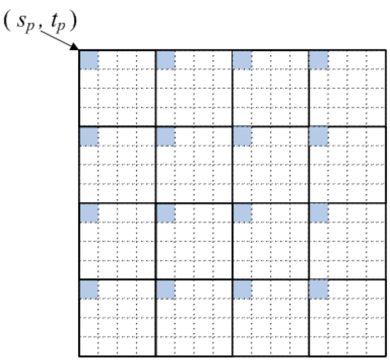

Fig. 1: Pixel grouping pattern for calculation of the partial distortion.

3. PROPOSED ALGORITHM

Modified PDE algorithms have been published by using adjacent motion vectors in the spatial or temporal domain, spiral scan algorithm and cascaded algorithms to other fast ones [4]-[5]. Ability to reject impossible candidates in the PDE algorithm depends on the search strategy, which makes minimum matching error be detected faster. For the purpose, spiral search is very efficient. PDE algorithm with spiral search rejects impossible candidates faster than simple PDE. Therefore, we employ the spiral search in the proposing matching scan algorithms.

0	**8**	**2**	**10**
12	**4**	**14**	**6**
3	**11**	**1**	**9**
15	**7**	**13**	**5**

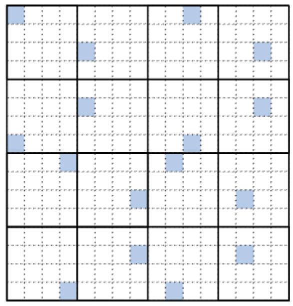

Fig. 2: Proposed pixel grouping pattern.

To improve matching scan strategy of NPDS, we need more efficient matching scan order of uniform error distribution for each sub-block. Our proposed algorithm improved sub-block matching strategy using 4x4 normalized dithering matching scan order to spread sub-block error distribution uniformly. Fig. 2 shows dithering matching order in 4×4 matrix and pixel grouping pattern in each MB. Eq. (5) shows proposed SAD values for each sub-block is as follows. In Eq. (5), (x,y) denotes the candidate motion vector, and (ds_p,dt_p) indicates the offsets of the upper left corner point of the pth partial distortion from the upper left corner of the MB.

$$d_p = \sum_{k=1}^{3}\sum_{l=1}^{3}\left| \begin{array}{l} f_t(i+4k+ds_p, j+4l+dt_p) \\ - f_{t-1}(i+4k+ds_p+x, j+4l+dt_p+y) \end{array} \right| \quad (5)$$

Our algorithm also doesn't have ideally distributed sub-block matching error but improve uniform distribution for each block. Distribution error mostly occurred in the first sub-block matching case. To reduce prediction error in our algorithm, we must multiply or add factor to partial $SAD_{\min}$. Therefore, we consider the probability of max error distribution for every MB in each test videos, and find multiply factor between pth accumulated SAD_p and partial $SAD_{\min}$ comparison for each sub-block. Fig. 3 shows accumulated probability of error rate of 100 frames of 'foreman', 'trevor', 'claire' and 'grand mother' video sequences. In these sequences, 'foreman', has higher motion variance than the other image sequences. We consider accumulated 98% probability of error factor for 'foreman' video sequence, take the factor value 1.7 is equal to $log_6(6+N-1)$. We compare it with factor with log value ($log_{base}(base+N-1)$)in Eq. (6). The meaning of the symbols in Eq. (6) is when N is 16 , the factor come to 1.

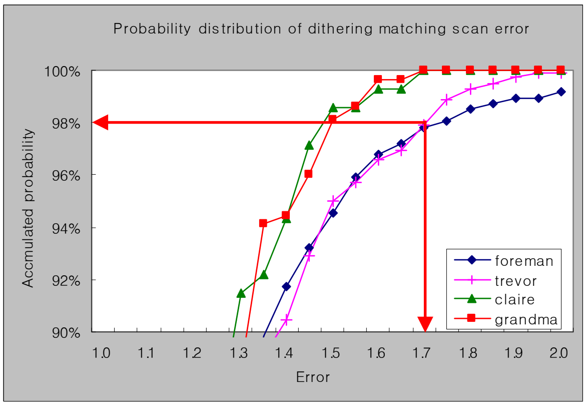

Fig. 3: Probability distribution of dithering matching scan.

$$SAD_p \ge p \times \frac{1}{N} \times SAD_{min} \times \log_{base}(base + N - p) \qquad (6)$$

3. EXPERIMENTAL RESULT AND DISCUSSION

To compare the performance of the proposed algorithm with the conventional algorithms, we use 100 frames of 'foreman', 'trevor', 'coastguard', 'claire', 'mobile' and 'grand mother' image sequences. Matching block size is 16x16 pixels and the search window is ± 7 pixels. Image format is QCIF (176×144) for each sequence and only forward prediction is used. The simulation results are shown in terms of average numbers of checking rows with reference of that of full search. All results in Table 1 were considered with overhead calculation for complexity measure. All the algorithms employed spiral search scheme to make use of the distribution of motion vectors. Figure 4~5 show the reduced computation of average checking rows and PSNR difference for various matching scans based on sequential and proposed matching scan based on partial SAD value comparison with 10fps 'foreman' sequence.

Table 1 show computed average checking rows from various algorithms in all sequences for frame rate 10 fps with adaptive threshold. Average checking rows of conventional FS without any fast algorithm are matching block size, 16. As we described above, the references [9], [10] show importance and efficiency of spiral scan in PDE algorithm.

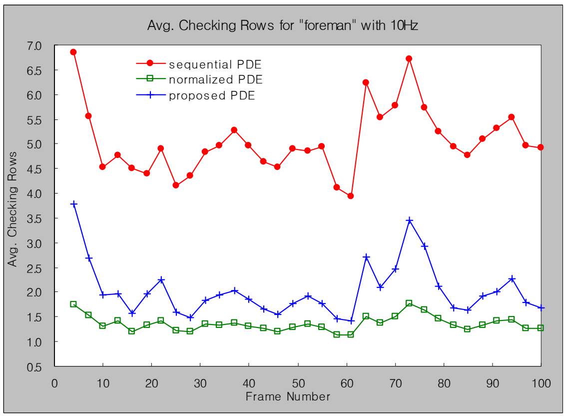

Fig. 4: Average computations for "foreman" sequence of the frame rate 10fps.

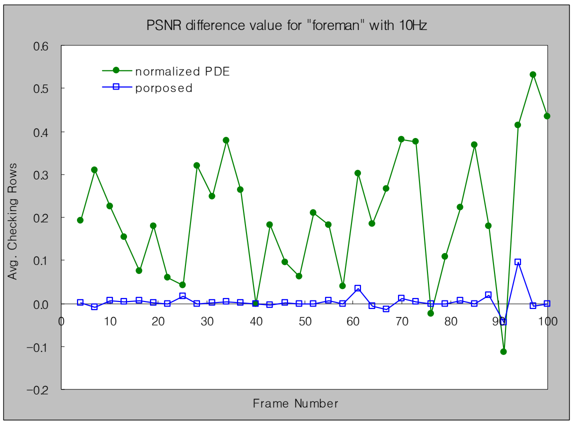

Fig. 5: PSNR difference for "foreman" sequence of 10fps.

Table 1: Computed average checking rows with various matching scans of 10fps.

Algs.	Foreman	Coastguard	Trevor	Claire	Grand	Mobile
PDE	5.11	4.91	4.57	4.45	2.02	4.67
Proposed	2.03	1.93	1.81	1.27	1.11	1.97
NPDS	1.08	0.97	0.93	0.84	0.84	0.86

Table 2: Average PSNR of all sequences for the frame rates of 10fps.

Algs.	Foreman	Coastguard	Trevor	Claire	Grand	Mobile
PDE	29.50	26.37	28.64	37.51	39.01	21.77
Proposed	29.50	26.37	28.63	37.51	39.01	21.77
NPDS	29.29	26.16	28.36	37.40	38.98	21.56

In "trevor" sequence of Table 1, we can see that the computational reduction ratio from the proposed algorithm for PDE is about 60%. Table 2 present PSNR for all sequences for 10fps. As described previously, PSNR is different for all sequences according to the scaling factors and algorithms. While the prediction quality is kept similar to original FS algorithm, our proposed algorithm reduced computation efficiently and additional computation for matching order by adjusting the scaling factor adaptively.

5. CONCLUSION

In this paper, we propose improved sub-block matching scan algorithm using normalized dithering matching scan which can reduce only unnecessary computation significantly. The proposed is based on normalized dithering order matching scan and calibration of threshold error using LOG value for each sub-block continuously for efficient elimination of unlike candidate blocks while keeping the same prediction quality compared with conventional full search algorithm. Our algorithm reduces 60% of computations for block matching error compared with PDE algorithm without any prediction quality, and our algorithm will be useful to real-time video coding applications using MPEG-4 AVC or MPEG-2.

6. REFERENCES

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