Advanced Block Matching Algorithm for Motion Estimation and Motion Compensation

Hyo-Moon Cho, Sang-Bock Cho

Abstract – The partial distortion elimination (PDE) scheme is used to decrease the sum of absolute difference (SAD) computational complexity, since the SAD calculation has been taken much potion of the video compression. In motion estimation (ME) based on PDE, it is ideal that the initial value of SAD in summing performance has large value. The traditional scan order methods have many operation time and high operational complexity because these adopted the division or multiplication. In this paper, we introduce the new scan order and search order by using only adder. We define the average value which is called to rough average value (RAVR). Which is to reduce the computational complexity and increase the operational speed and then we can obtain the improvement of SAD performance. And also this RAVR is used to decide the search order sequence, since the difference RAVR between the current block and candidate block is small then this candidate block has high probability to suitable candidate. Thus, our proposed algorithm combines above two main concepts and suffers the improving SAD performance and the easy hardware implementation methods.

Key Words : Sum of Absolute Difference, Partial Distortion Elimination, Motion Estimation, Video compression

1. Introduction

In general block matching algorithm (BMA), the sequence of the SAD calculation is ordered from left to right and from upper to bottom by specified sequence and executed by accumulating them. And BMA is classified into exhaustive search algorithm (ESA) and the fast search algorithm (FSA). Although, the ESA can obtain the optimal result by searching exhaustively for the best matching block within a search window, its high computational cost limits its practical application [2~4]. The ESA estimates the analogy between candidate block by calculating SAD for exhaustive area.

Today's, to reduce the SAD computational complexity, the PDE is widely-used [7]. The main concept of it, which is to eliminate the SAD redundancy, SAD computation is stopped when the accumulating of SAD value is greater than the given SAD value. From this basic concept, we are known that it is efficient as the early larger value is accumulated. Thus traditional PDE method is not suitable to improve the SAD performance. The changing of scan order to improve the SAD performance has been studied widely and active. The scan order is sequence order that is accumulated the pixel error. Therefore, the final result of the accumulated SAD value is irrelevant to the scan order. To achieve the efficient SAD performance, we propose the advanced scan order which changes the scan order to take large accumulated value, initially. And it is to reduce the SAD computational complexity. The popular methods of the scan order are "Bayer Dither Matrix Scan Order (BDMSO)" [8] and "Scan Order by Localizing Complexity (SOLC)" [9]. The DBMSO use the Bayer dither matrix (DBM) and its result is linear. The SOLC, which is the highest performance, extracts the complexity on the block and then calculates from high complexity to low. The traditional scan order methods have many operational time and high computational complexity because of adopting the division or multiplication.

In this paper, we introduce the new scan order and search order by using only adder. To do this, we introduce the new SAD calculation method, which is refer to RAVR(Rough Average Value). And we found that if the difference RAVR between the current block and block candidate is small then this candidate block has high probability to suitable candidate. Thus, we decide the searching order as small RAVR value sequences.

2. The conventional scan order and search algorithm.

The BMA finds the optimal motion vectors (MVs) that minimize the difference between reference block and candidate block. Fig. 1 shows the basic concept of block matching. The SAD is used to match criteria, and is defined as

$$SAD = \sum_{i=0}^{M-1}\sum_{j=0}^{N-1}|f_t(i,j) - f_{t-1}(i+x, j+y)| \qquad (1)$$

The PDE method is used to reduce the computational complexity efficiently and is shown in (2).

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$$PSAD = \sum_{i=0}^{k}\sum_{j=0}^{N-1}|f_t(i,j) - f_{t-1}(i+x, j+y)| \quad \text{for } k = 0, 1, 2, \ldots, N \qquad (2)$$

The reducing of calculation in obtaining a motion vector with the PDE algorithm depends on how fast global minimum of matching distortion is detected. If we find the global minimum of distortion in the calculation of the matching error faster, then the complete computation of the matching error in a block is avoided, and k in (2) is determined faster.

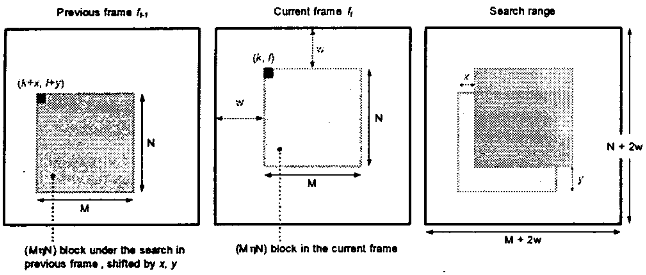

Figure 1. Block matching algorithm

The PDE compare with SAD value, which is obtained by period, and the given SAD value then the calculation is stopped when the partial SAD value is greater than given SAD value. As the concept of the PDE, it is more efficient as early SAD value has large i.e., it is desirable to make the value of SAD to be rapidly increased in motion estimation.

2.1 Scan order

2.1.1 Bayer Dither Matrix Scan Order

Generally, Bayer dither matrix (BDM) is constructed by rectangular matrix. The continuously sequence number in the matrix is far as possible. The accumulating progress is linearly increased. However, this method is not suitable to implement, because much memory access time is needed.

2.1.2 Scan Order by Localizing Complexity

The scan order is decided as the block complexity, that is the block with highest complexity is first and next order is second highest complexity block, and so on. The block complexity is executed by gradient computation. The flow of this method is as figure 3. The increasing of the SAD of this method is more rapidly than the DBM method, the SAD calculation in the sub-block is executed as continuous sequence thus memory access time is not large.

2.2 Search Order

The computational complexity depends on the SAD calculation. Thus, the PDE method, which is improved the SAD computation, reduces the computational complexity in BM computation. And the other important factor is search order. This is BM executing order among the sub-block candidates. If optimal sub-block is found early then the SAD calculation may be avoided for rest sub-block candidates by PDE method. Thus effective search order affects to the SAD computational complexity.

2.2.1 Sequential Search

This method progresses from left to right and up to bottom and find the matching criteria. This method is so simple and easy to implement.

2.2.2 Spiral Search

This method progresses to spiral direction from initial motion vector. This premises that the optimal candidate blocks are neared by initial position. This is powerful than sequential search for computational complexity.

3 Proposed Algorithm

3.1 Basic Concept

To obtain the average value, the division is executed. Therefore, our new calculation method which use only adder without divider is as below;

The pixel value is finite and its value is given from system environments. Therefore we assume the center of given pixel-value range is average value. And then we calculate the summation of the difference between the pixel-value and the center value as (3).

$$Dev = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(f(i,j) - C), \qquad (3)$$

where, *Dev* is summation of the deviation, and C is constant which is the center value of given pixel-value range. The *Dev* may be positive or negative.

And its general form is as below;

$$RAVR = \{k | C \pm (k-1) + \alpha\} \quad k = 0, 1, 2, \ldots, C-1 \qquad (4)$$

The maximum block size is 16X16 then MN is maximum 256. This is implemented by using registers like as look up table (LUT). The average value is fractional number although the pixel value must be integer. Thus, it is allowed the obtaining the approximated average value or rough value, it is called to RAVR, because this calculation is used to scan order, only. And we define the value of α to four classes such as 0~0.25, 0.26~0.5, 0.51~0.75, and 0.76~1.0 and we can take these values because as we know the MN. Therefore we can obtain the final RAVR value of the current block without divider.

Traditional fast search algorithms have been developed based on successive elimination algorithm (SEA). The SEA is eliminates redundancy SAD computation by using the DC, we refer to RAVR, value between current block and candidate block. In practice, the sub-block with minimum difference of DC value has higher probability of matching block. And this is evaluated by experimental.

3.2 Procedure for scan order

Setp 1: calculate the average value of the current block.

Step 2: calculate the difference between each pixel in the current block and RAVR as (5)

$$Diff = |f_t(i,j) - m| \tag{5}$$

Step 3: segments the current block to sub-block and sums the each pixel in sub-block as (6)

$$r = \sum_{i=s_x}^{s_x+M_{sub}} \sum_{j=s_y}^{s_y+N_{sub}} Diff = \sum_{i=s_x}^{s_x+M_{sub}} \sum_{j=s_y}^{s_y+N_{sub}} |f_t(i,j) - m| \tag{6}$$

Step 4: reorder the scan order as down sequence from step 3 and corresponds to sub-block.

Step 5: calculate SAD as reordering sequence which is from step 4 as (7)

$$PSAD(k) = \sum_{r=0}^{k} \sum_{i=s_x}^{s_x+M_{sub}} \sum_{j=s_y}^{s_y+N_{sub}} |f_t(i,j) - f_{t-1}(i+x, j+y)| \tag{7}$$

where, s_x and s_y represent the position of sub-block, and M_sub and N_sub indicate the size of sub-block, and r is reordered sub-block index of down sequence.

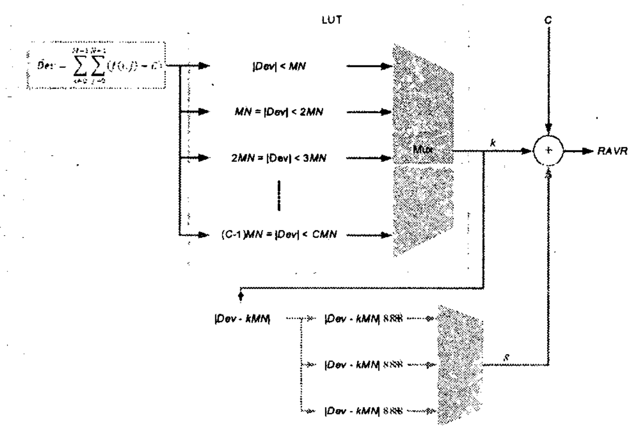

Figure 2. RAVR block diagram.

3.3 Procedure for Search Order

Today's the most effective search algorithm is spiral search algorithm and it is based on that the probability, of which the optimal candidate block is nearby the initial candidate block, is highest. However this method could not obtain the effectiveness for moving picture with fast motion. Thus, the spiral method is applied at initial candidate block and under distance two. And then over than it, we find candidate blocks with the minimum DC difference.

4 Experimental Results and conclusion

We used the moving picture to experiment by using PC camera and used PDE method with 16-pixel period and bubble sorting method is used. And the frame number is 30frame, MPEG-4 encoder is used and macro block size 16X16. The used sample images, which are captured, are shown in fig. 3. And their image size is SIF grade. In this paper, we presented new calculation algorithm and architecture to improve the PDE performance. And also modified spiral method is proposed which is based on the difference of RAVR. By the experiment, we applied proposed algorithm to practice images and we obtain the about 9% improvement ratio. The proposed algorithm is designed by using adder only. Thus it is allowed to easy hardware implementation for image processing system such as H.264 codec design and the super resolution reconstruction algorithms.

(a) Bookrack (b) Walking (c) Studying

Figure 6. Sample images used in experiment.

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