EFFICIENT BLOCK MOTION ESTIMATION USING SECTOR BASED APPROACH

Humaira Nisar and Tae-Sun Choi, Senior Member, IEEE

Gwangju Institute of Science and Technology, Gwangju, Korea
humaira@gist.ac.kr,tschoi@gist.ac.kr

ABSTRACT

This paper suggests a simple scheme in which the search pattern is divided into a number of sectors based on the spatio-temporal correlation information. In the first step five neighboring blocks are searched for finding the predicted motion vector. The predictive motion vector thus obtained is chosen as the initial search center. This predictive search center is found to be closer to the global minimum and thus decreases the effects of the monotonic error surface assumption and its impact on the motion field estimates. Secondly the prediction information is used to obtain the direction of predicted motion vector. Based on the direction of predicted motion vector the search area is divided into four sectors. Final search pattern is adaptive and depends on the sector selected and significantly reduces the computational complexity. Experiments show the speed improvement of the proposed algorithm as compared to other fast search algorithms, in addition the image quality measured in terms of PSNR also shows good results.

Index Terms— Motion Estimation, Spatial Correlation, Temporal Correlation, Motion Vector

1. INTRODUCTION

Block matching motion estimation (BMME) and compensation is an essential part of several video coding standards such as MPEG-1/2/4 and ITU-T H.261/263/263+, since it allows us to exploit temporal correlation and reduce the redundancy that exists between the frames of video sequences which leads to higher compression. In BBME the current frame is partitioned into square blocks of pixels and the best match of these blocks is found inside the reference frame using a predefined distortion criterion. The best match is then used as a predictor for the block in the current frame, whereas the displacement between the two blocks is usually defined as the motion vector (MV), which is associated with the current block. In the encoder it is only necessary to send the motion vector and the residue block defined as the difference between the current block and the predictor. This requires fewer bits than the direct coding of the original.

Full Search (FS) is the most straightforward and optimal block matching algorithm (BMA) which searches exhaustively inside the search window to find the motion vector. Despite the very heavy computations required in FS it is still widely used in video coding applications due to its simplicity and ease of hardware implementation. Several fast block matching motion estimation algorithms [1]-[10] have been proposed so far. These fast algorithms involve approaches like Unimodal Error Surface Assumption (UESA), variable search range instead of fixed one, methods using multi-resolution, spatial and temporal correlation of motion vectors, pixel decimation etc.

Some well known examples are the Three Step Search (TSS) [3], New Three Step Search (NTSS) [4], Four Step Search (FSS) [6], DS [10] etc. Experimental results show that these algorithms reduce the computational requirements significantly by checking only some points inside the search window, while keeping a good error performance when compared with the FS algorithm.

In this paper we use the correlated motion information both in the spatial and temporal domain to predict the starting point of search. In addition to this our algorithm also uses information regarding the direction of predicted Motion Vector PMV to choose adaptively between different search patterns.

2. PROPOSED ALGORITHM

2.1. Motion Vector Prediction (MVP)

The motion vector prediction is based on spatio-temporal correlation information [11]. Only horizontal and vertical neighboring blocks are used for prediction, as shown in Fig. 1. The first step of our algorithm roughly searches five neighboring MVs for an initial search point which is closer to the global optimum. The motion vectors from the current frame n are $MV_{SL}(n)$ (Spatial Left), $MV_{SA}(n)$ (Spatial Above), whereas $MV_{TR}(n-1)$ (Temporal Right), $MV_{TB}(n-1)$ (Temporal Below) and $MV_{P}(n-1)$ (Previous) belong to the previous frame (n-1). We will calculate the predicted motion vector by weighted mean and median prediction methods:

1-4244-1437-7/07/$20.00 ©2007 IEEE

$$\mathrm{PMV} = \alpha 1 * (\mathrm{MV}_{TR}(n-1), \mathrm{MV}_{TB}(n-1), \mathrm{MV}_{P}(n-1) + \alpha 2 * (\mathrm{MV}_{SL}(n), \mathrm{MV}_{SA}(n) \qquad (1)$$

$$\mathrm{PMV} = \mathrm{median}\ (\mathrm{MV}_{TR}(n-1), \mathrm{MV}_{TB}(n-1), \mathrm{MV}_{P}(n-1), \mathrm{MV}_{SL}(n), \mathrm{MV}_{SA}(n))(\qquad 2)$$

Here α1 and α2 are weighted mean coefficients whose values are computed experimentally. The x and y component of weighted mean (1) and median (2) predicted motion vectors are computed independently. As confirmed by our experimental results, only the vectors corresponding to the closest blocks should be used. Including poorly correlated motion vectors in the computation adversely affects prediction accuracy. Once the predicted motion vector is obtained the first step of the algorithm is to move the initial search center to the predicted location.

2.2. Direction of Prediction

The prediction information is used to predict the direction of the motion of the current block. This is based on the predicted (initial) motion vector PMV and the motion vector of the previous block (i.e. the motion vector of the same block in the previous frame) $\mathrm{MV}_P(n-1)$. The direction information helps to check only some points along that direction. The whole space is partitioned into four sectors, as shown in Fig. 2. The area in which PMV is located, gives the direction of motion.

2.3. Four Sectored Search Pattern

2.3.1. Case 0: Stationary Blocks

For stationary blocks the initial search center is considered same as the actual search center. To capture any motion the algorithm takes two steps as shown in Fig. 3.

1. Initially the algorithm checks 8 points around the search center. If the center point is the minimum distortion point then we will stop the search, otherwise go to step 2. The minimum distortion point is calculated using the sum of absolute difference method.
2. In this step the number of points checked depends on the minimum position in the last step. So for the edge points 3 new points are checked whereas for corner points 5 new points are checked.

2.3.2.Case V: Small Motion Blocks

For the case when absolute value of $Px<=1$ and absolute value of $Py<=1$, then those blocks will be assumed as small motion blocks (Px and Py stand for x and y components of the predicted motion vector). To capture this motion the algorithm will take the steps as shown in Fig. 4.

1. Initially the algorithm checks 8 points around the search center. If the minimum location lies on the search center then the algorithm goes to step 4. Otherwise go to step 2
2. In this step the diagonal points around the search center are checked, and algorithm goes to step 3 if min location is at the center else go to step 4.
3. If the minimum point lies on the search center then horizontal and vertical points around the search pattern are used.
4. In this step 8 points around the search center are checked.

2.3.3. Case I-Case IV: Medium and Large Motion Blocks

Case I: Sector I ranges from -45 degree to 45 degree.
Case II: Sector II ranges from 45 degree to 135 degree.
Case III: Sector III ranges from 135 degree to 225 degree.
Case IV: Sector IV ranges from 225 degree to 315 degree.

If PMV lies in this range then its search pattern is defined by 5 points plus initial search center as in Fig. 5 (a). In case of moving blocks the motion can be classified as Medium Motion when $Px <= 3$ and $Py<= 3$ and Large Motion when $Px > 3$ and/or $Py > 3$. To capture this kind of motion the algorithm takes the following steps:

1. First step search pattern as shown in Fig.5 (a)
2. The 2nd step search pattern is shown in Fig. 5 (b).

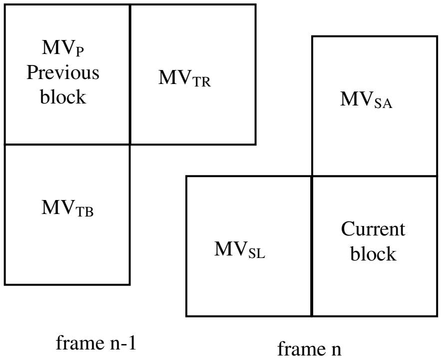

Fig. 1. Blocks for spatio-temporal correlation information

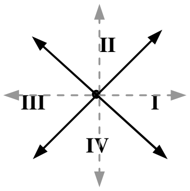

Fig. 2. Configuration of four sectors with respect to different possible directions of PMV. Solid lines represent the boundaries of sectors

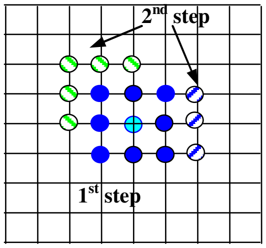

Fig. 3. Case 0: Stationary Blocks. Dark points represent the 1st search step whereas shaded points represent the 2nd search step

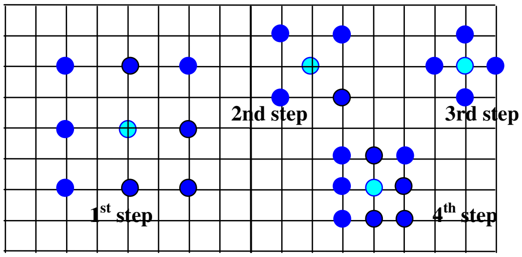

Fig. 4. Case V: Small Motion Blocks, 1st step (Large Square Pattern), 2nd step (Diagonal points), 3rd step (Horizontal/Vertical points), 4th step (Small Square Pattern)

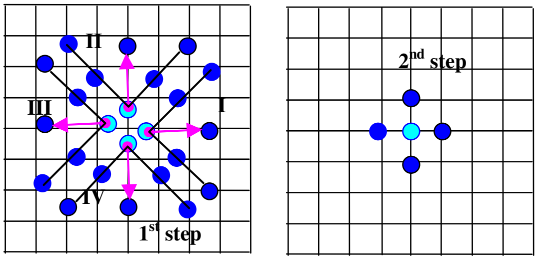

Fig. 5. (a) 1st Step Search pattern corresponding to 4 sectors. Arrow shows the moving direction of the predicted motion vector, (b) 2nd Step search pattern for 4 sectors (Case I- Case IV)

3. EXPERIMENTS

The proposed algorithm is simulated using the luminance components of the first 150 frames of Miss America, and 300 frames of Hall Monitor video sequence. The image format of Miss America and Hall Monitor is CIF (352x288) Each pixel in the image sequences is uniformly quantized to 8 bits. The block size selected is 16x16 pixels and the maximum motion displacement of search area is ± 7 in both horizontal and vertical directions. Sum of absolute difference (SAD) distortion function is used as the block distortion measure (BDM). The performance has been compared in terms of Peak Signal to Noise Ratio (PSNR) between estimated and original frames. The computational speed up has been obtained by getting the average search number (Av. Search No.) required for the motion vector estimation. α1 and α2 are selected to be .333 and .666 respectively.

Fig. 6 and Fig. 7 gives the experimental results for average PSNR comparisons. Table 1 gives the experimental results for average search number comparisons. From the comparisons it is seen that the proposed algorithm has better performance than other algorithms. The computational complexity of the proposed algorithm is also much less than other algorithms. It is also seen that the prediction pattern and search pattern adopted by the search algorithm is very robust, as when we compare the proposed algorithm 1 in which FS is used at the first step with proposed algorithm 2 where FS is not used then we observe from Fig. 7 that there is not much difference in the final PSNR. This proves the capability of the proposed algorithm to present a robust estimation of motion vectors. Similar is the case with the proposed algorithm 3 and 4. Hence we can easily discard the FS algorithm used at the first step as it has caused only an increase in the computational complexity with no appreciable affect on the PSNR.

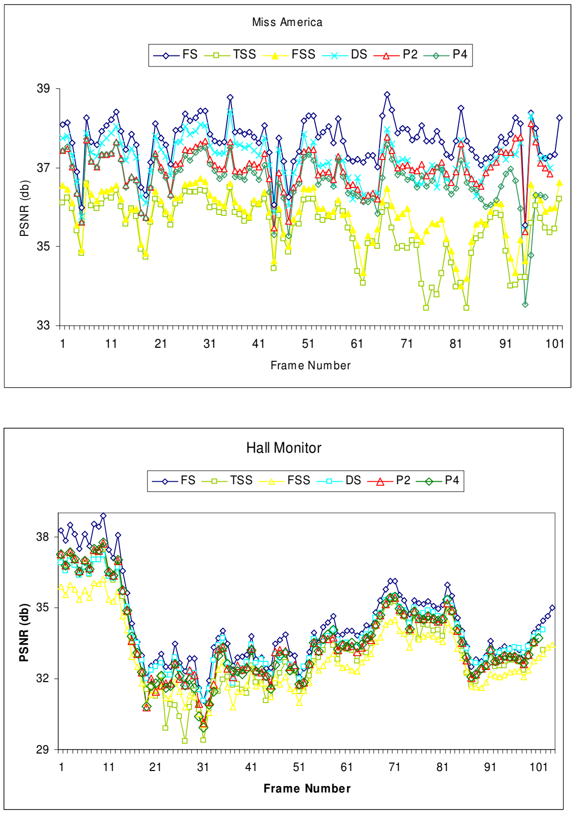

Fig. 6. PSNR Comparison for (a) Miss America sequence (b) Hall Monitor Sequence, P2 is for mean prediction and P4 for median prediction

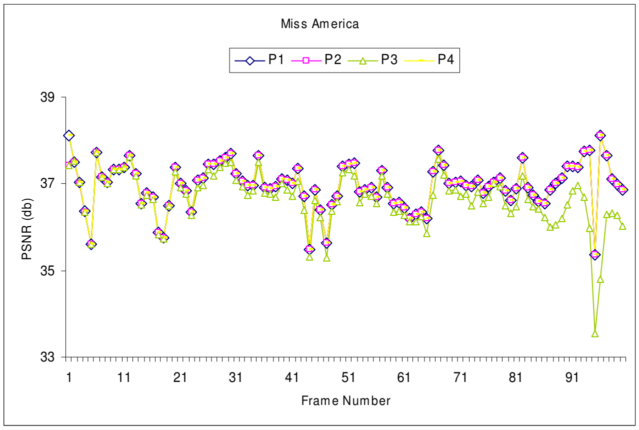

Fig. 7. PSNR Comparison for Miss America sequence.

TABLE 1 EXPERIMENTAL RESULTS FOR AVERAGE SEARCH NUMBER

P1: Mean Prediction + FS at First Step
P2: Mean Prediction Only
P3: Median Prediction + FS at First Step
P4: Median Prediction Only

Algorithms	Miss America	Hall Monitor
FS	204.28	204.28
TSS	24.53	24.5
FSS	18.21	16.13
DS	15.71	12.34
P1	12.44	9.49
P2	11.12	8.84
P3	11.89	10.35
P4	10.62	9.7

4. CONCLUSION

The proposed algorithm is based on the spatio-temporal correlation information available in the reference and current frames. This information is then used to define the direction of motion vectors, on which is based different search patterns, to get an accurate estimation of the minimum block distortion measure. Experimental results show that the proposed algorithm has improved error performance and less computational complexity as compared to other fast search algorithms.

5. ACKNOWLEDGMENT

This work was supported by the basic research project through a grant provided by the Gwangju Institute of Science and Technology in 2007.

5. REFERENCES

[1] Puri, H. M. Hang and D. L. Schilling, “An efficient Block matching algorithm for motion compensated coding,” Proc. IEEE Int. Conf. Acoust., Speech, and Signal Proc., pp. 1063-1066, 1987.

[2] H. Nisar and T. S. Choi, “A new four step search algorithm with minimum checking points for block motion estimation,” Proceedings of MICC and ISCE’99, Melaka, Malaysia, pp. 211-215, 1999.

[3] J. R. Jain and A. K. Jain, “Displacement measurement and its application in interframe image coding,” IEEE Trans. on Communications, Vol. COM-29, No. 12, pp. 1799-1808, Dec 1981.

[4] R. Li, B. Zeng and M. L. Liou, "A new three step search algorithm for block motion estimation," IEEE Trans. on Circuits and Systems for Video Technology, Vol. 4, No. 4, pp. 438-442, Aug. 1994.

[5] K. H. K. Chow and M. L. Liou, “Generic motion search algorithm for video compression,” IEEE Trans. on Circuits and Systems for Video Technology, Vol. 3, pp. 148-157, Apr. 1993.

[6] L. M. Po and W. C. Ma, “A novel four-step search algorithm for fast block motion estimation,” IEEE Trans. on Circuits and Systems for Video Technology, Vol. 6, No. 3, pp. 313-317, Jun. 1996.

[7] T. Koga, K. Iinuma, A. Hirano, Y. Iijima and T. Ishiguro, "Motion compensated interframe coding for video conferencing," Pro. Nat. Telecommun. Conf., New Orleans, pp. G5.3.1-5.3.5, Nov. 1981.

[8] L. M. Po and W. C. Ma, “New center biased search algorithm for block motion estimation,” Proc. of International Conference on Image Processing, USA, Vol. 1, pp. 410-413, 1995.

[9] K. R. Namuduri, Senior Member, IEEE, “Motion Estimation Using Spatio-Temporal Contextual Information”, IEEE Transactions On Circuits And Systems For Video Technology, Vol. 14, No. 8, August 2004.

[10] S. Zhu and K. K. Ma, “A new diamond search algorithm for fast block matching motion estimation,” IEEE Trans. Image Process., Vol. 9, No. 2, pp. 287-290, Feb 2000.

[11] Humaira Nisar and Tae-Sun Choi, “An Adaptive Block Motion Estimation Algorithm Based on Spatio Temporal Correlation”, Digest of Technical papers, pp. 393-394, International Conference on Consumer Electronics, Jan 7-11, 2006.