An Operationally Cost-Effective Block Matching Motion Estimation ESAT Algorithm with Skipping Method

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ABSTRACT - In this paper Enhanced Summed Area Table (ESAT) with elimination is proposed. Block-Matching (BM) Motion Estimation (ME) algorithm is widely used in most of the video coding systems. The advantage of this algorithm is in terms of reduced temporal redundancy in inter frames of video sequences. Though many block matching algorithms have been proposed to reduce the computational complexity of motion estimation, the computationally cost of effective Block-Matching (BM) ME algorithm is better choice for video conferencing, video telecasting and mobile communications applications. An operationally cost- effective BMME algorithm using Enhanced Summed Area Table (ESAT) with elimination Video data need to be stored and transmitted. However, due to limitations of storage capacity and transmission bandwidth, these numerousvideo data isto be compressed before they are stored and transmitted. So, videocompression coding system has become progressively more important. Block-Matching Motion Estimation Algorithm (BMMEA) is used in several video coding systems, because it can largelycurtail the temporal redundancy in inter frames of video sequences and maintaining the motion prediction quality relatively to the full-search algorithm. Though there areseveral algorithms that have been proposed to recedethe computational complexity of ME. The computationally cost of effective block-matching motion estimation algorithm is still required for video telecasting and mobile communications. Thispaper presents an operationally cost effective BMMEA Enhanced Summed Area Table Method (ESATM) with skipping technique. The proposed algorithm skips a lot of unnecessary operations before calculating block matching distortion. The simulation results showed that the proposed algorithm can effectively reduce the computational complexity of the motion estimation with SATM meanwhile guarantee the motion prediction quality. The paper is divided into 5 sections. Section 2 is the related work while the proposed work is presented in section 3 of this paper. Further section 4 and 5 discuss the simulation result and conclusion respectively.

II. RELATED WORK

For video data compression, BMA for ME is a more efficient technique in video coding system. It can methodicallyabate temporal redundancy of video sequences. In the BM ME method, the frame of video sequence is method is developed. The proposed algorithm skips more number of unnecessary operations by incorporating suitableconditions before calculating block matching distortion. Through simulation results the effectiveness of proposed algorithm is shown which effectively reduces the computational complexity of the motion estimation with ESAT while guarantee the motion prediction quality. The results show that about 72% operations have been skipped or eliminated.

Keywords: Video, BM, ME and ESAT

I. INTRODUCTION

firstly split into a successions of non-overlapping N × N sub-image blocks. Due to its simplicity and efficacy, the BM MEA has been widely adopted by many video coding systems such as H.264 and MPEG-4. For this, the Full Search Algorithm(FSA) is the modestME algorithm. It can obtain the optimal Motion Vector (MV) and the best matching quality. However, since the FSA needs to exhaustively check all the candidate matching points in the search window, it can lead to a more number of computations. So, ME occupies over 50 % computational weight in the current video compression system. In order to curtail the computational complexity of ME and get faster the process of video compression, numerous fast MEAs have been proposed in current years. These fast MEAs can be classified into two important methods: (i) Method is to search templates to reduce the search points of ME [1-12]; & (ii) Method adopting some reasonable strategies to decrease the amount of the calculation of the real BM distortion in the process of ME[13-21]. However, the most effective algorithm widely adopted is all-layer motion estimation (AME) search algorithm [22]. The All layer Motion Estimation (AME) is an efficient hierarchical MEA which performs ME on layers [14]. This algorithm boosts the search speed over MME by usingtwofold techniques namely Mean Inequality Elimination (MIE) method and an Improved Checker board Partial Distortion Search (ICPDS) scheme. The MIE method is an early termination method which castoffs the unnecessary search points during ME on the layers and hence reduces the calculations of ME without any loss in the matching quality. Further to curtail the number of calculations of ME, AME has employed ICPDS scheme is adopted to compute the partial distortions on the layers.

III. PROPOSED WORK

A. Block Based Motion Estimation Algorithm with Enhanced Summed Area Table

Let A and B represent macro block and candidate block of size M X N as shown in Fig.1 (a) and (b) respectively. Assume the motion estimation is performed on the layer *l*=3 where each macro pixel represents sum norm of block of size $\frac{M}{8} \times \frac{N}{8}$ as shown in Fig.2(a)and (b) respectively.

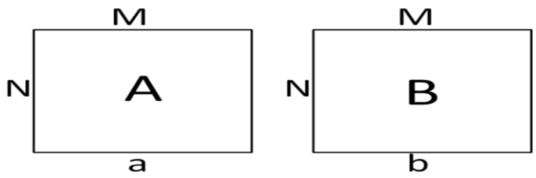

Figure 1: (a) Macro block (b) Candidate block of size M X N respectively.

The PSAD and Sum Norm Difference (SND) between the blocks A and Bare calculated as below

$$PSAD = \sum_{i=0}^{\left(\frac{M}{8}\right)-1} \sum_{j=0}^{\left(\frac{N}{8}\right)-1} \left|A_{ij} - B_{ij}\right| \qquad (1)$$

Where A_{ij} and B_{ij} represents sum norms of sub blocks (macro pixels) of size $\frac{M}{8} \times \frac{N}{8}$ at location (i,j) in the macro sub block and candidate sub block respectively.

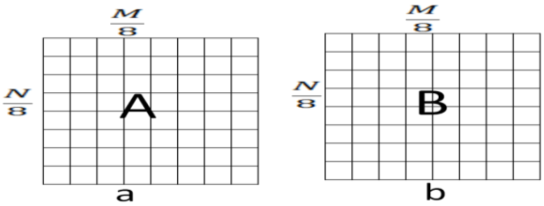

Figure 2:(a) Macro sub blocks; and (b) Candidate sub blocks of size $\frac{M}{8} \times \frac{N}{8}$ respectively.

There are three cases in which sum norm of macro block is either greater or less than sum norm of candidate block.

Case-I

$$\sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} A_{ij} > \sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} B_{ij} \qquad (2)$$

Then SND in can be calculated as

$$SND = \left| \sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} A_{ij} - \sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} B_{ij} \right| \qquad (3)$$

SND can simplified as

$$SND = \sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} A_{ij} - \sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} B_{ij} \qquad (4)$$

Further SND simplified as eq.(5)

$$SND = \sum_{i=0}^{\frac{M}{8}-1} \sum_{\substack{j=0 \\ (A_{ij} > B_{ij})}}^{\frac{N}{8}-1} (A_{ij} - B_{ij}) + \sum_{i=0}^{\frac{M}{8}-1} \sum_{\substack{j=0 \\ (A_{ij} < B_{ij})}}^{\frac{N}{8}-1} (A_{ij} - B_{ij}) \qquad (5)$$

Finally PSAD can be expressed as follows

$$PSAD = \sum_{i=0}^{\frac{M}{8}-1} \sum_{\substack{j=0 \\ (A_{ij}>B_{ij})}}^{\frac{N}{8}-1} (A_{ij} - B_{ij}) - \sum_{i=0}^{\frac{M}{8}-1} \sum_{\substack{j=0 \\ (A_{ij}<B_{ij})}}^{\frac{N}{8}-1} (A_{ij} - B_{ij}) \quad (6)$$

by using the eq.5 and eq.6the PSAD can be evaluated as

$$PSAD = SND - 2 \sum_{i=0}^{\frac{M}{8}-1} \sum_{\substack{j=0 \\ (A_{ij}<B_{ij})}}^{\frac{N}{8}-1} (A_{ij} - B_{ij}) \quad (7)$$

Case-II

$$\sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} A_{ij} < \sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} B_{ij}$$

Here SND can be calculated as

$$SND = \sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} B_{ij} - \sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} A_{ij} \quad (8)$$

Further SND simplified as eq.(9)

$$SND = \sum_{i=0}^{\frac{M}{8}-1} \sum_{\substack{j=0 \\ (A_{ij}<B_{ij})}}^{\frac{N}{8}-1} (B_{ij} - A_{ij}) + \sum_{i=0}^{\frac{M}{8}-1} \sum_{\substack{j=0 \\ (A_{ij}>B_{ij})}}^{\frac{N}{8}-1} (B_{ij} - A_{ij}) \quad (9)$$

Now by using the eq.1 and eq.5, the PSAD can be estimated as

$$PSAD = SND + 2 \sum_{i=0}^{\frac{M}{8}-1} \sum_{\substack{j=0 \\ (A_{ij}>B_{ij})}}^{\frac{N}{8}-1} (A_{ij} - B_{ij}) \quad (10)$$

Case-III

$$\text{If } \sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} A_{ij} = \sum_{i=0}^{\frac{M}{8}-1} \sum_{j=0}^{\frac{N}{8}-1} B_{ij} \quad (11)$$

Then either eq.7 or eq.10 can be used to evaluate the PSAD because both are equal.

B. Evaluation and Analysis of ANOB

The PSAD can be evaluated in two ways. In the first way, PSAD requires $\frac{M}{8} \times \frac{N}{8}$ addition, subtraction and absolute operation. Later the PSAD is to evaluate by using eq.(7). Here the addition, subtraction and absolute operation on the macro pixels which satisfy the condition $A_{ij}>B_{ij}$ are skipped while calculating the PSAD. Hence approximately 73% of additions, subtractions and absolute operations are skipped. Similarly in case (2),the addition, subtraction and absolute operation on the macro pixels which satisfy the condition $A_{ij}<B_{ij}$ are nearly 73% which are skipped. Thereby values of ANOB are reduced drastically. Hence significant improvement in speed is resulted.

C. Evaluation of PSNR

Mean square error is one of the estimation of prediction quality given by eq.(12)

$$MSE = \frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} [A(i,j) - B(i,j)]^2 \quad (12)$$

Where MN is the size of macro block A,B are the values of pixels of macro block and candidate block respectively location at (i,j)

PSNR is the final estimate of prediction quality for a frame given by eq.(13)

$$\text{PSNR} = 20\log_{10} \frac{P^2}{MSE} \quad (13)$$

where P is number of bits represented to a pixel in a frame.

IV. RESULTS AND DISCUSSION

To estimate the efficiency of the proposed algorithm, with various frame sizes ranging from 100 to 298of five video sequences are considered given in table1have been used in the simulations. Wide variety of test video sequences of various video formats and resolutions for different motions of video with varying frame rates are considered. It can be observed clearly from table 3 that the proposed algorithm takes very less number of operations than those required by the other blockbased algorithms. It is evident from the table 3 that the video sequence of football required more number of ANOB values (45688) for FGSEA. It is also clear that the proposed ESAT requires 11323 ANOB values only. From this table it is evident that for FLOWER video, the number of operations is very less i.e.25857 using proposed algorithm ESAT whereas EHS-DOIS, FGSEA MME, AME and ESAT algorithms take 56715, 14058, 13037, 10446 and 7852 operations respectively. Percentage of speed improvement of proposed method over existing algorithms for 7 different video sequences is presented in table 4. The Table-3 summarizes the ANOB of proposed algorithm, MME and various other fast block matching algorithms.

Table 1: Test sequences used in simulation.

S. No.	Video Sequence	Video Format	Resolution	Frame Rate(fps)
1	Football	CIF	352x288	30
2	Waterfall	CIF	352x288	29
3	Mobile	CIF	352x288	29
4	Foreman	CIF	352x288	29
5	Cricket	QCIF	176x144	29
6	Flower	QCIF	176x144	29
7	Soccer	CIF	352x288	30

Table 2: Video sequence name and snapshot used in simulation.

Football	Waterfall	Mobile	Foreman	Cricket	Flower	Soccer
						

Table 3: ANOB of the various fast block-based ME methods using ESATM algorithm for macro block size of 32X32.

S. No.	Video sequence	Existing Methods				Proposed Methods	
		FGSEA	EHS-DOIS	MME	AME	SATM	ESATM
1	Football	45688	132470	16169	16695	13031	11323
2	Waterfall	20561	86172	12940	11926	9620	6405
3	Mobile	21377	104060	13224	12297	9862	6699
4	Foreman	31816	80468	13985	13341	10570	8170
5	Cricket	29952	75842	14323	13384	10675	7874
6	Flower	25857	56715	14058	13037	10446	7852
7	Soccer	42614	138200	15358	15445	12112	10211

Table 4: The percentage of Speed Improvement (SI) of ESAT over existing algorithms for macro block size of 32X32.

S. No.	Video sequence	FGSEA	EHS-DOIS	MME	AME	SAT
1	Football	75.21	14.52	29.97	32.17	13.10
2	Waterfall	68.84	92.56	50.50	46.29	33.41
3	Mobile	68.66	93.56	49.34	45.52	32.07
4	Foreman	74.32	89.84	41.58	38.76	22.70
5	Cricket	73.71	89.61	45.02	41.16	26.23
6	Flower	69.63	86.15	44.14	39.77	24.83
7	Soccer	76.03	92.61	33.51	33.88	15.69
8	Average % SI for ESAT	72.34%	88.50%	42.01%	39.65%	24.01%

It is noticed from table-4 that percentage of speed improvement with ESAT over existing algorithms is good. The ESTA algorithm obtains highest speed improvement of 93.56% for video sequence of mobile against EHS-DOIS algorithm and also it is evident that ESAT performs least percentage of speed obtains 14.52% for the video sequence of Akiyo compared with EHS-DOIS algorithm. Percentage of skipping operations per frame using ESAT algorithm for various video sequences is presented in table5. Table5: represents that the proposed ESAT algorithm has highest percentage of skipping of operations per frame (72.20%) for cricket video sequence compared with other video sequences. Second highest percentage of skipping of operations per frame (69.69%) for flower video sequence. Moreover it is evident that it has least value of percentage of skipping (61.02%) for the football video sequence.

Table 6: displays that the average PSNR of ESAT is same as that of AME and SAT systems. When compared with FFS block-based ME algorithms (EHS-DOIS, FGSEA and MME), the ESAT algorithm saves about 97% computations while maintaining the PSNR values. From the table 6, it is evident that SAT and ESAT achieves high quality of video i.e. 32.05dB% and 36.25dB% respectively compared with EHS-DOIS, FGSEA, MME and AME algorithms for Waterfall video sequence. It is also clear that least PSNR value i.e. 21.36dB is for football video sequence. waterfall video PSNR value reaches high value i.e. 32.81dB, 32.64dB, 33.04dB, 36.09dB,33.05dB and 36.25dB for the existing algorithms EHS-DOIS, FGSEA, MME, AME and ESAT, SAT respectively compared with other video sequences. To demonstrate the efficiency of the proposed system, figures 3,4 and 5 show ANOB and PSNR respectively for all the algorithms using a foot ball video sequence.

From Fig.3, it is very clear that the number of operations of ESAT process is lesser in comparison with the remaining algorithms. Thus, the motion estimation process requires less computations. From the Fig.3, it is very clear that at frame number 125 FGSEA algorithm requires highest ANOB values (59450) and it is observed that this algorithm has second and third highest ANOB values around 75 frames and 152 frames respectively for football video this is because the object moment is very fast in that duration of specified frames.

Table 5: Percentage of skipping of operations per frame using proposed ESAT algorithm.

Video ID	Video sequence	No. of frames	% of Skipping operations per frame ESAT
1	Football	258	61.02
2	Waterfall	258	64.40
3	Mobile	298	65.00
4	Foreman	298	66.67
5	Cricket	298	72.20
6	Flower	297	69.69
7	Soccer	148	62.15

Table 6: The average PSNR (dB) of ESAT algorithm compared with the other algorithms.

S. No.	Video sequence	Existing Algorithms				Proposed	
		EHS-DOIS	FGSEA	MME	AME	SAT	ESAT
1	Football	21.36	19.61	21.79	22.58	21.80	22.30
2	Waterfall	32.81	32.64	33.05	36.09	33.05	36.25
3	Mobile	21.64	21.94	22.65	23.51	22.65	23.61
4	Foreman	27.67	27.35	28.89	30.39	28.89	29.77
5	Cricket	31.87	29.20	32.36	33.59	32.36	33.23
6	Flower	28.55	26.13	29.23	30.51	29.23	29.32
7	Soccer	23.13	22.10	23.71	24.46	23.70	23.72

In order to show the efficiency of the proposed algorithm effectively, the ANOB and PSNR for all the algorithms using a News video sequence are shown in Fig.3 and Fig.4 respectively. From Fig. 3, it is very clear that the number of operations required by the ESAT algorithm is less when compared to remaining algorithms. Thus, the motion estimation process requires less computations. From the Fig.3 it is very clear that at frame number 150 FGSEA algorithm requires highest ANOB values (45000) and it is observed that this algorithm has second and third highest ANOB values around 202 frames and 110 frames respectively for Football video. This is because the object moment is very fast in that duration of specified frames. From Fig.4 it can be observed that the ESAT algorithm is able to achieve same PSNR value for AME and ESAT but with a smaller number of computations required.

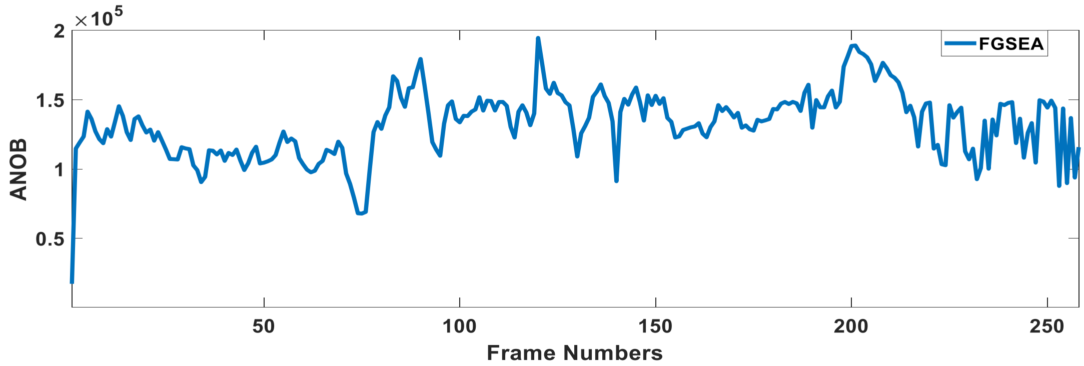

Figure 3: ANOB in each frame for FGSEA algorithm using foot ball vedeo sequence.

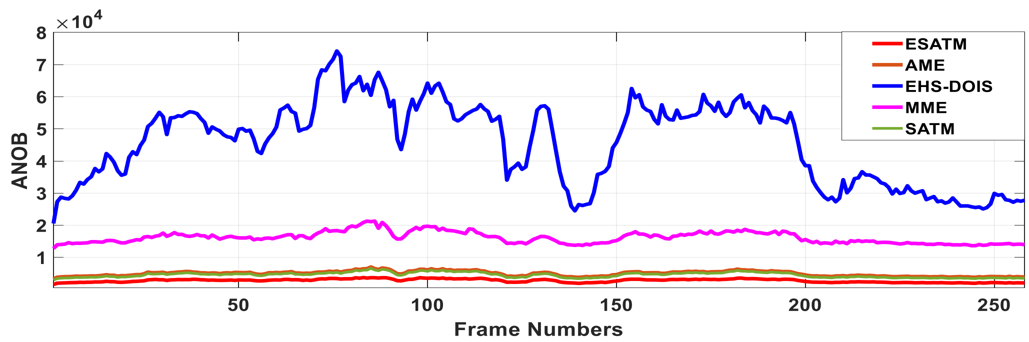

Figure 4: ANOB in each frame for various algorithm except FGESA using foot ball vedeo sequence.

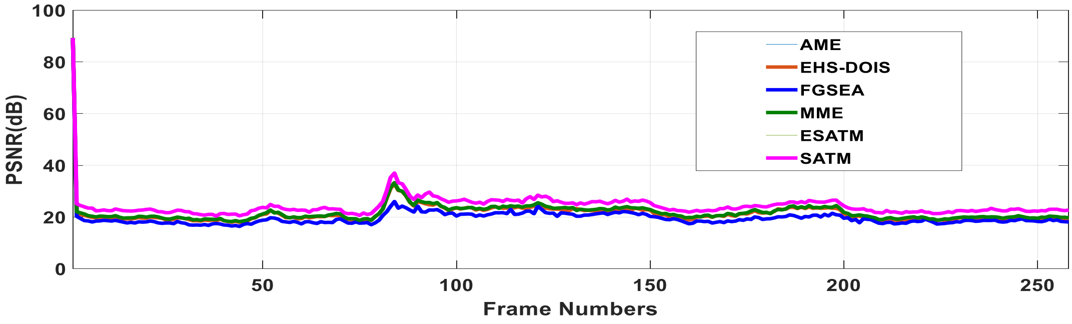

Figure 5: The average PSNR(dB) in each frame for various algorithms using foot ball vedeo sequence.

In table 3 ANOB values are presented for proposed algorithm along various existing block matching algorithms. The size of macro block is 32x32 with number of frames of video sequence is from 100 to 298. It can be observed clearly from table 3 that the proposed algorithm takes very less number ofoperations than those required by the existing block-based algorithms. To estimate the efficiency of the proposed algorithm, with various frame sizes ranging from 100 to 298 of seven video sequences are considered given in table-3 have been used in the simulations. The search range is selected as ±15 for high definition of all video sequences. The block size is chosen as 32x32 and with this block size, four layers can be constructed (*l*=0 to 3). The AME and the ESATM algorithms perform the motion estimation on the layers at *l*=1,2&3 using ODS, TDS & FCS patterns. Wide variety of test video sequences of various video formats and resolutions for different motions of video with varying frames rates are considered.

V. CONCLUSION

An operationally costeffective block-matching motion estimation algorithm using Enhanced Summed Area Table (ESAT) with skipping technique is developed. It is observed that the video sequence of football requires more number of ANOB values (45688) for FGSEA where as the proposed ESAT requires only 11323 ANOB values. It is also noticed that for water fall video, number of operations is very less ANOB values of 6405. ESTAM algorithm achieves highest speed improvement of72.34%,88.50%,42.01%,39.65% and 24.01% over FGSEA, EHS-DOIS, AME, MME and SAT respectively, with the motion prediction quality very close to the Full-Search algorithm is still maintained.

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