Implementation of Efficient Block Based Motion Estimation Algorithm using Skipping Technique

B. Prabhakar, D. Krishna Reddy

***Abstract:** Block-Matching (BM)Motion Estimation(ME) algorithm is used in most of the video coding systems. The advantage offered is in terms of reduced temporal redundancy in inter frames of video sequences. Though many BM algorithms have been proposed to reduce the computational complexity of ME, 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 skipping technique is developed. The proposed algorithm in this paper skips more number of unnecessary operations by incorporating suitable conditions before calculating block matching distortion. Through simulation results the effectiveness of proposed algorithmis shown which effectively curtails the computational complexity of the ME with ESAT while guarantee the motion prediction quality.The results show that about 79.85% operations have been skipped or eliminated.*

***Keywords:** Video, BMME, ESAT*

I. INTRODUCTION

Video raw data Have to be stored and transmitted. However, due to limitations of storage capacity and transmission bandwidth, these numerousvideo data is be compressed before they are stored and transmitted. So, videocompression coding system has become progressively more important. BMMEA is used in several video compression systems because it can largelycurtail the temporal redundancy in inter frames of video sequences and maintaining the motion estimation quality relatively to the Full Search Algorithm (FSA). Though there areseveral algorithms that have been proposed to recede the complexity calculations of motion estimation. The computationally cost of effective block-matching motion estimation algorithm is still required for video telecasting and mobile communications. This paper 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.

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***** Correspondence Author
B. Prabhaka, Dept. of ECE, JNTUHCEJ Jagtial, Telangana,Inida
Dr.D. Krishna Reddy, Dept. of ECE BIT,Hyderabad,Telangana, India.

II. RELATED WORK

For video data compression, BMA for ME is a more effective technique in video compression system. It can redundancy in a video. In the BM ME method, the frame of video sequence is firstly split into a succession of non-overlapping subblocks of size N × N .Due to its simplicity and efficacy, the BM MEA has been widely implemented by many video coding systems such asMPEG-4 and H.264/AVC. For this, the FSA is the modest ME algorithm. The best matching quality and the optimal Motion Vector (MV) can be obtained. However, since the FSA needs to comprehensively check all the candidate matching points in the search window which leads to a larger computations. So, ME reside 50 % computational weight in the current video coding. In order to curtail the computational complexity of ME and get faster the process of video coding, 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 curtail the search points of ME [1-12]; & (ii) Method employing certain approaches to decrease the number 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 AME is an efficient hierarchical MEA which performs ME on layers [14]. This algorithm boosts the search speed over MME by using twofold techniques namely Mean Inequality Elimination (MIE) method and an Improved Checker board Partial Distortion Search (ICPDS) approach. 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 ME 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.

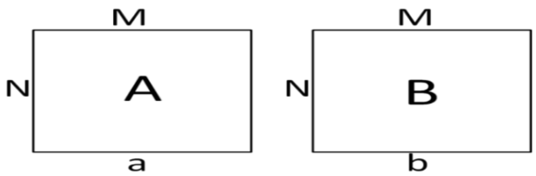

Figure 1: (a) Macro block (b) Candidate block of size M X N respectively.

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

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

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.

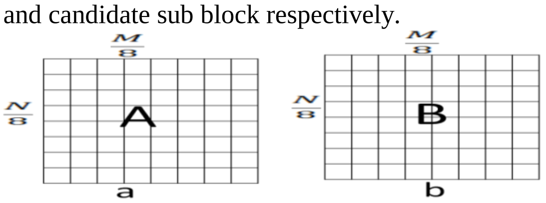

Figure 2:(a) Macro sub blocks; and (b) Candidate sub blocks of size $\frac{M}{8} \times \frac{N}{8}$ respectively.

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

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

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

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

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)

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

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

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

Case-III

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

Then either eq.7 or eq.710 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 andabsolute 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)

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

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 2 that the proposed algorithm takes very less number of operations than those required by the other blockbased algorithms. It is evident from the table 2 that the video sequence of football required more number of ANOB values (62730)for FGSEA.
It is also clear that the proposed ESAT requires 2783 ANOB values only.From this table it is evident that for Akiyo video, the number of operations is very less i.e.1513 using proposed algorithm ESAT where as EHS-DOIS, FGSEA MME, AME and SAT algorithms take 5156, 6923, 3199, 3230 and 2837operations respectively.

Percentage of speed improvement of proposed method over existing algorithms for 5 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 2 indicates that the five video sequences and respective video snap shot.

Table 1:Test sequences used in simulation

S.No	Video Sequence	Video Format	Resolution	Frame Rate(fps)
1	Football	CIF	352x288	30
2	Akiyo	QCIF	176x144	29
3	News	QCIF	176x144	29
4	Vehicle Scooty	Full HD	1920x1080	29
5	NSS_Rally_Ces	4CIF	704x576	29

Table 2: Video sequence name and snapshot used in simulation

FOOTBALL	AKIYO	NEWS	VEHICLE SCOOTY	NSS-RALLY-CES
				

Table 3: ANOB of the various fast block-based motion estimation algorithms using ESATM algorithm.

S.No.	Video sequence	Existing Methods				Proposed Methods	
		FGSEA	EHS-DOIS	MME	AME	SATM	ESATM
1	Football	62730	11909	4385	5873	4556	2783
2	Akiyo	6923	5156	3199	3230	2837	1513
3	News	8544	5279	3236	3322	2889	1575
4	Vehicle Scooty	51347	15945	4527	4322	3624	3009
5	NSS_Rally_Ces	16003	8139	3659	3762	3446	1937

Table 4: The percentage of Speed Improvement (SI) of ESAT over existing algorithms.

S.No.	Video sequence	FGSEA	EHS-DOIS	MME	AME	SAT
1	Football	95.56	76.63	36.53	52.61	38.91
2	Akiyo	78.14	70.65	52.7	53.15	46.66
3	News	81.56	70.16	51.32	52.58	45.48
4	Vehicle Scooty	94.13	81.12	33.53	30.37	16.97
5	NSS_Rally_Ces	87.89	76.2	47.06	48.51	43.78
6	Average % SI for ESAT	87.45%	74.95%	44.22%	47.44%	38.36%

It is clear from table-4 that percentage of speed improvement with ESAT over existing algorithms is good. The ESTA algorithm obtains highest speed improvement of 95.56% for video sequence of football against FGSEA algorithm and also it is evident that ESAT performs least percentage of speed obtains 78.14% for the video sequence of Akiyo compared with FGSEA algorithm.
The ESAT algorithm obtains second highest improvement of 81.12% for the video sequence of vehicle scooty over EHS-DOIS algorithm and also the proposed algorithm performs least percentage of improvement over 69.10% for the video sequence of suzie (girl) compared to EHS-DOIS.Percentage of Skipping operations per frame using ESAT algorithm for various video sequences is presented in table5.
From the table 5, it is noticed that the proposed ESAT algorithm has highest percentage of skipping of operations per frame (79.85%) for Akiyo video compared with other video sequences. And, it is evident that the proposed algorithm has least value of percentage of skipping (66.09%) for the football video sequence.

The PSNR values per frame in the proposed algorithm over other block-based motion estimation algorithms have been presented in Table6. It canbe observed from table 6, that the average PSNR of the ESAT algorithm is same as that of AME and SAT algorithms. When compared with fast full search block-based motion estimation 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 ESAT and SAT achieves high quality of video i.e. 44.49dB% and 44.45dB% respectively compared with EHS-DOIS, FGSEA, MME and AME algorithms for Akiyo video sequence.

It is also clear that least PSNR value i.e. 22.31dB for mobile video sequence. Akiyo video PSNR value reaches high value i.e. 41.90dB, 42.28dB, 42.20dB, 44.27dB and 44.49dB for the existing algorithms EHS-DOIS, FGSEA, MME, AME and SAT respectively compared with other video sequences this is because the motion of the object in this video is slow.

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	66.09
2	Akiyo	298	79.85
3	News	297	75.62
4	Vehicle Scooty	100	70.61
5	NSS_Rally_Ces	100	78.39

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	22.80	24.72	23.29	23.16	24.24	24.23
2	Akiyo	41.90	42.28	42.20	44.27	44.49	44.45
3	News	34.65	35.09	34.88	36.18	36.20	36.20
4	Vehicle Scooty	29.94	32.16	30.06	31.17	30.06	31.76
5	NSS Rally Ces	28.13	30.83	30.22	31.04	31.49	31.50

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 245 frames and 96 frames respectively for News 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.

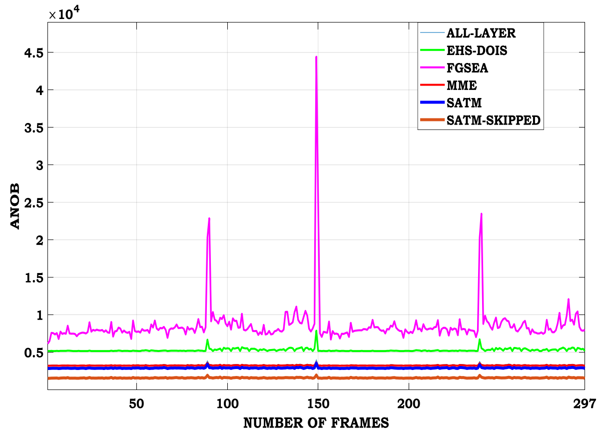

Figure 3: ANOB in each frame for all various algorithms using to News video sequence.

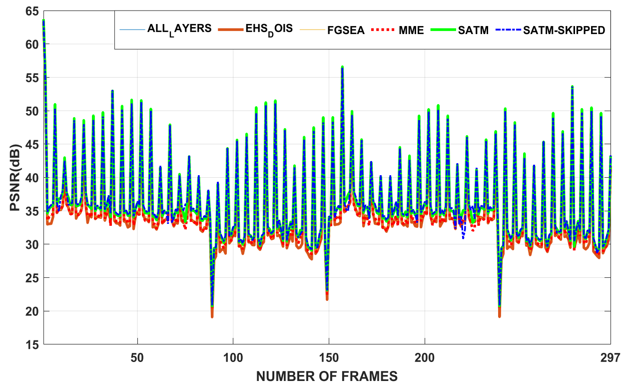

Figure 4: The Average PSNR (dB) in each frame for various algorithms to News video sequence.

In table 3 ANOB values are presented for proposed algorithm along various existing block matching algorithms. 32x32 is the size of macro block 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 of operations 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 ten 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 cost effective 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 (62730) for FGSEA where as the proposed ESAT requires only 2783 ANOB values. It is also noticed that for Akiyo video, number of operations is very less ANOB values of 1513. ESTAM algorithm achieves highest speed improvement of 87.45%, 74.95%, 44.22%, 47.44% and 38.36% 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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AUTHORS PROFILE

B.Prabhakar, is a Associate Professor, Department of ECE at JNTUHCEJ Jagtial (Dist.). Presently he is perusing Ph.D in wireless communication. His research interest incude Mobile commonication, video processing, image processing and communication. Member of professional bodies LMISTE and FIETE

Dr.D.Krishnareddy, is Professor & HOD of ECE-Dept.,CBIT,Hyderabad. His research interest incude Mobile commonication,GPS and 3G.Member of professional bodies LMISTE,FIETE and MIEEE