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An Efficient Motion Estimation Schemes for Application Targeting High Quality HEVC Schemes

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Abstract: In video coding the Motion Estimation (ME) is accomplished by two types of algorithm, namely, Full Search and Fast Search algorithm. The time and computational complexity of full search made them inefficient for motion estimation. On the other hand, the improved time efficiency of the Fast Search algorithm made them a popular choice for motion estimation. A novel approach to develop the fast motion estimation algorithm for High Efficiency Video Coding (HEVC) is proposed in this paper. The proposed algorithm is implemented in HEVC using the HM 15.0 reference software and the proposed algorithm is evaluated in terms of Peak Signal to Noise Ratio (PSNR), motion estimation time and Mean Square Error (MSE). The evaluation is performed using various standard videos such as Coast guard, Container, Harbour, Mother, Mobile, Bridge, Crew, City, Sea and Ice. The proposed algorithm outperforms the conventional UMHexagonS algorithm under various parametric evaluations. The proposed algorithm achieves an average PSNR gain of 0.4%, 1% and 0.52% for Quantization Parameter Q_P=20, Q_P=25 and Q_P=30 respectively. In similar, the plot for ME time against the number of frames, shows that the motion estimation time is reduced in the proposed algorithm. Finally, the Mean Square Error (MSE) is computed and found to be reduced when compared to conventional algorithm.

Key words: Motion Estimation (ME) · Block Matching Algorithm (BMA) · HEVC · Fast Search algorithm · HM 15.0

INTRODUCTION

The video application such as, video coding and real-time video playback, conferencing, transmission, data storage and surveillance are in need of high compression ratio due to the bounded channel bandwidth. The high compression ratio can be achieved by eliminating the temporal redundancy in the video sequence and this temporal redundancy are eliminated by the utilizing the powerful technique called as Block Matching Motion Estimation (BMME) [1].

The Block Matching Algorithm (BMA) will identify the best motion vector in reference frame with correspondence to the current frame. The Block Matching Algorithm (BMA) is accepted as the international standard for the audio and video coding such as Moving Picture Experts Group-1 (MPEG-1) [2], MPEG-2 [3] and MPEG [4]. Also, this algorithm is used in High Efficiency Video Coding (HEVC) [5] codec (coder/decoder) such as, H.261 [6], H.262 [7], H.263 [8], H.264 [9] and H.265 [10]. The basic flow of codec with motion estimation and motion compensation is shown in Figure 1. In video sequence, with respect to the previous frame the encoder will estimate the motion vector in the current frame using Block Matching Algorithm (BMA). The block from the previous frame is used to build the motion compensated block of the current frame. The encoder will send the motion vector of the compensated block (image) and to determine the motion vector for the sequence of frame in the video, this block (compensated block) is considered as a reference frame. The process of motion estimation is reversed in the decoder to form the decompressed video.

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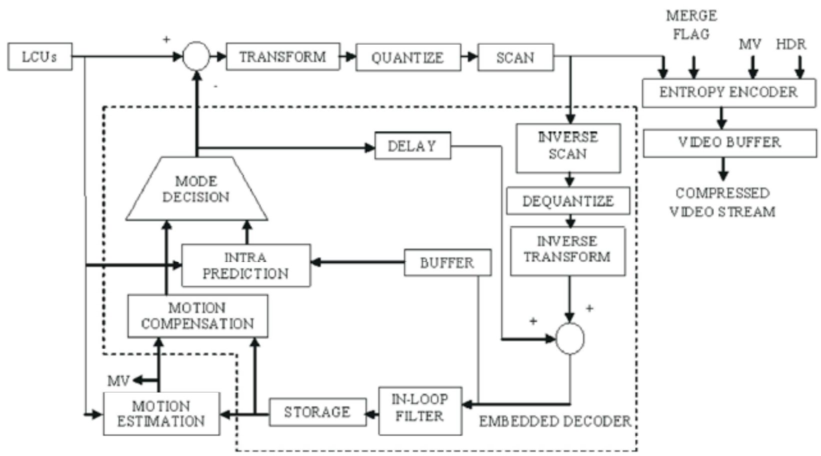

Fig. 1: Coder Architecture

Related Block Matching Algorithm (BMA): However, the compression of the video leads to less bandwidth usage, but 50% - 90% of the encoding time will be dissipated on determining the Motion Estimation (ME) [11]. The block matching is determined by two types of algorithm, namely Full Search [12-13] and Fast Search [14] algorithm. Compared to the fast search algorithm, the full search algorithm follows exhaustive search that leads to high computational time and complexity. To overcome the constraints of Full Search (FS) algorithm, various fast search algorithms have been proposed such as, new three step search [15], diamond search [16], four step search [17], cross search [18] and hexagonal search [19]. In [20], the motion vector is predicted by various features such as, block sum and block variance sum, the integral frame attributes are used to compute these features. The adaptive dual cross search algorithm is proposed in [21] for motion estimation that is more efficient than traditional algorithm such as, three step search, orthogonal and diamond search. The real distortion calculation and high computational complexity are reduced by adopting the enhanced hexagonal search algorithm [22] for motion estimation. The number of memory access and power consumption of motion estimation [23] is reduced by combining the weighted one-bit transformation and diamond search algorithm. In [24], the speed of hexagonal and diamond search is increased up to 30% by adopting the novel point oriented inner search technique. The modified diamond search algorithm [25] is proposed to achieve a lesser number of search points and to reduce the computational complexity. The CDHS algorithm [26] achieves 144% and 73% faster motion estimation than diamond search and cross diamond search respectively.

Problem Identification: The knowledge of Block Matching Algorithm (BMA) from previous section reveals that to design a motion estimation algorithm, we have to consider the speed and complexity of computation, the number of search point in each move and prediction of initial search point. Many research works have been proposed by modifying the fundamental fast algorithm such as diamond search algorithm [27-29] and hexagon search algorithm [30, 31].

The probability of finding the motion vector by various search algorithms in a macro block is depicted in Figure 2. From Figure 2 the possibility of predicting the motion vector in the horizontal direction is high when compared to a vertical direction. The idle search pattern of circle shape with possible 13 search point is shown in Figure 3. We choose hexagon after an initial search point is predicted, since the diagonal shape is far away from the shape of a circle. In addition the hexagon and diamond shape can be differentiated into two types based on the search points covered as shown in Figure 4. Hence, by formulating the problem in different algorithm, this paper proposes a novel approach to develop the fast motion estimation algorithm.

Prediction of Initial Search Point: The major drawback of UEAS (Unimodal Error Surface Assumption) [32] is the possibility of entering into the local minimum [33] during the block matching search. The adverse effect of UEAS can be overcome by efficiently using the correlation in the sequence of frame. Also, the accurate search point is achieved by the complete use of correlation. The unique fact about the natural video sequence is that, the temporal and spatial neighboring block of video sequence has a

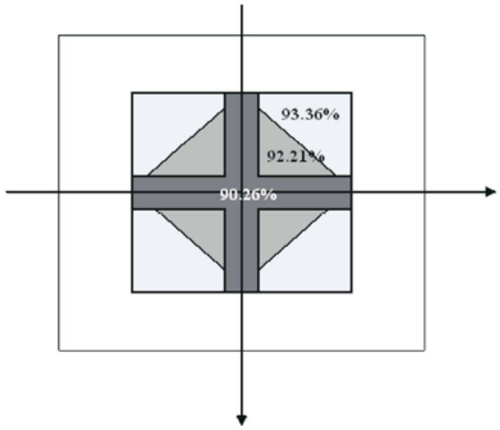

Fig. 2: Probability of Motion Estimation

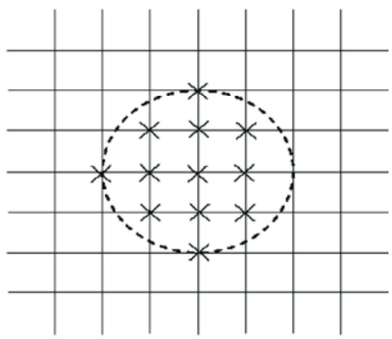

Fig. 3: Idle Search Pattern

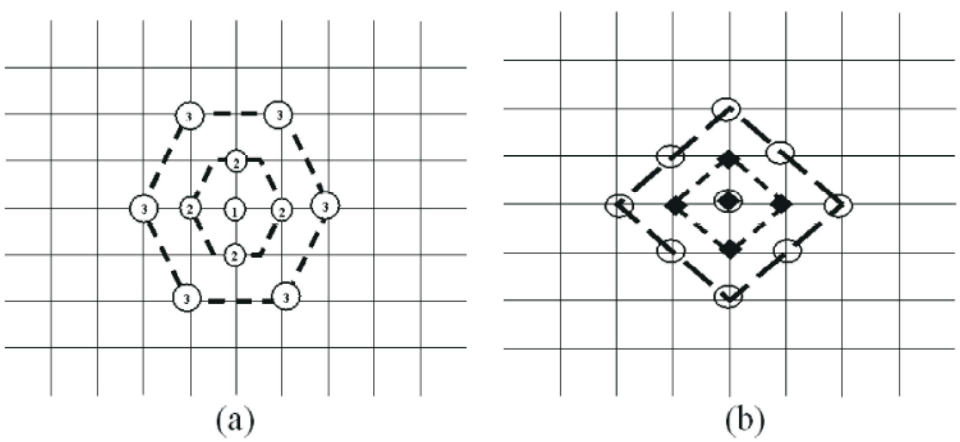

Fig. 4: (a) Hexagon (b) Diamond

high correlation in terms of Motion Vector (MV). In the temporal domain, the collocated blocks of two consecutive frames of natural video have a strong correlation between them. In contrast the correlation exists between neighboring blocks of a macro block in spatial domain. In order to reduce the local minimum and make use of complete correlation the initial search point is predicted by the median predictive model. Let us consider a 5x5 macroblock in the current frame and reference frame as shown in Figure 5. Here the current motion vector is present in the position (2,2) and in correspondence with this, the Initial Search Point (ISP) in the reference frame is calculated by determining the median value of position (1,2), (1,3) and (2,1). The Initial Search Point (ISP) for reference frame with correspondence to the current frame can be computed by using (1). Here position (1,2), (1,3) and (2,1) represents the top, top-right and left of the current motion vector position respectively.

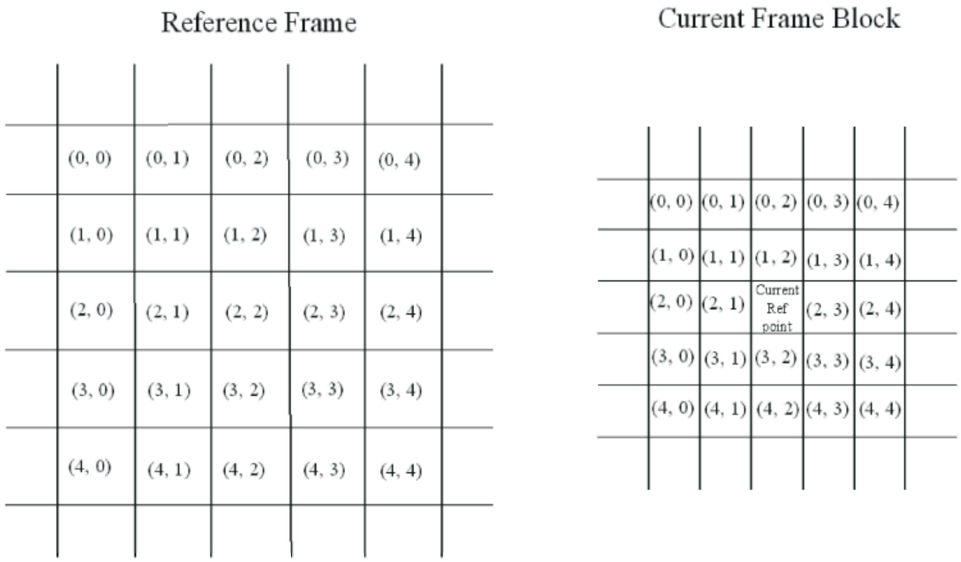

Fig. 5: 5x5 Macro block

$$ISP = median\ \{(1,2), (1,3), (2,1)\} \quad (1)$$

The distribution of motion vector in a sequence of natural video is computed by conducting an experiment with standard video such as mother, harbor and bus. The HM 15.0 [34] reference codec of High Efficiency Video Coding (HEVC) is used to conduct the experiment for motion vector distribution.

The motion vector distribution of various standard video is computed for three different resolutions such as Quarter Common Intermediate Format (QCIF), Common Intermediate Format (CIF) and High Definition (HD1080). In similar, the Quantization Parameter (Q_P) is assumed as 20, 25 and 30. The motion vector is calculated for 4 different positions, namely, (0,0), (x,0), (0,y) and (x,y).

Where, (0,0) denotes the initial search point, (x,0) denotes the motion vector in the horizontal direction with respect to (ISP), (0,y) denotes the motion vector in vertical direction with respect to (ISP) and (x,y) represent other possible directions. The evaluation from Table 1 disclose, as the Quantization Parameter (Q_P) increases the possibility of motion vector in (0,0) increases and the possibility of motion vector in (x,y) decreases. Whereas, the change in Quantization Parameter (Q_P) is not affecting the possibility of motion vector in (x,0) and (0,y) directions. The promising results from Table 1 shows that (0,0) achieves an average of 66.92% and on the other hand (x,0), (0,y) and (x,y) achieves 24.29%, 7.57% and 3.84% respectively. Hence, to achieve the higher efficiency, the proposed algorithm consider (0,0) as Initial Search Point.

Table 1: Average Search Pattern Direction

Quantization Parameter (Q_P)=20					
Resolution	Frame	(0,0) (%)	(x,0) (%)	(0,y) (%)	(x,y) (%)
QCIF	Mother	78.27	36.33	14.35	9.41
CIF	Harbour	69.83	21.09	7.14	2.56
HD (1080)	Bus	40.65	15.95	1.83	4.13
Average	-	62.92	24.46	7.77	5.37
Quantization Parameter (Q_P)=25					
Resolution	Frame	(0,0) (%)	(x,0) (%)	(0,y) (%)	(x,y) (%)
QCIF	Mother	81.25	35.95	14.07	8.05
CIF	Harbour	72.76	21.05	6.89	1.15
HD (1080)	Bus	45.75	15.35	1.19	0.56
Average	-	66.59	24.12	7.38	3.25
Quantization Parameter (Q_P)=30					
Resolution	Frame	(0,0) (%)	(x,0) (%)	(0,y) (%)	(x,y) (%)
QCIF	Mother	86.36	36.15	14.65	6.09
CIF	Harbour	75.59	21.25	7.05	0.45
HD (1080)	Bus	51.80	15.50	1.02	2.13
Average	-	71.25	24.30	7.57	2.89
Average Result					
Average	Frame	(0,0) (%)	(x,0) (%)	(0,y) (%)	(x,y) (%)
QCIF	Mother	62.92	24.46	7.77	5.37
CIF	Harbour	66.59	24.12	7.38	2.89
HD (1080)	Bus	71.25	24.30	7.57	3.25
Average	-	66.92	24.29	7.57	3.84

Proposed Motion Estimation Algorithm: The evaluation from Table 1 shows that an average of 3.84% is achieved by assuming the Initial Search Point (ISP) as (x,y). In similar, the average of (x,0) and (0,y) is smaller when compared to (0,0). Hence, in our work we consider the Initial Search Point (ISP) as (0,0) to determine the motion vector efficiently. The flow chart of the propose Motion Estimation (ME) algorithm is shown in Figure 6.

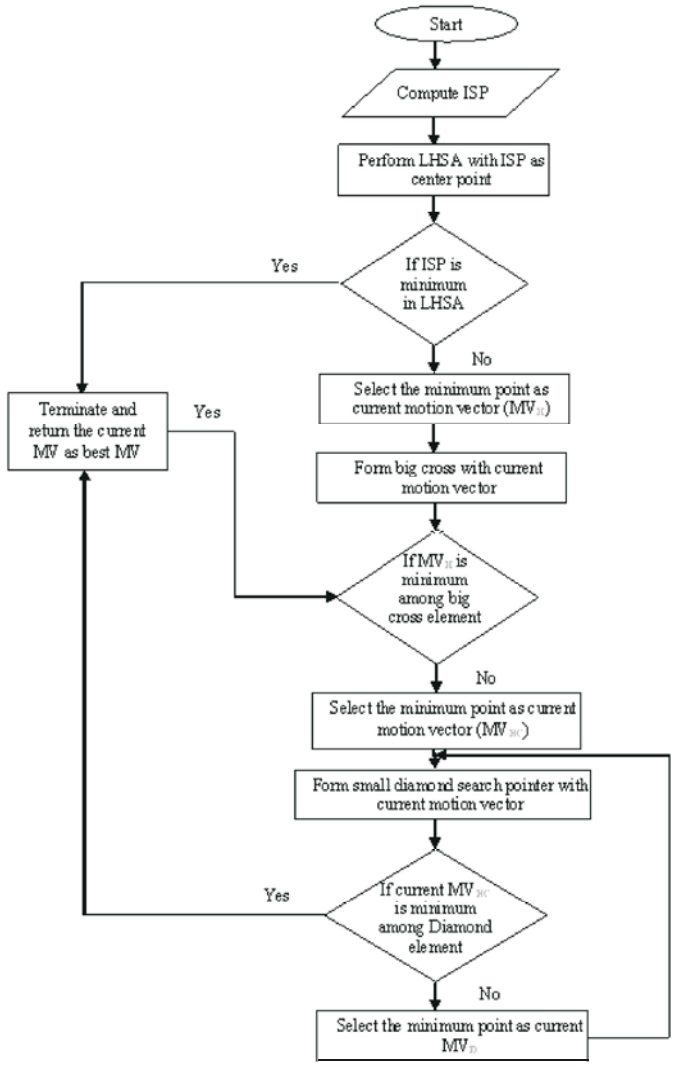

Fig. 6: Flowchart for Proposed Algorithm

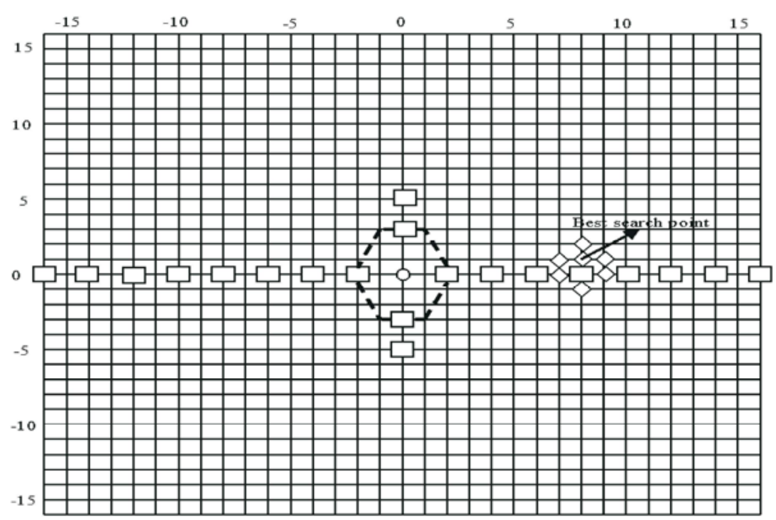

Fig. 7: Search Pattern of Proposed Algorithm

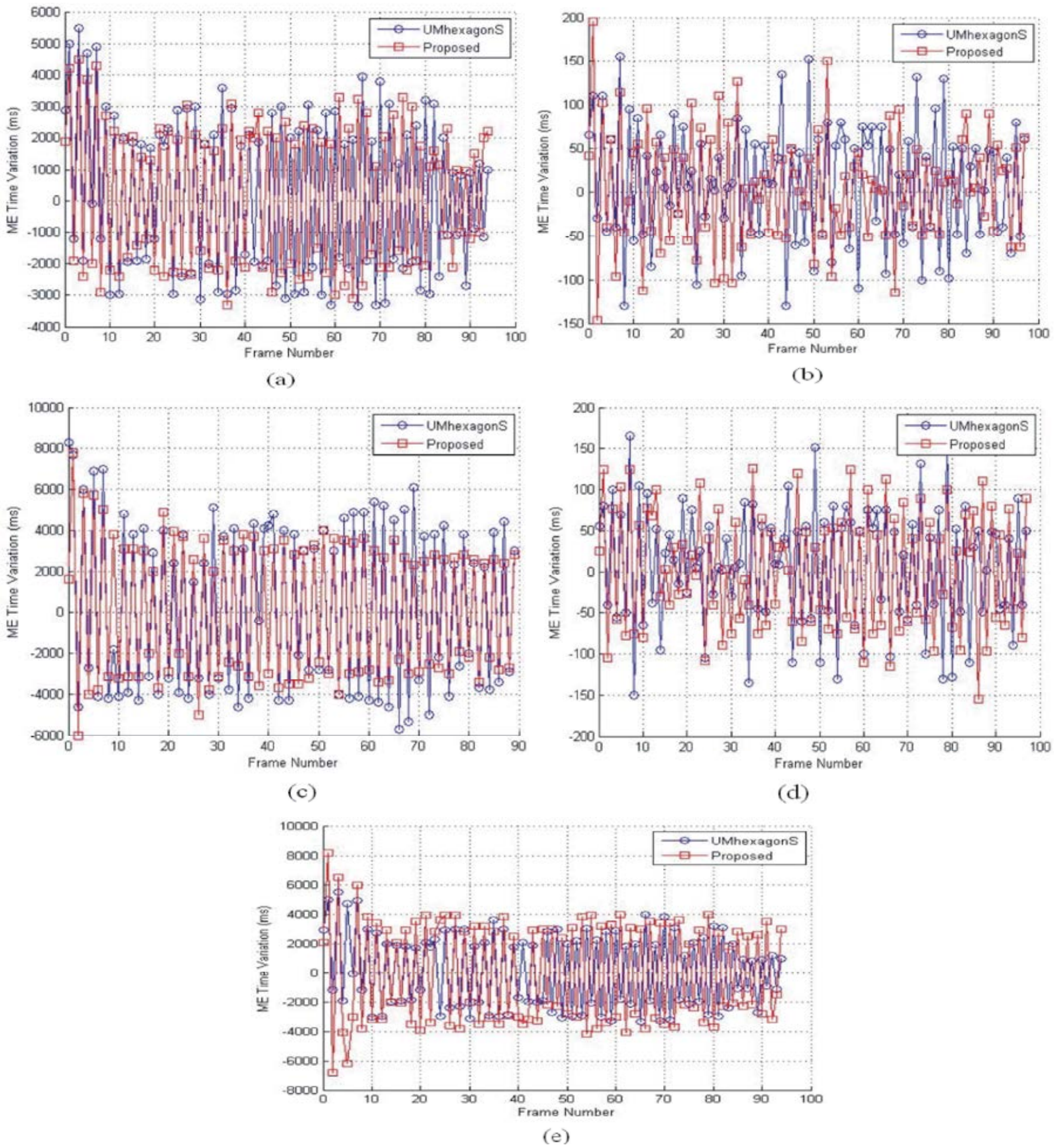

Fig. 8: (a) Coast guard (b) Container (c) Harbour (d) Mother (e) Mobile

The Initial Search Point (ISP) is computed using the median predictive model and it is considered as positions (0,0) in the reference frame. Then, Large Hexagon Search Algorithm (LHSA) is performed by keeping the ISP as a center. If the ISP is minimum in the Large Hexagon Search Pattern (LHSP) then terminate and return the value as best Motion Vector (MV). In contrast, if the ISP is not minimum then select the minimum point from the hexagon pattern as current Motion Vector (MV_H). Now, form the Big Cross Search Pattern (BCSP) by keeping the current motion vector (i.e. MV_H) as the center. Here, MV_H is returned as a best motion vector, if and only MV_H is minimum among the big cross element, otherwise, select the minimum point as current Motion Vector (MV_{BC}). Then perform Small Diamond Search Algorithm (SDSA) by considering the center point as (MV_{BC})..

If MV_{BC} is minimum among the diamond pattern element, then return it as Motion Vector (MV), otherwise perform diamond pattern (i.e. center point as MV_D) as shown in Figure 7.

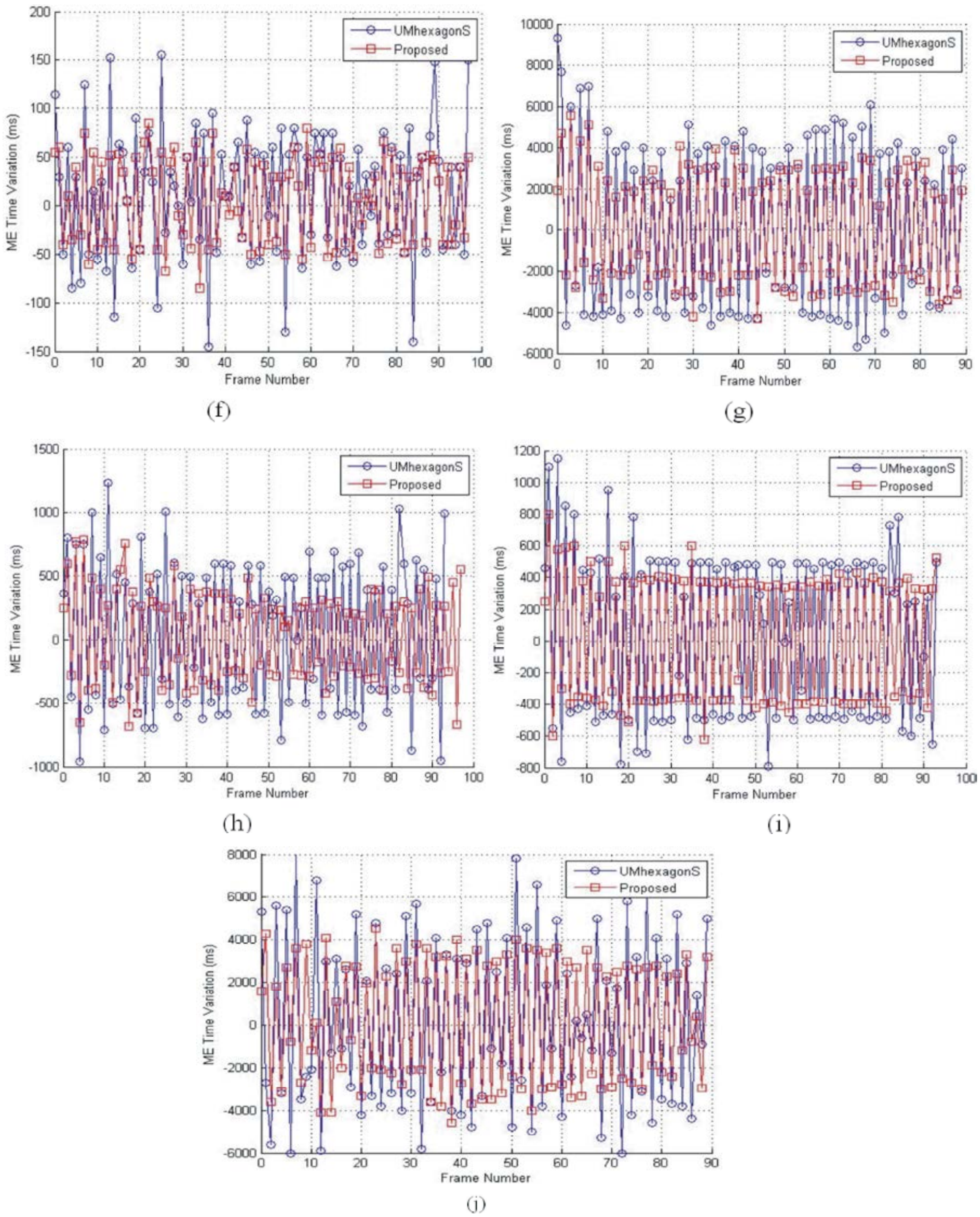

Fig. 9: (f) Bridge (g) Crew (h) City (i) Sea (j) Ice

Performance Evaluation Proposed Me: The reference software HM 15.0 is used to implement and evaluate the efficiency of proposed Motion Estimation (ME) algorithm in High Efficiency Video Coding (HEVC). The proposed Motion Estimation (ME) algorithm is compared with UMHexagonS and evaluated in terms of Motion Estimation (ME) time, Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE). The PSNR of the proposed algorithm is evaluated for ten various standard videos such as coast guard, container, harbor, mother, mobile,

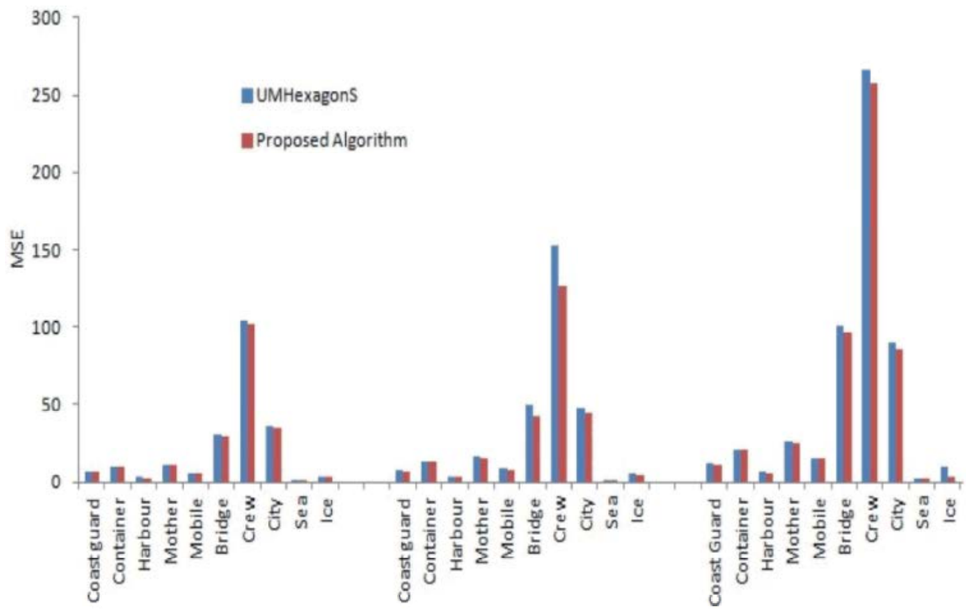

Fig. 10: MSE Achieved by Proposed Algorithm

Table 2: Average PSNR for Q_p=20

Q_P=20	PSNR (%)	
Standard Video	UMHexagonS	Proposed Algorithm
Coast guard	40.04	40.16
Container	38.15	38.22
Harbour	43.47	43.58
Mother	37.58	37.66
Mobile	40.33	40.45
Bridge	33.35	33.48
Crew	27.95	28.07
City	32.60	32.75
Sea	47.75	47.98
Ice	42.13	42.50
Average	38.34	38.49

Table 3. Average PSNR for Q_p=25

Q_P=25	PSNR (%)	
Standard Video	UMHexagonS	Proposed Algorithm
Coast guard	39.43	39.58
Container	36.82	36.95
Harbour	42.25	42.47
Mother	36.05	36.19
Mobile	38.60	39.03
Bridge	31.17	31.89
Crew	26.29	27.09
City	31.35	31.62
Sea	45.63	46.15
Ice	40.97	41.30
Average	36.86	37.23

Table 4: Average PSNR for Q_p=30

Q_P=30	PSNR (%)	
Standard Video	UMHexagonS	Proposed Algorithm
Coast guard	37.15	37.60
Container	34.89	34.98
Harbour	40.18	40.35
Mother	33.97	34.20
Mobile	36.25	36.37
Bridge	28.11	28.30
Crew	23.88	24.02
City	28.59	28.78
Sea	43.85	43.90
Ice	38.20	38.42
Average	34.51	34.69

crew, city, sea and ice. In addition, to complicate the evaluation process the PSNR is evaluated by assuming the Quantization Points (Q_P) such as 20, 25 and 30. The achieved PSNR for the Quantization Points (Q_P=20) is shown in Table 2. The average PSNR achieved by the proposed algorithm (for Q_P=20) is 38.49%, which is higher than UMHexagonS (38.34%).The PSNR for various videos by assuming the Quantization Points (Q_P=25) is shown in Table 3. Here, the proposed algorithm achieves an average PSNR of 37.23%, gaining approximately 1% than the conventional UMHexagonS algorithm. In similar, the achieved PSNR for the various videos by assuming the Quantization Points (Q_P=30) is shown in Table 4.

The proposed algorithm achieves a gain of 0.52% than the conventional UMHexagonS algorithm. Another vital parameter that would test the efficiency of the motion estimation algorithm is Motion Estimation (ME) time.

The graphs were plotted for Motion Estimation (ME) time against the number of frames. The proposed algorithm requires less motion estimation time when compared to a conventional UMHexagonS algorithm to encode entire frames. The Motion Estimation (ME) time for various videos against the number of frames is shown in Figure 8 and Figure 9. The time graph shows that the proposed algorithm achieves lesser time for encoding the maximum number of frames, but the graph also reveals that the proposed algorithm achieves higher Motion Estimation (ME) time than UMHexagonS in some of the frames. However, this has no effect on the Peak Signal to Noise Ratio (PSNR) of the proposed algorithm. The hidden advantage behind the low motion estimation time is that, the motion estimation time is reduced if and only the computational complexity is reduced. Hence, the proposed algorithm is easy to compute and efficient to implement.

Also the efficiency of the proposed algorithm is evaluated in terms of Mean Square Error (MSE). Likewise, in PSNR, the Mean Square Error (MSE) is evaluated for various videos, assuming the Quantization Points Q_P=20, Q_P=25 and Q_P=30. The proposed Motion Estimation (ME) algorithm achieves less Means Square Error (MSE) than the conventional UMHexagonS algorithm for entire videos as shown in Figure 10. In related to PSNR, as the Quantization Points (Q_P) increase the Mean Square Error (MSE) reduces.

CONCLUSION

A novel approach to develop a fast motion estimation algorithm for High Efficiency Video Coding (HEVC) is proposed in this paper. The reference software model HM 15.0 is used to implement the proposed algorithm in HEVC coder. The efficiency of the proposed algorithm is examined under various parameters such as Peak Signal to Noise Ratio (PSNR), motion estimation time and Mean Square Error (MSE). Further, to complicate the evaluation and to demonstrate the efficiency of the proposed algorithm, the Quantization Parameter (Q_P) is varied from 20 to 30 at the interval of 5. In entire cases the proposed algorithm outperforms the conventional UMHexagonS algorithm. As of now, the proposed algorithm is implemented and evaluated at software level. In future, hardware architecture for the proposed algorithm is realized and comparison can be made between the hardware and software realization of the proposed algorithm.

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