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Star Diamond-Diamond Search Block Matching Motion Estimation Algorithm for H.264/AVC Video Codec

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Abstract: Motion estimation is early procedure for video compression and is related to the compression efficiency by reducing temporal redundancies. Motion estimation is the most important part of a video encoder and half of coding complexity or computational time depends on it. There were various ME algorithms proposed and implemented to minimize the computational time. H.264/AVC codec offers many coding technique for achieving high compression gains as compare to other standards. These techniques dramatically increase the computational complexity of the block based motion estimation, which consumes up to 80% of the entire encoder's computations. In this paper, we proposed Star Diamond-Diamond Search Algorithm for Block matching motion Estimation technique. This proposed technique provides reduction in computational complexity and encoding time without compromising the quality of the video sequence.

keywords: Diamond search; Star diamond search; Star diamond-diamond search; Motion vector; Motion estimation; Motion compensation; PSNR; H.264/AVC

I. INTRODUCTION

Block based motion estimation has been adopted in all the existing video coding standards [1-13]. It is mainly used to reduce the temporal redundancy between frames [9]. This is achieved by allowing blocks from currently coded frames to be matched with ones from reference frames. Only the blocks' differences along with a set of displacements need to be coded in a process known as inter prediction. Entire image or some parts of it are associated with motion vector which can represent by a translational version to approximate the motion of real cameras [3]. The image sequences forms the video, the video is worked on the concept of motion estimation and compensation. Block Matching algorithms is relies on rectangular blocks and motion vector is formed for each block. It also includes all Pixels inside each blocks has same motion, Block Matching Algorithms are also employed for hardware realization due to its regularity and simplicity [5,7,13]. DS algorithm is exactly the same as 4 step search, but the search point pattern is changed from a square to a diamond, and there is no limit on the number of steps that the algorithm can take. DS uses two different types of fixed patterns, one is Large Diamond Search Pattern (LDSP) and the other is Small Diamond Search Pattern (SDSP) [1]. From the statistical study and analysis of the motion vectors in real images, and in order to reduce the computing time the strategy of search Star Diamond (SD) carried out in two phases. The first phase consists making a coarse search "Star" made up of 9 point the second search made up of 5 points of search forming Small Diamond [5,7]. The H.264/AVC standard has evolved video coding in the last few years and is the latest recommended and developed by ITU and ISO [11]. H.264/AVC provides latest innovations in video compression techniques to provide robust video quality with less bit rate per frame and also save bit rate compared to other previous standard techniques. It also used for many applications such as HD video, video conferencing, streaming, broadcasting, multimedia tools etc. different tools are used to achieve high compression gain in H.264/AVC. As a result to improve

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coding performance, the computational complexity of the encoding process also increased. In recent days, the great advances in real-time and portable multimedia devices necessitate the need for a computationally efficient video codec design that will allow for a reliable and robust video quality [4].
Motion estimation and compensation is the process which has seen the highest activity and research interest in the past years. This paper evaluates the Star Diamond-Diamond search block matching algorithms. It also presents a comparative table with respect to the PSNR and Computation time required for motion estimation. The algorithms that have been evaluated are Diamond search (DS), Star Diamond Search (SDS), and proposed Star Diamond-Diamond Search (SDDS). Section I explains block matching algorithm and H.264/AVC in general and literature review and problem identification. Section II explains proposed algorithm with flow. Section III explains results and discussion. Section IV explains conclusion with references.

1.1 Literature Review

The DS algorithm uses LDSP and SDSP which uses 3 and 5 point search pattern to estimate the motion in frames. As the search pattern is neither too small nor too big and the fact that there is no limit to the number of steps, this algorithm can find global minimum very accurately. The end result should see a PSNR close to that of ES while computational expense is less [1,9,5]. A new star search pattern improves the performance of DS Algorithm and achieves better performance with quit low computational complexity compared to other popular block matching algorithms. Video sequence has wide range of motion content and this algorithm offer stable performance [6].
Star-Diamond search pattern is the combination of star refinement and diamond search pattern which gives better result as compare to diamond search and is also having less complexity due to this less complexity number of computations are less and gives gain in PSNR [9].

1.2 Problem Identification

Form the study of various papers we find that the algorithms which are used for motion estimation is more time consuming and also having more complex [1,9,6,8]. So in this paper we propose Star Diamond – Diamond search algorithm for motion estimation which gives less computations and better PSNR and also it can used in H.264/AVC [9] which gives good bit rate and high quality video.

II. PROPOSED MOTION ESTIMATION ALGORITHM

Diamond search block matching motion estimation is the well-known ME algorithm that is used to exhaustively find the best match candidate block in the reference frame [1,2]. It checks all points in the search area and consequently it costs too much computational time. In addition, the computational time complexity of the motion estimation process increases dramatically as variable block sizes and multiple reference frames are used in the H.264/AVC standard [9]. Although provides the best quality amongst various ME algorithms, its computational complexity is less. Therefore, many efforts were directed to accelerate the motion estimation process which is considered the most time consuming part in the video encoding process.

2.1 Star Diamond Diamond Search Algorithm

We have done statistical study and analysis of the motion vectors in real images to reduce the computing time we proposed an algorithm Star Diamond- Diamond Search (SDDS) which consists of making a coarse search “Star” made up of 9 points as shown in Figure 1a, the second search made up of 5 points of search forming Small Diamond (Figure 1b). First we apply Diamond search algorithm in current and previous frame, the compensated output image is considered as previous frame for Star diamond search and current frame is same as previous. The result of combined algorithm gives better PSNR and less computation than DS algorithm.

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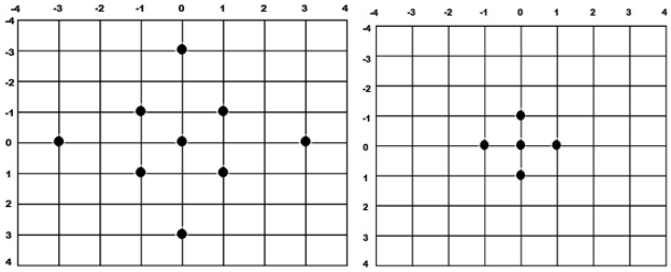

(a) (b)

Figure 1: (a) Star diamond search pattern. (b) Small diamond search pattern.

2.2 Proposed Algorithm Steps

Phase I: 9 points are tested by centered the origin of current point by star diamond search. SADmin Point searched then goes to phase II.
Phase II: The star pattern changed from star to small diamond search pattern and calculates SADmin and continues till the search center not located. this calculate the motion vector and Star pattern run only once to detect the direction of motion vectors, if it is stationary, vertical, diagonal or horizontal.
Phase III: The SADmin point which found in every stage will be the center point of the next step until this point will be a central point.

2.3 Block Diagram

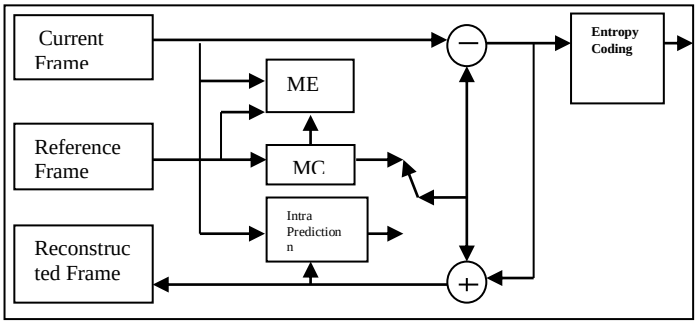

Figure 2: Proposed motion estimation and codec process flow.

Step 1: Conversion into frame from test video.
Step 2: Assign first frame as a reference frame.
Step 3: Assign second frame as a target frame and the first frame act as a reference frame for the second frame.
Step 4: Find correlation between current frame and reference frame.
Step 5: Motion estimation will be done if there is correlation between current and reference frame and motion vector is calculated.
Step 6: Motion is compensated after motion vector calculation.
Step 7: Entropy coding done and encoded bit stream generated.
Step 8: Decoder side bit stream is converted into reconstructed frames (Figure 2).

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III. RESULTS AND DISCUSSION

For All image sequences following performance parameters are used:-

1. Mean Square Error (MSE)

$$\text{MSE} = \frac{1}{Q\times Q}\sum_{X=1}^{Q}\sum_{Y=1}^{Q}[I_o\ (X,Y) - I_c\ (X,Y)]^2 \ (1)$$

Where

$I_0(X,Y)$ = Original Image

$I_c(X,Y)$ = Compressed Image

Q = Dimensions of the Image

In the Image Error will be low when the value of MSE is Low [10,12].

2. Mean Absolute Difference (MAD)

$$MAD = \frac{1}{Q\times Q}\sum_{X=1}^{Q}\sum_{Y=1}^{Q}[I_o\ (X,Y) - I_c\ (X,Y)]^2 \ (2)$$

3. Peak Signal to Noise Ratio (PSNR)

$$\text{PSNR} = 10\log_{10}\left(\frac{255\times 255}{\text{MSE}}\right) (3)$$

From Equation (3), we observed that Peak Signal to Noise Ratio (PSNR) is inversely proportional to the Mean Square Error (MSE) i.e., higher value of PSNR can be achieved by decreasing the value of MSE [10,12].

4. The Number of Calculated Points (NCP) is defined by:

$$NCP = \frac{P\times SAD}{mb} (4)$$

Where: P is the total number of SAD calculated between two frames for all blocks to find all motion vectors. SAD (Sum Absolute Difference). Micro Block (mb) is number of blocks on devised frame into blocks with size T×T.

3.1 Performance Evaluation Using Different Parameters

In this paper many videos with a distance of 2 between current frame and reference frame was used to generate the frame-by-frame results of the algorithms. Here we have used more than hundred videos of resolution 352×192 (w×h), macro block (mb) size of 16 and P =7 for motion estimation and QP = 27 for Encoder and Decoder and this experiment is performed in matlab software version 2012a (7.14.0.739) with windows 10 AMD A8-7410 APU and 64-bit operating system.

Image Sequences	Diamond Search (DS)	Star Diamond Search (SD)	Star Diamond & Diamond Search Combination
Big_buck_bunny_scene_CIF	37.7888	37.7853	38.0192
Car_CIF	30.2254	30.2994	30.8512
Flamingo_CIF	33.6439	33.5851	33.7115
Highway_CIF	32.8267	32.8496	32.9691
Meerkat_CIF	29.5524	29.6316	29.6882
Train_CIF	39.4717	39.4717	39.4784
Walking_CIF	28.4124	28.317	28.4272

Table 1: Performance evaluation in terms PSNRavg(dB).

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Image Sequences	Diamond Search (DS)	Star Diamond Search (SD)	Star Diamond and Diamond Search Combination
Big_buck_bunny_scene_CIF	12.1441	12.1272	12.0636
Car_CIF	15.8259	15.6541	14.2825
Flamingo_CIF	16.3106	15.9944	15.079
Highway_CIF	12.3734	12.3591	12.1417
Meerkat_CIF	12.7713	12.7774	12.3749
Train_CIF	11.8785	11.8757	11.8719
Walking_CIF	15.1789	13.5142	13.71

Table 2: Performance evaluation in terms avg computations.

Image Sequences	Diamond Search (DS)	Star Diamond Search (SD)	Star Diamond & Diamond Search Combination
Big_buck_bunny_scene_CIF	758.1333	758.075	767.8833
Car_CIF	545.9083	551.6541	555.1458
Flamingo_CIF	750.1583	749.5333	751.2
Highway_CIF	1172.4833	1172.4833	1175.825
Meerkat_CIF	1285.9125	1286.2791	1286.3875
Train_CIF	955.5166	955.5166	955.5166
Walking_CIF	1486.2208	1486.2208	1486.2208

Table 3: Performance evaluation in terms of Kbits/second for H.264 encoder [11].

Image Sequences	Diamond Search (DS)	Star Diamond Search (SD)	Star Diamond and Diamond Search Combination
Big_buck_bunny_scene_CIF	758.1333	758.075	767.8833
Car_CIF	545.9083	551.6541	555.1458
Flamingo_CIF	750.1583	749.5333	751.2
Highway_CIF	1172.4833	1172.4833	1175.825
Meerkat_CIF	1285.9125	1286.2791	1286.3875
Train_CIF	955.5166	955.5166	955.5166
Walking_CIF	1486.2208	1486.2208	1486.2208

Table 4: Performance evaluation in terms of PSNRavg(dB) for H.264 decoder.

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Sequences	Diamond Search Algorithm			Star Diamond-Diamond Algorithm		
	PSNR	Bit-rate	NCP	PSNR (%)	Bit-rate (%)	NCP(%)
Big_buck_bunny_scene_CIF	37.7888	758.1333	12.1441	+0.37	+7.66	-0.11
Car_CIF	30.2254	545.9083	15.8259	+0.29	+5.54	-0.14
Flamingo_CIF	33.6439	750.1583	16.3106	+0.32	+7.7	-0.15
Highway_CIF	32.8267	1172.4833	12.3734	+0.31	+11.74	-0.11
Meerkat_CIF	29.5524	1285.9125	12.7713	+0.28	+12.85	-0.11
Train_CIF	39.4717	955.5166	11.8785	+0.38	-	-0.1
Walking_CIF	28.4124	1486.2208	15.1789	+0.27	-	-0.14

Table 5: Performance comparison between DS and SDDS.

Sequences	Diamond Search Algorithm			Star Diamond-Diamond Algorithm		
	PSNR	Bit-rate	NCP	PSNR(%)	Bit-rate(%)	NCP(%)
Big_buck_bunny_scene_CIF	37.7853	758.075	12.1272	+0.37	+7.66	-0.11
Car_CIF	30.2994	551.6541	15.6541	+0.29	+5.54	-0.14
Flamingo_CIF	33.5851	749.5333	15.9944	+0.32	+7.5	-0.11
Highway_CIF	32.8496	1172.4833	12.3591	+0.31	+11.7	-0.11
Meerkat_CIF	29.6316	1286.2791	12.7774	+0.28	+12.85	-0.11
Train_CIF	39.4717	955.5166	11.8757	+0.38	-	-0.1
Walking_CIF	28.317	1486.2208	13.5142	+0.27	-	-0.12

Table 6: Performance comparison between SDS and SDDS.

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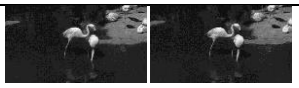
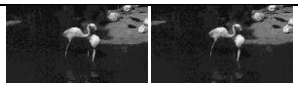
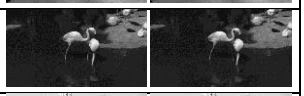
Sequence Name	Original Sequence	Motion Compensated Sequences		
		Diamond Search	Star Diamond Search	Star Diamond-Diamond Search
Big_buck_bunny_scene_CIF				
Car_CIF				
Flamingo_CIF				
Highway_CIF				
Meerkat_CIF				
Train_CIF				
Walking_CIF				

Table 6: Image sequence evaluation original sequence and motion estimated sequence.

Here we have shown some image sequence from our experiment. From Table 1 we can see that PSNR increases in SDDS from both DS and SDS. From Table 2 we see average computation is less for SDDS and form Table 3 shows the bit-rate in Kbps (25 Frame/second uncompressed) for encoder outputs which also show increment with high quality of frames.

After decoding original frames are reconstructed and corresponding PSNR is shown in Table 4 and also we have made a comparison table for DS, SDS, SDDS algorithms in terms of % evaluation of PSNR, Bit-rate and number of computation in Tables 5 and Table 6. From Table 7 we can see original image sequence and compensated image sequence for algorithms

IV. CONCLUSION

After evaluation of different parameters of proposed methods it has been found that Star Diamond-diamond search algorithm outperform then DS algorithm and SDS in terms of PSNR and less number of search points. A star Diamond Search algorithm was also giving good results at an acceptable degradation in image quality. This paper shows the performance analysis of proposed Star Diamond-Diamond Search block matching algorithms for H.264 codec for reliable video compression with respect to bit-rate and gain in PSNR and less computation.

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