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CHDS: A FAST SEARCH ALGORITHM FOR MOTION ESTIMATION IN VIDEO CODING STANDARDS

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ABSTRACT

In this paper, we propose a new hybrid Cross Hexagon Diamond Search algorithm (CHDS) using cross-shaped search pattern as the initial step and asymmetric hexagon-shaped patterns and small diamond pattern as the subsequent steps for fast block motion estimation. In block motion estimation, search pattern with different shape or size and the center biased motion vector distribution characteristics has a great impact on search speed and distortion performance. The previously developed fast search algorithms focus on improvement of either coarse search or inner search. The Proposed CHDS algorithm reduces the number of search points by exploiting the distortion information in the neighbouring search points. Simulations are done using MATLAB and our experimental results indicate that the proposed CHDS algorithm reduces an average of 39.78% of time for motion estimation compared to New Hexagon Search (NHEXS), 10.86% of time for motion estimation compared to Hexagon Search (HS) and 38.64% of time for motion estimation compared to Diamond Search (DS).

Keywords: *Motion Estimation, Block Matching, Motion Vector, Search Algorithm.*

1. INTRODUCTION

Video coding technology is a research focus of digital video media. In real time processing, to enable the transmission and storage, the video bit stream must be drastically reduced. There is a lot of redundant information in a digital video, and this redundancy is explored by the inter frame prediction operation in video coding standards. Motion Estimation (ME) is the main operation of the inter frame prediction [5, 12]. It is a process of estimating the pixels of the current frame from a reference frame. ME algorithms are used to compute the displacement between current frame and reference frame. The intensity value of a pixel in the current frame and in reference frame has some correlation with its neighborhood which will determine the best matching position of pixels intensity values in the reference frame. The difference in positions of current frame and the reference frame is calculated so as to find the best match. This difference is defined as the displacement vector and it is known as the Motion Vector (MV) [2, 8] as shown in Figure 1. The similarity criterion is used to compare the candidate blocks with each original block and in our work we use Mean Absolute Difference (MAD) as the criteria given by the mathematical expression in (1).

$$MAD(x,y,u,v)=\frac{1}{256}\sum_{i=0}^{i=15}\sum_{j=0}^{j=15}\left|A_{(x+i,y+j)}-B_{((x+u)+i,(y+v)+j)}\right| \quad (1)$$

where, (x,y) is the position of current block and (u,v) denotes the motion vector of current block (A) relative to the block in the reference frame (B).

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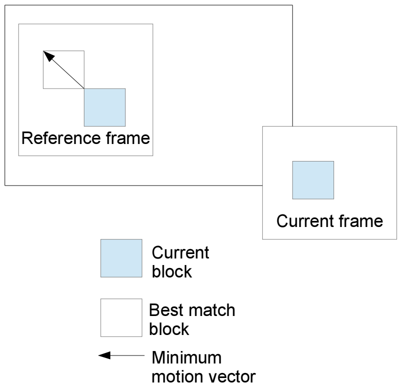

Figure 1: Motion Estimation and Motion Vector

Block-matching algorithms are used widely due to its simplicity and it is easy to be applied. In block based ME approach, the current frame is divided into non overlapping Blocks. H.264/AVC is a Video Codec standard for video compression and has a wide range of application from low bit rate (internet streaming) to High Definition Television (HDTV) broadcast. In H.264, the seven possible modes of a block are 16×16, 16×8, 8×16, 8×8, 8×4, 4×8, 4×4 as shown in Figure 2. These are called macro blocks and for each such current frame, one best MV is calculated in the reference frame. Here, an inherent assumption is made that the entire block undergoes translational motion. The algorithms that use block based ME technique are known as block matching ME algorithms. Since ME process consumes up to 60–80% of computational power of the encoder process, still researches are carried out for an efficient and fast motion estimation algorithms which becomes significant [6].

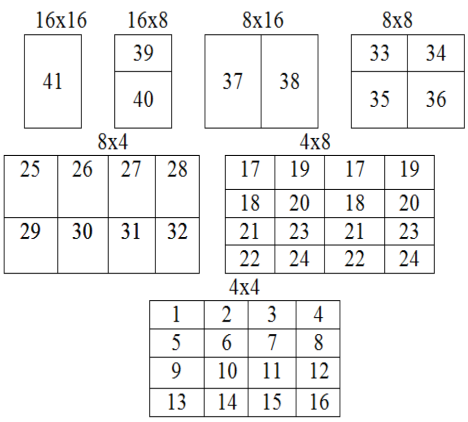

Figure 2: Variable Block Size

The video coding standards like MPEG2, H.264/AVC [20] and the emerging High Efficiency Video Coding Standard (HEVC) [7] do not restrict how the ME is done. Based on this fact, there is a vast space to explore a new algorithm as a solution for the ME. These solutions are evaluated according based on complexity and objective quality of the digital video. In the literature, a number of fast ME algorithms have been proposed. These algorithms include fixed set of search patterns such as Three Step Search (3SS) proposed by Koga et al [17], New Three Step Search (NTSS) proposed by Li Ren-xiang et al [16], Four Step Search (4SS) proposed by L.M. Po et al [18], Diamond Search (DS) [19] and Hexagon Search (HS) [2, 3]. The drawback is that these algorithms suffer from the local minima problem and have less adaptability and search efficiency to track large motions. Hybrid algorithms which combine various search patterns are used to avoid being trapped in local minima. The existing algorithms are focused on reduction of the number of search points which has great impact on reduction of motion estimation time which is the main objective to be dealt in Video Coding. Our research work focuses on further improvement in the existing algorithms and at the same time reducing the number of search points when compared to the existing algorithms in the literature. It uses the aspect of combining several search patterns to achieve the objective of the work. In this paper, a novel fast block matching hybrid algorithm called new cross hexagon diamond search algorithm (CHDS) is proposed. It uses cross-shaped search pattern as the initial steps and large hexagon-shaped patterns and small diamond patterns as the subsequent steps for fast block motion estimation. It results in higher motion estimation speed and also reduces the number of search points. This paper is organized as follows. Section 2 explains about the existing Motion estimation algorithms. Section 3 briefly discusses about the proposed CHDS algorithm. Section 4 shows the experimental results in a variety of video sequences to verify the efficiency of the proposed algorithm followed by the concluding remarks in Section 5.

2. EXISTING MOTION ESTIMATION ALGORITHMS

In this section, we have described about the existing motion estimation algorithms in the literature such as cross search, DS and HS. All these algorithms are based on the center biased MV distribution characteristics [14]. The Cross Search algorithm was introduced by M. Ghanbari in 1990. The cross pattern can be either symmetrical or unsymmetrical [10] depending on the algorithm used. The algorithm has a low computational complexity. However, it is not the best in terms of

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compensation. The Small Cross Search Pattern (SCSP) and Large Cross Search Pattern (LCSP) are used as initiative steps in the algorithm as proposed by Kamel Belloulata et al [6]. The SCSP and LCSP are illustrated in Figure 3.

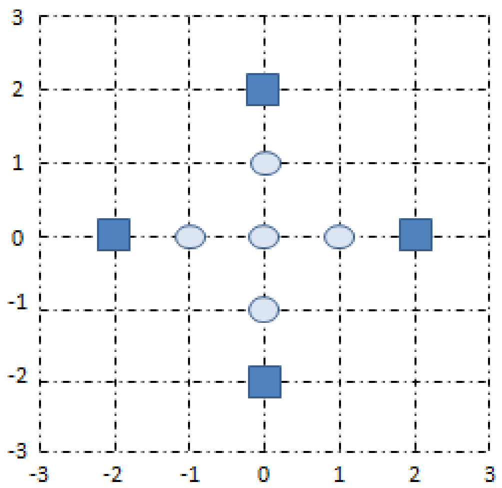

Figure 3: SCSP And LCSP Pattern

The New diamond search algorithm (DS) has been proposed by S. Zhu and K. K. Ma in 2000. The DS algorithm utilizes two different types of fixed search patterns. The first pattern called large diamond search pattern (LDSP) and the second pattern called small diamond search pattern (SDSP) shown in Figure 4. The LDSP consisting of nine checking points from which eight points surround the center one to compose a diamond shape. The SDSP consisting of five checking points and it forms a smaller diamond shape [9, 11, 13, 15]. The advantages of DS can be summarized as: in large motion content, optimal minimum can be got using fewer points. It is faster than the traditional method of 4SS for small motion contents. In terms of search mode, it is highly sensitive in all directions. It is harder to fall into the local minimum, when compared to other methods.

Zhu et al. [5] investigated the research and proposed a Hexagon based search algorithm that achieves better speed improvement up than DS algorithm with similar distortion performance. The HS can find the same motion vector in the motion field with fewer search points than the DS algorithm [1, 4, 13].

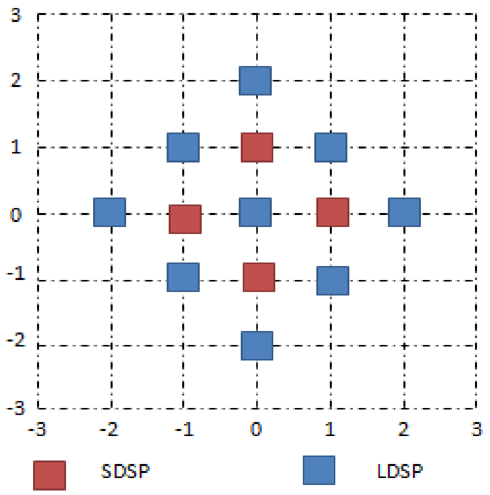

Figure 4 : Large And Small Diamond Search Pattern

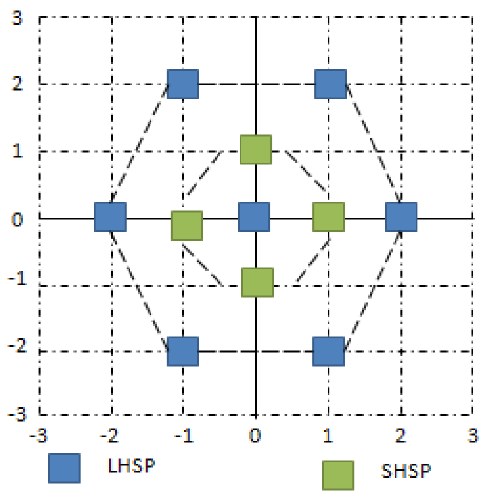

Figure 5 : Large And Small Hexagon Search Pattern

3. PROPOSED ALGORITHM

Most of the search algorithms focus on improvement of either coarse search or inner search. Thereby, a fast inner search is desirable and in our opinion, appropriate utilization of the surrounding information in the given search region would yield a faster and accurate inner search. This is been adopted in our algorithm to achieve overall minimum number of search points. The new proposed algorithm concentrates on reduction of ME complexity. The following section will explain the way by which the hybrid algorithm is developed using the available patterns.

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3.1: Algorithm Development

The algorithm is designed using three patterns: Symmetric Cross, Asymmetric hexagon and Small Diamond Pattern. Figure 8 shows the search pattern of the proposed algorithm. The Cross search pattern is of pixel distance± 2 from the center point. Asymmetric hexagon with distance of ±1 and ±2 from center is used for both Horizontal and Vertical hexagon patterns. Small diamond search is the final step which uses pixel distance ±1 from the center. The initial point is assumed to be at the location (0, 0). The steps for the proposed algorithm are given below:

Step 1: The Symmetrical Cross search pattern as shown in Figure 6 is initialized. Calculate the MAD for all five points and search point with minimum cost is obtained. If the minimum cost is found to be at center point, then go to step 3.

Step 2: If the minimum cost is in horizontal direction of the search points in the cross search pattern (along X-axis), then perform asymmetric horizontal hexagon search, with minimum cost from step 1 as center point as shown in Figure 7a. Else perform asymmetric vertical hexagon search (along Y axis) as shown in Figure 7b.

Step 3: Switch from the coarse search to the fine resolution inner search to find out absolute motion vector. With minimum cost from previous search as center, a small diamond pattern with pixel distance ±1 as shown in Figure 8 is formed and search for minimum cost. The resultant search point is the final solution for motion vector.

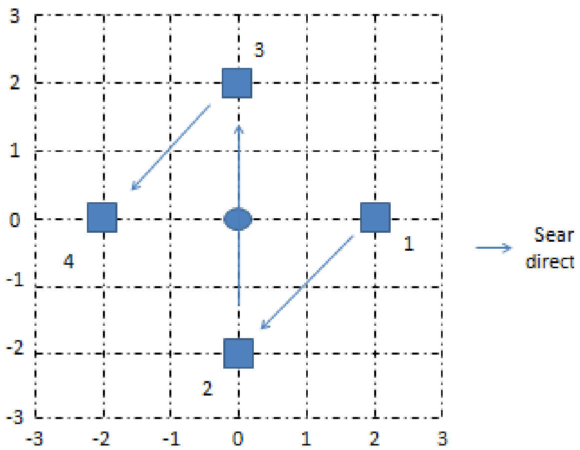
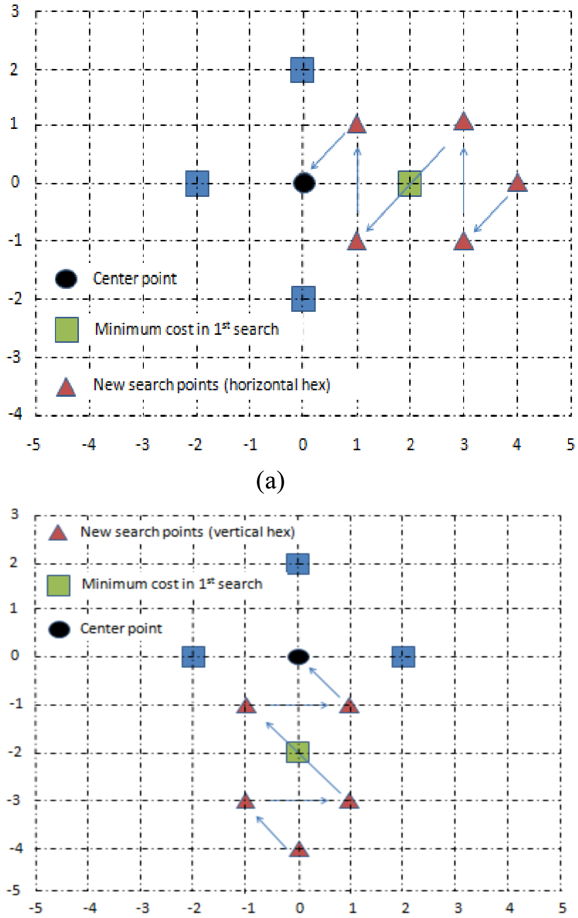


Figure 6 : First Search

The search starts from the central point (0, 0) and continues according to the distance parameters. The first search is performed using cross search pattern with 5 search points having distance ± 2 from the center point. Initially search starts from the center point; Figure 6 shows the first search and its search directions. The second search has 7 search points with two reuse points. Second search uses both horizontal and vertical hexagon patterns. The hexagon pattern used is asymmetric with distance of ± 1 and ±2 from the center point. The decision to use horizontal or vertical hexagon is made such that, if the minimum cost point from first search is along the horizontal points (x-axis) of the cross search, then horizontal hexagon is used and if the minimum cost point from first search is along the vertical points (y-axis) of the cross search, then vertical hexagon is used. Thus the proposed algorithm concentrates for motion of video sequence both on horizontal and vertical directions. The final search is done using small diamond search pattern with search distance ±1 from the center. The small diamond search has 5 search points and this is the final search to find the motion vector for the given current block.



(a)

(b)

Figure 7 : Second Search Decisions using (a) Horizontal Hexagon and (b) Vertical Hexagon Pattern

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The Proposed CHDS algorithm adopts the following Pseudocode to find the minimum cost:

```
Perform initial Cross Search
Centre Point <= Minimum point of Cross Pattern
points <=7
i <= 0
Repeat
MAD(i) <= Execute Vertical Hexagon Pattern points
i++
while (i < points && Centre Point along Y-axis)
Repeat
MAD(i)<=Execute Horizontal Hexagon Pattern points
i++
while (i < points && Centre Point along X-axis)
Minimum cost <= minimum (MAD(i))
Centre Point <= Minimum point of Hexagon Pattern
Perform Diamond Search
Minimum cost <= minimum (MAD(i))
Generate vector (Minimum cost)
```

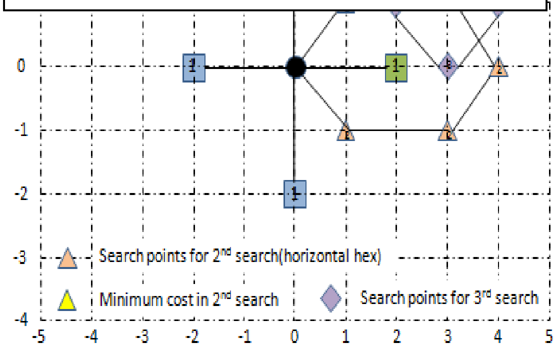

Figure 8 : Search Pattern for Proposed Algorithm

3.2: Analysis of Algorithm

Let us assume that the best match block of the current block is at the position (4,-1) as shown in Figure 9. The cross search pattern consists of five search points. Minimum block distortion (MBD) point is the most matching point having minimum MAD with reference block in the current search. Initially we start the search at the location (0, 0). If the MBD point is at one of the four corners of the cross, that is at the location (2, 0), the algorithm searches for the five new non-overlapping search points around it to form a hexagon along horizontal axis. The minimum MBD is found at location (4, 0) from second search, and then the algorithm searches for four search points around it to form a small diamond pattern. Thus by exploiting the continuity, the search point with minimum MBD is located at (4,-1) by using 14 points for computation. For the same assumption, the HS algorithm proposed by Ce Zhu et al[9] requires 17 search points; NHEXS algorithm proposed by Kamel Belloulata et al [6] requires 22 search points. Thereby, the number of search points has been reduced in the proposed algorithm.

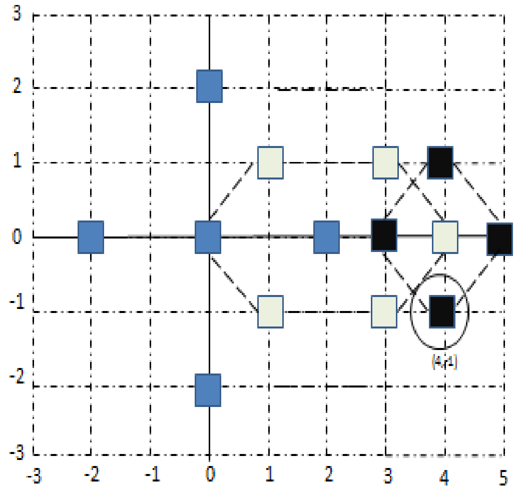

Figure 9 : Proposed Algorithm Search Path

4. EXPERIMENTAL RESULTS

The algorithms are simulated using MATLAB 7.10.0.499 (R2010a). The algorithm is applied to the first 30 frames of sequences "Foreman" with a resolution of 352x288, "Mobile" with a resolution of 352 x 288, "BQMALL" with a resolution of 832x480 and "MOBISODE" with a resolution of 832x480. These sequences vary in motion content as well as frame size. Simulations are carried out on Windows 8.1 OS platform with Intel I3-2310M @ 2.10 GHz CPU and 4GB RAM.

The experimental setup is as follows: the block size of 16 x16, the maximum displacement in the search area is ± 2 pixels in both horizontal and vertical directions and MAD as distortion measurement. To evaluate the performance of the new CHDS algorithm featured with inner search, we compare it against the existing methods. To obtain the realistic results of motion estimation for different video sequences, the comparison of the proposed CHDS algorithm is done against the algorithms: NHEXS proposed by Kamel Belloulata et al [6], HS proposed by Ce Zhu et al [9], the DS proposed by S. Zhu and K. K. Ma [19] in terms of number of search points, average computational

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time savings for motion estimation and Peak Signal to Noise Ratio (PSNR). The existing and the proposed algorithms are real time simulated for a block size of 16x16 using MATLAB and the results are tabulated as follows.

Table 1 show the simulation results of ME time for different search patterns such as the DS, HS, NHEXS and proposed CHDS algorithm. It can be clearly seen that the average ME Time of our proposed algorithm shows that there is an appreciable decrease of 10-40% of ME Time compared to other existing search algorithms.

The ΔME Time and ΔPSNR denotes the CPU time reduction in ME process and improvement of PSNR of the encoded image respectively [10]. They are defined as in equations (2), (3) and (4):

$$\Delta METime = MET_{proposed} - MET_{original} \quad (2)$$

$$\%\Delta METime = \frac{\left(MET_{proposed} - MET_{original}\right)}{MET_{original}} \times 100 \quad (3)$$

$$\Delta PSNR = PSNR_{proposed} - PSNR_{original} \quad (4)$$

Table 1 Simulation Results for ME Time

Sequence	ME Time (sec) for 30 frames			
	[19]	[9]	[6]	Proposed
FOREMAN	19.38067	12.83549	20.54283	11.66460
MOBILE	16.47202	12.86197	20.14048	11.04509
BQMALL	62.53369	46.87516	57.56691	42.00814
MOBISOD E	77.04055	43.59222	69.83413	39.30178
Average	43.85673	29.04121	42.02109	26.0049

where MET $_{proposed}$ and $PSNR_{proposed}$ denotes the ME time and PSNR of the proposed algorithm and $MET_{original}$, $PSNR_{original}$ represents the ME time and PSNR of DS, NHEXS and HS.

Table 2 shows the improvement in PSNR and average reduction of ME Time for proposed algorithm when compared to existing search patterns. The proposed CHDS algorithm saves 38.64%, 10.86% and 39.78% of total ME time compared to Diamond, Hexagon and New-Cross Hexagon search pattern respectively.

The comparison is shown in Figure 10 for thirty frames of different video sequences. When compared to the existing algorithms, the proposed scheme can reduce the ME time of the encoded image, as the frame number increases. The limiation of the work is further improvement in ME time could be achieved with hardware resource utilization.

Table 3 shows that the proposed CHDS algorithm consumes the smallest number of search points compared to other algorithms. The average search points per block with the observations are CHDS<<HS<<NHEXS<<DS.

In order to demonstrate the performance of the proposed algorithm, the Figure 11gives the result of the average number of computations per block for different video sequences as the frame number increases. It clearly manifests the superiority of the proposed CHDS algorithm to the other methods in terms of number of computations used.

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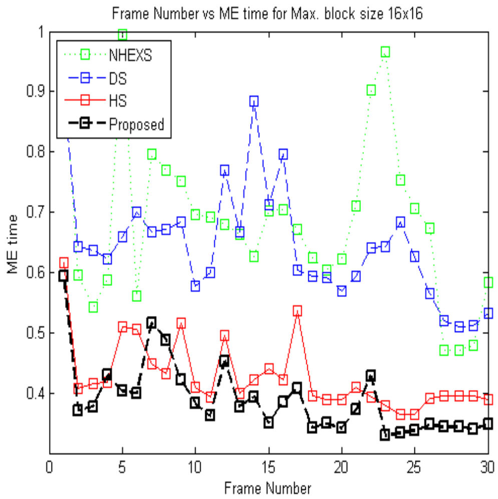
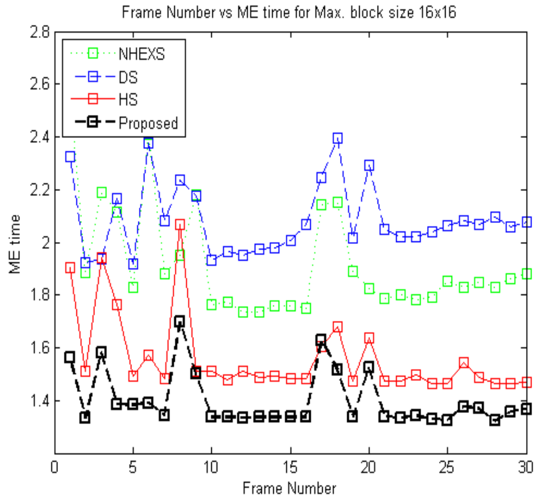
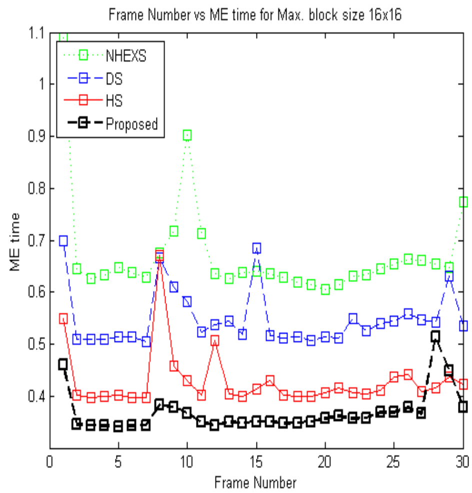


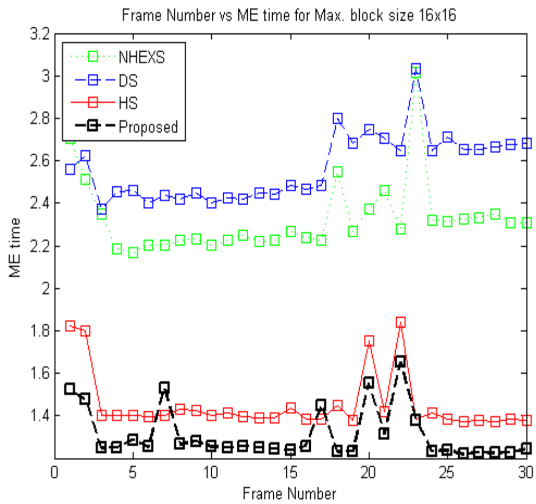
a) Foreman Sequence



c) BQMall Sequence



b) Mobile Sequence



d) Mobisode Sequence

Figure 10 : Performance Comparison of DS, HEXS, NHEXS and the Proposed CHDS for a) Foreman Sequence b) Mobile Sequence c) Mobisode Sequence d) BQMALL Sequence in terms of Time Reduction in ME Process

Table 2 Simulation Results Showing PSNR Improvement and Average Reduction of ME Time

Sequence	**ΔPSNR (dB)**			**ΔME Time (sec)**		
	Proposed vs DS	**Proposed VS HS**	**Proposed vs NHEXS**	**Proposed vs DS**	**Proposed vs HS**	**Proposed vs NHEXS**
FOREMAN	2.06100	0.28172	3.66466	-7.71606	-1.17089	-8.87822
MOBILE	2.64899	-0.77990	4.48102	-5.42693	-1.81688	-9.09539
BQMALL	1.12293	0.81034	1.50547	-20.52555	-4.86702	-15.55878
MOBISODE	3.48379	1.60837	2.71776	-37.73877	-4.29045	-30.53235
Average % Time savings of proposed algorithm				38.64	10.86	39.78

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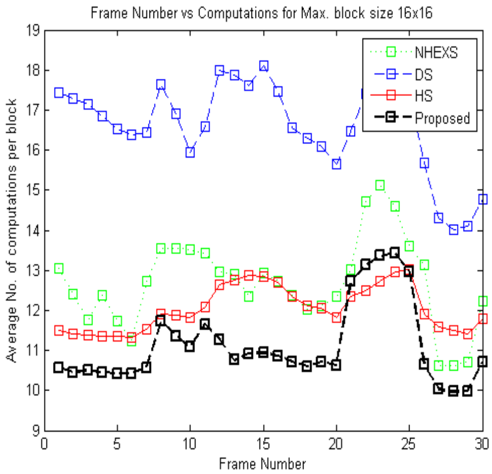
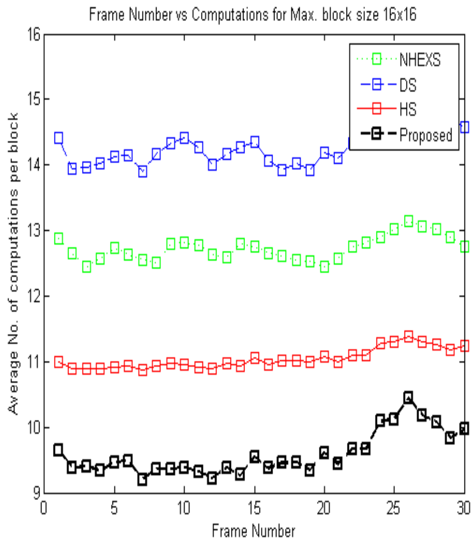
Table 3 Average Number of Search Points Per Block

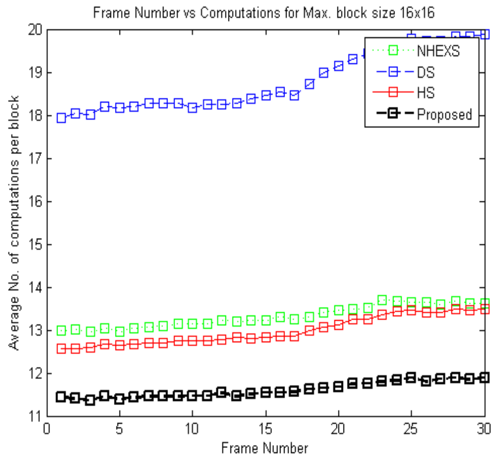
Sequence	Average no. of Search points (computations) for each block			
	DS	HS	NHEXS	Proposed
FOREMAN	16.63817	12.04662	12.68317	11.12005
MOBILE	14.32350	11.04308	12.73074	9.58329
BQMALL	15.51905	11.43994	11.20496	10.40267
MOBISODE	18.79306	12.98219	13.31057	11.60417
Average	**16.31845**	**11.87796**	**12.48236**	**10.67755**



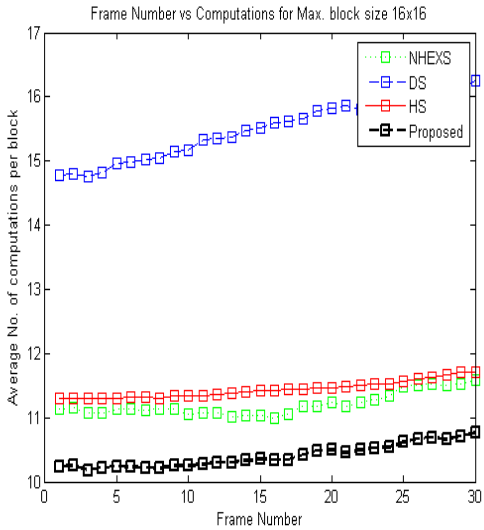
a) Foreman Sequence



b) Mobile Sequence



c) Mobisode Sequence



d) BQMall Sequence

Figure11 : Performance Comparison of DS, HEXS, NHEXS and the Proposed CHDS for (a) Foreman Sequence (b) Mobile Sequence (c) Mobisode Sequence (d) BQMALL Sequence in terms of Average Number of Computations Per Block

5. CONCLUSION

In this paper, we propose a new CHDS algorithm for fast Motion Estimation. The simulation results reveal that the proposed algorithm reduces an average of 39.78% of time for motion estimation compared to NHEXS, 10.86% of time for motion estimation compared to HS and 38.64% of time for motion estimation compared to DS, for motion in video sequences with a block size of 16x16. The proposed algorithm also shows an appreciable improvement in quality and reduction in number of computations per block when compared to the

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previous algorithms. The experimental results have demonstrated that the proposed CHDS algorithm outperforms tshe previous algorithms and it works well in different formats of video sequences with various motion activities.

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