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A Performance Analysis of Block Based motion estimation algorithm based on Hexagonal Search Pattern

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Abstract — *Block matching motion estimation is the efficient method of video coding systems. This paper presents a review of the different traditional block matching algorithms used for motion estimation in video compression. Based on Experimental study it is justify that the HEXBS algorithm perform fastest as compared with several other popular fast algorithms. A hexagon based search Pattern may find any motion vector in motion field with fewer search points than the DS algorithm. Due to the larger motion vector the HEXBS gain more significant the speedup than DS. This paper present performance analysis on different types of block matching algorithms based on hexagonal pattern search that includes HEXBS, EHEXBS, EHIS, EHS2, HDGP, MFHS algorithm.*

Keywords- *Motion Estimation, Motion Compensation, Block matching algorithm, HEXBS*

I. INTRODUCTION

With rapid advances for multimedia Communication with moving video pictures is rapidly increasing, because it achieve high processing speed and low computational time simultaneously without loses quality of video. A main problem in a real time video is the higher requirement for bandwidth and storage space. So, the video compression plays an important role for efficient storage and transmission of digital signal in multimedia. The real time video scene have spatial, temporal and statistical correlation which arises data redundancy between frames. The huge amount of temporal correlation, known as temporal redundancy which must be reduced to be stored and transmitted efficiently for digital video. [3] Motion estimation (ME) and Motion Compensation (MC) are the primary and popular technique to reduce the temporal redundancy between adjacent frames of a video sequence. Motion estimation uses interframe coding and achieve a very high compression ratio by exploiting the heavy temporary redundancy between successive frames, when comparing with the intraframe coding. Motion estimation inspecting the movement of objects in frame sequence to try to obtain vectors representing the estimated motion. By using the knowledge of object motion, Motion compensation achieve data compression. One of the most attractive and efficient method for motion estimation is Block Matching Algorithm (BMA) technique. BMA is the most popular method due to its effectiveness and implementation simplicity for the current international video compression standards like H.261, H.263, MPEG-1, MPEG-2 and MPEG-4 [1] [4] [5].

A many fast block matching algorithms have been proposed to reduce the computation of motion estimation for example, Exhaustive Search (ES), 2-D logarithmic search (LOGS), Three Step Search (TSS), conjugate direction search (CDS), New Three step Search (NTSS),Four Step Search (4SS), block-based gradient descent search (BBGDS), diamond Search (DS), and hexagon-based search algorithm (HEXBS) etc.

II. STUDY TRADITIONAL ALGORITHM

Since in most cases video encoder consumes roughly 70% of the computational load due to motion estimation, there is a need for a simple, fast, and efficient motion estimation algorithm [7]. The search algorithm determining the overall computation complexity and accuracy of motion estimation. A many fast block matching algorithm have different patterns like square or rectangular pattern and some non-square block or geometric pattern or shapes based patterns.Search patterns with various sizes and shapes have great impact on both search comutational speed and accuracy.The simplest BMA is known as Full search or exhaustive search algorithm. This technique evaluated all possible displacements in the search window to find the best matching block. FS [2] finds the best possible match with good accuracy in searching and gives the highest PSNR compare with other BMA but based on computational complexity, it is very expensive BMA. The major drawback of this algorithm is that larger the search Window requires more numbers of computations. So it is not a good choice for real-time video coding implementation.

Three-Step Search (3SS) [6] developed by Koga et al introduced in 1981, which employs rectangular search patterns with different sizes. TSS is one of well-known algorithm because of its simplicity, good performance and significant computational reduction. In the first step, TSS algorithm uses a uniformly allocated checking point pattern. It is not efficient for small motion estimation others like 2D-logarithmic search (2DLOG) [8] and orthogonal search (OSA) [9] algorithms which performed searching in either orthogonal or linear direction. 2D-logarithmic search (2DLOG) [8] employs a cross search pattern (+) in each step. Although this algorithm requires more steps than the TSS but can be more accurate in the case of large search window. It takes a more computation time so 2D-LogSearch can fail (miss the global minimum, which would be found by Exhaustive Search).

Orthogonal search [9] is a combination of the TSS and 2D-logarithmic search. It has both vertical stage and a horizontal stage for searching for the optimal block. These fast algorithms result in speed improvement but in the case of possessing high motion content, quality is varied amongst the nature of video sequences. Renxiang Li et al. proposed a new three step search algorithm [10] in 1994. The center-biased NTSS algorithm is an extended version of TSS which tends to achieve much superior performance with fewer number of search points on average. However, NTSS loses the regularity and simplicity of TSS to some extent. Processing time of NTSS is complex as compare to TSS.

Four Step Search (4SS) algorithm [11] was introduced by Lai-Man Po, and Wing-Chung Ma in 1996 which is similar to NTSS. 4SS also uses center-biased searching and has a halfway stop provision. The MSE comparisons for 4SS produce better performance than the TSS and has similar performance as compared with the NTSS. It is because the performance of 4SS is maintained for image sequence that contains complex movement such as camera zooming and fast motion. It is very Complex to implement and takes a processing time longer as compare to TSS, NTSS and DS.

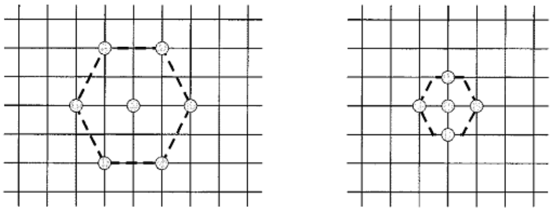
ShaZhu, and Kai-Kuang Ma developed Diamond Search (DS) algorithm in 2000. DS [3] algorithm employs non rectangular search pattern. This algorithms is fastest search methods by reducing the number of search points in the process of block motion estimation.It also outperforms the well-known TSS algorithm and achieves close performance compared to NTSS while reducing computation by 20%-25% approximately.

Ce Zhu et el. had proposed novel algorithm using a hexagon-based search pattern [12] to achieve further improvement. Hexagon-based search pattern has shown the significant improvement over other fast algorithms such as DS. DS uses a diamond search pattern, while HEXBS adopts a hexagonal search pattern to achieve faster processing by using fewer search points being evaluated.

III. STUDY EXISTING BLOCK MATCHING ALGORITHM BASED ON HEXAGON –BASED SEARCH PATTERN

3.1 Hexagon-Based Search Pattern for Fast Block Motion Estimation

Hexagon-based search pattern algorithm (HEXBS) [12] has been proposed by Ce Zhu, Xiao Lin, and Lap-Pui Chau in 2002.Hexagon-based search pattern algorithm (HEXBS) is a search pattern to find motion estimation. A hexagon-based search pattern employs two different types of search pattern. The first pattern called large HEXBS pattern and other called small HEXBS pattern as shown in fig 1.



(a) (b)

Fig. 1. Hexagon-based search (HEXBS): (a) large hexagonal patterns (b) small hexagonal patterns

The searching procedure for HEXBS is shown in fig.2 A hexagon-based search pattern consists of seven checking points with the center surrounded by six endpoints of the hexagon with the two edge points (up and down) being excluded.

The first step uses the large hexagonal pattern for searching with seven checking points. If the minimum block distortion (MBD) is found at the centre, then switch to small hexagonal pattern, which consist of four checking points for the focused inner search. Otherwise, the search continues around the point.

With MBD using the same large hexagonal pattern. Analysis of HEXBS algorithm over the DS algorithm shows that a speed improvement rate can be as high as over 80% for locating some motion vectors in certain scenarios. In short, HEXBS method used substantially smaller number of search points when comparing with NTSS, 4SS, or DS, nearly half the number of NTSS. Generally speaking, HEXBS algorithm can save more search points in case of larger motion vector.

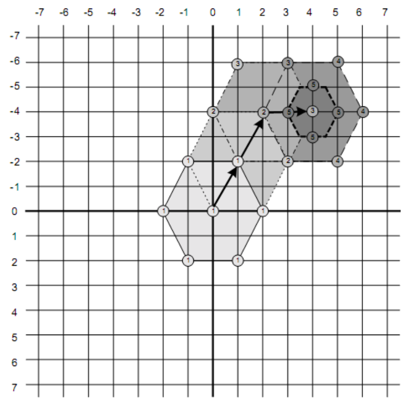


Fig. 2. Search path example locating the motion vector (+4, -4) by HEXBS. Note that a small HEXBS pattern is applied in the final step after the best candidate search point at step 3 remains the best at step 4. Totally 20 (=7+3+3+3+4) search points are evaluated in 5 steps.

3.2 Enhanced Hexagonal Search for Fast Block Motion Estimation

An Enhanced hexagonal search algorithm (EHEXBS) [13] has been proposed by Ce Zhu, Xiao Lin, Lappui Chau, and Lai-Man Po in 2004. An enhanced hexagonal search employed a novel fast inner search by exploiting the distortion information of the evaluated points. An enhanced HEXBS is developed by incorporating the 6-side-based fast inner search scheme.

There are two aspect to reduce number of search points for the enhanced HEXBS algorithm, i.e., one from the prediction for a good starting point using the predictive HEXBS, and the other from the fast inner search. An enhanced HEXBS has consistently gained the fastest motion estimation in terms of number of search points with smaller MSE distortions than the HEXBS and almost the same MSE distortions as the predictive HEXBS. Based on experimental studied we conclude that an enhanced HEXBS algorithm perform well then original HEXBS with search speed and distortion performance, up to 57% in both speed-improvement rate and distortion-decrease rate.

3.3 Efficient hexagonal inner search for fast motion estimation

A novel inner search algorithm known as efficient hexagonal inner search (EHIS) [14], has been developed by Chorng-Yann Su, Yi-Pin Hsu, and Cheng-Tao Chang in 2005. It is also proposed to further reduce the number of search points. An EHEXBS used six checked points along the perimeter of the hexagon to determine the checked inner points, but it doesn't check center of the hexagon. EHIS use the central minimal distortion information and exploit the distortion information of the points located on the hexagonal pattern.

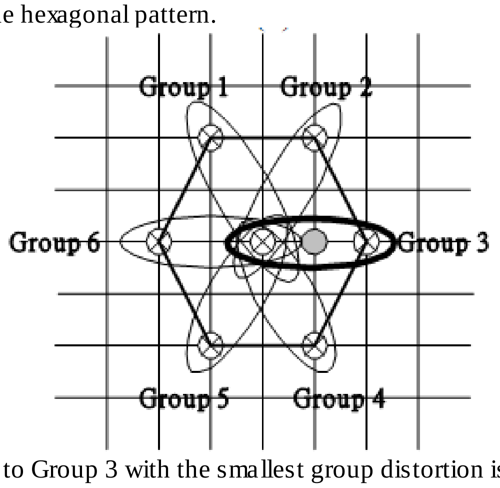


Fig.3 One inner point nearest to Group 3 with the smallest group distortion is going to be checked.

EHIS follows group style by grouping each end-point of the hexagon with the center point of the hexagon together, that are shown in fig 3. In EHIS comparison can be done directly on the distortions of the six end-points of the hexagon because all the groups contain the distortion information of the center point. So EHIS omits the overhead of six additions for calculating the group distortions. Based on experimental study EHIS performs better than the EHEXBS in terms of the number of search points or the mean squared error.

3.4 New Enhanced Hexagon-Based Search Using Point-Oriented Inner Search for Fast Block Motion Estimation

Lai-Man Po, Chi-Wang Ting and Ka-Ho Ng are developed New Enhanced Hexagon-Based Search Using Point-Oriented Inner Search for Fast Block Motion Estimation in 2007 [15]. A new point-oriented inner search technique has been employed in

second version of EHEXBS which can further speedup the HEXBS in both large and small motion environments. In this approach, new grouping principles are developed based on an analyzed statistic of the inner area. An Enhanced hexagon-based search version-2 (EHS2) used mean internal distance (MID) as a measurement for the correlation between the inner points and coarse points.
Experimental study for enhanced hexagon-based search version-2 (EHS2) is faster than the HEXBS up to 34% with negligible PSNR degradation is kept below 0.25dB. EHS2+ significantly reduces 15% to 34% computations over the original HEXBS.

3.5 Motion Vector Estimation Search using Hexagon-Diamond Pattern for Video Sequences, Grid Point and Block-Based

S. S. S. Ranjit, S. K. Subramaniam, S. I. Md Salim are proposed hexagon-diamond grid pattern (HDGP) using the block-matching motion vector estimation technique [16]. This algorithm is implemented based on hexagon and diamond pattern using the grid technique. The block-matching method will estimate the motion vector during the comparison of grid points in the hexagon and diamond pattern.

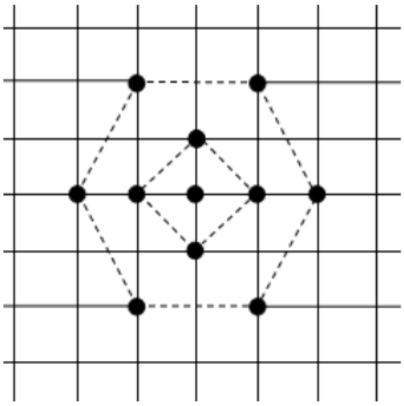


Figure 4. Hexagon-diamond grid pattern.

Hexagon grid pattern consists of two search patterns shown in figure 4. The first one is seven search points including the center point. Another is small diamond grid pattern, consists of five search points which is located inside the hexagon including the center point. Based on experimental study, in terms of PSNR points HDGP algorithm achieved close performance compared with the FS and DS algorithms, while outperforming TSS and NTSS algorithm. The HDGP and DS algorithms have the same number of average search points. HDGP algorithm have compact processing of search points that will increase the PSNR point's measurement and improve the image quality.

3.6 Multipath Flatted-Hexagon Search for Block Motion Estimation

Chao-Ho Chen et. El. has been proposed multipath flatted-hexagon search (MFHS) algorithm in 2010. Each search path of MFHS uses the search process of FHS [17], exclusive of finding the next search-paths. For judging which paths are required for approaching the optimal solution, a dynamic threshold is introduced to find the local minimum points that may be in the direction of the global minimum. For every search step a local minimum is determined by the absolute difference between SAD value of someone point and SADmin is smaller than or equal to a threshold T.

MFHS employing the flatted hexagonal search pattern with multipath search process, so it will cope with the local-minimal trapping problem to achieve a high matching probability with a moderate number of search points required.
MFHS algorithm is not suitable for larger frame size, like CCIR601 format (i.e., 720 × 480). So, the search performance of MFHS will be degraded owing to its small-size search pattern. Based on experimental study MFHS can achieve an average matching probability up to 98% near to that of FS and about 10 times of checking points faster than FS. MFHS algorithm is suitable for low-resolution (e.g. CIF, 352x288 or SIF, 352x240) image sequences.

IV. CONCLUSIONS

In all type of motion estimation algorithm based on Hexagon based search algorithm perform best as compared to other algorithm. In this paper we have presented a performance analysis on study of variation in Hexagon based search algorithm like Hexagon-based search pattern algorithm (HEXBS), Enhanced hexagonal search algorithm (EHEXBS), efficient hexagonal inner search (EHIS), New Enhanced Hexagon-Based Search Using Point-Oriented Inner Search (EHS2), hexagon-diamond grid pattern (HDGP) and multipath flatted-hexagon search (MFHS). Here we have described the searching process and performance for each algorithm in detail.

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