Analysis of Low Complexity Motion Estimation Algorithms for H.264 Video Compression Standard

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***Abstract*— The Low complexity Novel Cross Diamond Hexagonal Search algorithm is implemented and its performance is compared with Full Search, Three Step Search, New Three Step Search, Diamond Search, and Hexagonal Search Algorithm. The experimental results showed that the Novel Cross Diamond Hexagonal Search algorithm performs more efficiently than diamond search and hexagonal search algorithm with lower computational complexity and similar quality is maintained. The algorithm uses two hexagonal search patterns in conjunction with diamond search pattern. The profiling results of the all these algorithms are also checked.**

***Keywords:* Fast block matching motion estimation, Cross Diamond Hexagonal search.**

I. INTRODUCTION

Interframe predictive coding is used to eliminate the large amount of temporal and spatial redundancy that exists in video sequences and helps in compressing them[3]. In conventional predictive coding the difference between the current frame and the predicted frame (based on the previous frame) is coded and transmitted. The better the prediction, the smaller the error and hence the transmission bit rate[6]. If a scene is still, then a good prediction for a particular pel in the current frame is the same pel in the previous frame and the error is zero. However, when there is motion in a sequence, then a pel on the same part of the moving object is a better prediction for the current pel. The use of the knowledge of the displacement of an object in successive frames is called Motion Compensation. There are a large number of motion compensation algorithms for interframe predictive coding. In this study, however, we have focused only on one class of such algorithms, called the Block Matching Algorithms. These algorithms estimate the amount of motion on a block by block basis, i.e. for each block in the current frame, a block from the previous frame is found, that is said to match this block based on a certain criterion. There are number of criteria to evaluate the "goodness" of a match and some of them are:

1. Mean Squared Error
2. Sum of Absolute Difference
3. Peak Signal To Noise Ratio

Some of these criteria are simple to evaluate, while others are more involved. Different kinds of algorithms use different criteria for comparison of blocks. One of the first algorithms to be used for block based motion compensation is what is called the Full Search or the Exhaustive Search. In this, each block within a given search window is compared to the current block and the best match is obtained (based on one of the comparison criterion). Although, this algorithm is the best one in terms of the quality of the predicted image and the simplicity of the algorithm, it is very computationally intensive. With the realization that motion compensation is the most computationally intensive operation in the coding and transmitting of video streams, people started looking for more efficient algorithms. However, there is a trade-off between the efficiency of the algorithm and the quality of the prediction image. Keeping this trade-off in mind a lot of algorithms have been developed. These algorithms are called Sub-Optimal because although they are computationally more efficient than the Full search, they do not give as good a quality as it.

There are several approaches to reducing the computational complexity. For instance there are the Signature Based Algorithms that reduce the computation by using several stages, in each of which a different comparison criterion is used. In the first stage all the blocks are evaluated using a computationally simple criterion and then based on the results of this stage a subset of the candidates is picked for the next stage, where a more complex criterion is used. There are algorithms that exploit the limitations of the human observers. These algorithms reduce computational complexity by reducing the candidates that are chosen for the comparison, based on the knowledge that the human eyes cannot perceive fast motion with full resolution. So they use what is called a coarse quantization of vectors i.e. around the centre of the search area all blocks are evaluated as potential matches

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Some algorithms are based on the nature of the image data than the limitations of the human observers. It is believed by these algorithms that very good matches are likely to be found in the vicinity of reasonably good matches. Although this assumption might not be necessarily true, it is useful for reducing the computation as the search can be broken down into stages where the algorithm successively narrows down on the regions of good matches. There are a large number of algorithms that make this assumption and these may be classified as algorithms based on the Principle of Locality. One of the problems with these algorithms is that they can converge to a local minimum rather than to the global minimum. These algorithms can be modified by changing the manner in which the algorithm narrows down the search area. For instance the extent of reduction of the search area can be made a function of the two smallest distortions in the previous stage, rather than just the smallest distortion. Such algorithms are called the Dynamic search Window algorithms.

In this paper, we implemented two novel cross-diamond-hexagonal search (CDHS) algorithms by employing a smaller cross-shaped pattern before the first step of CDS and replacing the diamond-shaped pattern with hexagonal search patterns (HSP) in subsequent steps. The rest of the paper is organized as follows. Section II presents the proposed search patterns used in CDHSs. In Section III, the algorithmic flow of the CDHSs will be described and followed with a theoretical analysis on the gain in search points by using CDHSs over CDS and DS.

II LOW COMPLEXITY TECHNIQUES

The sub sampling of data, early termination threshold and triangle inequality mechanism is used for low complexity motion estimation implementation of the algorithms. Sub Sampling of the frame is done before finding the motion vectors. Triangle inequality technique is used to reduce the number of calculations in the motion estimation phase. According to triangle inequality technique (i.e. equations of the form

$$\sum_{block}|S_k - S_{k-1}| \geq \left|\sum_{block} S_k - S_{k-1}\right| = \left|\sum_{block} S_k - \sum_{block} S_{k-1}\right|$$

can be used for early termination.

The early termination threshold can be used to terminate the SAD calculation if SAD value exceeds the current minimum SAD values.

The profiling test results are carried out for foreman and carphone sequences. The number of search points are taken as measure of computational complexity. The profiling is carried out with the help of Microsoft visual C++ compiler profiling option. The time taken to execute the motion estimation function is reported in the profiling test. The test environment is set up on a separate test machine with Pentium III 700MHz processor and 64 MB RAM.

Table I Shows the execution time of different algorithms and number of blocks searched

Motion Estimation Algorithm	Execution Time ms	Number of Search points	Low Complexity implementation execution time ms
Full Search	234.059	9801	92.937
Three Step Search	85.104	2009	36.680
New Three Step Search	45.582	1540	26.882
Diamond Search	73.501	1249	53.006
Hexagonal Search	43.970	1249	35.309
Cross Diamond Hexagonal Search	33.564	660	28.510

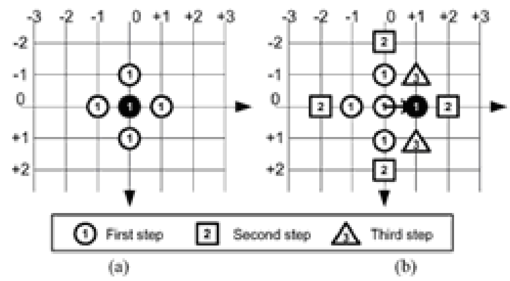

Fig 1 (a) Shows the first stop for cross diamond hexagonal search algorithm. (b) Shows Third step stop for the cross diamond hexagonal search algorithm [1]

III.CROSS-DIAMOND-HEXAGONAL SEARCH

A. Flow of the CDHSs

The CDHS algorithms differ from DS, HEXBS, and CDS by performing a highly cross-center-biased search with SCSP in the first step. In addition, the search may involve up to two different patterns: diamond-shaped LDSP (Large Diamond Search pattern) and hexagonal pair LHSP (Large Hexagonal Search Pattern). The common strategy amongst them is employing a halfway-stop technique. The following summarizes the CDHS algorithms.

Step (i) Starting: A minimum BDM point is found from the five checking points of SCSP at the center of search area. If the minimum BDM occurs at SCSP center, the search stops.

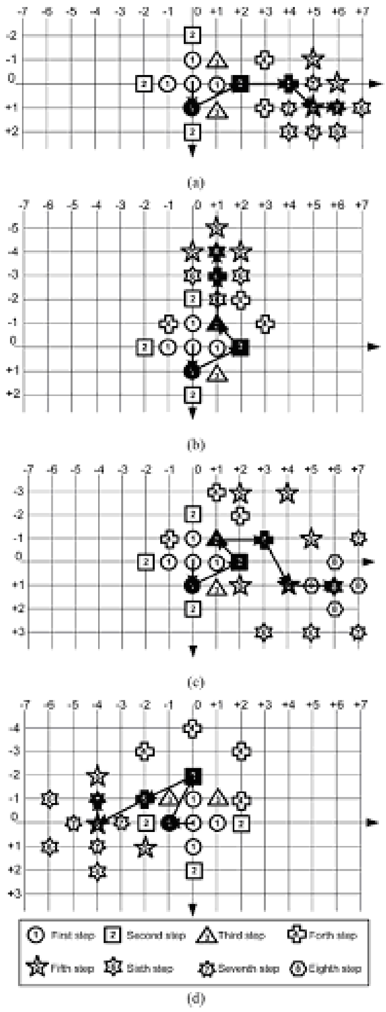

Fig 2. (a) Search replaces LDSP pattern with HF-HSP (b) Search follows VF-HSP (c) Shows CDHS-T with HT-HSP[1]

[This is called first-step-stop as shown in Fig. 1(a).] Step (ii) Large Cross Searching: The four outermost points of the central LCSP are evaluated, i.e., the four candidates at (+/-2, 0) and (0,+/-2). This step guides another possible correct direction for the subsequent steps. Step (iii) Half-diamond Searching: Two additional points of the central LDSP closest to the current minimum BDM of the central LCSP are checked, i.e., two of the four candidate points located at (+/-1,+/-1) . If the minimum BDM found in previous steps is at any endpoint of SCSP, i.e., (+/-1 , 0) or (0,+/-1), and the new minimum BDM found in this step still coincides with this point, the search stops. [This is called third-step-stop, as shown in Fig. 1(b).] Step (iv) Searching: – Case (1): If LDSP is used in previous step and the minimum BDM is found located at any point on diamond edge, a new LDSP is formed by repositioning the previous minimum BDM point as the center of LDSP. – Case (2): If LDSP is used in previous step and the minimum BDM is found located at either of the horizontal (vertical) diamond corners, a new horizontal (vertical) LHSP is formed by repositioning the previous minimum BDM as the center of LHSP. – Case (3): Otherwise, a new LHSP of the same shape is formed by repositioning the previous minimum BDM as the center of LHSP.

For any case above (LDSP-> LDSP, LDSP-> LHSP, or LHSP->LHSP), three new checking points are evaluated. If the new minimum BDM point is still at the center of the newly formed LDSP or LHSP, go to the final Step (v) (Ending). Otherwise, this step is repeated again. Step (v) Ending: With the minimum BDM point in the previous step as the center, a new SDSP is formed if LDSP is used in previous step; otherwise, a SHSP is employed instead. Identify the new minimum BDM point, which is the final motion vector, from the four new candidate points2 in SDSP or SHSP. Two halfway-stop examples for small motion paths are shown in Fig. 1 and four typical search paths using CDHS-F and CDHS-T are shown in Fig. 2. In Fig. 2(a), the search replaces LDSP pattern with HF-HSP and gives final motion vector at MV(+6,+1). Similarly, another example using CDHS-F with final MV(+6,+1) is shown in Fig. 2(b), in which the search initially follows diagonal direction using LDSP and turn into vertical direction using VF-HSP at a vertical diamond corner. Both proposed CDHS-F and CDHS-T will stop and truncate the search pattern at boundaries of search area. For instance, Fig. 2(c) shows an example of CDHS-T with HT-HSP truncated at seventh step and the final MV (+6,+1) is identified by the minimum BDM point, which coincides at the center of patterns used in sixth and eighth step. Another example using CDHS-T with final MV(-4,-1) is shown in Fig. 2(d). It is noted that the proposed CDHS-T requires two more checking points in the transitional step [Step (iv), Case (2)] when switching into LHSP, as shown in Fig. 2(c) and (d).

IV. RESULT

The Full search, Three step search and New Three Step Search algorithm, Diamond Search, Hexagonal Search and Cross Diamond Hexagonal Search algorithm are implemented and their performance is evaluated based on PSNR MSE and SAD. The test sequence of carphone and foreman are used to evaluate the performance of the motion estimation algorithms. The motion estimation results for frame 9 in the carphone sequence are shown. The profiling results with execution time and number of search points are obtained.

V. CONCLUSION

The cross diamond hexagonal search algorithm performs better than full search, three step search ,new three step search, diamond search and hexagonal search algorithms in terms of number of search points and execution speed.

The comparison of Mean Square Error, Sum of Absolute Difference and Peak Signal To Noise Ration for carphone sequence clearly show that the Novell Cross Diamond Hexagonal Search algorithm performance is better than three step search, new three step search, diamond search and Hexagonal search algorithm.

Fig 3.The motion estimation results for the carphone sequence frame 9 and reference frame1

Fig 4. The reconstructed frame and original frame 9 in the foreman sequence

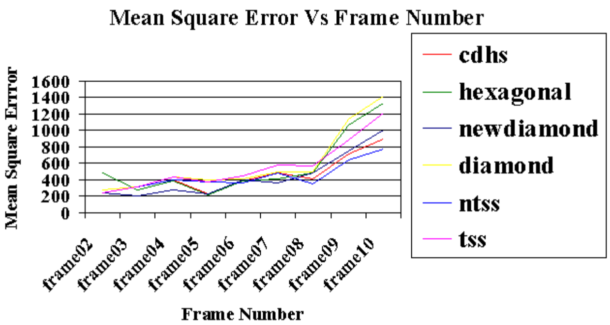

Fig 5. The MSE comparison for all the algorithms of carphone test sequence

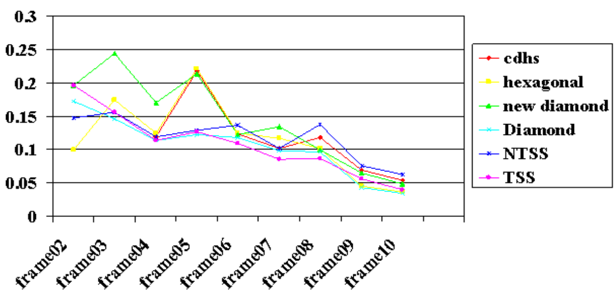

Fig 6. The PSNR comparison of all the algorithms of carphone test sequence

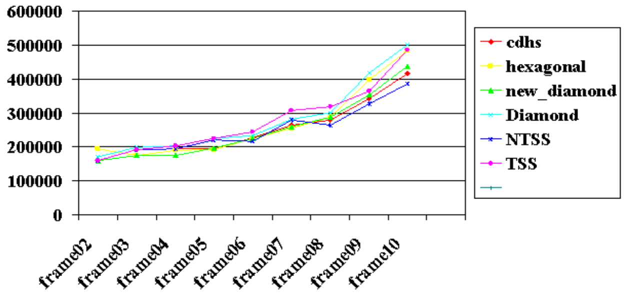

Fig 7. The SAD comparison of all the algorithms for carphone Sequence

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ISBN: 978-988-17012-2-0