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Parametric Analysis of Diamond Search Algorithm for Fast Motion Estimation

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Abstract—Motion estimation (ME) techniques are used for reducing temporal redundancies in videos. These techniques should provide good prediction with low computational load. Hence, block matching ME techniques are universally used because of lower computational complexity. The computational load of Block matching algorithms can be varied by adopting different matching criteria (e.g. MSE, MAD), block size and the searching parameter (p). This research paper does the parametric analysis of Diamond Search (DS) algorithm which is a fast block based motion estimation technique. In this paper, the performance of DS is evaluated by varying the value block size and the matching criteria and taking search parameter value 'p'=7. The results obtained are compared against the Full Search (FS) algorithm. Simulation results show that as the block size increases the number of computations and the PSNR of these algorithms decreases. Also, changing the cost function from MSE to MAD influences the value of PSNR and computations. Regarding the image quality, the DS results are very close to the PSNR results of FS, but once again the DS algorithm needs fewer searches per block than the FS.

***Keywords**—Motion estimation, Block matching algorithms, Diamond Search, Full Search.*

I. INTRODUCTION

Most of the video compression standard uses DCT transform coding to reduce spatial redundancy [1] and block based motion estimation/compensation [2] to reduce the temporal redundancy. Block matching algorithm [2], is a method in which each frame is divided into number of non overlapping blocks of equal sizes. Each block present in the current frame is matched against all candidate blocks which are present within a search window of the reference frame. These candidate blocks of reference frame are just the displaced versions of original block present in the current frame. The best matched candidate block is calculated and its displacement (motion vector) is being recorded. The process of block matching algorithm uses a value called "Block Distortion Measure" (BDM) to rate similarity between two blocks [3]. Nevertheless, speeding up of the process is a major constraint. A large number of fast block matching algorithms (BMAs) has been anticipated for motion estimation by limiting the number of search locations [4].

The computational complexity of a block based motion estimation technique can then be determined by four factors [5]: search algorithm, search range parameter, cost function/evaluate function and block size.

The objective of this paper is to evaluate various combinations of motion estimation schemes, distortion measures, block and search parameter sizes. The motion estimation algorithms considered in this paper are (a) full search (FS), and (b) diamond search (DS). The cost functions considered are (a) Mean Squared Error (MSE), and (b) Mean Absolute Difference (MAE).

This research paper is organized as follows: Section II discusses the Full Search and Diamond Search algorithm with the highlights of their advantages and disadvantages. Section III describes the parameters of block matching in detail. Section IV simulates FS and DS algorithm for their performances on varying values of different parameters. These two algorithms are compared with each other in terms of computational complexity & PSNR. Finally section V includes conclusion based on the results obtained in section IV.

II. BLOCK BASED MOTION ESTIMATION ALGORITHM

Different techniques are available for searching the motion in the video but here we will discuss only Full Search and Diamond Search algorithm in detail.

A. Full Search (FS)

This algorithm [6] also called Exhaustive Search (ES), calculates cost function at each possible location in the search window. FS is the most computationally expensive block matching algorithm of all. It finds the best possible match and gives the highest PSNR amongst any block matching algorithm. The basic disadvantage of FS is that the larger the search window gets the more computations it requires.

B. Diamond Search (DS)

The DS [7] algorithm employs two search patterns. Its first pattern is called large diamond search pattern (LDSP), comprises nine checking points from which eight points surround the center one to compose a diamond shape. Its second pattern comprises of five checking points to form a small diamond shape which is called small diamond search pattern (SDSP). In the searching procedure of the DS algorithm, LDSP is repeatedly used until the minimum block distortion (MBD) occurs at the center point. The searching pattern is then switched from LDSP to SDSP when it reaches at the final search stage. Out of five checking points present in SDSP, the position yielding the minimum block distortion (MBD) gives the motion vector of the best matched block.

DS has no limit on the number of steps that the algorithm can take but the search should remain inside the defined search range. The end result in terms of PSNR is close to that of ES while computational expense should be significantly less [8].

The main disadvantage [9] of DS is that it does not perform as well for sequences containing large or complex motion. This is mainly due to three limitations of DS: 1) it does not exploit the motion correlation between adjacent frames or blocks; 2) it exhaustively evaluates all eight neighbouring points around the diamond center; and 3) it cannot stop the search early even when the SAD at a particular checking point is already very small.

III. PARAMETERS OF BLOCK MATCHING

The parameters involved in block-based motion estimation are the cost function, search parameter, blocks size and performance measure.

A. Cost Function

Of the several cost functions that have been developed, we consider a few which are more commonly used. These are, Mean Absolute Difference (MAD) [10] and Mean Squared Error (MSE) [11]. The matching of one block with another is based on the output of these cost functions. The block that results in the least cost is the one that matches the closest to current block. Mean Absolute Difference (MAD) formula can be given by equation (i). Mean Squared Error (MSE) is another way of calculating cost function and it is given by equation (ii).

$$MAD(i,j) = \frac{1}{NXN}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}|Cij - Rij| \qquad \text{.......................... (i)}$$

$$MSE(i,j) = \frac{1}{NXN}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(Cij - Rij)^{\wedge}2 \qquad \text{...………………. (ii)}$$

where N is the side of the block, Cij and Rij are the pixels being compared in current block and reference block, respectively.

B. Search Parameter

The search area for a good block match is constrained up top pixels on all four sides of the corresponding block in previous frame [12]. This p is called as the search parameter. Larger motions require a larger value of p and the larger the search parameter the more computationally expensive the process of motion estimation becomes.

The ideal size for a search window depends on several factors:

- The resolution of each image (a big window is obviously suitable for a very high resolution).
- The scene type (scenes with fast motion are usually benefited from a big search window in contrary to scenes with small motion).
- The available computational resources.

C. Block Size

Another important parameter of the block matching technique is the block size [13]. If the block size taken is smaller, then this algorithm will give better prediction quality. There are various reasons responsible for this. If we take smaller block size then it reduces the effect of the accuracy problem. In other words we can say that with a smaller block size, there is very little possibility that the block will contain different objects that moves in different directions. In addition to this, a smaller block size provides a better piecewise translational approximation to non-translational motion. But smaller block size also gives more number of blocks and as a result we get more motion vectors per frame. Hence, this improved prediction quality comes at the expense of a larger motion vector overhead. Usually video coding standards makes use of a block size of 16*16 as a compromise between prediction quality and motion overhead.

D. Performance Measure Parameter

Peak-Signal-to-Noise-Ratio (PSNR) [14] given by equation (iii) characterizes the motion compensated image that is created by using motion vectors and blocks from the reference frame.

$$PSNR = 10\log_{10}\left(\frac{255^{\wedge}2}{MSE}\right) \qquad \text{………………….. (iii)}$$

IV. SIMULATION RESULTS

In this section two different types of block matching algorithms will be implemented using the MATLAB environment. The algorithms which are implemented are: Exhaustive Search (ES) and Diamond Search (DS). The PSNR measure was used, which characterizes the image motion compensation that has been created by the use of the motion vectors and the macroblocks of the reference frame. For each method, the current frame is divided into macroblocks with sizes of 16x16, 8x 8 and 4x 4 by keeping the search parameter 'p'=7 pixels. The video sequence which was used to conduct our experiment is the "Miss America" sequence, which is in the .ras format. We have also varied the cost function from MSE to MAD to analyze its influence on the PSNR and computational load. So we executed the MATLAB code, and obtained the following results mentioned in the table I.

TABLE I COMPARISON OF THE AVERAGE NUMBER OF COMPUTATIONS AND THE AVERAGE PSNR FOR DIFFERENT MACROBLOCK SIZES AND COST FUNCTIONS FOR FS AND DS ALGORITHM

Cost Function	***MSE***			***MAD***		
Search Parameter	P=7			P=7		
Block Size	***16x16***	***8x 8***	***4x 4***	***16x16***	***8x 8***	***4x 4***
FS_Av_Computation	***204.28***	***214.51***	***217.48***	***204.28***	***214.51***	***217.48***
DS_Av_Computation	***16.16***	***17.55***	***18.02***	***16.24***	***17.58***	***18.07***
FS_Av_PSNR (dB)	***37.87***	***38.64***	***40.35***	***37.80***	***38.54***	***40.15***
DS_Av_PSNR (dB)	***37.60***	***38.22***	***39.38***	***37.50***	***38.11***	***39.19***
Speed improvement ratio of DS over FS (%)	***92.08***	***91.81***	***91.71***	***92.04***	***91.80***	***91.68***

As it can been seen from the above table that FS algorithm requires a bigger number of calculations than the DS algorithm. Hence DS algorithm takes less search points per macroblock, having thus the less computational load than the FS algorithm.

From table 1, we can conclude that as the macroblock size is increased the number of computations and the PSNR of each algorithm are decreased. Also, changing the cost function i.e. MSE to MAD results in the decreased value of both the PSNR and the number of computations.

V. CONCLUSION

Regarding the image quality, the DS results are very close to the PSNR results of FS, but once again the DS algorithm needs fewer searches per macroblock than the FS. In this paper we have analyzed the influence of block size and the cost function on computational complexity and PSNR results, by decreasing the block size from 16x16 pixels to 4x 4 pixels and varying cost function from MSE to MAD. Hence we found that Diamond Search algorithm needs fewer calculations than FS algorithms and therefore it is the best of the fast block matching algorithm studied in this work. Here we obtained the speed improvement of DS over FS in the range of 91% to 92%.

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