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Improved Logarithmic Search for Efficient Video Compression

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Abstract*: For efficient video compression, the BMAs should be designed and implemented in such a way that that the Motion Estimation takes very less time and will have lesser complexity. In this paper, two new algorithms namely Improved Logarithmic Search (ILS) and Zero motion predicted ILS (ZMILS) are proposed which are based on the basic idea of Three Steps Search (TSS) algorithm. In these BMA, the search pattern of proposed algorithms changes the efficiency both in terms of complications required for each macro block (MB) and quality of the compensated images. We improved the TSS and NTSS by changing the searching pattern of locations in reference frame and by adding no movement early prediction case with these algorithms we further reduced the computations. The computations required by the new developed algorithm are lesser per macro block and even 50% of few existing techniques while retaining the quality of the reconstructed image.

***Keywords* : ILS, ZMILS; Mean Absolute Difference; motion vector (MV).**

I. INTRODUCTION

The demand for video and use of video has increased drastically in last 5 years for which it is very much important to process the videos as fast as possible while retaining the quality of the image. For processing, we also need to store the videos and then to encode them. For storing video, much storage space is required and therefore there is an increase in time for processing and to encode them. So we need to compress the videos for faster processing and lesser storage requirements. In the process of encoding the video and compression of it, motion estimation (ME)([1]-[5]) plays a vital role by finding displacement vector which is known as motion vectors (MV)([1]-[5]) of candidate block by using some search techniques which are called Block Matching Algorithms (BMA)([1]-[3]). The Block matching is basically a search technique and requires lot of computations.

Best matching macro block (MB) is found in reference frame using suitable BMA and the process is called Motion estimation (ME). To reduce the temporal redundancy non liner class of coding i.e. predictive coding is done in which ME is used. Deciding and finding out MV is vital in achieving good quality video compression. At one hand, ME techniques will have to find optimal matching MB's displacement vector with minimum difficulties and at the same time required to retain the feature of image. The objective of ME is to maintain a good balance between computational cost i.e. no. of search points required per MB and the worth of the decoded video which is denoted by the values of Peak signal to noise ratio (PSNR)([2]-[8])

Difference in coordinate position i.e. Motion Vector of the MB of candidate frame and the matching MB in reference frame is found by comparing/matching the corresponding frames in the two frames. The matching is done at block level as pixel to pixel matching may results in wrong results as two different pixels may have the same values. Moreover the pixel based matching is computationally expensive as well as time consuming. Instead of pixel based matching, the frames are first divided into some regular shaped say 8x8 or 16x16 regions which are known as macro blocks (MB) and then compared. The MB of candidate frame and past or future frame are compared using the matching criteria and the position of the MB which has the minimum value of matching criteria becomes the position of best match and their coordinate difference is the resultant MV. The complete process mentioned above is known as Motion Estimation (ME).

Our paper is organized in seven segments. All existing literature is illustrated in Segment II. Segment III identifies the Prediction types; Section IV elaborates the various matching criteria used. Proposed method is briefed in Segment V, Segment VI gives the arrangements & fallouts and segment VII explains the comparison with existing BMA followed by conclusion & Acknowledgement

II. LITERATURE SURVEY

Block matching in reference frames can be done in many ways. Initially the candidate block is searched at each point of the reference frame for finding out best match. This technique is referred to Full Search (FS) ([1],[2],[5]-[8]). It takes so many computations and time for each single macro Block. So new algorithms were proposed which reduces the computational complexity to a great extent without much compromise in video quality. The oldest among the fast BMA was Three step Search (TSS) ([5]-[10]) which has computational complexity of avg. 25 i.e. it examines an average of 25 MB to find best match per MB. To find the best matching MB location, New Three Step Search (NTSS) ([8]-[10]) searches 17 to 33 MB per MB, 2D Logarithmic Search (2DLS) [8] searches 13 to 17 MB,

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Diamond Search (DS) ([8], [9], [12]) searches an average of 13 MB. Amongst the other existing BMAs Hexagonal Search [7], Cross Search (CS) [14],[15], Adaptive Rood Pattern Search (ARPS)([8], [9], [16],[18]), Cross Diamond Search (CDS) ([15],[20]) etc. are evident.

An upgraded version of 2DLS and TSS is proposed which has the features of both TSS and 2DLS. ILS is applied on different videos and the obtained results are compared with many other BMAs with respect to Computations required per macro block and reconstructed image quality. Further addition of Zero Motion Pre Adjustment criteria to the proposed ILS further lessened search points per MB.

III. PREDICTION TYPES (FP & BP):

In the encoding of video, we can use both previous and future frame to find out the finest matching MB in any of the two frames used as frame of reference. When the old frame is used to predict the position of macro block of current frame, we call it as a forward prediction (FP).

When the future frame is used for as a reference for prediction of MV i.e. finest match of the current block, we refer it as the backward prediction technique (BP). When both past and future frames are used to predict the best match, we call it as a bidirectional prediction.

IV. SIMILARITY MEASURES

To find out the match between candidate MB of current frame k and MB in reference frame k+1(say) either Mean Square Error (MSE) or Mean Absolute Difference (MAD) or Sum of Absolute Difference (SAD) are used whereas to check the quality of decoded image cum video, PSNR values are used.

A. Mean Absolute Difference (MAD):

The MAD of corresponding MB in two consecutive frames for the position (d_1,d_2) is calculated using Eq. (1)

$$MAD(d_1,d_2) = \frac{1}{N_1 x N_2}\sum_{(n_1,n_2)\in B}\sum \left|s(n_1,n_2,k) - s(n_1 + d_1, n_2 + d_2, k+1)\right|$$

(1)

B. Sum of absolute difference (SAD):

Sum of absolute difference (SAD) is another criteria for matching which has lesser computations and is calculated by Eq. (2)

$$SAD(i,j) = \sum_{m=1}^{M}\sum_{n=1}^{N}\left|X_{m,n} - X^{R}_{m+i,n+j}\right| \quad (2)$$

C. Peak signal to Noise Ratio (PSNR)

PSNR values are used to indicate the feature of reconstructed image. Higher values will indicate the better quality image. It is calculated using Eq. (3)

$$PSNR = 10 \log 10 (255^2 /MSE) \quad (3)$$

V. PROPOSED METHOD

In the process of video compression, ME is the key area where most of the research work is done. The major and most important concern of all BMAs were to reduce the time and complexity associated with ME. Since the pattern of search points has impact on the efficiency and results of the algorithm, based on three step search (TSS) and 2DLS, new Improved Logarithmic Search (ILS) is proposed.

A. Improved Logarithmic Search (ILS)

The search techniques are developed based on the different pattern of search points. This technique also has difference with the earlier techniques only in pattern of search points. The search pattern produces better result. This technique has the computational complexity than that of TSS, 2DLS, 4SS, NTSS whereas it maintains the quality of compensated image. The search is also done with initial step size 4, search range +7 and for macro block of size mxn. The ILS follows the following steps:

i. Searching starts with 5 initial points including the center where the candidate block resides. The 4 points are selected across a Cross 'X' pattern for lowest cost. The minimum cost point will be taken as new center and the step size will become two.

ii. A total of 5 points are checked with the new Center found in last step but cost is calculated only at new 4 points in similar to cross arrangement. The midpoint is shifted to the new minimum cost location and step size will become 1.

iii. With step size 1 and taking minimum point of last step as center, another 4 new points are examined for minimum cost in similar pattern. The point with least cost corresponds to the best matching MB's position and will give the best MV.

The proposed algorithm searches 5+4+4=13 search points per each MB but the PSNR values are different than that of the previous algorithm.

B. Zero motion adjusted ILS (ZMILS):

Here we have added the concept of zero motion pre-adjustment with ILS algorithm where search is stopped in between if tiniest cost point resides at the midpoint of the first step. This modified version is termed as Zero Motion Adjusted ILS (ZMILS) which reduces the computational cost to almost 50% than that of ILS and searches average 5 points per MB.

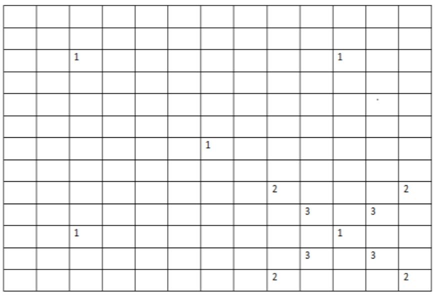

Fig.1: Search pattern in ILS (1, 2 & 3 are the step nos.)

VI. SETUP & RESULTS

The SAD value is used as a comparison measure in the proposed algorithm. The MB sizes are taken as 8x8 and 16x16 whereas search parameter is taken as +7 for our experiment which provides a maximum search area of (2x7+1)x (2x7+1)=225 blocks. The implementation is carried out in Windows 10 environment and using MATLAB R2016a equipped with 500GB Hard Drive and 2 GB RAM.

Different types of videos are used for implementation of proposed Algorithm which is mentioned in Table 1. The results obtained by proposed algorithm shows the number of places essentials to be tested per MB and the average PSNR values corresponding to each MB.

A. Video sequences used:

The following are the video sequences on which we have implemented the techniques and their outputs are depicted in Table 1.

Table 1: videos used for investigation

Video format & dimension	Name
Mp4 (240x360, 30 frames)	SampleVideo
ras (176x352, 30 frames)	Missa
qcif (176x244, 30 frames)	Football
qcif (240 x 360, 30 frames)	Claire
sif (244x360, 30 frames	Salesman

B. Experimental results of ILS:

The motion vectors obtained by using Improved Logarithmic Search on the above mentioned video "missa" and corresponding compensated pictures are revealed below in Fig. 2 and Fig. 3.

Reconstructed image by using MB size 8x8 vs 16x16

a) Compensated images of 'missa' video sequence

Image I Image P Image Comp

(a) Past frame (b) Current Frame (c)Reconstructed image

Fig.2: FP using 16x16 sized MB

Figure 2 showed the experimental results obtained for video sequence "missa" [26] with macro block size 16x16. The total macro block becomes 397. So a total of 4698 computations are required for that. The computations required per macro block are 11.8636.

Image I Image P imageComp

(d) Past frame (e)Current Frame (f) Reconstructed image

Fig.3: FP using 8x8 sized MB

In the above case, we implemented the technique on video sequence "missa" with macro block size 16x16.

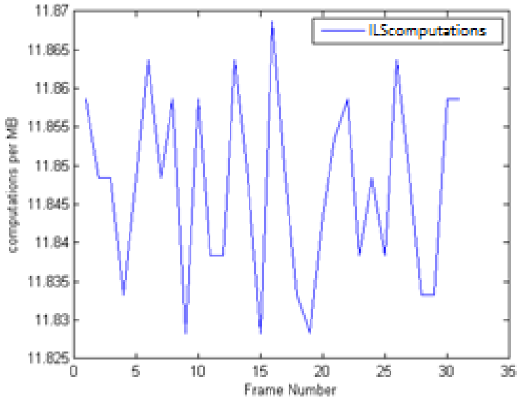

Fig.4: Computations required per macro block Vs frame number (mbSize 16x16) in ILS

The total macro block becomes 1585 and a total of 19716 computations are required for that. The average computations required per macro block is 12.4470. The computations required by ILS per macro block for the first 30 frames of 'missa' video are depicted in Fig. 4.

C. Experimental Results of ILS with Zero Motion Pre-adjustment (ZMILS)

The addition of Zero motion pre adjustment to ILS has reduced computations required per macro block from 12.4470 to 5.4141 and corresponding PSNR value for video sequence 'missa' reduces to 34.4861. The figure 5 depicts the number of test locations necessary to be checked per MB where first 30 frames of video 'missa.ras' are taken.

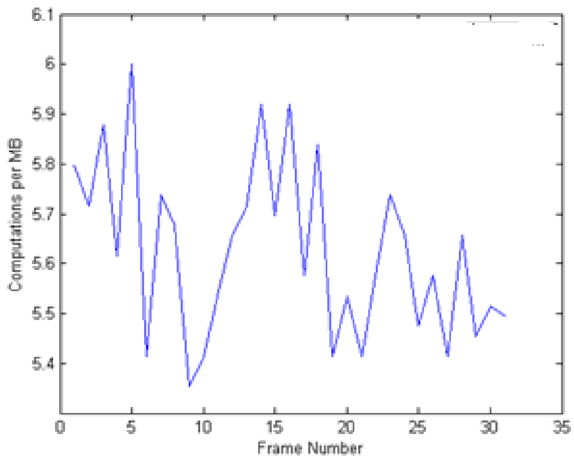

Fig. 5: Computations per Vs Frame No. of 'missa' using ZMILS

VII. Comparison with the Existing BMA

We have applied few existing techniques and newly developed techniques on the same video sequences mentioned above. The results are compared w.r.t. the number of complications compulsory per macro block and the PSNR values. It has been observed that the newly developed ILS takes almost 50% of the computations than that of TSS and even takes lesser steps when compared with NTSS, Four Steps Search (FSS) and Diamond Search (DS) etc.

Addition of Zero motion Pre adjustment to ILS further reduces the computations. The detail analysis is given below and shown in figure 6.

The results obtained by different algorithms than that of developed ILS and ZMILS is also shown in Table 2.

Table 2: Outcomes of different Algorithms

Algorithm used	Avg. Computations per MB	PSNR
FS	225	38.455
TSS	25	36.76
NTSS	21	36.65
4SS	17	35.943
ILS	11	34.67
ZMILS	5	34.232

A. Complexity point of view:

FS algorithm: The FS ([21]-[25]) examines a sum of $(2p+1)^2$ locations to find out identical MB. If the search range is taken as p=$\pm$7, for each MB, FS searches at least 225 MB.

TSS algorithm: TSS ([22]-[25]) algorithm finishes in 3 steps with reducing step size in each step. If the search area is taken same as FS, it searches an average of 25 MB for each MB to find its best match.

NTSS algorithm: The NTSS ([22]-[26]) is the modified variety of TSS which searches a lowest of 17 locations to find best matching MB and in worst case it searches 33 locations for best match.

ILS: This algorithm applies the concept of TSS and 2DLS. It has the computational complexity is found to be 11 to 13 only which is better than TSS, NTSS etc.

ZMILS: The adjustment of zero motion prediction results in an average of 5 checking points to find the best MV.

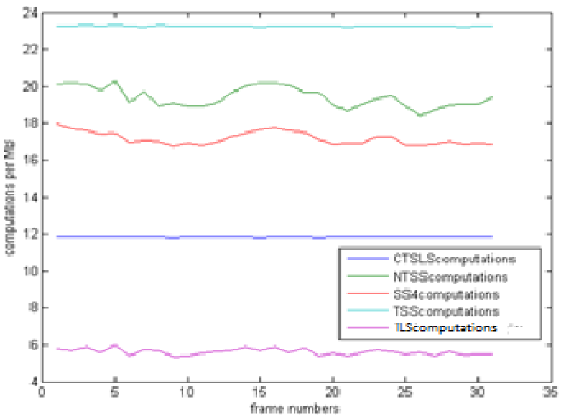

Fig. 6: Computations taken per macro block vs frame no. for "missa"

VIII. CONCLUSION

After implementing the newly developed techniques on different test videos and results are compared with the few existing techniques. We have observed that ILS takes almost 50% of the computations than that taken by TSS per macro block. It takes even lesser computations than the existing NTSS, DS, 2DLS and Four Step Search (SS4). The ZMILS further reduces the computations while retaining almost similar PSNR values i.e. compensated image's quality almost similar. We can conclude that our proposed BMA namely ILS and ZMILS are more efficient than most of the existing BMA.

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