COMPARISON AND SIMULATION BASED ANALYSIS OF AN OPTIMIZED BLOCK MATCHING ALGORITHM WITH FOUR STEP SEARCH ALGORITHM

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Abstract: *With advancement in technology and increased video applications, block based motion estimation is the basic need for video coding systems. The four step search block matching algorithm is very simple, robust and easy to implement. It provides centre biased searching scheme and halfway provision to stop in order to reduce the computational cost. This algorithm checks for minimum of 17 points to find best match for each macro block with minimum cost and has maximum of 27 checking points. It is comparatively less complex than three step search. Thus, it is widely used for various moving image applications such as T. V monitoring, video conferencing etc. In this paper, a new block matching algorithm is proposed which is very simple and efficient. The proposed algorithm is also a four step search with reduction in number of search points at every step. Experimental results shows that proposed algorithm achieves high PSNR using less number of search points and requires less time for computations resulting in less computational complexity.*

Key Words: 4SS, Block matching algorithm, MAD, Motion compensation, Motion estimation, MSE, MPC, PSNR, SAD, Video compression

1. Introduction

Raw video consist of continuous sequence of frames or moving images taken at various intervals of time. So, the principles of video compression are based on image compression. Advance in technology and new generations bring an environment where there is high demand for communication with moving picture or video. Now a day's video signal processing becomes an attractive area of research. Digital videos are used in various applications such as multimedia broadcasting, remote sensing, remote monitoring, medical imaging, military etc and it is expected that in future, real time video communication will be common. Digital video is advantageous as compared to analog video as it provides the interactive interface to users. Digital videos are less prone to noise and easy to transmit over medium. At present High definition videos are more preferred due to its improved quality. A major problem in video is that it requires large storage space as well as large bandwidth for transmission.

However, there is limited channel bandwidth. So, for efficient communication, the concept of video compression is introduced. Video compression is a technique for transforming video signal in compact representation keeping the quality of the video signal as close as to the original one. Compression is achieved by reducing the data redundancy which occurs due to spatial, temporal, and statistical co-relation between successive frames. The MPEG format consists of three parts to reduce the data redundancy. Motion estimation and compensation reduces temporal redundancy between two frames in time domain. The transform coding remove the spatial dependency in frame and entropy coding is used to reduce statistical redundancy over the residue. Motion estimation and compensation is most important module on typical video encoder. There are two approaches for motion estimation: (1) pixel-based motion estimation, (2) block-based motion estimation. Block based motion estimation is widely used for video encoding. Motion estimation finds the displacement between the two successive frames. One is called current frame and the other is called as reference frame. The reference frame occurs before and after the current frame, called backward and forward motion estimation. There is a very little change in spatial arrangements of objects between the two frames in digital video. That's why it is good to send it over the network and to store the difference between two successive frames. Motion compensation finds the prediction of future frames and the difference of compensated image and current image is encoded and decoded. The difference frame is called residue and it contain less details than the actual frame. Due to reduction in details, video compression is achieved. On the decoder side, decoded difference image is added to compensate image to accurately synthesize current frame from the previous frame. Thus, compression efficiency is improved.

2. Block matching Algorithm

Block matching is an approach which is adopted to fulfil the purpose of motion estimation in video compression, aim of which is to reduce the temporal redundancy in between the video sequences.

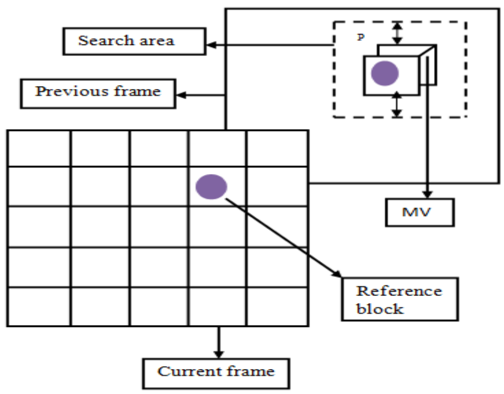

Fig. 1. Basic idea of block matching technique [Source: Hussain Ahmed Choudhury et al., 2011]

Figure 1 below illustrates a method of block-matching rule. Block matching algorithm is very simple and the initial one for motion estimation. In this algorithm, each of the frames is divided into group of macro blocks, which consist of both the chrominance and luminance block. The chrominance represent the colour and the luminance represents the intensity/brightness [Source: Razali Yaakob et al., 2013]. For coding efficiency, the motion estimation is performed on luminance block. Each of the luminance blocks in present frame is matched against the candidate block lies in the search area on reference frame as shown in figure 1. The best matched candidate block is observed and its motion vector is recorded. For finding the best match we compare the luminance block against each of the candidates block which lies within the defined search area that is constrained up to p pixels around the current block in reference frame in both horizontal and vertical direction [Neha Singh et al., 2016].

2.1 Existing Four-Step search algorithm

The four step search algorithm provides centre biased searching scheme and halfway provision to stop in order to reduce the computational cost. This algorithm was developed in 1996 [S Sangeeta Mishra et al., 2014]. This algorithm checks for minimum of 17 points to find best match for each macro block with minimum cost and has maximum of 27 checking points [S Immanuel Alex Pandian et al., 2011].

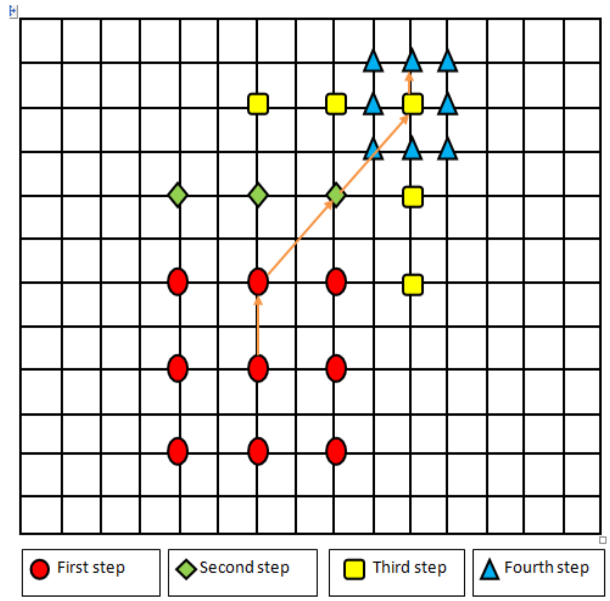

Fig. 2. Four step search procedure [Source: Aroha Barjatya, 2004]

3. Matching Criterion

As we know, block matching is a part of image matching. In most of the image processing tasks, it is necessary to examine two portions of image or two images on pixel to pixel basis. These two images regions/images are chosen from a spatial image sequence. The main aim of the examination is to find the similarity in between these two images or two image portions.

The similarity or correlation measure is main element in matching process. On the other side, a more efficient way to block matching is to find out minimum dissimilarity or matching error. There are various types of matching criterion, described below.

1. Mean of square error(MSE)
2. Sum of absolute difference(SAD)
3. Mean absolute difference(MAD)
4. Matching pixel count

For implementing the block motion estimation, the current video frame is partitioned into various non-overlapping blocks and the motion vector is calculated for each of the candidate block with respect to reference frame. For each of these matching criterions, a squared block of size N×N symbols is considered. Let k is the candidate frame and k-1 is past frame. Then, the intensity of pixel co-ordinate (n_1, n_2) in frame k is given by S (n_1, n2, k).

1. **Mean square error:** Consider k-1 as past frame then, for backward motion estimation, mean square error of block of pixels computed at displacement (i, j) in reference frame is given using equation 1.
   MSE (i, j) = $\frac{1}{n^2}\sum_{n1=0}^{n-1}\sum_{n2=0}^{n-1}[S(\mathbf{n1},\mathbf{n2},\mathbf{k}) - \mathbf{S}(\mathbf{n1}+\mathbf{i},\mathbf{n2}+\mathbf{i},\mathbf{k}-\mathbf{1})]^{\wedge}\mathbf{2}$ …………… **(eq. 1)**

2. **Sum of absolute difference**: Like MSE, SAD makes the error values positive but instead of summing up the squared difference, the absolute differences are summed up. SAD measure at displacement (i, j) is defined using equation 2.
   SAD (i, j) = $\frac{1}{n^2}\sum_{n1=0}^{n-1}\sum_{n2=0}^{n-1}[S(\mathbf{n1},\mathbf{n2},\mathbf{k}) - \mathbf{S}(\mathbf{n1}+\mathbf{i},\mathbf{n2}+\mathbf{i},\mathbf{k}-\mathbf{1})]$ ………………. **(eq. 2)**

3. **Mean absolute difference**: In this criterion, square of absolute differences is summed up and is given using eq. 2.3.
   MAD (i, j) = $\frac{1}{n^2}\sum_{n1=0}^{n-1}\sum_{n2=0}^{n-1}|[S(n1,n2,k) - S(n1+i,n2+i,k-1)]^{\wedge}2|$ ………… **(eq. 3)**

4. **Proposed Algorithm**

The proposed algorithm is very simple and efficient. In proposed algorithm, each step has two phases. The search area is separated into 4 quadrants as shown in figure 3(a). In first phase, the algorithm checks for three locations A, B and C. A is at the origin and B and C are at S = 4 locations in orthogonal directions away from A as defined in figure 3(b).

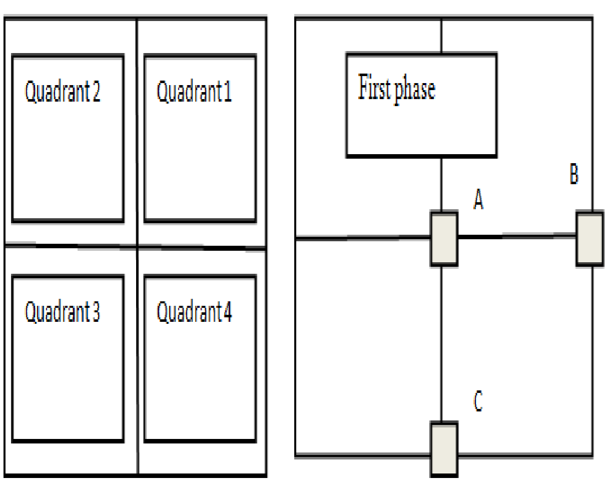

Fig. 3. (a) Partition of search area into quadrants **(b)** Search points in first phase of proposed algorithm [Source: own elaboration]

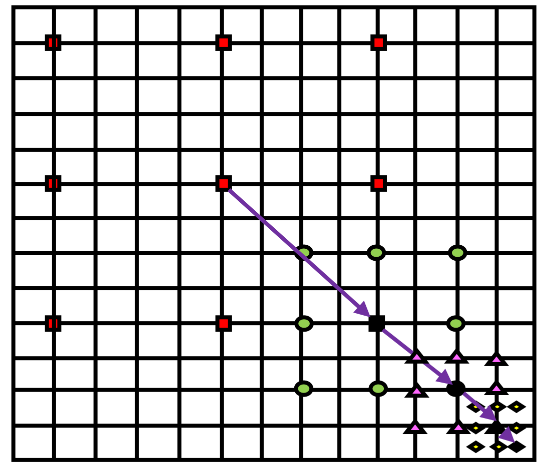

Fig 4.3: Proposed block matching procedure [Source: own elaboration]

Depending on the MAD calculated at 3 locations, the first phase chooses one of the 4 possible quadrants to search for second phase. The second phase finds the location with the lowest weight and sets it as the new origin. Fig. 4 defines the complete proposed algorithm process started with searching from centre location keeping s=4 and ends at step size reduced to 0.5.

4. Simulation Results

We realised a video sequence Xylophone.mpg with frames= 140. We consider the first 10 frames and value of search parameter p is taken as 9 and find out the following results in three different cases of macroblock.

- **Case1: When Macro Block size = 4, P=9, No. of frames= 10, Video sequence: Xylophone.mpg**

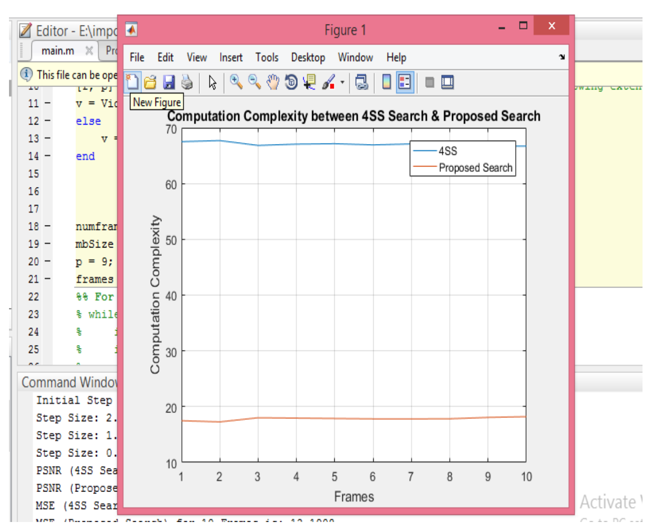

Fig. 4. Computational complexity between 4SS and proposed algorithm, mb=4

Figure 4 shows the graphs of computational complexity for both the existing 4 step search and proposed algorithm when the macroblock size is 4,number of frames=10 and search parameter is taken as 9. In graph, the red line shows the results for proposed algorithm and blue line shows the results for existing algorithm. The graphs shows that computational complexity of proposed algorithm is less than the existing algorithm which means less number of computations are required in case of new algorithm.

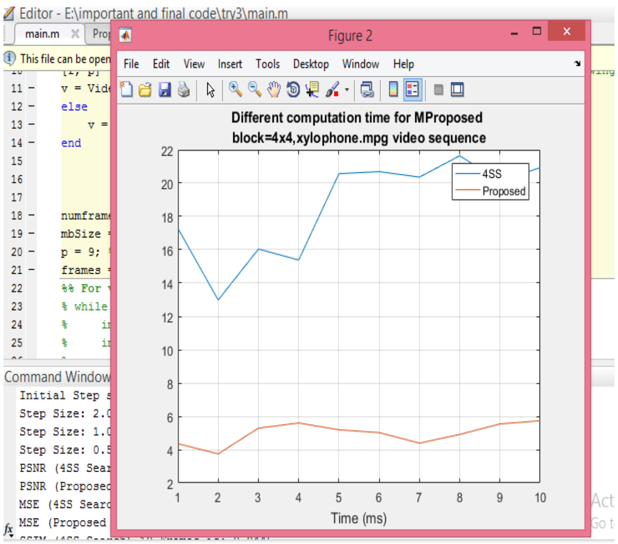

Fig. 5. Computation time required in 4SS and proposed algorithm, Mb=4

Figure 5 shows the graphical results of computational time required in both the existing 4 step search and proposed algorithm when macro block size=4, p=9 and number of frames=10. The graph curves and legend describe that less computation time is required in case of proposed algorithm than the existing one.

The similarities in structure of both the existing and proposed algorithm when macroblock size taken as 4 is described by the curves in figure 6. Their structures are almost similar however, for proposed algorithm it is somewhat small as it requires less number of search points.

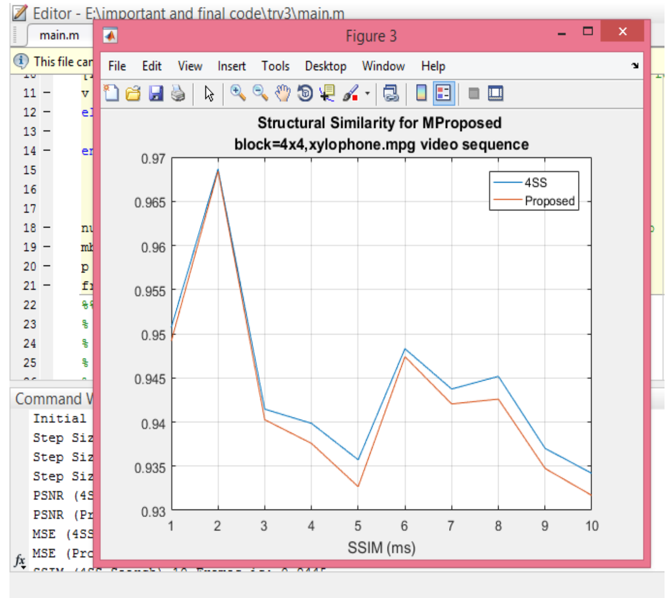

Fig. 6. Structural similarity between 4SS and existing algorithm, Mb=4

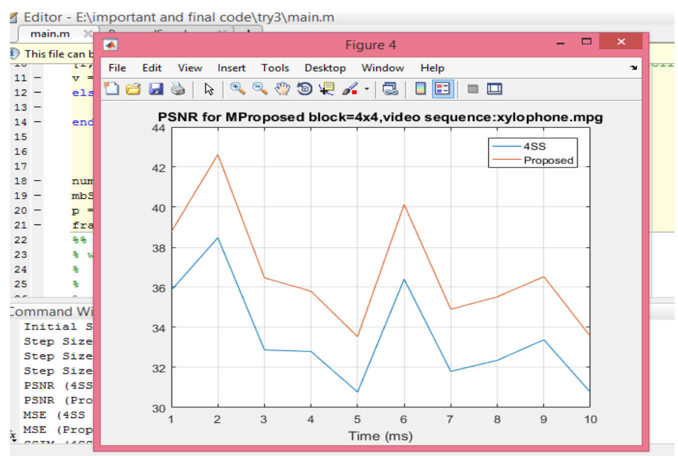

Fig. 7. PSNR value for 4SS and existing algorithm, Mb=4

Figure 7 defines the two curves: red and blue. The red curve shows graphical results for PSNR value in case of proposed algorithm and the blue curve defines the graphical results for PSNR value in case of existing 4 step search algorithm. The results state that proposed algorithm achieves high PSNR than existing algorithm when macroblock size is taken as 4 and search parameter value as 9 for 10 frames. The PSNR values, mean square error values for both algorithms compared when mb=4, p=9 and number of frames= 10 is shown in figure 8. Fig 8 also shows the step size taken at every step of search in proposed algorithm.

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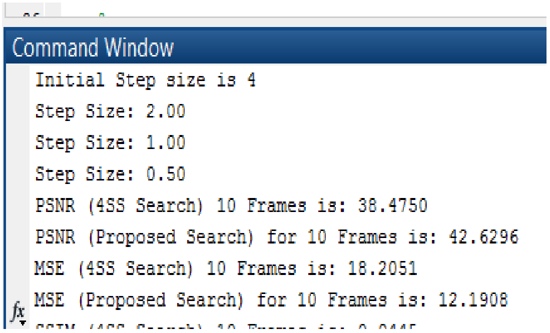

Fig. 8. Results for MSE and PSNR values, mb=4, p=9 and frames=10

- **Case 2: When Macro Block size = 8, P=7, No. of frames= 10, Video sequence: Xylophone.mpg.**

Figure 9 shows the graphs of computational complexity for both the existing 4 step search and proposed algorithm when the macroblock size is 8,number of frames=10 and search parameter is taken as 9. In graph, the red line shows the results for proposed algorithm and blue line shows the results for existing algorithm. The graphs shows that computational complexity of proposed algorithm is less than the existing algorithm which means less number of computations are required in case of new algorithm.

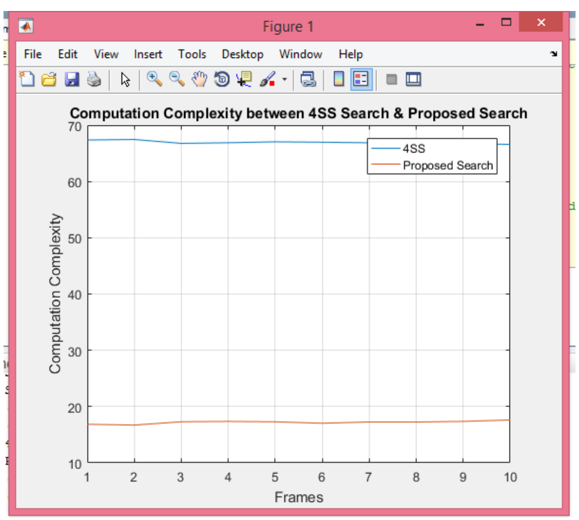

Fig. 9. Computational complexity between 4SS and proposed algorithm, mb=8

In figure 10, the graphical results of computational time required in both the existing 4 step search and proposed algorithm when macro block size=8, p=9 and number of frames=10 are shown. The graph curves and legend describe that less computation time is required in case of proposed algorithm than the existing one.

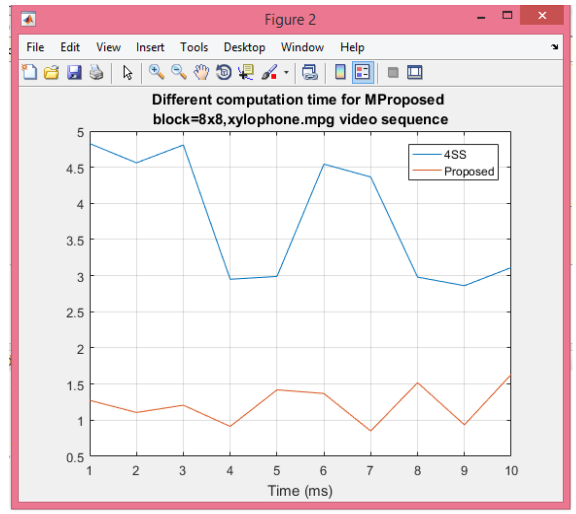

Fig. 10. Computation time required in 4SS and proposed algorithm, Mb=8

The similarities in structure of both the existing and proposed algorithm when macroblock size taken as 8 is described by the curves in figure 11. Their structures are almost similar however, for proposed algorithm it is somewhat small as it requires less number of search points.

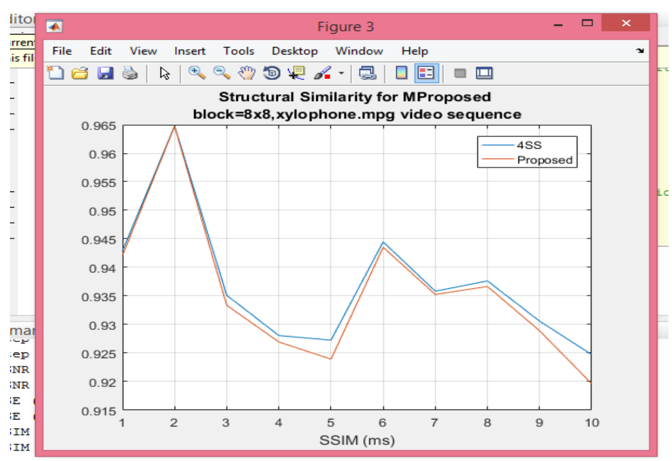

Fig 11: Structural similarity between 4SS and existing algorithm, Mb=8

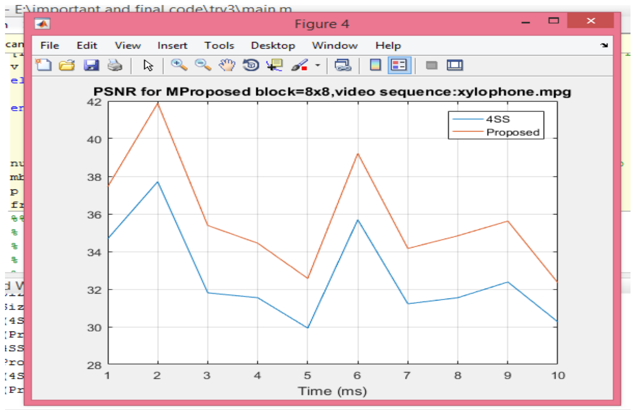

Fig 12: PSNR value for 4SS and existing algorithm, Mb=8

Figure 12 defines the two curves: red and blue. The red curve shows graphical results for PSNR value in case of proposed algorithm and the blue curve defines the graphical results for PSNR value in case of existing 4 step search algorithm. The results state that proposed algorithm achieves high PSNR than existing algorithm when macroblock size is taken as 8 and search parameter value as 9 for 10 frames. The PSNR values, mean square error values for both algorithms compared when mb=8, p=9 and number of frames= 10 is shown in figure 13. Fig 13 also shows the step size taken at every step of search in proposed algorithm.

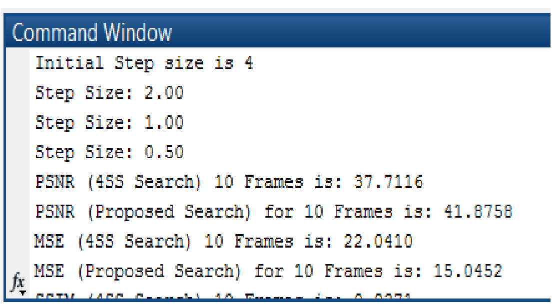

Fig 13: Results for MSE and PSNR values, mb=8, p=9 and frames=10

5. Comparison Table

Table 1: Comparison between existing four step search block matching algorithm and new proposed algorithm.

Video sequence: Xylophone.mpg					
Existing 4 step search algorithm					
Macro block size	**Search parameter**	**No. of frames**	**SSIM**	**MSE**	**PSNR**
4	9	10	0.944	18.205	38.4750
8	9	10	0.937	22.041	37.7116
New proposed algorithm					
Macro block size	**Search parameter**	**No. of frames**	**SSIM**	**MSE**	**PSNR**
4	9	10	0.968	12.190	42.6296
8	9	10	0.964	15.045	41.8758

Table 1 show that on using same video sequence, no. of frames, macroblock size and search parameter, the proposed algorithm gives better results than the existing algorithm. Like, when mb size is 4, p=9, no. of frames= 10, the existing algorithm achieves SSIM=0.9445, MSE= 18.2051 and PSNR= 38.4750 while proposed algorithm achieves SSIM=0.9684, MSE= 12.1908 and PSNR= 42.6296. This shows that when macro block size decreases, PSNR value increases and MSE decreases.

6. Conclusion

In this work, a new block matching algorithm has been proposed for motion estimation process in video compression that uses its neighbouring blocks for predicting the motion vector of candidate block in current frame. The existing 4ss search method is also developed and compared. The results of proposed algorithm are carried out on same video sequence for different macro block size and its performance is compared with the existing 4 step search. After the exhaustive study, it is observed that the proposed algorithm outperforms the existing search algorithms in terms of PSNR, computation complexity and time. The proposed method uses fewer numbers of blocks in search prediction thus, it requires less computational time.

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