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Biblographic Survey and Comparison Of Different Block Matching Algorithms

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Abstract: In communication world dealing with transfer and reception of digital video, practically, it is not possible to store the full moving image sequence because of the problems that encountered during its storage and transmission. Due to this reason, video compression is essentially required. The basic idea behind the compression technology is to remove the redundant data from the video file so that it can be transmitted over the network line using less number of bits and can be effectively stored on system disks. For video compression, motion estimation is the key element for finding the motion between successive frames and is achieved using block matching algorithm. In this paper, literature survey of block based motion estimation algorithms is carried out. It compares five basic block matching based motion estimation algorithms namely exhaustive search (ES), three step search (TSS), new three step search (NTSS), four step search (FSS) and diamond search (DS) algorithm on the basis of number of search location and their advantages and disadvantages. The algorithms concluded in this paper are used for various standards.

Keywords: Motion estimation, Block matching ES, TSS, NTSS, DS, FSS, HBS.

1. INTRODUCTION

Now days, modern world is dealing with the HD (high definition) or very high quality videos which requires large amount of storage space and transmission bandwidth. For efficient communication using such videos, it is highly required to compress the video file without affecting its visual quality. Compression is of two types: (1) Lossy compression, removes the unnecessary data from the file and the reconstructed file is not similar to that of original file (2) Lossless compression, which is noiseless and reconstructed file is similar to that of original file. Lossy compression is usually employed for compressing a digital video file. Video compression is important for transmission of digital data in multimedia communication. The basic concept behind the video compression is to save the required number of bits for encoding a digital video. The video compression process consists of video coding that removes the high co-relation between continuous frames for improving the coding efficiency. This can be achieved by motion estimation and compensation methods. In real world, encoders based on motion estimation are widely used for video compression techniques. Figure 1 describes the basic process of motion estimated and compensated video coding. In this process, using current frame and previous frame, displacement between them is calculated and motion vectors are stored using motion estimation process. Then motion compensation uses these motion vectors and selects the one which gives less error and add it to previous frame and generate motion compensated prediction. This prediction is then subtracted from current frame to generate difference signal. The difference signal is then encoded and decoded. The decoded displaced frame when added to previous frame, it gives exact replica of current frame and is used as future reference frame. The frame which is encoded using its previous frame is caller inter-frame and the frame which is encoded individually, is known as intra-frame.

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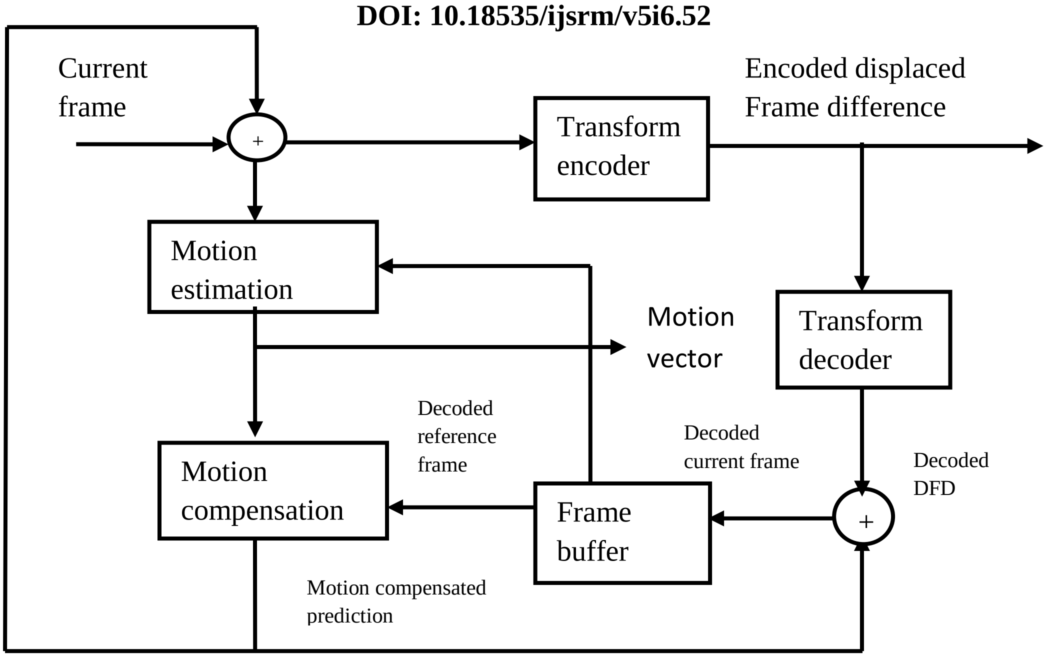

Fig 1: Motion estimated and compensated video coding

1.1 Motion estimation:

Motion estimation is a technique which analyses the previous and future frames to find out the blocks that are not changed and also find the motion vector for each of the block. Motion estimation can also be defined as an inter-coding technique, which is a mechanism for finding co-relation in between two successive frames when the order of occurrence is considered. One of the frames is reference frame and the other is current frame. Motion estimation is a method to find displacement of blocks which in turn explains the alteration of an image into another image, generally for adjoining frames in video sequence. The whole idea behind motion estimation is to reduce no. of bits by sending the encoded difference image that is highly compressed in comparison of sending full frame. Thus, high compression efficiency is achieved with the help of motion estimation process as it concludes 80% of computational part in video compression. There are two main approaches for achieving motion estimation shown in figure 2.

1. Pixel based ME: The pixel based motion estimation approach seeks to determine motion vectors for every pixel in the image.
2. Block-based ME: block based motion estimation is widely used method for video coding. In this method, the candidates frame is divided into matrix of non-overlapping blocks and a single motion vector is computed for the entire block.

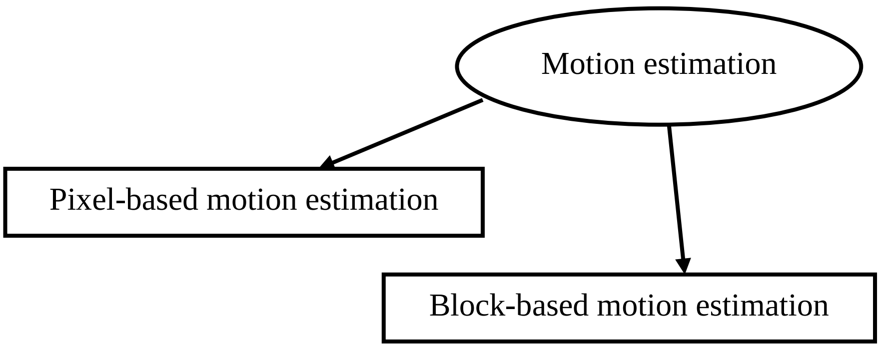

Fig 2: Approaches for motion estimation process [Source: own elaboration]

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1.2 Block matching algorithm:

Block matching algorithm is the simplest algorithm used for motion estimation. In this algorithm, each of the frames is divided into group of non- overlapping macro blocks, which consist of both the chrominance and luminance block. The chrominance represent the colour and the luminance represents the intensity/brightness. For coding efficiency, the motion estimation process is performed on the luminance block. Each of the luminance blocks in present frame is matched against the candidate block lies in the search area on reference frame. The candidate blocks are simply the displaced version of original block. The best matched candidate block is observed and its motion vector is determined in the reference frame which stipulates movement of the macro block from one position to another in previous frame. Figure 3 below illustrates block matching process.

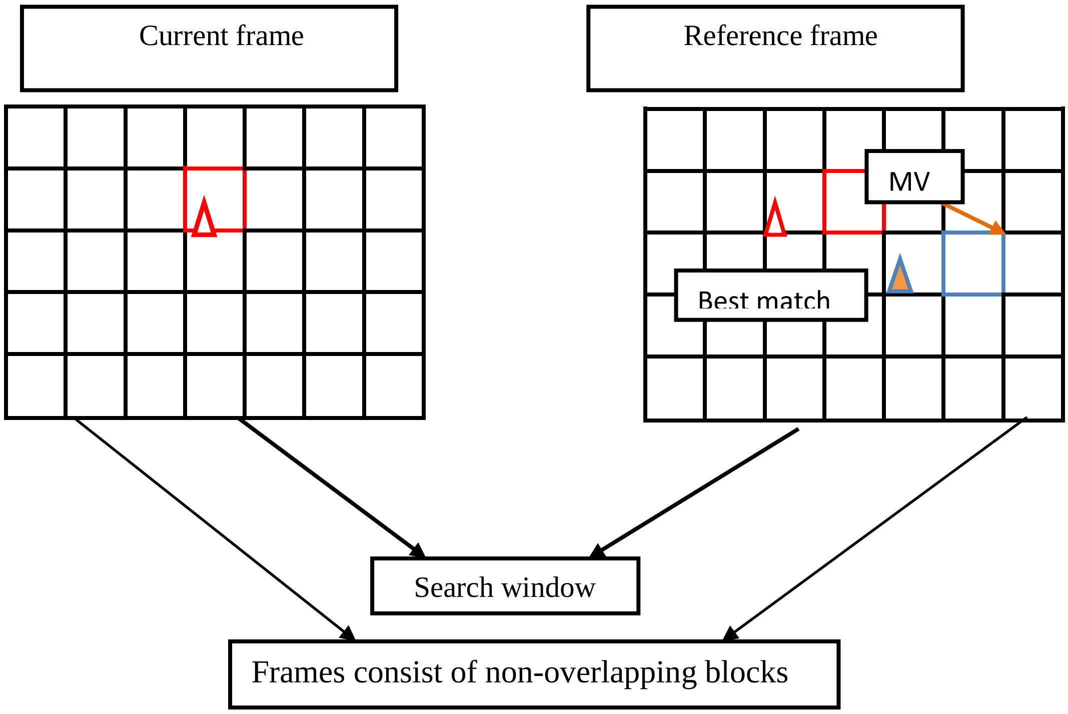

Fig 3: Block matching process

This paper is organised in way as follows: section II describes the surveyed literature of different block based matching algorithms. In section III, the reviewed algorithms are compared and in section IV, conclusion is made.

2. CONCISE LITERATURE REVIEW

Digital video coding has gradually increased its importance since the 90s when MPEG-1 first emerged. It had large impact on video delivery, storage and presentation when compared to analogue video. This eliminates the need of high band width as required in analogue video delivery. With this important characteristic, many application areas have emerged. For example, set top box video playback using compact disk, video conferencing over IP networks, P2P video delivery, mobile TV broadcasting etc.

A major problem in a video is the high requirement of bandwidth. A typical system needs to send dozens of individual frames over second to create an illusion of a moving picture. For this reason, several standards were introduced to create an illusion of a moving picture. For this reason, several standards for compression of the video have been developed. Each individual frame is coded so that redundancy is removed. Furthermore, between consecutive frames, a great deal of redundancy is removed with a motion compensation system. Representing video material in a digital form requires a large number of bits. The volume of data generated by digitizing a video signal is too large for most storage and transmission systems (despite the continual increase in storage capacity and transmission 'bandwidth'). This means the compression is essential for most digital video applications. Various contributions have been done by different researchers in the field of video compression.

Table1: Review of block matching algorithms [Source: own elaboration]

Domain	Year	Author
Exhaustive Search	2004	Aroha Barjatya
	2011	D.V. Manjunatha and Sainarayanan
	2011	S. Immanuel Alex Pandian, G. Josemin Bala, and Becky Alma George
	2011	Hussain Ahmed Choudhury and Monjul Saikia
	2012	Chittaranjan Pradhan and Dipannita Adak
	2012	Darshna D. Jagiwala and S. N. Shah
	2012	M. R. Khammar
	2013	Razali Yaakob, Alihossein Aryanfar, Alfian Abdul Halin and Nasir Sulaiman
	2013	Bhavina Patel, R.V.Kshirsagar, and Vilas Nitnaware
	2014	L.C.Manikandan and R. K. Selvakumar
	2014	Sudhakar and Letitia
	2014	S Sangeeta Mishra, Chittaranjan Pradhan, and Alka Singh
	2015	Nasir Mahmud Khokhar and Wail Harasani
	2016	Tejas B. N., Bharathi S H, and Vidya Sagar K. N
Three Step Search	1998	Deepak Turaga, Mohamed Alkanhal
	2004	Aroha Barjatya
	2011	Ionut Pirnog, Cristian Anghel, Andrei Alexandru Enescu, and Constantin Paleologu
	2011	D.V. Manjunatha and Sainarayanan
	2011	S. Immanuel Alex Pandian, G. Josemin Bala, and Becky Alma George
	2011	Hussain Ahmed Choudhury and Monjul Saikia
	2012	Chittaranjan Pradhan and Dipannita Adak
	2012	Namrata Verma, Tejeshwari Sahu and Pallavi Sahu
	2012	Darshna D. Jagiwala and S. N. Shah
	2013	Ms. Bhavina Patel, R.V.Kshirsagar, and Vilas Nitnaware
	2014	L.C.Manikandan and R. K. Selvakumar
	2014	Sudhakar and Letitia
	2014	S Sangeeta Mishra, Chittaranjan Pradhan, and Alka Singh
	2015	S. M. Kulkarni, D. S. Bormane, and S. L. Nalbalwar
	2016	Tejas B. N., Bharathi S H, and Vidya Sagar K. N
	2017	Shailesh D. Kamble, Nileshsingh V. Thakur, and Preeti R. Bajaj
New Three Step Search	1994	Renxiang Li, Bing Zeng, and Ming L. Liou
	2004	Aroha Barjatya
	2011	Ionut Pirnog, Cristian Anghel, Andrei Alexandru Enescu, and Constantin Paleologu
	2011	D.V. Manjunatha and Sainarayanan
	2011	S. Immanuel Alex Pandian, G. Josemin Bala, and Becky Alma George
	2011	Hussain Ahmed Choudhury and Monjul Saikia
	2011	Chittaranjan Pradhan and Dipannita Adak
	2013	Razali Yaakob, Alihossein Aryanfar, Alfian Abdul Halin and Nasir Sulaiman

	2013	Ms. Bhavina Patel, R.V.Kshirsagar, and Vilas Nitnaware
	2014	L.C.Manikandan and R. K. Selvakumar
New Three Step Search	2014	Sudhakar and Letitia
	2014	S Sangeeta Mishra, Chittaranjan Pradhan, and Alka Singh
	2017	Shailesh D. Kamble, Nileshsingh V. Thakur, and Preeti R. Bajaj
Four Step Search	1996	Lai-Man Po and Wing-Chung Ma
	1998	Deepak Turaga, Mohamed Alkanhal
	2004	Aroha Barjatya
	2011	Ionut Pirnog, Cristian Anghel
	2011	S. Immanuel Alex Pandian, G. Josemin Bala, and Becky Alma George
	2011	Hussain Ahmed Choudhury and Monjul Saikia
	2012	Chittaranjan Pradhan and Dipannita Adak
	2012	Darshna D. Jagiwala and Prof. Mrs. S. N. Shah
	2012	M. R. Khammar
	2013	Ms. Bhavina Patel, R.V.Kshirsagar, and Vilas Nitnaware
	2014	L.C.Manikandan and R. K. Selvakumar
	2014	Sudhakar and Letitia
	2014	S Sangeeta Mishra, Chittaranjan Pradhan, and Alka Singh
	2015	Nasir Mahmud Khokhar and Wail Harasani
Diamond Search	2000	Shan Zhu and Kai-Kuang Ma
	2004	Aroha Barjatya
	2011	D.V. Manjunatha and Sainarayanan
	2011	S. Immanuel Alex Pandian, G. Josemin Bala, and Becky Alma George
	2011	Chittaranjan Pradhan and Dipannita Adak
	2012	Darshna D. Jagiwala and S. N. Shah
	2012	M. R. Khamma
	2013	Ms. Bhavina Patel, R.V.Kshirsagar, and Vilas Nitnaware
	2013	Chetan S Dhamande and Prashant A. Bhalge
	2014	L.C.Manikandan and R. K. Selvakumar
	2014	Sudhakar and Letitia
	2014	S Sangeeta Mishra, Chittaranjan Pradhan, and Alka Singh
	2015	Nasir Mahmud Khokhar and Wail Harasani
	2016	Muhammad Muzammil, Zeshan Aslam Khan, M. Obaid Ullah, and Imdad Ali
	2016	Tejas B. N., Bharathi S H, and Vidya Sagar K. N
Adaptive Rood Pattern Search	1999	Jie-Bin Xu, Lai-Man Po, and Chok-Kwan Cheung
	2004	Aroha Barjatya
	2011	Ionu Pirnog, Cristian Anghel, Andrei Alexandru Enescu, and Constantin Paleologu
	2011	Hussain Ahmed Choudhury and Monjul Saikia
	2012	Darshna D. Jagiwala and S. N. ShahE3
	2013	Razali Yaakob, Alihossein Aryanfar, Alfian Abdul Halin and Nasir Sulaiman
	2013	Ms. Bhavina Patel, R.V.Kshirsagar, and Vilas Nitnaware
	2013	Chetan S Dhamande and Prashant A. Bhalge
	2014	Sudhakar and Letitia
	2016	Muhammad Muzammil, Zeshan Aslam Khan, M. Obaid Ullah, and Imdad Ali
	2016	Tejas B. N., Bharathi S H, and Vidya Sagar K. N
Hexagonal Based Search	2002	Ce Zhu, Xiao Lin and Lap-Pui Chau
	2011	S. Immanuel Alex Pandian, G. Josemin Bala, and Becky Alma George
	2011	Chittaranjan Pradhan and Dipannita Adak
	2013	Ms. Bhavina Patel, R.V.Kshirsagar, and Vilas Nitnaware
	2013	Chetan S Dhamande and Prashant A. Bhalge
	2014	S Sangeeta Mishra, Chittaranjan Pradhan, and Alka Singh

	2015	Nasir Mahmud Khokhar and Wail Harasani
	2016	Muhammad Muzammil, Zeshan Aslam Khan, M. Obaid Ullah, and Imdad Ali
Simple and Efficient Search	1997	Jianhua Lu and Ming L. Liou
	2004	Aroha Barjatya
	2008	M. Ezhilarasan and P. Thambidurai
	2013	Razali Yaakob, Alihossein Aryanfar, Alfian Abdul Halin and Nasir Sulaiman
	2014	Sudhakar and Letitia
Cross Search	1990	M. Ghanbari
	1998	Deepak Turaga, and Mohamed Alkanhal
	2011	Hussain Ahmed Choudhury and Monjul Saikia
	2014	S Sangeeta Mishra, Chittaranjan Pradhan, and Alka Singh
Orthogonal Search	1987	A. Puri, H.-M. Hang, and D. L. Schilling
	1998	Deepak Turaga, and Mohamed Alkanhal
	2011	Ionut Pirnog, Cristian Anghel, Andrei Alexandru Enescu, and Constantin Paleologu
Cross Diamond Search	2003	Chi-Wai Lam , Lai-Man Po and Chun Ho Cheung
	2008	M. Ezhilarasan and P. Thambidurai
	2014	L.C.Manikandan and R. K. Selvakumar
Novel Hexagon Based Search	2001	Ce Zhu, Xiao Lin, Lap-Pui Chau,Keng-Pang Lim, Hock-Ann Ang, and Choo-Yin Ong
	2008	M. Ezhilarasan and P. Thambidurai
	2015	Nasir Mahmud Khokhar and Wail Harasani
Two Dimensional Logarithmic Search	1998	Deepak Turaga, and Mohamed Alkanhal,
	2014	S Sangeeta Mishra, Chittaranjan Pradhan, and Alka Singh

III. BLOCK MATCHING ALGORITHMS:

The goal of block-based motion estimation is to model the input current frame more accurately by using the future or previous frame while maintaining the computational complexity quite acceptable. Block based matching algorithms are used for finding the motion vectors in motion estimation process. Different algorithms generate the different motion vectors. Full search algorithm provides the good result among all the proposed algorithms. Other algorithms provide near to optimal result with respect to full search, but at low computational cost. In this paper, we will study different types of block matching algorithms, which are utilised highly in present coding standards.

- **Full Search (FS) algorithm/Exhaustive search algorithm**

Full Search algorithm is the simplest method for motion estimation. This algorithm calculates the cost function at every possible location in the search window. It compares the current block in present frame with all candidate frame lies in the search area of the reference frame. The point, at which block distortion measure (BDM) is minimum, is calculated by MSE formula.

- **Three Step Search algorithm**

This algorithm was introduced by Koga et al. in 1981[S. Immanuel Alex Pandian et al., 2011]. It is the earliest fast block matching algorithm. The 3 step search algorithm has been designed to reduce the number of search blocks within the search window location. This algorithm uses 3×3 grid search patterns at every step. When minimum value of MAD is found, it is used as motion vector [Sudhakar et al., 2014]. It is another form of two-dimensional logarithmic search providing the better performance. It became popular for low bit rate video compression applications such as video conferencing, due to its simplicity [S Sangeeta Mishra et al., 2014]. This algorithm is robust and it provides near optimal performance. The algorithm searches for best motion vector in finite search pattern. This algorithm computes the cost for 25 macro blocks [D. V. Manjunatha et al., 2011].

- **New Three Step Search algorithm (NTSS)**

NTSS is one of the widely accepted fast algorithms and earlier is used for implementing standards like MPEG-1 and H.261 [M. S. Bhavina Patel et al., 2013]. This algorithm was developed in 1994. It is the modified version of TSS. It also takes 3 steps but it reduces the number of computations required to find the best matched block [Hussain Ahmed Choudhury et al., 2011]. This algorithm provides better motion estimation with low amplitude. NTSS provides centre-biased searching scheme i.e. it takes additional 8 steps in centre as compared to that of TSS [S Sangeeta Mishra et al., 2014]. It also provides the provision for halfway stop to reduce the computational cost [Aroha Barjatya, 2004]

- **Four Step Search algorithm**

The four step search algorithm also provides centre biased searching scheme and halfway provision to stop in order to reduce the computational cost. This algorithm was developed in 1996. In 4SS, we uses 5×5 window instead of 9×9 window in case of TSS [S Sangeeta Mishra et al., 2014]. This algorithm reduces search points and is more robust than TSS [S Immanuel Alex Pandian et al., 2011].

- **Diamond Search algorithm (DS) :**

DS is famous algorithm and it was developed in 2000. This algorithm is widely accepted for MPEG-4 compression standard [Nasir Mahmud Khokhar et al., 2015]. Diamond search algorithm is similar to four step search The only difference is that the search pattern we use is of diamond shape instead of square [M. R. Khammar, 2012; Sudhakar et al., 2014]. DS uses two types of fixed diamond patterns to compute SAD

1. Large Diamond Search Pattern (LDSP): It consists of 9 checking points out of which 8 point surround the centre point to form a diamond shape.
2. Small Diamond Search Pattern (SDSP): It consists of 5 checking points to form smaller shape of diamond [Chetan S Dhamande et al., 2013]

IV. COMPARISON

Here, depending upon the above studied literature, the five algorithms namely exhaustive search, three step search, new three step search, four step search and diamond search are compared on the basis of number of locations at which the algorithm computes the cost and their advantages and disadvantages.

Table 2: Difference between algorithms on the basis of search points [Source: own elaboration]

Algorithm	Year	Number of Search points
Exhaustive search	Benchmark	225
3 step search	1981	25
New three step search	1994	Minimum: 17 Maximum: 33
Four step search	1996	Minimum: 17 Maximum: 27
Diamond search (4 step)	2000	Minimum: 13 Maximum: 23

Table 3: Difference between algorithms on the basis of advantages and disadvantages [Source: own elaboration]

Algorithm	Advantages	Disadvantages
Exhaustive search	1. Simplest method	1. Computationally expensive

	2. Provides highest PSNR among all algorithms. 3. Gives good accuracy while finding the best match.	2. Computationally complex when search window is large. 3. Unsuitable for real-time encoding
Three step search	1. Earliest fast block matching algorithm. 2. Robust and provides near optimal performance. 3. Uses finite search pattern	It is not efficient for identifying small motions. Designed for fixed block size.
New three step search	1. It reduces the number of computations required to find the best matched block. 2. Provides better motion estimation with low amplitude. 3. Provides centre-biased searching scheme and halfway stop provision to reduce the computational cost	It is not efficient for identifying small motions.
Four step search	1. Provides centre-biased searching scheme and halfway stop provision to reduce the computational cost. 2. Requires less number of search points than that of three step search. 3. Efficient find small motions.	Checkpoints lead to wrong motion vector if moving image sequence is very fast.
Diamond search	1. It provides PSNR closer to that of exhaustive search using less number of search points 2. Computationally less complex and finds the accurate global minimum.	1. This algorithm does not exploit motion correlation between the successive frames. 2. There is no limit on number of steps that the algorithm can take.

IV. CONCLUSION

After the review process, it is concluded that the diamond search algorithm is the best matching algorithm as it provides PSNR similar to that of Exhaustive search algorithms with reduced number of search points and without any degradation in image quality. Diamond search algorithm is computationally less complex as compared to that of Exhaustive, three step, new three step and four step search algorithms.

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