International Journal on Recent and Innovation Trends in Computing and Communication ISSN: 2321-8169
Volume: 5 Issue: 2 26 – 32

A Review Paper On Motion Estimation Techniques

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Abstract— Motion estimation (ME) is a primary action for video compression. Actually, it leads to heavily to the compression efficiency by eliminating temporal redundancies. This approach is one among the critical part in a video encoder and can take itself greater than half of the coding complexity or computational coding time. Several fast ME algorithms were proposed as well as realized. In this paper, we offers a brief review on various motion estimation techniques mainly block matching motion estimation techniques. The paper additionally presents a very brief introduction to the whole flow of video motion vector calculation.

Keywords—*Diamond Search, Motion vector, Exhustive Search Motion Estimation,4 Step Search,Three Step Search.*

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I. INTRODUCTION

Motion estimation is the process of determining motion vectors that describe the transformation from one 2D image to another; usually from adjacent frames in a video sequence. It is an ill-posed problem as the motion is in three dimensions but the images are a projection of the 3D scene onto a 2D plane. The motion vectors may relate to the whole image (global motion estimation) or specific parts, such as rectangular blocks, arbitrary shaped patches or even per pixel. The motion vectors may be represented by a translational model or many other models that can approximate the motion of a real video camera, such as rotation and translation in all three dimensions and zoom. The combination of images creates the video the video is operated on the theory of motion estimation and compensation. The two methods of motion estimation block matching and Pel-reccursive algorithms. In PRA method to find out the motion estimation gradient methods are applied in individual Pels. Block Matching algorithms is based on rectangular blocks and for each block gives one motion vector Block matching Algorithms accepts that All Pels inside the blocks has same motion because of simplicity and regularity BMA are also used for hardware realization[5][22][23].

Motion estimation is the process which has seen the highest activity and research interest in the past two decades. This paper evaluates the fundamental block matching algorithms from the mid-1980s up to the recent fast block matching algorithms. It also presents a literature review of few papers. The algorithms that have been evaluated are Exhaustive Search (ES), Three Step Search (TSS), New Three Step Search (NTSS), Simple and Efficient TSS (SES), Four Step Search (4SS), Diamond Search (DS), and Adaptive Rood Pattern Search (ARPS). Section II explains block matching in general and then the above algorithms in detail. Section III compares them and presents some simulation results. Section IV is a literature survey of the more recent algorithms, followed by summary and references [5][23].

II. BLOCK DIAGRAM OF MOTION ESTIMATION

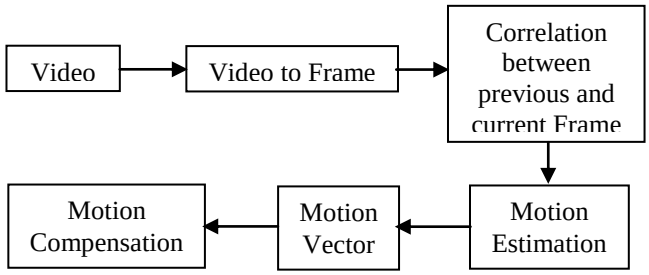

Fig 1 Motion Estimation Process flow

III. PROCEDURE FOR MOTION ESTIMATION

FOR MOTION ESTIMATION FOLLOWING STEPS ARE USED:-

1) Convert the video into the frames.
2) The first frame becomes reference frame.
3) Now the 2nd frame becomes the target frame and the first frame act as a reference frame for the 2nd frame.
4) Now it finds correlation between current frame and reference frame.
5) If there is correlation then it finds the motion estimation.
6) After Motion Vector calculation Motion is compensated.

A. Abbreviations and Acronyms

BMA - Block Matching Algorithms
DS - Diamond Search
ES - Exhaustive Search
FSS - Four Step Search
MB - Macro Block
NTSS - New Three Step Search
PSNR - Peak Signal to Noise Ratio

ARPS - Adaptive Rood Pattern Search

B. Equations

In All images following performance parameters are used:-

1. Mean Square Error(MSE)

$$MSE=\frac{1}{Q\times Q}\sum_{U=1}^{Q}\sum_{V=1}^{V}[I_o\ (U,V)-I_c\ (U,V)]^2 \quad (1)$$

Where

$I_0(U,V)$= Original Image

$I_c(U,V)$= Compressed Image

Q= Dimensions of the Image

In the Image Error will be low when the value of MSE is Low.

2. Mean Absolute Difference (MAD)

$$MAD=\frac{1}{Q\times Q}\sum_{U=1}^{Q}\sum_{V=1}^{V}[I_o\ (U,V)-I_c\ (U,V)]^2 \ (2)$$

3. Peak Signal to Noise Ratio (PSNR)

$$PSNR = 10\log_{10}\left(\frac{255\times255}{MSE}\right) \quad (3)$$

From equation (3) we observed that Peak Signal to Noise Ratio (PSNR) is inversely proportional to the Mean Square Error (MSE) i.e. higher value of PSNR can be achieved by decreasing the value of MSE[1][5].

IV. Motion Estimation Techniques

Motion estimation is the most expensive and time consuming process for the entire video compression technique. The methods for finding motion vectors can be categorised into pixel based methods ("direct") and feature based methods ("indirect").

Direct Method includes Block matching algorithm, Phase correlation or frequency domain methods, Pixel recursive algorithms, Optical flow. The Block matching algorithm has following types of methods:

A. Exhustive Search

This algorithm calculates the cost function at each possible location in the search window. This leads to the best possible match of the macro-block in the reference frame with a block to another frame. The resulting motion compensated image has highest peak signal-to-noise ratio as compared to any other block matching algorithm. However this is the most computationally extensive block matching algorithm among all. A larger search window requires greater number of computations [5][23].

B. Three Step Search

This algorithm is based on a coarse-to-fine approach with logarithmic decreasing in step size as shown. The initial step size is half of the maximum motion displacement d. For each step, nine checking points are matched and the minimum BDM point of that step is chosen as the starting center of the next step. For d = 7, the number of checking points required is (9 + 8 + 8) =25. For larger search window (i.e. larger d), 3SS can be easily extended to n-steps using the same searching strategy with the number of checking points required equals to [1 + 8 log2(d + 1)][5][1].

C. Two Dimentional Logirithmic Search

TDLS is closely related to TSS however it is more accurate for estimating motion vectors for a large search window size. The algorithm can be Start with search location at the centre. Select an initial step size say, S = 8. Search for 4 locations at a distance of S from centre on the X and Y axes. Find the location of point with least cost function If a point other than centre is the best matching point, Select this point as the new centre Repeat steps 2 to 3. If the best matching point is at the centre, set S = S/2 If S = 1, all 8 locations around the centre at a distance S are searched. Set the motion vector as the point with least cost function[5][22].

D. New Three Step Search

TSS uses a uniformly allocated checking pattern and is prone to miss small motions. NTSS is an improvement over TSS as it provides a centre biased search scheme and has provisions to stop half way to reduce the computational cost. It was one of the first widely accepted fast algorithms and frequently used for implementing earlier standards like MPEG1 and H.261.[5][23].

E. Simple and Efficient Search

The idea behind TSS is that the error surface due to motion in every macro block is unmoral. An unmoral surface is a bowl shaped surface such that the weights generated by the cost function increase monotonically from the global minimum. However a unimoral surface cannot have two minimums in opposite directions and hence the 8 point fixed pattern search of TSS can be further modified to incorporate this and save computations. SES is the extension of TSS that incorporates this assumption [23].

F. Four Step Search

Four step searches is an improvement over TSS in terms of lower computational cost and better peak signal-to-noise ratio. Similar to NTSS, FSS also employs centre biased searching and has a halfway stop provision [5][1].

G. Diamond Search

Diamond Search (DS) algorithm uses a diamond search point pattern and the algorithm run exactly the same as 4SS. However, there is no limit on the number of steps that the algorithm can take.

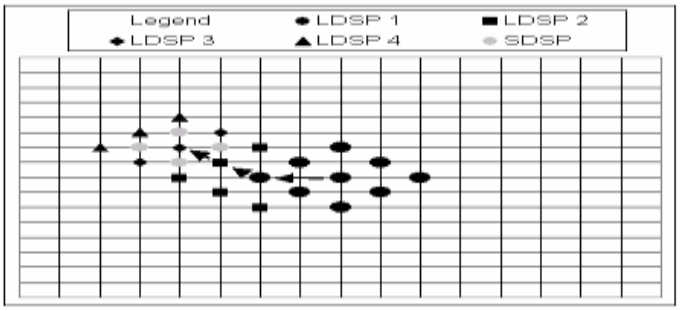

Fig. 2 Diamond Search Pattern

Fig. 2 Diamond Search procedure this figure shows the large diamond search pattern and the small diamond search pattern. It also shows an example path to motion vector in five search steps four times of LDSP and one time of SDSP. Two different types of fixed patterns are used for search, Large Diamond Search Pattern (LDSP) and Small Diamond Search Pattern (SDSP) [5][21][22][23].

H. Adaptive Rood Pattern Search

ARPS is the fast matching algorithm as compared to other existing algorithm. Adaptive Motion Estimation Method (ARPS) algorithm makes use of the fact that the general motion in a frame is usually coherent, i.e. if the macro blocks around the current macro block moved in a particular direction then there is a high probability that the current macro block will also have a similar motion vector. This algorithm uses the Motion vector of the macro block to its immediate left to predict its own motion vector. Searching in the ARPS algorithm is based on two stages: initial search & Refined local search. Initial search is applied to the beginning of each macro block then refined local search. By using that search we can avoid unnecessary searching in the macro block. In the initial search stage based on the available motion vector of the neighboring motion blocks ARPS size is determined dynamically for each micro blocks. Adaptive search pattern is used in the initial search stage and unit size pattern are used in the refined local search until the final motion vector is found [1][5].

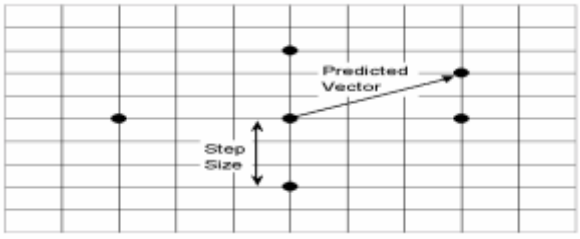

Fig. 3 ARPS search Pattern

In the above example fig.3 the predicted motion vector points to (4,-5). 4 and -5 are the X and Y-coordinate of the predicted motion vector .The value of step size S=max (|M|, |N|), hence S=5.

Phase correlation is an approach to estimate the relative translative offset between two similar images (digital image correlation) or other data sets. It is commonly used in image registration and relies on a frequency-domain representation of the data, usually calculated by fast Fourier transforms. The term is applied particularly to a subset of cross-correlation techniques that isolate the phase information from the Fourier-space representation of the cross-correlogram. In electronics, control systems engineering, and statistics, the frequency domain refers to the analysis of mathematical functions or signals with respect to frequency, rather than time.[1] Put simply, a time-domain graph shows how a signal changes over time, whereas a frequency-domain graph shows how much of the signal lies within each given frequency band over a range of frequencies. A frequency-domain representation can also include information on the phase shift that must be applied to each sinusoid in order to be able to recombine the frequency components to recover the original time signal [6][12][20].

The recursive X-Y cut is a top-down page segmentation technique that decomposes a document image recursively into a set of rectangular blocks. The algorithm works by projecting the document bitmap (i.e. summing up all the pixels in a line) to the sides of the document page. By this method, a white space density graph is produced, with peaks for vertical or horizontal whitespace lines. These peaks define the cuts of the document and are used top-down to segment the document into smaller pieces [4][9].

Optical flow or optic flow is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer and a scene. The concept of optical flow was introduced by the American psychologist James J. Gibson in the 1940s to describe the visual stimulus provided to animals moving through the world. Gibson stressed the importance of optic flow for affordance perception, the ability to discern possibilities for action within the environment. Followers of Gibson and his ecological approach to psychology have further demonstrated the role of the optical flow stimulus for the perception of movement by the observer in the world; perception of the shape, distance and movement of objects in the world; and the control of locomotion [14].

Indirect methods use features, such as corner detection, and match corresponding features between frames, usually with a statistical function applied over a local or global area. The purpose of the statistical function is to remove matches that do not correspond to the actual motion. Statistical functions that have been successfully used include RANSAC [7][8][13].

V. COMPARATIVE ANALYSIS OF DIFFERENT MOTION ESTIMATION TECHNIQUE

Here the comparative analysis of different Motion estimation technique are summarised with the help of there application there advantages and disadvantages. So from this analysis we find that the block matching algorithms gives better computational efficiency especially Diamond search algorithm, ARPS algorithm. There PSNR values are high for fast motion sequences and in enhancement in search pattern in the Diamond search gives better results like HDS,MDS,ODS,FDS,SDS.

As are shown by description in previous page, 4SS, DS and ARPS come pretty close to the search points of FS. While the FS takes on an average searches per macro block, DS and 4SS drop that number by more then an order of magnitude. ARPS further drops by a factor of 2 compared to DS. Although PSNR performance of 4SS, DS, and ARPS is relatively the same.

Table I: Comparison of various motion estimation techniques

Year	Algorithm	Application	Advantages	Disadvantages
Benchmark	Exhaustive search (ES)	To obtain best picture quality and highest PSNR.	Best picture quality and highest PSNR	High computational time (slow).
1981	Three Step Search (TSS)	recommended in MPEG2	Optimum performance ,less complexity, recommended in MPEG2	Allocation of the check point at the first stage leaves several gaps which becomes inefficient small motion estimation.
1994	New Three Step Search (NTSS)	More efficient then TSS for small motion	More efficient then TSS for small motion	It is designed especially for fixed block size. A slightly drop in MAE & PSNR and more complexity in step logic when compare with TSS due to many block patterns are taken in consideration under different MD point.
1996	Four Step Search (4SS)	Initial small step size so more efficient for small MV	Initial small step size so more efficient for small MV	Allocation of the check point may lead to wrong direction of MV if there are using to compensate over very fast movement sequence and more complexity in step logic due to many block patterns are taken in consideration under different MD point like NTSS.
2000	Diamond Search (DS)	adopted and incorporated in MPEG-4 verification model	More search points as compare to other methods.	1) it does not exploit the motion correlation between adjacent frames or blocks; 2) it exhaustively evaluates all eight neighbouring points around the diamond centre; 3) it cannot stop the search early even when the SAD at a particular checking point is already small enough.
2010	Hexagon-Diamond Search (HDS)	video conferencing over wireless networks	Improve speed rate as compare to other methods.	For vigorous motion content HDS provides slight degradation in video quality around 9.9%, when compared to NTSS algorithm and FS algorithm.
2011	Modified Diamond Search (MDS)	video sequences with simple and slow motion vectors	Improve speed rate as compare to other methods.	It may also be trapped in local minima.
2012	Fast Diamond Search (FDS)	implemented in the reference software of the standard H.264	Improve speed rate as compare to other methods.	Degradation in the coding efficiency compared to the conventional FS and DS.
2014	Orthogonal-Diamond Search (ODS)	Video sequences with slow motion vectors.	Improve speed rate as compare to other methods.	Slight degradation in quality for moderate and fast motion sequences compared to the small motion sequence.
2015	Star -Diamond Search (SDS)	implemented in the reference software of the standard H.264	Improve speed rate and complexity to other methods.	Achieve good efficiency in quality of fast motion sequences compared to the small motion sequence, less computational time and less complex to other methods.

So from the above comparison we can say that the improvement of search parameters on the Diamond Search algorithm we can increase the performance in terms of computational time and PSNR and reduce system complexity.

VI. COMPREHENSIVE REVIEW OF RESEARCHES

The extensive literature collected associated with the video processing system using different motion estimation techniques is critically reviewed and given during this section.

S Zhu, KK Ma(1998) [1] Proposed a new star search algorithm for fast block matching motion estimation. In this paper SS algorithm improved the performance of the DS algorithm and constantly achieved better performance with quite low computational load.

X. Q. Gao, et al(2000) [2] presented A Multilevel Successive Elimination Algorithm for Block Matching Motion Estimation In this paper The computation costs of the FS algorithm and other fast search algorithms can be saved significantly average block matching time reduced.

S Zhu, KK Ma (2000) [3] In this paper which is based on A New Diamond Search Algorithm for Fast Block-Matching Motion Estimation. With the help of DS algorithm Computational coast reduced 22% as compared to other BMA.

V. Argyriou and T. Vlachos(2003) [4] Presented a paper on sub-pixel motion estimation using gradient cross correlation. They have analysed that One of the most attractive features of the gradient cross correlation scheme is that it gives a high degree of computational efficiency and can be implemented by fast transformation algorithms in the frequency domain PSNR increased.

ArohBarjatya (2004) [5] In this paper which is based on Block Matching Algorithms. In this pape PSNR performance of 4SS, DS, and ARPS is relatively the same, ARPS takes a factor of 2 less computations and hence is the best of the fast block matching algorithms studied For Motion Estimation.

IsmailiAlaoui El Mehdi ,Ibn El Haj Elhassane (2007)[6] presented a paper which is based on Estimation of motion fields from noisy image sequences using Generalized-Cross-Correlation Method.. They analysed that the effects of noise may be enhanced, thereby corrupting the estimate of the motion vector. This is avoided by using the WIENER estimator and PSNR increased to 9.3%.

Fernanda Brandi1, Ricardo de Queiroz1 et al (2008) [7] Praposed a paper which is based on Super-Resolution of Video using Key frames and Motion estimation. Here author interested in reversed-complexity (distributed) coding methods, wherein few key frames are encoded at normal resolution, while the rest are down sampled and encoded at reduced resolution along with the enhancement layers PSNR Max achieved 33.3dB.

MatanProtter and Michael Elad(2009) [8] In this paper which is based on Super Resolution with probabilistic Motion Estimation. SRR is very accurate motion estimation technique between frame for a successful process PSNR increased to 33.7dB.

Yasser Ismail, et al IEEE(2009) [9] Proposed Fast Variable Padding Motion Estimation Using Smart Zero Motion Prejudgment Technique for Pixel and Frequency Domains.the proposed fast ME technique is able to achieve approximately a 99.4% reduction in ME time compared to the conventional full search block-based ME.

Nils Hasler1, Bodo Rosenhahn1 et al (2009) [10] presented a paper which is based on Markerless Motion Capture with Unsynchronized moving Cameras. Error (MSE) Error is min for climbing video sequence and max for running video sequence.

HasanDemirel(2009) [11] In this paper which is based on Improved Motion-Based Localized Super Resolution Technique Using Discrete Wavelet Transform For Low Resolution Video Enhancement. The results based on PSNR values, in comparison with the global super resolution method, show improvement in PSNR Max 34.19dB.

JianwenLuo, and Elisa E. Konofagou(2010) [12] Praposed a paper which is based on A Fast Normalized Cross-Correlation Calculation Method for Motion Estimation. A time-efficient sum-table method was implemented by author in the field of ultrasound-based motion estimation to rapidly calculate the NCC. Processing time increased with respect to direct method upto 47%.

AbdelatiMalekAmel, et al (2010) [13] In this paper which is based on Video Shot Boundary detection using motion activity descriptor. In this context, the motion activity descriptor was applied for different video sequence. With the use of ARPS max value of Precision = 72.72% for news.

Thomas Brox and Jitendra Malik (2011) [14] Presented a paper which is based on Large Displacement Optical Flow: descriptor Matching in Variational Motion Estimation. In this paper, Author present a way to approach the problem of dense sampling time by integrating rich descriptors into the variational optical flow setting.

Manish Okade, P. K. Biswas (2012) [15] praposed a paper which is based on Fast Camera Motion Estimation using Discrete Wavelet Transform on block motion vectors. In this paper author propose to use the discrete wavelet transform on the block motion vector field for estimating the camera (global) motion parameters in the compressed domain It shows 12% saving in processing time.

Ying Liu,et al (2013) [17] Presented a paper which is based on Motion-Aware Decoding of Compressed-Sensed Video. In

this paper, author consider a video system where acquisition is carried out in the form of direct compressive sampling (CS) with no other form of sophisticated encoding sparsity-aware de-coders significantly outperform the conventional fixed-basis intraframe and interframe decoders up to 1.5 to 2 dB .

S. Izadpanahi, H. Demirel(2013) [18] Proposed a paper which is based on Motion based video super resolution using edge directed interpolation and complex wavelet transform. This paper proposes a novel super resolution technique using dual tree complex wavelet transform (DT-CWT) and new edge directional interpolation (NEDI) based on localizing motion blocks in consecutive frames the PSNR is calculated 34.02 as compare to normalized techniques.

Hassan Kibeya et al (2014) [21] On concluding a paper which is based on TZ Search Pattern Search Improvement for HEVC Motion Estimation Modules Author present an different search pattern for motion vector fields and finds better motion vector calculation with star and raster refinement and accuracy is increased with this approach.

F. Michielin,et al(2014) [20] In this a parallel true motion estimation method based on binarized cross correlation In this paper the Author show a similar vector field estimation in comparison to the standard SAD based recursive search method with the considerable advantage of a possible parallel implementation This avoids the intra-frame recursion typical of the RS systems to permit a parallel implementation.

DjoudiKerfa & M. F. Belbachir (2015) [22] presented a paper which is based Star diamond: an efficient algorithm for fast block matching motion estimation in H264/AVC video codec In this paper Star Diamond is less complex than Diamond: there is an improvement of 7.86 % on average over all the corpus used in this paper.

M. ObaidUllah et al (2016) [23] In this paper which is based on Performance analysis of block matching motion estimation algorithms for HD videos with different search parameters In this paper the Author show It is concluded that ARPS is better than all other algorithms for HD videos over PSNR.

VII. CONCLUSION

After review process it has been found that DS algorithm gives performance closer to the ES algorithm at minimum number of search points. Also the different variants of DS algorithms are also giving good results at an acceptable degradation in image quality especially Diamond Search algorithm. In DS algorithm we can increase the efficiency of system and to reduce complexity and computational time as compare to other DS algorithms. Hence the speed of these block based motion estimation algorithms can be improved by reducing number of search point and by using early termination process. This paper shows the advantages of most popular block matching algorithms, with their comparative study.

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