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AN EVALUATION OF MOTION ESTIMATION TECHNIQUES IN VIDEO COMPRESSION

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Abstract— In the contemporary era, the field of video compression technology has flourished significantly, offering a diverse array of techniques applicable across video transmission, high-definition television (HDTV), and broadcast digital video. Central to achieving superior video compression quality is Motion Estimation (ME), a pivotal component known for its considerable computational complexity and memory demands. Although conventionally associated with video encoding, the utility of Motion Estimation has transcended its original domain. In present times, researchers from diverse fields, beyond video encoding, are increasingly harnessing ME to address real-time challenges within their respective domains. This survey paper aims to comprehensively examine the role of Motion Estimation in video compression techniques for video processing. It focuses particularly on determining optimal data compression levels, evaluating the efficiency of different techniques, and conducting comparative analyses. This study also contrasts contemporary video compression methods with conventional approaches such as Exhaustive Search (ES), Adaptive Rood Pattern (ARP), Run Length, and Huffman coding. The established conventional techniques will be practically implemented using the MATLAB platform. The performance of the video compression methodology will be assessed through key metrics including Compression Ratio (CR), Peak Signal to Noise Ratio (PSNR), and exploration of search patterns.

***keywords*—**Motion Estimation (ME); CR; PSNR; Video Encoding

1.INTRODUCTION

Video compression pertains to the reduction of data volume necessary for representing video images [5]. Its primary utilization is within contexts like video conferencing and real-time applications. Notably, encoders founded on motion estimation hold prominence in the realm of video compression techniques [7]. Video images, comprising dynamic visuals, are typically sampled at frequent intervals—typically 25 frames per second—and subsequently arranged as a sequence of frames [4]. By employing a model depicting the movement of objects across frames, the encoder deduces the motion transpiring between the reference frame and the present frame. This procedural facet is termed motion estimation (ME) [9]. Distinguished by its computational intricacy and memory requisites [1], motion estimation stands as a pivotal facet for achieving high-quality video compression. Its significance resonates within the core of both video compression and video processing applications [4]. Given its adeptness at mitigating temporal redundancies, motion estimation has seamlessly integrated itself into the foundation of all high-compression video codecs [5]. The effectiveness of video compression hinges on the motion estimation algorithm, underscoring the necessity for crafting swift motion estimation techniques suited for real-time applications [12]. A motion estimation algorithm's proficiency aligns intricately with its encoding speed, compression ratio, and the resulting image quality upon decoding. Block-based motion estimation algorithms have gained widespread traction in video coding due to their inherent simplicity and the coding efficiency they afford in terms of motion vectors [6]. As a pivotal element within block-based video compression systems, motion estimation plays a vital role by capitalizing on the temporal redundancies between successive frames in a video sequence, thereby facilitating significant data compression [2].

II. RESEARCHERS RELATED WORK

In this context, the selection of a block Xuena Bao et al have developed a hardware efficient fast algorithm with a lossless frame recompression scheme and early-level termination strategy for large search range (SR) motion estimation (ME) utilized in beyond high dentition video encoder. To achieve high ME quality for hierarchical motion search, added an advanced hierarchical ME scheme which processes the multi resolution motion search with an efficient refining stage. In addition, a lossless frame recompression scheme based on this ME algorithm was presented to further reduce bandwidth. That method terminates high-level redundant motion searches by establishing thresholds based on current block mode and motion search level; it also applies the early refinement termination in order to avoid unnecessary refinement for high levels. Experimental results have shown that the total scheme has a much lower bit rate increasing compared with previous works especially for high motion sequences, while achieving a considerable saving of memory and bandwidth cost for large.

Humaira Nisar have presented a motion estimation algorithm that is suitable for all kinds of video sequences. The proposed algorithm involves a multistage approach that includes motion vector prediction and motion classification using the characteristics of video sequences. In the first step, spatio-temporal correlation has been used for initial search centre prediction. Secondly, the homogeneity analysis helps to identify smooth and random motion. Thirdly, global minimum prediction based on uni-modal error surface assumption helps to identify the proximity of global minimum. Fourthly, adaptive search pattern selection takes into account various types of motion content by dynamically switching between stationary, center biased and, uniform search patterns. Finally, the early termination of the search process was adaptive and is based on the homogeneity between the neighbouring blocks. The self-tuning property enables the algorithm to perform well for several types of benchmark sequences, yielding better video quality and less complexity as compared to other ME algorithms.

Avishek Saha et al. have focused on reducing the number of search locations in block matching based motion Both half-pixel and quarter-pixel searches were guided by a model free estimation of the SAD surface using a two dimensional kernel method. While giving an equivalent rate distortion performance, this approach approximately halves the number of quarter-pixel search positions giving an overall speed up of approximately 10% compared to the EPZS quarter-pixel method.

III MOTION ESTIMATION

Why Motion Estimation?

Image data in an image sequence remains mostly the same between frames along motion trajectories. This is the same as saying that the scene content does not change much from frame to frame. To exploit the image data redundancy in image sequences there is a need to estimate motion in the image sequence so one can process along motion trajectories after motion estimation, modules

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such as noise reduction and compression can be executed. Note that this is a practical approach to what is a JOINT problem of motion estimation AND noise reduction or motion estimation AND compression.

A. *Motion Detection*

Motion estimation is typically the most compute intensive part of video processing. It is therefore sensible to perform motion estimation only where motion is present. Recall the simple translational motion model (will drop arguments for displacement function d to make things easier to read.)

$C_n(x) = C_{n-1}(x + d_{n,n-1}) + e(x)$ ------ (1)

$C_n(i,j) = C_{n-1}(i+dx, j+dy) + e(i,j)$ ------- (2)

The lower equation reminds you explicitly that x = [i, *j*] andd = [*dx, dy*]. Without motion we have

$C_n(x) = C_{n-1}(x) + e(x)$ ------------ (3)

It is expected that |*e(.)*| will be small where d = 0 but BIG where d *6*= 0. Therefore we can detect motion by measuring the Pixel Difference (PD) = $|C_n(x) – C_{n-1}(x)|$. The PD is then threshold to detect motion.

Assuming that motion is detected at a site when *m*(x) = 1,the motion detector can be written as

$$m(x) = \begin{cases} 1, if \ |Cn(x) - Cn - 1(x)| > Ez \\ 0 \quad Otherwise \end{cases}$$ ---------------- (4)

Where E_z is the threshold intensity difference used to flag motion 5 is typical.

Problems with Pixel Difference

Unfortunately, the PD can be `noisy' because of noise in the sequence. This can cause `ragged' edges in detected motion regions, and holes in otherwise completely moving objects. This can be overcome by smoothing the PD (using spatial Gaussian Filter for example) before thresholding. This causes `leakage' of detected motion into non-moving areas. Alternatively, one can use a block based strategy instead and average the PD over blocks to make a block-based motion detection decision. Note that we only want to do this to limit the image area over which we will be trying to estimate motion. Therefore it is sufficient for false alarms to be keptreasonably low.

Changes between adjacent frames are mainly due to the movement of the space-time objects. So by using a model for estimating the motion of the objects between frames, it iseasier for the encoder to estimate the motion that occurred between the reference frame and the current frame. This process is called motion estimation (ME). The ME block diagram is shown in Figure 1a. The concept of Motion Compensation (MC) technique is that to provide a better prediction of the current frame, the encoder uses the motion model and information's to move the contents of the reference frame. This process is known as motion compensation (MC), and the prediction produced for this

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purpose is called the motion compensated prediction (MCP) or the displaced-frame (DF). The difference of ME from motion compensation is that, the ME detects the movement of objects in an image sequence and it will try to obtain the motion vectors representing the estimated motion. Apart from ME the motion compensation techniques uses the knowledge of object motion so obtained in order to achieve data compression. So we can say that ME techniques form the core part of video compression as well as video processing applications.

There are different search algorithms developed for finding the motion estimation. The algorithms are used to estimate the accurate motion between frames. When ME is performed by an MPEG-2 encoder it groups the pixels into 16×16 macro blocks. The MPEG- 4 AVC encoders can further divide these macro blocks into small partitions (as small as 4 ×4). It is also possible to divide, even for variable size within the same macro block. Partitions are allowed for ensuring more accuracy in ME process. The reason is that areas with high motion can be isolated from those with less movement.

Given the image sequence model below, the motion estimation problem is to estimate *d* at all pixel sites that are at moving object locations. The image sequence model is restated below for convenience.

$C_n(x) = C_{n-1}(x + d_{n,n-1}) + e(x)$ ----------------- (5)

Solution of this expression for motion is a massive optimization problem, requiring the choice of values for d at all sites to minimize some function of the error *e*(x). It is typical to choose the value of d such that it results in the minimum Displaced Frame Difference (DFD) defined as

$DFD(x) = C_n(x) – C_{n-1}(x + d_{n,n-1})$ ---------------- (6)

The problem is complicated by the fact that the motion variable d is an argument to the image function d_{n-1}

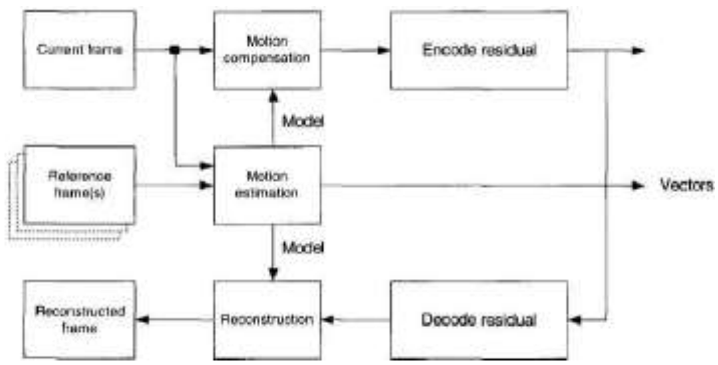

Fig 1 : Motion Estimation Block Diagram

SUMMARY OF VIDEO COMPRESSION TECHNIQUES

Table 1. Summary of the video compression techniques.

S. No.	Techniques	Methodology
[1]	Particle Swarn Optimization (PSO)	Motion estimation through block matching fundamentally embodies an optimization challenge. In this regard, the conventional Particle Swarm Optimization (PSO) approach emerges as proficient in attaining notable precision within block matching.
[2]	Block matching using DCT and DWT	Block matching algorithm helps to find motion vector for each blocks within a search range and finds a best match that minimize an error measure.
[3]	Active Mesh Based Motion Compensation Algorithm	A novel mesh-based algorithm has been introduced for motion estimation and compensation within the wavelet domain. This technique centers around the minimization of mesh energy through innovative energy functions. The algorithm comprises two primary approaches: firstly, the motion estimation of consecutive frames, and secondly, motion estimation and subsequent compensation within the wavelet sub-bands.
[4]	PCA based method	A video consists of interconnected frames presented in a sequence, allowing the application of Principal Component Analysis (PCA) to these closely related frames. Unlike Discrete Cosine Transform (DCT), which doesn't minimize frequency response bandwidth, PCA preserves frame edges, preventing their deterioration.
[5]	Pattern Based Pixel Decimation	An innovative pixel decimation block matching algorithm has been introduced to address limitations within conventional pixel decimation methods. This pattern-based algorithm effectively alleviates the computational load of the Full Search Algorithm (FSA), while simultaneously minimizing the rise in prediction error for the anticipated frames.
[6]	Accordion Function	In this proposed method input video to reduce the spectral And temporal redundancies using accordion function. it converts the temporal redundancy into the spatial redundancy, which was removed using Discrete Cosine Transform (DCT)

[7]	Adaptive Neighborhood Elimination Algorithm (ANEA)	The newly suggested NEA leverages the spatial correlation inherent in collocated Macro blocks. By dynamically and adaptively curtailing the pool of candidate blocks, this methodology effectively surmounts the constraints associated with fixed pattern-based shortcomings prevalent in existing fast Block Matching Algorithms (BMAs). This innovative Adaptive NEA (ANEA) yields significantly elevated levels of reconstructed video quality, coupled with remarkably efficient coding.

The following table 2 represents the PSNR value, Average no of Search Points, Compression Ratio for the existing HUFFMAN, and Run length techniques. From Table 2, Huffman encoder technique have better PSNR rate when compared to the other existing Run length encoder. Average Number of search points for the Huffman technique and the existing Run length encoder techniques are almost the same. But the PSNR and the compression ratio of the Huffman method is high when compared to other existing techniques.

Table 2. PSNR values, Compression Ratio, Average no of Search Points for the Huffman and Run length encoder

Video frames	**HUFFMAN**			**RUNLENGTH**		
	PSNR	**CR**	**Average Search Points**	**PSNR**	**CR**	**Average Search Points**
	3.701	0.734	0.0156	7.28	0.976	0.0156
	6.685	0.615	0.0156	8.17	0.977	0.156
	3.520	0.837	0.156	7.63	0.961	0.0156

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	9.650	0.802	0.0156	8.59	0.884	0.0156
	6.971	0.932	0.0156	8.07	0.8902	0.0156
	15.878	0.642	0.0126	8.11	0.935	0.0156
	12.869	0.931	0.0156	8.90	0.996	0.0156
	8.567	0.669	0.0256	7.12	0.959	0.0156
	4.96	0.798	0.015	7.91	0.984	0.0156

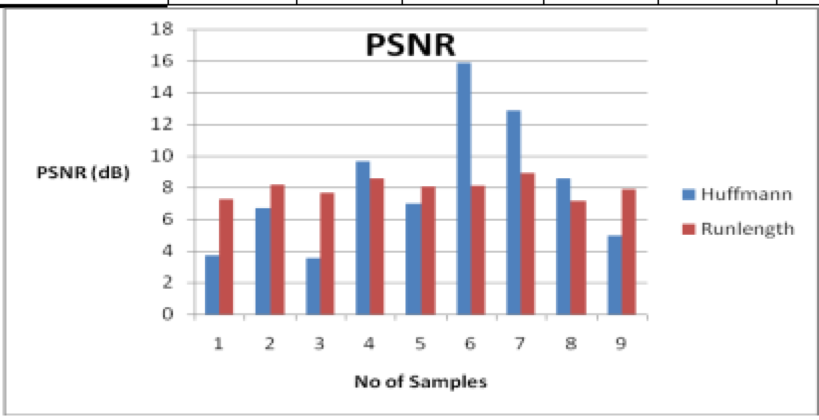

Figure 2: Illustrates the graphical representation of PSNR valuein Huffman and Run length encoder

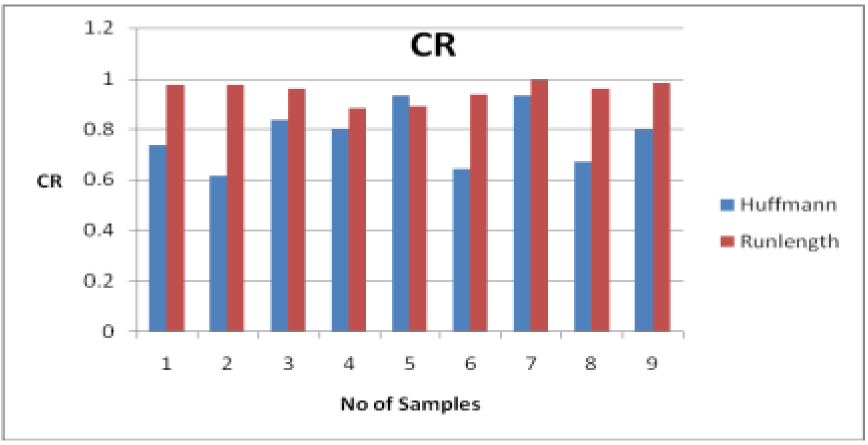

Figure 3: Illustrates the graphical representation of PSNRvalue in Huffman and Run length encoder

CONCLUSION AND FUTURE SCOPE OF WORK

In spite of various algorithms proposed for video compressions, a number of challenges remain unanswered. In this paper we survey various Motion Estimation techniques for video compression that have seen, that all the schemes discussed above Huffman , Runlength, PSO, Block matching using DCT and DWT, Active mesh based Motion Compensation Algorithm, PCA based method, Pattern Based Pixel Decimation, Accord Function, ANEA, Wavelet based Rate Scalable Method. From review of various ME in video compression papers it infers that there are still lots of improvement of video compression technique. Huffman encoder produces higher compression ratio value than the other existing Run length algorithms for the different kinds of dataset images. Hence from the Performance Analysis our Huffman System gives better motion estimation than any other existing techniques. This survey paper is very helpful for finding the ME in video compression of current trends and next level of problem identification with Modified Pixel- Based Motion Estimation (MPME) technique in order to reduce the shortcoming in the existing method.

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