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Motion Estimation Scheme for Video Coding Using Hybrid Discrete Cosine Transform and Modified Unsymmetrical-Cross Multi Hexagon-Grid Search Algorithm

[1]R. Sudhakar and [2]S. Letitia

[1]SBC Engineering College, Anna University, Chennai, Tamilnadu, India
[2]Thanthai Periyar Govt. Institute of Technology, Anna University, Chennai, Tamilnadu, India

Abstract: Digital video compression technologies have become an essential part of motion estimation technique. The motion estimation of H.264/AVC is a time consuming process. Many algorithms were proposed for the video stream motion estimation, but they have a high computational complexity which significantly increases the encoder complexity. This paper proposes the Modified Unsymmetrical-Cross Multi Hexagon-Grid Search (MUMHexagonS) algorithm is utilized for motion estimation searching process and the 3-D DCT (Three-Dimensional Discrete cosine Transform) technique for video compression. The traditional search patterns are replaced by the Asymmetrical Improved Cross Search Pattern, Minimized square search and Modified Uneven Multi-Hexagon Grid Search Pattern. The proposed motion estimation and video compression framework reduce the motion estimation time, compression time, computation cost and it achieves the better encoding efficiency and good video quality.

Key words: Video compression · Unsymmetrical Cross Multi Hexagon-Grid Search (UMHexagonS) · DCT (Discrete Cosine transform) · Motion estimation · Encoding

INTRODUCTION

A digital video consists of a sequence of images displayed in the quick constant rate. The motion estimation determines the object movement in the sequence of images and finds the motion vectors (MV_s) representing the movement. If gains and implement the knowledge about the objects in the image sequence and achieve data compression. Mostly the image data in the image sequence do not show much change from frame to frame. Hence there is need to predict the motion in the image sequence to exploit the redundancies in the image sequence. This continuous sequence of frames has the file size larger than the normal document file. So it is impractical to store and transfer such video file. Therefore, the video compression is used to send the video effectively through a network. It is a technique to compress the video that remove or reduce the redundant frames in the video and results in relatively small size compressed video. Basically, it is a combined problem of motion estimation and noise reduction (video compression).

Numerous algorithms are present to estimate the movement of the object in a video/ image sequence. Mainly 2D-logarithm search algorithm, three step search algorithm, four step search algorithm, diamond search algorithm, hexagon-base search algorithm, etc. As the expectation of this paper, all the above mentioned algorithms used to reduce the search points and achieve the best video quality, but they have the constant search pattern which reduces the coding quality and accuracy [1]. Considering the next part after the motion estimation, there are many video coding techniques availablefor video compression namely MPEG-2, MPEG-4 and H.263. The purpose of video coding standards is to allow the compression techniques to reduce the bitrate of the video in terms of redundancies and encode the remaining minimum set of frames. But mostly these video coding standards provide high computational and encoder complexity.

To overcome these issues of motion estimation and video compression, this paper utilizes the Unsymmetrical-Cross Multi Hexagon-Grid Search (UMHexagonS) algorithm with some modification in the searching

Corresponding Author: R. Sudhakar, SBC Engineering College, Anna University, Chennai, Tamilnadu, India.

patterns for motion estimation in the video sequence and 3-D DCT (Three-Dimensional Discrete cosine Transform) method which encodes the video at lower bitrate with the minimum set of frames after eliminating the spatial and temporal redundancies. The motion estimation algorithm is modified in the proposed system which changes the searching pattern of the algorithm and searches the similar correlated frames and removes them as redundant frames which lead to the reduction of video file size. TheModified Unsymmetrical-Cross Multi Hexagon-Grid Search (MUMHexagonS) algorithm is implemented along with the 3-D DCT method reduces the motion estimation time, compression time, computation cost and it achieves the better encoding efficiency and good video quality [2].

Related Work: The H.264/AVC is a well performed video coding standard still achieves high computational complexity and low encoding speed. So the UMH algorithm is implemented along with the motion estimation strategies and distributed rule for search points. The paper [3] proposes a low complexity motion estimation scheme which proves better efficiency in video coding performance. The simulation result in final represents that the proposed system proves better encoding speed, high quality video, low bit rate, video compression when compared with the full search algorithm.

The author in [4] proposed a mesh based algorithm for motion compensation and estimation using wavelet domain. The mesh algorithm based on energy function which improves the accuracy of motion compensation and estimation of video pixels. Two different types of algorithms are used in this method such as motion estimation of sequential frames and motion compensation and estimation using in the wavelet sub-bands. The retained energy criteria are based on the 3D volume of coefficients. This coder obtained the all sub-band maximum energy. The algorithm was tested using the some video sequences and the proposed method gives a significant performance using PSNR values.

The paper [5] analysis the performance of the three motion estimation algorithms used for the determining the movement of the objects in the video sequence. The three motions estimation algorithms are namely Enhances Predictive Zonal Search (EPZS), Unsymmetrical-cross Multi Hexagon-grid search (UMHex) and Simplified Unsymmetrical-cross Multi Hexagon-grid search (SUMHex). Finally the result of this comparative study shows that the EPZS suits best for the video with high and moderate motion and the SUMHex suits best for the video with low motion and the Mean Square Error (MSE) are productively same for all the motion estimation algorithms.

Digitized information is a rapidly growing component of emerging video and multimedia services. In its raw digitized form visual information places large demands on bandwidth and storage requirements of applications. Picture and video compression is a key enabling technology for overcoming this problem. In paper [6] the author proposed that the motion estimation is one the current field in which researches continuously exploring new algorithms to enhance its results, motion estimation is used in various fields life security, traffic monitoring and medical imaging. The temporal prediction technique used in MPEG video is based on motion estimation. The basic premise of motion estimation is that in most cases, consecutive video frames will be similar except for changes induced by objects moving within the frames.

In paper [7] the author proposed a method to remove the blocking artifacts in the existing image compression methods. The familiar Discrete Cosine Transform (DCT) is used to compress the image, whereas the proposed fractal image compression technique is used to eliminate the repeated compression of the adjacent blocks. The adjacent blocks with similar features are determined by the Euclidean distance measure and the image encoding is done through the Huffman coding. Many comparative analyses have been made to prove the proposed system is the best.

A motion estimation algorithm in used different search points and the video compression is based on the block based motion estimation algorithm. The searching points contain a different pattern size and shape; it has a significant of distortion performance and searching speed. The square and octagon searching pattern is employed in the block based motion estimation. The octagon pattern contains the 13 point structures and the square pattern contains the 8 point structure. The Unsymmetrical-cross Multi-hexagon-grid Search (UMHexS) algorithm is used to speed up the searching process. The proposed method was using state of the art motion estimation approach for performance evaluation [8].

The computation time and the complexity of video compression becomes a significant drawback for motion estimation. The paper transforms the video signal from 3D to 2D pattern to reduce the complexity and computational time involved in the video compression process. Usually the video signals have more temporal redundancies than the spatial redundancies, so the video frames are organized in such a manner to remove both redundancies. The Approximated DCT is implemented newly along with RLE method which decreases the multiplication complexity and reduces the retained coefficient sequence without reduction in data [9].

Intelligent transportation system (ITS) component detects the moving objects, while detecting the traffic system, it offers only a limited bandwidth for video communication. To overcome this problem the rate control scheme is implemented [10] to alter the bit rates to match the bandwidth of the network. Then the appropriate motion detection is achieved by utilizing an approach called Analysis-based radial basis function network.

The integration of wireless access technologies with IP based mobile devices leads to the best video and audio distribution. The performance of video distribution is analyzed in [11]. The utilization of concurrent multipath transfer is used for data transmissions and simultaneously for the re-transmission of rotating queries to achieve best video delivery.

Proposed Modified Unsymmetrical-Cross Multi Hexagon-Grid Search (MUMHexagonS) Algorithm: H.264/AVC is the most popular video coding standards which enhance the compression performance of the video and it has a remarkable efficiency in the rate distortion optimization when compared to the existing standards. This video coding standard is encoding the video based on blocks. The video is divided into video cubes and again divided into macro-blocks that are encoded using frames in the future or previously encoded frames. This is called inter frame coding. This process of finding the motion vector in the frame to the same or closest motion vector in the reference or previous frame is called as motion estimation. The performance of the motion estimation is mainly influenced by the accuracy and motion velocity (speed) of the motion vector. The sum of absolute difference (SAD) which is a matching criterion embraced to measure the accuracy and motion speed of the vector between two different frames [12]. The SAD is computed as

$$SAD(x,y) = \sum_{p=1}^{P}\sum_{q=1}^{Q}|I_r(p,q) - I_{r-1}(p+x,q+y) \quad (1)$$

where (x, y) represents the change in motion vector, I_r and I_{r-1} represents the present and last frame and the size of the macro-block is denoted by PxQ. The optimal search point is reached when the Sum of Absolute Difference value SAD(x,y) is minimum or zero [13].

Modifications in Proposed Algorithm: Motion estimation is a very time consuming and computationally cost effective compared with the whole video compression process [8]. Minimizing the number of search points to find the motion vector quickly leads to the time consumption and less computational cost. The most popular algorithm used along with the motion estimation process is Unsymmetrical-Cross Multi Hexagon-Grid Search (UMHexagonS) algorithm which consists of four traditional steps. They are: a) Motion prediction modes; b) Asymmetrical cross search; c) Uneven multi-level hexagon search; d) Extended hexagon grid search. As known by the existing research of motion estimation using the UMHexagonS algorithm in the H.264/AVC standard performs with better efficiency and improved encoding computation, but it is still time consuming due to the numerous search points.

Hence, in the proposed system, predict the motion vector in a quick way by changing some steps in the UMHexagonS algorithm which reduces the number of search points in the frames in such a way it reduces the searching time and improves the computational and encoding efficiency. The proposed improved Modified Unsymmetrical-Cross Multi Hexagon-Grid Search (MUMHexagonS) algorithm incorporates the following four steps: a) Initial Point Search; b) Asymmetrical improved cross search pattern; c) Uneven transformed multi-level hexagon search; d) Extended hexagon grid search.

Initial Point Search: This method is derived from the traditional UMHexagonS algorithm which finds the starting search point as a search center to the next step. This can be done using any of the four following steps: the Median prediction, the up-layer prediction, the neighboring frame reference prediction and the corresponding-block prediction.

The median frame prediction is widely used for spatial prediction. Since the theme of the paper is to reduce the spatial and temporal redundancies, the median prediction is used here to find the initial search point [9]. Consider that the frames of block B are surrounded by the block A on the left, block C on the top and the block D on the right top as depicted in the Figure1. All these frame blocks are adapting the same motion feature. Thus the motion vector of current frame block E is predicted by the equation:

$$MV_B = median[MV_A, MV_C, MV_D] \quad (2)$$

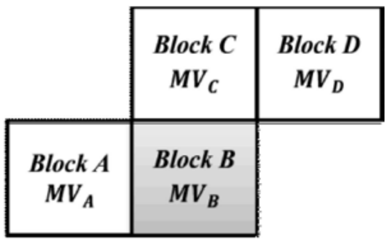


Fig. 1: Median prediction of motion vector

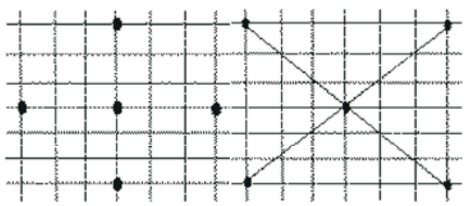


Fig. 2a:Traditional cross search pattern

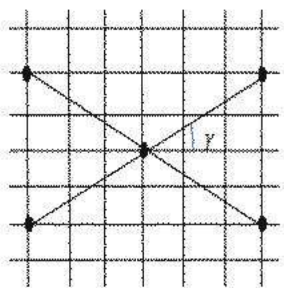
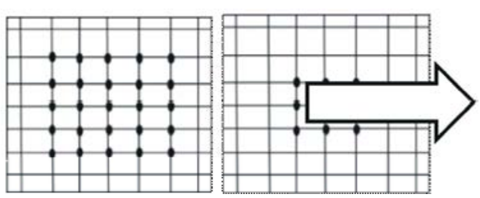


Fig. 2b: Improved cross search pattern



5x5Square Pattern 3x3 Square Pattern

Fig. 3: Square Pattern

After the median frame prediction, the sum of absolute difference (SAD) is calculated by the equation (1). The proposed algorithm embraces the different searching pattern based on the SAD value. If the SAD value is zero, then that is the exact point of motion vectors. If the SAD value is minimal, then the predicted initial search point is near to the actual motion vector [14].

Asymmetrical Improved Cross Search Pattern: Traditional asymmetrical cross search pattern and the uneven multi hexagon grid search usually search the optimal motion vector not in a thorough manner. It is a desultory search process. The process of searching optimal motion vector search point is always done with the large range of search. Hence the proposed asymmetrical improved cross search pattern is implemented here with the concept of changing the traditional cross search of horizontal and vertical path in the combined vertical and horizontal path motion vector search [2]. This improved cross pattern is shown in the Figure 2a and 2b with comparison of traditional cross search for better understanding.

The direction of the motion vectors in the improved cross pattern is represented by the angle γ which can be computed as

$$\gamma = \frac{MV_V}{MV_H} \tag{3}$$

where MV_H and MV_V are the horizontal and vertical motion vectors.

This improved cross search initializes the search in the direction in terms of fast motion and then in the directions in terms of slow motion. The main advantage of this improved cross search pattern is that it reduces the search points which in turn it find the optimal search centers much faster and efficiently.

Minimized Square Search Pattern: In the traditional UMHexagonS algorithm, after the asymmetrical cross search, 5x5 small rectangular full search is performed as part of it. Since it has 25 search points, the computation part is very complex. Considering the statistical information it is found that the real time environmental images have attained more than 80% motion vector search center by using the 5x5 grid portion. Here in the proposed system, the small rectangular search of 3x3 full search is performed which reduces the search points from 25 to 9. This concept of implementing the 3x3 small rectangular search pattern [1] not only searches the best match,but also reduces the search points; it also reduces the search time and decreases the computational complexity. The Figure 3 demonstrates the transformation of 5x5 square patterns to 3x3 square patterns and the search center as the center.

Uneven Transformed Multi-Hexagon Grid Search Pattern: Usually a 16 point multi-hexagon grid search applies to different ranges in the traditional uneven multi-hexagon grid search. But in the modified uneven multi hexagon grid search pattern, the search region is partitioned into 32 regions under 3 layers. The motion vectors,mostly occur in the center or boundary of the search window. Considering this characteristic into

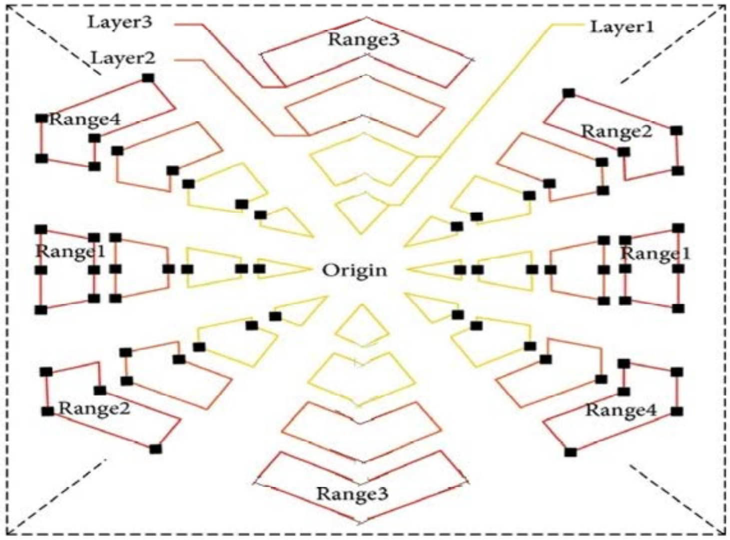


Fig. 4: Modified Uneven Multi-Hexagon Grid Search Pattern

account and also due to the cross search pattern is changed, the layer 1 incorporates 16 regions of 18 search points. Layer 2 incorporate 4 regions of 18 search points. Layer 3 incorporates 4 regions of 30 search points. By using the traditional method, the match point is determined using 32 regions in normal. But in the Modified Uneven Multi Hexagon Grid Search after the improved cross search pattern, it reduced to 26 regions as shown in the Figure 4. If the minimized square search pattern did not find the exact motion vector, then uneven transformed Multi-Hexagon Grid search pattern which minimize the search points and is used to find the optimal search center for the next extended hexagon search pattern.

Extended Hexagon Search Pattern: The extended hexagon search is the final most search patterns in the UMHexagonS algorithm which comprises of a large hexagon search which has six search points and a small diamond search which has four search points applied in a small range to find the motion vector more precisely. This search pattern is taken from the traditional UMHexagonS algorithm. The hexagon search is applied iteratively and find the search point which has minimum rate distortion cost. That point becomes the search center of the next diamond search and the search point with minimum rate distortion cost is found by applying the diamond search repeatedly. The search point with minimum rate distortion cost is the final motion vector for the current block.

The video cube partition from the whole video sequence is taken as input to the motion estimation process. The sequence of steps in the proposed framework as shown in Figure 5 is explained in the following session:

Step 1 (Initial Search Point Prediction): In the first of motion estimation process, the initial search point is found by using the median motion vector predictor.

Step 2 (Decision): The Sum of Absolute Difference (SAD) is calculated using the equation (1).

- If the SAD is zero, then the exact motion vector point of the block is found.
- If the SAD value is small, then go to step 8
- If the SAD value is big, then go to step 7
- If the SAD value is very big, then procedure with the next step.

Step 3 (Asymmetrical Improved Cross Search): Fix the initial search point from the step1 as search center and perform asymmetrical improved cross search and find the best optimal search point.

Step 4 (Minimized Square Search): Take the optimal search point from the step3 as search center and perform minimized 3x3 square search pattern is performed.

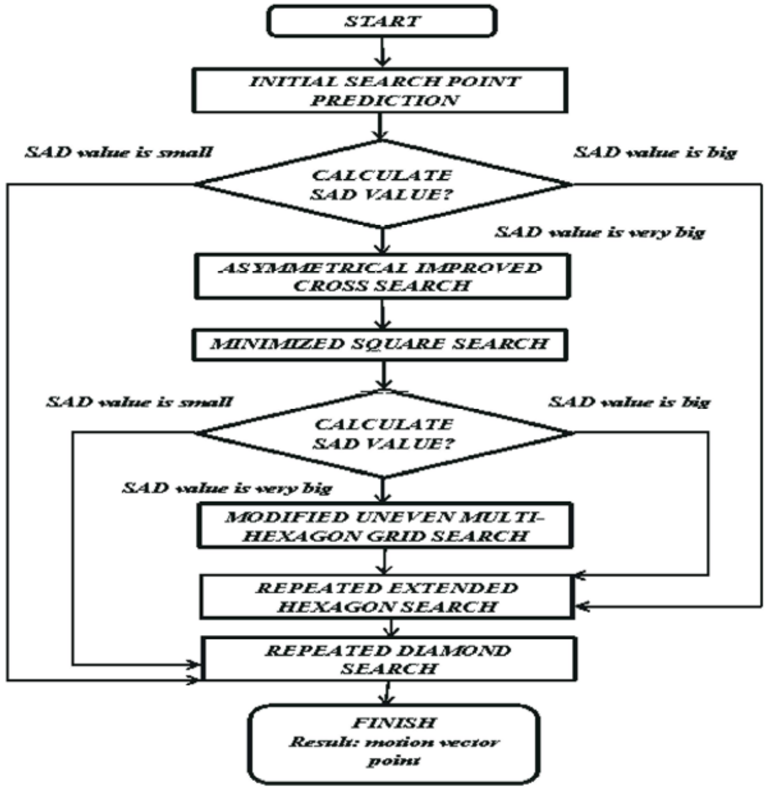


Fig. 5: Flow chart of the proposed algorithm

Step 5 (Decision): Again the Sum of Absolute Difference (SAD) is calculated using the equation (1).

- If the SAD is zero, then the exact motion vector point of the block is found.
- If the SAD value is small, then go to step 8
- If the SAD value is big, then go to step 7
- If the SAD value is very big, then procedure with the next step.

Step 6 (Modified Uneven- Multi Hexagon Grid Search): Take the determined search point from the step4 as search center and modified uneven multi hexagon search is performed.

Step 7 (Repeated Extended Hexagon Search): Fix the optimal search point from the step 6 as search center and the repeated hexagon search is performed.

Step 8 (Repeated Diamond Search): Again, take the optimal search point from the step7 as search center and perform repeated diamond search.

Step 9 (Result): The resulting point from the step8 (repeated diamond search) is the optimal motion vector point.

Video Compression Using Three-dimensional Discrete Cosine Transform (3-D DCT): After detecting the movement of the moving objects using motion estimation using MUMHexagonS algorithm, the video cubes from the video is compressed using Three-Dimensional Discrete Cosine Transform (3-D DCT).The Three-Dimensional Discrete Cosine Transform algorithm for video compression comprises of three major steps in order, namely 3-D DCT compression, quantization and finally entropy encoder. Initially the 3-D DCT compression starts with the process of each video cube which overlaps in the temporal dimension that decreases the correlation between successive frames by removing it with respect to time and in the spatial dimension which decrease the error in the frames which is not present in the original video cube.

The compressed video is not in the standard form which contains some information and the redundant frames in the cube boundary which is useful to build the connection between the video cubes. Hence the quantization is a step in lossy compression, which removes the vital portion in the image which is needed to connect two cubes. The main concept of quantization is to reduce the unwanted coefficients (usually the AC coefficients) and reduce the dynamic range of the important pixel coefficients which ultimately improve the video compression ratio.

After the quantization process, the entropy encoder encodes the resultant quantized video cubes and adds efficiency to the compression. The resultant video cube will be a compressed visual form of the video cube without having any sequential order. The popular available entropy encoding schemes are Huffman encoding and Arithmetic encoding. Huffman encoding is used in the case of image and video compression. The Huffman coding read the coefficients of all the frames in the video cube in a zigzag way and the priority of reading is given to the coefficients along the three axes (i.e.) A, B, C axes. Thus the entropy encoding as the last step of 3-D DCT video compression provides lossless compression and less storage space for the video to transfer.

RESULTS AND DISCUSSION

The performance of the proposed Modified Unsymmetrical-Cross Multi Hexagon-Grid Search (MUMHexagonS)algorithm is compared with the traditional Unsymmetrical-Cross Multi Hexagon-Grid Search (UMHexagonS) algorithm. This comparison is done in terms of searching time of motion vectors, motion time estimation and good quality video.

The search time of each block achieved by both UMHexagonS algorithm and the proposed MUMHexagonS algorithm is depicted in the Figure 6. It shows that the proposed MUMHexagonS search the motion vector with minimum time when compared to the traditional UMHexagonS algorithm. Even though the proposed MUMHexagonS algorithm attempts to minimize the search points in the search area, it completes the searching process quickly with increasing search points.

The motion estimation time of both the algorithm is depicted in the Figure 7. The MUMHexagonS algorithm predicts the motion of the moving object in the video quickly than the UMHexagonS algorithm from the entire video sequence. This graph shows that the motion estimation time of the MUMHexagonS is quite less when compared to the UMHexagonS algorithm.

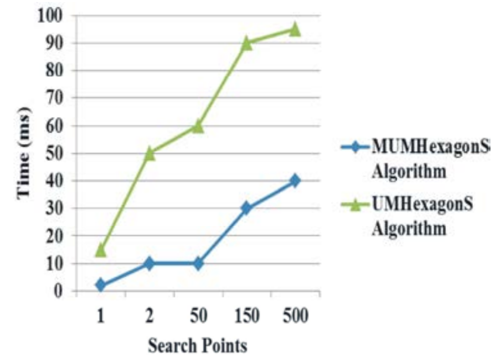


Fig. 6: Search time of motion vector (MV)

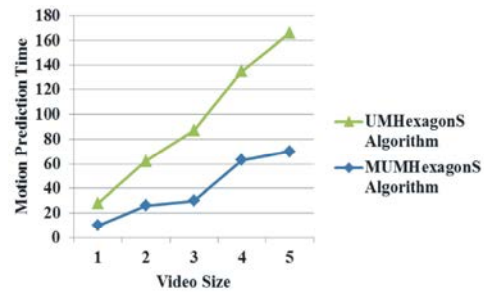


Fig. 7: Motion estimation time

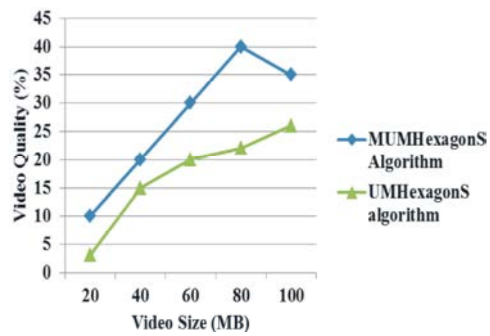


Fig. 8: Video quality

The video resolution of both the UMHexagonS algorithm and the proposed MUMHexagonS algorithm is depicted in the Figure8. It shows that the proposed algorithm gives better video picture resolution than the existing algorithm for motion estimation with respect to the video size.

CONCLUSION

The paper proposed a motion estimation algorithm by modifying the traditional steps used in the UMHexagonS motion estimation algorithm based on the H.264 video coding standard. The proposed algorithm minimizes the search points in the blocks of the video which in turn reduces the search time, increases the efficiency of video encoding and motion estimation. Performance evaluation of the proposed algorithm is compared with the existing traditional UMHexagonS algorithm in terms of video quality, search time and motion estimation time. Finally the video compression is done by using the 3-DCT video compression technique. Thus the proposed Modified Unsymmetrical-Cross Multi Hexagon-Grid Search (MUMHexagonS) algorithm proves that it performs efficiently in real time motion estimation and video coding applications.

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