DESIGN OF DIAMOND SEARCH SHEME FOR MOTION ESTIMATION AND COMPENSATION IN VIDEO CODIND

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

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DECLARATION

We hereby declare that the work entitled "DESIGN OF DIAMOND SEARCH SHEME FOR MOTION ESTIMATION AND COMPENSATION IN VIDEO CODIND" is submitted in partial fulfillment of the requirement for the award of the degree in B.TECH, in University College of Engineering, BIT Campus, Anna University, Tiruchirappalli. It is the record of our own work carried out during the academic year 2018 – 2019 under the supervision and guidance of **Mrs. S.CHITRADEVI**, Department of Information Technology University College of Engineering, BIT Campus, Anna University, Tiruchirappalli. The extent and source of information are derived from the existing literature and have been indicated through the dissertation at the appropriate places.

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ABSTRACT

In recent years, the strength of multimedia is rapid, and it influences the need for storage of memory devices. Therefore, Compression plays a significant role by reducing the data redundancy and saves more memory space. This is in fact highly notable in the storage of videos as it occupies more memory spaces.

In this project work, a method for motion estimation and compensation in video coding with diamond search algorithm for the purpose of video compression is proposed. It uses diamond search algorithm to estimate the search area for finding the best match in the next frame with respect to each block in the current frame. The quality of the match found will be contingent upon the value of the Mean Absolute Difference, more commonly known as MAD, between two blocks.

In this project, the motion vectors produced during motion estimation are utilized in the motion compensation process in order to produce the predicted frame for subsequent DCT compression. The performance of the proposed scheme is experimented with good number of standard videos and measured with Mean Square Error (MSE) to evaluate the result.

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LIST OF ABBREVIATIONS

DCT - Discrete Cosine Transformation

MAD - Mean Absolute Difference

MSE - Mean Square Error

DS -Diamond Search

RDS - Reduced Diamond Search

LDSP - Large Diamond-Shaped Pattern

SDSP - Small Diamond-Shaped Pattern

BMME-Block Matching Motion Estimation

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Compression is the process of converting a data file in such a way that it consumes less space than original file. The file can be of any type i.e., text, audio, image or a video. Recently, the growth of multimedia-based applications has increased the need of efficiency and compression. Videos are collections of frames where the redundant information is expected to be removed for the purpose of compensation. The main fundamental steps in video compression are the motion estimation and motion compensation. They play a dominant role in bit rate reduction. Moreover, these methods also influence the visual quality of the reconstructed video. Image prediction research aims to reduce the space needed to represent the video.

1.2 BENEFITS

There are some benefits that encourage researchers to focus on the video compression. These are:

- It reduces the probability of transmission errors since fewer bits are transferred.
- Compressed files also take up less storage space.
- It increases the efficiency.

Even though the compression influences the visual quality of video which is reconstructed as the final details are sacrificed in the prediction of frames, the major details are preserved and make the constructed frame equal to the original frame.

In this project there are mainly three essential steps considered to reconstruct the frames. These are,

1. Transformation coding
2. Motion Estimation and
3. Motion Compensation

For motion estimation, various block matching algorithms are widely used. Also, in this thesis, the mathematical transformation taken to encode is the Discrete Cosine Transform (DCT) has a general summarization the DCT has advantage of less computational complexity while encouraging performance.

1.3 OBJECTIVES OF THE PROJECT WORK

The project work aims to

- Increase the quality of the image
- Increase the accuracy of the match block

Encoding in DCT for efficient processing increases the quality with satisfactory performance.

1.4 CONTRIBUTION IN THE PROJECT

In this project work, analysis is initially made on each step of the video compression technique. It is observed that the motion estimation and compensation plays a very significant role in video compression. So, various algorithms involved in motion estimation are studied. Additionally a motion estimation technique is proposed using diamond search algorithm to find the motion vector.

1.5 ORGANIZATION OF THE REPORT

The report is organized as follows

- Literature survey
- Architectural design
- Diamond search motion estimation
- Video compression

In chapter 2 the related literature to the proposed work collected and presented. In chapter 3 the DCT mathematical representation is presented and chapter 4 and chapter 5 propose architecture design and algorithm is presented. Chapter 6 the experiment and result is given and chapter 7 is conclusion for the proposed system.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

Many researchers have proposed various techniques for video compression in their context of analysis and their views. In order to gather idea about the existing system, various literatures based on motion estimation and compensation have been studied.

2.2. LITERATURE SURVEY

In[1], Edouard Fran et.al for submitted a coding algorithm by video compression based on region of the frame for the purpose of motion compensation. It provides the coding of I-frames and the prediction of P-frames.

Motion-Estimation and Compensated Coding reduce the temporal redundancy. The temporal redundancy is a main property of video signals as detected by motion estimation . This process calculates the motion vector[2]. Block-based Motion Estimation is the procedure of estimating block motion by comparing with blocks in the search area within another frame in the sequence. Block-based compression method is done with a fixed block size. Therefore, the per-block bit-budget grows as the image gets smaller, and the compression distortion decreases.

A Diamond Search Algorithm for Fast Block-Matching Motion Estimation is designed by Shan Zhu and Kai-Kuang Ma (2000), the compact shape of the search patterns used in the Diamond Search algorithm increases the possibility of finding the global minimum point located inside the search pattern[3]. Fast and accurate block-based search technique is highly desirable to assure much reduced processing delay while maintaining good reconstructed image quality.

In[4], A cross-diamond search algorithm for fast block motion estimation designed by Chun-Ho Cheung and Lai-Man Po .The Diamond Search algorithm has a Large diamond-shaped pattern (LDSP) and Small diamond-shaped pattern (SDSP).The diamond-shaped pattern, which tries to behave as an ideal circle-shaped coverage for considering all possible directions of an investigating motion vector. Using FS with mean absolute distortion (MAD) as the block distortion measure (BDM) is used.

A fast motion estimation based on modified diamond search patterns had been reported by H. So, et.al, in[5]. It has been developed using different search patterns and introduced a halfway-stop technique that thresholds the motion compensation error with priority order between neighbour blocks.

R.Krishnamoorthy et.al, reported a motion compensation algorithm in frequency domain with orthogonal polynomial [6]. Here current frame and the next frame are partitioned into (8x8) blocks and subjected to Orthogonal Polynomials Transformation. It searches for the best motion vectors in the subsequent frames in the frequency domain.

As the most significant part in video coding is the motion estimation, it directly influences the visual quality of the decoded video. Hence, most of the researchers have concentrated on block matching algorithm based motion estimation technique[7]. Rahul et.al, provided a full search block matching algorithm with fast search in spatial domain for motion estimation.

In[8],the frequency domain based motion estimation that simplifies the usual video coder structure with its frequency coefficients is reported. There have been many works produced on motion estimation in frequency domain. Mingzhou Song et. al discussed on motion estimation using logarithmic search, which reduces spatial redundancy but failed to bound complexity.

Significance of block matching algorithm is larger in motion estimation as it plays a greater role in quality of the decoded video. The importance of fast and simplified estimation technique was explained by Ezhilarasan et.al, in[9] introducing a block matching criteria with modified full search algorithm which had decent complexity.

Multiple-reference-frame is used in motion estimation and mode decision for H.263-to-H.264 transcoder which is reported by Jiajun Bu, et.al,in[10], The straightforward Full Search for ME on each reference frame motion vectors for 16x16-mode or 8x8-mode blocks referring to previous adjacent frame is done. Some adaptive threshold techniques can also be used here. However, the computational cost will be increased.

2.3. CONCLUSION

In this chapter the literature related to motion estimation and compensation for the propose of establishing frequency domain video coding is presented. In the next chapter, the proposed system overview of motion estimation is presented.

CHAPTER 3

MATHEMATICAL PRELIMINARIES ON DISCRETE COSINE TRANSFORM USED FOR VIDEO COMPRESSION

3.1 INTRODUCTION

The video coding utilizing proposed diamond shaped search for motion estimation and subsequent compensation used transform coding technology. In image transform coding technology unitary transform is used for purpose of converting original pixel values of the frame and converted into uncorrelated domain.

Several transforms exists for this purpose example of transformation are

- Discrete Cosine Transformation (DCT)
- Discrete Fourier Transformation (DFT)
- Wavelet Transformation (WT)
- Plant Transform(PT)
- Karhunen-Loeve Transform (KLT) are available.

In this project DCT is utilized for the transform coding, due to its energy presentation and low computation complexity.

3.2 BASIC STEPS OF VIDEO COMPRESSION

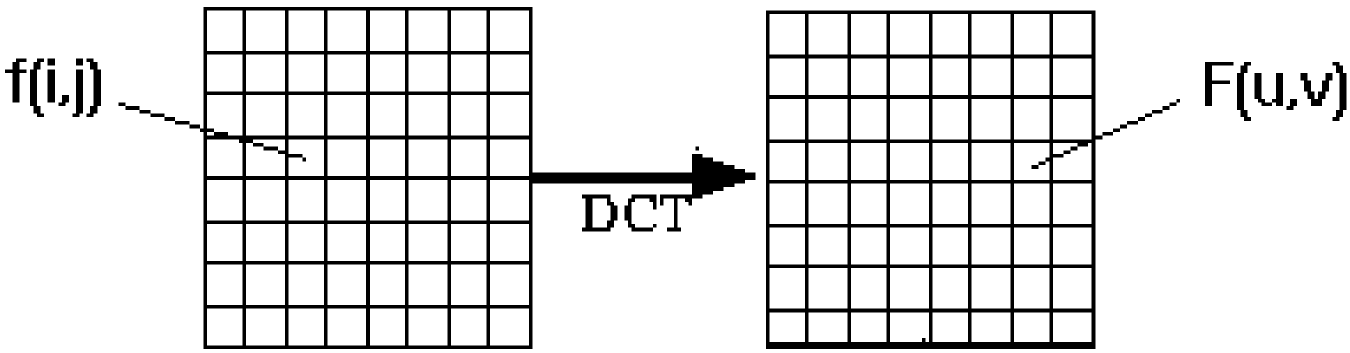
1. Motion Estimation
2. Motion Compensation
3. Discrete Cosine Transform
4. Quantization
5. Run Length Encoding
6. Huffman Coding

To briefly explanation of motion estimation and compensation in chapter4 and chapter 5

3.3 DISCRETE COSINE TRANSFORM

DCT based image coding is the basic for all the image and video compression. The discrete cosine transform helps separate the image into parts of differing importance. The DCT is similar to the discrete Fourier transform: It transforms a signal or image from the spatial domain to the frequency domain.

DCT is using the separates an image into block of pixel of differing with respect to overall image. DCT is a lossy compression technique of image compression.



3.4 DCT ENCODING

The general equation for a 1D (*N* data items) DCT is defined by the following equation:

$$F(u) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1} \Lambda(i).cos\left[\frac{\pi.u}{2.N}(2i+1)\right] f(i)$$

the corresponding ***inverse*** 1D DCT transform is simple $F^{-1}(u)$, i.e.:

$$f(x) = \sum_{u=0}^{N-1} a(u)\left(Z(u)\cos\left[\frac{\pi(2x+1)u}{2N}\right]\right)$$

The general equation for a 2D (*N* by *M* image) DCT is defined by the following equation:

$$F(u,v) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \left(\frac{2}{M}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} \Lambda(i).\Lambda(j).cos\left[\frac{\pi.u}{2.N}(2i+1)\right] cos\left[\frac{\pi.v}{2.M}(2j+1)\right].f(i,j)$$

the corresponding ***inverse*** 2D DCT transform is simple $F^{-1}(u,v)$, i.e.:

$$f(x,y) = \frac{C_v}{2}\sum_{y=0}^{7}\left[\frac{C_u}{2}\sum_{x=0}^{7} F(u,v)\cos\left(\frac{(2x+1)u\pi}{16}\right)\right]\cos\left(\frac{(2y+1)v\pi}{16}\right)$$

The basic operation of the DCT is as follows:

1. The input image is N by M;
2. f(i,j) is the intensity of the pixel in row i and column j;
3. For most images, much of the signal energy lies at low frequencies; these appear in the upper left corner of the DCT.
4. Compression is achieved since the lower right values represent higher frequencies, and are often small - small enough to be neglected with little visible distortion.
5. 8 bit pixels have levels from 0 to 255.

Therefore an 8 point DCT would be:

It is computationally easier to implement and more efficient to regard the DCT as a set of basic functions which gives a known input array size (8 x 8) can be pre-computed and stored. This involves simply computing values for a convolution mask (8 x8 window) that get applied (sum m values x pixel the window overlap with image apply window across all rows/columns of image). The values are simply calculated from the DCT formula.

3.5 QUANTIZATION

Quantization is achieved by dividing each element in the transformed image matrix by the corresponding element in the quantization matrix. Then round off the nearest integer value. As the Quantization is a lossy process and loss of some information. This loss of the information is irreversible.

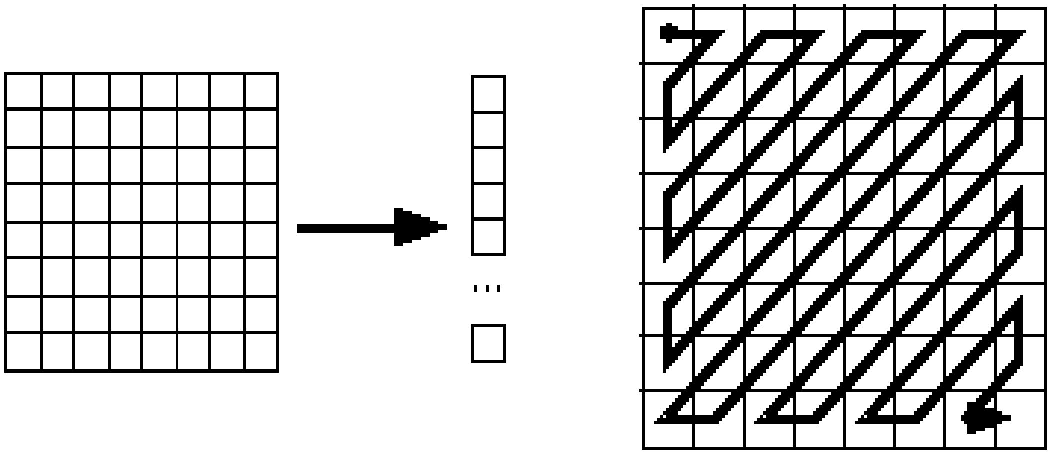
3.6 RUN LENGTH ENCODING

Run-length encoding is the next stage of the compression process. It encodes the runs of zeroes. If pixel values are correlated to their nearest pixel, then there will be sequences of the same value. Suppose the data is 00000…0(ten times). Now instead of writing ten zeroes one can send only 0-10, which means that zero occurs 10 times. Therefore by performing RLE in a zigzag manner.

3.7 ZIG – ZAG SCAN

The zig-zag scanning pattern for run-length coding of the quantized DCT coefficients is established in the original MPEG standard.

It is using in the transform coefficient Maps 8 x 8 to a 1 x 64 vector.



3.8 HUFFMAN ENCODING

The fundamental idea behind Huffman encoding is that symbols, which occur more frequently, should be represented by fewer bits, while those occurring less frequently should be represented by more number of bits.

Example of Huffman encoding

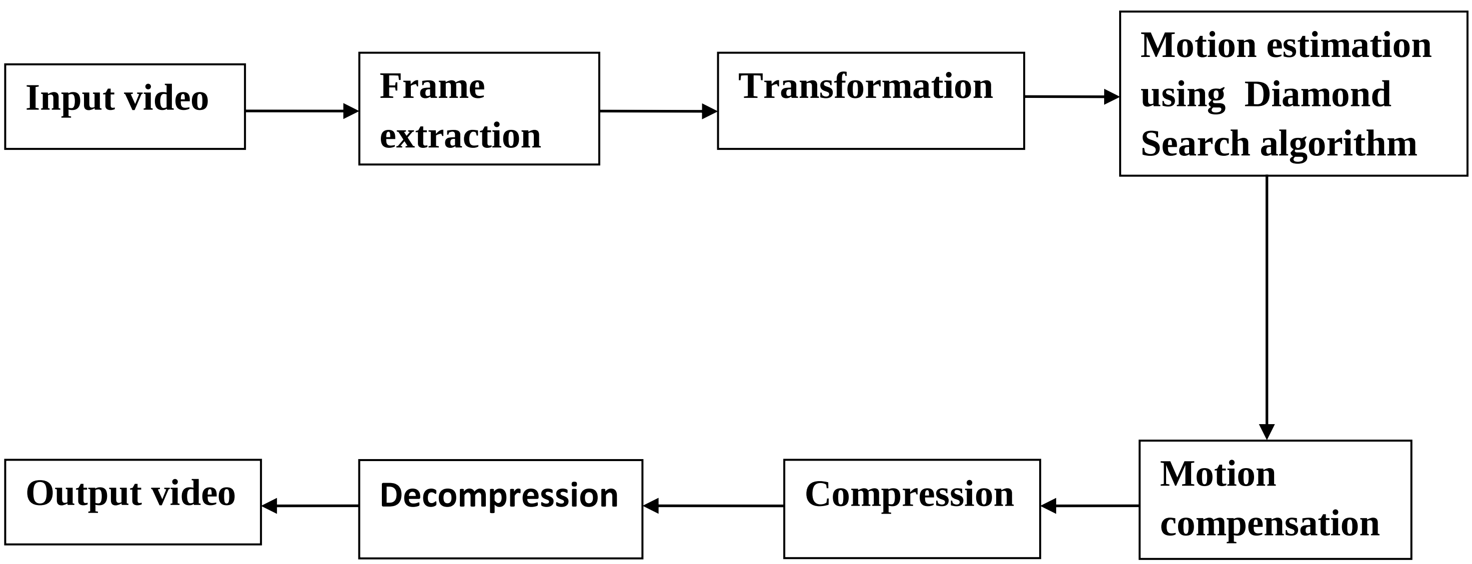
Symbol	Probability	Iteration 1	Iteration 2	Length in bits
S1	0.4 (1)	0.4 (1)	0.6 (0)	1
S2	0.3 (00)	0.3 (00)	0.4 (1)	2
S3	0.2 (010)	0.3 (01)		3
S4	0.1 (011)			3

CHAPTER 4

PROPOSED SYSTEM

4.1 OVERVIEW

This chapter describes the architectural design of the motion estimation and compensation system. Motion estimation and compensation is one of the part of the video compression. The architectural diagram of the proposed system presented in figure 3.1. The output of the each stage is the corresponding input to the further stages till the end stage.



4.1 ARCHITECTURAL DIAGRAM OF PROPOSE SYSTEM

The input video is standard video which is successfully followed the extraction of the frames of size (M x N) from the input video. And the sub block of macro block (n x n) where n $\leq M, N$ converting into macro block formation and transformation to frequency domain. The difference between the micro blocks is predicted. It is used to predict the motion estimation and compensation. The motion estimation involves various stages like sub block formation, MAD calculation and the modified techniques in diamond search is used to calculate the motion vector value.

4.2 SYSTEM ANALYSIS

4.2.1 Input frame

The input frames are extracted from the standard video. Both current frame and next frame of any dimension is taken as input to the system.

4.2.2 Macro block formation

The image of size M x N is divided into macro blocks of size (n x n) where n $\leq M, N$ which m akes the process simple and iteration. The values are subtracted to check the occurrence of motion between two consecutive frames. It is done to detect the areas of motion.

The MAD values which calculated using following formula:

$$\mathbf{MAD}(\boldsymbol{i},\boldsymbol{j}) = \mathbf{1/N^2}\sum_{\boldsymbol{k=0}}^{\boldsymbol{N-1}}\sum_{\boldsymbol{l=0}}^{\boldsymbol{N-1}} |\boldsymbol{C}(\boldsymbol{x}+\boldsymbol{k},\boldsymbol{y}+\boldsymbol{l}) - \boldsymbol{R}(\boldsymbol{x}+\boldsymbol{i}+\boldsymbol{k},\boldsymbol{y}+\boldsymbol{J}+\boldsymbol{l})\,|$$

where,

N is the size of the macro block.

(x, y) as the origin of the macro block in the Target frame.

$C(x + k, y + l)$ be pixels in the macro block in the Target (current) frame

$R(x + i + k, y + j + l)$ be pixels in the macro block in the Reference frame,

k and l are indices for pixels in the macro block

i and j are the horizontal and vertical displacements.

4.2.3 Micro Block Formation

Now the original orthogonally transformed frames are taken and the areas that are marked is divided into micro blocks of size less than the fixed size of the macro blocks.

4.2.4 Transformation

Transformation is used to transform the frames into transform co-efficient. The transform coefficient is called as a pixel values.

4.2.5 Motion Estimation

The motion vectors of each micro block is calculated by proposed block matching algorithm with Diamond Search and the output of this stage is motion vectors of each micro block.

Motion estimation is done by performing block matching in the search area which is optimal with respect to the mean absolute difference (MAD).

4.2.6 Diamond search

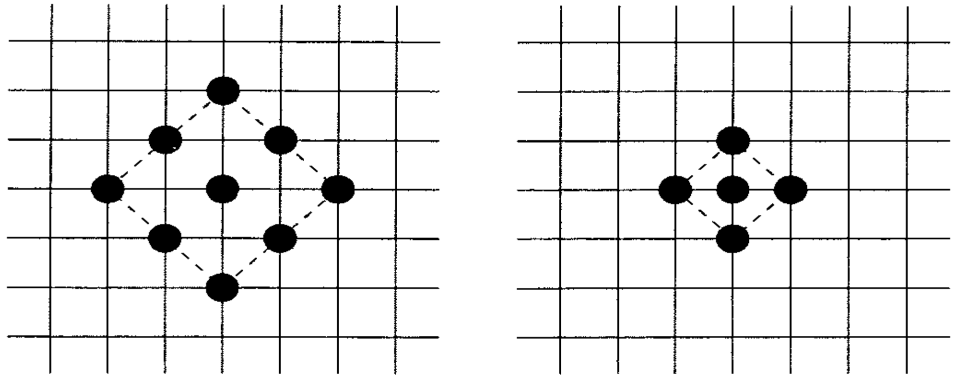
Diamond Search algorithm increases the possibility of finding the, global minimum point located inside the search pattern. Therefore, the DS algorithm tends to produce smaller or at least similar motion estimation error compared with other fast BMA's.

Diamond search contains two types of diamond patterns.

(a)Large diamond search pattern (LDSP)

(b)Small diamond search pattern (SDSP)

The first pattern of LDSP contains nine checking points from eight points surround the one centre point. Then another pattern contains five checking points from which four surround the one centre point.



(a) Large diamond search pattern (LDSP) (b) Small diamond search pattern (SDSP)

4.2.7 Motion Compensation

The motion vectors produced from the above proposed method are utilized in the motion compensation process in order to produce the predicted frame. The motion compensated frame is thus produced by adding the motion vector to the current frame.

4.2.8 Output Frame

The motion compensated frame is provided as the input to the compression technique where the coefficients are quantized and encoded to produce the output compressed frame.

4.3 SYSTEM ENVIRONMENT

4.3.1 Hardware

Processor : Any Processor above 1.2 GHz

RAM : 128 MB

Hard Disk : 10 GB

Input Device : Standard Keyboard, Mouse

Output Device : VGA Monitor

4.3.2 Software

Front-End : Java

CHAPTER 5

PROPOSED MOTION ESTIMATION AND COMPENSATION TECHNIQUE

The proposed technique aims to reduce the computational complexity also increases the accuracy. The stages are;

- Macro block conversion
- Motion estimation
- Motion compensation
- Performance measure

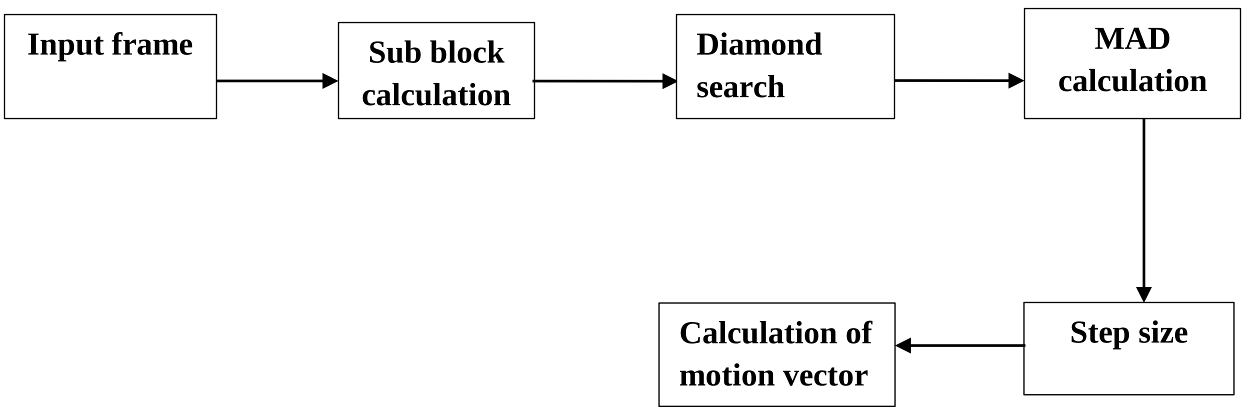
5.1 MACRO BLOCK CONVERSION

Macro block is a processing unit in video compression. A macro block is divided into transform blocks which serve as input to the linear block transform. Output of every stage is similarly input to the next stage.

5.2 MOTION ESTIMATON

The block matching motion estimation (BMME) to detecting the temporal redundancy between successive frame. Motion estimation is the process of determining motion vectors that describe the transformation from one image to another usually from adjacent frames in a video sequence.

The motion vectors may relate to the whole image or specific parts, such as rectangular blocks, arbitrary shaped patches or even per pixel.



5.1 THE ARCHITECTURAL DESIGN FOR PROPOSED MOTION ESTIMATION

The micro blocks formed are taken as input for motion estimation. The diamond search algorithm uses a uniformly distributed search pattern in each diamond search pattern regularity .

The sub blocks at the distance of step size is picked, one from the current frame, for which the match block is to be found out and nine blocks from the subsequent frame. The difference in the pixel values of sub blocks between both frames is calculated.

Motion estimation is done by performing block matching in the search area which is optimal with respect to the mean absolute difference (MAD).

Algorithm : Proposed system of Motion estimation and compensation

Input : A frame and its subsequent frame from a standard video

Output : Motion compensated frame.

Begin

Step 1: Pick an initial step size. Pick a centre block and 8 x 8 sub blocks at a distance of step size from the centre block in frequency domain.

Step 2: Calculate the difference between each sub block with the centre block of current frame.

Step 3: Calculate the Mean Absolute Difference, commonly known as MAD, using the average of the difference calculated in Step 2.

Step 4: Fix the block with the lowest MAD as the best match block.

Step 5: Double the step size. Move the centre to the best match block.

Step 6: Repeat step 1 to step 5 till the step size becomes greater than 8.

End

5.3 MOTION COMPENSATION

Motion compensation is an algorithmic technique used to predict a frame in a video, given the previous and future frames by accounting for motion of the camera and objects in the video.

In reference to a video file, this means much of the information that represents one frame will be the same as the information used in the next frame.

Using motion compensation a video stream will contain some full frames then the only information stored for the frames in between would be the information needed to transform the previous frames into the next frame.

5.4 PERFORMANCE MESURE

To evaluate the effectiveness of the proposed Discrete Cosine Transformation based motion estimation and compensation scheme, standard measure viz. Mean Square Error (MSE), is used.

The Mathematical formula for computation of MSE is:

$$\mathbf{MSE} = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - \mathrm{K}(i,j)^2]$$

where $I(i,j)$ and $\mathrm{K}(i,j)$ represent the intensity of the actual frame and resultant frame pixel positions at (i,j) and m , n are the height and width of the frame.

CHAPTER 6

EXPERIMENT AND RESULTS

The proposed motion estimation and compensation scheme are experimented with 20 standard benchmark videos, with pixel values in the range 0-255 in each of the RGB colour space. One such standard frame is presented in Figure 6.1 (a) representing the current frame and (b) representing the subsequent frame.

The current and the next frame are in RGB colour model and are partitioned into blocks and subjected to Discrete Cosine Transformation as described in chapter 3.

In addition to that, both the frames are subtracted to detect the areas of the motion. MAD values are calculated for each and every block by fixing the threshold as 32 as described in previous chapter. Now, the original frames are taken and areas of motion is subjected to micro block formation i.e., the frame is divided into blocks. This is only done for the blocks where MAD is greater than the fixed threshold. After the micro block formation diamond search is applied. For the blocks, where the mad value is equal to zero, the motion vector is kept as (0, 0) and for the other blocks the motion vector is calculated.

The diamond search as described in the previous chapter is performed with initial step size as one and doubled iteratively. Later, the motion vectors produced are added to current block to obtain the motion compensated frame as described in previous chapter.

The results of proposed motion estimation and compensation corresponding to the video frames shown in figure 6.1 (a) and figure 6.1 (b) are presented in Figure 6.2.

Fig 6.1(a) Current frame

Fig 6.1(b) Next frame

FIGURE 6.2. Results of motion estimation and compensation with corresponding to the video frame shown in figure 6.1.

FIGURE 6.3. Results of compressed final output of the motion compensated image shown in figure 6.2.

In order to measure the distortion between the actual frame and the resultant frame, MSE has been used as described in sub section 4.4 The lesser value of MSE denotes the better compensation of the motion in the predicted frame.

The performance comparison between the proposed technique and existing methods are presented in a tabular form in table 6.1

TABLE 6.1. Results of performance of proposed scheme and comparison with existing schemes

Technique	**MSE value**
Proposed Motion Estimation and Compensation scheme	3.07
Integer-pel Motion Estimation in DCT using TSS	6.81
Half-pel Motion Estimation in DCT	5.75

CHAPTER 7

CONCLUSION

7.1GENERAL DISCUSSION

In recent years, huge volume of multimedia is being transmitted over network due to rapid improvement in communication technology. This data includes video and for that, video compression is one of the enhancing fields for storage purposes. This results in easy storage and transmission of video with reduced network bandwidth. These methods also influence the visual quality of the reconstructed video after video compression.

With an objective to obtain a good quality of reconstructed picture, in this project, initially a transform coding technique with Discrete Cosine Transformation model is presented. The motion vectors are estimated and successively used to reconstruct the predicted frame.

The Modification of the motion estimation algorithm by using variable block size and diamond search contributes to the efficiency of the technique. The model has been experimented with standard bench mark images and the performance is measured with MSE, besides comparing with standard existing schemas.

7.2 SUMMARY

The contributions made in the project work are summarized below:

- Accuracy in motion vectors as motion estimation is carried out in frequency domain

- The usage of proposed motion estimation algorithm i.e., diamond search method predicts the match block exactly which improves the quality of the reconstructed frame.

7.3 FUTURE WORKS

Motion estimation using diamond search followed by motion compensation in frequency domain is expected to achieve low bit rate DCT video compression. This results in easy storage and transmission of video with reduced network bandwidth. Also, this work provides future scope for performing video compression in frequency domain with low bit rate. Also, reduce the complexity and the deblocking filter is planned to be devised for the reduction of blocking artefact after the compression of the frames.

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