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Performance Evaluation of Low Bitrate Video Compression using Adaptive Motion Matching

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Abstract: The main goal of evolving image/video coding standardization is to achieve low bit rate, high image quality with reasonable computational cost for efficient data storage and transmission with acceptable distortion during video compression. The current scheme improves the generic decimation-quantization compression scheme by rescaling the data at the decoder side by introducing low complexity single-image Super Resolution(SR) techniques and by jointly exploring the down sampling/up sampling processes. The proposed approach uses a block compensation engine introduced by using Motion Matching based Sampling, quantization and scaling in order to reduce data processing/scanning time of computational units and maintains a low bit rate.This method scans the motion similarity between spatial and temporal regions for efficient video codec design and performs 2D correlation analysis in the video blocks and frames. This video compression scheme significantly improves compression performance along with 50% reduction in bitrate for equal perceptual video quality. Our proposed approach maintains a low bitrate along with reduced complexity and can achieve a high compression ratio.

Keywords: Super_Resolution, video compression, Up/Down sampling, Block Compensation, Motion Matching, Motion Similarity, Video Codec, throughput.

I. Introduction

Digital video communication is one of the important stream and it is being used in a wide range of applications like HDTV, video telephony, DVD and teleconferencing. A Digital video is a representation of moving visual images in the form of encoded digital data. Each picture in the digital video sequence is the 2D projection of the 3D world. The digital video is captured as a series of digital pictures or sampled in space and time from an analog video signal. A frame of digital video can be seen as a 2D array of pixels. Each pixel value represents the color and intensity value of a specific spatial location at a specific time. The Red-Green-Blue (RGB) color space is typically used to capture and display the digital pictures. Each pixel is represented by one R, G, and B components. Most of the video compression standards are based on a set of principles that reduce the redundancy in order to meet the severe bitrate requirement when transmitted over bandwidth limited channels. Numerous Algorithms have been developed to address the temporal resolution improvement of a video sequence. The most prevalent one is the Block Matching Algorithm (BMA) which is utilized to derive the motion vector of each block to be interpolated frame.

The goal of the proposed algorithm is to improve the quality of up-sampled frames while keeping the down-sampled frames faithful to the original ones. To decrease the space and computational complexity of the proposed algorithm, a block-wise implementation of the proposed down-sampling method is also provided.Unlike image compression in video compression we use steps like motion estimation and video compensation to reduce redundancies and irrelevancies and to reduce time complexity. The steps of motion estimation and compensation make compression more efficient and accurate.

II. Related Works

In this section, a review of different video compression techniques and performance parameter is made so that an efficient codec can be designed.

R. Sudheer Babu and Dr.K.E.Sreenivasa Murthy,presented a paper entitled “A Survey on the Methods of Super-Resolution Image Reconstruction” this provides knowledge about various approaches to the super-resolution problem – frequency domain techniques, spatial domain techniques and the Bayesian (MAP) approach and the set theoretic POCS methods were compared. The suggested future works were Motion Estimation, Degradation Model and Restoration Algorithm [1].

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MuzhirShaban Al-Ani and Talal Ali Hammouri,presented a paper entitled “Video Compression Algorithm Based on Frame Difference Approaches”,this explores about a video compression approach,based on frames difference approaches are that concentrates on the calculation of frame near distance. Many factors are applied in the selection of meaningful frames,by similar frames are eliminated[3].

S.Ponlatha and R.S.Sabeenian, presented a paper entitled “Comparison of Video Compression Standards”,this describes the emerging standards and new video compression techniques such as H.265 and VP8.This work is designed to improve the compression factor and thereby lowering the computational overhead[5].

S. Bhuvaneswari, A. Anitha and P. Narmada Devi, presented a paper entitled “Image Compression using High Efficient Video Coding (HEVC) Technique”,this introduces the parallel time multiplexed 2-D architectures for each 8*8 data blocks.Designs were systematically assessed and compared and concludes DCT approximation is best in terms of low computational complexity and high speed[8].

Georgios Georgis, George Lentaris and Dionysios Reisis, presented a paper entitled,“Reduced Complexity Super-Resolution for Low-Bitrate Video Compression”this improves a generic decimation-quantization compression scheme by introducing low complexity single-image super resolution techniques for rescaling the data at the decoder side and by jointly optimizing the downsampling / upsampling processes. The enhanced scheme achieves improvement of the quality and system’s complexity compared to conventional codecs and can be easily modified to meet various diverse requirements.[14]Finally, we note that decimation_quantisation scheme along with joint exploration of up/downsampling have been also utilized in various video compression extensions, such as Scalable Video Coding (SVC) and Multiview Video plus Depth (MVD)

The paper is organized as follows, Section 2 shows the decimation-quantization compression scheme along with Motion Estimation and Compensation with respect to H.265 standards along with the description of proposed methodology. Section 3 discusses about the results and performance analysis and finally section 4 concludes the project.

III. PROPOSED SCHEME

The main theme of this thesis is to design a efficient H.265/HEVC video codec with low complexity and low bitrate**.**To design an efficient low bit rate video transmission video codec with high compression ratio,a highly accurate Block Matching based Adaptive Motion Estimation and Motion Compensation technique along with upsampling/downsampling is proposed.Motion Estimation (ME) is made by Cross Diamond Search(CDS) under Block Matching Algorithm.We are eliminating the redundancy in the input video by using Block Matching Algorithms(BMA).The number of search points and minimum motion vector are also the important factors..

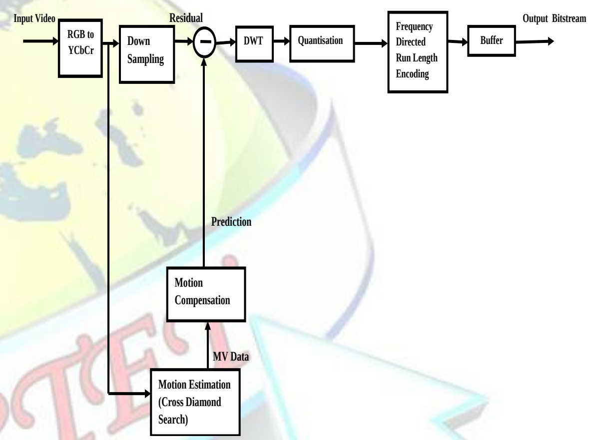

Figure 1 Block Diagram of Encoder

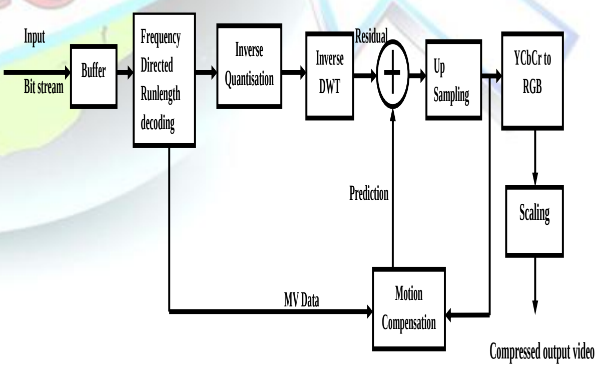

Figure 2 Block Diagram of Decoder

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Figure 1 and 2 portrays the block diagram of the encoder and decoder of video compression respectively. The proposed system methodology is described as follows

3.1 METHODOLOGY

The video compression is the most useful and comparatively new field in data compression.The proposed system we uses a decimation_quantisation scheme along with joint exploration of sampling, it hybridizes the properties of DWT with the help of Cross Diamond Search (CDS) Algorithm for Motion Estimation and Frequency Directed Run Length Coding.

i) Video to Frame Conversion

At first we convert the video to frames by taking .avi video as input and number of frames per seconds(FPS) obtained as frame output can be 20.We propose to write the code in such a way that we can get output frames in any format like .jpg, .png, .tiff etc. The image frames will be saved serially like 1.jpg, 2.jpg, 3.jpg, 4.jpg .

ii) RGB to YCbCr colour conversion

RGB input image stores the colour in form of RBG that is, Red, Blue and Green planes but YCbCr stores colours in form of Luminance (luma) or brightness and Chrominance (chroma) or hue. The human eye is more sensitive to luma information than chroma information. Therefore to offer improved compression ratio we convert the RBG planes of the video frames into YCbCr planes.

iii)Sampling

The down sampling and up sampling schemes are combined to preserve all the low frequency DWT coefficients of the original image. The original high bit rate video is downsampled by 2 to low resolution video at the encoder side. The encoder and the decoder are conventional blocks generating the compressed bit stream and the decoded frames respectively.To obtain the original size video up sampling is done by 4 at the decoder side. In this project, the down sampling factor is 2 and up sampling factor is 4.

iv)Motion Estimation and Compensation

The objective of Motion Estimation and Motion Compensation is to calculate the motion vectors or in simple words moving pixels, between reference frame and current frame.Changes between frames are mainly due to the movement of objects.Using a model of the motion of objects between frames, the encoder estimates the motion that occurred between the reference frame and the current frame. This process is called Motion Estimation (ME). The encoder then uses this motion model and information to move the contents of the reference frame to provide a better prediction of the current frame. This process is known as Motion Compensation (MC).The reference frame employed for ME can occur temporally before or after the current frame.If we compress the whole frames of the video at once we have to compress redundant data over and over again which is unnecessary and lengthy process.The most commonly used ME method is the Block Matching Motion Estimation(BMME) algorithm, this algorithm is used in this project.An effective and popular method to reduce the temporal redundancy called block matching (BMME),this inspires us to investigate why DS pattern can yield speed improvement over some square shaped search patterns.In this project, Cross Diamond Search(CDS) algorithm is proposed to attain a computationally efficient search with a reasonable distortion performance , by computing the sum of absolute difference (SAD) values for fewer search locations in a given search range.Motion guesstimate and reparation is use in both compression and decompression.

A.**In Compression**: In compression we calculate difference between reference frame and current frame and send the difference matrix or difference frame for compression.

B. **In Decompression:** After decompression the resultant data is not a video frame it still a difference frame to achieve reconstructed frame we add the reference frame to that difference frame.

The main advantage of motion estimation and motion compensation step is that it reduces the time complexity of the system and also reduces the size of data.

v)Discrete Wavelet Transform (DWT)

The transform unit reduces spatial redundancy within a picture. Its input is the residue picture calculated by the motion estimation unit. Since the residue picture has high correlation between neighbouring pixels, the transformed data is easier to compress than the original residue data since the energy of the transformed data is localized.2D-DWT is obtained via the implementation of low pass and high pass filters on rows and columns of image respectively. A low pass filter and a high pass filter are chosen, such that they exactly halve the frequency range between themselves.DWT is a multispectral technique used for converting signal or image into four different bands such as low-low (LL), low-high (LH), high-low (HL) and high-high (HH). 2D-Discrete Wavelet Transform (DWT) is performed at the encoder side only to the first frame of the video as it doesn't have a previous reference frame and the Inverse Discrete Wavelet Transform is preformed at the decoder side.

vi)Quantization and De-quantization

The human eye characteristics allow removing a lot of redundant information in higher frequency coefficients.It is

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done by dividing each frequency component by a suitable constant and by consecutive rounding to the nearest integer to achieve more compression ratio and PSNR.The transformed data are called transform coefficients and they are passed to the quantization unit.In this system to perform quantization on the difference frame the round value of difference frame is divided by the quantization-scale.The quantization-scale used here is 2.The quantization decreases the weight of values in the matrix,the lesser the value,the less number of bits is required to be stored.Quantization reassigns the values into a direction.Dequantization is the reverse process of quantization,in dequantization we have to multiply the quantization-scale into decoded frame which is the result of decompression algorithm.Quantizing in multi-dimension, provides a means to achieve better quality and high compression ratios.Quantisation is performed at the encoder side and Inverse Quantisation is carried out at the decoder side.

vii)Frequency Directed Run Length Encoding

An effective alternative to constant area coding is to represent each row of an image or bit plane by a sequence of lengths that describe successive runs of black and white pixels.Frequency Directed Run Length Encoding is done at the encoder side,the obtained encoded values are stored in a buffer. At the decoder side Frequency Directed Run Length Decoding is done to the encoded output in the buffer for further processing.

viii)Scaling

Resizing of video frames is also required when a viewer is tuned to two different TV channels with frames from one of the channels being displayed in a corner of the screen.The resizing ratio preferably used can be of 64x64, 128x128 or 256x256. The better result of the compressed image can be displayed when the resizing ratio of 256x256.

3.2 Overview of the proposed system

Initially the input video is converted into frames and then we have to perform the whole compression process on each and every plane of the frame of the video. The planes of the first frame of video is saves as a reference frame after converting it into YCbCr rest of the planes are compressed with reference of the corresponding planes of reference frame.The plane to be transformed is called current frame and it should be in YCbCr format.The input frames are down-sampled by a factor 2 which have the same number of bits as the input signal. And the after decoding we up-sample the output of both filters and add them to get reproduced signal. After that we execute Motion Estimation and Compensation by Block Matching based Cross Diamond Search(CDS) algorithm.The result of that process is called difference frame.The Discrete Wavelet Transform is applied only to the difference frame.After quantization that difference frame is called quantized frame which is sends to encoder to compression. The output of encoder is a data which cannot be seen as a frame. To perform decompression we pass that Hexadecimal data through the decoder. Afterwards we perform de-quantization and add the reference frame to that de-quantized frame in order to perform Inverse DWT and inverse motion estimation and compensation.The process of upsampling by factor 4 is also done at the decoder side.Then further transformation of the reconstructed frame into RBG and rescaling is also done to get the desired compressed video frame output.The PSNR,MSE values along with Compression Ratio(CR) are also computed to show the better performance of the proposed system than the existing system.

3.3 Performance Evaluation

Peak signal-to-noise ratio (PSNR) is the standard method for quantitatively comparing a compressed image with the original.PSNR is measured in decibels (dB).Hence, the PSNR is calculated as

$$PSNR=10Log10\ (R^2/MSE)$$

Compression Ratio(CR) can be defined as the ratio between original frame size and compressed frame size. In general, the higher the compression ratio, the smaller is the size of the compressed file.

$$\text{Compression Ratio}=\frac{\text{Uncompressed frame size}}{\text{Compressed frame size}}$$

IV. Results And Discussion

Basically video processing can't be carried out with the entire video,so initially we have to convert the input video into frames for further processing. **Figure 1** displays the input video used in MATLAB for frame conversion.

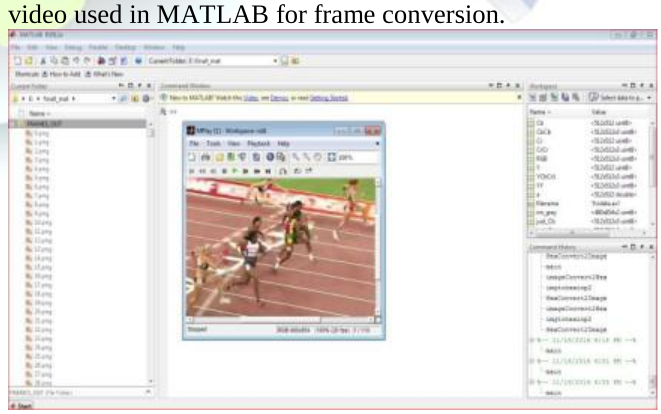

Figure 1 Video Input

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During video to frame conversion, the input video gets converted into numerous frames according to the size of the video in the rate of approximately 20 frames/sec as shown in **figure 2.**For conversion of video to frames we use the Graphical User Interface(GUI) which gives the user friendly environment.

Figure 2 Video to Frame Conversion

The video frame is converted from RGB to YCbCr as shown in **figure 3**, as humans are less sensitive to color than luminance.

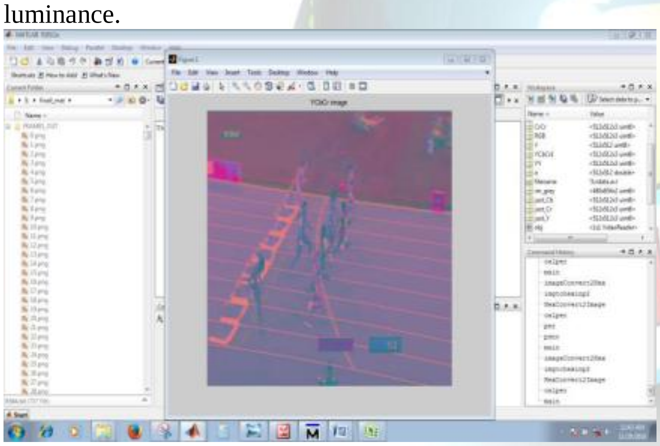

Figure 3 RGB to YCbCr Colour Conversion Output

Then we execute Motion Estimation and Compensation by Block Matching based Cross Diamond Search (CDS) algorithm on mainly considering the Absolute Difference between the current frame and reference frame, further encoding and decoding is done by using Run Length Coding(RLC) in ModelSim-Altera 6.4a (QuartusII 9.0).During the process of decoding the obtained hexadecimal text (.txt) file is Motion compensated, inverse transformed, Inverse quantized, scaled to 256x256 and the reconstructed compressed image with size reduction from 420 kb to 15.6 kb is obtained as output as in **figure 4**.

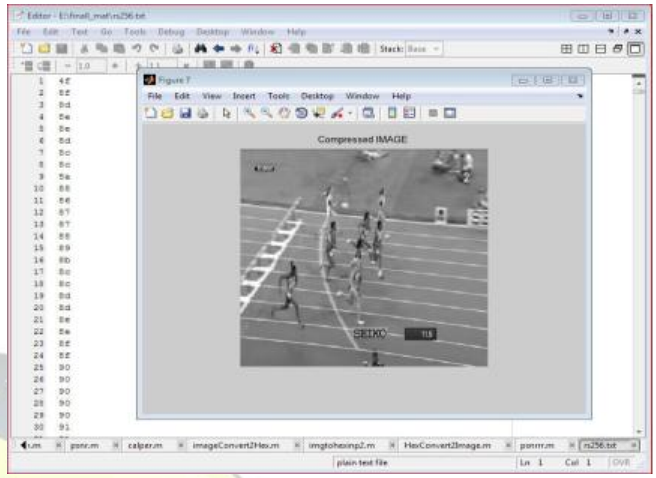

Figure 4 Compressed Image

This **figure 5** clearly concludes the reduction in MSE(Mean Square Error) on a comparison between the random frames(Frame 10,20….90) of the video input and the obtained compressed frame output(Frame 100).

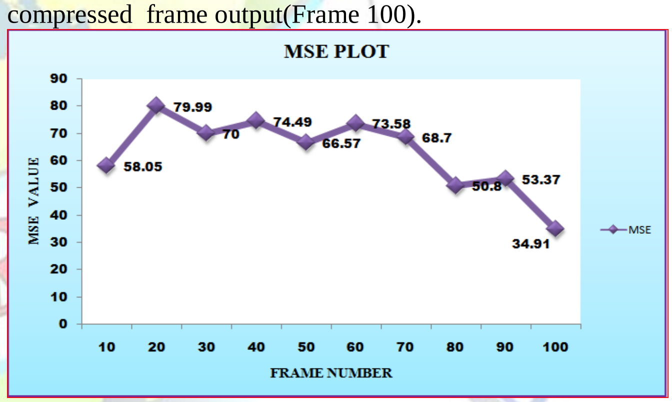

Figure 5 MSE Analysis Plot

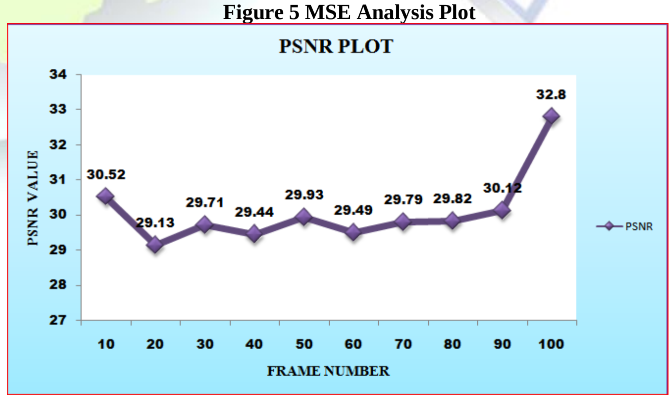

Figure 6 PSNR Analysis Plot

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This **figure 6** clearly concludes the increase in PSNR on a comparison between the random frames(Frame 10,20….90) of the video input and the obtained compressed frame output(Frame 100).The high PSNR value of 32.8 shows that the proposed system provides better results than the existing system by 3.5 dB PSNR quality improvement.

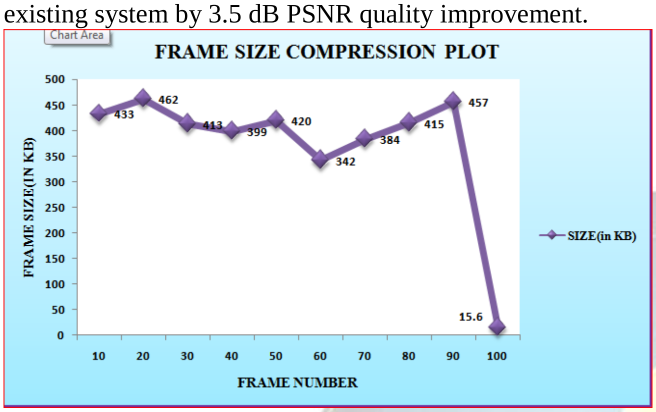

Figure 7 Frame Size Compression Analysis Plot

This **figure 7** concludes the reduction in frame size on a comparison between random frames (Frame 10, 20 ….90) of the video input and the obtained compressed frame output(Frame 100).The reduced frame size value of 15.6 KB shows that the proposed system provides better compression ratio of 26.218.The values presented in above graphs varies from video to video. In this project, to demonstrate the working of the proposed system we input athlete.avi video and all values are for this video, if any other video is used then these values may be different.

Table 1 Performance Analysis

Parameters	Obtained Value
Power	56.25 mW
PSNR(Approximately in all frames)	≈29.3 dB
PSNR(Compressed frame)	32.8 dB
MSE(Approximately in all frames)	≈66.172
MSE(Compressed frame)	34.91
Frame Size(Approximately in all frames)	≈409 KB
Frame Size(Compressed Frame)	15.6 KB
Compression Ratio	26.218

The area,power and time analysis for the designed .v files used in the process of video compression is made by using the software, Quartus II 9.0sp2 Web Edition. Better PSNR implies smaller differences between the reconstructed and the original frames thus yielding lower bit needs when coding them and, hence saving the overall bitrate when coding the whole sequence.The compressed video will be having less size than the original file and the quality of the video will be almost equal to that of the original input video.

V. Conclusion

Video Coding lies at the core of multimedia and video compression has become an important area of research due to practical limitations on the amount of information that can be stored, processed, or transmitted. In this video compression process,Motion Estimation is the most important part and it reduces 70% to 90% of the system complexity. In this project, many videos are tested to insure the efficiency of this technique, in addition a good performance results has been obtained. In order to speed up the search, a Cross Diamond Search (CDS) algorithm based Motion Estimation (ME) techniques is proposed. The simulation results of the proposed system portrays that it minimizes the prediction error and the number of search points per frame when compared to the existing system. This approach offers not only significant computational time savings but also flexibility to an encoder for heterogeneous applications working towards complexity distortion optimality. The high PSNR value of 32.8 shows that the proposed system provides better results than the existing system by 3.5 dB PSNR quality improvement. The MSE value is found to be minimized in the compressed frame output concluding the efficient design of the proposed system. The reduced frame size value of 15.6 KB shows that the proposed system provides high compression ratio of 26.218.

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