A Novel Framework of Deblocking Filter using H.264 for Enhanced Compression Performance

Pradeep Kumar N.S[1], H.N. Suresh[2]
[1]Associate Professor
Department of Electronics & Communication Engg.
South East Asian College of Engineering & Technology,
Bangalore, India
E-Mail: pradeepkumarnsvtu@gmail.com
[2]Professor
Department of Electronics & Instrumentation Engg.
Bangalore Institute of Technology,
Bangalore, India

Abstract— At present, there are availability of different forms of multimedia compression standard with many from research archives and many in research pipeline using H.264. Unfortunately, existing compression techniques leads to significant amount of blocking artifacts arising from the frames and only way to control it is with the de-blocking filter. Existing literatures using H.264 were reviewed to find using filtering using in-loop de-blocking resulting in maximized computational complexity. Therefore, the proposed system introduces a novel framework that uses enhanced H.264 that is responsible for exploring the better boundary regions selection process. A simplified encoding mechanism using rate-distortion optimization techniques is utilized that has been witnessed to minimize the computational complexity in comparison to existing H.264.

Keywords- Intra-Frame Prediction, Multimedia Files, Encoder, H.264, Bit stream.

1. Introduction

Digital compression includes giving up some level of image value for a lesser bit rate that encourages transmission and capacity [1]. Compression not just requires an abnormal state of execution from the processor additionally some adaptability in the plan since various sorts of video applications have distinctive arrangements of necessities for determination, transfer speed, and strength. Crude advanced video requires a ton of information to be transmitted or put away. For instance, without any compression, standard-definition (SD) computerized TV in North America commonly requires an information rate of more than 165 Mbps or extra than 100 GB mandatory to store up a typical motion picture. Intra-frame prediction is a feature introduced in H.264/AVC which is not present in previous standards [2][3][4]. It explores the spatial redundancy in a frame, by producing a predicted block based on spatial neighbor samples already processed in this frame. This prediction mainly acts where the motion estimation, which explores the temporal redundancy, does not produce a good match for P and B macro blocks and in intra-frames (I-frames), which contain only Intra macro blocks and the motion estimation cannot be applied. Intra frames typically occur at a lower rate than P and B frames. However, the efficient prediction on these frames is determinant to coding efficiency and video quality [5][6][7]. The existing researchers have presented results of compression efficiency and computational complexity of H.264/AVC intra-frame encoder when compared to JPEG and JPEG2000 encoders. The complexity of intra-frame encoder is based on the following steps: i) to generate all candidate prediction blocks; ii) to decide which prediction block produces the best match compared to original block; iii) to encode the chosen block and iv) to reconstruct neighbor samples for the next prediction. In a real-time intra-frame encoder hardware design targeting high-definition videos, the design space exploration is huge. A high-level hardware-based simulation model is appropriate to explore such design space, which real-time is the main design restriction. Compression essentially implies decreasing picture information. As specified already, a digitized simple video grouping can contain up to 165 Mbps of information. To decrease the media overheads for disseminating these groupings, the accompanying procedures are utilized to accomplish achieve diminishments in picture information:

- Reduce color gradations inside the image.
- Reduce color determination w.r.t fundamental light intensity.
- Remove little, undetectable parts of photos.
- Compare contiguous pictures and remove details of unaltered between two pictures.

The initial three are picture based compression schemes, where only single frames are assessed and compressed in a packed at once. The last one is or video compression procedure where distinctive neighboring frames are contrasted as a path with further diminished the picture information. These strategies depend on a precise comprehension of how the human mind and eyes cooperate to frame a complex visual framework. The designed model is based on the architecture showed in Fig 1. It is divided into four main modules: i) Sample Predictor proceeds the interpolations over the neighbor samples to generate the predicted samples; ii) SAD Calculator calculates the SAD between the predicted block and the original block; iii) I4MB Mode Decision, which compares the SADs of each prediction mode for the 4x4 block and chooses

ISSN 2229-5518

the best mode; iv) Intra Neighbors: manages the memory that stores the neighbor samples and it is also responsible for the intra encoder control. The architecture is organized in just one data path to process I4MB, I16MB and 8x8 chroma predictions. Firstly, an I4MB is predicted. In the interval which the best block for this prediction is transformed and quantized by T/Q and IT/IQ blocks, a 4x4 partition of 16MB, is processed by the architecture.

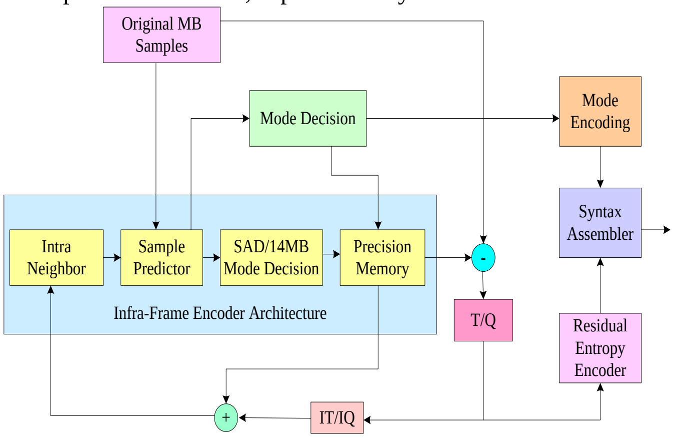

Figure 1 Intra frame encoder architecture

This approach forces the use of buffers to store the predicted samples while the final mode decision has not been taken. Sample Predictor module generates the predicted samples for the I4MB blocks, I16MB partitions, and chroma 8x8 blocks. Four samples per clock cycle are produced for each mode. In this way, after 4 cycles, the 4x4 block prediction is done for all modes in parallel. The SAD calculation module works in the pipeline with the Sample Predictor, and its function is to subtract the four predicted samples from the original MB samples, generating the difference between each sample, and accumulate these differences. So, after the first predicted line is generated, the SAD calculator starts to accumulate the SAD during four consecutive cycles. During quantization, which is the essential data source of information misfortune, the DCT expressions are separated by a quantization framework, which considers human visual observation. Higher frequencies wind up with a zero section after quantization, and space were decreased altogether.

$$FQuantised = F(u,v) DIV \ Q(u,v) \qquad (1)$$

Where Q is the quantization Matrix of measurement N. The way Q is picked characterizes the last pressure level and in this way independently. As the relationship between the adjoining pieces is high, just the contrasts between the DC-terms are put away, rather than putting away all qualities freely. The AC-terms are then put away in a crisscross way with expanding recurrence values. This representation is ideal for the following coding step since same qualities are put away beside each other; as specified the majority. A MPEG video can be comprehended as an arrangement of frames. Since two progressive edges of a video arrangement frequently have little contrasts, the MPEG-standard offers a method for diminishing this transient excess. It utilizes three sorts of edges: I-frame, P-frame and lastly B-frames. Fig 2. Shows the zig zags way for storage of the frequencies.

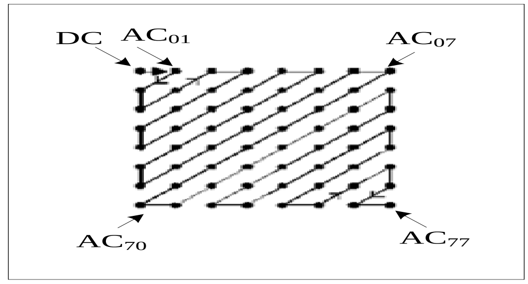

Figure 2 Zig-Zag-way for store the frequencies

The I-frames are "key-frames," which have no reference to different edges and their pressure can't be reproduced without their referencing outline, because lone the distinctions are put away. The B-edges are a two directional variant of the P-outline, alluding to both bearings. B-frames can't since they are interjected from forward and in reverse casings. P-edges and B-casings are called entomb coded outlines, though I-frames.

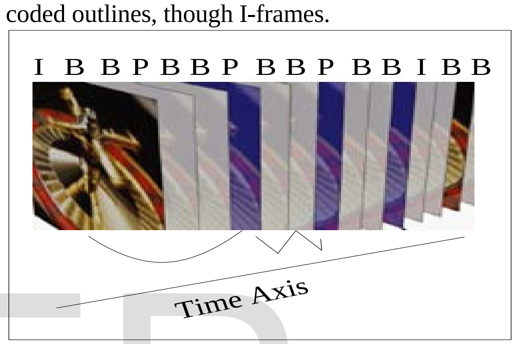

Figure 3 A MPEG frame grouping with two conceivable references: a P-frame denoting to an intra and bidirectional frame denoting to two P-frames

Fig.3. shows a MPEG frame grouping with two conceivable references: a p-frame denoting to an intra a bidirectional frame denoting to two p frames. The utilization of the specific casing sort characterizes the quality and the pressure proportion of the compacted video. I-outlines increment the quality (and size), though the use of B-casings packs better additionally delivers poorer quality. The separation between two I-edges can be viewed a MPEG-video. By and by taking after succession appeared to give great results for quality and pressure level: IBBPBBPBBPBBIBBP. Section 2 document closely investigates and writes literature reviews on the reconstruction of intra-frames. Section 3 briefly explains the issues in video compression. Section 4 clearly presented a proposed methodology of this paper. Section 5 gives the demonstration of the proposed method with results. Finally, Section 6 presents the conclusion of this paper alongside the future research direction of this paper.

2. Related Work

This section of document closely investigates and writes an inference about intra-frame prediction and a reconstructing mode decision of video input signals.

Van et al. [8] proposed a strategy to lessen the interpreting multifaceted nature of the versatile video stream by sharing the intra mode prediction amongst layers and wiping out all other between layer conditions. Zhu et al. [9] executed a streamlined Rate-Distortion (RD) cost estimation calculations, which depend on the Hadamard change and the changing assessment without the standard remodeling. Hota et al. [10] presented a new method for intra mode decision of blocks in video encoding, with possible neighbor pixel selection comprising of both source and reconstructed pixels, is presented. Jridi et al. [11] proposed technique depends on two key thoughts. Reconstructed results are found to approve the logical model and demonstrate that the proposed expectation takes out more excess calculations than the current strategies. Chakareski et al. [12] investigated an existing system for overcoming encoding problems. Varadarajan et al. [13] presented texture-based active sensors such as the Kinect to offer advantages in comparison with traditional 3D capture systems. The algorithm detects salient edge-like structures in RGB and D images and performs cross-coding across the modalities to yield a scalable system for 3D video coding.

Motra et al. [14] proposed a strategy to diminish the quantity of intra-forecast modes. This technique arranges to utilize associated data to accelerate intra mode decision. Lee et al. [15] proposed a calculation for video encoding system. Park et al. [16] presented a method that skips the complex encoding processes of the coding unit (CU) for HEVC intra-frame coding. To speed-up the encoding process that recursively explores all sizes of CUs, most researchers have exploited spatial information thus far. On the other hand, the temporal correlation among frames has not been thoroughly investigated. The temporal correlation as an early termination method for skipping ineffective unit sizes and associated cost. The efficiency of the proposed method, showing a 32% time saving with a 0.2 % BD-rate loss on average compared to HEVC test model 10.0 under all-intra configuration.

Chen et al. [17] presented a technique based on block coding algorithm for HEVC intra-frame coding. Pixels in each prediction block are divided into two parts: half pixels are coded by a smart padding technique together with a constrained quantization algorithm; whereas the other half are reconstructed by simple linear interpolations along the prediction direction utilizing the neighboring reference pixels and the first half coded pixels. In the implementation, a competition mechanism is employed between this new method and the original HEVC intra-coding to choose the best mode for each prediction block. Simulation results show that about 2% BD-rate reduction has been achieved on HEVC's intra coding. Sanchez et al. [18] introduces the depth map coding that includes four Depth Modeling Modes and these new features have inserted extra effort on the intra prediction. This extra effort is undesired and contributes to increasing the power consumption, which is a huge problem especially for embedded-systems. Huang et al. [19] presented an H.264/AVC is an effective standard for video coding.

Li et al. [20] has adopted Haar transform and presented an efficient technique to categorize the block edge characteristics. The result of the training was found to significantly minimize the quantity of computational operations in the edge model determination. In order to ensure optimal video compression technique, it is also essential to undergo the study of transcoding procedure to visualize the acceptability of the compatibility issues using H.264. Study in this direction was carried out by Liu et al. [21] where the authors have considered mobile transcoding of MPEG-2 video to H.264/AVC format. The outcome of the study shows that energy trend of DCT of macro-blocks of MPEG-2 is potentially correlated to the intra-prediction modes of H.264/AVC. Study towards fast intro-coding scheme was emphasized by Wu et al. [22], where the authors have discussed about the existing outcomes of the study and showed significant reduction in the encoding time, however, there exist low quality video while reconstruction. Similar work is presented by Shen et al. [23], where quad tree structured Coding Unit (QTS-CU) is used for provisioning the recursive splitting process into N- equal sized block, where N=4. The mechanism exhibits effective correlation among the three namely 1) prediction mode, 2) Motion Vector and 3) Rate distortion cost for varied depth levels and spatially-temporally coding units with overall minimization of 49% to 52 % computational complexities on multiple kinds of video sequences for different coding mechanisms. Studies toward adoption of orthogonal modes elimination strategy was seen in the work of Peiman et al. [24]. The authors have used RD theory and selected only one of the orthogonal modes. Studies towards accelerating the mode decision process is also witnessed in literatures for the target of minimizing the quantity of methods mandatory to be tested for each macro blocks.

You et al. [25] have used RD theory in the H.264 encoder to enhance coding performance by considering the accuracy of intra-prediction for the next blocks during the mode-decision process of present blocks. So, the computational complexity still exists in this system in spite of enhanced coding efficiency. There exist many literatures which witnessed a hardware approach or realization of compression techniques for video as an FPGA implementation. For better coding efficiency, it is required to furnish better coding interoperability. Study in such direction was carried out by Su et al. [26] to provide the interoperability between MPEG-2 and H.264/AVC. The investigational outcomes disclose that typical 85% of computation time (a speed-up factor of seven) can be reduced compared to the encoding schemes. But one of such significant study for ensuring low complexity was observed in the work carried out by Bharanitharan et al.[27] that adopts the adopts discrete cross differences for minimizing the unlikely candidate modes in the RDO calculation. The study includes both the vertical as well as horizontal difference among multiple locations using edge features vector.

3. Problem Identification

Basically, majority of the researchers working on H.264 standard deploys the deblocking filter for the purpose of enhancing the signal quality of reconstructed outcome while performing decoding. The major problem in this operation is that it uses motion compensation based prediction as well as Discrete Cosine Transformation for eliminating any forms of artifacts that are incorporated by block-based operations. At present time, all the researchers reported of improved performance with respect to video frames. However, such operations are carried out at the cost of computational complexities that are never being found to be emphasized on any existing techniques. Another significant identification of problem is precise identification of edges for a given frame which is very much essential operation for constructing deblocking filter.

4. Proposed Methodology

The prime purpose of the proposed system is to design a novel deblocking filter to reduce the computational complexity for reconstruction of intra-frame of a video signal. The schematic diagram of the proposed system is exhibited in Fig.4. The proposed system will apply the principle of H.264 that considers both forward and reconstruction path for data flow. The proposed system considers and input frame for the purpose of encoding, where each and every frame is subjected to processing in both inter and intra mode. In due course of H.264 encoder design, the predicted macro block is created depending on the newly generated reconstructed image. Here, the input video is divided into a number of frames; then each frame is subjected to quantization as well as the RGB image is converted to Gray format. The encode I-frame by appending the I-frame header by '111 1'. Append I-frame bit stream by 11100 to this signal. Similarly, the P-frame is encoded by appending P-frame header by '0000'. Then perform inverse quantization scheme. However, in the proposed system intra-frame coding is performed by formulating the samples of predicted macro-blocks in the current frame, which was priory encoded and were subjected to reconstruction.

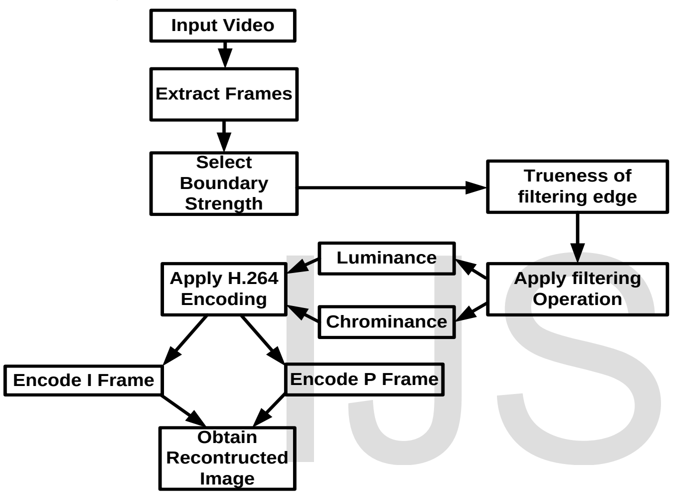

Figure 4 System design architecture of the proposed method

Finally, the predicted macro block is subtracted from the existing macro block to generate the remnant macro blocks. The proposed system also performs various mathematical operations like transformation, quantization, and inverse operation for both. By adopting scalar quantization technique in the proposed system, the scaling is performed. The proposed system also considers multiple directions for performing intra-prediction, where the outcome of the study was evaluated with PSNR value, Bit stream value as well as encoded time for the different value of quality parameters as well a different frame length. The evaluation of the proposed system is performed in standard datasets. The proposed system is implemented in standard 32 bit Windows OS with 4 GB RAM considering Matlab as the programming tool. The implementation part of the proposed system is carried out considering H.264 encoder design principles that adopt the mechanism of intra-coded macro blocks.

The technique mainly performs selection of the strength of boundary using modes of coding corresponding to adjacent blocks of 4x4. The trueness of the edge of filter is then analyzed which results in switching off the filtering process in case of positive edges. The chrominance as well as the luminance block is subjected to the filtering operation for each 4x4 blocks depending on the strength of boundary. The mechanism finally ensures that computational complexity associated with deblocking operation be addressed unlike existing system.

The significant steps of implementing the proposed deblocking filter using H.264 are as follows:

- *Read a video file.*
- *Encoding input parameters.*
- *Display frames.*
- *Setup HxW, macroblock size of P frames.*
- *Get first frame.*
- *Convert RGB to Gray image.*
- *Initialize Quantized and inverse quantized matrix.*
- *Allocate Buffer for Reconstructed Image.*
- *Perform quantization.*
- *Extract input video sequence dimension.*
- *Perform total bits per frames.*
- *Set height, width and block size of image.*
- *Encode I-frame*
    - *Append I-frame header by ('1 1 1 1')*
    - *Apply Proposed Deblocking Filtering (H.264*
    - *Append I-frame bitstream ('1 1 1 0 0 …')*
    - *Reference frame [P-frame].*
- *Encode P-frame.*
    - *Append P-frame header by ('0 0 0 0 ')*
    - *Apply Proposed Deblocking Filtering (H.264*
    - *Append I-frame bitstream ('1 1 0 0 …')*
    - *Extract P-frame.*
- *Perform Inverse Quantization*
- *Perform Reconstruct Frames.*
- *Repeat Step 6 and Step 7 for RGB format.*
- *Calculate PSNR, Bit stream, and Time.*

5. Algorithm Implementation

The video file is processed in order to extract the number of frames and especially I frame. Therefore, the real input to the algorithm are number of frames, I frame, and extracted size of the macro blocks. The number of frames n is initialized followed by further input of quality parameter QP.

Algorithm for Intra-Frame Prediction

Input: n (number of frames), I (I-frame), b_s (size of macroblock), h/w (height and width of frame), H (Header), QP (Quality Parameter)

Output: I_{rec} (Reconstructed Image)

Start

1. init *n*, I, b_s, QP

4. bitstream→[H '1111']

5. **For** all seq

6. Seq=*deblock_Filt* (seq, QP)

7. **End**

8. F_{rec}→Seq

ISSN 2229-5518

9. Encode P-Frame

10. Extract I_{rec}

The process of encoding setup initiates by block size with computed height and width. The first part of the encoding process involves the usage of header. The dependable parameters of header matrix are height h, width w, quality parameter, first and last frame. All the elements of header matrix are mapped in form of another matrix called as bits. The second step is to carry out encoding I frame. For this purpose, I Frame header '1111' is appended with the bit-stream followed by extraction of the I frame. We apply a novel cost function of intra-frame prediction mode decision that is responsible for obtaining reduced encoding time. The algorithm for the cost function takes the input of sequence and quality parameter. It first extracts the size of the sequence. The algorithm for cost function reads the row (m) and column (n) element of the frame with a difference of 16 units followed by extraction of coded header. A conditional constructs C in formed with two variable i and j whose values corresponds with a series of elements starts with (m, n) and ends with (m+15, n+15) with a difference of 4. Hence, we consider the condition of no prediction when both i and j value corresponds to 1. Similarly, we consider horizontal prediction for i value corresponding to 1 and vertical prediction if j value is corresponding to 1. We also apply encoding using Golomb codes genc that computes the difference of current and previous frame. A new function of cost optimization is used which is mainly responsible for minimizing the coding error. It uses integer-based transform followed by quantization and encoding. This function significantly control the response time of the algorithm while performing encoding operation.

6. Results and Discussion

The experiment considers analyzing the outcomes on variation values of quantization factor. Table 1 to 3 shows the visual outcomes of the proposed system considering Foreman frame as a reference where the outcomes were analyzed on different quality parameters (0, 10, 20, 30 and 40). All the outcomes are reconstructed frames with higher sharpness in the outcome frames. The outcomes also show that proposed system doesn't require higher end quantization, as the outcomes show that better resolution figures can be obtained till the quantization factor of 10. Although increasing quantization factor doesn't affect the image quality significantly, still it is not required. In all the tables, we can observe that our proposed method JM gives better PSNR value, i.e., good perceptional quality of the video, less bitrates, good compression ratio and very less encoding time is required to encoder all the frame present in the video signal. We also show that for a different video, we calculated all the parameters, then also our proposed method achieves the good perceptional quality of video frames. For this purpose, a video clip is selected whose size is 100 MB with frame width of 320 and frame height of 240. The frame rate of the considered clip is 30 frames per second.

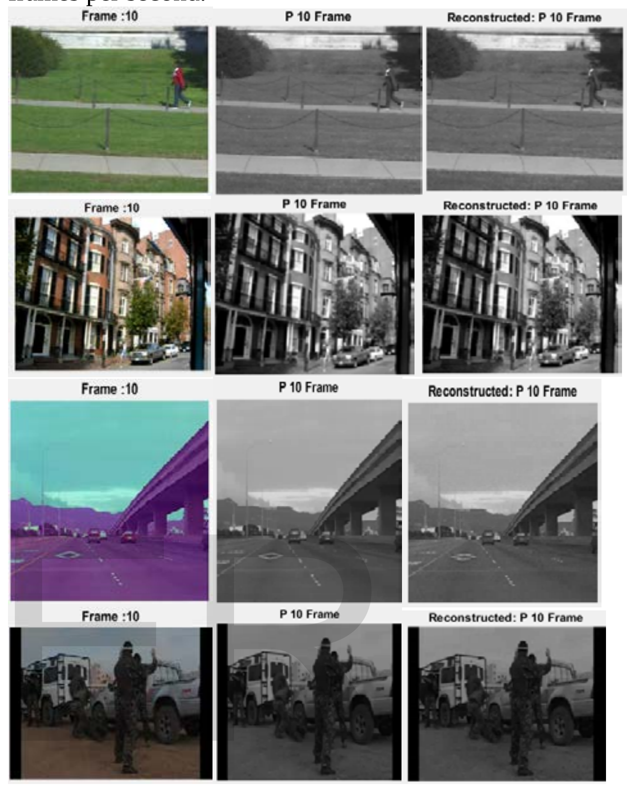

Figure 5 Visual Outcomes

Fig.5 showcase the visual outcome where the first one show original frame, second one shows the process intermediate frame while last one is the reconstructed frame. All this frames are finally assessed for its effectiveness with respect to bitrate, PSNR, and Encoding Time (T). The comparative analysis is carried out with respect to existing H.264 and proposed H.264 for exploring success rate in deblocking mechanism.

Table 1 Comparison based on PSNR, Bitrate and Encoding Time (No of Frames=10)

QP Value	Method	PSNR (in dB)	Bitrate	T (Sec)
QP=10	Existing	52.074621	90022	1.831013
	Proposed	52.129783	88472	1.196662
QP=15	Existing	47.940211	63952	1.566638
	Proposed	47.948912	62330	0.958345
QP=20	Existing	43.794239	42251	1.379040
	Proposed	43.889276	41079	0.766323

QP=25	Existing	40.262793	26932	1.268066
	Proposed	40.314927	25839	0.651369
QP=30	Existing	37.211268	16188	1.198137
	Proposed	37.112088	14734	0.580196
QP=35	Existing	34.331348	10945	1.172708
	Proposed	34.191072	9220	0.552510
QP=40	Existing	31.460256	8151	1.164500
	Proposed	31.377319	6276	0.535335

Table 2 Comparison based on Computational Time (No of Frames=10, 50 and 100)

QP Value	Method	T (Sec) Frames=10	T (Sec) Frames=50	T (Sec) Frames=100
QP=10	Existing	1.831013	1.865440	3.513156
	Proposed	1.196662	1.202230	1.491595
QP=15	Existing	1.566638	1.564442	2.962820
	Proposed	0.958345	0.955273	1.497943
QP=20	Existing	1.379040	1.398473	3.381036
	Proposed	0.766323	0.762997	1.471530
QP=25	Existing	1.268066	1.256129	3.341162
	Proposed	0.651369	0.646563	1.488576
QP=30	Existing	1.198137	1.187668	3.368934
	Proposed	0.580196	0.576944	1.482268
QP=35	Existing	1.172708	1.156754	3.319515
	Proposed	0.552510	0.548751	1.492357
QP=40	Existing	1.164500	1.143878	3.352653
	Proposed	0.535335	0.526780	1.484750

Table 3 Comparisons result obtained for different videos for different parameters, No of Frame=10

		Video1.AVI		Video2.AVI		Video3.MP4		Video4,MP4	
		Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
QP=10	PSNR	52.074621	52.129783	52.241812	52.154814	53.594421	53.676590	53.507864	53.595627
	Bitrate	90022	88472	135051	134163	57539	56110	73191	72293
	T	5.290139	3.318893	6.158422	4.178540	4.678216	2.674802	5.050370	2.998157

QP=15	**PSNR**	47.940211	47.948912	47.896642	47.899566	49.934596	50.010009	49.441164	49.503711
	Bitrate	63952	62330	111418	110692	42079	40487	56921	55917
	T	4.518944	2.689934	4.391935	3.890888	4.371235	2.315824	4.609675	2.670456
QP=20	**PSNR**	43.794239	43.889276	43.170366	43.179891	46.159717	46.074251	45.069906	45.141546
	Bitrate	42251	41079	89790	88550	30313	29156	42514	41452
	T	4.011813	2.192836	5.355000	3.412965	3.933720	2.020146	4.375598	2.331359
QP=25	**PSNR**	40.262793	40.314927	38.622882	38.656657	42.431536	42.333067	41.086206	41.116293
	Bitrate	26932	25839	69122	68175	22136	20911	30555	29643
	T	3.678148	1.862803	4.895495	3.059270	3.799400	1.818996	3.932432	2.117017
QP=30	**PSNR**	37.211268	37.112088	33.983153	34.041765	38.645086	38.511831	37.195310	37.179534
	Bitrate	16188	14734	47690	46995	15396	14064	20509	19321
	T	3.495287	1.665995	4.458301	2.438297	3.612417	1.720794	3.734966	1.835365
QP=35	**PSNR**	34.331348	34.191072	29.895967	29.928409	35.145190	35.036977	33.723852	33.573171
	Bitrate	10945	9220	30913	29739	10948	9515	13964	12756
	T	3.425579	1.556456	3.914586	2.030782	3.500524	1.383902	3.567786	1.641499
QP=40	**PSNR**	31.460256	31.377319	26.613226	26.516773	31.833967	31.768697	30.754926	30.672026
	Bitrate	8151	6276	18782	17708	8130	6648	10095	8518
	T	3.406733	1.499230	3.205165	1.760161	3.474914	1.576388	3.511279	1.612088

7. CONCLUSION

This proposed work simulated using a Matlab tool to enhance a method to predict and reduce the encoding time of the intra frames in a video sequence. It used two different techniques to enhance the encoding time. In both the methods results will be produced for different QP values, as well as different videos. Here we used bit rate, PSNR and encoding time as a performance parameters to analyse the both the methods. Form this simulation we can observe that, our proposed method JM will give better PSNR value as well as the reduced encoding time for more number of the frame. In this paper, we give 3 different tables as well as the results obtained in the different video for different quality parameters. As a future work, it is planned to model the entropy encoder to evaluate the trade-off among superiority and quantity of hardware to used different similarity metric to model the intra-frame prediction and intra-frame encoding models.

REFERENCES

[1] V. Bhaskaran, K. Konstantinides, Image and Video Compression Standards: Algorithms and Architectures, Springer Science & Business Media, 2013

[2] G. Correa, P. Assuncao, L. Agostini, L. A. da Silva Cruz, Complexity-Aware High Efficiency Video Coding, Springer-Technology & ENgineering, 2015

[3] L. F. R. Lucas, E. A. B. Silva, Sérgio Manuel Maciel de Faria, Efficient Predictive Algorithms for Image Compression, Springer-technology & Engineering, 2017

[4] M. A. Joshi, M. S. Raval, Y. H. Dandawate, K. R. Joshi, S. P. Metkar, Image and Video Compression: Fundamentals, Techniques, and Applications, CRC Press, 2014

[5] B. Zatt, M. Shafique, S. Bampi, J. Henkel, 3D Video Coding for Embedded Devices: Energy Efficient Algorithms and Architectures, Springer Science & Business Media, 2014

[6] A. N.Ali, C. C.Menard, Compression of Biomedical Images and Signals, John Wiley & Sons, 2013

[7] K. S. Thaung, Advanced Information Technology in Education, Springer Science & Business Media, 2012

[8] L. P. Van, J. De Praeter, G. Van Wallendael, P. R. Alface and P. Lambert, "Intra-frame sharing for low-complexity decoding of SHVC video," *2016 IEEE International Conference on Consumer Electronics (ICCE)*, Las Vegas, NV, 2016, pp. 297-298.

[9] J. Zhu, Z. Liu, D. Wang, Q. Han and Y. Song, "Fast prediction mode decision with hadamard transform based rate-distortion cost estimation for HEVC intra coding," 2013 IEEE International Conference on Image Processing, Melbourne, VIC, 2013, pp. 1977-1981.

[10] M. Hota and P. K. Ranjan, "A fast intra mode decision technique,"Control Communication and Computing (ICCC), 2013 International Conference on, Thiruvananthapuram, 2013, pp. 143-148.

[11] M. Jridi, P. K. Meher and A. Alfalou, "Zero-quantised discrete cosine transform coefficients prediction technique for intra-frame video encoding," in IET Image Processing, vol. 7, no. 2, pp. 165-173, March 2013.

[12] J. Chakareski, "Adaptive multiview video streaming: challenges and opportunities," in IEEE Communications Magazine, vol. 51, no. 5, pp. 94-100, May 2013.

[13] K. M. Varadarajan, K. Zhou and M. Vincze, "RGB and depth intra-frame Cross-Compression for low bandwidth 3D video," Pattern Recognition (ICPR), 2012 21st International Conference on, Tsukuba, 2012, pp. 955-958.

[14] A. S. Motra, A. Gupta, M. Shukla, P. Bansal and V. bansal, "Fast intra mode decision for HEVC video encoder," Software, Telecommunications and Computer Networks (SoftCOM), 2012 20th International Conference on, Split, 2012, pp. 1-5.

[15] Y. Lee, J. Kim and C. M. Kyung, "Energy-Aware Video Encoding for Image Quality Improvement in Battery-Operated Surveillance Camera," in IEEE Transactions on Very Large Scale Integration (VLSI) Systems, vol. 20, no. 2, pp. 310-318, Feb. 2012.

[16] S. h. Park, S. h. Lee, H. Xu and E. S. Jang, "Temporal correlation-based fast encoding algorithm in HEVC intra frame coding," Consumer Electronics - Berlin (ICCE-Berlin), 2015 IEEE 5th International Conference on, Berlin, 2015, pp. 113-115.

[17] Chen Chen, B. Zeng, S. Zhu, Zexiang Miao and Liaoyuan Zeng, "A new block-based coding method for HEVC intra coding," Multimedia & Expo Workshops (ICMEW), 2015 IEEE International Conference on, Turin, 2015, pp. 1-6.

[18] G. Sanchez, M. Saldanha, G. Balota, B. Zatt, M. Porto and L. Agostini, "A complexity reduction algorithm for depth maps intra prediction on the 3D-HEVC," Visual Communications and Image Processing Conference, 2014 IEEE, Valletta, 2014, pp. 137-140.

[19] H. Huang, F. Wei and F. Ye, "Efficient intra prediction based on line with adaptive gradient detection for high definition videos," 2012 3rd IEEE International Conference on Network Infrastructure and Digital Content, Beijing, 2012, pp. 406-410.

[20] H. Li, K. NgiNgan, Z. Wei, "Fast and Efficient Method for Block Edge Classification and Its Application in H.264/AVC Video Coding," IEEE Transactions on Circuits and Systems for Video Technology, vol.18, no.6, pp.756,768, June 2008

[21] X. Liu, K-Y Yoo, S. W. Kim, "Low complexity intra prediction algorithm for MPEG-2 to H.264/AVC transcoder," IEEE Transactions on Consumer Electronics, vol.56, no.2, pp.987,994, May 2010

[22] C-Y Wu, P-C Su, "Fast Intra-Coding for H.264/AVC by Using Projection-Based Predicted Block Residuals," IEEE Transactions on Multimedia, vol.15, no.5, pp.1083,1093, Aug. 2013

[23] L. Shen, Z. Zhang, Z Liu, "Adaptive Inter-Mode Decision for HEVC Jointly Utilizing Inter-Level and Spatiotemporal Correlations," IEEE Transactions on Circuits and Systems for Video Technology, vol.24, no.10, pp.1709,1722, Oct. 2014.

[24] H. Pejman, F. Zargari, "An efficient fast intra mode decision method based on orthogonal modes elimination," IEEE Transactions on Consumer Electronics, vol.58, no.4, pp.1445,1452, November 2012

[25] J. You, C. Choi, J. Jeong, "Modified rate distortion optimization using inter-block dependence for H.264/AVC intra coding," IEEE Transactions on Consumer Electronics, vol.54, no.3, 2008

[26] C. Su, Y. Lin, "Zero-block inter/intra mode decision for mpeg-2 to H.264/AVC inter P-frame transcoding," IEEE-IET Image Processing, vol.4, no.6, pp.494,504, December 2010

[27] K. Bharanitharan, B-D Liu, J-F Yang, W-C Tsai, "A Low Complexity Detection of Discrete Cross Differences for Fast H.264/AVC Intra Prediction," IEEE Transactions on Multimedia, vol.10, no.7, pp.1250,1260, Nov. 2008