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Evaluation and Analysis of Rate Control Methods for H.264/AVC and MPEG-4 Video Codec

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ABSTRACT

Audio, image and video signals produce a vast amount of data. The only solution of this problem is to compress data before storage and transmission. In general there is the three crucial terms as, Bit Rate Reduction, Fast Data Transfer and Reduction in Storage. Rate control is a vigorous factor in video coding. In video communications, rate control must ensure the coded bitstream can be transmitted effectively and make full use of the narrow bandwidth. There are various test models usually suggested by a standard during the development of video codes models in order to video coding which should be suffienciently be efficient based on H.264 at very low bit rate. These models are Test Model Number 5 (TMN5), Test Model Number 8 for H.263, and Verification Model 8 (VM8) for MPEG-4 and H.264 etc. In this work, Rate control analysis for H.264, MPEG-4 performed. For Rate control analysis test model verification model version 8.0 is adopted.

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1. INTRODUCTION

Standardization maintains its key place in those technologies backed by a large number of manufacturers, and thus, a standard form in video coding is a necessary aspect. Discrete Cosine Transform (DCT) base coding algorithm oscillates the resulting bit rate according to the video sequence nature. Modification in the size, the texture, and the speed of a moving object are among the main causes of bit rate change. A rate controller achieves a well-reconstructed video quality and transmission of constant bit rate over a circuit switched network [1], [2]. The bit rate fluctuations should not be present in reconstructed video, which is usually achieved by means of a transmission buffer that is inherent in the interframe coding scheme. The H.261 was developed as first video codec for video conferencing International Telecommunication Union-Telecommunication sector.Compression performance of H.263 developed by ITU-T can be improved by stimulating three rate control methods: In Constant Bit Rate application, there is an important issue of both bit rate control and buffer regulation. There are two constraints—low-latency and buffer constraints for which scalable bit rate control (SRC) has been designed. For achieving the target bit rate, a variable frame rate is usually done. Almost same technique can also extend to macroblock layers and slice. The two rate control methods for MPEG-4 that are used in this work are as follows:

OFFLINE: In this option, the bit rate control takes the form of changing the quantization levels over the frames encoded after the first I- or P-frame. There will be no frame skipping in this mode [3], [4].
ONLINE: In this mode, the bit rate control is accomplished by adaptively changing the quantization values at the macroblock level. Frame skipping is allowed in this mode [4].

2. FUNCTION OF RATE CONTROL

For an available network, bandwidth rate control encodes the video bandwidth, ensures that the coded bitstream can be transmitted successfully, and utilizes the limited bandwidth. On the other hand, we can say that the channel of the resulting video output may be fixed or variable transmission rate. If successive frames are used in video sequence, they are very similar and each frame output bit changes with the operating input image. Therefore, the bitstream should acquire the characteristics of a rapidly changing of frame [5-7].

3. OVERVIEW OF RATE CONTROL

However, using a buffer has few limitations (such as the propagation delay of a real time communication will be longer if buffer is too big which is not accepted). Video coding algorithm of mainstream DCT quantization method is adopted to eliminate video signals, the visual physiology redundant than lossless higher compression ratio and will not decrease the video quality significantly [8]. Distortion factor D can be select as any cost function, absolute square cost function etc.In the image coding D is computed as:

$$D = E\{[f(x, y) - g(x, y)]^2$$

4. H.264 AND ITS PARAMETERS

There are several additional features to make it superior over its predecessor, are listed below [9], [10]. There are two context schemes, CAVLC (context-adaptive variable-length coding) and CABAC (context-adaptive binary arithmetic coding), to increase coding efficiency. In H.264 there are various sizes & shapes of blocks of many type for motion compensation, such as 8x4, 4*8 and 4*4, are supported. ¼ pixel motion estimation improves prediction accuracy.

The H.264/AVC encoder and decoder is shown in Figure 1 and Figure 2.

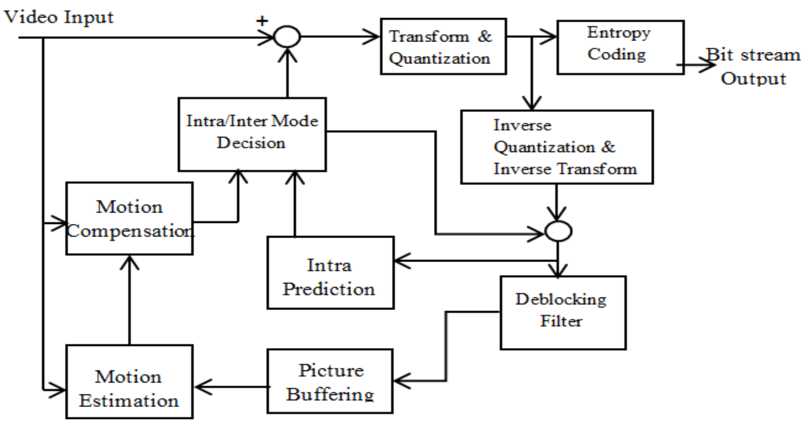

Figure 1. Block diagram of H.264/AVC encoder

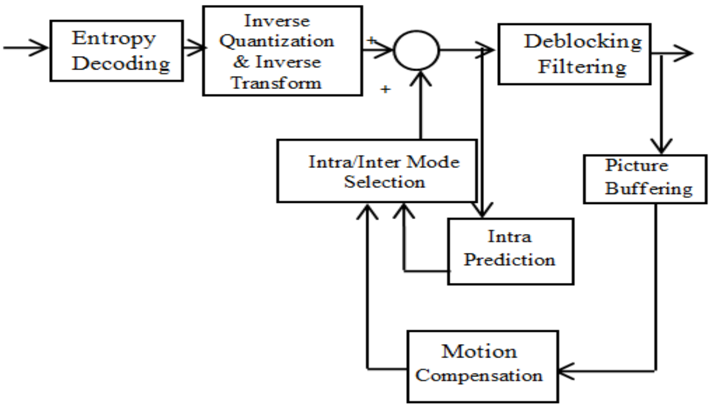

Figure 2. Block diagram of H.264/AVC decoder

5. MPEG-4 AND ITS PARAMETERS

A transmission buffer is usually needed to smooth out the bit rate fluctuations, which are inherent in the interframe coding scheme [11], [12]. Constant bit rate over a switched network [13] for transmission is the main objective of rate controller. There are many advanced features of MPEG-4 which are not present in MPEG-1/2. The block diagram of a MPEG-4 video coder is shown in Figure 3.

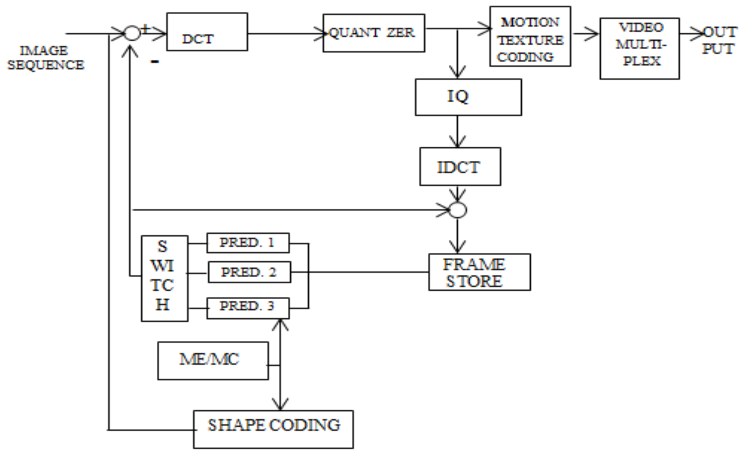

Figure 3. Block diagram of MPEG-4 coder

Where,

DCT - Discrete Cosine Transform
IDCT - Inverse Discrete Cosine Transform
ME/MC- Motion Estimation/Motion Compensation
Pred. – Prediction

6. RATE CONTROL SCHEME IN MPEG-4

The MPEG group officially initiated an MPEG-4 adopted VM8 (Verification Model 8) to realize rate control. MPEG-4 adopted VM8 (Verification Model 8) to realize rate control.

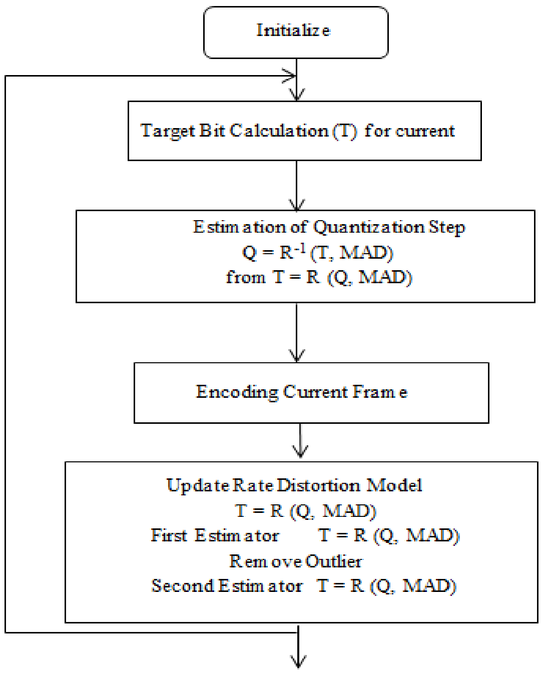

Figure 4. Procedure of the MPEG-4 VM8 rate control algorithm

Where,

MAD – Mean Absolute Difference
Q – Quantizer Parameter
T – Target Bit

There are five steps in the MPEG-4 VM8 rate control algorithm shown in Figure 4: Initialization Computation of the target bit rate (TBR) before encoding The computation of TBR is based on the bits available and the last encoded frame bits [14]. Encoding current frame after encoding, model parameters are updated [15].

7. RATE CONTROL SCHEME IN H.264

In this proposed work, the rate control for the forecast frame done after encoding the I-frames using the base line profile encoding i.e. CAVLC encoding and taking the mention data from it. The rate control block diagram Figure 3 explains how the QP parameter is approximated. The residuals between the current and reference frame is estimated. Mean Absolute Deviation (MAD) values are obtained by summing the residuals. The value of QP is initialized to a range manually [16]. Figure 5 shows rate control by estimating the quantization parameters or rate control algorithm.

QP limiter is used to limit the demanded QP to a range and the parameters are estimated for the procedure by using these parameters, rate control is performed on the input video to get an output video. This procedure ensures controlled bit-rate and better compression ratio.

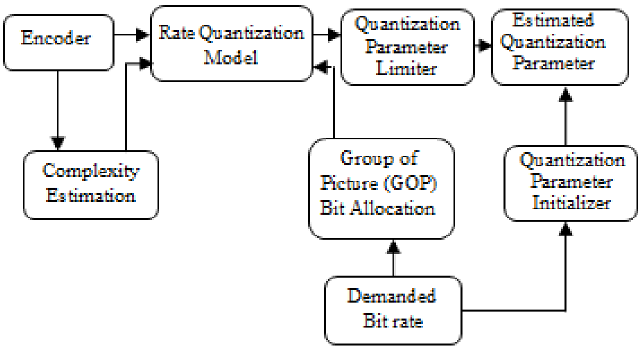

Figure 5. Rate control by estimating the quantization parameters

8. SIMULATION, IMPLEMENTATION DETAILS AND RESULTS OBTAINED

Performance metrics are used to assess the quality of the obtained video. The test video sequence is Heart at frame rate 24 per second. The performance metrics on which the video quality adjudged are Compression ratio, Mean Square Error, Peak Signal to Noise Ratio, correlation coefficient, PRD and SSIM.

$$COC = \frac{\sum_{x=0}^{X-1}\sum_{y=0}^{Y-1} i(x,y)\, e(x,y)}{\sqrt{\sum_{x=0}^{X-1}\sum_{y=0}^{Y-1} i(x,y)^2}\ \sqrt{\sum_{x=0}^{X-1}\sum_{y=0}^{Y-1} e(x,y)^2}} \tag{1}$$

Mean square error (MSE)

$$MSE = \frac{1}{XY}\sum_{x=1}^{X}\sum_{y=1}^{Y}[i(x,y) - e(x,y)]^2 \tag{2}$$

Where,

i (x, y) = Intensity of input pixel (for each U, V,Y) e (x, y) = Intensity of output pixel (for each U, V,Y)

The PSNR for each frame is defined as:

$$PSNR = 10\log_{10}(\frac{255}{MSE})^2 = 20\log_{10}(\frac{255}{MSE})(\text{for each Y, U, V}) \quad (3)$$

The PSNR for entire video sequence is defined in terms of Average PSNR

$$\text{Average PSNR} = \frac{i}{t}\sum_{i=1}^{t} PSNR(i) \quad \text{for each(Y, U \&V)} \quad (4)$$

Where t is total number of frames in video and PSNR (i) is the PSNR value for i^{th} frame.
It should be noted here that improvement in the subjective quality of decoded video is acquire at the cost of increased computational is complicated

The SSIM is a structural similarity index (similarity measuring full reference metric between two images, means the measurement of image quality support on a mention initial uncompressed or distortion-free image). It can also be understood as an improved version of traditional methods like PSNR and MSE, generally which is inconsistent with human eye perception.

$$SSIM(x, y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (5)$$

Where,

$c_1 = (k_1L)^2$ and $c_2 = (k_2L)^2$

In the equation of c_1, c_2 and L is the dynamic range of the pixel-values and k_1 = 0.01, k_2 =0.03 by default. Equation (5) of SSIM is appropriate only on Y ie. luma. Its value ranges from -1 and 1, where 1 is only possible if two sets of data are identical. Generally it is considered on window sizes of 8×8.

Table 1. Heart Video Sequence Simulation Results for Base Profile and Cabac Enabled

Data Rate (Mbps)	PSNR(dB) Base Profile	PSNR(dB) CABAC Enabled	SSIM Base Profile	SSIM CABAC Enabled
0	31.9	32.3	0.88	0.88
0.2	37.3	37.6	0.93	0.932
0.5	42	42.4	0.96	0.963
0.8	44.5	45	0.972	0.972
1	45.9	46.5	0.974	0.974
1.2	46.9	47.4	0.974	0.9755
1.5	47.9	48.5	0.976	0.9764
1.8	48.8	49.7	0.977	0.978
2	49.7	50.2	0.979	0.9798
2.2	50.5	50.9	0.98	0.982
2.5	51.1	51.6	0.981	0.984

Figure 6 shows comparative performance with reference to SSIM. Figure 7 and Figure 8 shows sequence Heart and Mobile respectively. Table 1 is elaborating the SSIM profile for sequence Shields. Table 2 tells about the detail of sequence Mobile. Table 3 gives the summary of results obtained in this work regarding the performance of MPEG-4 codec for various rate control methods at 14.4 and 100 kbps target bit rates. It is observed that online & offline rate control methods have almost same performance as far PSNR is concerned. When rate control is applied and target bit rate is reduced, it is observed that the PSNR, bit rate and storage requirement also reduces. No control method corresponds to fixed quantization parameter. Table 4 gives comparative statement for quantization parameter, mean square error, peak signal to noise ratio, compression ratio and similarity index. Detail of sequence mobile is illustrated in Table 2.

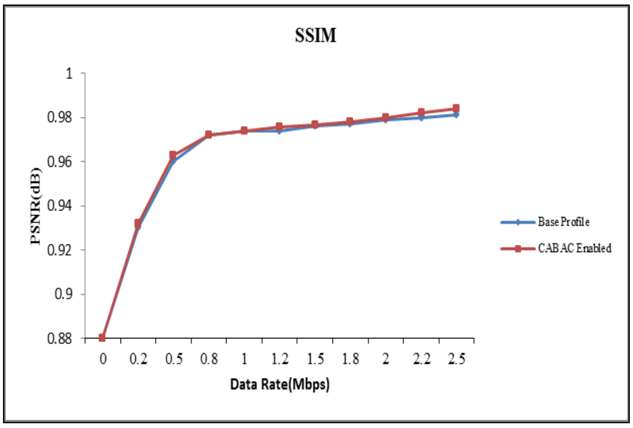

Figure 6. Comparative Performance of MPEG-4 Video Coder for Shields video sequence for Base profile and CABAC enabled, SSIM profile

Sequence title: Heart
Resolution: 176x144

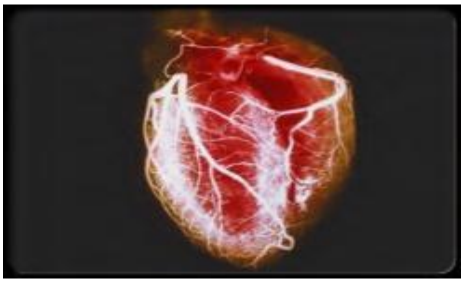

Figure 7. Snapshot of “Heart” video sequence, frame 30

Figure 8. Snapshot of “Mobile” video sequence

Table 2. Detail of the Video Sequence Mobile

S.No.	Detail of Sequence	
1	Name	Mobile
2	Size	CIF (352x288)
3	Total size[byte]	23612683
4	Frames	300
5	Playing time[s]	10.03Min
6	frame size[byte]	79
7	Max frame size[byte]	118449
8	Mean frame size[byte]	78447.45

Table 3. Mobile Video Sequence Simulation Results for Mpeg-4 Video Codec

Target bit rate (Kbps)	Various Parameter	(a) No Control over bit rate	(b) Bit Rate Control Offline	(c) Bit rate Control Online(with frame skipping)	(d) Bit rate Control Online(without frame skipping
100	Average PSNR Y	48.44	34.12	34.55	34.54
	Average PSNR U	49.78	38.15	38.83	39.12
	Average PSNR V	49.88	38.35	38.87	39.41
	Bit rate (kb/sec)	98.95	99.5	99.9	99.9
	Compression ratio	7:01	95:01:00	95:01:00	95:01:00
14.4	Average PSNR Y	44.44	27.85	27.83	27.49
	Average PSNR U	45.78	33.7	34.75	33.68
	Average PSNR V	46.36	34.15	35.17	33.95
	Bit rate (kb/sec)	1478.3	44	15.7	27
	Compression Ratio	7:01	205:01:00	556:01:00	304:01:00

Table 4. Comparative Statement for Qp, Mse, Psnr, Cr and Ssim

S.No.	Quantization Parameter	MSE	PSNR	SSIM	Compression Ratio
1.	10	0.32	54.33	0.99	11.5
2.	15	0.51	52.12	0.98	13.3
3.	20	1.82	47.24	0.96	25.4
4.	25	2.99	43.44	0.95	29.3
5.	27	3.42	42.89	0.94	34.6
6.	30	7.991	39.21	0.91	39.7
7.	35	14.78	35.11	0.85	42.4
8.	40	20.71	33.2	0.78	44.0
9.	45	28.62	31.6	0.73	44.9
10.	50	39.12	30.7	0.69	46.1

9. CONCLUSION

In this paper H.264 and MPEG-4 basic features are discussed along with how the performance is influenced by rate controller for H.264/AVC and MPEG-4. There are test model VM8 verification model version 8.0 is used for the analysis of H.264/AVC and MPEG-4. In constant bit-rate applications, both on-line and off-line rate control methods gives the obtained bit-rate very close to the target bit rate (TBR) for a moderate target bit rates (medium and high). However, for low bit rate applications only online method results in the actual bit-rate being close to the TBR bit rate. There are many other parameters and functionalities in MPEG-4 which are aimed to be investigated in future.

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