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A VARIANCE DISTORTION RATE CONTROL SCHEME FOR COMBINED SPATIAL-TEMPORAL SCALABLE VIDEO CODING

L. BALAJI

Velammal Institute of Technology, Anna University, Chennai, India
maildhanabal@gmail.com

A. DHANALAKSHMI

Panimalar Engineering College, Anna University, Chennai, India
dhanalakshmi248@gmail.com

C. CHELLASWAMY

Rajalakshmi Institute of Technology, Anna University, Chennai, India
chella_info@yahoo.co.in

Rate Control plays an important role in video compression for transportation over heterogeneous network bandwidth varying conditions. A combined spatial-temporal rate control scheme is proposed for scalable video coding. Introductory quantization parameter estimation is determined based on complete variance distortion method for I frame of first GOP and estimates buffer occupancy level. With the estimated buffer level, target bits are determined considering the coding complexity is proposed in the rate control scheme. In addition, a proportional integral and derivative (PID) controller that calculates the error and minimize fluctuation between the actual buffer fullness and target buffer fullness for competent buffer utilization. As a result, the proposed scheme exploits entire buffer exclusive of crossing overflow and underflow level. The investigational results are compared with other two benchmark schemes and the proposed scheme can able to achieve better target bit adjustment with condensed fluctuations and competent buffer utilization.

Key words: H.264 SVC, Rate control, Bit Rate, PSNR, Buffer, PID controller

1 Introduction

Different categories of video applications in the areas of digital wireless communication, multimedia broadcasting, etc., for various types of video applications, continuous development of video coding standards has emerged since 1980s. The International Telecommunications Union Telecommunication Standardization (ITU-T) created Video Coding Experts Group (VCEG) and International Standards Organization (ISO) and International Electrotechnical Commission (IEC) built up the Moving Picture Experts Group (MPEG). Afterward, ITU-T and ISO/IEC have mutually created Joint Video Team (JVT) to feed the video coding benchmarks advancement.

The JVT has developed a scalable extension, to the H.264/Advanced Video Coding (AVC) standard known as Scalable Video Coding (SVC). SVC acquires every one of the components of H.264/AVC, for example, efficiency in coding, variable square size blocks, numerous reference frames, dynamic filter, transformation of blocks, and so forth. Along with these characteristics, SVC gives new extra tools [26] to regulate for variable bit rate condition. Scalable Video Coding (SVC) expected to adjust to a variable target bit rate for a sudden transfer speed varieties, network alert conditions over an unpredictable channel.SVC is a layered video coding, which include H.264/AVC backward compatible base layer and one or more enhancement layers. The ability of SVC encoder to decode the full video with the available partial bit-stream makes more attractive. SVC encoder generates single bit-stream compatible for multiple terminals display capabilities. Bit-stream consists of bits generated due to BL and EL. The BL is of lower frame rate, lower size and low quality but needs to be intra coded. Whereas the EL, added to the base layer based on availability for better improvement of the video. SVC is scalable in three aspects temporal, spatial and quality scalability. Temporal Scalability generates variable frame rate for heterogeneous display capabilities using Hierarchical B Picture Prediction (HBP). Video comprised of frames consisting of Intra (I), Predictive (P) and Bi directional Predictive (B) frames. At this time I frames are referred as instantaneous decoding refresh (IDR) frames that hold entire information; therefore it has to be given additional significance. Predictive frames are unidirectional frame that can be expected from I frame; therefore it has to be given less significance than I frame. B frames are extracted from both I and P frames in frontward and rearward directions; hence less significance could be given. The frames having less significance information can generate more efficiency in coding while more significant information generates more. Spatial scalability produces bit-stream with uneven frame resolutions for diverse display capabilities. It includes Inter layer intra Prediction, Inter layer inter Prediction and Inter layer residual prediction that achieves greater efficiency in coding. Quality scalability produces bit-stream in 3 strategies such as coarse grain scalability (CGS), medium grain scalability (MGS) and fine grain scalability (FGS).

Conventional video coding frameworks encode video at a settled target bit rate for specific applications. With the sensational enhancements in video, for example, video on Demand (VOD), Streaming video and broadcasting causes higher requests on video correspondence. Video correspondence over heterogeneous systems with comparable quality video over disparate gadget abilities is a testing issue. However video creates bit-stream with variable bit rate which must be agreed over an unchanging bit rate channel. Also, fluctuation of bit rate occurs drastically due to various issues such as congestion, link failure, node failure etc., in the network part; hence quality of the video is poor. Such fluctuation has to be controlled properly while transmitting video to different networks. To meet all these requirements a better video coding strategy that support more scalable, flexible and completely accessible bit-stream has drawn much attention both from industry and academia [23, 10]. The better choice is to provide more bits to more important information and fewer bits to less important information which motivates variable bit rate encoding. A Rate control scheme is used to improve the video coding performance and adapt different network bandwidth varying conditions. An efficient rate control scheme needed to effectively code variable bit rate video at a constant bit rate. Basically, a rate control scheme holds three parts: bit allocation, rate distortion control and updating [12]. The parameters need to be considered includes target bits, buffer level and quantization parameter for the video unit. The target bits estimated based on quantization parameter (QP) which is updated after encoding each frame noticing the status of buffer level.

2 Related Work

Number of rate control schemes proposed for video coding standards, like Test Model 5 (TM5) [29] for MPEG-2, Test Model Near-term8 (TMN8) [7] for H.263, Verification Model 8 (VM8) [31] for MPEG4, JVT-G012 for H.264/AVC, and JVT-W043 for SVC. Rate distortion model is an essential element while growing such productive rate control schemes. Few models, for example, the direct model [29], second-order model [7, 31] domain straight model [8], and Logarithmic model [27], exploited as a part of conventional video coding benchmarks. The connection between the target bits and quantization parameter which expresses the quadratic rate distortion (RD) model is utilized in SVC.

A vigorous dynamic with proportional integral derivative rate control rate control scheme is proposed [28] for MPEG 4. This scheme accomplishes precise bit rate and achieves successful occupancy in buffer. In SVC, distinctive types of rate control schemes, both in spatial [20, 18] and temporal [35, 2, 18] are proposed. In temporal layer rate control scheme, [35] proposed assigning bit asset in light of hierarchical B picture prediction (HBP) to various temporal layers. In [20], weighting parameters is make use to allot bits to various temporal layers and the QP for coding unit is found in light of rate quantization [19]. An ideal rate distortion execution is accomplished in [2] utilizing multipass temporal layer rate control scheme subsequent to investigating the distortion reliance in HBP. In spatial layer, the rate control scheme assumes a fundamental part by making utilization of the connection among interlayer rate quantization (RQ) attributes to enhance the execution. In [20], base layer utilize mean absolute difference (MAD) of texture residuals and enhancement layer exploit a switchable MAD calculation to detach the QP issue [17] among rate control and rate streamlining strategy. In [18] a multipass rate control scheme was acquired subsequent to distinguishing the reliance connection with rate and distortion among spatial layers. However different rate control schemes were characterized for SVC, yet are basic to get a precise RQ model to accomplish better RD execution.

Though different rate control schemes applied for single layer coding, but couple of schemes utilized for SVC, despite the fact that the association among various layers is not distinguished. Another real necessity in enhancing SVC rate control execution is to discover introductory QP estimation for the first frame of GOP. Determining introductory QP reduces artefacts, thus the nature of video subsequently the coding efficiency can be improved. In [17], an introductory QP decides in view of bits per pixel which does not consider for various types of video sequence. In [33], an introductory QP is resolved in view of experimental model for first frame and does not consider about the coding difficulty of the sequence. So the estimated coding difficulty measure is not equivalent to the actual difficulty of various beginning video frames. With different layers in SVC, it is attractive to characterize an underlying QP scheme for each coding layer. In [9] a dynamic rate quantization introduction for each spatial coding layer is proposed. With HBP beginning QP estimation for base layer is achieved and enhancement layers QP obtained in view of recognizing the frame size and bit rate, however the buffer is not used appropriately.

A buffer is an essential segment in rate control scheme which delivers constant bit rate taking input as variable bit rate. Additionally, the buffer can enhance or distort the nature of the video in light of overflow and underflow threshold level. In this paper we concentrate on evaluating introductory QP as well as efficient usage of the buffer threshold level without bounds conceivable. At first we decide the QP for the beginning frame of each spatial and temporal layer in view of complete variance distortion [34] and the occupancy of the buffer is known. The target bits for the next frame determined based on available bits in the buffer. The determined target bits are balanced by the coding difficulty and buffer occupancy in light of QP which will be refreshed without fail.

3 Variance Distortion Rate Control Scheme

An effective rate control scheme which efficiently exploits buffer occupancy is proposed. For any rate control scheme, introductory quantization parameter estimation is an important parameter to be obtained. We obtain the introductory parameter based on complete variance distortion. The bits generated after encoding I frame of first GOP occupy the buffer. The remaining bits to occupy in the buffer are the target bit which is estimated for the remaining sequence of frames. The estimated target bits will be adjusted according to coding complexity and buffer occupancy. Figure 1 demonstrates the block of proposed PID supported buffer rate control scheme. The error signal produced from the buffer amid target buffer fullness and present buffer fullness is hold by the PID (proportional integral derivative) controller. Afterward, the PID controller updates the quantization parameter.

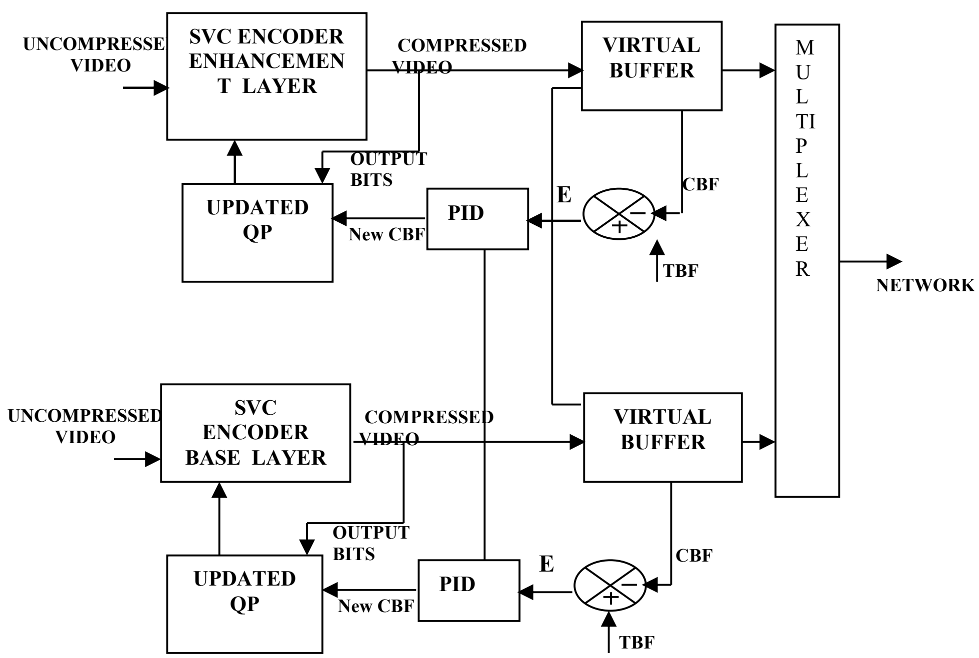

Figure 1 PID based Buffer Rate Control Model

The error produced from the buffer is flattened by three kinds which comprise present, past and future errors [34]. The PID controller from control systems engineering has an inbuilt feature of control without the knowledge of any system. The same can be applied here for video coding, the proportional part considers present error, integrative part considers past error and derivative part predicts future errors. Accordingly the errors are smoothed and update the QP. With the usage of PID controller not only controls smoothing error but also involves efficient utilization of the buffer occupancy level. The buffer in the rate control is not much used efficiently in certain schemes [9, 33]. Buffer crosses the overflow and underflow borders [33] for dissimilar video sequences while inefficient use of the buffer [9]. The methods followed in the scheme at each level are described below.

3.1 Initialization Level

The initialization level contains fixing up encoding parameters and buffer dimension. The buffer dimension is initialized according to users delay necessity, and the target buffer fullness can be assigned to any stage of the buffer dimension based on users' needful requirements. The default buffer dimension TBF is fixed to one half of the target bit rate. A given quantization parameter (QP) is initialized to encode the first I frame of group of pictures (GOP). After encoding first frame, the actual bits can be obtained, rest of the bits available for the remaining frame sequence to be encoded. The quantization parameter for first I frame can be obtained using the following equation

$$QP_{I,j} = m.\log_2 QSize_{I,j} + n \tag{1}$$

$$Qsize_{I,j} = \frac{d_{TV} - j}{j} \tag{2}$$

$$d_{TV} = \frac{TV(Y_q(x,y) - Y_{q-1}(x,y))}{TV(Y_q(x,y))} \tag{3}$$

m and n are model parameters and assume to set empirically, m=8 and n=2 after repeated iterations, $Qsize_{I,j}$ denotes quantization step size for I frame of jth GOP, d_{TV} denotes complete variance distortion and $Y_q(x,y)$ & $Y_{q-1}(x,y)$ denote the luminance component of a pixel in the current frame and previous frame. The result of this equation is rounded to an integer. To avoid buffer overflow and underflow, the following condition must be satisfied.

$$K_{bits}(QP_{I,j} \mid QP_{I,j-1}, R_{I,j-1}) + CBF < 0.85TBF \tag{4}$$

$$K_{bits}(QP_{I,j}) = \begin{cases} R_{I,j-1}.^{QP_{I,j}-QP_{I,j-1}}; QP_{I,j-1} < QP_{I,j} \\ R_{I,j-1}.^{QP_{I,j-1}-QP_{I,j}}; QP_{I,j-1} \geq QP_{I,j} \end{cases} \tag{5}$$

where $K_{bits}()$ denotes the function of bit estimation, CBF denote current buffer fullness, TBF denote target buffer fullness, $QP_{I,j}, R_{I,j}$ denotes quantization parameter and bits generated for I or P frame of jth GOP, $QP_{I,j-1}, R_{I,j-1}$ denotes quantization parameter and bits generated for I or P frame of (j-1)th GOP.

3.2 Introductory Target Bit Estimation

The target number of bits is estimated initially based on weighted mean, $\mathrm{T}_{avg}(\mathrm{t})$ for the type of current frame as given by the equation,

$$\mathrm{T}_{avg}(\mathrm{t}) = \alpha_M(\mathrm{t})\frac{B_{rem}(\mathrm{t})}{\alpha_I(\mathrm{t})\mathrm{n}_I(\mathrm{t}) + \alpha_P(\mathrm{t})\mathrm{n}_P(\mathrm{t}) + \alpha_B(\mathrm{t})\mathrm{n}_B(\mathrm{t})} \tag{6}$$

where $B_{rem}(\mathrm{t})$ denotes the remaining bits available to encode the other frames in the sequence, $\mathrm{n}_I(\mathrm{t}), \mathrm{n}_P(\mathrm{t}), \mathrm{n}_B(\mathrm{t})$ denotes the number of I, P or B frames $\alpha_I(\mathrm{t}), \alpha_P(\mathrm{t}), \alpha_B(\mathrm{t})$ denotes their weight factors, $\alpha_M(\mathrm{t})$ is $\alpha_I(\mathrm{t}), \alpha_P(\mathrm{t}) or \alpha_B(\mathrm{t})$ corresponding to a current frame type.

3.3 Target Bits Adjustment based on Coding Complexity

It is necessary to analyze the characteristics of macro blocks before target bit estimation. As variance-like measure is usually used in bit allocation [25, 16, 3, 30, 15], we propose to adopt the difference between macro blocks to define the coding complexity of all frames to be encoded at time

$$CC_{PB}(\mathrm{t}) = n_{MB} MC_{\mathrm{var}} \tag{7}$$

where $CC_{PB}(\mathrm{t})$ denote coding complexity for P or B frame, n_{MB} denote number of macroblocks and MC_{var} denote variance of the motion compensated residue. Variance of motion compensated value can be expressed as,

$$MC_{\mathrm{var}} = \frac{\sum_{j=1}^{n_i(\mathrm{t})} (Y(\mathrm{t}) - \overline{Y_{avg}(\mathrm{t})})^2}{n_i(\mathrm{t})} \tag{8}$$

where $Y(\mathrm{t})$ denote luminance value of pixel, $\overline{Y_{avg}(\mathrm{t})}$ denote average pixel value and $n_i(\mathrm{t})$ denote number of non transparent pixel value. Since the coding complexity is computed based on its motion-compensated residual, when a macroblock changes its features, its coding complexity also updates by some degree simultaneously. To avoid very large fluctuations of coding complexities and obtain smooth coding qualities along the coding time, we hope this coding complexity only acts as fine-tuning to target bit allocation for each encoding time instant, thus its influence should not be too strong.

To adjust coding qualities among multiple objects within a frame, the scheme sets weight for each object. The larger the weight for an object, the more target bits should be allocated to it. Then, we can calculate the average coding complexity for previous -frames, and for previous frames before time. Here, and are the number of the most recently coded and frames used in computing and respectively. The introductory target bit budget of the current frame, , is then adjusted by

$$T_{bc}(\mathrm{t}) = T_{avg}(\mathrm{t}).\frac{CC_{PB}(\mathrm{t})}{C_{avg}(\mathrm{t})} \tag{9}$$

where $T_{bc}(\mathrm{t})$ denote introductory target bit of the current frame, $T_{avg}(\mathrm{t})$ denote average target bits, $CC_{PB}(\mathrm{t})$ denote coding complexity and $C_{avg}(\mathrm{t})$ denote average complexity. The number of target bits is estimated only for P and B frames. Hence, appropriate bits can be adaptively allocated to the current frame and coding quality can be kept consistent.

3.4 Target Bits Adjustment based on Buffer Occupancy

The bit target is further refined based on the buffer fullness so as to get more accurate target bit estimation. The aim of buffer control is to keep buffer fullness around the target level to reduce the chances of buffer overflow or underflow: if the buffer occupancy exceeds the target level, the target bits are decreased to some extent; similarly, if it is below the target level, the target bits are increased by some degree. The VM8 and other schemes adopt a simple nonlinear proportional buffer controller, whose control ability is rather less powerful. As shown in our experiments, when the complexity of a sequence changes drastically, the buffer tends to be out of control, especially in low bit rate cases. The PID controller is by far the most popular feedback controller in the automatic control area [5, 24], and is especially suitable for unpredictable or imprecise processes to be controlled, which is one of the characteristics of video coding process since we cannot precisely predict the coming frames. The popularity of the PID technique is mainly attributed to its simplicity and good performance in a wide range of operating conditions. Here, we apply this scheme to the buffer control in video coding. From the viewpoint of automatic control systems, the structure of our scheme is a prediction plus feedback control system, but not a pure feedback system [14].

Our goal is to keep the buffer occupancy around the target buffer fullness, and minimize the deviation between the target buffer fullness and the actual buffer fullness. The error signal, $e(\mathrm{t})$ which measures the difference between the target buffer fullness and the actual output (current buffer fullness) at time, is defined as

$$e(\mathrm{t}) = \frac{\left(\frac{TBF}{2} - CBF(\mathrm{t})\right)}{\frac{TBF}{2}} \tag{10}$$

This error signal is sent to the PID controller

$$\mathrm{u(t)} = \mathrm{K}_p\left[e(\mathrm{t}) + \mathrm{K}_I\int_0^t e(\mathrm{t})d + K_D\frac{e(t)}{dt}\right] \tag{11}$$

where K_p, K_I and K_D are the proportional, integrative, and derivative control parameters, respectively. The first term in (11) is the proportional action, it is the main component and can reduce the error between the current buffer fullness and the target buffer fullness, but cannot fully eliminate this error. The integral controller, the second term in (11), has the effect of eliminating the steady-state error by this way: when the error lasts, it can gradually enhance the control strength. But it may cause the transient response worsening. The derivative controller, the third term, has the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response. The three-mode PID controller combines the advantages of each individual controller, and thus, improves both the transient and the steady-state response.

Then, the target bits can be further adjusted by

$$TB(\mathrm{t}) = (1 + \mathrm{u(t)})TB(\mathrm{t}) \tag{12}$$

where $TB(\mathrm{t})$ denote target bits. To obtain a minimum visual quality for each frame, the lower bound of the target bits imposed to each frame in VM8 is, and the target bit rate and frame rate required by the application. This means each frame must obtain at least the average number of bits per frame without considering its coding complexity, and thus the complete target bitrate actually allocated to frames is certainly equal or larger than the application's target bitrate. Since we think that only fewer bits are needed to maintain acceptable qualities for some frames with low complexity, we decrease this lower bound to

$$TB(\mathrm{t})_{\max} = \frac{TB_{rate}}{4F} \tag{13}$$

where TB_{rate} denote target bit rate. For most applications, overflow is much worse than under flow, so maximum bits should be more strictly constrained than the minimum one. To avoid buffer overflow, the maximum number of bits is given as

$$TB(\mathrm{t})_{\min} = \frac{2TB_{rate}}{F} \tag{14}$$

3.5 Encoding Frame and Updating QP

After encoding macro blocks within a frame, the encoder updates the R-D model of each macro block for the corresponding frame type based on the encoding results of the current macro block as well as the macro block. The virtual buffer fullness is updated by

$$BFull(t) = BFull(t) + [B_{actual}(t) - B_{leave}(t)] \tag{15}$$

where $BFull(t)$ denote buffer fullness, $B_{actual}(t)$ denote the number of actual bits used for encoding the current frame and $B_{leave}(t)$ denote the number of bits to be output from the virtual buffer per frame [28]

$$B_{leave}(\mathrm{t}) = \alpha_M(\mathrm{t})\frac{B_{rem}(\mathrm{t})}{\alpha_I(\mathrm{t})\mathrm{n}_I(\mathrm{t}) + \alpha_P(\mathrm{t})\mathrm{n}_P(\mathrm{t}) + \alpha_B(\mathrm{t})\mathrm{n}_B(\mathrm{t})} \tag{16}$$

Actually, the right side of (16) is the same as that of (6), because we hope the introductory target bits which to be put into the buffer should roughly equal to the bits to be output from the buffer per frame, so as to keep buffer fullness around the target level and derive a useful signal of buffer fullness. The Quantization parameter will be updated by the following equations

$$QP = QP_{prev} + TB(\mathrm{t})_{\max} \tag{17}$$

$$QP = QP_{prev} - TB(\mathrm{t})_{\min} \tag{18}$$

where QP_{prev} denote previous QP value, $TB(\mathrm{t})_{\max}$ denote maximum target bits and $TB(\mathrm{t})_{\min}$ denote minimum target bits.

3.6 Summary of the Proposed Scheme

1. Introductory Quantization Parameter for I frame of first GOP of each layer is determined using (1) and the target buffer fullness is estimated using (4) & (5)
2. Adjust target bits for P frame or B frame using (9)
3. Update buffer fullness by adding actual bits generated and calculate the difference bits to be sent as output from buffer per frame using (15). If buffer fullness >85% of buffer size, next frame is skipped due to varying the bit rate.
4. Repeat step 2 and 6 for next frame, until the end of a sequence.

4 Experimental Result

The proposed rate control scheme is implemented using JSVM reference software 9.19.15 [32] with the simulation parameters as shown in Table 1. The system configuration includes Intel i5 processor with 2.67 GHz clock speed and 320 GB hard disk with operating system of Windows 7. We took five video sequences such as bus, city, crew, football and foreman each of QCIF and CIF with 15 fps and 30 fps for base layer and enhancement layer with a GOP of size 16. We encode a complete of 150 frames for all sequences with fixed search range of 32.

Table 1 Simulation Parameters

Base Layer Mode	AVC Compatible
Intra Period	-1
Frames to be Encoded	150
Resolution	BL (QCIF) & EL (CIF)
GOP Size	16
Number of Ref Frames	1
Search Range	32
Search Function	SAD for Ful Pel & Hadamard for Sub Pel
Frame Rate	BL (15 fps) & EL (30 fps)
Codec	JSVM 9.19.15

Table 2 shows the comparison of bit rate and PSNR for the proposed rate control scheme with the existing benchmark schemes and JSVM. Each sequence having QCIF and CIF are encoded and the frame rates of 3.75, 7.5 and 15 frames per second are considered for comparison. The bit rate and PSNR for each scheme of different video sequences are not common. From the analysis the traditional

JSVM consumes few bit rates in turn minimum PSNR with other schemes. The other two schemes Liu2008 and Hu2012 have better improvement in PSNR with the increment number of bits. The proposed rate control scheme too maintains a stable PSNR level and bit rate with Liu2008 and Hu2012. In addition, the proposed scheme makes use of the buffer effectively with the PID controller which lags in previous schemes.

Table 2 Comparison between proposed and existing schemes

Sequence	Resolution	Frame rate	JSVM		Liu2008		Hu2012		Proposed	
			Bitrate	PSNR	Bitrate	PSNR	Bitrate	PSNR	Bitrate	PSNR
Bus	**QCIF**	3.75	160.83	37.78	161.06	38.00	161.48	38.21	161.37	38.02
		7.5	221.80	36.65	222.03	36.87	222.45	37.09	222.12	36.86
		15	288.65	35.59	288.89	35.81	289.31	36.00	289.19	36.01
	CIF	3.75	462.14	36.45	462.34	36.59	462.63	36.77	462.30	36.54
		7.5	623.39	35.48	623.59	35.62	623.88	35.79	623.74	35.94
		15	785.15	34.60	785.35	34.74	785.64	34.91	785.67	34.87
City	**QCIF**	3.75	89.70	38.48	89.93	38.70	90.35	38.90	90.24	38.72
		7.5	115.61	37.91	115.84	38.13	116.26	38.35	115.93	38.12
		15	137.89	37.29	138.13	37.51	138.55	37.71	138.43	37.72
	CIF	3.75	381.63	36.16	381.83	36.30	382.12	36.48	381.79	36.24
		7.5	486.23	35.33	486.43	35.47	486.72	35.64	486.58	35.79
		15	573.67	34.64	573.87	34.78	574.16	34.95	574.19	34.91
Crew	**QCIF**	3.75	65.71	40.39	65.94	40.61	66.36	40.82	66.25	40.63
		7.5	90.58	39.48	90.81	39.70	91.23	39.93	90.90	39.69
		15	128.47	38.56	128.70	38.78	129.12	38.97	129.00	38.98
	CIF	3.75	148.80	39.51	149.00	39.65	149.29	39.82	148.96	39.59
		7.5	204.82	38.67	205.02	38.81	205.31	38.98	205.17	39.13
		15	292.83	37.92	293.03	38.06	293.32	38.22	293.35	38.18
Football	**QCIF**	3.75	207.64	37.21	207.87	37.43	208.29	37.63	208.18	37.45
		7.5	309.36	35.95	309.59	36.17	310.01	36.39	309.68	36.16
		15	417.21	34.79	417.45	35.01	417.87	35.20	417.75	35.21
	CIF	3.75	439.30	36.57	439.50	36.71	439.79	36.88	439.46	36.65
		7.5	691.09	35.43	691.29	35.57	691.58	35.73	691.45	35.88
		15	992.13	34.34	992.33	34.48	992.62	34.65	992.66	34.61
Foreman	**QCIF**	3.75	76.78	39.38	77.01	39.60	77.43	39.80	77.32	39.62
		7.5	109.62	38.65	109.85	38.87	110.27	39.09	109.94	38.86
		15	142.12	38.03	142.35	38.25	142.77	38.44	142.66	38.45
	CIF	3.75	172.36	38.31	172.56	38.45	172.85	38.62	172.52	38.39
		7.5	241.73	37.73	241.93	37.87	242.22	38.04	242.08	38.19
		15	310.72	37.21	310.92	37.35	311.21	37.52	311.24	37.48
Average	**QCIF**		170.80	37.74	171.03	37.96	171.45	38.17	171.26	38.03
	CIF		453.73	36.56	453.93	36.70	454.22	36.87	454.08	36.82

Figure 2 and Figure 3 shows the efficient utilization of the buffer for both base layer and enhancement layer. The PID controller reduces the error smoothly between the target buffer and current buffer fullness. Compared to other rate control scheme which takes only error as input, the proposed PID controller includes proportional part considers present error, integrative part considers past error and derivative part to predict future errors. From Control systems, the best part to control in the absence of any knowledge, the PID controller. Using this PID controller bit rates can be controlled accordingly based on QP for video coding.

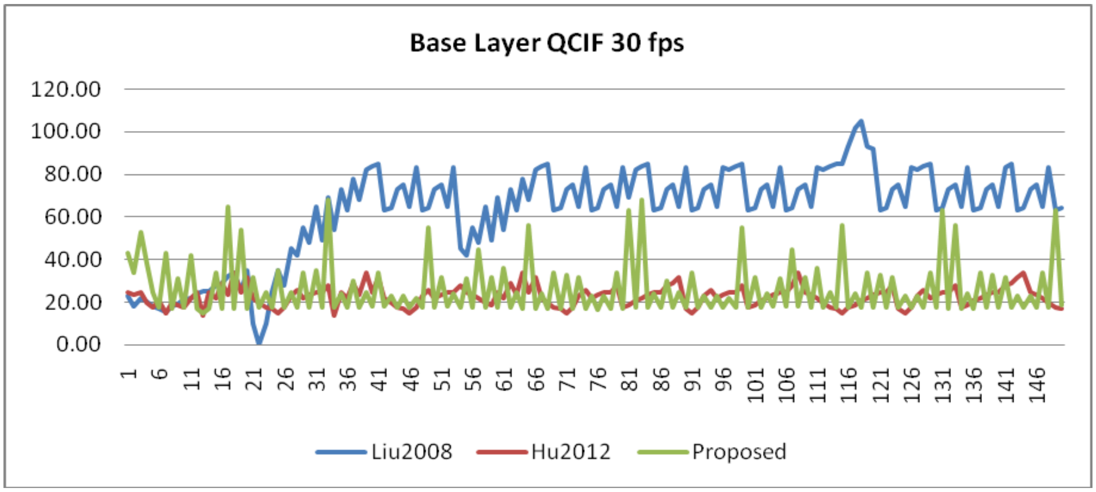

Figure 2 Comparative analysis of buffer occupancy for Base Layer

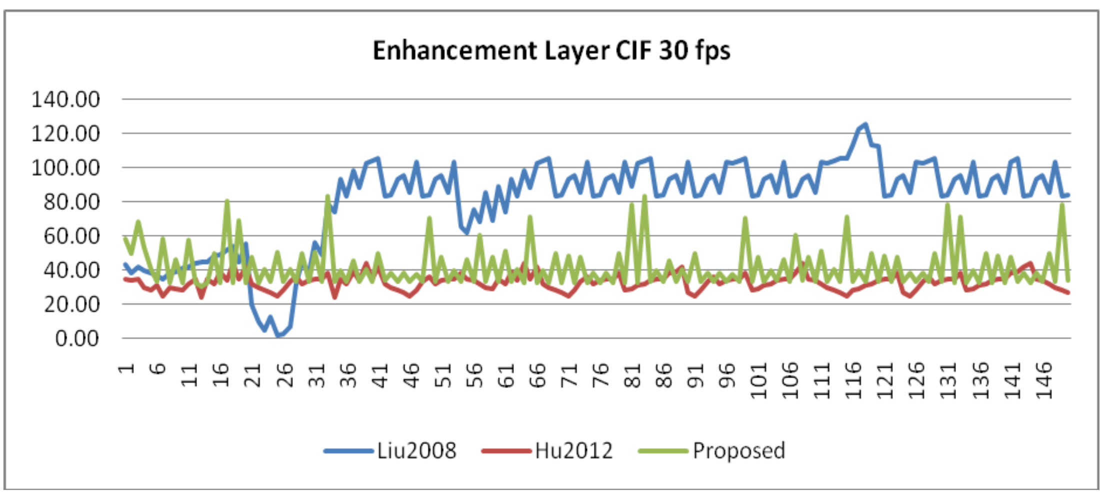

Figure 3 Comparative analysis of buffer occupancy for Enhancement Layer

A rate control scheme proposed for combined spatial and temporal scalable video coding produces better results in effectively utilizing the buffer. The scheme also stands on par with the previous rate control schemes in terms of PSNR and bit rate.

5 Conclusion

A combined spatial-temporal rate control scheme is proposed for scalable video coding which estimates introductory quantization parameter. Complete variance distortion based introductory QP achieves efficient rate control at the buffer occupancy level. With the estimated buffer level, target bits are determined considering the coding complexity. A proportional integral and derivative (PID) controller calculates the error and minimizes the fluctuation between the actual buffer fullness and target buffer fullness. The proposed scheme successfully exploits entire buffer exclusive of crossing overflow and underflow. The investigational results are compared with other two benchmark schemes and the proposed scheme can able to achieve better target bit adjustment with condensed fluctuations and competent buffer utilization.

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