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On Enhancing H.264 Rate Control by PSNR-Based Frame Complexity Estimation

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***Abstract*—This paper presents an enhancement to the frame layer buffer status-based H.264 rate control method. The enhancement is by using a PSNR-based frame complexity estimation to improve the existing mean absolute difference based (MAD-based) complexity measure. Bit allocation to each frame is not just computed by encoder buffer status but also adjusted by combined frame complexity measure. Simulation results show that the H.264 encoder, using the proposed algorithm, can achieve better visual performance than that of the existing H.264 JVT rate control method (JVT_G012).**

I. INTRODUCTION

H.264/AVC was developed jointly by ISO/IEC and ITU-T to double the coding efficiency in comparison with other recent existing video coding standards such as MPEG-4 for a broad variety of applications. With many sophisticated coding features and technologies involved, rate control for H.264 is more difficult than those for previous standards. Recent studies on bit allocation for rate control include those that were based primarily on the buffer status, as in [3] and [4], and those that considered video complexity, as in [5] and [6]. Although mean absolute difference (MAD) of residuals has been considered recently as a means in estimating the complexity of a frame [2], it is difficult to obtain a good estimate of MAD for H.264 frame prior to the actual coding, due to the complex rate-distortion optimization (RDO) problem, as described in JVT-G012 [1]. A simple PSNR-based frame complexity estimation scheme is therefore proposed to enhance the correctness of frame complexity measure. The complexity result is then added to the buffer-based technique to obtain a more accurate target bits estimation for frames. Such bit estimation will be essential in determining the quantization parameter (QP).

II. PSNR-BASED FRAME COMPLEXITY ENHANCEMENT FOR BIT ALLOCATION

In [2], MAD ratio of residuals is adopted as complexity measure of current frame. MAD ratio ($MAD_{ratio,j}$) is the ratio of the predicted MAD of current frame j to the average MAD of all previously encoded P frames in the group of pictures (GOP). The reason why we use predicted MAD is that it would be impractical to obtain the actual MAD of current frame prior to actual encoding in H.264, due to the complex RDO process [1]. This prediction of MAD fails when the motion in a frame becomes fast and complex or when there is a scene change. We therefore propose a PSNR-based method to compensate this inadequacy of the MAD-based method.

We first calculate the $PSNR_{skip,j}$ of a frame by assuming that the frame be skipped and interpolated from the nearest previously reconstructed frame j-1. We then define PSNR drop by $PSNR_{drop,j} = PSNR_{j-1} - PSNR_{skip,j}$. Finally we define *estimated* PSNR drop ratio ($PSNR_{drop\text{-}ratio,j}$) as the ratio of the PSNR drop of the current frame to the average PSNR drop of all previously coded P frames in the GOP. The *actual* PSNR drop ratio is the ratio of the PSNR drop of the current frame to the average PSNR drop of all coded P frames in the GOP. Figure 1 shows $PSNR_{drop\text{-}ratio}$ for the sequence "Foreman". It is clear that the estimation is very accurate (average estimation error is as small as 0.04). Higher PSNR drop ratio implies higher frame complexity, possibly due to scene change or high motion. The reason is that the relative large prediction error occurs when current frame is a frame with high motion or scene change.

Our final frame complexity measure FC is a weighted combination of $MAD_{ratio,j}$ and $PSNR_{drop\text{-}ratio,j}$, given by

$$FC = \omega * MAD_{ratio,j} + (1-\omega) PSNR_{drop\text{-}ratio,j} \qquad (1)$$

where ω is a weighting factor and its typical value is set to 0.70 in our experiments.

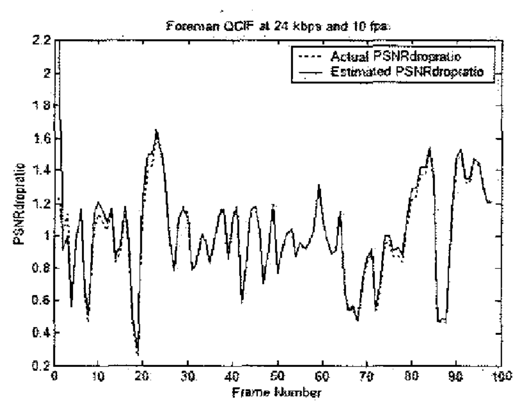

Fig. 1 PSNR drop ratio of each frame for sequence "Foreman"

The target number of bits for the current frame, T, is a weighted combination of two parts: (a) the number of bits computed based on the buffer status (denoted as T_{buf}) [1]; and (b) the number of bits by scaling the average bits of all

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not yet coded frames adjusted by the complexity of the frame FC (denoted as T_r). T is given by

$$T = \beta * T_r + (1-\beta) * T_{buf} \quad (2)$$

$$T_{buf} = (u/F_r) - \gamma \cdot (B_c - B_t) \quad (3)$$

$$T_r = \begin{cases} 0.8 \cdot FC \cdot R_r / N_r & FC < 1.1 \\ (0.88 + 0.3 \cdot (FC - 1.1)) \cdot R_r / N_r & 1.1 \le FC < 2.0 \\ 1.15 & FC \ge 2.0 \end{cases} \quad (4)$$

where β is a weighting factor and its typical value is 0.70, B_c is the current buffer occupancy, B_t is the target buffer level of the current frame [1], u is the channel bandwidth, F_r is the predefined frame rate (hence u/F_r is bits/frame flowing out), γ is a constant with typical value of 0.75, R_r is the number of bits remaining for encoding the sequence, and N_r is the number of P-frames remaining to be coded. In (4), bit allocation is biased toward frames with higher complexity, to help improve visual quality during high motions or scene changes. After obtaining T, the QP of current frame is computed based on the quadratic R-Q model [4].

III. EXPERIMENTAL RESULS

In our experiments, test platform JM6.1 [7] is adopted. The JVT rate control scheme [1] is selected as a reference for comparison. Frame skipping is implemented in our scheme and in the JVT scheme [1], whenever necessary. All test sequences used are in QCIF 4:2:0 formats. The PSNR of each frame in "Foreman" is plotted in Figure 2. It is clear that the average PSNR and its standard deviation were significantly improved by using our method. The results of other test videos are listed in Table I. We achieved an average PSNR gain of 0.50 dB and reduced PSNR deviation well, especially in video sequences with high motions (such as "Foreman"). Table I also shows that both JVT [1] and our scheme achieved accurate target bit rates. The visual quality improvement is due to applying our enhanced frame complexity measure in bit allocation.

IV. CONCLUSION

In this paper, a PSNR-based frame complexity measure is developed to enhance the existing MAD-based method and is applied to our bit allocation for rate control. Our proposed method improves visual quality and its variation.

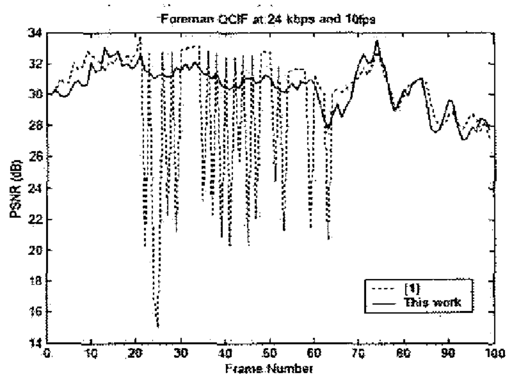

Fig. 2 PSNR of each frame for sequence "Foreman"

TABLE I
SIMULATION RESULTS OF PROPOSED ALGORITHM IN TERMS OF PSNR (DB) AND BIT RATES (KBPS)

Sequence	Frame Rate (fps)	Average PSNR (dB)			PSNR Std. Deviation		Bit Rates (kbps)	
		[1]	Ours	Gain	[1]	Ours	[1]	Ours
Akiyo (24 kbps)	10	40.03	40.35	+0.32	1.77	1.80	23.93	23.89
Akiyo (48 kbps)	30	41.58	41.89	+0.31	1.46	1.47	47.93	47.92
Foreman (24 kbps)	10	29.48	30.49	+1.01	4.07	1.43	24.30	24.01
Foreman (48 kbps)	10	33.24	33.75	+0.51	3.38	1.42	47.81	48.00
News (24 kbps)	30	30.31	30.67	+0.36	0.82	1.00	24.08	24.15
Salesman (24 kbps)	30	32.10	32.58	+0.48	1.69	1.97	24.05	24.09

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