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An Adaptive Quantization Based PVC Scheme for HEVC

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ABSTRACT

In order to achieve highly compact representation for videos, we propose an adaptive quantization based perceptual video coding (PVC) scheme in this paper. Because human only perceive the limited discrete-scale quality levels, the perceptual quantization is transformed into the problem of how to determine the maximum quantization parameter (Qp) under the same perceptual quality level. So, the relationship between perceptual quality level and quantization parameter is analyzed with the statistical way in this paper. The frame-level Qp value for each quality level is determined based on the maximum probability criterion. Then, the just noticeable distortion is estimated to guide the Qp adjustment in the coding unit level (CU-level). In summary, the perceptual quantization is achieved in both the frame level and the CU level according to characteristics of human visual system (HVS). Experimental results show that the proposed PVC scheme achieves substantial bitrate reduction with better subjective and objective quality in comparison with other PVC schemes.

INTRODUCTION

In prevailing video coding standards, numerous technologies have been proposed to remove the redundancy within videos. Actually, the small variation in pixel difference is cannot perceived by human visual system (HVS), which means that a large amount of perceptual redundancy can be removed. To further improve the compression, the perceptual video coding (PVC) has attracted wide attention in recent year.

In the prevailing perceptual video coding schemes, the just noticeable distortion (JND), i.e. the minimum distortion can be perceived by HVS, and perception-based quantization algorithms are utilized to achieve the reduction of bitrate with negligible perceptual quality loss. However, the HVS is an extremely complex system and the process of signal processing in this system has not been fully understood, resulting in the proposed JND models are not accurate enough. In addition, the relationship between the perceptual quality and the quantization parameter (or the quantization step) has not been fully studied and analyzed.

In order to improve the situation, this paper proposes a two-level adaptive quantization based PVC scheme to improve the compress with better perceptual quality, i.e., the Qp is adaptive in both the frame level and the coding unit level (CU-level). In our statistical experiment, the perceptual quality of the compressed video is divided into three levels. All Qps (0-51) are also divided into three groups according to the three distribution functions. The frame-level quantization parameter for each Qp group is determined by the maximum probability criterion in our statistical experiment. In addition, the JND characteristic is incorporated into CU-level quantization.

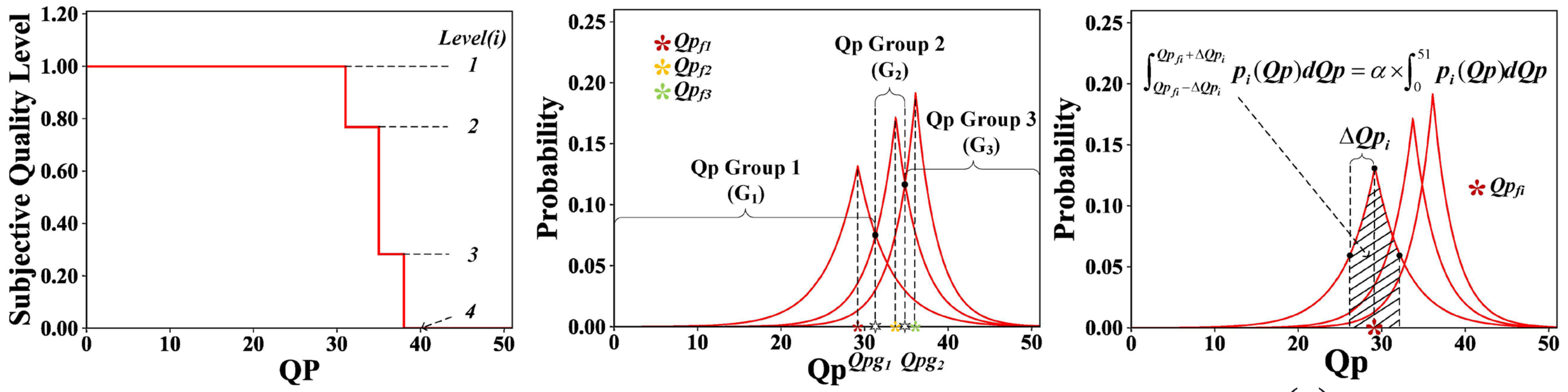
TWO-LEVEL PERCEPTUAL QUANTIZATION

To obtain high compression efficiency for videos, we propose an adaptive quantization based perceptual video coding (PVC) scheme in this paper. As shown in Figure 1-(a), human only perceive limited discrete-scale quality levels [1]. So, we find the maximum quantization parameters (Qps) for all quality levels according to our statistical experiment, and apply them in perceptual quantization in frame level. In addition, the just noticeable distortion (JND) is estimated to adjust the perceptual quantization in coding unit (CU) level.

As shown in Figure 1-(b), according to the maximum Qp distribution of each level, all Qps are divided into three groups and the perceptual Qp for each group is determined based on maximum probability criterion. In practical coding, for a given Qp, Qp_{fi} is chosen as the frame-level perceptual Qp in the case of $Qp \in G_i$. Then, the perceptual Qp for each CU (Qp_{ci}) is calculated based on the average JND value of the frame ($\bar{J}_f$) and the current CU ($\bar{J}_{CU}$) as follows:

$$Qp_{ci}=Qp_{fi}+\frac{\bar{J}_{CU}-\bar{J}_f}{J_{fmax}-\bar{J}_f}\bullet\Delta Qp_i \qquad (1)$$

J_{fmax} is the maximum JND value of the frame. ΔQp_i is the maximum Qp offset based on Qp_{fi}. , determined as shown in Figure 1-(c). Thus, the Qps for all CUs in one frame fall in the range of $[Qp_{fi}-\Delta Qp_i, Qp_{fi}+\Delta Qp_i]$.



(a) (b) (c)

Figure 1: The perceptual Qps determination: (a) Quality levels in all Qps; (b) Three Qp groups and corresponding perceptual Qps; (c) The CU-level Qp range in i-th quality level.

RESULT

To verify the effectiveness of the proposed perceptual quantization scheme, we have integrated it into a version of HEVC reference codec (HM-16.17) to compare with the original HM16.17. For the convenience of comparing performance with Bae's PVC scheme [2] the proposed PVC scheme has also been incorporated into HM11.0.

In Table 1, PSNR and Multi-scale structural similarity (MS-SSIM) are applied to measure the objective quality and the perceptual quality of the compressed videos. In terms of MS-SSIM, the average reduction for all sequences is 0.003, indicating that the proposed PVC scheme achieves similar perceptual quality to the original HM 16.17. Under the condition of similar perceptual quality, the proposed PVC scheme achieves 13.09% bit rate reduction on average.

As shown in Table 2, the DMOS (differential mean opinion score) values of the proposed PVC scheme are closer to zero with small standard deviation values in the DMOS range of -100 to +100, demonstrating that it has better perceptual quality and is more consistent with the original HM 11.0 compared with Bae's PVC scheme. And the average bitrate reduction among test sequences is higher.

Table 1 Average Objective and Subjective test results for the proposed PVC scheme vs HM 16.17 in All-Intra Main Profile

Class	Avg-ΔP(dB)	Avg-ΔM	Avg-ΔR(%)
4K	-0.794	-0.003	-15.15
A	-1.292	-0.004	-13.14
B	-0.883	-0.003	-13.70
C	-1.210	-0.003	-11.51
D	-1.333	-0.003	-11.50
E	-0.774	-0.001	-10.74
All-Seqs	-1.015	-0.003	-13.09

Table 2 Objective and Subjective test result for Bae's PVC scheme [2] and Proposed PVC Scheme vs HM 11.0 in All-Intra Main Profile

Seq.	QP	ΔP(dB)		ΔR(%)		DMOS(std)	
		Bae's JND	Prop.	Bae's JND	Prop.	Bae's JND	Prop.
BQTerrace	22	-3.96	-4.75	-39.96	-35.86	-0.7(0.9)	-0.2(0.4)
	27	-2.12	-0.81	-16.43	-11.06	-0.6(1.0)	-0.3(0.5)
	32	-0.52	-0.59	-0.02	-9.26	-0.4(1.0)	-0.5(0.5)
	37	-0.10	-0.00	-0.58	0.03	-0.8(0.7)	0.5(0.8)
Cactus	22	-2.74	-2.47	-27.94	-39.16	-0.8(1.1)	0.0(0.0)
	27	-1.43	-0.47	-8.33	-10.15	-0.7(0.8)	-0.2(0.4)
	32	-0.35	-0.45	-1.52	-9.34	-0.5(1.7)	-0.3(1.0)
	37	-0.05	-0.00	-0.39	0.12	-0.2(0.9)	0.3(0.8)
ParkScene	22	-3.38	-2.66	-24.28	-32.65	-0.7(1.0)	-0.2(0.4)
	27	-1.65	-0.57	-7.95	-9.67	-0.3(0.7)	-0.2(0.4)
	32	-0.33	-0.52	-1.97	-10.01	-0.4(0.7)	-0.5(0.8)
	37	-0.02	0.01	-0.55	0.29	0.1(0.7)	0.0(0.9)
BQMall	22	-3.90	-2.96	-23.31	-27.49	-0.7(0.9)	-0.5(0.5)
	27	-2.39	-0.71	-9.75	-8.64	-1.0(1.1)	-0.5(0.5)
	32	-0.53	-0.63	-0.55	-8.35	0.1(0.9)	-0.2(1.0)
	37	-0.07	0.00	-0.32	0.01	0.3(1.0)	0.3(1.0)
PartyScene	22	-4.76	-4.40	-32.85	-28.92	-0.8(0.9)	-0.3(1.0)
	27	-3.35	-0.95	-16.88	-9.27	-0.6(0.9)	0.0(0.6)
	32	-0.42	-0.77	-0.91	-8.95	-0.5(1.0)	-0.2(1.0)
	37	-0.05	-0.00	-0.40	-0.06	-0.2(1.0)	0.2(1.0)
RaceHorses	22	-3.96	-3.59	-26.75	-27.85	-0.2(1.6)	-0.2(0.4)
	27	-2.65	-0.88	-15.64	-9.48	-0.7(0.9)	-0.2(0.8)
	32	-0.32	-0.75	-0.57	-9.75	-0.2(0.6)	-0.7(0.5)
	37	-0.03	0.00	-0.35	0.26	-0.4(0.8)	-0.2(1.0)
Avg		-1.63	-1.21	-10.76	-12.72	-0.5(0.9)	-0.2(0.7)

CONCLUSION

In this paper, we proposed an adaptive quantization based PVC scheme which performs perceptual quantization in both the frame level and the CU level. Firstly, according to the analysis of the relationship between the perceptual quality and the quantization parameters, the frame-level Qp is determined to achieve the perceptual quantization for video coding. Secondly, the JND threshold is incorporated into the quantization to achieve the Qp perceptual adjustment in the CU level. The subjective and objective experimental results show that the proposed perceptual quantization based PVC scheme reduces the bit rate effectively with negligible perceptual quality loss.

REFERENCES

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