FLICKER REDUCTION IN INTRA CODED FRAMES OF H.264/AVC

Seong Soo Chun, Han-Jin Ryu, and Sanghoon Sull

Department of Electronics and Computer Engineering, Korea University
E-mail: sschun@mpeg.korea.ac.kr, hanjin@mpeg.korea.ac.kr, sull@mpeg.korea.ac.kr

ABSTRACT

The H.264/AVC video coding standard adopted a new intra prediction technique that enables high coding efficiency for intra coded frames. However, it is known to produce more flickers in intra coded frames when the modes are selected based on conventional rate distortion optimized mode decision methods. In this paper, we propose to use a modified distortion measure for rate distortion optimized mode decision to reduce flicker in intra coded frames of H.264/AVC. Experimental results show that our proposed method can reduce significant amount of flicker maintaining similar PSNR and bitrate.

Index Terms— H.264/AVC, flicker, intra prediction, rate-distortion optimized mode decision

1. INTRODUCTION

THE H.264/AVC is the newest video coding standard developed by ITU-T Video Coding Experts Group (VCEG) and ISO/IEC MPEG Video Group named Joint Video Group (JVT) [1]. H.264/AVC is intended for use in a wide range of applications including high bitrate applications such as HDTV broadcasting and low bitrate applications such as video delivery to mobile devices. The high coding efficiency of H.264, that gives perceptually equivalent video quality at much less bitrate compared to traditional video coding standards such as MPEG-2 [2], is expected to encourage TV and internet broadcasters to fast adopt the new H.264 video coding technology.

The high coding efficiency of H.264 is not a result of a single feature but a combination of various advanced features. Among various advanced features, H.264/AVC adopted a new intra prediction technique to reduce spatial redundancy between adjacent macroblocks. Although the newly adopted intra prediction technique adopted in H.264/AVC enables high coding efficiency for intra frame coding, it is known to produce more flicker [3]. Flicker is an artifact produced by significantly extended difference of encoded values relative to pixel differences which were originally similar between two frames. Flicker is enlarged in low bit rate videos due to coarse quantization and becomes extremely visible in static regions where little motion is involved. In order to reduce flicker, Fan et. al [3] proposed a flicker reduction method for H.264/AVC by quantizing the intra prediction signal such the selected intra prediction mode have little effect on flicker. Although Fan's method is known to reduce flickers, they alter the intra prediction process and their resulting bitstreams are not H.264/AVC standard compliant. In this paper, we propose to use a modified distortion measure for rate distortion optimized mode decision to reduce flicker in intra coded frames of H.264/AVC.

2. FLICKER IN INTRA CODED FRAMES OF H.264/AVC

One of the reasons that flicker artifacts occur in video is due to small changes in pixel values that may occur although the static region in the video frame seem identical. This small change of pixels values in the spatial domain might have a significant impact on the transformed coefficients after quantization and dequantization. This problem has been addressed in Motion JPEG2000 which employs still image compression on each frame of a video without using any interframe technique such as motion compensation [4]. The same flickering effect may be observed for sequences encoded by H.264/AVC with only intra coded frames. Moreover, it has been reported in [3], that flicker is more noticeable in all intra frame coded sequences of H.264/AVC compared to all intra frame coded sequences of traditional image/video coding standards such as MPEG-4.

The main reason for the increased flicker is due to different intra prediction signals that may be used to intra code a macroblock that is originally similar between two successive frames. The difference in prediction signal is caused either by a differently selected intra prediction mode, or different decoded values of neighboring macroblocks used for intra prediction, or a combination of the two. This difference in prediction signal has an impact on the transform coefficients of the residual signal after quantization and dequantization and produces significantly different encoded values for similar macroblocks. In order to verify the effects of intra prediction in producing flicker artifacts, an objective measure for the amount of flicker artifacts needs to be defined. We used the flicker measure S defined in [3] which can be expressed as:

$$
\begin{aligned}
S &= \frac{1}{\operatorname{card}(I)} \sum_{(\mathbf{x},t)\in I} \left[\delta_t(\mathbf{x}) - \hat{\delta}_t(\mathbf{x}) \right]^2, \\
I &= \left\{ I_i \mid \sum_{(\mathbf{x},t)\in I_i} [\delta_t(\mathbf{x})]^2 < \varepsilon, i = 1,2,\ldots,N \right\}, \\
\delta_t(\mathbf{x}) &= \left| f_t(\mathbf{x}) - f_{t-1}(\mathbf{x}) \right|, \\
\hat{\delta}_t(\mathbf{x}) &= \left| f_t(\mathbf{x}) - \hat{f}_{t-1}(\mathbf{x}) \right|,
\end{aligned} \tag{1}
$$

where card(I) denotes the cardinality of I, I_i denotes each i^{th} macroblock from a set of N macroblocks, and $f_t(\mathbf{x})$ and $\hat{f}_t(\mathbf{x})$ represent the pixel values at coordinates $\mathbf{x}=(x_0, x_1)$ of the input and reconstructed frames at time (frame) t, respectively. Thus, the flicker measure S indicates the average extended pixel difference of reconstructed macroblocks between two frames which were originally similar in pixel value. In Table 1, we encoded two test sequences (100 frames, Q=32) with only intra coded frames given all available intra prediction modes and with DC mode only. From the results in Table 1, it can be seen that H.264/AVC adopting various intra prediction modes does in fact produce more flicker artifacts. Subjective testing of the encoded frames also showed that more flickers eare introduced as the available number of intra prediction modes is increased.

Table 1 Flicker measurement of two video sequences

	All Intra Modes	Only DC Mode
Akiyo	1378	565
Container	1801	933

Not only does flicker occur in all intra coded frame sequences but also in periodically inserted intra coded frames of motion compensated coded sequences. The flicker may be noticeable in intra coded frames especially for low/medium activity video sequences and/or video sequences coded with high quantization step sizes. This is mainly due to a significant number of macroblocks that tend to be coded in "skip mode" in such conditions. Since the pixel values of an intra coded frame are simply reused in skipped macroblocks, similar flicker artifact may be noticeable in periodically inserted intra coded frames of motion compensated coded sequences as those sequences encoded with only intra coded frames.

3. PROPOSED FLICKER REDUCTION IN INTRA CODED FRAMES

To reduce flicker in intra coded frames, our proposed method is composed of two steps. First, a candidate set of macroblocks that are susceptible to flicker is selected in intra coded frames. Then for a selected candidate set of macroblocks, a modified distortion measure is used for rate distortion optimized intra mode selection to reduce flicker.

3.1. Selection of candidate macroblocks

Through subjective testing, it was observed that flicker is extremely visible in areas of the intra coded frame that is static and no moving objects appear. Therefore, we firstly select a candidate set of macroblocks that corresponds to static regions in intra coded frames. The macroblocks in intra coded frames that satisfy the following condition

$$\sum_{(\mathbf{x},t)\in I} [f_t(\mathbf{x}) - f_{t-1}(\mathbf{x})]^2 < T, \tag{2}$$

for a certain threshold value T are selected as target macroblocks, where I denotes the candidate macroblock, and $f_t(\mathbf{x})$ is the input pixel value at $\mathbf{x} = (x_0, x_1)$ in frame t. We then apply our proposed intra prediction mode selection method for the selected candidate sets of macroblocks.

3.2. Intra prediction mode selection

The current JVT Model (JM) software [5] uses a rate-distortion optimized intra prediction mode selection algorithm based on Lagrange technique [6, 7]. Let $\mathbf{I} = (I_1, I_2, \ldots, I_N)$ denote a group of N macroblocks. The objective of rate distortion optimized mode decision is to find a vector of N macroblock modes $\mathbf{M} = (M_1, M_2, \ldots, M_N)$ such that the total distortion is minimized subject to a rate constraint R_T which can be expressed as

$$
\begin{aligned}
&\arg\min_{\mathbf{M}} \sum_{i=1}^{N} D(I_i, M_i) \\
&subject\ to \\
&\sum_{i=1}^{N} R(I_i, M_i) < R_T,
\end{aligned} \tag{3}
$$

where $D(I_i, M_i)$ and $R(I_i, M_i)$ represents the distortion and rate resulting from quantization of macroblock I_i with a particular mode M_i. Assuming macroblock independency [7], the constraint problem in (3) can be expressed as an unconstrained problem and expressed as

$$
\begin{aligned}
&\sum_{i=1}^{N} \arg\min_{M_i} J(I_i, M_i) \\
&with \\
&J(I_i, M_i) = D(I_i, M_i) + \lambda_{MODE} R(I_i, M_i).
\end{aligned} \tag{4}
$$

Therefore, the problem in (4) can be solved by independently selecting the mode M_i that minimizes the rate distortion cost function $J(I_i, M_i)$ for each macroblock I_i.

Conventionally the distortion measure $D(I_i, M_i)$ in (4) is measured as a sum of squared differences ε_{SSD} between the reconstructed and the original macroblock pixels defined as

$$\varepsilon_{SSD} = \sum_{(\mathbf{x},t)\in I_i} \left[f_t(\mathbf{x}) - \hat{f}_t(\mathbf{x}) \right]^2, \qquad (5)$$

where $f_t(\mathbf{x})$ is the original pixel value and $\hat{f}_t(\mathbf{x})$ is the corresponding reconstructed pixel value at $\mathbf{x} = (x_0, x_1)$ in frame t.

In order to reduce flicker, we propose to use a modified distortion measure for rate distortion optimized mode decision in (4). The distortion measure is defined as

$$\begin{aligned} & D(I_i, M_i) = \varepsilon_{SSD} + S_{Flicker} \\ & with \\ & S_{Flicker} = \sum_{(\mathbf{x},t)\in I_i} \left[\delta_t(\mathbf{x}) - \hat{\delta}_t(\mathbf{x}) \right]^2, \\ & \delta_t(\mathbf{x}) = \left| f_t(\mathbf{x}) - f_{t-1}(\mathbf{x}) \right|, \\ & \hat{\delta}_t(\mathbf{x}) = \left| \hat{f}_t(\mathbf{x}) - \hat{f}_{t-1}(\mathbf{x}) \right|, \end{aligned} \qquad (6)$$

where a new term $S_{Flicker}$ is added to measure the amount of flicker which is also considered to be a part of distortion.

In order to find the lagrange multiplier λ_{MODE} that controls the intra prediction mode decision when evaluating (4) using our proposed distortion measure, we conducted an experiment to obtain the relationship between the quantization parameter Q and the lagrange multiplier λ_{MODE}. Similar to the experiment conducted in [8], we varied lagrange multiplier λ_{MODE} over seven values: 5, 25, 50, 100, 250, 500, 1000, and obtained the quantization parameter Q that minimizes the rate distortion cost function in (4) while encoding 100 frames of video sequences "Akiyo", "Container", "Mobile", and "Garden". In Fig. 1, the bold line shows the function

$$\lambda_{MODE}(Q) = 0.85 \times 2^{(Q-12)/3}, \qquad (7)$$

which is the approximated relationship between Q and λ_{MODE} currently used in JM software, and the dotted lines show the resulting average value of selected Q for a given value of λ_{MODE} for each video sequences. Preliminary results show that for a given quantization parameter, it is reasonable to use the same relationship between Q and λ_{MODE} in (7) even when our modified distortion measure is used for rate distortion cost function in (4).

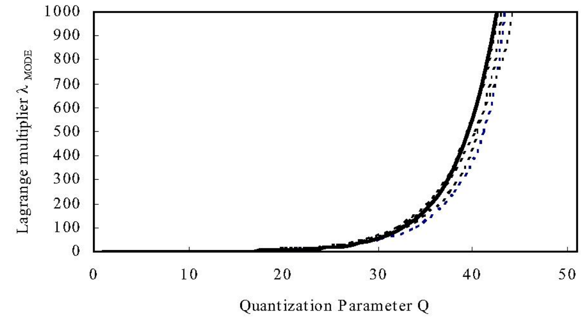

Fig. 1 Lagrange multiplier λ_{MODE} vs. Quantization parameter Q.

Table 2 Test Conditions

Video Sequence	Akiyo	Container
Frame rate (Hz)	30	30
Total frames	100	100
Quantization Q	27, 32, 38, 44	
Coding option	R-D optimization on (High Complexity), All I structure and IPPPP structure, CABAC	
Encoder	JM98 encoder	

4. EXPERIMENTAL RESULTS

To show the effectiveness of our proposed method, it was implemented based on JM98 software [5]. The test conditions are shown in Table 2.

For the evaluation of the proposed method, we measured the bitrate, PSNR, and the flicker measure S (ε set to 500) between the proposed method and the original JM encoder.

Table 3, 4, 5 and 6 show the tabulate performance comparison of the proposed method with the original JM encoder. Note that in these tables, positive and negative values of Δincrement represent an increase and decrease in value, respectively.

The experimental results show that our proposed method can reduce flicker in both all intra coded sequences, and motion compensated sequence. There was a significant decrease of flicker in between 22.1% and 49.5% for all intra coded frame sequences and a decrease of flicker in between 13.5% and 35.2% for IPPP structured motion compensated sequences while maintaining similar PSNR. Subjective quality testing also showed that the decoded images of our proposed method looked better due to a decrease in flicker. On the other hand, our proposed method showed an increase in bitrate in between 0.3% and 2.6%, and a negliglible increase in encoding time (within 0.5%) due to the modified distortion measure which requires more computation compared to the original JM software.

Table 3 Results of all intra coded sequence "Akiyo"

Measures	*Q*	Original	Proposed	ΔIncrement
PSNR (dB)	28	38.97	38.98	0.01 dB
	32	35.94	35.92	-0.02 dB
	38	31.77	31.80	0.03 dB
	44	28.15	28.09	-0.06 dB
Bitrate (Kbps)	28	567.4	578.0	1.9 %
	32	398.6	407.0	2.1 %
	38	227.9	231.0	1.3 %
	44	135.0	135.9	0.7 %
Flicker (S)	28	731.5	570.1	-22.1 %
	32	1378.4	975.6	-29.2 %
	38	2824.9	1426.6	-49.5 %
	44	4644.6	3372.3	-27.4 %

Table 4 Results of all intra coded sequence "Container"

Measures	*Q*	Original	Proposed	ΔIncrement
PSNR (dB)	28	37.23	37.25	0.02 dB
	32	34.33	34.36	0.03 dB
	38	30.23	30.28	0.05 dB
	44	26.19	26.20	0.02 dB
Bitrate (Kbps)	28	739.8	752.6	1.7 %
	32	503.7	514.7	2.2 %
	38	268.6	275.7	2.6 %
	44	138.1	140.2	1.5 %
Flicker (*S*)	28	1077.1	771.6	-28.4 %
	32	1801.3	1163.0	-35.4 %
	38	3553.7	2078.8	-41.5 %
	44	7615.1	4409.0	-42.1 %

Table 5 Results of IPPPP coded sequence "Akiyo"

Measures	*Q*	Original	Proposed	ΔIncrement
PSNR (dB)	28	38.95	38.92	-0.04 dB
	32	36.09	36.08	-0.01 dB
	38	32.02	32.00	-0.02 dB
	44	28.34	28.25	-0.08 dB
Bitrate (Kbps)	28	129.4	132.0	2.1 %
	32	89.3	91.2	2.1 %
	38	51.0	51.6	1.3 %
	44	30.5	30.6	0.3 %
Flicker (*S*)	28	353.3	293.6	-16.9 %
	32	608.7	526.7	-13.5 %
	38	1142.2	840.4	-26.4 %
	44	1760.3	1287.5	-26.9 %

Table 6 Results of IPPPP coded sequence "Container"

Measures	*Q*	Original	Proposed	ΔIncrement
PSNR (dB)	28	37.01	37.03	0.02 dB
	32	34.37	34.38	0.01 dB
	38	30.49	30.43	-0.06 dB
	44	26.55	26.42	-0.13 dB
Bitrate (Kbps)	28	164.1	167.6	2.1 %
	32	110.2	112.8	2.4 %
	38	59.0	60.5	2.4 %
	44	31.4	31.7	0.8 %
Flicker (*S*)	28	527.4	450.2	-14.6 %
	32	802.2	598.8	-25.4 %
	38	1475.1	955.9	-35.2 %
	44	2823.8	1933.4	-31.5 %

5. CONCLUSIONS

In this paper, we presented a method for intra prediction mode decision to reduce flickers in intra coded frames of H.264/AVC. It was shown through our experimental results that our proposed modified measure, for rate distortion optimized mode selection, reduced a significant amount of flicker in intra coded frames of H.264/AVC with a negligible change in PSNR and bitrate.

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