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LETTER

Adaptive Scan Pattern for Quantized Coefficients in Intra Coding of H.264

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SUMMARY Various scanning algorithms have been proposed to enhance the performance of intra prediction of H.264 codec. In this paper, an adaptive scanning scheme is proposed to achieve the entropy coding gain in intra coding, where scanning patterns are updated based on the probabilistic distribution of quantized coefficients of previous macroblocks so that the consecutive zeros are located at the rear part of the scanned data stream. Simulation results show that the average bit-rate reduction is about 2.15% in common test conditions.

key words: *H.264, intra prediction, scanning*

1. Introduction

Among the coding tools adopted in H.264, the intra prediction using directional spatial correlation is very important to achieving high picture quality and compression ratio. For the luminance components, the current block is predicted by a 4×4 block, a 8×8 block, and a 16×16 block. The residual data resulting from intra prediction is transformed and quantized. The quantized data is scanned along a zig-zag pattern regardless of direction mode. The scanned data is encoded by entropy coder, such as CAVLC (context-based adaptive variable-length coding) or CABAC (context-based adaptive binary arithmetic coding).

Various algorithms [1]–[4] have been proposed to develop the efficient scan schemes for intra prediction. These research works have studied the scan patterns for vertical and horizontal predictions. Xiaopeng Fan *et al.* [1] described that the probability distribution of the coefficient values is related to the selected mode. Thus, they used some modified scan patterns depending on the prediction mode. Kim *et al.* [2] utilized the similarity between the boundary pixels of surrounding blocks. Jie Jia *et al.* [3] proposed a modified field scanning scheme for vertical and horizontal prediction modes. Choi *et al.* [4] proposed six scan patterns including zig-zag pattern in the case where intra 4 × 4 prediction is used only.

In this paper, we propose an efficient scanning scheme where the scan patterns are adaptively updated according to the probability distribution of the quantized residual data. The proposed algorithm updates the scan pattern such that the consecutive zero values are located at the rear part of the scanned data stream.

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2. Adaptive Scanning Algorithm

The efficiency of the entropy coding is dominated by the number of consecutive zero coefficients which are scanned along a scanning pattern. The performance of the entropy coder increases as the number of the consecutive zero values located at the rear part of the scanned data stream increases. From empirical simulation using training data, we can see that the probabilistic distribution of zero value is varied according to the selected mode. Thus, the optimal scan patterns to maximize the number of the consecutive zeros are different for the selected modes. To increase the efficiency of the entropy coding, we propose an adaptive scanning scheme where the scan patterns are updated according to probability distribution functions (PDFs) of quantized coefficients of previous MBs (macroblocks).

Figure 1 shows the proposed block diagram using the adaptive scanning scheme where the updated scan patterns are used in RD (rate-distortion) optimization process to decide an optimal direction mode. The proposed technique consists of two phases; (a) zero value counting for the quantized coefficients, (b) updating the scan patterns according to the counted numbers. In the first phase, the number of coefficients quantized as zero value at each location of the encoded blocks is counted. The accumulated numbers of zero values generated from all previous intra MBs are stored. The second phase updates the scanning patterns so that the consecutive zeros are located at the rear part of the scanned data stream. The counting and updating processes are applied for each mode independently. Thus, each prediction mode uses a different scanning pattern. In this scheme, after a current block has been encoded by using the k th intra prediction mode ($k = 0, 1, 2, \cdots, 8$ for 4×4 block), the zero counter for

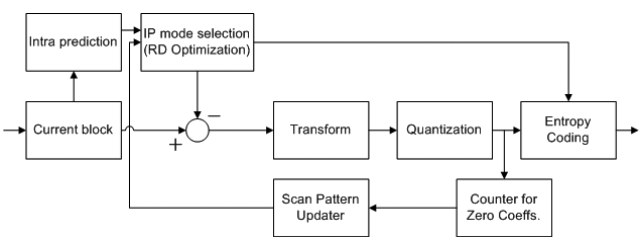

Fig. 1 Block diagram for intra coding using the proposed scanning scheme.

Table 1 Average bit reduction and average PSNR difference between conventional and proposed schemes using 4×4 mode only.

	Proposed scheme		Fan [1]		Kim [2]		Jia [3]	
	BDPSNR (dB)	ΔBit (%)	BDPSNR (dB)	ΔBit (%)	BDPSNR (dB)	ΔBit (%)	BDPSNR (dB)	ΔBit (%)
Carphone	0.21	−2.25	0.12	−1.38	0.15	−1.60	0.12	−1.38
Container	0.24	−2.34	0.16	−1.56	0.17	−1.66	0.13	−1.29
News	0.20	−1.81	0.12	−1.13	0.13	−1.18	0.11	−1.01
Paris	0.25	−2.18	0.17	−1.50	0.21	−1.83	0.17	−1.46
Average	**0.22**	**−2.15**	**0.14**	**−1.39**	**0.16**	**−1.57**	**0.13**	**−1.28**

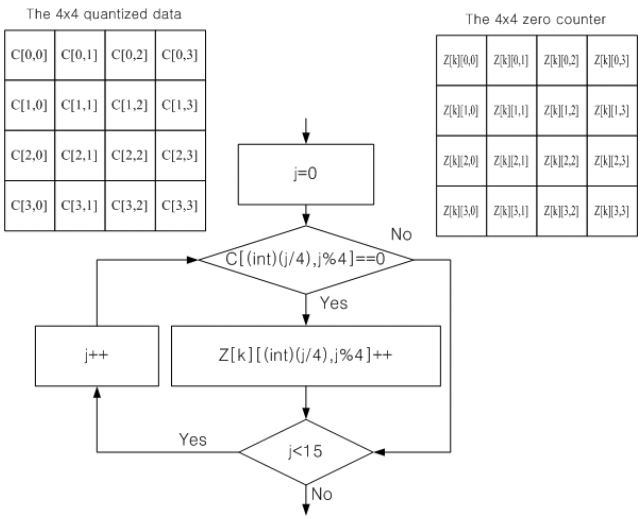

Fig. 2 The flowchart for zero-counter.

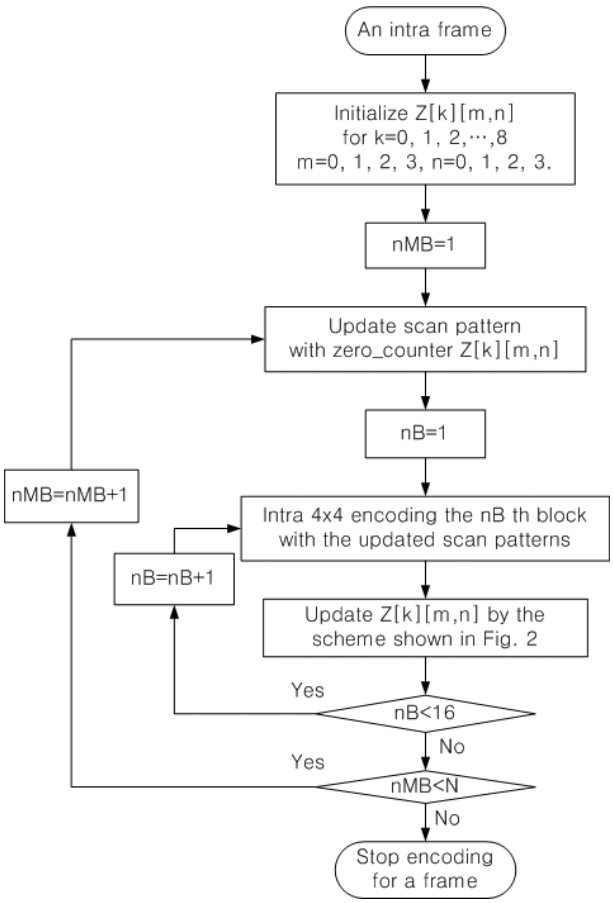

Fig. 3 Proposed intra coding scheme using adaptive scanning algorithm.

the k th mode is updated. The counting process for the zero counter $Z[k][m,n]$ of a particular mode k is shown in Fig. 2, where $m = 0, 1, 2, 3$ and $n = 0, 1, 2, 3$. When the quantized coeffients $C[m^*, n^*]$ are 0, the corresponding $Z[k][m^*, n^*]$ increases. Scan patterns are modified according to the accumulated zero counters. The modified scanning patterns are used in rate-distortion optimization process for a next MB.

The scan pattern updater modifies the patterns whose scanning order is equal to the increasing order of the contents of $Z[k][m,n]$ for a fixed k. The coefficient corresponding to the lower $Z[k][m,n]$ is scanned before those to the higher $Z[k][m,n]$. The modified scan pattern is an updated version of the scan pattern which is used to encode the next MB.

The overall algorithm to encode a frame is summarized in Fig. 3 where N is the number of MBs in a frame. For blocks in the 1st MB of a frame, the initial zero-counters $Z[k][m,n]$s are used for all modes. The initial zero-counters have been made by encoding various training video sequences with intra only mode. The initial scan patterns have been also made by applying the updating process with the initial zero counters.

3. Simulation Results

Computer simulations using test video sequences were performed to evaluate the proposed algorithm. The test video sequences are Carphone, Container, and News whose spatial resolution is QCIF (176×144), and Paris whose spatial resolution is CIF (352×288). These test sequences are not included in the training data set which is used to make initial zero counters. The simulations were conducted with JM11 [5]. In the simulation, rate-distortion optimization is used. CAVLC is used as entropy coding method. Since the proposed scheme is used for intra coding, GOP structure is set to I only. The test sequences were encoded with quantization parameters, 18, 21, 24, and 27, and the number of frames is 150.

In Tables 1 and 2, the average bit rate reduction is calculated based on the Bjontegaard measurement method [6]. The scheme used for 16×16 block is equal to that for 4×4

Table 2 Average bit reduction and average PSNR difference between conventional and proposed schemes using 4×4 mode and zig-zag 16×16 mode.

	Proposed scheme		Fan [1]		Kim [2]		Jia [3]	
	BDPSNR (dB)	ΔBit (%)	BDPSNR (dB)	ΔBit (%)	BDPSNR (dB)	ΔBit (%)	BDPSNR (dB)	ΔBit (%)
Carphone	0.20	−2.21	0.12	−1.38	0.13	−1.50	0.11	−1.29
Container	0.21	−2.22	0.14	−1.47	0.15	−1.57	0.12	−1.23
News	0.22	−1.98	0.13	−1.22	0.14	−1.30	0.11	−1.03
Paris	0.24	−2.13	0.17	−1.50	0.20	−1.79	0.16	−1.45
Average	**0.22**	**−2.14**	**0.14**	**−1.39**	**0.16**	**−1.54**	**0.13**	**−1.25**

Table 3 Overall encoding and decoding times when the H.264 codecs using the conventional and proposed schemes encode 150 frames.

	Encoding Time [sec]		Decoding Time [sec]	
	Conventional scheme [5]	Proposed scheme	Conventional scheme [5]	Proposed scheme
Carphone	14.79	15.10	1.05	1.26
Container	15.47	15.93	1.17	1.21
News	15.56	16.28	1.11	1.28
Paris	71.64	73.67	4.88	5.45
Average	**29.36**	**30.25**	**2.05**	**2.30**

block, except for the block size and the number of the considered directions ($k = 0, 1, 2, 3$). As we can see from the tables, the proposed scheme reduces the bit rate about 2.15% on average with small improvement of image quality.

To evaluate the computational complexity of the proposed scheme, the CPU times consumed by the codecs are checked for various sequences. As shown in Table 3, the additional computing time required by proposed scheme is negligible. These simulation results show the computational complexity of proposed scheme is slightly higher than that of the conventional scheme, while bit rate is much reduced.

4. Conclusions

We proposed an adaptive scanning algorithm for intra prediction. The updated scan pattern is used for each mode independently. Experimental results verify the proposed scheme reduced bit rates by 2.15% with some improvement of image quality. As for computational complexity, the proposed scheme is slightly more complex than the H.264 codec.

Acknowledgements

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