Adaptive Coefficient Scanning Based on the Intra Prediction Mode

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ABSTRACT—This letter presents an adaptive coefficient scanning method for intra mode coding in H.264. The proposed adaptive scanning uses six alternative scanning orders based on the intra prediction mode. Experimental results show that the proposed method improves the coding efficiency up to 3% compared to conventional scanning methods without additional computations.

Keywords—H.264, intra prediction, alternate scan.

I. Introduction

H.264 is the state-of-the-art video compression standard which has been created to provide high compression efficiency using multiple reference motion estimation, intra prediction, and so on [1], [2]. In H.264 intra coding, spatial correlation between adjacent blocks is exploited. Then, the block of interest is predicted from the surrounding blocks according to their directional information. The prediction error between the actual block and its intra prediction is encoded [3].

We observed that H.264 intra prediction tends to produce directional edges in the prediction error according to the selected prediction mode. Figure 1 shows an original image and its prediction error caused by the horizontal-up intra prediction. In Fig. 1(b), some directional edges appear. This means that the energy distribution of the prediction error in the discrete cosine transform (DCT) domain is different from those of unpredicted blocks. In general, DCT coefficients tend to have coefficient energy concentrated at lower frequencies. However, in the case of the residual error produced by intra prediction, the coefficient energy distribution depends on the selected intra prediction mode.

Based on this observation, we propose an adaptive scanning method which uses a different scanning for each intra prediction mode. In [4], Lee and others proposed an adaptive scanning method to improve the intra coding efficiency of H.264/AVC. However, the adaptive scanning was applied only to vertical and horizontal prediction. In our proposed method, we employ six different scanning orders according to the intra prediction mode and the distribution of coefficients in frequency domain. The proposed adaptive scanning method for intra prediction can improve the coding efficiency without additional computations.

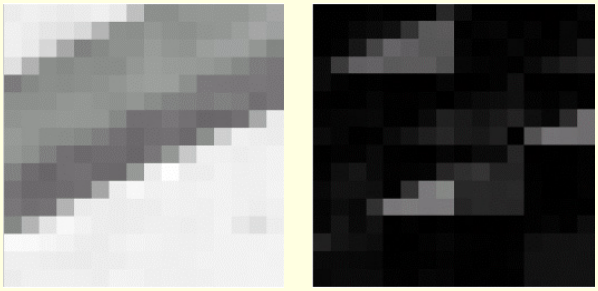

Fig. 1. Intra-predicted images: (a) original and (b) residual error.

II. Proposed Adaptive Scanning Method

In H.264, for the luminance (luma) components, intra prediction can be used for each 4×4 sub-block or 16×16 macroblock. There are 9 prediction modes for 4×4 luma blocks and 4 prediction modes for 16×16 luma blocks. Figure 2 illustrates the 9 prediction modes for the 4×4 luma block. For

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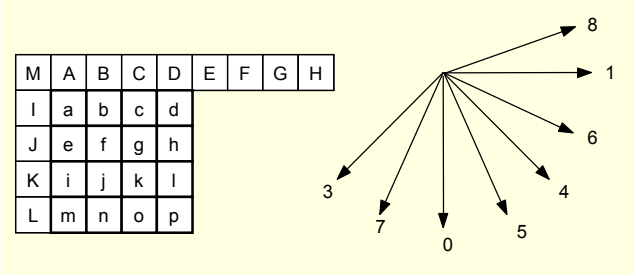

Fig. 2. Example of 4×4 prediction mode.

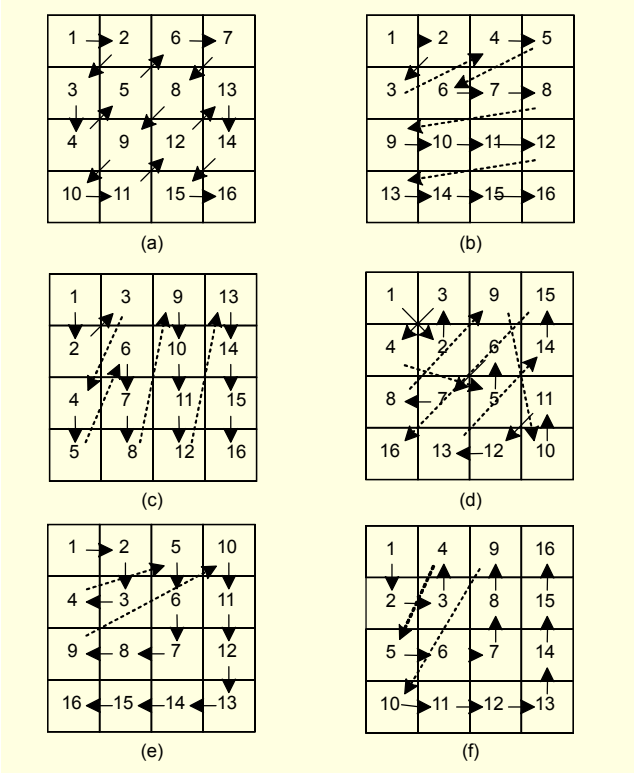

Fig. 3. Scanning orders of the proposed adaptive scheme: (a) zig-zag, (b) vertical, (c) horizontal, (d) diagonal, (e) vertical-diagonal, and (f) horizontal-diagonal.

the chrominance (chroma) components, 4 prediction modes are applied to the two 8×8 U and V chroma blocks.

When the coefficients are scanned for run-length coding, it is well known that, by first scanning high-energy coefficients, long run-lengths can be avoided, thereby allowing more efficient coding of the data. Since the energy distribution of intra prediction error has a directional bias depending on the selected intra prediction mode, the proposed adaptive scanning method uses a different scanning for each intra prediction mode to obtain shorter run-lengths.

We employ five different scannings in addition to zig-zag scanning; all six scannings for 4×4 are shown in Fig. 3. After selecting the best mode among the 9 intra prediction modes in Fig. 1, we can choose a suitable scanning from the 6 possible

Table 1. Adaptive scanning type selection depending on the prediction mode.

Prediction mode (in Fig. 1)	Orientation	Scanning type (in Fig. 2)
0	Vertical	(b)
1	Horizontal	(c)
2	DC	(a)
3 or 4	Diagonal	(d)
5 or 7	Vertical-diagonal	(e)
6 or 8	Horizontal-diagonal	(f)

scannings in Fig. 3, according to the direction of the selected intra mode. If the vertical mode (mode 0 in Fig. 2) is selected, then the vertical scanning of Fig. 3(b) is utilized. For DC prediction, typical zig-zag scanning is applied. When intra mode 3 or 4 is chosen, the scanning of Fig. 3(d) is used. Table 1 shows the suitable scanning type and orientation for all 9 intra prediction modes. These scanning orders are based on the energy distribution of the transformed coefficients. The vertical and horizontal scannings, respectively, are identical to the alternate scanning in the field mode and its transpose. For the 16×16 block, we use three different scanning orders. These scanning methods are zig-zag, vertical, and horizontal.

III. Experimental Results

In order to evaluate the performance of our adaptive scanning method, we compare the proposed method with the conventional zig-zag scanning and Lee's method [4]. The simulations were conducted using JM 96 with "News" and "Foreman" (352×288) sequences. The quantization parameters (QPs) were fixed without consideration of rate-distortion optimization. All experiments were conducted for the intra predicted frame, not for the field image.

Tables 2 and 3 show comparisons of the coding efficiency and the computational complexity of the proposed adaptive scanning method and those of conventional methods. In terms of the bit rate, the proposed method consistently outperforms Lee's method and zig-zag scanning. The proposed method improves coding efficiency by up to 3% in comparison to zig-zag scanning, while maintaining the same PSNRs for each sequence. The improvement of coding efficiency is better at high bit rates than at low bit rates. Moreover, since only the scanning order is changed in the proposed method, the computational gain is negligible.

Figure 4 shows the average PSNRs of the reconstructed images. At the same bit rate, the proposed adaptive scanning

Table 2. Comparison of coding efficiency and computational complexity using the first 100 frames of News sequence.

QP	Zig-zag (average bits)	Lee's (average bits)	Proposed (average bits)	Bit-rate gain (%)	Computational gain (%)
10	97,153	95,589	94,252	- 2.98	0.02
20	50,410	49,892	49,061	- 2.67	0.01
30	23,499	23,104	22,895	- 2.51	0.01
40	9,655	9,509	9,452	- 2.10	0.01

Table 3. Comparison of coding efficiency and computational complexity using the first 100 frames of Foreman sequence.

QP	Zig-zag (average bits)	Lee's (average bits)	Proposed (average bits)	Bit-rate gain (%)	Computational gain (%)
10	114,279	112,491	110,911	- 2.94	0.02
20	55,109	54,198	53,590	- 2.73	0.02
30	21,643	21,327	21,094	- 2.51	0.01
40	7,921	7,845	7,779	- 1.84	0.01

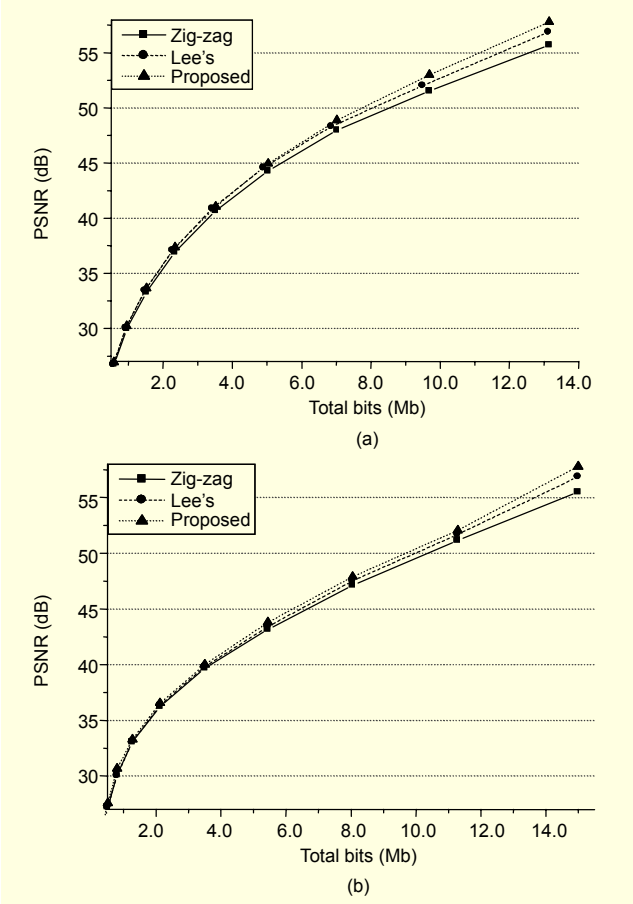

Fig. 4. Comparison of PSNRs between adaptive scanning and zig-zag scanning: (a) News and (b) Foreman sequences.

Fig. 5. Comparison of decoded images (QP=30): (a) zig-zag and (b) adaptive.

method has PSNRs from 0.3 to 1.2 dB higher than Lee's method or the conventional zig-zag scanning. The PSNR performance improves as the total number of bits increases. From those results, we can see that the proposed method can provide better visual quality with more detailed information, as shown in Fig. 5. From those results, we can conclude that the proposed method can be utilized to for H.264 intra prediction in addition to various intra coding methods based on the intra prediction approach.

IV. Conclusion

This letter proposed an adaptive coefficient scanning method for intra mode coding in H.264. The proposed adaptive scanning uses a different scanning for each intra prediction mode. Experimental results show that the proposed adaptive coefficient scanning method improves the coding efficiency up to 3% compared to the conventional methods without additional computations.

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