An Improved Intra Prediction Scheme of H.264/AVC

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ABSTRACT

In H.264/AVC standard, the intra-frame prediction scheme is employed for better coding efficiency. Using the already encoded adjacent upper and left pixels, the intra prediction is performed. In this paper, we present an improved intra prediction scheme of H.264/AVC. By taking into account the error of the adjacent bottom and right pixels in intra mode decision, our scheme shows better results than those of the typical intra prediction of H.264/AVC in coding efficiency at the expense of slight increase of complexity and bit-rate. Experimental results show that the average PSNR is increased by up to 0.16dB.

1. INTRODUCTION

The latest video coding standard H.264/AVC yields much higher coding efficiency than that of the previous standards at the expense of higher computational complexity [1][2]. Enhanced motion-compensated prediction, multiple reference pictures and generalized B pictures, spatial intra prediction, small block-size transform in integer precision, content-adaptive in-loop deblocking filter, and enhanced entropy coding methods are those factors contributed to the success of the H.264/AVC [3].

Among those innovative ideas, spatial intra prediction method is one of the key factors and it is reported in [4] that the performance of H.264/AVC intra-frame outperforms that of the state-of-the-art JPEG2000 still image compression standard.

A number of papers have been reported which present the fast algorithms in intra prediction of H.264/AVC [5][6][7]. However, regarding enhancing the coding efficiency, no report has been made whose output complies with the H.264/AVC standard as far as we know.

In this paper, we present an improved intra prediction scheme of H.264/AVC. By taking into account the error of the adjacent bottom and right pixels in 4 × 4 intra mode decision, our scheme shows better results than those of the typical intra prediction of H.264/AVC in coding efficiency at the expense of slight increase of complexity and bit-rate. Our proposed scheme achieves up to 0.16dB coding gain at the expense of about 1~2% increase of bit-rate.

The rest of the paper is organized as follows. Section 2 gives a review of the typical intra prediction of H.264/AVC. Section 3 presents our proposed intra prediction scheme. Experimental results and analyses are provided in Section 4. Finally Section 5 provides conclusions.

2. INTRA PREDICTION OF H.264/AVC

2.1. Intra Prediction Modes

In this section, we review the intra prediction of H.264/AVC. The H.264/AVC standard exploits the spatial correlation for intra prediction. The current block is predicted by adjacent upper and left pixels which are already encoded and decoded. There are two luma intra macroblock modes. One is 4 × 4 luma intra prediction mode and the other is 16 × 16 luma intra prediction mode. For 4 × 4 luma intra prediction mode, there are 9 candidate modes [1]. One is DC prediction, and the other 8 directional prediction modes are provided. Figure 1 shows the schematic illustration of the nine 4 × 4 luma intra prediction modes. For 16 × 16 luma intra prediction, 4 modes (vertical, horizon, DC, and plane) are provided. Figure 2 show the schematic illustration of the 4 16 × 16 luma intra prediction modes [8].

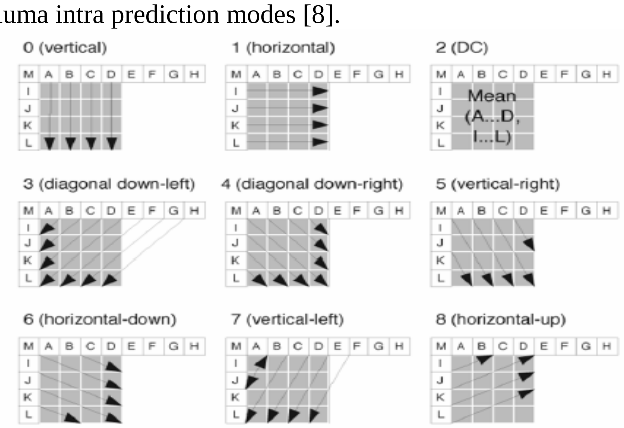


Figure 1. Nine 4 × 4 Luma Intra Prediction Modes

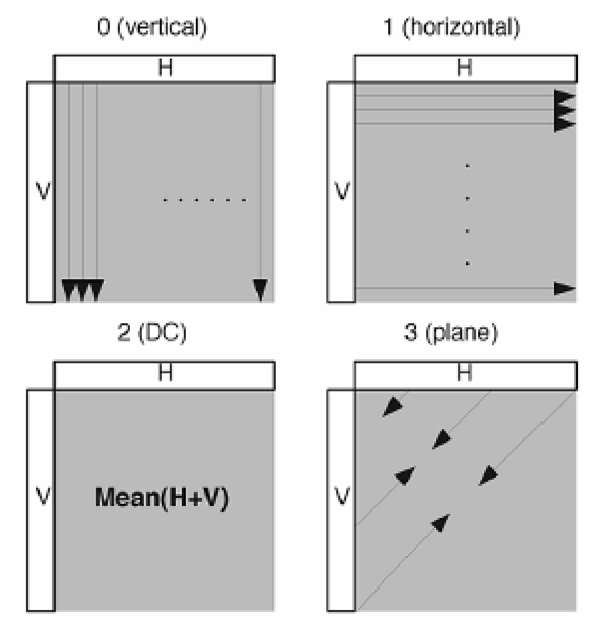


Figure 2. Four 16 × 16 Luma Intra Prediction Modes

There are 4 chroma intra prediction modes, which is very similar to 16 × 16 luma intra prediction except different block size (8 × 8). Chroma intra prediction is performed independent of luma intra prediction.

2.2. Mode Decision

For a better coding efficiency, the H.264/AVC encoder determines the mode that is based on the concept of rate-distortion optimization. That is, the encoder encodes the block using all the modes available and determines the one which gives the best performance in the sense of rate-distortion optimization. For this task, the Lagrangian cost function is given as (1):

$$\begin{aligned} & J(o,r,m|QP,\lambda_{MODE}) \\ & = SSD(o,r,m|QP,\lambda_{MODE}) + \lambda_{MODE} \times R(o,r,m|QP) \end{aligned} \quad (1)$$

where J is the Lagrangian cost function, the QP is the macroblock quantization parameter, λ_{MODE} is the Lagrangian multiplier (usually given as $0.85 \times 2^{\frac{QP}{3}}$, dependent on QP), SSD is the sum of squared differences between the original block o and the reconstructed block r at each candidate mode m, and R denotes the number of bits associated with the candidate mode m.

3. PROPOSED SCHEME

In this section, we explain the proposed intra prediction scheme. As is described in Section 2, the intra prediction exploits the spatial correlation of neighboring pixels. The current block is predicted by adjacent upper and left pixels which are already encoded and decoded.

Assume that the H.264/AVC encoder tries to find a best 4 × 4 luma prediction mode. Then the encoder predicts samples from the encoded values of neighboring blocks. Those predicted values are obtained by the weighted average of neighboring pixels. (Figure. 1)

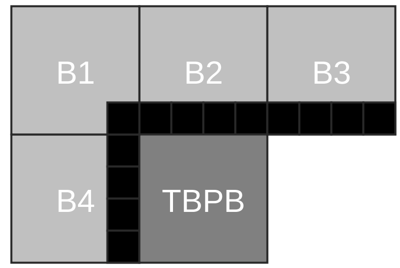


Figure 3. Neighboring Pixels in 4 × 4 Luma Intra Prediction

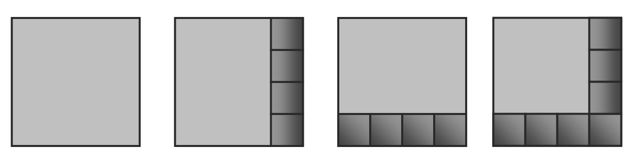
Figure 3 shows the neighboring pixels(black) which are relevant in predicting the TBPB (to be predicted block). Therefore, for a better prediction of TBPB, the values of neighboring pixels must be as close to those of the original pixels as possible. Note that the neighboring pixels are already encoded and decoded for a prediction stage. Note also that no other pixels except neighboring pixels affect the predicting TBPB. The closer the values of the neighboring pixels are to those of the original pixels, the more accurate the predicted values will be.

Taking this observation into account, we conjecture that despite a certain mode is optimal in the sense of the typical rate-distortion theory, it can be non-optimal if we consider the prediction of to be encoded neighbor blocks.

Based on the above discussion, we propose a modified Lagrangian cost function as follows:

$$\begin{aligned} & J_{PROP}(o,r,m|QP,\lambda_{MODE}) \\ & = J + \alpha(QP) \times PBSSD \\ & = SSD + \lambda_{MODE} \times R + \alpha(QP) \times PBSSD \end{aligned} \quad (2)$$

where $\alpha(QP)$ is adjustable parameter, J is the typical Lagrangian cost function (1), and the other parameters are the same as the equation (1) and are omitted for brevity. $PBSSD$ is the partial boundary sum of squared differences between the original partial block o and the reconstructed partial block r at each candidate mode m. According to the relative position of the block in slice, partial block is defined as Figure 4.



(a) Bottom-Right (b) Bottom (c) Rightmost (d) General

Figure 4. Definition of Partial Blocks

That is, when the block is located at the (a)bottom and rightmost in the slice, *PBSSD* is 0. When the block is located at the (b)bottom or (c)rightmost in the slice, *PBSSD* considers only the rightmost pixels or bottom pixels respectively. In general case, *PBSSD* considers the pixels which are denoted at (d).

Note that when the 4 × 4 luma intra prediction is over according to the modified Lagrangian cost function, the cost should be compensated to be compared with the other modes (e.g. 16 × 16 luma intra prediction, inter prediction, etc.).

4. EXPERIMENTAL RESULTS

The proposed algorithm is integrated with the version of 12.2 of the H.264/AVC reference software (JM12.2 [9]) for the performance evaluation. The configuration in our experiments is intra-frame only coding, baseline profile, and fixed QP . The proposed scheme is only applied to 4 × 4 luma intra prediction. The scheme of 16 × 16 luma intra prediction and the scheme of chroma intra prediction are not changed. We tested 300-frame CIF sequences of Foreman, Mobile, Stefan. The adjustable parameter $\alpha(QP)$ is set to 1 for presentational purpose.

Table 1, 2, and 3 show the results between the performance of proposed scheme and that of the original JM12.2. From the results, we can see that ranging from 0.11dB to 0.16dB PSNR gain is attained compared with the original JM12.2 intra prediction scheme. The increase of bitrate also occurs ranging from 0.9% to 2% which is negligible.

Table 1. Experimental Results of Stefan Sequence

	QP	**PSNR(dB)**	**Bitrate (kbps)**
Proposed	24	40.78	6357.21
Original		40.65	6291.71
Proposed	27	38.23	5097.05
Original		38.10	5036.93
Proposed	30	35.60	3995.74
Original		35.46	3938.74
Proposed	33	33.14	3032.22
Original		32.99	2982.25
Proposed	36	30.63	2276.88
Original		30.47	2231.86

Table 2. Experimental Results of Mobile Sequence

	QP	**PSNR(dB)**	**Bitrate (kbps)**
Proposed	24	39.82	9749.57
Original		39.69	9664.73
Proposed	27	37.03	7946.56
Original		36.91	7868.01
Proposed	30	34.19	6365.46
Original		34.06	6290.60
Proposed	33	31.54	4888.44
Original		31.41	4821.79
Proposed	36	28.91	3682.24
Original		28.78	3623.99

Table 3. Experimental Results of Foreman Sequence

	QP	**PSNR(dB)**	**Bitrate (kbps)**
Proposed	24	40.61	3803.03
Original		40.49	3742.27
Proposed	27	38.39	2809.86
Original		38.28	2764.54
Proposed	30	36.31	2032.76
Original		36.20	1996.01
Proposed	33	34.36	1451.74
Original		34.25	1426.46
Proposed	36	32.44	1021.00
Original		32.32	1002.07

5. CONCLUSIONS

In this paper, we present an improved intra prediction scheme of H.264/AVC. By taking into account the error of the adjacent bottom and right pixels in 4 × 4 luma intra mode decision, our scheme shows better results than those of the typical intra prediction of H.264/AVC in coding efficiency at the expense of slight increase of complexity and bit-rate. Experimental results show that the average PSNR is increased by up to 0.16dB. As far as we know, this is the first attempt to enhance the coding efficiency of the intra prediction, whose output still complies with the H.264/AVC standard. This scheme is also easily applied to the 8 × 8 luma intra prediction scheme in the H.264/AVC high profile.

6. REFERENCES

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