# Intra-Mixture Prediction Mode and Enhanced Most Probable Mode Estimation for Intra Coding

Jinho Lee, Jin Soo Choi, Jinwoo Hong, and Haechul Choi

*ABSTRACT—We present intra-mixture prediction (IMP) mode for intra prediction and an enhanced estimation method for most probable mode (MPM). IMP mode supports more flexibility in intra prediction by mixing 4×4 blocks and 8×8 blocks in one macroblock, while the enhanced MPM estimation extends the number of referenced neighboring blocks and efficiently uses their prediction modes depending on their positions. Simulation results show that the combination of both proposed methods provides a bit reduction in the Bjøntegaard delta bitrate by an average of 2.56% compared to H.264/AVC.*

*Keywords—H.264/AVC, intra prediction, intra-mixture prediction mode, most probable mode.*

## I. Introduction

Recently, the ISO/IEC JTC1/SC29 WG11 Moving Picture Experts Group (MPEG) has been trying to start a new video coding standard activity, called High-Performance Video Coding [1]. The ITU-T Q.6/16 Video Coding Experts Group (VCEG) has also released requirements for a next-generation video coding project [2]. These standard groups urgently encourage new video coding algorithms for the new video coding standards. In accordance with the standard status, we propose a coding tool to enhance coding efficiency.

The latest video coding standard is H.264/AVC [3], which supports intra prediction with various block sizes and directional prediction modes. One macroblock (MB) can be coded as a 16×16 block using four Intra_16×16 directional prediction modes, or sixteen individual 4×4 blocks using nine Intra_4×4 directional prediction modes. Additionally, in the H.264/AVC High Profile, an MB can also be split into four individual 8×8 blocks using nine Intra_8×8 directional prediction modes. For intra prediction, H.264/AVC also supports most probable mode (MPM) in the entropy coding process to reduce syntax elements indicating intra prediction modes.

Note that H.264/AVC does not allow using Intra_4×4 together with Intra_8×8 in one MB. This may lead to a limitation of expressing the characteristics of an image texture. Therefore, we propose a new intra prediction mode, called intra-mixture prediction (IMP) mode. By mixing 4×4 and 8×8 blocks in an MB, IMP mode supports more flexibility in intra prediction. We also propose an enhanced MPM estimation method in which more reference neighboring blocks are used and MPM is derived from their prediction mode directions, which have different weights according to their positions.

## II. Proposed Methods

The Intra_8×8 prediction mode of H.264/AVC High Profile has basically the same concept as the Intra_4×4 prediction mode, but with a prediction block size of 8×8 rather than 4×4. However, the number of blocks in an MB is fixed (sixteen blocks for Intra_4×4 and four blocks for Intra_8×8), even though it is better for some sub-MBs to be split into four 4×4 blocks when a part of the image has complicated texture. Therefore, if 4×4 and 8×8 blocks can be mixed in an MB, it is more efficient in a rate-distortion sense.

The proposed intra prediction mode, IMP mode, allows an MB to consist of mixed sub-MBs where some sub-MBs are

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Jinho Lee (phone: +82 42 860 5656, email: jinosoul@etri.re.kr), Jin Soo Choi (email: jschoi@etri.re.kr), Jinwoo Hong (email: jwhong@etri.re.kr), and Haechul Choi (phone: +82 42 860 1808, email: choihc@etri.re.kr) are with the Broadcasting & Telecommunications Convergence Research Laboratory, ETRI, Daejeon, Rep. of Korea.

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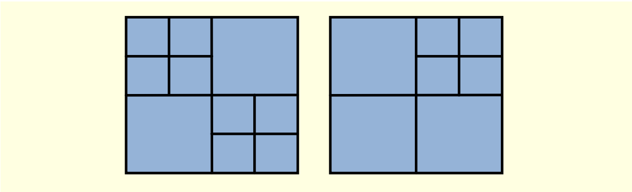

Fig. 1. Examples of intra-mixture prediction mode.

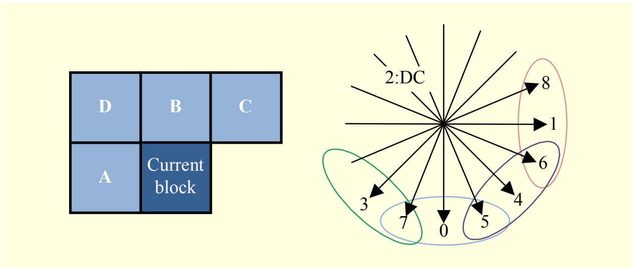


Fig. 2. Neighboring blocks and categorized directional prediction modes for enhanced MPM estimation.

Table 1. Weight values on the lines of conditions.

| Block | Conditions | Weight value |
|---|---|---|
| A (B) | if A (B) = = 1 (0) | mode 1 (0) += 4 |
| | else if A (B) = = 6 or 8 (5 or 7) | mode 6 or 8 (5 or 7) += 3 |
| | else | other mode += 2 |
| C (D) | if C (D) = = 3 (4) | mode 3 (4) += 3 |
| | else if C (D) = = 7 or 8 (5 or 6) | mode 7 or 8 (5 or 6) += 2 |
| | else | other mode += 1 |

4×4 blocks and the others are 8×8 blocks as shown in Fig. 1. Thus, by mixing 4×4 and 8×8 blocks, IMP mode has fourteen types. Figure 1 shows two examples of IMP mode. To implement our proposed method, we revise the syntax elements. First, if an MB is coded as IMP mode, we send a flag for each sub-MB which indicates whether the sub-MB is coded as four 4×4 blocks or one 8×8 block. Second, *mb_type* of the IMP mode is set to 1, and other *mb_type* values are shifted except the *mb_type* value of 0.

We also propose an enhanced MPM estimation method. We have observed that the intra prediction modes of the current block and neighboring blocks are highly correlated. For that reason, the proposed enhanced MPM estimation method uses the directional mode information of encoded neighboring blocks. We extend the referenced neighboring blocks as shown in Fig. 2. That is, the information of upper-right block C and upper-left block D are used as well as left block A and upper block B, whereas H.264/AVC uses blocks A and B.

The proposed algorithm is based on the observation that, if the direction from the neighboring block to the current block is identical to the prediction mode direction of the neighboring block, there is high possibility that the best prediction mode of the current block is also identical to the prediction mode direction. For example, if block A, located on the horizontal line, is coded as the intra horizontal prediction mode of 1, the best prediction mode of the current block is likely to be horizontal. Therefore, we differently assigned the weight value to each directional prediction mode of neighboring blocks depending on the location and prediction mode direction of the neighboring block. Table 1 shows the weight values determined heuristically by statistics resulting from simulation. The statistics show that the modes of upper and left blocks have a more effect than upper-right or upper-left blocks. The weight values of blocks C and D are therefore smaller than blocks A and B. If the prediction mode of block A is 1, our algorithm gives the highest weight value of 4 to mode 1, and if the prediction mode of block A is 6 or 8, the weight value for the mode is assigned as 3. For the rest of the modes, a weight value of 2 is given. In the same manner, the weight values are given for blocks B, C, and D according to the condition of Table 1. Consequently, the weight value for each prediction mode of the neighboring blocks is counted up and the mode having the highest weight value sum becomes the MPM of the current block.

## III. Simulation Results

We simulated the proposed method using reference software JM 13.2 and compared it to High Profile including Intra_8×8 prediction mode. To see the improvement of our method, we computed the Bjøntegaard delta (BD) bitrate [4], which accurately represents the relationship between bitrate and peak signal-to-noise ratio (PSNR). Each sequence consists of 300 frames, all of which are encoded as I frames using CAVLC and rate-distortion optimization.

To evaluate the performance of IMP mode, we investigated the percentages of the intra prediction modes. As shown in

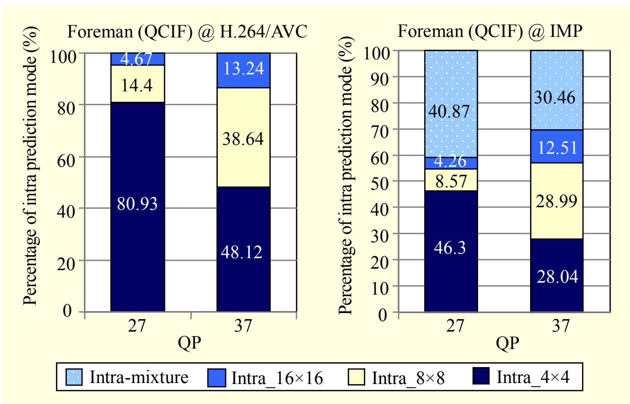


Fig. 3. Percentages of intra prediction modes for Foreman.

Table 2 Simulation results of H.264/AVC and proposed method.

| Sequence | QP | H.264/AVC | | Proposed method | | BD-bitrate (%) | BD-PSNR (dB) |
|---|---|---|---|---|---|---|---|
| | | Bitrate (kbps) | PSNR (dB) | Bitrate (kbps) | PSNR (dB) | | |
| Foreman (QCIF) | 27 | 843.23 | 38.00 | 834.27 | 38.10 | -4.16 | 0.27 |
| | 32 | 498.07 | 34.31 | 488.88 | 34.43 | | |
| | 37 | 299.04 | 31.10 | 290.23 | 31.24 | | |
| | 42 | 172.09 | 27.99 | 167.88 | 28.14 | | |
| Carphone (QCIF) | 27 | 761.47 | 39.13 | 758.45 | 39.24 | -2.69 | 0.19 |
| | 32 | 473.67 | 35.37 | 469.11 | 35.48 | | |
| | 37 | 294.72 | 32.00 | 291.57 | 32.15 | | |
| | 42 | 167.39 | 28.54 | 167.99 | 28.73 | | |
| Foreman (CIF) | 27 | 2769.4 | 38.42 | 2756.73 | 38.52 | -2.77 | 0.15 |
| | 32 | 1567.10 | 34.97 | 1552.17 | 35.06 | | |
| | 37 | 886.94 | 32.02 | 876.70 | 32.13 | | |
| | 42 | 471.94 | 29.14 | 469.11 | 29.24 | | |
| Hall (CIF) | 27 | 2099.64 | 39.56 | 2098.16 | 39.67 | -2.84 | 0.20 |
| | 32 | 1300.90 | 36.51 | 1292.60 | 36.65 | | |
| | 37 | 839.28 | 33.35 | 836.14 | 33.58 | | |
| | 42 | 513.96 | 29.79 | 517.84 | 30.00 | | |
| Bigships (720p) | 27 | 20996.71 | 38.80 | 21024.46 | 38.88 | -1.39 | 0.07 |
| | 32 | 11717.26 | 35.50 | 11760.24 | 35.60 | | |
| | 37 | 6601.55 | 32.72 | 6631.80 | 32.82 | | |
| | 42 | 3397.92 | 29.88 | 3455.05 | 29.96 | | |
| Night (720p) | 27 | 23785.30 | 39.43 | 23822.37 | 39.54 | -1.53 | 0.10 |
| | 32 | 14263.93 | 35.86 | 14298.30 | 35.98 | | |
| | 37 | 8679.42 | 32.72 | 8722.17 | 32.85 | | |
| | 42 | 4836.77 | 29.42 | 4901.04 | 29.56 | | |

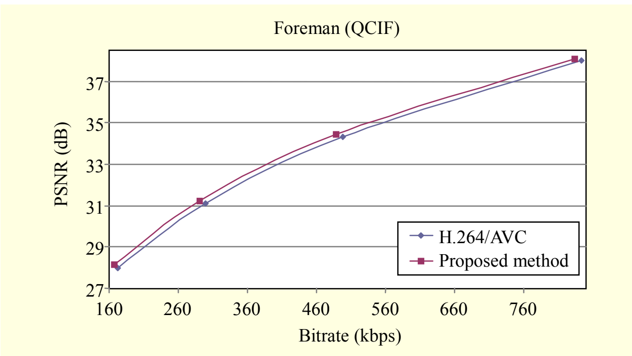


Fig. 4. Rate-distortion curves.

Fig. 3, after we applied IMP mode, a large percentage of Intra_4×4 was moved to Intra-mixture, whereas the percentages of Intra_16×16 were slightly decreased. We found that IMP mode has a large proportion and affects Intra_4×4 and Intra_8×8 more than Intra_16×16.

Table 2 shows the experimental results for various sequences, and Fig. 4 shows the rate-distortion curves of the results. The best BD-bitrate performance is -4.16% for the Foreman sequence with QCIF size, and the worst BD-bitrate is -1.39% for the Bigships sequence with 720p. The average improvement of the proposed method is 3.43% at QCIF size, 2.81% at CIF size, and 1.46% at 720p size.

The percentage of Intra_4×4 increases as the resolution of the sequence decreases, and the percentage of Intra-mixture also increases. Moreover, since the MPM is used in Intra_4×4 and Intra_8×8 prediction modes, the performance of the proposed method was well represented in low-resolution video sequences such as QCIF and CIF. Therefore, the combination of both proposed methods achieved better performance for low-resolution video sequences than high-resolution video sequences.

## IV. Conclusion

In this letter, we presented IMP mode and an enhanced MPM estimation method for intra prediction. In terms of the normative issue of video coding standards, a combination of the proposed methods achieved good performance in six test sequences. In particular, for low-resolution sequences (QCIF), a higher percentage of bit saving was achieved at the same distortion measure relative to the others (CIF and 720p). Thus, the proposed method may be useful for low-bitrate applications.

We will expand the proposed method to a mixture of 16×16 and 8×8 intra prediction and a new MPM estimation for 8×8 or 16×16 intra blocks when a super MB [5] is used.

## References


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