

# Study on HEVC Intra Prediction Algorithm and Its Optimization Technique

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**Abstract.** The high efficiency video coding (HEVC) standard was developed by JCT-VC in 2010 and was officially released in 2013. Compared to the previous video coding standard of H.264/AVC, HEVC can save about 50% bit-rate for equal perceptual video quality, but the computational complexity significantly increases. Therefore current research is focusing on decreasing the computational complexity and improving the coding timeliness of the HEVC video coding algorithm.

## Introduction

As a developed new generation of international video coding standard, high efficiency video coding (HEVC) integrates a number of new coding techniques. Originally, HEVC is designed to promote 50% compression ratio of H.264 in the case of the same basic configuration parameters. However, there is 30% to 40% promotion of compression ratio in the final draft. In HEVC intra prediction technology, this promotion is brought by 35 intra prediction modes and the prediction units of more sizes. In intra prediction process, the prediction mode of prediction unit is obtained only through a rough selection and a rate distortion optimization selection. Since all the prediction units of different sizes have to go through these two processes, the intra prediction process comes to be time consuming. Therefore, in our study, based on the key techniques of HEVC intra prediction, we propose to utilize the multi-level intra mode decision optimization algorithm for correlation between prediction modes and correlation between prediction modes of adjacent prediction units. This optimization algorithm is effect to further promote the compression ratio of intra prediction process.

## Key Techniques of HEVC Intra Prediction

**Intra Directional Prediction Mode.** In prediction, HEVC takes the encoded a column of pixels on the left and a row of pixels on the top as reference pixel, to predict the current block. When the prediction direction is positive, only the main reference pixels to be used; when the prediction direction is negative, deputy reference pixels will be added in prediction, as shown in Fig. 1.

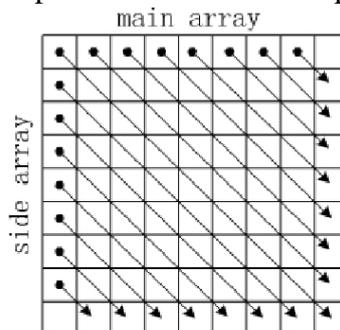


Fig. 1. Negative angle prediction

HEVC is using a lookup table (LUT) technology, to simplify the calculation process. Thus, Y intercept of vertical prediction or X intercept of horizontal prediction can be calculated as follow:

$$\Delta_{IntSide} = (\text{invAbsAngTable}[\text{absAngIndex}] * (I + 1)) \gg 8 \quad (1)$$

$$\Delta_{FractSide} = (\text{invAbsAngTable}[\text{absAngIndex}] * (I + 1)) \% 256 \quad (2)$$

In the equation,

$$\text{invAbsAngTable} = [4096, 1638, 910, 630, 482, 390, 315, 256] \quad (3)$$

By the LUT technology, division calculation is simplified. According to the predicted direction, the main reference pixel expands along the projected sample point of the deputy reference pixels, as shown in Fig. 2

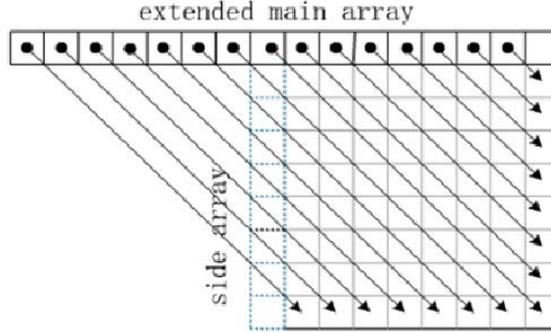


Fig. 2. Final negative angle prediction mode

With the final negative angle prediction mode, the fractional part is also omitted as follow:

$$\Delta_{Integar} = (\text{invAbsAngTable}[\text{absAngIndex}] * (I + 1) + 128) \gg 8 \quad (4)$$

Finally, in the mode prediction process of direction process, we just use the extended primary reference pixel to predict all the sample points by simple linear interpolation method.

**Intra Non-Directional Prediction Mode.** DC mode and Planar mode are two widely used non-directional prediction modes. As same as H. 264/AVC, DC mode is used in relatively smooth texture, and it uses the same prediction value for the current whole prediction unit.

To make the block edges by DC mode prediction more smooth, HEVC adopt certain filtering scheme to treat with its corresponding change unit, as shown in Fig. 3:

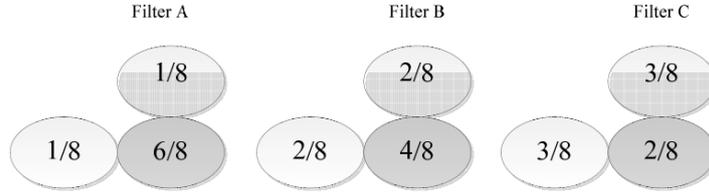


Fig. 3. DC mode filtering scheme

For blocks of different sizes, HEVC Use different intensities filter: Filter A for 4×4 block; Filter B for 8×8 block; Filter C for 16×16 block.

Planar prediction mode is also used in smooth texture area, but it adopt different prediction value to predict each pixel of the current block, as shown in Fig. 4:

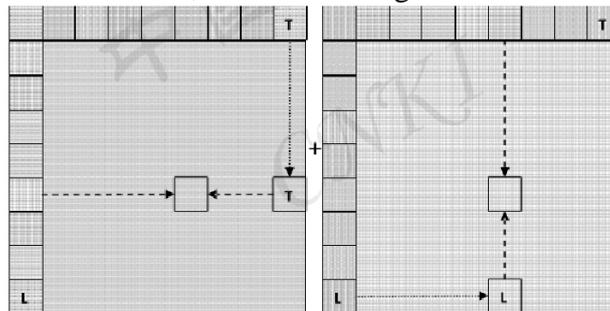


Fig. 4. Planar prediction process

For each pixel in the block, we use linear interpolations of both horizontal and vertical direction as prediction value of current pixel:

$$P(x, y) = ((S - x) * P(0, y) + x * P(0, S) + (S - y) * P(x, 0) + y * P(S, 0) + S) / 2S \quad (5)$$

In the equation,  $P(x, y)$  refers to the current pixel to be predicted;  $P(0, y)$  refers to the reference pixel in the same row as the current pixel;  $P(x, 0)$  refers to the e reference pixel in the same column as the current pixel;  $P(0, S)$  refers to the pixels marked as  $T$ ;  $P(S, 0)$  refers to the pixels marked as  $L$ ;  $S$  refers to the width of the current prediction unit.

For Chroma pixels, there is only five coding mode: horizontal mode, vertical mode, DC mode, DM mode and LM mode. DM mode is referring to directly use the prediction mode of current block brightness pixels as Chroma pixels prediction value.

### HEVC Intra Prediction Fast Mode Decision Optimization Algorithm

For prediction units of different sizes, HEVC intra prediction requires 35 rough mode decision processes and many the rate distortion optimization processes of the candidate prediction model, which leads to the problem of high computational complexity. To solve this problem, we propose to utilize the multi-level intra mode decision optimization algorithm for correlation between prediction modes and correlation between prediction modes of adjacent prediction units. The algorithm process is:

- a) Initial candidate mode set  $S_0$ , RMD process, retain  $N'$  prediction modes;
- b) Retain the prediction mode set  $S_1$ , RMD process composed by adjacent modes of the  $N'$  prediction modes;
- c) Merger the MPM mode set and  $N'$  prediction modes;
- d) Utilize the relation between MPM mode,  $N'$  prediction modes and Hadamard transform cost value, to optimize the candidate mode set;
- e) Decide for optimal prediction mode by RQT process;
- f) FDOQ process, determine conversion unit division way.

The first four steps are the optimized parts of the algorithm. The definition of initial candidate mode  $S_0$  is as follow:

$$\begin{cases} S_0 = A \cup B \\ A = \{0, 1\} \\ B = \{2i \mid i = 1, \dots, 17\} \end{cases} \quad (6)$$

the adjacent mode set of prediction mode is defined as follow:

$$\begin{cases} \Phi, x = 0 \text{ or } x = 1 \\ \{x + 1\}, x = 2 \\ \{x - 1, x + 1\}, 2 < x < 34 \\ \{x - 1\}, x = 34 \end{cases} \quad (7)$$

In the equation,  $S(x)$  refers to the prediction mode set comprised by prediction mode  $x$ . The candidate mode set optimization algorithm after RMD process is shown as Fig. 5:

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Algorithm : FILTER-MODE
Input  : S1, S2, M1, M2, C1, C2, M'
Output : S0

1.  if 1.5*C1 < C2 && M1 ∈ S1
2.      then S0 = {M1}
3.  else if (M1 ∈ S2 || M2 ∈ S2) && (M1 == M' || M2 == M')
4.      then S0 = {M1, M2}
5.  end if

6.  if |S0| > 2
7.      for each mode M ∈ S0
8.          if HSAD(M) > 1.5C1
9.              then S0 = S0 - {M}
10.         end for
11. end if

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Fig. 5. Candidate mode set optimization algorithm

In the figure, S0 refers to the optimized prediction mode set; S1 refers to the prediction mode set by MPM; S2 refers to the prediction mode set of various prediction units; M1 and M2 refers to the optimal and sub-optimal prediction mode of the N prediction modes by RMD process; C1 and C2 respectively refer to corresponding optimal and sub-optimal Hadamard transform cost value; M' refers to the prediction mode of the upper layer depth prediction unit.

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