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| *Title:* | **Weighted Prediction** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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| *Source:* | Technicolor | | |

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# Abstract

This document presents results of Weighted Prediction (WP) and associated analysis tool implementation into HM. This report is an AHG18 outcome.

The WP has been specially designed to compensate Illumination variation in video sequences. It is part of the AVC standard and this feature is useful in video encoder and video splicing applications in particular.

Experimental results of WP and analysis tool have been made on Fade sequences generated with a fading tool provided in AHG18.

The results reports that WP in Explicit mode has a gain between 17-28% (depending on the config) for the test sequences with linear fade when weights are known in advance, and between 15-29% (depending on the config) when the WP analysis tool is used.

# Introduction

WP has been specially designed to compensate Illumination variation in video sequences. The principle consists in replacing the inter prediction signal *P* by a linear weighted prediction signal *P’*:

Uni-directional prediction: *P’ = w × P + o*

Bi-directional prediction: *P’ = (w0 × P0 + o0 + w1 × P1 + o1) / 2*

Originally, WP was specially designed to handle Fading and Cross-Fading. However, better efficiency is obtained when the reference pictures can be chosen arbitrary at the encoder as with the MMCO[[1]](#footnote-1) system in AVC.

WP can also manage local illumination variations using reference picture list with duplicate references [1]. It can also be used to generate cross-fading transitions in video splicing applications.

WP has very limited overhead in PPS (3 bits) and slice header contains only non default WP scaling values (wi,oi).

Since WP is an optional PPS parameter, it may be switch on only when necessary.

In JCTVC-E041, it was reported WP had larger gain than other IC tools previously proposed in JCTVC [2].

# The Weighted Prediction principle

The WP is an adaptive weighting of Inter prediction signal to compensate Illumination variation between the reference pictures and the current one. It can be applied in uni-prediction (1) or in bi-prediction (2).

predPartC[ x, y ] = ( ( predPartL0C[ x, y ] \* w0 +) >> shift ) + o0 (1)

predPartC[ x, y ] = ( ( predPartL0C[ x, y ] \* w0 + predPartL1C[ x, y ] \* w1 + shift ) >>   
 ( shift + 1 ) ) + ( ( o0 + o1 + 1 ) >> 1 ) (2)

Depending on the type of slice (P\_SLICE or B\_SLICE), one can choose the weighting algorithm:

* Default: the default HEVC uni-prediction or bi-prediction.
* Explicit: the weighting factors are transmitted explicitly in the slice header.
* Implicit: the weighting factors for bi-prediction are derived from the distance of the current POC with the POC of the reference pictures, relatively to the distance between references POC (B\_SLICE only).

The presence of weighting factors and the weighting method to use are indicated in the PPS with **weighted\_pred\_flag** and **weighted\_bipred\_idc** (Table 1). If present, the adaptive weighting factor parameters are transmitted in the slice header for each allowable reference picture. Syntax for coding of the weighting factors is similar to that done in AVC and is detailed in Annex.

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| --- | --- | --- | --- | --- |
| **P\_SLICE** | |  | **B\_SLICE** | |
| **Weighted\_pred\_flag** | **Weighting method** |  | **Weighted\_bipred\_idc** | **Weighting method** |
| 0 | Default |  | 0 | Default |
| 1 | Explicit |  | 1 | Explicit |
|  |  |  | 2 | Implicit |

Table ‑: Interpretation of weighted\_pred\_flag and weighted\_bipred\_idc values.

Explicit: If present, the weighting factor parameters allow deriving the corresponding weights (wi) and offset (oi) values for explicit weighting prediction (equations 1 and 2), both in uni-prediction and bi-prediction. If not present, default (HEVC original) weighting is used.

Implicit: The weights (wi) and offset (oi) prediction are determined with the following equation (3):

w0 = 1 – α w1=α where: , oi=0 (3)

In equation (3), α Є [-1.;2.]. Practically, to avoid floating point multiplication the equation (3) is implemented using only integer multiplications and shift (cf. Annex). Implicit weighting method is used in case of linear fade or cross-fade typically.

# Weighted Prediction implementation in HM

The Weighted Prediction has been implemented in HM3.0, HM3.3 and is provided with this proposal. The corresponding code is encapsulated with #defines WEIGHT\_PRED. Three new input parameters have been added in the cfg file:

weighted\_pred\_flag (-wpP) : 0 (default) or 1

weighted\_bipred\_idc (-wpBidc) : 0 (default), 1 or 2

weighted\_pred\_analysis (-wpA) : 0 (default) or 1

The main change in HM software code concerns the motion estimation (SAD, SSE, HAD…)[[2]](#footnote-2) and the motion compensation (inter prediction). The syntax adds (PPS and slice header) are minimal.

Additionally, code encapsulated with #defines WEIGHT\_PRED\_TEST allows for loading explicit weighting parameters:

WpScalingFile (-wpF) : input file containing explicit weighting parameters

# Analysis tool

In order to test the WP in Explicit mode, in the case the WP Explicit parameters are not known, a pre-analysis function has been added in the HM encoder. For each slice to encode, this analysis tool computes automatically the WP weights and offset values to be apply with each reference frame in L0 and L1, for Luminance and Chrominance samples.

The WP parameters are derived using histogram matching between the slice (original samples) to encode and the corresponding global motion compensated (GMC) region in the reference frame (reconstructed samples). The GMC is built using the co-located motion vectors when available (else no GMC is performed).



Figure : Histogram matching is made in the global motion compensated grey region.

The optimal weighting parameters (w,o) are estimated by minimizing (Least Mean Square) the quadratic error between the cumulative histogram *L* of the original slice samples and the weighted cumulative histogram of the corresponding reference samples (4). This is done by solving a 2 linear equation system corresponding to the partial derivative of the quadratic error function (5).

(4)

(5)

The organigram of the analysis software is depicted in Figure 2. A first step consists in collecting the histograms of the current (orginal) and of the references (re-constructed) frames. The second step estimates the WP parameters using (4) and (5) and finally a confidence test allows for determining whether the WP parameters will be applied or not. We evaluated 2 methods for this third stage:

* **Method 1:** Heuristic method comparing the standard deviation σL of the reference frame histogram with the quadratic error function:

(6)

If (6) is established, then WP parameters are used, else they are not used.

* **Method 2:** The WP parameters validity is established comparing the global motion compensated (GMC) SAD between the current frame and the reference frame corrected with WP parameters and without WP weightings.



Figure : Organigram of the analysis tool for WP parameters estimation.

# Test sequences

To test and validate the weighting prediction implementation, a simple Fading tool is provided. This software tool creates linear fading sequences, and a file containing the corresponding explicit weighting parameters may be generated to test explicit WP in HM.

In the past, for experiments involving weighted prediction in H.264/AVC, linear and sigmoid fades varying in length from 1 to 3 seconds were applied to the regular test sequences [3][4][5].

In our experiments, we use same conditions as in [6]: a linear fade is applied to the first 2 seconds of the regular sequence set and the experiments are done with the 2-second sequences. A linear fade-out (sequence to black or white) is applied in the 1st half and a linear fade-in (respectively black or white to sequence) in the 2nd half (Figure 1). The fade strength is limited to the range [0.25, 0.75] instead of [0, 1] to avoid extreme PSNR numbers at the frame level that cause abnormal rate-distortion graphs.



Figure : Linear Fade-to-black or Fade-to-white weights applied on the sequence and the black/white pictures respectively.

# Experimental results

We present results obtained with HM3.0 . Results of WP parameters estimation with method 2 are also available with HM3.3 .

## Weighting Prediction using Explicit parameters

The WP implementation has been tested with the regular HEVC High-Efficiency and Low-Complexity config parameters (except all intra, since WP is not used with Intra), using the WP parameters used to build the fade sequences (fading tool).

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|  | **High-Efficiency – Fade-Black** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -18.5 | -20.9 | -21.7 |  |  |  |  |  |  |
| **Class B** | -19.8 | -20.0 | -20.4 | -25.6 | -19.5 | -19.1 | -24.6 | -14.6 | -10.5 |
| **Class C** | -16.2 | -16.9 | -17.9 | -14.5 | -13.8 | -14.7 | -15.0 | -13.3 | -14.6 |
| **Class D** | -15.5 | -15.2 | -15.7 | -13.6 | -14.9 | -15.4 | -16.5 | -16.3 | -17.4 |
| **Class E** |  |  |  | -40.6 | -14.3 | -21.2 | -41.6 | -18.5 | -20.1 |
| **All** | **-17.6** | **-18.4** | **-19.0** | **-22.6** | **-16.0** | **-17.5** | **-23.4** | **-15.5** | **-15.0** |
| **Enc. time** | **119%** | | | **115%** | | | **100%** | | |
| **Dec. time** | **99%** | | | **90%** | | | **88%** | | |

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|  | **Low-Complexity – Fade-Black** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -20.3 | -18.6 | -18.7 |  |  |  |  |  |  |
| **Class B** | -21.2 | -17.0 | -21.3 | -31.8 | -38.6 | -33.4 | -29.9 | -33.9 | -25.5 |
| **Class C** | -18.8 | -16.8 | -19.7 | -19.6 | -29.5 | -27.0 | -20.2 | -27.4 | -25.4 |
| **Class D** | -18.0 | -14.0 | -17.6 | -18.1 | -25.4 | -23.1 | -20.4 | -24.3 | -22.4 |
| **Class E** |  |  |  | -46.6 | -33.9 | -39.2 | -47.2 | -29.6 | -33.6 |
| **All** | **-19.7** | **-16.6** | **-19.5** | **-28.1** | **-32.1** | **-30.3** | **-28.3** | **-29.1** | **-26.2** |
| **Enc. time** | **126%** | | | **124%** | | | **107%** | | |
| **Dec. time** | **95%** | | | **89%** | | | **86%** | | |

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|  | **High-Efficiency – Fade-White** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -20.6 | -24.0 | -25.0 |  |  |  |  |  |  |
| **Class B** | -21.5 | -24.0 | -23.4 | -25.0 | -20.2 | -19.9 | -24.5 | -17.3 | -13.7 |
| **Class C** | -16.2 | -18.2 | -19.0 | -14.2 | -14.5 | -15.2 | -14.9 | -14.6 | -15.4 |
| **Class D** | -14.5 | -14.9 | -14.8 | -10.5 | -15.3 | -15.2 | -14.2 | -15.6 | -15.8 |
| **Class E** |  |  |  | -36.1 | -18.6 | -20.6 | -37.4 | -15.4 | -19.8 |
| **All** | **-18.4** | **-20.5** | **-20.7** | **-20.8** | **-17.3** | **-17.7** | **-21.9** | **-15.8** | **-15.8** |
| **Enc. time** | **117%** | | | **114%** | | | **100%** | | |
| **Dec. time** | **70%** | | | **94%** | | | **90%** | | |

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|  | **Low-Complexity – Fade-White** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -21.6 | -21.5 | -22.4 |  |  |  |  |  |  |
| **Class B** | -23.1 | -22.2 | -25.5 | -33.2 | -41.0 | -38.2 | -31.9 | -35.3 | -30.0 |
| **Class C** | -18.8 | -18.6 | -21.5 | -20.2 | -32.1 | -29.0 | -20.6 | -29.6 | -27.5 |
| **Class D** | -17.2 | -15.6 | -19.6 | -16.3 | -27.4 | -25.7 | -19.2 | -26.7 | -25.4 |
| **Class E** |  |  |  | -43.8 | -36.3 | -41.7 | -44.3 | -31.2 | -34.4 |
| **All** | **-20.3** | **-19.6** | **-22.4** | **-27.7** | **-34.5** | **-33.4** | **-28.2** | **-31.0** | **-29.0** |
| **Enc. time** | **122%** | | | **123%** | | | **105%** | | |
| **Dec. time** | **69%** | | | **93%** | | | **88%** | | |

## Weighting Prediction using WP estimation module

The WP estimation module has been tested with the regular HEVC High-Efficiency and Low-Complexity config parameters (except all intra, since WP is not used with Intra). The results have been cross-checked by INRIA [7] and Toshiba [8].

We present results obtained with method 1 (AHG18\_HM3.0\_WP\_20110627\_v6.zip) and method 2 (AHG18\_HM3.0\_WP\_20110705\_v9.zip), with HM3.0. Implementation and results of method 2 in HM3.3 are also available (AHG18\_HM3.3\_WP\_20110712.zip).

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|  |  | **Random access** | | | | | **Low Delay B** | | | | | **Low Delay P** | | | | |
|  |  | **Y BD-rate** | | **U BD-rate** | | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | | **V BD-rate** | |  | |  | |  |
|  |  | **High-Efficiency – Fade-Black** | | | | | | | | | | | | | | |
| **Method 1** | **All** | **-15.5** | | **-10.1** | | **-9.2** | **-19.3** | **-5.0** | | **-6.5** | | **-19.4** | | **-3.6** | | **-2.6** |
|  | **Enc. time** | **121%** | | | | | **118%** | | | | | **103%** | | | | |
|  | **Dec. time** | **104%** | | | | | **96%** | | | | | **91%** | | | | |
| **Method 2** | **All** | **-15,8** | **-14,9** | | **-15,7** | | **-21,2** | | **-14,8** | | **-14,6** | **-21,7** | **-14,0** | | **-13,7** | |
|  | **Enc. time** | **120%** | | | | | **116%** | | | | | **102%** | | | | |
|  | **Dec. time** | **99%** | | | | | **91%** | | | | | **98%** | | | | |
|  |  | **Low-Complexity – Fade-Black** | | | | | | | | | | | | | | |
| **Method 1** | **All** | **-17.8** | | **-11.4** | | **-11.3** | **-26.4** | **-24.4** | | **-25.2** | | **-25.9** | | **-23.7** | | **-23.3** |
|  | **Enc. time** | **128%** | | | | | **127%** | | | | | **110%** | | | | |
|  | **Dec. time** | **91%** | | | | | **96%** | | | | | **88%** | | | | |
| **Method 2** | **All** | **-17,6** | **-15,4** | | **-16,5** | | **-27,3** | | **-31,3** | | **-28,6** | **-27,4** | **-29,9** | | **-26,1** | |
|  | **Enc. time** | **127%** | | | | | **126%** | | | | | **108%** | | | | |
|  | **Dec. time** | **90%** | | | | | **83%** | | | | | **82%** | | | | |

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|  |  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  |  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
|  |  | **High-Efficiency – Fade-White** | | | | | | | | |
| **Method 1** | **All** | **-17.9** | **-13.0** | **-12.7** | **-20.5** | **-7.6** | **-6.6** | **-20.5** | **-4.6** | **-3.4** |
| **Enc. time** | **117%** | | | **114%** | | | **99%** | | |
| **Dec. time** | **102%** | | | **94%** | | | **85%** | | |
| **Method 2** | **All** | **-18,5** | **-18,6** | **-19,0** | **-22,8** | **-17,3** | **-15,8** | **-23,2** | **-15,5** | **-14,8** |
| **Enc. time** | **116%** | | | **113%** | | | **97%** | | |
| **Dec. time** | **103%** | | | **89%** | | | **89%** | | |
|  |  | **Low-Complexity – Fade-White** | | | | | | | | |
| **Method 1** | **All** | **-20.4** | **-14.7** | **-14.8** | **-29.1** | **-27.6** | **-27.9** | **-28.7** | **-26.2** | **-25.8** |
| **Enc. time** | **123%** | | | **122%** | | | **104%** | | |
| **Dec. time** | **95%** | | | **90%** | | | **90%** | | |
| **Method 2** | **All** | **-20,4** | **-18,9** | **-20,1** | **-30,1** | **-34,3** | **-31,5** | **-30,2** | **-32,7** | **-28,5** |
| **Enc. time** | **123%** | | | **121%** | | | **102%** | | |
| **Dec. time** | **99%** | | | **84%** | | | **85%** | | |

The WP parameters validity test of method 2 is more precise than method 1 as reported by the results. Method 2 (using SAD at encoder side) is also supposed to be more complex than method 1 but results do not confirm this tendency.

### Method 1: detailed results

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|  | **High-Efficiency – Fade-Black** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -16.9 | -14.0 | -10.8 |  |  |  |  |  |  |
| **Class B** | -17.6 | -9.6 | -5.3 | -21.7 | -5.6 | -4.5 | -20.8 | -2.3 | 5.0 |
| **Class C** | -13.7 | -8.9 | -11.0 | -11.0 | -3.9 | -4.9 | -11.3 | -3.3 | -4.2 |
| **Class D** | -13.5 | -7.9 | -10.5 | -11.2 | -1.1 | -7.7 | -13.3 | -2.7 | -9.7 |
| **Class E** |  |  |  | -37.1 | -10.9 | -10.4 | -36.1 | -7.3 | -3.5 |
| **All** | **-15.5** | **-10.1** | **-9.1** | **-19.3** | **-5.0** | **-6.5** | **-19.4** | **-3.6** | **-2.6** |
| **Enc. time** | **121%** | | | **118%** | | | **103%** | | |
| **Dec. time** | **104%** | | | **96%** | | | **91%** | | |

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|  | **Low-Complexity – Fade-Black** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -18.5 | -13.5 | -11.4 |  |  |  |  |  |  |
| **Class B** | -19.6 | -10.2 | -9.6 | -30.2 | -26.5 | -21.8 | -28.0 | -22.9 | -17.9 |
| **Class C** | -16.2 | -11.7 | -11.5 | -16.8 | -24.0 | -19.6 | -16.9 | -22.5 | -17.9 |
| **Class D** | -16.2 | -10.5 | -13.1 | -16.0 | -16.9 | -21.3 | -17.9 | -19.6 | -22.3 |
| **Class E** |  |  |  | -46.6 | -31.5 | -43.4 | -45.0 | -31.9 | -40.9 |
| **All** | **-17.8** | **-11.4** | **-11.3** | **-26.4** | **-24.4** | **-25.2** | **-25.9** | **-23.7** | **-23.3** |
| **Enc. time** | **128%** | | | **127%** | | | **110%** | | |
| **Dec. time** | **91%** | | | **96%** | | | **88%** | | |

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|  | **High-Efficiency – Fade-White** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -20.6 | -18.2 | -16.7 |  |  |  |  |  |  |
| **Class B** | -20.9 | -13.9 | -9.8 | -24.5 | -8.9 | -4.7 | -23.3 | -3.8 | 4.7 |
| **Class C** | -15.0 | -11.3 | -13.5 | -12.3 | -5.5 | -6.7 | -12.4 | -4.2 | -5.8 |
| **Class D** | -14.4 | -8.4 | -11.5 | -10.6 | -3.7 | -8.4 | -13.2 | -2.8 | -8.6 |
| **Class E** |  |  |  | -37.7 | -13.3 | -7.2 | -36.4 | -8.7 | -6.7 |
| **All** | **-17.9** | **-13.0** | **-12.7** | **-20.5** | **-7.6** | **-6.6** | **-20.5** | **-4.6** | **-3.4** |
| **Enc. time** | **117%** | | | **114%** | | | **99%** | | |
| **Dec. time** | **102%** | | | **94%** | | | **85%** | | |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Low-Complexity – Fade-White** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -22.2 | -16.1 | -14.4 |  |  |  |  |  |  |
| **Class B** | -23.5 | -16.0 | -14.8 | -34.9 | -30.1 | -26.9 | -32.8 | -26.5 | -21.8 |
| **Class C** | -17.8 | -14.5 | -14.1 | -18.8 | -26.7 | -21.2 | -18.9 | -24.5 | -19.9 |
| **Class D** | -17.3 | -12.1 | -15.7 | -17.2 | -20.6 | -22.9 | -19.1 | -21.8 | -24.6 |
| **Class E** |  |  |  | -49.0 | -34.1 | -45.2 | -47.5 | -33.7 | -41.8 |
| **All** | **-20.4** | **-14.7** | **-14.8** | **-29.1** | **-27.6** | **-27.9** | **-28.7** | **-26.2** | **-25.8** |
| **Enc. time** | **123%** | | | **122%** | | | **104%** | | |
| **Dec. time** | **95%** | | | **90%** | | | **90%** | | |

### Method 2: detailed results

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **High-Efficiency – Fade-Black** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -17,3 | -19,4 | -19,6 |  |  |  |  |  |  |
| **Class B** | -18,1 | -17,7 | -18,4 | -23,8 | -17,5 | -17,0 | -22,9 | -14,5 | -13,3 |
| **Class C** | -13,6 | -11,8 | -11,9 | -11,7 | -8,7 | -8,1 | -12,2 | -8,2 | -7,1 |
| **Class D** | -13,5 | -10,1 | -12,1 | -11,8 | -8,5 | -11,0 | -14,2 | -9,5 | -12,9 |
| **Class E** |  |  |  | -42,1 | -27,0 | -24,1 | -42,6 | -27,0 | -24,2 |
| **All** | **-15,8** | **-14,9** | **-15,7** | **-21,2** | **-14,8** | **-14,6** | **-21,7** | **-14,0** | **-13,7** |
| **Enc. time** | **120%** | | | **116%** | | | **102%** | | |
| **Dec. time** | **99%** | | | **91%** | | | **98%** | | |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Low-Complexity – Fade-Black** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -18,8 | -18,5 | -19,3 |  |  |  |  |  |  |
| **Class B** | -19,5 | -17,1 | -18,7 | -30,9 | -34,1 | -29,6 | -28,9 | -31,1 | -23,8 |
| **Class C** | -15,9 | -13,3 | -12,8 | -17,1 | -27,4 | -22,7 | -17,4 | -25,7 | -21,7 |
| **Class D** | -15,8 | -12,5 | -14,7 | -17,0 | -24,1 | -23,2 | -19,2 | -24,5 | -22,7 |
| **Class E** |  |  |  | -49,0 | -41,5 | -41,6 | -49,1 | -40,9 | -40,2 |
| **All** | **-17,6** | **-15,4** | **-16,5** | **-27,3** | **-31,3** | **-28,6** | **-27,4** | **-29,9** | **-26,1** |
| **Enc. time** | **127%** | | | **126%** | | | **108%** | | |
| **Dec. time** | **90%** | | | **83%** | | | **82%** | | |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **High-Efficiency – Fade-White** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -21,2 | -24,0 | -24,6 |  |  |  |  |  |  |
| **Class B** | -21,9 | -22,9 | -22,6 | -26,9 | -20,2 | -18,3 | -25,7 | -17,4 | -13,7 |
| **Class C** | -15,4 | -14,7 | -14,8 | -13,8 | -10,6 | -9,9 | -14,2 | -10,5 | -10,1 |
| **Class D** | -14,7 | -11,8 | -12,9 | -11,5 | -9,9 | -12,3 | -14,3 | -9,4 | -11,9 |
| **Class E** |  |  |  | -43,0 | -31,4 | -24,2 | -42,8 | -27,2 | -26,8 |
| **All** | **-18,5** | **-18,6** | **-19,0** | **-22,8** | **-17,3** | **-15,8** | **-23,2** | **-15,5** | **-14,8** |
| **Enc. time** | **116%** | | | **113%** | | | **97%** | | |
| **Dec. time** | **103%** | | | **89%** | | | **89%** | | |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Low-Complexity – Fade-White** | | | | | | | | |
|  | **Random access** | | | **Low Delay B** | | | **Low Delay P** | | |
|  | **Y BD-rate** | **U BD-rate** | **Y BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** | **Y BD-rate** | **Y BD-rate** | **V BD-rate** |
| **Class A** | -22,2 | -21,2 | -22,3 |  |  |  |  |  |  |
| **Class B** | -23,6 | -22,8 | -23,3 | -35,3 | -37,2 | -34,0 | -33,6 | -33,6 | -27,3 |
| **Class C** | -17,8 | -15,9 | -15,8 | -20,1 | -29,9 | -25,0 | -20,2 | -27,6 | -23,9 |
| **Class D** | -17,3 | -14,9 | -18,2 | -17,6 | -26,1 | -25,2 | -20,0 | -28,0 | -25,1 |
| **Class E** |  |  |  | -51,5 | -46,1 | -44,6 | -51,4 | -44,5 | -41,1 |
| **All** | **-20,4** | **-18,9** | **-20,1** | **-30,1** | **-34,3** | **-31,5** | **-30,2** | **-32,7** | **-28,5** |
| **Enc. time** | **123%** | | | **121%** | | | **102%** | | |
| **Dec. time** | **99%** | | | **84%** | | | **85%** | | |

# Conclusion

In this contribution, implementation of Weighted Prediction (WP) in HM and of WP parameters estimation module in HM encoder is proposed. Experiments results done with 2 seconds fading sequences are presented. While WP has no impact for regular sequence set, large gains (17%-29%) can be obtained for sequences with linear fade, with reduced complexity at the decoder side.

It is stated WP is a simple tool with negligible overhead. In AVC, WP has been adopted and is used in many proprietary applications (ex: video encoders, video splicers…).

Therefore it is recommended to adopt WP in HEVC and to include this WP implementation (method 2) into HM.

# Patent rights declaration(s)

**Technicolor may have current or pending patent rights relating to the technology described in this contribution and, conditioned on reciprocity, is prepared to grant licenses under reasonable and non-discriminatory terms as necessary for implementation of the resulting ITU-T Recommendation | ISO/IEC International Standard (per box 2 of the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form).**

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# Annex: Weighted Prediction syntax

**PPS Parameters**

**weighted\_pred\_flag** equal to 0 specifies that weighted prediction shall not be applied to P and SP slices. weighted\_pred\_flag equal to 1 specifies that weighted prediction shall be applied to P and SP slices.

**weighted\_bipred\_idc** equal to 0 specifies that the default weighted prediction shall be applied to B slices. weighted\_bipred\_idc equal to 1 specifies that explicit weighted prediction shall be applied to B slices. weighted\_bipred\_idc equal to 2 specifies that implicit weighted prediction shall be applied to B slices. The value of weighted\_bipred\_idc shall be in the range of 0 to 2, inclusive.

**Slice Header Parameters** present if (weighted\_pred\_flag && sliceP) or (weighted\_bipred\_idc=1 & sliceB)

**luma\_log2\_weight\_denom** is the base 2 logarithm of the denominator for all luma weighting factors. The value of luma\_log2\_weight\_denom shall be in the range of 0 to 7, inclusive.

**chroma\_log2\_weight\_denom** is the base 2 logarithm of the denominator for all chroma weighting factors. The value of chroma\_log2\_weight\_denom shall be in the range of 0 to 7, inclusive.

**luma\_weight\_l0\_flag** equal to 1 specifies that weighting factors for the luma component of list 0 prediction are present. luma\_weight\_l0\_flag equal to 0 specifies that these weighting factors are not present.

**luma\_weight\_l0[** i **]** is the weighting factor applied to the luma prediction value for list 0 prediction using RefPicList0[ i ]. When luma\_weight\_l0\_flag is equal to 1, the value of luma\_weight\_l0[ i ] shall be in the range of –128 to 127, inclusive. When luma\_weight\_l0\_flagis equal to 0, luma\_weight\_l0[ i ] shall be inferred to be equal to 2luma\_log2\_weight\_denom for RefPicList0[ i ].

**luma\_offset\_l0[** i **]** is the additive offset applied to the luma prediction value for list 0 prediction using RefPicList0[ i ]. The value of luma\_offset\_l0[ i ] shall be in the range of –128 to 127, inclusive. When luma\_weight\_l0\_flagis equal to 0, luma\_offset\_l0[ i ] shall be inferred as equal to 0 for RefPicList0[ i ].

**chroma\_weight\_l0\_flag** equal to 1 specifies that weighting factors for the chroma prediction values of list 0 prediction are present. chroma\_weight\_l0\_flag equal to 0 specifies that these weighting factors are not present.

**chroma\_weight\_l0[** i **][** j **]** is the weighting factor applied to the chroma prediction values for list 0 prediction using RefPicList0[ i ] with j equal to 0 for Cb and j equal to 1 for Cr. When chroma\_weight\_l0\_flag is equal to 1, the value of chroma\_weight\_l0[ i ][ j ] shall be in the range of –128 to 127, inclusive. When chroma\_weight\_l0\_flag is equal to 0**,** chroma\_weight\_l0[ i ][ j ] shall be inferred to be equal to 2chroma\_log2\_weight\_denom for RefPicList0[ i ].

**chroma\_offset\_l0[** i **][** j **]** is the additive offset applied to the chroma prediction values for list 0 prediction using RefPicList0[ i ] with j equal to 0 for Cb and j equal to 1 for Cr. The value of chroma\_offset\_l0[ i ][ j ] shall be in the range of -128 to 127, inclusive. When chroma\_weight\_l0\_flag is equal to 0**,** chroma\_offset\_l0[ i ][ j ] shall be inferred to be equal to 0 for RefPicList0[ i ].

**luma\_weight\_l1\_flag, luma\_weight\_l1**, **luma\_offset\_l1**, **chroma\_weight\_l1\_flag**, **chroma\_weight\_l1**, **chroma\_offset\_l1** have the same semantics as luma\_weight\_l0\_flag, luma\_weight\_l0, luma\_offset\_l0, chroma\_weight\_l0\_flag, chroma\_weight\_l0, chroma\_offset\_l0, respectively, with l0, list 0, and List0 replaced by l1, list 1, and List1, respectively.

**Weighting Prediction algorithm:**

**weighted\_pred\_flag=0 default weighted prediction process ( ½ ; ½ )**

predFlagL0=1, predFlagL1=0 => predPartC[ x, y ] = predPartL0C[ x, y ]

predFlagL0=0, predFlagL1=1 => predPartC[ x, y ] = predPartL1C[ x, y ]

predFlagL0=1, predFlagL1=1 => predPartC[ x, y ] = ( predPartL0C[ x, y ] + predPartL1C[ x, y ] + 1 ) >> 1

**weighted\_pred\_flag=1 weighted sample prediction process ( w0 ; w1 )**

**For Luma component:**

predFlagL0=1, predFlagL1=0 :

if( logWD >= 1 )   
 predPartC[ x, y ] = Clip1C( ( ( predPartL0C[ x, y ] \* w0 + 2logWD - 1 ) >> logWD ) + o0 )   
else  
 predPartC[ x, y ] = Clip1C( predPartL0C[ x, y ] \* w0 + o0 )

predFlagL0=0, predFlagL1=1 :

if( logWD >= 1 )  
 predPartC[ x, y ] = Clip1C( ( ( predPartL1C[ x, y ] \* w1 + 2logWD - 1 ) >> logWD ) + o1 )   
else  
 predPartC[ x, y ] = Clip1C( predPartL1C[ x, y ] \* w1 + o1 )

predFlagL0=1, predFlagL1=1 :

predPartC[ x, y ] = Clip1C( ( ( predPartL0C[ x, y ] \* w0 + predPartL1C[ x, y ] \* w1 + 2logWD ) >>   
 ( logWD + 1 ) ) + ( ( o0 + o1 + 1 ) >> 1 ) )

**For Chroma component:**

predFlagL0=1, predFlagL1=0 :

if( logWD >= 1 )   
 predPartC[ x, y ] = Clip1C( ( ( (predPartL0C[ x, y ] - offC) \* w0 + 2logWD - 1 ) >> logWD ) + o0 + offC )   
else  
 predPartC[ x, y ] = Clip1C( (predPartL0C[ x, y ] - offC) \* w0 + o0 + offC )

predFlagL0=0, predFlagL1=1 :

if( logWD >= 1 )  
 predPartC[ x, y ] = Clip1C( ( ( (predPartL1C[ x, y ] - offC) \* w1 + 2logWD - 1 ) >> logWD ) + o1 + offC )   
else  
 predPartC[ x, y ] = Clip1C( (predPartL1C[ x, y ] - offC) \* w1 + o1 + offC )

predFlagL0=1, predFlagL1=1 :

predPartC[ x, y ] = Clip1C( ( ( (predPartL0C[ x, y ] - offC) \* w0 + (predPartL1C[ x, y ] - offC) \* w1 + 2logWD ) >>   
 ( logWD + 1 ) ) + ( ( o0 + o1 + 1 ) >> 1 ) + offC )

**weighted\_bipred\_idc=2 in B slice** **implicit weighted prediction (applicable for B slices only):**

logWD = 5, o0 = 0, o1 = 0

If DiffPicOrderCnt( pic1, pic0 ) is equal to 0 or one or both of pic1 and pic0 is marked as "used for long-term reference" or ( DistScaleFactor >> 2 ) < -64 or ( DistScaleFactor >> 2 ) > 128, w0 and w1 are derived as:

w0=32, w1=32

Otherwise:

w0 = 64 – (DistScaleFactor >> 2), w1 = DistScaleFactor >> 2

DiffPicOrderCnt( picA, picB ) = PicOrderCnt( picA ) - PicOrderCnt( picB ) (8-2)

tx = ( 16 384 + Abs( td / 2 ) ) / td (8-194)

DistScaleFactor = Clip3( -1024, 1023, ( tb \* tx + 32 ) >> 6 ) (8-195)

tb = Clip3( -128, 127, DiffPicOrderCnt( currPicOrField, pic0 ) ) (8-198)

td = Clip3( -128, 127, DiffPicOrderCnt( pic1, pic0 ) ) (8-199)

**weighted\_pred\_flag=1 in P slice, or weighted\_bipred\_idc=1 in B slice,** **explicit weighted prediction :**

Luma component:

logWD = luma\_log2\_weight\_denom (8-284)

w0 = luma\_weight\_l0[refIdxL0] (8-285)

w1 = luma\_weight\_l1[refIdxL1] (8-286)

o0 = luma\_offset\_l0[refIdxL0] \* ( 1 << ( BitDepthY – 8 ) ) (8-287)

o1 = luma\_offset\_l1[refIdxL1] \* ( 1 << ( BitDepthY – 8 ) ) (8-288)

Chroma component (iCbCr = 0 for Cb, iCbCr = 1 for Cr):

logWD = chroma\_log2\_weight\_denom (8-289)

w0 = chroma\_weight\_l0[refIdxL0][ iCbCr ] (8-290)

w1 = chroma\_weight\_l1[refIdxL1][ iCbCr ] (8-291)

o0 = chroma\_offset\_l0[refIdxL0][ iCbCr ] \* ( 1 << ( BitDepthC – 8 ) ) (8-292)

o1 = chroma\_offset\_l1[refIdxL1][ iCbCr ] \* ( 1 << ( BitDepthC – 8 ) ) (8-293)

offC = 128 \* ( 1 << ( BitDepthC – 8 ) )

If predFlagL0=1 and predFlagL=1, the following constraint shall be obeyed (explicit weighted prediction only, because always the case in implicit):

-128 <= w0 + w1 <= ( ( logWD = = 7 ) ? 127 : 128 ) (8‑294)

NOTE – For explicit mode weighted prediction with logWD equal to 7, when one of the two weights w0 or w1 is inferred to be equal to 128 (as a consequence of luma\_weight\_l0\_flag, luma\_weight\_l1\_flag, chroma\_weight\_l0\_flag, or chroma\_weight\_l1\_flag equal to 0), the other weight (w1 or w0) must have a negative value in order for the constraint expressed in Equation to hold (and therefore the other flag luma\_weight\_l0\_flag, luma\_weight\_l1\_flag, chroma\_weight\_l0\_flag, or chroma\_weight\_l1\_flag must be equal to 1).

**Syntax:**

* se(v): signed integer Exp-Golomb-coded syntax element with the left bit first. The parsing process for this descriptor is specified in subclause .
* u(n): unsigned integer using n bits. When n is "v" in the syntax table, the number of bits varies in a manner dependent on the value of other syntax elements. The parsing process for this descriptor is specified by the return value of the function read\_bits( n ) interpreted as a binary representation of an unsigned integer with most significant bit written first.
* ue(v): unsigned integer Exp-Golomb-coded syntax element with the left bit first. The parsing process for this descriptor is specified in subclause .

|  |  |  |
| --- | --- | --- |
| pred\_weight\_table( ) { | C | Descriptor |
| **luma\_log2\_weight\_denom** | 2 | ue(v) |
| if( chroma\_format\_idc != 0 ) |  |  |
| **chroma\_log2\_weight\_denom** | 2 | ue(v) |
| for( i = 0; i <= num\_ref\_idx\_l0\_active\_minus1; i++ ) { |  |  |
| **luma\_weight\_l0\_flag** | 2 | u(1) |
| if( luma\_weight\_l0\_flag ) { |  |  |
| **luma\_weight\_l0[** i **]** | 2 | se(v) |
| **luma\_offset\_l0[** i **]** | 2 | se(v) |
| } |  |  |
| if ( chroma\_format\_idc != 0 ) { |  |  |
| **chroma\_weight\_l0\_flag** | 2 | u(1) |
| if( chroma\_weight\_l0\_flag ) |  |  |
| for( j =0; j < 2; j++ ) { |  |  |
| **chroma\_weight\_l0[** i **][** j **]** | 2 | se(v) |
| **chroma\_offset\_l0[** i **][** j **]** | 2 | se(v) |
| } |  |  |
| } |  |  |
| } |  |  |
| if( slice\_type = = B ) |  |  |
| for( i = 0; i <= num\_ref\_idx\_l1\_active\_minus1; i++ ) { |  |  |
| **luma\_weight\_l1\_flag** | 2 | u(1) |
| if( luma\_weight\_l1\_flag ) { |  |  |
| **luma\_weight\_l1[** i **]** | 2 | se(v) |
| **luma\_offset\_l1[** i **]** | 2 | se(v) |
| } |  |  |
| if( chroma\_format\_idc != 0 ) { |  |  |
| **chroma\_weight\_l1\_flag** | 2 | u(1) |
| if( chroma\_weight\_l1\_flag ) |  |  |
| for( j = 0; j < 2; j++ ) { |  |  |
| **chroma\_weight\_l1[** i **][** j **]** | 2 | se(v) |
| **chroma\_offset\_l1[** i **][** j **]** | 2 | se(v) |
| } |  |  |
| **}** |  |  |
| } |  |  |
| } |  |  |

1. Memory Management Command Operation. [↑](#footnote-ref-1)
2. For simplicity, only the generic (whatever block size) weighted version of the SAD, SSE and HAD functions has been implemented, but the fixed block size version derivation are straightforward. [↑](#footnote-ref-2)