

# **JCTVC-M0188**

## **UPSAMPLING BASED ON SAMPLING GRID INFORMATION FOR ALIGNED INTER LAYER PREDICTION**

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# Introduction

- Problem 1
  - Upsampling in Test Model and in SHM-1.0 do not match
    - Upsampling in SHM-1.0 is correct.
    - Phase selection of chroma vertical upsampling in Test Model is incorrect.
- Problem 2
  - Current upsampling design in Test Model assumes zero-phase shift between BL and EL sequences.
  - If the assumption doesn't hold, the upsample BL picture is misaligned with EL picture, causing inaccurate inter layer prediction and thus performance loss.
- Proposed method
  - For Problem 1: two options to fix it.
  - For Problem 2: signal the sampling grid offsets between layers and use the offsets to adjust phase selection in upsampling, thus achieving aligned inter layer prediction

# Fix Problem 1

- Solution 1: directly use the phase selection method in SHM-1.0  
The sample location (xRef16, yRef16) is calculated by **division-free** operations, as below.

The variable xRef16 is derived as follows:

```
iShiftX = 16;  
iAddX = 1 << ( iShiftX - 5 );  
iShiftXM4 = iShiftX - 4;  
iScaleX = ( ( PicWRL << iShiftX ) + ( ScaledW >> 1 ) ) / ScaledW;  
xRef16 = (xP*iScaleX + iAddX) >> iShiftXM4;
```

The variable yRef16 is derived as follows:

- If cIdx is equal to 0, the variable yRef16 is derived as follow:

```
iShiftY = 16;  
iAddY = 1 << ( iShiftY - 5 );  
iShiftYM4 = iShiftY - 4;  
iScaleY = ( ( PicHRL << iShiftY ) + ( ScaledH >> 1 ) ) / ScaledH;  
yRef16 = (yP*iScaleY + iAddY) >> iShiftYM4;
```

- Otherwise, the variable yRef16 is derived as follow:

```
iShiftY = 16;  
iAddY = ( ( (PicHRL) << (iShiftY - 2) ) + (ScaledH >> 1) ) / ScaledH + (1 << ( iShiftY - 5 ));  
iDeltaY = 4;  
iShiftYM4 = iShiftY - 4;  
iScaleY = ( ( PicHRL << iShiftY ) + ( ScaledH >> 1 ) ) / ScaledH;  
yRef16 = ((yP*iScaleY + iAddY) >> iShiftYM4) - iDeltaY;
```

# Fix Problem 1

- Solution 2: make a minor correction in Test Model 1

In Section G.6.2, a sample location (xRef16, yRef16) specifying the reference layer sample location in units of 1/16-th sample relative to the top-left sample of the reference layer picture is calculated as below.

The variable xRef16 is derived as follow:

$$xRef16 = ( \underline{xP} * PicWRL * 16 + ScaledW / 2 ) / ScaledW \quad (G-3)$$

The variable yRef16 is derived as follows:

- If cIdx is equal to 0, the variable yRef16 is derived as follow:

$$yRef16 = (yP * PicHRL * 16 + ScaledH / \underline{2}) / ScaledH \quad (G-4)$$

- Otherwise, the variable yRef16 is derived as follow:

$$yRef16 = ( \underline{yP} * PicHRL * 16 + \text{ScaledH} / 2 ) / ScaledH - \text{offset} \quad (G-5)$$

where the value of offset is derived as follows:

if (ScaledH is equal to PicHRL )

offset = 0

otherwise if (ScaledH is equal to 1.5 \* PicHRL )

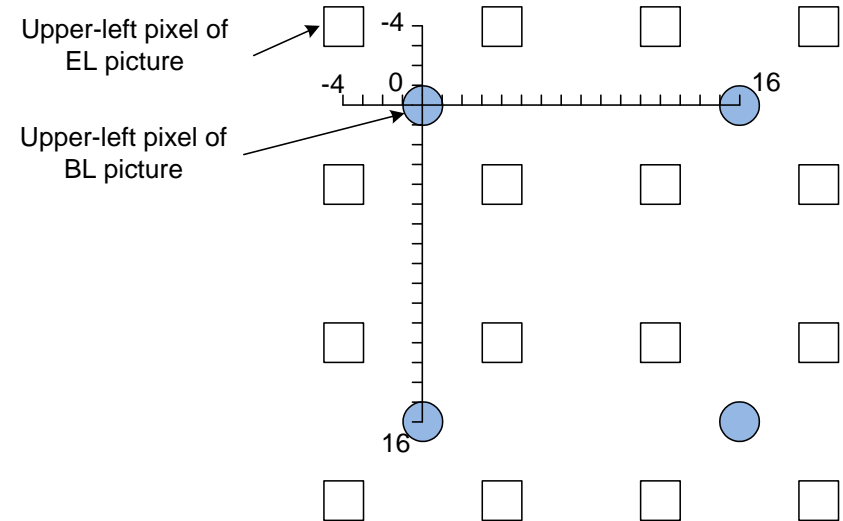
offset = 1

otherwise if (ScaledH is equal to 2.0 \* PicHRL )

offset = 2

# Fix Problem 2 – Sampling Grid Offset Determination

- Downsampling is not normative, and downsampling filter may not always be zero phase shift
- Example: 0.5-sample phase shift



- Sampling grid alignment: the relative positions of the upper-left pixels in BL and EL pictures
- Precision: 1/16-pixel in terms of BL sampling grid
$$\text{SamplingGridOffsetX} = \text{Position}_{\text{Hori}, \text{BL}} - \text{Position}_{\text{Hori}, \text{EL}}$$
$$\text{SamplingGridOffsetY} = \text{Position}_{\text{Vert}, \text{BL}} - \text{Position}_{\text{Vert}, \text{EL}}$$
- In the example  
 $\text{SamplingGridOffsetX} = 4$ ,  $\text{SamplingGridOffsetY} = 4$

## Fix Problem 2 – Sampling Grid Signaling

- Syntax of sampling grid information

sampling_grid_information( ) {	<b>Descriptor</b>
<b>sampling_grid_info_present_flag</b>	u(1)
if ( sampling_grid_info_present_flag ) {	
<b>sampling_grid_abs_offset_x</b>	u(4)
<b>sampling_grid_abs_offset_y</b>	u(4)
<b>sampling_grid_sign_x</b>	u(1)
<b>sampling_grid_sign_y</b>	u(1)
}	

**sampling\_grid\_info\_present\_flag** means whether sampling grid information is present in bitstream.

**sampling\_grid\_abs\_offset\_x** and **sampling\_grid\_sign\_x** together specify the value of variable SamplingGridOffsetX as follows:

$$\text{SamplingGridOffsetX} = (1 - \text{sampling\_grid\_sign\_x} * 2) * \text{sampling\_grid\_abs\_offset\_x}$$

**sampling\_grid\_abs\_offset\_y** and **sampling\_grid\_sign\_y** together specify the value of variable SamplingGridOffsetY as follows:

$$\text{SamplingGridOffsetY} = (1 - \text{sampling\_grid\_sign\_y} * 2) * \text{sampling\_grid\_abs\_offset\_y}$$

The value of **sampling\_grid\_abs\_offset\_x** and **sampling\_grid\_abs\_offset\_y** should be in the range of 0 to 15, inclusive.

## Fix Problem 2 – Sampling Grid Signaling (Cont.)

- Option 1: Signal sampling grid info. in SPS extension

sps_extension ( ) {	<b>Descriptor</b>
<b>inter_view_mv_vert_constraint_flag</b>	u(1)
sampling_grid_information()	
}	

- Option 2: Signal sampling grid info. in VPS extension

vps_extension( ) {	<b>Descriptor</b>
.....	
for( i = 1; i <= vps_max_layers_minus1; i++ )	
for( j = 0; j < i; j++ ) {	
<b>direct_dependency_flag[ i ][ j ]</b>	u(1)
if (direct_dependency_flag[ i ][ j ] )	
sampling_grid_information( i , j )	
}	

## Fix Problem 2 – Upsampling Adjustment

- Solution 1: Aligned with SHM-1.0 (division free)

The variable xRef16 is derived as follows:

- If cIdx is equal to 0, the variable xRef16 is derived as follow:  
iShiftX = 16;  
iAddX = 1 << ( iShiftX - 5 );  
iShiftXM4 = iShiftX - 4;  
iScaleX = ( ( PicWRL << iShiftX ) + ( ScaledW >> 1 ) ) / ScaledW;  
xRef16 = ( ( xP\*iScaleX + iAddX ) >> iShiftXM4 ) - SamplingGridOffsetX;
- Otherwise, the variable xRef16 is derived as follow:  
iShiftX = 16;  
iAddX = 1 << ( iShiftX - 5 );  
iShiftXM4 = iShiftX - 4;  
iScaleX = ( ( PicWRL << iShiftX ) + ( ScaledW >> 1 ) ) / ScaledW;  
xRef16 = ( ( xP\*iScaleX + iAddX ) >> iShiftXM4 ) - SamplingGridOffsetX/2;

The variable yRef16 is derived as follows:

- If cIdx is equal to 0, the variable yRef16 is derived as follow:  
iShiftY = 16;  
iAddY = 1 << ( iShiftY - 5 );  
iShiftYM4 = iShiftY - 4;  
iScaleY = ( ( PicHRL << iShiftY ) + ( ScaledH >> 1 ) ) / ScaledH;  
yRef16 = ( ( yP\*iScaleY + iAddY ) >> iShiftYM4 ) - SamplingGridOffsetY;
- Otherwise, the variable yRef16 is derived as follow:  
iShiftY = 16;  
iAddY = ( ( ( PicHRL ) << ( iShiftY - 2 ) ) + ( ScaledH >> 1 ) ) / ScaledH + ( 1 << ( iShiftY - 5 ) );  
iDeltaY = 4;  
iShiftYM4 = iShiftY - 4;  
iScaleY = ( ( PicHRL << iShiftY ) + ( ScaledH >> 1 ) ) / ScaledH;  
yRef16 = ( ( yP\*iScaleY + iAddY ) >> iShiftYM4 ) - iDeltaY - SamplingGridOffsetY/2;



# Fix Problem 2 – Upsampling Adjustment

- Solution 2: Aligned with Test Model 1

In SHVC Test Model 1, the calculation in Section G.6.2 of is proposed to be changed as below. |

The variable xRef16 is derived as follows:

- If cIdx is equal to 0, the variable xRef16 is derived as follow:

$$xRef16 = ( \underline{xP} * PicWRL * 16 + ScaledW / 2 ) / ScaledW - SamplingGridOffsetX \quad (G-3)$$

- Otherwise, the variable xRef16 is derived as follow:

$$xRef16 = ( \underline{xP} * PicWRL * 16 + ScaledW / 2 ) / ScaledW - SamplingGridOffsetX/2 \quad (G-4)$$

The variable yRef16 is derived as follows:

- If cIdx is equal to 0, the variable yRef16 is derived as follow:

$$yRef16 = ( yP * PicHRL * 16 + ScaledH / 2 ) / ScaledH - SamplingGridOffsetY \quad (G-5)$$

- Otherwise, the variable yRef16 is derived as follow:

$$yRef16 = ( \underline{yP} * PicHRL * 16 + \cancel{ScaledH / 2} ) / ScaledH - offset - SamplingGridOffsetY/2 \quad (G-6)$$

where the value of offset is derived as follows:

if (ScaledH is equal to PicHRL )

offset = 0

otherwise if (ScaledH is equal to 1.5 \* PicHRL )

offset = 1

otherwise if (ScaledH is equal to 2.0 \* PicHRL )

offset = 2

# Fix Problem 2 – 16-Phase Resampling Filters

- A subset of 16-phase resampling filters are defined in Test Model 1 / SHM-1.0.
- Various sample grid offsets (-15 to 15) require a full set of 16-phase filters
- Missing filters in Test Model 1 / SHM-1.0 are proposed (orange shade): DCT-IF

**16-phase luma resampling filter**

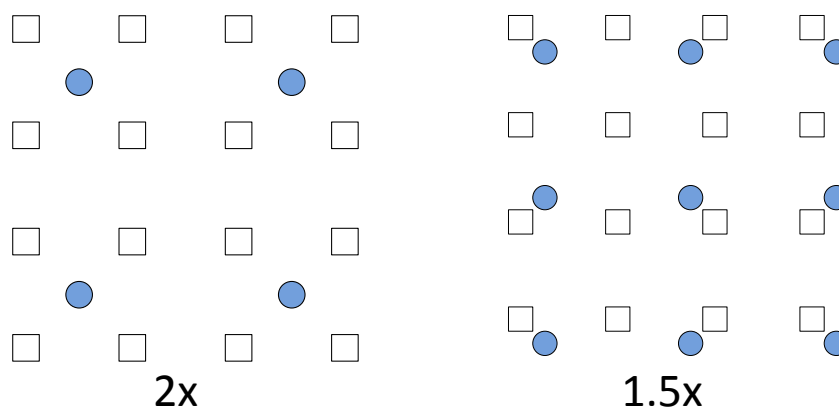
phase p	interpolation filter coefficients							
	$f_L[p, 0]$	$f_L[p, 1]$	$f_L[p, 2]$	$f_L[p, 3]$	$f_L[p, 4]$	$f_L[p, 5]$	$f_L[p, 6]$	$f_L[p, 7]$
0	0	0	0	64	0	0	0	0
1	0	1	-3	63	4	-2	1	0
2	-1	2	-6	62	9	-3	1	0
3	-1	3	-8	60	13	-5	2	0
4	-1	4	-10	57	19	-7	3	-1
5	-1	4	-11	52	26	-8	3	-1
6	-1	4	-11	49	29	-9	4	-1
7	-1	4	-12	45	35	-10	4	-1
8	-1	4	-11	40	40	-11	4	-1
9	-1	4	-10	35	45	-12	4	-1
10	-1	4	-9	29	49	-11	4	-1
11	-1	3	-8	26	52	-11	4	-1
12	-1	3	-7	19	57	-10	4	-1
13	0	2	-5	13	60	-8	3	-1
14	0	1	-3	9	62	-6	2	-1
15	0	1	-2	4	63	-3	1	0

**16-phase chroma resampling filter**

phase p	interpolation filter coefficients			
	$f_C[p, 0]$	$f_C[p, 1]$	$f_C[p, 2]$	$f_C[p, 3]$
0	0	64	0	0
1	-2	62	4	0
2	-2	58	10	-2
3	-4	56	14	-2
4	-4	54	16	-2
5	-6	52	20	-2
6	-6	46	28	-4
7	-4	42	30	-4
8	-4	36	36	-4
9	-4	30	42	-4
10	-4	28	46	-6
11	-2	20	52	-6
12	-2	16	54	-4
13	-2	14	56	-4
14	-2	10	58	-2
15	0	4	62	-2

# Simulations

- The proposed scheme doesn't influence the performance under the current CTC
  - BL and EL sequences have zero-phase shift.
- Sequences used for tests: non-zero phase shift between BL and EL
  - Recommended in San Jose meeting (Feb. 2012) as first set of CfP test sequences
  - Downsampling software in [1] and downloadable from <ftp.tnt.uni-hannover.de>
  - Offset for 1.5x:  $\text{SamplingGridOffsetX} = \text{SamplingGridOffsetY} = 3$
  - Offset for 2x:  $\text{SamplingGridOffsetX} = \text{SamplingGridOffsetY} = 4$



[1] J. Dong, Y. He, Y. Ye, "Downsampling filter for anchor generation for scalable extensions of HEVC," m23485, 99th MPEG meeting, San Jose, USA, Feb. 1-10, 2012.

# Experimental Results – RefIdx Framework

	AI HEVC 2x			AI HEVC 1.5x		
	Y	U	V	Y	U	V
Class A	-14.3%	-16.1%	-16.8%			
Class B	-7.8%	-9.0%	-8.8%	-8.0%	-9.8%	-9.8%
<b>Overall (Test vs Ref)</b>	-9.7%	-11.0%	-11.1%	-8.0%	-9.8%	-9.8%
BL Match	Matched			Matched		

	RA HEVC 2x			RA HEVC 1.5x		
	Y	U	V	Y	U	V
Class A	-10.6%	-6.1%	-7.5%			
Class B	-5.5%	-3.8%	-2.9%	-6.2%	-5.1%	-4.7%
<b>Overall (Test vs Ref)</b>	-7.0%	-4.4%	-4.2%	-6.2%	-5.1%	-4.7%
BL Match	Matched			Matched		

	LD-P HEVC 2x			LD-P HEVC 1.5x		
	Y	U	V	Y	U	V
Class A	-9.0%	-3.4%	-4.8%			
Class B	-4.7%	-3.3%	-2.7%	-6.4%	-4.9%	-4.7%
<b>Overall (Test vs Ref)</b>	-5.9%	-3.3%	-3.3%	-6.4%	-4.9%	-4.7%
BL Match	Matched			Matched		

	LD-B HEVC 2x			LD-B HEVC 1.5x		
	Y	U	V	Y	U	V
Class A	-7.8%	-2.8%	-4.2%			
Class B	-3.9%	-2.8%	-2.4%	-5.8%	-4.5%	-4.2%
<b>Overall (Test vs Ref)</b>	-5.0%	-2.8%	-2.9%	-5.8%	-4.5%	-4.2%
BL Match	Matched			Matched		

# Experimental Results – IntraBL Framework

	AI HEVC 2x			AI HEVC 1.5x		
	Y	U	V	Y	U	V
Class A	-14.3%	-16.4%	-17.1%			
Class B	-7.8%	-9.1%	-8.9%	-8.0%	-9.7%	-9.7%
<b>Overall (Test vs Ref)</b>	-9.7%	-11.2%	-11.3%	-8.0%	-9.7%	-9.7%
BL Match	Matched			Matched		

	RA HEVC 2x			RA HEVC 1.5x		
	Y	U	V	Y	U	V
Class A	-10.6%	-6.0%	-7.4%			
Class B	-5.5%	-3.9%	-3.0%	-6.2%	-5.0%	-4.4%
<b>Overall (Test vs Ref)</b>	-6.9%	-4.5%	-4.3%	-6.2%	-5.0%	-4.4%
BL Match	Matched			Matched		

	LD-P HEVC 2x			LD-P HEVC 1.5x		
	Y	U	V	Y	U	V
Class A	-8.7%	-3.0%	-4.3%			
Class B	-4.5%	-3.2%	-2.4%	-6.2%	-4.3%	-3.8%
<b>Overall (Test vs Ref)</b>	-5.7%	-3.2%	-2.9%	-6.2%	-4.3%	-3.8%
BL Match	Matched			Matched		

	LD-B HEVC 2x			LD-B HEVC 1.5x		
	Y	U	V	Y	U	V
Class A	-7.9%	-2.3%	-3.6%			
Class B	-4.1%	-3.2%	-2.6%	-6.0%	-4.8%	-4.5%
<b>Overall (Test vs Ref)</b>	-5.2%	-2.9%	-2.9%	-6.0%	-4.8%	-4.5%
BL Match	Matched			Matched		

# Conclusion

- This proposal addresses two problems in Test Model
  - Problem 1: Incorrectness in chroma vertical upsampling
  - Problem 2: Non-zero phase shift between EL and BL pictures due to downsampling currently not addressed.
- Technical summary:
  - Provide 2 options to fix Problem 1. Option 1 is division free.
  - Achieve aligned sampling grids of EL and upsampled BL pictures by
    1. signalling the sampling grid offsets between layers in the bitstream
    2. incorporating the signaled offsets into phase filter selection
- Performance on coding BL and EL sequences with phase shift

	Y	U	V
AI	-8.8%	-10.4%	-10.5%
RA	-6.6%	-4.8%	-4.4%
LDP	-6.2%	-4.1%	-4.0%
LDB	-5.4%	-3.7%	-3.6%

- We suggest adopting the proposed scheme into SHVC working draft.