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| --- | --- | --- | --- |
| *Title:* | **VUI extension and SEI for chroma sampling filter** | | |
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| *Purpose:* | Proposal | | |
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# Abstract

Since chroma formats that are called 4:2:0, 4:2:2 and 4:4:4 are used at the video coding technology, some kinds of chroma format conversions are needed when output video is translated or displayed. Although the sample location of chroma format can be specified at VUI in current draft specification, there is no information regarding chroma sampling filter. This contribution provides a framework to send recommended up-sampling and down-sampling filter coefficients for chroma format conversion by using VUI and SEI message. Especially, it is possible to solve a problem of error accumulation when chroma conversions are repeated.

# Introduction

Since chroma formats that are called 4:2:0, 4:2:2 and 4:4:4 are used at the video coding technology, some kinds of chroma format conversions are needed when output video is translated or displayed. Although the sample location of chroma format can be specified at VUI in current draft specification [1], there is no information regarding chroma sampling filter. Therefore, some losses of chroma format conversion are caused. Especially, it is known that there is a problem of error accumulation when the chroma format is converted repeatedly.

For example, when a 4:2:0 video decoder and encoder are connected via a 4:2:2 serial interface such as SMPTE ST 292-1, the 4:2:0 data is decoded and converted to 4:2:2 by up-sampling the color difference component. In the 4:2:0 video encoder, the 4:2:2 video data is converted to 4:2:0 video data by down-sampling the color difference component. In this case, there typically exists a color difference mismatch between the 4:2:0 video data from the decoder and the 4:2:0 video data to be encoded.

Several stages of codec concatenation are common through the video processing chain. As a result, color difference signal mismatch between 4:2:0 video data input to 4:2:0 video encoder and 4:2:0 video output from 4:2:0 video decoder is accumulated and the degradation becomes visible.

SMPTE RP 2050-1:2012 [2] and EG 2050-2:2012 [3] define filter coefficient sets of 4:2:2/4:2:0 and 4:2:0/4:2:2 inter-format conversion to minimize degradation caused by concatenation. This is achieved by making the 4:2:2/4:2:0 inter-format filter sets satisfy complementing reconstruction filters. The use of these filter coefficients preserves the color difference signal resolution of the first 4:2:0 sub-sampling.

The property of chroma sampling filter is reported in [4][[1]](#footnote-1). Below figures showing are excerpted from [4]. In this figure, “Non-Degrade 4:2:0 filter Set” means the chroma sampling filter of SMPTE RP 2050-1:2012, and “Reference Filter Set” means the chroma sampling filter in MPEG-2 TM5 [5].

Regarding design problem for chroma sampling filter, there are another discussions. In JCTVC-K0211[6], several filters are designed to minimize loss in a single 4:2:2/4:2:0/4:2:2 (or 4:4:4/4:2:0/4:4:4) conversion.

With the goal to support coding of 4:2:2 chroma format using 4:4:4 or 4:2:0 codecs, proposals JCTVC-K0302 [7] and JCTVC-L0162 [8] investigate performance of such solutions. It has been shown that when 4:2:2 format is coded using 4:4:4 codec, the performance in terms of BD-rates does not suffer significantly. While the performance depends on selected resampling filters, this approach introduces average BD-rate in range -5.9% to +6.6% for chroma components [8] confirming that the performance of this coding option is suitable in required scenarios.

In this contribution, considering comments on JCTVC-K0152 [9] at the Shanghai meeting, we would like to propose a specification of additional VUI and SEI message for chroma sampling filter generally due to reduce conversion losses of chroma format.

|  |  |
| --- | --- |
| Test sequence | PSNR degradation |
| kanji_org  Original sequence “Character”  1,920x1,080/60i |  |
| mobile  VQEG test sequence “Mobile & Calendar”  720x576/50i |  |
| org  VCEG test sequence “F1 Car”  720x576/50i |  |

**Figure 1** Example of PSNR degradation suppression in chroma component

# Chroma sampling filter hint SEI

## Syntax

|  |  |
| --- | --- |
| sei\_payload( payloadType, payloadSize ) { | Descriptor |
| ... |  |
| else if( payloadType = = XXX) |  |
| chroma\_sampling\_filter\_hint( payloadSize) |  |
| else |  |
| reserved\_sei\_message( payloadSize ) |  |
| if( !byte\_aligned( ) ) { |  |
| **bit\_equal\_to\_one** /\* equal to 1 \*/ | f(1) |
| while( !byte\_aligned( ) ) |  |
| **bit\_equal\_to\_zero** /\* equal to 0 \*/ | f(1) |
| } |  |
| } |  |

## Semantics

Table D‑1 – Persistence scope of prefix SEI messages (informative)

|  |  |
| --- | --- |
| SEI message | Persistence scope |
| buffering period | The remainder of the bitstream |
| … | … |
| chroma sampling filter hint | The remainder of the bitstream |

### D.1.X Chroma sampling filter hint SEI syntax

|  |  |
| --- | --- |
| chroma\_sampling\_filter\_hint( payloadSize ) { | **Descriptor** |
| **target\_format\_idc** | ue(v) |
| **perfect\_reconstruction\_flag** | u(1) |
| if( ver\_chroma\_filter\_idc == 1 ) { |  |
| **num\_vertical\_filters** | ue(v) |
| NumVerFilters = num\_vertical\_filters |  |
| if( NumVerFilters > 0 ) |  |
| for( i=0; i < NumVerFilters; i++) { |  |
| **ver\_tap\_length\_minus1[** i **]** | ue(v) |
| for( j=0; j <= ver\_tap\_length\_minus1[ i ]; j++) { |  |
| **ver\_filter\_coeff[** i **][** j **]** | se(v) |
| } |  |
| } |  |
| } |  |
| if( hor\_chroma\_filter\_idc == 1 ) { |  |
| **num\_horizontal\_filters** | ue(v) |
| NumHorFilters = num\_horizontal\_filters |  |
| if( NumHorFilters > 0 ) |  |
| for( i=0; i < NumHorFilters; i++) { |  |
| **hor\_tap\_length\_minus1[** i **]** | ue(v) |
| for( j=0; j <= hor\_tap\_length\_minus1[ i ]; j++) { |  |
| **hor\_filter\_coeff[** i **][** j **]** | se(v) |
| } |  |
| } |  |
| } |  |
| } |  |

### D.2.X Chroma sampling filter hint SEI semantics

The chroma sampling filter hint SEI message provides the recommended coefficients of a chroma sampling filter. If the coefficients of chroma sampling filter both at an encoder and a decoder are designed based on the coefficients signalled in the chroma sampling filter hint SEI message, the color difference degradation will be expected to be minimized.

**target\_format\_idc** specifies the output of chroma sampling relative to that of the luma sampling as specified in subclause 6.2. The value of target\_format\_idc shall be in the range of 1 to 3, inclusive.

**perfect\_reconstruction\_flag** equal to 1 specifies that the chroma sampling filter coefficients satisfy perfect reconstruction condition which mean that up-sampled results are identical when down-sampling and up-sampling are repeated. perfect\_reconstruction\_flag equal to 0 indicates that the chroma sampling filter coefficients may not satisfy perfect reconstruction condition.

**num\_vertical\_filters** specifies the number of filters used for chroma sampling in vertical direction.

**ver\_tap\_length\_minus1[]** + 1specifies the number of tap length of a filter in vertical direction. The value of ver\_tap\_length\_minus1 shall be in the range of 0 to 31, inclusive.

**ver\_filter\_coeff[][]** specifies the value of a filter coefficient in vertical direction. The value of ver\_filter\_coeff[i][] shall be in the range of −231 + 1 to 231 − 1, inclusive.

FV[DistinctParityFlag][i] is set to ver\_filter\_coeff[i][].

**num\_horizontal\_filters** specifies the number of filters used for chroma sampling in horizontal direction.

**hor\_tap\_length\_minus1[]** + 1specifies the number of tap length of a filter in horizontal direction. The value of hor\_tap\_length\_minus1 shall be in the range of 0 to 31, inclusive.

**hor\_filter\_coeff[][]** specifies the value of a filter coefficient in horizontal direction. The value of hor\_filter\_coeff[][] shall be in the range of −231 + 1 to 231 − 1, inclusive.

FH[0][i] is set to hor\_filter\_coeff[i][].

# VUI extension parameters

## Sequence parameter set RBSP syntax

|  |  |
| --- | --- |
| sps\_parameter\_set\_rbsp( ) { | Descriptor |
| **…** |  |
| if( sps\_extension\_flag ) { |  |
| if (vui\_parameters\_present\_flag ) |  |
| **vui\_extension\_parameters\_present\_flag** | u(1) |
| **if ( vui\_extension\_parameters\_present\_flag )** |  |
| vui\_extension\_parameters( ) |  |
| while( more\_rbsp\_data( ) ) |  |
| **sps\_extension\_data\_flag** | u(1) |
| rbsp\_trailing\_bits( ) |  |
| } |  |

## Sequence parameter set RBSP semantics

**sps\_extension\_flag** equal to 0 specifies that no sps\_extension\_data\_flag syntax elements are present in the SPS RBSP syntax structure. ~~sps\_extension\_flag shall be equal to 0 in bitstreams conforming to this version of this Specification. The value of 1 for sps\_extension\_flag is reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore all sps\_extension\_data\_flag syntax elements that follow the value 1 for sps\_extension\_flag in an SPS NAL unit.~~

**vui\_extension\_parameters\_present\_flag** equal to 1 specifies that the vui\_extension\_parameters( ) syntax structure as specified in Annex E is present. vui\_parameters\_present\_flag equal to 0 specifies that the vui\_extension\_parameters( ) syntax structure as specified in Annex E is not present.

## VUI extension parameters syntax

|  |  |
| --- | --- |
| vui\_extension\_parameters( ) { | Descriptor |
| if( chroma\_loc\_info\_present\_flag ) { |  |
| **chroma\_filter\_info\_present\_flag** | u(1) |
| if( chroma\_filter\_info\_present\_flag) { |  |
| **ver\_chroma\_filter\_idc** | u(8) |
| **hor\_chroma\_filter\_idc** | u(8) |
| **ver\_filtering\_process\_flag** | u(1) |
| **}** |  |
| } |  |
| } |  |

## VUI extension parameters semantics

**chroma\_filter\_info\_present\_flag** equal to 1 specifies that chroma sampling filter information is present. If chroma\_filter\_info\_present\_flag is equal to 0, chroma sampling filter information is not present in the bitstream and is inferred as 0.

**ver\_chroma\_filter\_idc** specified the preferred chroma sampling filter in vertical direction for the output decoded pictures and for input pictures at an encoder which takes the output decoded pictures as an input.

When ver\_chroma\_filter\_idc is equal to 1, the coefficients of chroma sampling filter in vertical direction are signalled in the chroma sampling filter hint SEI. When ver\_chroma\_filter\_idc is not equal to 0, the coefficients of chroma sampling filter are specified in Table E-X1.

**hor\_chroma\_filter\_idc** specified the preferable chroma sampling filter in horizontal direction for the output decoded pictures and possibly for input pictures at an encoder which takes the output decoded pictures as an input.

When hor\_chroma\_filter\_idc is equal to 1, the coefficients of chroma sampling filter in horizontal direction are signalled in the chroma sampling filter hint SEI. When hor\_chroma\_filter\_idc is not equal to 0, the coefficients of chroma sampling filter are specified in Table E-X2.

**ver\_filtering\_process\_flag** specified how chroma sampling filter in vertical direction is performed. If ver\_filtering\_process\_flag is equal to 1, chroma sampling filter is applied in field-basis (i.e. only chroma samples of the same parity is used for filtering). Otherwise, chroma sampling filter is applied in frame-basis.

Variable DistinctParityFlag is derived as follows:

DistinctParityFlag = ( (ver\_filtering\_process\_flag == 1 ) ? 1: 0

Table E-X1 speficies the coefficients of chroma sampling filter in vertical direction. When ver\_chroma\_filter\_idc is greater than 1, the usage of filter coefficients FV[][]is specified in Table E-X1\_1.

Table E-X1 Chroma filter index in vertical direction

| Value | Vertical chroma sampling filter | Informative Remark |
| --- | --- | --- |
| 0 | Unspecified | Chroma filter is unknown or is determined by the application. |
| 1 | User-defined | Filter coefficients are specified in the chroma sampling filter hint SEI messasge |
| 2 | FV[0][0] = {-3, -19, 34, 500, 500, 34, -19. 3}  FV[0][1] = {19, 103, 1037, -135}  FV[1][0] = {-8, -26, 115, 586, 409, -48, -4, 0}  FV[1][1] = {24, -41, 1169, -128}  FV[1][2] = {-76, 783, 330, -13} | SMPTE RP 2050-1:2012  Chroma sample type should be 0. |
| 3 | FV[0][0] ={1,0,-3,0,10,16,10,0-1,0,1}  FV[0][1] ={1}  FV[0][2] ={-1,5,5,-1} | Chroma sample type should be 2, 3, 4 or 5 and DistinctParityFlag should be equal to 0. |
| 4 … 255 | Reserved | For future use by ITU‑T | ISO/IEC |

Table E-X1\_1 Usage of filter coefficients in vertical direction

| Chroma sample type | DistinctParityFlag | NumVerFilters | Usage |
| --- | --- | --- | --- |
| 0 or 1 | 0 | 3 | FV[0][0] is used for down-sampling of every line.  FV[0][1] is used for up-sampling of every even line  FV[0][2] is used for up-sampling of every odd line |
| 1 | 3 | FV[1][0] is used for down-sampling of every line in top-field.  Flipped FV[1][0] is used for down-sampling of every line in bottom-field.  FV[1][1] is used for up-sampling of every even line in top-field.  FV[1][2] is used for up-sampling of every odd line in top-field.  Flipped FV[1][2] is used for up-sampling of every even line in bottom-field.  Flipped FV[1][1] is used for up-sampling of every odd line in bottom-field. |
| 2 or 3 | 0 | 3 | FV[0][0] is used for down-sampling of every line.  FV[0][1] is used for up-sampling of every even line.  FV[0][2] is used for up-sampling of every odd line. |
| 1 | 5 | FV[1][0] is used for down-sampling of every line in top-field.  FV[1][1] is used for down-sampling of every line in bottom-field.  FV[1][2] is used for up-sampling of every even line in top-field.  FV[1][3] is used for up-sampling of every odd line in top-field.  FV[1][4] is used for up-sampling of every even line in bottom-field.  Flipped FV[1][4] is used for up-sampling of every odd line in bottom-field. |
| 4 or 5 | 0 | 3 | FV[0][0] is used for down-sampling of every line.  FV[0][1] is used for up-sampling of every odd line.  FV[0][2] is used for up-sampling of every even line. |
| 1 | 5 | FV[1][0] is used for down-sampling of every line in bottom-field.  FV[1][1] is used for down-sampling of every line in top-field.  FV[1][2] is used for up-sampling of every odd line in bottom-field.  FV[1][3] is used for up-sampling of every even line in bottom-field.  FV[1][4] is used for up-sampling of every even line in top-field.  Flipped FV[1][4] is used for up-sampling of every odd line in top-field. |

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O

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Odd line

Figure E-X2\_2 (Informative) Design principle of vertical up/down-sampling filter for progressive scan.



Figure E-X1\_3 (Informative) Design principle of vertical up/down-sampling filter for interlaced scan.

Table E-X2 speficies the coefficients of chroma sampling filter in horizontal direction. When hor\_chroma\_filter\_idc is greater than 1, the usage of filter coefficients FH[][]is specified in Table E-X2\_1.

Table E-X2 Chroma filter index in horizontal direction

| Value | Horizontal chroma sampling filter | Informative Remark |
| --- | --- | --- |
| 0 | Unspecified | Chroma filter is unknown or is determined by the application. |
| 1 | User-defined | Filter coefficients are specified in the chroma sampling filter hint SEI messasge |
| 2 | FH[0][0] = {-1, 2, 6, 2, -1}  FH[0][1] = {1}  FH[0][2] = {1, 1} | ITU-T Rec. T.800 | ISO/IEC15444-1, 5/3 filter  Chroma sample type should be 0, 2 or 4. |
| 3 | FH[0][0] = {1, 0, -3, 0, 10, 16, 10,0, -3, 0, 1}  FH[0][1] = {1}  FH[0][2] = {-1, 5, 5, -1} | Chroma sample type should be 0, 2 or 4. |
| 4 … 255 | Reserved | For future use by ITU‑T | ISO/IEC |

Table E-X2\_1 Usage of filter coefficients in horizontal direction

| Chroma sample type | NumHorFilters | Usage |
| --- | --- | --- |
| 0 or 2 or 4 | 3 | FH[0][0] is used for down-sampling of every column.  FH[0][1] is used for up-sampling of every even column  FH[0][2] is used for up-sampling of every odd column |
| 1 or 3 or 5 | 2 | FH[0][0] is used for down-sampling of every column.  FH[0][1] is used for up-sampling of every even column  Flipped FH[0][1] is used for up-sampling of every odd column |

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Figure E-X2\_2 (Informative) Design principle of horizontal up/down-sampling filter.

NOTE1 – SMPTE EG2050-2:2012 provides details on a possible implementation of the filter defined in SMPTE RP2050-1:2012.

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[10] T. Chujoh, K.Kazui, P.Topiwala, W.Dai, M.Krishnan, M.Mrak and A.Gabriellini “Additional VUI and SEI for chroma sampling filter,” Joint Collaborative Team on Video Coding, JCTVC-L0077, Geneva, Jan.. 2013.

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1. The content written in the attached PFD document is equivalent to [4]. [↑](#footnote-ref-1)