|  |  |
| --- | --- |
| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  14th Meeting: Vienna, AT, 25 July – 2 Aug. 2013 | Document: JCTVC-N0229\_r2 |

|  |  |  |  |
| --- | --- | --- | --- |
| *Title:* | **Non-SCE3: Region based Inter-layer Cross-Color Filtering** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
| *Author(s) or Contact(s):* | Xiang Li, Wei Pu, Jianle Chen, Marta Karczewicz  Elena Alshina, Alexander Alshin, YongJin Cho | Tel: Email: | +1 858 658 3923  [lxiang@qti.qualcomm.com](mailto:lxiang@qti.qualcomm.com)  +82 10 3026 1305 [elena\_a.alshin@samsung.com](mailto:elena_a.alshin@samsung.com) |
| *Source:* | Qualcomm Incorporated, Samsung Eletronics, Ltd. | | |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Abstract

In this proposal, a region based inter-layer cross-color filtering is proposed. With this method, each chroma component in an enhancement picture is equally split into 1, 4, 16 regions and one set of cross-color filter parameters is signaled for each region. It is asserted that the proposed region based filtering significantly improves the coding performance by providing better local adaptation. It is reported that 1.4%, 11.1%, and 22.0% BD-rate reduction of Y, U, and V components were obtained on average for AI cases. For inter cases (RA, LD-B and LD-P), 0.4%, 11.0%, and 20.1% BD-rate reduction of Y, U, and V components were achieved on average.

# Introduction

Inter-layer cross-color filtering was proposed in [1][2] to improve chroma quality of inter-layer reference picture. High-frequency information is extracted from corresponding up-sampled luma component and is used to enhance up-sampled chroma components. In [3], reconstructed base layer luma component instead of up-sampled luma signal was used to extract the high-frequency information to reduce coding delay. In both methods, only one set of filter parameters is signaled for each chroma component in an enhancement picture so that all samples of one component in a whole picture share the same high-pass filter.

Given the nature of high-pass filter, one set of filter parameters for one chroma component may not be able to efficiently adapt to video content, especially when picture resolution is high. Therefore, region based inter-layer cross-color filtering is proposed on top of [3] in this document except that the fixed 16-bit shift in filter coefficient scaling is replaced by 14-bit shift. For each region of a chroma component, one set of filter parameters is signaled. The region partitioning is adaptively determined by the encoder.

# Technical details

## Region based inter-layer cross-color filtering

To obtain good adaptation to video content, an enhancement picture is split into equal-size regions. With a manner of quadtree partitioning, up to 64 regions are supported in the current implementation. For each chroma component of an enhancement picture, region number is indicated by partition depth where . For example, and indicate that Cb component is split into 4 region and Cr component is split into regions. For each region, a set of inter-layer cross-color filter parameters is signaled in bitstream. The scan order of regions is the same as the z-order in CU.

In the current implementation, the partitioning depth of each chroma component is adaptively determined by the encoder before coding an enhancement picture.

## 8-point cross-shaped filter

In [1][2][3], inter-layer cross-color filter with 3x4 shape is used. To save computational and signaling cost, filter with 8-point cross-shape was proposed in [4] as shown in Figure 1. Compared to the 3x4 shaped filter, the 8-point cross-shaped filter leads to 0.5% chroma BD-rate loss on average when only one partition is used for each chroma component [4].



Figure 8-point cross-shaped filter proposed in [4]

In region based scheme, the signaling cost of filter parameters is increased a lot when more than 4 regions are used. In this case, it is very important to keep signaling cost as low as possible. Moreover, the computational complexity of generating 8-point Wiener-Hopf equation and solving it is much lower than that of 12-point. Therefore, the 8-point cross shaped filter is used in this proposal.

# Complexity analysis

## Decoding complexity

To filter one chroma pixel, the following operations are needed.

* 8 multiplications and 7 additions used for the 8-point cross shaped filter.
* 1 multiplication for the scaling factor
* 1 addition to add the calculated offset to the chroma pixel to be enhanced.

In total, 9 multiplications and 8 additions are required to filter one chroma pixel. Compared to the 3x4 shaped filter used in [1][2][3], 4 multiplications and 4 additions are saved for each chroma pixel. That is the number of operations is roughly reduced by more than 30%.

In the worst case (SNR scalability), to filter a chroma W×H chroma block in an inter-layer reference picture, a (W+1)×(H+2) luma block in collocated base layer picture needs to be accessed, which may increase memory bandwidth. However in an efficient implementation, the luma block may be reused for both luma up-sampling and chroma filtering. Consequently, the actual increased memory access is quite limited.

## Encoding complexity

In addition to filter chroma components in inter-layer reference picture, filter parameters for each chroma region need to be determined at encoder side. To obtain coefficients of 8-point cross-shaped filter, Wiener-Hopf equation is to be solved. On one hand, more equations need to be solved when a chroma plane is split into more regions. On the other hand, more regions lead to better adaptation to video content and a potential better coding performance. How to achieve a good tradeoff is a task of smart encoders. In the current implementation, encoder adaptively determines the region number for each chroma component in inter-layer reference picture. Proposed syntax tables and semantics

## Sequence parameter set extension syntax and semantics

|  |  |
| --- | --- |
| sps\_extension( ) { | **Descriptor** |
| … |  |
| **sps\_inter\_layer\_cross\_color\_enable\_flag** | u(1) |
| if(sps\_inter\_layer\_cross\_color\_enable\_flag)**{** |  |
| **sps\_max\_inter\_layer\_cross\_color\_part\_log4** | ue(v) |
| } |  |
| } |  |

**sps\_inter\_layer\_cross\_color\_enable\_flag** equal to 1 specifies that inter-layer cross-color filtering is enabled. sps\_inter\_layer\_cross\_color\_enable\_flag equal to 0 specifies that inter-layer cross-color filtering is disabled. When not present, sps\_inter\_layer\_cross\_color\_enable\_flag is inferred to be equal to 0.

**sps\_max\_inter\_layer\_cross\_color\_part\_log4** specifies the maximal number of paritions used in inter-layer cross-color filtering. When not present, sps\_max\_inter\_layer\_cross\_color\_part\_log4 is inferred to be equal to 0.

## General slice segment header syntax and semantics

|  |  |
| --- | --- |
| slice\_segment\_header( ) { | Descriptor |
| **first\_slice\_segment\_in\_pic\_flag** | u(1) |
| …… |  |
| if(sps\_inter\_layer\_cross\_color\_enable\_flag){ |  |
| for(uv=0;uv<2;uv++){ |  |
| **pic\_inter\_layer\_cross\_color\_part\_log4**[uv] | ue(v) |
| for(i=0;i<PicInterLayerCrossColorPart[uv];i++) |  |
| inter\_layer\_cross\_color\_filter\_param(uv,i) |  |
| } |  |
| } |  |
| …… |  |
| } |  |

**pic\_inter\_layer\_cross\_color\_part\_log4**[uv] specifies variable PicInterLayerCrossColorPart[uv] which is the number of partitions used in inter-layer corss-color filtering for the chroma component in the current picture. pic\_inter\_layer\_cross\_color\_part\_log4[uv] shall be between 0 and sps\_max\_inter\_layer\_cross\_color\_part\_log4, inclusively. When not present, pic\_inter\_layer\_cross\_color\_part\_log4[uv] is inferred to be equal to 0.

## inter\_layer\_cross\_color\_filter\_param

|  |  |
| --- | --- |
| inter\_layer\_cross\_color\_filter\_param(uv,i){ |  |
| **inter\_layer\_cross\_color\_flag**[uv][i] | u(1) |
| if (inter\_layer\_cross\_color\_flag[uv][i]){ |  |
| for(j=0; j<7; j++) |  |
| **inter\_layer\_cross\_color\_filter\_coeff\_ plus8**[uv][i][j] | u(4) |
| **inter\_layer\_cross\_color\_filter\_scaling\_factor\_abs\_minus1**[uv][i] | u(10) |
| **inter\_layer\_cross\_color\_filter\_scaling\_factor\_sign**[uv][i] | u(1) |
| } |  |
| } |  |

**inter\_layer\_cross\_color\_flag**[uv][i] equal to 1 specifies that inter-layer cross-color filtering will be applied to the ith region of the chroma component uv. inter\_layer\_cross\_color\_flag[uv][i] equal to 0 specifies that inter-layer cross-color filtering will not be applied to the ith region of the chroma component uv. When not present, inter\_layer\_cross\_color\_flag is inferred to be equal to 0.

**inter\_layer\_cross\_color\_filter\_coeff\_plus8**[uv][i][j] minus 8 specifies the jth filter coefficient of the inter-layer cross-color filter for the ith region of the chroma component uv. The value of inter\_layer\_cross\_color\_filter\_coeff\_ plus8[uv][i][j] shall be in the range of 0 to 15, inclusivly.

**inter\_layer\_cross\_color\_filter\_scaling\_factor\_abs\_minus1**[uv][i] and **inter\_layer\_cross\_color\_filter\_scaling\_factor\_sign**[uv][i] together specify the value of variable InterLayerCrossColorFilterScalingFactor[uv][i] for the ith region of the chroma component uv as follows:

InterLayerCrossColorFilterScalingFactor[uv][i] = (1 – 2 \*inter\_layer\_cross\_color\_filter\_scaling\_factor\_sign[uv][i]) \* (inter\_layer\_cross\_color\_filter\_scaling\_factor\_abs\_minus1[uv][i]+1)

The value of inter\_layer\_cross\_color\_filter\_scaling\_factor\_abs\_minus1 shall be in the range of 1 to 1023, inclusively.

# Test Results

In this section, the proposed method is experimentally verified under SHVC common test conditions defined in [9].

## R-D performance

The R-D performance of the proposed method is provided as follows. Results with up to 64 regions (QTC=3), up to 16 regions (QTC=2), and up to 4 regions (QTC=1) are presented. In general, more regions lead to better local adaption and hence higher potential gain, especially for sequences with high resolutions. However, more regions also lead to higher signaling cost and encoding complexity. Under the current common test conditions, the proposed method with up to 16 regions shows the best tradeoff between coding performance and complexity, though the maximum region number may be a level related constraint.

### R-D results of up to 64 regions (QTC=3)



### R-D results of up to 16 regions (QTC=2)



### R-D results of up to 4 regions (QTC=1)



## Memory access evaluation

The memory access evaluation is based on the most recent version of JCTVC-M0455. In general, the proposed method slightly increases decoding memory access.

### Memory access of up to 64 regions (QTC=3)

#### PU level



#### Picture level



### Memory access of up to 16 regions

#### PU level



#### Picture level



### Memory access of up to 4 regions

#### PU level



#### Picture level



# Conclusions

In this proposal, a region based inter-layer cross-color filtering method is proposed. In general, the decoding complexity of region based inter-layer cross-color filtering is lower or similar to that of the original design (without local adaptation) while the coding performance is significantly improved. It is proposed to adopt the method and enable up to 16 regions in common test conditions.

# References

1. J. Dong, Y. He, Y. Ye, “Chroma enhancement for ILR picture”, JCTVC-L0059, Geneva, Switzerland, Jan. 2013.
2. J. Dong, Y. Ye, Y. He, “Chroma enhancement for ILR picture,” JCTVC-M0183, Incheon, Korean, 18–26 Apr. 2013
3. E. Alshina, A. Alshina, Y.Cho, “Non SCE4: simplified design of cross-color inter-layer (test 4.2.4),” JCTVC-M0089, Incheon, Korean, 18–26 Apr. 2013.
4. X. Li, J. Chen, W. Pu, M. Karczewicz, “Non-SCE4: Simplification of chroma enhancement for inter layer reference picture generation”, JCTVC-M0253, Incheon, Korean, 18–26 Apr. 2013.
5. [X. Li](mailto:lxiang@qti.qualcomm.com), [J. Boyce](mailto:jill@vidyo.com), [P. Onno](mailto:patrice.onno@crf.canon.fr), [Y. Ye](mailto:yan.ye@interdigital.com), “Common SHM test conditions and software reference configurations”, JCTVC-M1009, Incheon, Korean, 18–26 Apr. 2013.

# Patent rights declaration(s)

**Qualcomm Inc. 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).**

**Samsung Electronics, Ltd. 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).**