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**ORGANISATION INTERNATIONALE DE NORMALISATION**

**ISO/IEC JTC 1/SC 29/WG 11**

**CODING OF MOVING PICTURES AND AUDIO**

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**Gothenburg – July 2019**

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V-PCC CE 2.17 on smoothing

# Abstract

This document provides the description of Core Experiment 2.17 of PCC Category 2, on smoothing.

In V-PCC, geometry smoothing is applied to improve the quality of the decoded point cloud. The goal of the PCC Core Experiment 2.17 is to assess methods that propose quality improvements and/or complexity reduction in geometry smoothing.

During the previous meeting, the results of the previous CE2.17 [**m49237**] have shown that the patch border filtering method [**m47479**] increases the objective results and reduces the complexity with equivalent subjective quality. The group proposes to compare the complexity of both smoothing methods in this CE.

# Introduction

The goal of CE2.17 is to evaluate the performance in terms of quality (objective and subjective) and in terms of complexity (number of operations and memory usage). This CE will evaluate the two tools:

1. tool A: Patch Border Filtering [**m47479**]
2. tool B: geometry grid smoothing [**m43501**]

The experimental results of the CE will be evaluated by the 3DG/PCC AhG. The 3DG/PCC AhG group will make recommendations to the 3DG group for any changes in PCC TMC2.

# Mandates

Mandates for CE2.17 are as follows:

* Report performance of TMC2 without geometry grid smoothing
* Report performance of TMC2 with Patch Border Filtering
* Report performance of TMC2 with geometry grid smoothing
* Study possible modifications to algorithms to simplify their implementation and optimize the performance
* Assess performance of each CTC condition when applicable.
* Indicate any required modifications in the Draft International Standard (i.e. Syntax, Semantics, and the text for the process)
* Measure the decoder time of the three configurations.
* Possibly dynamic subjective evaluation if there’s consensus among participants in the CE about the need for subjective evaluation.
* Evaluate the complexity of the two proposed smoothing filters

# Participants

|  |  |  |  |
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(P=proponent, C=cross checker)

# Test Model, anchors and CTC

Tests are performed using the V-PCC R7.0 [w18666]. Test conditions specified in the Common Test Conditions document [w18665] with the changes as specified below. Objective results will be provided using the result spreadsheet template [w18668].

# Tools to be evaluated

## Tool A: m47479 on Patch Border Filtering

The main stage of the proposed process is the filtering of the borders of the patches according to the border of the other patches. The Figure 1 shows the main steps of this process.

Patches

* Border points
* Adjacentes patches list

(a)



(b)

(c)

(d)

Figure 1. Main operation: analysis of the patches to extract the border points and the adjacent patches lists (a), building of the neighborhood depth map based on the borders of the adjacent patches(b), deformation of the 2D patch contour (c) and the border filling (d).

This process must be performed for each patch and to prepare these operations, we must identify the 2D boundary points of the current patch and the adjacent patch list. These operations could be performed easily by studying the occupancy map and use the minimum and the maximum depth information to build the 3D bounding box of the patches and the adjacent patch list (Figure 1.a).

These data could be used to project on the patch depth map the border point of the adjacent patches. This operation creates by patch a neighborhood map contemning the depth value of the boundary points of the adjacent patches (Figure 1.b).

The main process consists to deform the 2D contour of the current patch to reduce the distance between this contour and the contours of the adjacent patches Figure 1.c. For each point of the contour, we could easily compute the distance to the other patches, based on the neighborhood map, and decide locally to update the contour and deform the patch. For each point of the contour, two kinds of deformations could be made:

* Erosion, that removes current point from the contour, and;
* Dilatation that increases the contour.

This process could be performed one time for all the contour points. If some points are removed or added in the contour, these new points must be processed again.

The last stage of the patch filtering process Figure 1.d is the filling process, which guarantees that there are no holes between two patches. This process has two steps, as shown in Figure 4:

* The first one locally changes the depth values of the patch’s contour points to smooth the transition between two patches (Figure 2.b)
* The second one adds 3D points between two patches to fill the hole that could appear in the depth direction (Figure 2.c).

12

8

7

7

6

6

12

10

8

7

6

6

6

6

7

8

10

12

depth

2D

coordinate

(a) Input to step 4

(b) Output from step 4 /

Input to step 5

6

6

7

8

9

10

12

11

depth

2D

coordinate

(c) Output from step 5

6

6

7

12

depth

7

8

2D

coordinate

Figure 2. Example of the fill seam operation.

The Figure 3 shows an example of the border point of the patch in the 3D space and the corresponding contour deformation process.

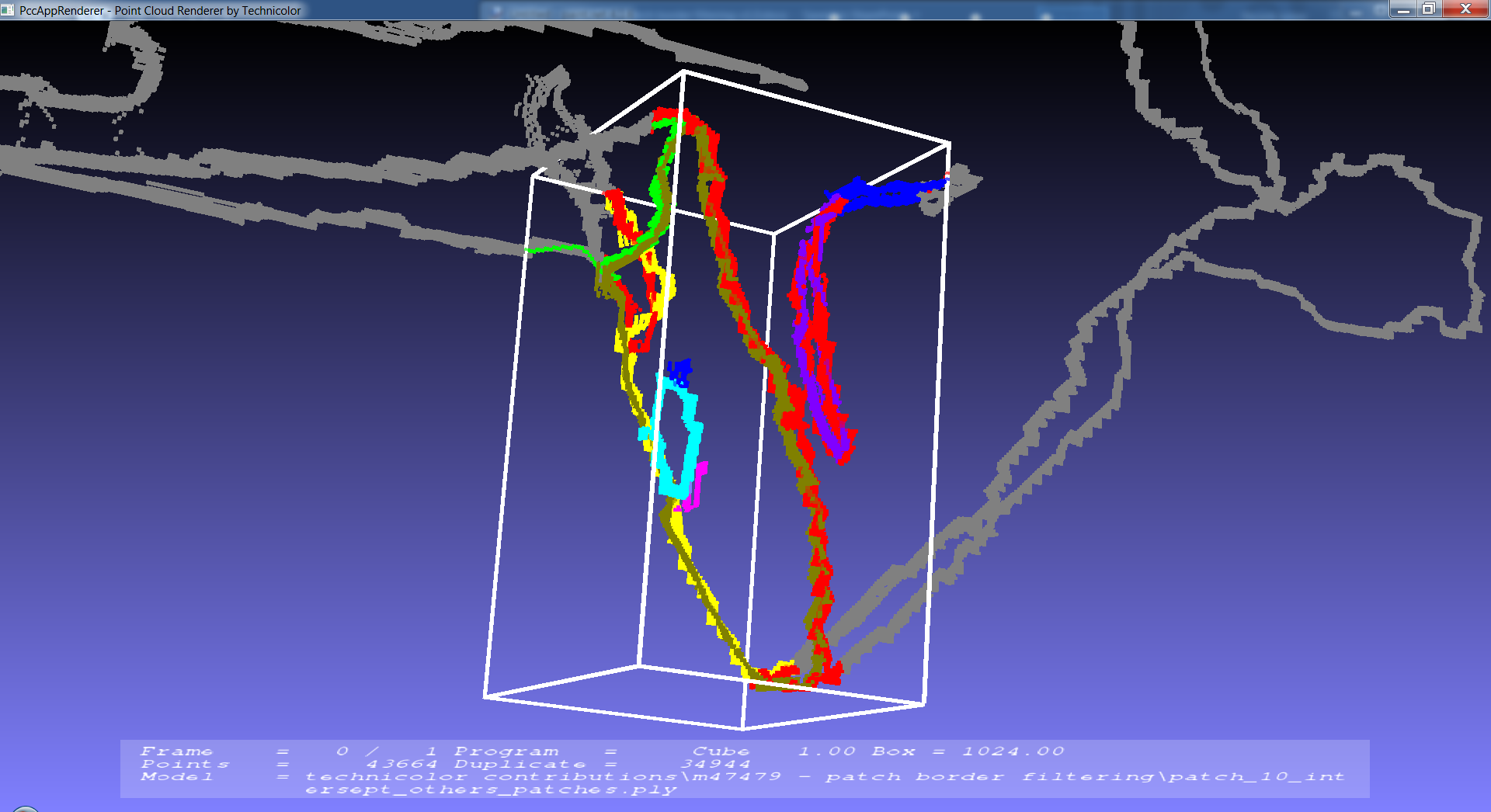


Figure 3 border point of the patch in the 3D space and the corresponding contour deformation process.

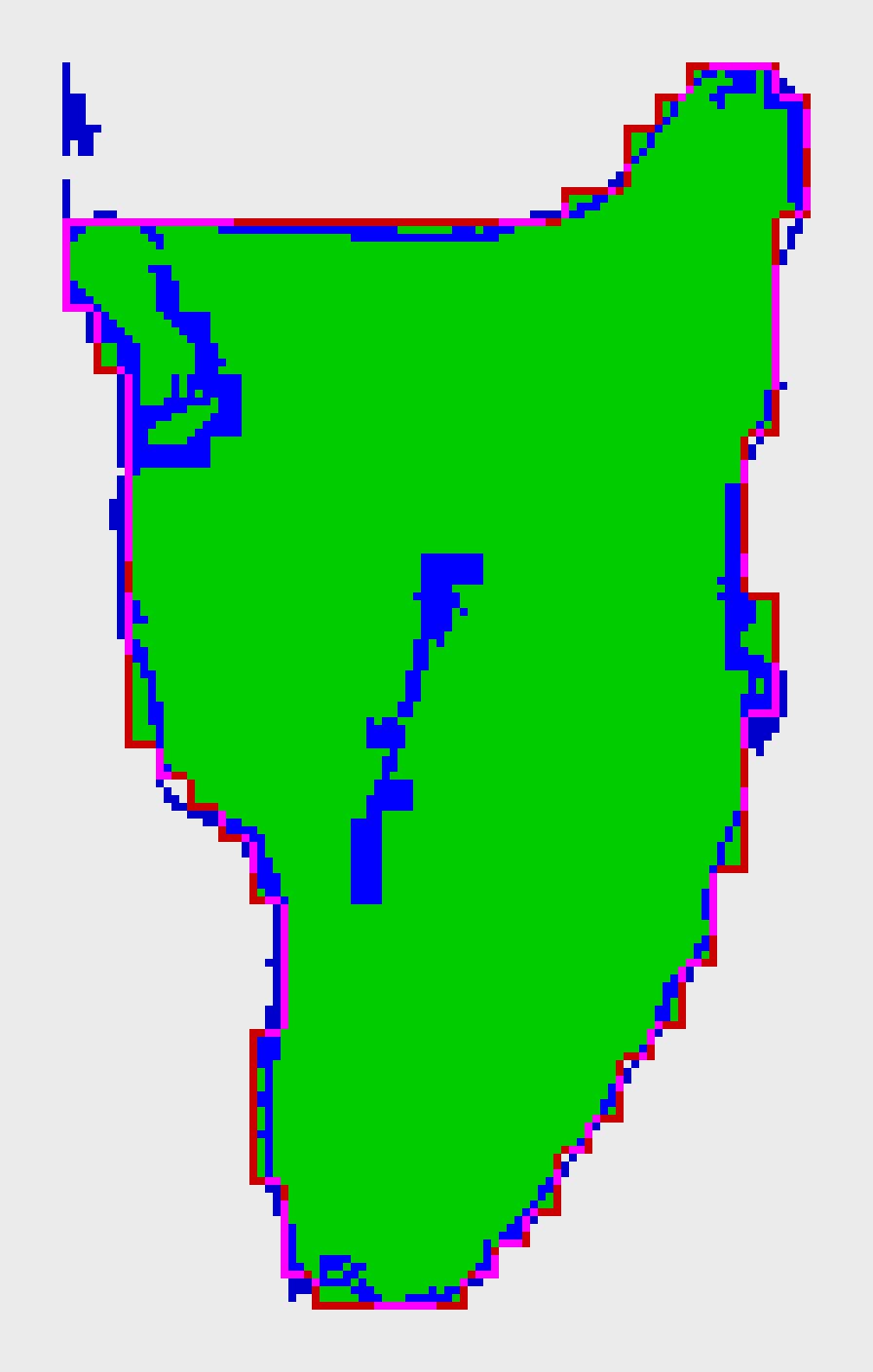
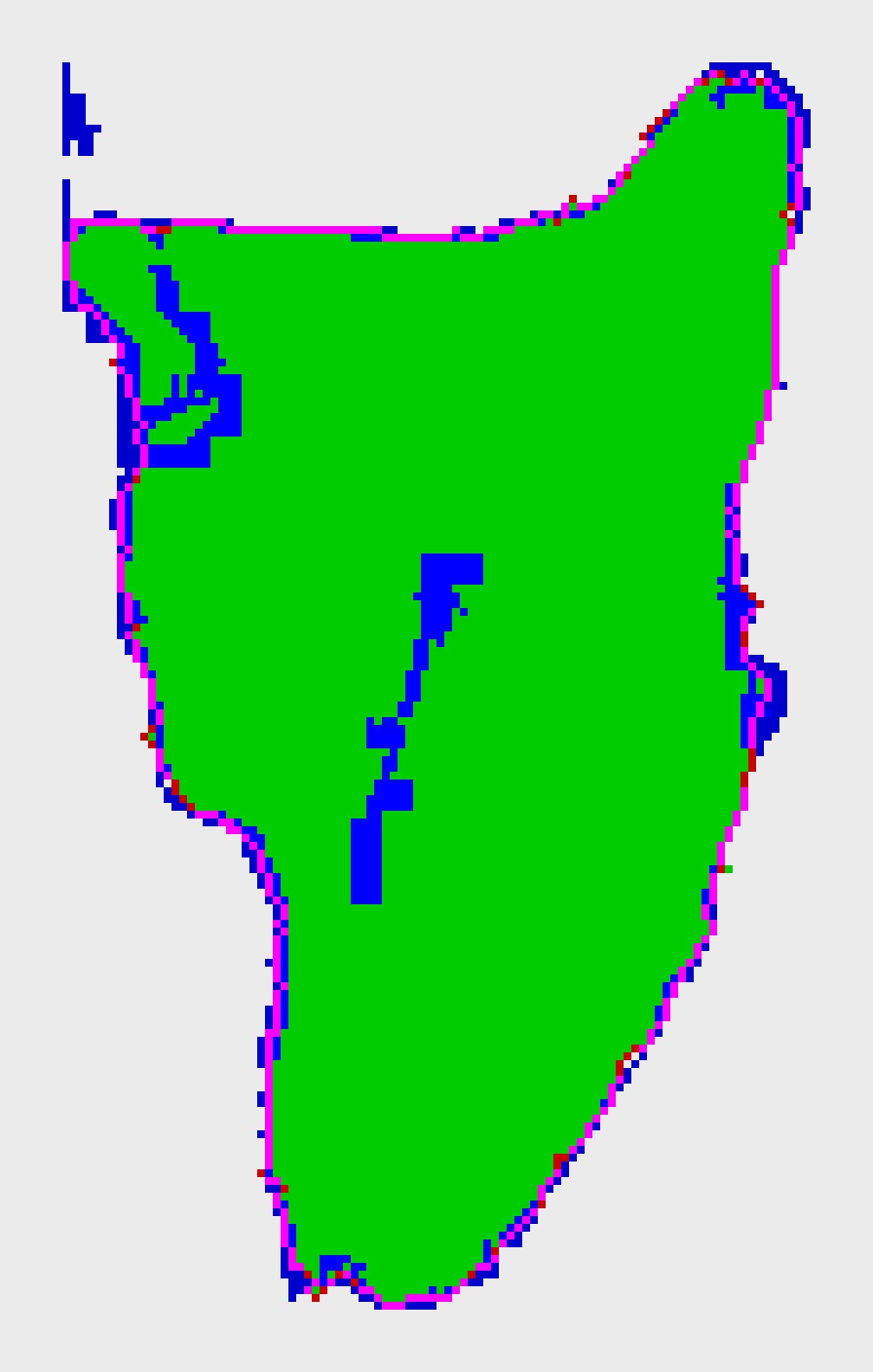
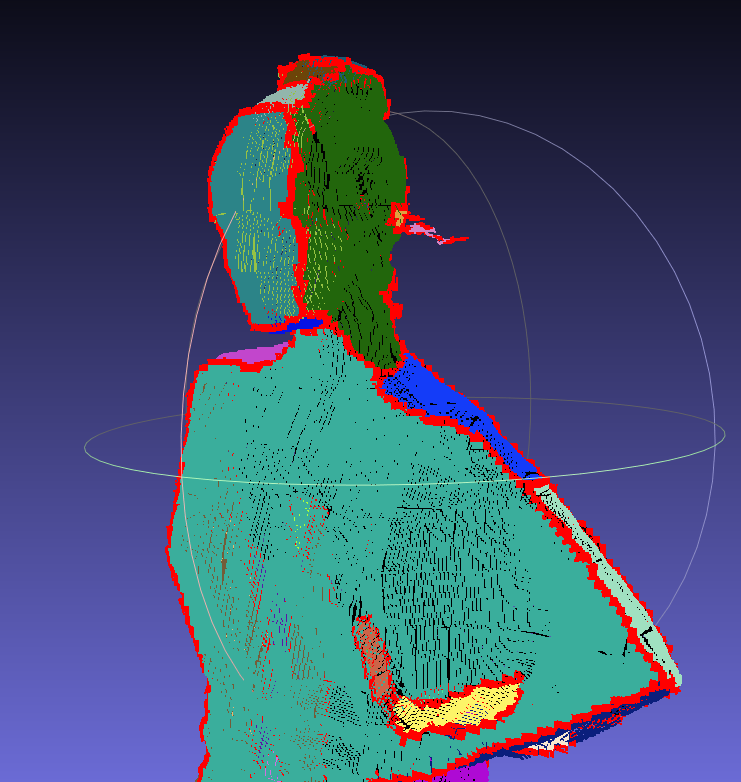
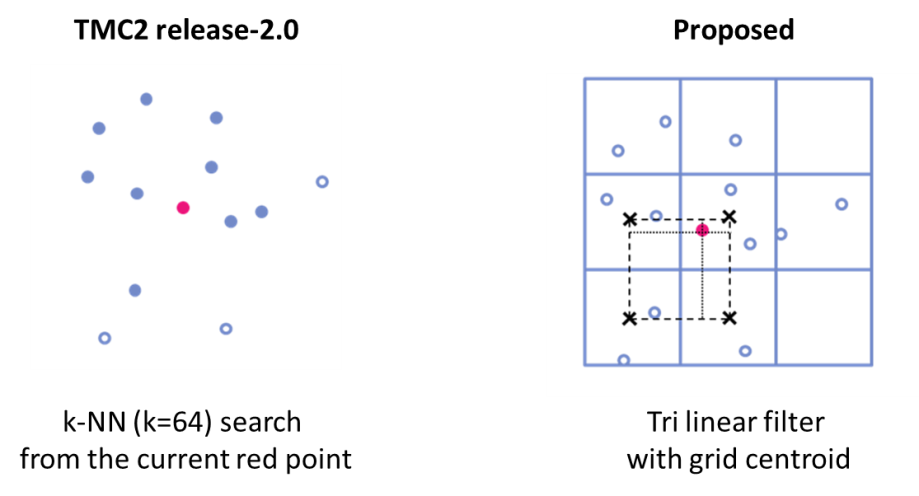
 

Figure 4 Example of patch picture: patch points (green), adjacent patch points (bleu) and current patch border (red) before patch filtering (left) and after (right).

## Tool B: Grid Geometry smoothing [m43501]

The process of geometry refinement aims to filter patch boundaries to improve the visual quality of the reconstructed point cloud. Smoothed geometry is used for attribute patch generation.

The method for point cloud smoothing is applied to the patch edges (fig. 5) and the centroid of the decoded points are calculated in a small grid beforehand. After the centroid and the number of points in the 2x2x2 grid are derived, a commonly used trilinear filter is applied with the centroid.

*Figure 5.* *Points for geometry smoothing and trilinear filter*

The grid\_size is 8 because the occPrecision (occupancy precision) is set to 4. However, occPrecision can be 1 in minimum so that the grid\_size becomes 2 in the case.

In the geometry grid smoothing, the bounding box is divided into the grids by grid\_size. The number of grids numOfGrid is calculated as follows.

numOfGrid = (boundingBox.x\_range/grid\_size) \*

(boundingBox.y\_range/grid\_size) \* (boundingBox.z\_range/grid\_size)

In the test model, it cashes the necessary information for the filtering for the entire decoded point cloud frame in advance. However, in another implementation, the memory size can be significantly reduced. In the minimum, it is needed for the trilinear filtering only to store the neighbour 2x2x2 grid information. It means, regardless of the grid\_size, theoretically, minimum memory size is obtained with numOfGrid=8 as

MinMemorySize = 8 \* (sizeof(int)\*4 +1) = 256 Byte

Fixed grid\_size for the grid smoothing has to be applied.

# Proposed tests

The proposed tests will assess the performance of the following three configurations (applied on top of the current CTC conditions):

* TMC2v7 Anchor, including tool B (**m43501**)
* TMC2v7 with tool A (**m47479**) enabled and tool B disabled
* TMC2v7 Anchor without geometry smoothing (i.e., tool B disabled)

The performance evaluation will focus on three aspects, detailed in the following subsections.

## Objective quality

Objective quality metrics will be used to measure the BD-BR PSNR gains. The standard reporting spreadsheet will be used to provide the results.

## Computational complexity

Analysis of the two smoothing methods to measure:

* Relative complexity of tool A versus tool B e.g. runtime(A)/runtime(B) – all other things being equal.
* Average number of operations (or representative value) per frame / point
* Memory usage

## Subjective quality

Dynamic subjective evaluation could be made if needed.

# Timeline

2019/07/29 MPEG #126 meeting ends

2019/07/26 Finalized CE, CTC

2019/08/02 TMC2 v7.0 tag published

2019/09/20 Code base and results delivered to cross-checkers (32 and ALL frames)

2019/09/27 Preliminary feedback from cross-checkers to proponents

2019/10/02 MPEG #128 contribution submission deadlines

2019/10/07 MPEG #128 meeting starts

# Document and software references

[w18665] Common Test Conditions for PCC, Gothenburg, Sweden, July 2019, ISO/IEC JTC1/SC29 WG11.

[w18666] V-PCC V7.0 software, Gothenburg, Sweden, July 2019, ISO/IEC JTC1/SC29 WG11.

[w18668] V-PCC performance evaluation and anchor results, Gothenburg, Sweden, July 2019, ISO/IEC JTC1/SC29 WG11.

[m47479] [VPCC][New proposal] Patch border filtering, Geneva, Switzerland, March 2019, ISO/IEC JTC1/SC29 WG11.

[m49237] [VPCC][CE] CE2.17 Patch Border Filtering Report, Gothenburg, Sweden, July 2019, ISO/IEC JTC1/SC29 WG11.

[m43501] PCC TMC2 low complexity geometry smoothing, Ljubljana, Slovenia, July 2018, ISO/IEC JTC1/SC29 WG11.