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**ISO/IEC JTC 1/SC 29/WG 7 N0509**

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| **Title** | **Common Test Conditions for G-PCC** |
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# Abstract

This document defines common test conditions and software reference configurations to be used in the context of core experiments (CE) conducted after the 10th WG7 (141th MPEG) meeting. These CTCs are recommended for use in technical contributions to the 142th and following MPEG meetings.

# Introduction

Common test conditions (CTC) are desirable to conduct experiments in a well-defined environment and ease the comparison of the outcome of experiments. The structure of this document reflects parts of the MPEG PCC CfP [1], with three content categories and a set of test conditions that are used to evaluate performance as follows:

* Category 1: Static Objects and Scenes
* Category 2: Dynamic Objects
* Category 3: Dynamic Acquisition

Table 1 – List of test conditions

|  |  |  |  |
| --- | --- | --- | --- |
| Condition | Test condition | AI | RA |
| C1 | Lossless Geometry – Lossy attributes | ✓ | ✓ |
| C2 | Near-lossless | Lossy Geometry – Lossy Attributes | ✓ | ✓ |
| CW | Lossless Geometry – Lossless Attributes | ✓ | ✓ |
| CY | Lossless Geometry – Near-lossless Attributes | ✓ | ✓ |

Note: “lossy”, “near-lossless” and “lossless” geometry/colour/reflectance encoding are defined in the “Requirements for Point Cloud Compression” output document [2]. For clarity, near-lossless implies a bounded error rather than the magnitude of the error (*i.e.* near-lossless does not necessarily imply nearly lossless).

A subset of these test conditions might be used for a particular experiment. For example, when testing trisoup geometry coding in TMC13, test conditions C1, CW and CY are not applicable.

The test model TMC13 is tested on in content categories 1 and 3. The software is available in the MPEG Gitlab repository at <http://mpegx.int-evry.fr/software/MPEG/PCC/TM/mpeg-pcc-tmc13>.

The test model GeS-TM is tested on in content category 2. The software is available in the MPEG Gitlab repository at <http://mpegx.int-evry.fr/software/MPEG/PCC/TM/mpeg-pcc-ges-tm>

The following sections define sequences and encoding parameters to be used for each category. Input contributions should include a set of results as complete as possible that apply to the proposal. Results should be reported using the attached Excel sheets.

# Test sequences

Below is a list of the 3D point cloud test material test sequences to be used. The test class is an indicator on the type of data contained in the point cloud, where:

* Category 3 is for dynamic acquisitions:
  + **Am. Frame** is for Automotive frame-based LiDAR acquired data and is split in two sub-classes
    - **spinning** is for spinning LiDAR sensors
    - **non-spinning** is for non-spinning LiDAR sensors,
  + **Am. Fused** is for Automotive LiDAR acquired data, fused and reprocessed,
* Category 2 is for dynamic objects:
  + The test class A, B or C is an indicator of how complex a point cloud is to encode, where A is the lowest and C the highest complexity,
* Category 1 is for static objects and scenes:
  + **Solid** is for Voxelised point clouds with continuous surfaces,
  + **Dense** is for not quite continuous,
  + **Sparse** is for not dense,
  + **Scant** is for verry sparse.

All test sequences are available in the MPEG Content repository accessible under the following URLs (MPEG password is required):

<http://mpegfs.int-evry.fr/mpegcontent/>

<https://content.mpeg.expert/data/>

Note: Downloaded test material should be verified with MD5 checksums. Each zip file of a test material contains an MD5 file (with the corresponding md5 sums for each file in the archive).

Notes:

1. The associated normals to compute distortion metric D2 (point-to-plane) are available for most sequences.
2. The order of the points as they are stored in the file is not necessary to be maintained in the decoded versions.
3. The Geometry Precision in Tables 2 and 3 indicate the known geometry precision of the test material. The data type in the PLY file describes the format stored in the file.

Table 2 – Test material datasets – Category 3, dynamic acquisition

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Class | Test material dataset filename | Frames | fps | No. Points | Geometry Precision | Peak Value (p) | Attributes |
| Am. Frame spinning | Ford\_01\_q\_1mm g | 1500 | 10 | ~100,000 / fr | 18 bit | 30000 | I |
| Ford\_02\_q\_1mm g | 1500 | 10 | ~100,000 / fr | 18 bit | 30000 | I |
| Ford\_03\_q\_1mm g | 1500 | 10 | ~100,000 / fr | 18 bit | 30000 | I |
| qnxadas-junction-approach h | 74 |  | ~32,000 / fr | 18 bit | 30000 | I |
| qnxadas-junction-exit h | 74 |  | ~32,000 / fr | 18 bit | 30000 | I |
| qnxadas-motorway-join h | 500 |  | ~32,000 / fr | 18 bit | 30000 | I |
| qnxadas-navigating-bends h | 300 |  | ~32,000 / fr | 18 bit | 30000 | I |
| Am. Frame non-spinning | InnovizQC1 k | 300 | 15 | ~120,000 / fr | 16 bit | 3000 | I |
| InnovizQC2 k | 300 | 15 | ~110,000 / fr | 16 bit | 3000 | I |
| InnovizQC3 k | 300 | 15 | ~130,000 / fr | 16 bit | 3000 | I |
| Am. Fused | citytunnel\_q1mm i | 1 |  | 19,948,121 | 21 bit | 30000 | R,G,B, I |
| overpass\_q1mm i | 1 |  | 5,255,920 | 20 bit | 30000 | R,G,B, I |
| tollbooth\_q1mm i | 1 |  | 7,148,516 | 21 bit | 30000 | R,G,B, I |

g) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Dynamic\_Acquisition/Ford/

h) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/BB-QNX

i) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Dynamic\_Acquisition/Mitsubishi/

k) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets/Qualcomm/

Table 3 – Test material datasets – Category 2, dynamic objects

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Class | Test material dataset filename | Frames | fps | No. Points | Geometry Precision | Peak Value (p) | Attributes |
| A | Queen n | 250 | 50 | ~1,000,000 / fr | 10 bit | 1023 | R,G,B |
| 8i VFB – Loot o,p | 300 | 30 | ~780,000 / fr | 10 bit | 1023 | R,G,B |
| 8i VFB – Red\_and\_Black o,p | 300 | 30 | ~700,000 / fr | 10 bit | 1023 | R,G,B |
| 8i VFB – Soldier o,p | 300 | 30 | ~1,500,000 / fr | 10 bit | 1023 | R,G,B |
| B | 8i VFB – Long\_dress o,p | 300 | 30 | ~800,000 / fr | 10 bit | 1023 | R,G,B |
| C | basketball\_player\_vox11 (frames 1-64) l | 64 | 30 | ~2,900,000 / fr | 11 bit | 2047 | R,G,B |
| dancer\_vox11 (frames 1-64) m | 64 | 30 | ~2,600,000 / fr | 11 bit | 2047 | R,G,B |

l) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Owlii/VoxelizedPointCloud/basketball\_player\_vox11.zip

m) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Owlii/VoxelizedPointCloud/dancer\_vox11.zip

n) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Dynamic\_Objects/People/Technicolor/queen.zip

o) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Dynamic\_Objects/People/8i/8iVFBv2\_ok.zip

p) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/normals/XYZRGB\_n/Dynamic\_Objects/People/ (with normals)

Table 4 – Test material datasets – Category 1, static objects and scenes

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Class | Test material dataset filename | Frames | fps | No. Points | Geometry Precision | Peak Value (p) | Attributes |
| Solid | basketball\_player\_vox11\_00000200 j | 1 |  | 2,925,514 | 11bit | 2047 | R,G,B |
| dancer\_vox11\_00000001 j | 1 |  | 2,592,758 | 11bit | 2047 | R,G,B |
| Facade\_00064\_vox11 TBD | 1 |  | 4,061,755 | 11 bit | 2047 | R,G,B |
| Longdress\_vox10\_1300 c | 1 |  | 857,966 | 10 bit | 1023 | R,G,B |
| Loot\_vox10\_1200 c | 1 |  | 805,285 | 10 bit | 1023 | R,G,B |
| Queen\_0200 d | 1 |  | 1,000,993 | 10 bit | 1023 | R,G,B |
| Redandblack\_vox10\_1550 c | 1 |  | 757,691 | 10 bit | 1023 | R,G,B |
| Soldier\_vox10\_0690 c | 1 |  | 1,089,091 | 10 bit | 1023 | R,G,B |
| Thaidancer\_viewdep\_vox12 b | 1 |  | 3,130,215 | 12 bit | 4095 | R,G,B |
| Dense | boxer\_viewdep\_vox12 b | 1 |  | 3,493,085 | 12bit | 4095 | R,G,B |
| Facade\_00009\_vox12 a | 1 |  | 1,596,085 | 12 bit | 4095 | R,G,B |
| Facade\_00015\_vox14 a | 1 |  | 8,907,880 | 14 bit | 16383 | R,G,B |
| Facade\_00064\_vox14 a | 1 |  | 19,702,134 | 14 bit | 16383 | R,G,B |
| Frog\_00067\_vox12 a | 1 |  | 3,614,251 | 12 bit | 4095 | R,G,B |
| Head\_00039\_vox12 a | 1 |  | 13,903,516 | 12 bit | 4095 | R,G,B |
| House\_without\_roof\_00057\_vox12 a | 1 |  | 4,848,745 | 12 bit | 4095 | R,G,B |
| Landscape\_00014\_vox14 a | 1 |  | 71,948,094 | 14 bit | 16383 | R,G,B |
| longdress\_viewdep\_vox12 b | 1 |  | 3,096,122 | 12 bit | 4095 | R,G,B |
| loot\_viewdep\_vox12 b | 1 |  | 3,017,285 | 12 bit | 4095 | R,G,B |
| redandblack\_viewdep\_vox12 b | 1 |  | 2,770,567 | 12 bit | 4095 | R,G,B |
| soldier\_viewdep\_vox12 b | 1 |  | 4,001,754 | 12 bit | 4095 | R,G,B |
| Sparse | Arco\_Valentino\_Dense\_vox12 a | 1 |  | 1,481,746 | 12 bit | 4095 | R,G,B |
| Egyptian\_mask\_vox12 a | 1 |  | 272,684 | 12 bit | 4095 | R,G,B |
| Palazzo\_Carignano\_Dense\_vox14 a | 1 |  | 4,187,594 | 14 bit | 16383 | R,G,B |
| Shiva\_00035\_vox12 a | 1 |  | 1,009,132 | 12 bit | 4095 | R,G,B |
| Stanford\_Area\_2\_vox16 a | 1 |  | 47,062,002 | 16 bit | 65535 | R,G,B |
| Stanford\_Area\_4\_vox16 a | 1 |  | 43,399,204 | 16 bit | 65535 | R,G,B |
| Statue\_Klimt\_vox12 a | 1 |  | 499,660 | 12 bit | 4095 | R,G,B |
| ULB\_Unicorn\_HiRes\_vox15 e | 1 |  | 63,787,119 | 15 bit | 32767 | R,G,B |
| ULB\_Unicorn\_vox13 e | 1 |  | 1,995,189 | 13 bit | 8191 | R,G,B |
| Scant | Arco\_Valentino\_Dense\_vox20 f | 1 |  | 1,530,552 | 20 bit | 1048575 | R,G,B |
| Egyptian\_mask\_vox20 f | 1 |  | 272,689 | 20 bit | 1048575 | R,G,B |
| Facade\_00009\_vox20 f | 1 |  | 1,602,990 | 20 bit | 1048575 | R,G,B |
| Facade\_00015\_vox20 f | 1 |  | 8,929,532 | 20 bit | 1048575 | R,G,B |
| Facade\_00064\_vox20 f | 1 |  | 19,714,629 | 20 bit | 1048575 | R,G,B |
| Frog\_00067\_vox20 f | 1 |  | 3,630,907 | 20 bit | 1048575 | R,G,B |
| Head\_00039\_vox20 f | 1 |  | 14,025,709 | 20 bit | 1048575 | R,G,B |
| House\_without\_roof\_00057\_vox20 f | 1 |  | 5,001,077 | 20 bit | 1048575 | R,G,B |
| Landscape\_00014\_vox20 f | 1 |  | 72,145,549 | 20 bit | 1048575 | R,G,B |
| Palazzo\_Carignano\_Dense\_vox20 f | 1 |  | 4,203,962 | 20 bit | 1048575 | R,G,B |
| Shiva\_00035\_vox20 f | 1 |  | 1,010,591 | 20 bit | 1048575 | R,G,B |
| Stanford\_Area\_2\_vox20 f | 1 |  | 47,062,018 | 20 bit | 1048575 | R,G,B |
| Stanford\_Area\_4\_vox20 f | 1 |  | 43,399,207 | 20 bit | 1048575 | R,G,B |
| Statue\_Klimt\_vox20 f | 1 |  | 499,886 | 20 bit | 1048575 | R,G,B |
| ULB\_Unicorn\_HiRes\_vox20 e | 1 |  | 63,864,641 | 20 bit | 1048575 | R,G,B |
| ULB\_Unicorn\_vox20 e | 1 |  | 2,000,297 | 20 bit | 1048575 | R,G,B |

a) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Static\_Objects\_and\_Scenes/Cat1\_quantized.zip

b) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/8i/8iVSLF

c) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Dynamic\_Objects/People/8i/8iVFBv2.zip

d) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Dynamic\_Objects/People/Technicolor/queen.zip

e) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Static\_Objects\_and\_Scenes/ULB\_Unicorn/

ULB\_Unicorn\_quantized.zip

f) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Static\_Objects\_and\_Scenes/Cat1\_quantized\_v2.zip

j) https://content.mpeg.expert/data/MPEG-I/Part05-PointCloudCompression/dataSets\_new/Owlii/VoxelizedPointCloud/

# Reporting

Proposals will be evaluated based on bit rate, objective quality metrics, and complexity. Two Excel sheets are provided together with this document to report the results. Proponents are expected to deliver a full set of results for each targeted testing condition.

Reference results for the unmodified test models are available after each update of the test model software, *e.g.* in [4] for TMC13 and in [5] for GeS-TM, including respective software tags.

## Bit rate reporting

Bitrates shall be reported overall, as well as separately for geometry, texture and metadata, where applicable. The provided Excel sheets reporting specify which data shall be reported for which testing conditions.

Rate shall be reported as bits per input point (bpp). The evaluation will be made based on the rate-distortion (RD) performance, and RD curves shall be plotted using PSNR as the quality measure for all categories.

## Distortion reporting

For geometric distortions D1 and D2, the PSNR calculated from the symmetric distortions shall be reported. The distortion metrics and calculation of PSNR is specified in Annex A.1 of this document.

Colour distortion is measured in *Y′CbCr* space with 3 separate MSE distortions, which are reported as PSNRs for each channel: *Y’* (Luma), *Cb* and *Cr* (Chroma). The reflectance distortion is also computed using MSE, but only for a single component, and the corresponding PSNR values are reported. The PSNRs for each component will be individually used to compare methods. All attribute PSNRs are also calculated from the symmetric distortions. Details on the attribute distortion calculation are provided in Annex A.2 of this document.

The provided distortion metric software provides all the required data. Details on running the software are provided in Annex A.3 of this document.

Any possible duplicated points in the reconstructed point cloud shall be reported. For distortion metrics reporting, the average over duplicated points shall be reported (setting --dropdups=2 for the distortion metric software).

In the case of lossy dynamic content (Category 3 Am. Frame), the reported distortion measures and number of duplicated points shall be averaged over all coded frames.

Proponents are advised that, upon acceptance for further evaluation, it will be required that additional metrics are made available, such as the reported distortion measures averaged over all coded frames (i.e., averaged over I frames, averaged over P frames, averaged over all frames) and a report of the PSNR per frame.

## Complexity reporting

The encoder and decoder runtimes shall be reported with respect to the unmodified test model runtimes on the same system. The software reports wall time and user time. In this case user time shall be reported.

In addition, contributions should contain the following aspects regarding codec complexity:

* theoretical study of the complexity on encoder and decoder, for example number of operations, memory access patterns, floating point operations, etc.
* execution time with respect to anchor software
* implications with respect to the video codec type, e.g. chroma subsampling, bit depth, profiles, type, tools
* suitability of the hardware implementation, i.e. avoid floating points, memory usage, potential for parallelization

## Distortion metric software

The metric software for calculating the objective distortion can be accessed from the MPEG GitLab:

<http://mpegx.int-evry.fr/software/MPEG/PCC/mpeg-pcc-dmetric.git>

The tag *release-v0.14* indicates the current released version of the software. In case a different version of the software shall be used, this will be specified in the most up-to-date reference result document, *e.g.* in [3] for TMC13. A readme.txt provided in the repository describes how to compile the metric software.

Annex A.3 provides details on how to run the evaluation software.

## Summary of reporting data per condition

The following table summarises the data to be reported per test condition.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Condition | C1 | C2 | CW | CY | Remarks |
| enc.bits.geometry | ✓ | ✓ | ✓ | ✓ |  |
| enc.bits.colour | ✓ | ✓ | ✓ | ✓ | source dependent |
| enc.bits.reflectance | ✓ | ✓ | ✓ | ✓ | source dependent |
| enc.ext.bits | ✓ | ✓ | ✓ | ✓ |  |
| dec.numpoints | ✓ | ✓ | ✓ | ✓ |  |
| dec.d1-psnr |  | ✓ | ✓ |  |  |
| dec.d2-psnr |  | ✓ | ✓ |  |  |
| dec.y-psnr | ✓ | ✓ | ✓ | ✓ | source dependent |
| dec.cb-psnr | ✓ | ✓ | ✓ | ✓ | source dependent |
| dec.cr-psnr | ✓ | ✓ | ✓ | ✓ | source dependent |
| dec.reflectance-psnr | ✓ | ✓ |  | ✓ | source dependent |
| dec.y-hpsnr |  |  |  | ✓ | source dependent |
| dec.cb-hpsnr |  |  |  | ✓ | source dependent |
| dec.cr-hpsnr |  |  |  | ✓ | source dependent |
| dec.reflectance-hpsnr |  |  |  | ✓ | source dependent |
| dec.utime | ✓ | ✓ | ✓ | ✓ |  |
| enc.utime | ✓ | ✓ | ✓ | ✓ |  |

*enc.ext.bits* represents the output stream/file size as measured by external means.

*dec.numpoints* is the number of decoded points in the entire sequence.

*dec.numpoints.mean* is the mean number of decoded points per frame.

*dec.numduppoints.mean* is the mean number of duplicate decoded points per frame.

*y-*, *cb-*, and *cr-*, are end-to-end distortion metrics that compare the output of the decoder with the input to the encoder.

*y-*, *cb*-, and *cr*-, are end-to-end hausdorff distortion metrics that compare the output of the decoder with the input of the encoder.

post-recolour distortion metrics compare the output of the decoder with the output of the recolouring process following geometry compression.

# Common test conditions for TMC13

This sub-section will be continuously updated as more detailed information is made available.

## Software – TMC13

The common software used for TMC 13 experiments is available from the MPEG GitLab:

<http://mpegx.int-evry.fr/software/MPEG/PCC/TM/mpeg-pcc-tmc13.git>

Software documentation and usage are described in [4].

## Output format

Decoded point clouds shall be output, and distortion measured using a binary PLY format.

## Coding parameters

The coding parameters for each test point are available in the /cfg directory of the provided software.

In the current state of the TMC13, the coding parameters specific to random access (RA) coding are available in /cfg/inter directory, and random access is only supported with sequences belonging to Category 3 Am. Frame class.

When coding multi-frame sequences in an all intra configuration (AI), all parameter sets must be repeated at the start of each frame. When coding multi-frame sequences in a random access configuration, all parameter sets must also be repeated at the start of each frame.

TMC13 contains distinct and mutually exclusive tools with overlapping functionality for geometry and attribute coding. The following sections describe the configuration of each tool when used in a particular condition. An experiment evaluating a codec modification should choose an appropriate set of tools, using the corresponding set as reference.

## Parameters for octree or trisoup geometry coding evaluation

The following parameters define the codec configuration to be used for evaluating octree or trisoup geometry coding.

The parameter planarEnabled is always set to 1 with the exception of

* solid test class content where it is set to 0, and
* dense test class where is it set according to the following table.

|  |  |
| --- | --- |
| Test material filename | planarEnabled |
| boxer\_viewdep\_vox12 | 0 |
| Facade\_00009\_vox12 | 1 |
| Facade\_00015\_vox14 | 1 |
| Facade\_00064\_vox14 | 1 |
| Frog\_00067\_vox12 | 1 |
| Head\_00039\_vox12 | 0 |
| House\_without\_roof\_00057\_vox12 | 1 |
| Landscape\_00014\_vox14 | 0 |
| longdress\_viewdep\_vox12 | 0 |
| loot\_viewdep\_vox12 | 0 |
| redandblack\_viewdep\_vox12 | 0 |
| soldier\_viewdep\_vox12 | 0 |

## Parameters for Category 3 Am. Frame class

The following parameters define the codec configuration to be used for evaluating octree or predictive tree geometry coding with Category 3 Am. Frame class, for sequences acquired with spinning LiDAR sensor.

* partitionMethod=0,

### Parameters for sequences acquired with spinning LiDAR sensor

The following parameters define the codec configuration to be used for evaluating octree or predictive tree geometry coding with Category 3 Am. Frame class, for sequences acquired with spinning LiDAR sensor.

* angularEnabled=1
* planarBufferDisabled=1 for octree geometry coding (it is not used otherwise).

the numLaser, lasersTheta, lasersZ and lasersNumPhiPerTurn parameters are set according to the following tables.

|  |  |
| --- | --- |
| Test material filename | numLaser |
| Ford\_01\_q\_1mm | 64 |
| Ford\_02\_q\_1mm | 64 |
| Ford\_03\_q\_1mm | 64 |
| qnxadas-junction-approach | 16 |
| qnxadas-junction-exit | 16 |
| qnxadas-motorway-join | 16 |
| qnxadas-navigating-bends | 16 |

|  |  |
| --- | --- |
| Test material filename | lasersTheta |
| Ford\_01\_q\_1mm  Ford\_02\_q\_1mm  Ford\_03\_q\_1mm | “-0.461611, -0.451281, -0.440090, -0.430000, -0.418945,  -0.408667, -0.398230, -0.388220, -0.377890, -0.367720,  -0.357393, -0.347628, -0.337549, -0.327694, -0.317849,  -0.308124, -0.298358, -0.289066, -0.279139, -0.269655,  -0.260049, -0.250622, -0.241152, -0.231731, -0.222362,  -0.213039, -0.203702, -0.194415, -0.185154, -0.175909,  -0.166688, -0.157484, -0.149826, -0.143746, -0.137673,  -0.131631, -0.125582, -0.119557, -0.113538, -0.107534,  -0.101530, -0.095548, -0.089562, -0.083590, -0.077623,  -0.071665, -0.065708, -0.059758, -0.053810, -0.047868,  -0.041931, -0.035993, -0.030061, -0.024124, -0.018193,  -0.012259, -0.006324, -0.000393,  0.005547,  0.011485,   0.017431,  0.023376,  0.029328,  0.035285” |
| qnxadas-junction-approach  qnxadas-junction-exit  qnxadas-motorway-join  qnxadas-navigating-bends | “-0.268099, -0.230939, -0.194419, -0.158398, -0.122788,  -0.087491, -0.052410, -0.017455,  0.017456,  0.052408,   0.087487,  0.122781,  0.158381,  0.194378,  0.230865,   0.267953” |

|  |  |
| --- | --- |
| Test material filename | lasersZ |
| Ford\_01\_q\_1mm  Ford\_02\_q\_1mm  Ford\_03\_q\_1mm | “29.900000, 26.600000, 28.300000, 24.600000, 26.800000,  25.100000, 24.800000, 22.400000, 22.400000, 21.900000,  23.000000, 20.700000, 21.100000, 20.300000, 19.900000,  19.000000, 18.900000, 15.300000, 17.300000, 16.000000,  16.200000, 15.100000, 14.800000, 14.400000, 13.800000,  13.000000, 12.700000, 12.100000, 11.500000, 11.000000,  10.400000,  9.800000, 10.700000, 10.300000, 10.000000,  9.400000,  9.100000,  8.600000,  8.200000,  7.700000,  7.400000,  6.800000,  6.500000,  6.000000,  5.600000,  5.100000,  4.700000,  4.300000,  3.900000,  3.500000,  3.000000,  2.600000,  2.100000,  1.800000,  1.300000,  0.900000,  0.500000, -0.100000, -0.400000, -0.900000,  -1.200000, -1.700000, -2.100000, -2.500000” |
| qnxadas-junction-approach  qnxadas-junction-exit  qnxadas-motorway-join  qnxadas-navigating-bends | “-2.000000, -1.500000, -1.300000, -1.100000, -1.000000,  -1.000000, -1.000000, -1.000000,  0.000000,  0.000000,  -0.100000, -0.200000, -0.200000, -0.200000, -0.300000,  -0.200000” |

|  |  |
| --- | --- |
| Test material filename | lasersNumPhiPerTurn |
| Ford\_01\_q\_1mm  Ford\_02\_q\_1mm  Ford\_03\_q\_1mm | “800, 800, 800, 800, 800, 800, 800, 800, 800, 800,  800, 800, 800, 800, 800, 800, 800, 800, 800, 800,  800, 800, 800, 800, 800, 800, 800, 800, 800, 800,  800, 800, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000, 4000” |
| qnxadas-junction-approach  qnxadas-junction-exit  qnxadas-motorway-join  qnxadas-navigating-bends | “360, 360, 360, 360, 360, 360, 360, 360, 360, 360, 360, 360,  360, 360, 360, 360” |

### Parameters for sequences acquired with non-spinning LiDAR sensor

For Category 3 Am. Frame class, for sequences acquired with non-spinning LiDAR sensor, the following parameters define the codec configuration:

* angularEnabled=0.

## Parameters with random access (RA), and with Category 3 Am. Frame class

With random access (RA), and with Category 3 Am. Frame class, the motionVectorPath parameter is set according to the following table.

|  |  |
| --- | --- |
| Test material filename | motionVectorPath |
| Ford\_01\_q\_1mm | ford\_01\_q1mm-global-motion-matrix-estimated.txt |
| Ford\_02\_q\_1mm | ford\_02\_q1mm-global-motion-matrix-estimated.txt |
| Ford\_03\_q\_1mm | ford\_03\_q1mm-global-motion-matrix-estimated.txt |
| qnxadas-junction-approach | qnxadas-junction-approach-global-motion-matrix-estimated.txt |
| qnxadas-junction-exit | qnxadas-junction-exit-global-motion-matrix-estimated.txt |
| qnxadas-motorway-join | qnxadas-motorway-join-global-motion-matrix-estimated.txt |
| qnxadas-navigating-bends | qnxadas-navigating-bends-global-motion-matrix-estimated.txt |
| InnovizQC1 | gps-innovizqc1-matrix.txt |
| InnovizQC2 | gps-innovizqc2-matrix.txt |
| InnovizQC3 | gps-innovizqc3-matrix.txt |

## Parameters for octree geometry coding evaluation

The following parameters define the codec configuration to be used in evaluation of octree geometry.

* geomTreeType=0.
* mergeDuplicatedPoints=1 for lossy geometry conditions.
* mergeDuplicatedPoints=0 for lossless geometry conditions.

### Category 3 Am. frame-based content

The following parameters define the codec configuration to be used in evaluation of octree geometry with Category 3 Am. frame-based content.

* inferredDirectCodingMode=3
* maxNumQtBtBeforeOt=6
* planarModeIdcmUse=0
* individual frames of sequences acquired with spinning LiDAR sensor shall be coded using sequence bounding box parameters seqOrigin and seqSizeWhd set according to the following table:

|  |  |  |
| --- | --- | --- |
| Test material filename | seqOrigin | seqSizeWhd |
| Ford\_01\_q\_1mm  Ford\_02\_q\_1mm  Ford\_03\_q\_1mm | “−131072, −131072, −131072” | “262143, 262143, 262143” |
| qnxadas-junction-approach  qnxadas-junction-exit  qnxadas-motorway-join  qnxadas-navigating-bends | “-32768, -32768, -32768” | “65535, 65535, 65535” |

### Lossless geometry (Conditions C1, CW, CY)

The positionQuantizationScale parameter is set to 1.

### Near-lossless geometry (Condition C2)

The positionQuantizationScale parameter is set according to the following table.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Geometry precision | R6 | R5 | R4 | R3 | R2 | R1 |
| >= 15 | 1/4 | 1/8 | 1/32 | 1/64 | 1/256 | 1/512 |
| 14 | 1/4 | 1/8 | 1/16 | 1/64 | 1/128 | 1/256 |
| 13 | 1/2 | 1/4 | 1/8 | 1/16 | 1/32 | 1/64 |
| 12 | 3/4 | 1/2 | 1/4 | 1/8 | 1/16 | 1/32 |
| 11 | 7/8 | 3/4 | 1/2 | 1/4 | 1/8 | 1/16 |
| 10 | 15/16 | 7/8 | 3/4 | 1/2 | 1/4 | 1/8 |

### Lossless & Lossy geometry (Conditions C1, C2, CW, CY), and random access (RA)

With random access (RA), parameter randomAccessPeriod is set to 32, and parameters interPredictionEnabled and globalMotionEnabled are set to 1.

For sequences belonging to Category 3 Am. Fused test class and acquired with non-spinning LiDAR sensor, the following parameters define the codec configuration to be used in evaluation of octree geometry with random access (RA):

* gmThresholdHistScale=10,
* gmThresholdMinZ=-250,
* gmThresholdMaxZ=250,
* gmThresholdLeftScale=0.2,
* gmThresholdRightScale=0.5,
* attrInterPredTranslationThresh=100.

## Parameters for predictive tree geometry coding evaluation

The parameters previously defined for octree coding and that may apply to predictive tree coding are set to same values unless otherwise specified in this sub-section. Together with the following parameters they define the codec configuration to be used in evaluation of predictive tree geometry.

* geomTreeType=1.

For sequences belonging to Category 3 Am. Fused test class, the parameter predGeomSort is set equal to 4 and predGeomAzimuthSortPrecision is set equal to 0.05. For the other sequences, predGeomSort is set equal to 0.

The parameter sortInputByAzimuth is set to 1 for sequences belonging to Category 3 Am. Frame test class, that are captured with spinning LIDAR, and to 0 for the other sequences.

For Category 3 Am. Frame class, for sequences acquired with non-spinning LiDAR sensor, the following parameters define the codec configuration:

* positionQuantisationEnabled=0
* positionBaseQp=0

### Lossless geometry (Conditions C1, CW, CY)

With Category 3 Am. Frame class, for sequences that are acquired with spinning LiDAR sensor, the positionAzimuthScaleLog2 parameter is set to 12, the attrSphericalMaxLog2 parameter is set to 17, and the positionAzimuthSpeed parameter is set according to the following table.

|  |  |
| --- | --- |
| Test material filename | positionAzimuthSpeed |
| Ford\_01\_q\_1mm | 4194 |
| Ford\_02\_q\_1mm | 4194 |
| Ford\_03\_q\_1mm | 4194 |
| qnxadas-junction-approach | 46604 |
| qnxadas-junction-exit | 46604 |
| qnxadas-motorway-join | 46604 |
| qnxadas-navigating-bends | 46604 |

### Lossy geometry (Condition C2)

With Category 3 Am. Frame class, for sequences that are acquired with spinning LiDAR sensor, the positionQuantisationEnabled parameter is set to 1, the positionBaseQp parameter is set to 58, the secondaryResidualDisabled parameter is set to 1, and the positionRadiusInvScaleLog2, positionAzimuthScaleLog2, attrSphericalMaxLog2 and positionAzimuthSpeed parameters are set according to the following tables.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Rate point | R6 | R5 | R4 | R3 | R2 | R1 |
| positionRadiusInvScaleLog2 | 1 | 2 | 4 | 5 | 7 | 8 |
| positionAzimuthScaleLog2 | 12 | 11 | 9 | 8 | 7 | 7 |
| attrSphericalMaxLog2 | 17 | 16 | 14 | 13 | 12 | 12 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Test material filename | positionAzimuthSpeed | | | | | |
|  | R6 | R5 | R4 | R3 | R2 | R1 |
| Ford\_01\_q\_1mm | 4194 | 2097 | 524 | 262 | 131 | 131 |
| Ford\_02\_q\_1mm | 4194 | 2097 | 524 | 262 | 131 | 131 |
| Ford\_03\_q\_1mm | 4194 | 2097 | 524 | 262 | 131 | 131 |
| qnxadas-junction-approach | 46604 | 23302 | 5826 | 2913 | 1456 | 1456 |
| qnxadas-junction-exit | 46604 | 23302 | 5826 | 2913 | 1456 | 1456 |
| qnxadas-motorway-join | 46604 | 23302 | 5826 | 2913 | 1456 | 1456 |
| qnxadas-navigating-bends | 46604 | 23302 | 5826 | 2913 | 1456 | 1456 |

### Lossless geometry (Conditions C1, CW, CY) and random access (RA)

With random access (RA), the same parameter values as for all intra (AI) are used unless otherwise specified below.

With Category 3 Am. Frame class, for sequences that are acquired with spinning LiDAR sensor, the interAzimScaleLog2 parameter is set according to the following table.

|  |  |
| --- | --- |
| Test material filename | interAzimScaleLog2 |
| Ford\_01\_q\_1mm | 11 |
| Ford\_02\_q\_1mm | 11 |
| Ford\_03\_q\_1mm | 11 |
| qnxadas-junction-approach | 15 |
| qnxadas-junction-exit | 15 |
| qnxadas-motorway-join | 15 |
| qnxadas-navigating-bends | 15 |

### Lossy geometry (Condition C2) and random access (RA)

With random access (RA), the same parameter values as for all intra (AI) are used unless otherwise specified below.

With Category 3 Am. Frame class, for sequences that are acquired with spinning LiDAR sensor, the interAzimScaleLog2 parameter is set according to the following table.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Test material filename | interAzimScaleLog2 | | | | | |
|  | R6 | R5 | R4 | R3 | R2 | R1 |
| Ford\_01\_q\_1mm | 11 | 10 | 8 | 7 | 6 | 6 |
| Ford\_02\_q\_1mm | 11 | 10 | 8 | 7 | 6 | 6 |
| Ford\_03\_q\_1mm | 11 | 10 | 8 | 7 | 6 | 6 |
| qnxadas-junction-approach | 15 | 14 | 12 | 11 | 10 | 10 |
| qnxadas-junction-exit | 15 | 14 | 12 | 11 | 10 | 10 |
| qnxadas-motorway-join | 15 | 14 | 12 | 11 | 10 | 10 |
| qnxadas-navigating-bends | 15 | 14 | 12 | 11 | 10 | 10 |

### Lossless & Lossy geometry (Conditions C1, C2, CW, CY), and random access (RA)

With random access (RA), and with Category 3 Am. Frame class, for sequence that are acquired with spinning LIDAR sensor, the resamplingEnabled parameter is set to 0.

## Parameters for trisoup geometry coding evaluation

The following parameters define the codec configuration to be used in evaluation of Trisoup geometry.

* trisoupQuantizationBits=2
* trisoupFineRayTracingEnabled=1
* trisoupImprovedEncoderEnabled=1
* inferredDirectCodingMode=0
* sliceMaxPointsTrisoup=1100000
* sliceMaxPoints=900000
* sliceMinPoints=449000

### Lossy geometry (Condition C2)

For all sequences the 4 rate points R4, R3, R2 and R1 shall be evaluated.

The trisoupHaloEnabled is set equal to 1 by default, but is set equal to 0 with ‘ULB\_Unicorn\_vox13’ and ‘ULB\_Unicorn\_vox20’ sequences.

The positionQuantizationScale parameter is set according to the following table. For a given test sequence, the same value is used for all rate points.

|  |  |  |
| --- | --- | --- |
| Test material filename | testDepth | positionQuantizationScale |
| Arco\_Valentino\_Dense\_vox12 | 9 | 1/8 |
| Arco\_Valentino\_Dense\_vox20 | 9 | 1/2048 |
| basketball\_player\_vox11\_00000200 | 11 | 1 |
| boxer\_viewdep\_vox12 | 11 | 1/2 |
| dancer\_vox11\_00000001 | 11 | 1 |
| Egyptian\_mask\_vox12 | 9 | 1/8 |
| Egyptian\_mask\_vox20 | 9 | 1/2048 |
| Facade\_00009\_vox12 | 11 | 1/2 |
| Facade\_00009\_vox20 | 11 | 1/512 |
| Facade\_00015\_vox14 | 12 | 1/4 |
| Facade\_00015\_vox20 | 12 | 1/256 |
| Facade\_00064\_vox11 | 11 | 1 |
| Facade\_00064\_vox14 | 12 | 1/4 |
| Facade\_00064\_vox20 | 12 | 1/256 |
| Frog\_00067\_vox12 | 11 | 1/2 |
| Frog\_00067\_vox20 | 11 | 1/512 |
| Head\_00039\_vox12 | 12 | 1 |
| Head\_00039\_vox20 | 12 | 1/256 |
| House\_without\_roof\_00057\_vox12 | 11 | 1/2 |
| House\_without\_roof\_00057\_vox20 | 11 | 1/512 |
| Landscape\_00014\_vox14 | 12 | 1/4 |
| Landscape\_00014\_vox20 | 12 | 1/256 |
| longdress\_viewdep\_vox12 | 11 | 1/2 |
| Longdress\_vox10\_1300 | 10 | 1 |
| loot\_viewdep\_vox12 | 11 | 1/2 |
| Loot\_vox10\_1200 | 10 | 1 |
| Palazzo\_Carignano\_Dense\_vox14 | 9 | 1/32 |
| Palazzo\_Carignano\_Dense\_vox20 | 9 | 1/2048 |
| Queen\_0200 | 10 | 1 |
| redandblack\_viewdep\_vox12 | 11 | 1/2 |
| Redandblack\_vox10\_1550 | 10 | 1 |
| Shiva\_00035\_vox12 | 10 | 1/4 |
| Shiva\_00035\_vox20 | 10 | 1/1024 |
| soldier\_viewdep\_vox12 | 11 | 1/2 |
| Soldier\_vox10\_0690 | 10 | 1 |
| Stanford\_Area\_2\_vox16 | 12 | 1/16 |
| Stanford\_Area\_2\_vox20 | 12 | 1/256 |
| Stanford\_Area\_4\_vox16 | 12 | 1/16 |
| Stanford\_Area\_4\_vox20 | 12 | 1/256 |
| Statue\_Klimt\_vox12 | 9 | 1/8 |
| Statue\_Klimt\_vox20 | 9 | 1/2048 |
| Thaidancer\_viewdep\_vox12 | 11 | 1/2 |
| ULB\_Unicorn\_HiRes\_vox15 | 12 | 1/8 |
| ULB\_Unicorn\_HiRes\_vox20 | 12 | 1/256 |
| ULB\_Unicorn\_vox13 | 11 | 1/4 |
| ULB\_Unicorn\_vox20 | 11 | 1/512 |

The trisoupNodeSizeLog2 parameter is set equal to commonTrisoupNodeSizeLog2 + trisoupNodeSizeLog2Offset. The value commonTrisoupNodeSizeLog2 and the trisoupCentroidResidualEnabled parameter are set according to the following table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Rate point | R4 | R3 | R2 | R1 |
| commonTrisoupNodeSizeLog2 | 2 | 3 | 4 | 5 |
| trisoupCentroidResidualEnabled | 0 | 1 | 1 | 1 |

The value trisoupNodeSizeLog2Offset is set according to the following table, or it is set to 0 for sequences not present in the table.

|  |  |
| --- | --- |
| Test material filename | trisoupNodeSizeLog2Offset |
| Facade\_00009\_vox12 | 1 |
| Facade\_00009\_vox20 | 1 |
| Frog\_00067\_vox12 | 1 |
| Frog\_00067\_vox20 | 1 |
| Head\_00039\_vox12 | 1 |
| Head\_00039\_vox20 | 1 |
| House\_without\_roof\_00057\_vox12 | 1 |
| House\_without\_roof\_00057\_vox20 | 1 |
| Shiva\_00035\_vox12 | 1 |
| Shiva\_00035\_vox20 | 1 |
| ULB\_Unicorn\_vox13 | 2 |
| ULB\_Unicorn\_vox20 | 2 |

## Parameters for RAHT, Predicting Transform, and Lifting Transform attribute coding evaluation

The following parameters define the codec configurations to be used in evaluation of RAHT, Predicting Transform, and Lifting Transform attribute coding:

* transformType=0 for RAHT coding,
* transformType=1 for Predicting Transform coding (used for lossless/near-lossless attributes coding),
* transformType=2 for Lifting Transform coding (used for lossy attributes coding).

With Category 3 Am. Frame class, for sequences that are acquired with spinning LiDAR sensor, the spherical\_coord\_flag parameter is set equal to 1.

When predicting transform coding or lifting transform coding is used for lossly (C1, C2) or lossless (CW) attributes coding with octree or predictive tree geometry coding, the lodDecimator parameter is set equal to 1 with sequences of Category 3 Am. Frame, and it is set equal to 2 with sequences of Category 3 Am. Fused.

When predicting transform coding or lifting transform coding is used for lossly (C1, C2) or lossless (CW) attributes coding, the lod\_neigh\_bias parameter is set equal to “1,1,2” with sequences of Category 3 Am. Fused.

When lifting transform coding is used with trisoup geometry coding, the lod\_neigh\_bias parameter is set equal to “1,1,8” with sequences of Category 3 Am Frame.

When predicting transform coding or lifting transform coding is used, unless otherwise specified, the levelOfDetailCount parameter is set equal to 12 for the evaluation on Category 1 sequences, and it is set equal to 10 for the evaluation on Category 3 sequences, at the exception of a subset of sequences for which is it set according to the following table:

|  |  |
| --- | --- |
| Test material filename | levelOfDetailCount |
| basketball\_player\_vox11\_00000200 | 11 |
| dancer\_vox11\_00000001 | 11 |
| Egyptian\_mask\_vox12 | 11 |
| Facade\_00015\_vox14 | 14 |
| Facade\_00064\_vox11 | 13 |
| Frog\_00067\_vox12 | 13 |
| Head\_00039\_vox12 | 13 |
| House\_without\_roof\_00057\_vox12 | 13 |

With Category 3 sequences, when predicting transform coding is used for lossless (CW) or near-lossless (CY) attributes coding, the direct\_avg\_predictor\_disabled\_flag parameter is set equal to 1, and levelOfDetailCount parameter is set equal to 0.

With sequences of Category 3 Am. Frame, when lifting transform coding is used for lossy attributes coding (C1, C2), the levelOfDetailCount parameter is set equal to 8 for rate point R1 and to 9 for rate point R2.

### Conditions C1 (Lossless geometry, lossy attributes) and C2 (Lossy geometry, lossy attributes)

*R'G'B'* attributes shall be coded in the ITU-R BT.709 (*Y′CbCr*) colour space (colourMatrix=1) with input/output conversion enabled (convertPlyColourspace=1).

The quantization parameter, qp, shall be set according to the following table for each rate point.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Rate point | R6 | R5 | R4 | R3 | R2 | R1 |
| qp | 22 | 28 | 34 | 40 | 46 | 51 |
| qp (trisoup) |  |  | 22 | 28 | 34 | 40 |

Offset shall be applied to the chroma quantization parameter depending on attribute coding method and conditions:

* qpChromaOffset=0 for Lifting transform,
* qpChromaOffset=-1 for RAHT with conditions C1,
* qpChromaOffset=-2 for RAHT with conditions C2.

### Conditions CW (Lossless geometry, lossless attributes)

The attribute coding in condition CW is only applicable to transforms that provide perfect reconstruction, such as the predicting level of detail transform.

The quantization parameter, qp, shall be set equat to 4.

*R′G′B′* attributes shall be coded in the *Y′CgCoR* colour space (colourMatrix=8) with input/output conversion enabled (convertPlyColourspace=1).

### Conditions CY (Lossless geometry, near-lossless attributes)

Condition CY is applicable only to transforms that support bounded reconstruction errors, such as the predicting level of detail transform.

*R′G′B′* attributes shall be coded without colour space conversion (colourMatrix=0).

The quantization parameter, qp, shall be set according to the following table for each rate point:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Rate point | R5 | R4 | R3 | R2 | R1 |
| qp | 34 | 28 | 22 | 16 | 10 |

No offset shall be applied to the chroma quantization parameter (qpChromaOffset=0).

# Common test conditions for GeS-TM

This sub-section will be continuously updated as more detailed information is made available.

## Software – GeS-TM

The common software used for GeS-TMC 13 experiments is available from the MPEG GitLab:

<http://mpegx.int-evry.fr/software/MPEG/PCC/TM/mpeg-pcc-ges-tm.git>

Software documentation and usage are described in [5].

## Output format

Decoded point clouds shall be output, and distortion measured using a binary PLY format.

## Coding parameters

The coding parameters for each test point are available in the /cfg directory of the provided software.

In the current state of the GeS-TM, the coding parameters specific to random access (RA) coding are available in /cfg/inter directory, and random access is only supported with sequences belonging to Category 2.

When coding multi-frame sequences in an all intra configuration (AI), all parameter sets must be repeated at the start of each frame. When coding multi-frame sequences in a random access configuration, all parameter sets must also be repeated at the start of each frame.

GeS-TM contains distinct and mutually exclusive tools with overlapping functionality for geometry and attribute coding. The following sections describe the configuration of each tool when used in a particular condition. An experiment evaluating a codec modification should choose an appropriate set of tools, using the corresponding set as reference.

GeS-TM evaluation shall be limited to Category 2 sequences and to a subset of test conditions which is provided in the following table.

|  |  |  |  |
| --- | --- | --- | --- |
| Condition | Test condition | AI | RA |
| C1 | Lossless Geometry – Lossy attributes | ✓ | ✓ |
| C2 | Near-lossless | Lossy Geometry – Lossy Attributes | ✓ | ✓ |
| CW | Lossless Geometry – Lossless Attributes |  |  |
| CY | Lossless Geometry – Near-lossless Attributes |  |  |

## Parameters for octree or trisoup geometry coding evaluation

The following parameters define the codec configuration to be used for evaluating octree or trisoup geometry coding.

The parameter planarEnabled is always set to 0.

The parameter inferredDirectCodingMode is always set to 0.

The parameter qtbtEnabled is always set to 0.

## Parameters for octree geometry coding evaluation

The following parameters define the codec configuration to be used in evaluation of octree geometry.

* geomTreeType=0.
* mergeDuplicatedPoints=1 for lossy geometry conditions.
* mergeDuplicatedPoints=0 for lossless geometry conditions.

### Lossless geometry (Conditions C1)

The positionQuantizationScale parameter is set to 1.

### Near-lossless geometry (Condition C2)

The positionQuantizationScale parameter is set according to the following table.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Geometry precision | R6 | R5 | R4 | R3 | R2 | R1 |
| >= 15 | 1/4 | 1/8 | 1/32 | 1/64 | 1/256 | 1/512 |
| 14 | 1/4 | 1/8 | 1/16 | 1/64 | 1/128 | 1/256 |
| 13 | 1/2 | 1/4 | 1/8 | 1/16 | 1/32 | 1/64 |
| 12 | 3/4 | 1/2 | 1/4 | 1/8 | 1/16 | 1/32 |
| 11 | 7/8 | 3/4 | 1/2 | 1/4 | 1/8 | 1/16 |
| 10 | 15/16 | 7/8 | 3/4 | 1/2 | 1/4 | 1/8 |

### Lossless & Lossy geometry (Conditions C1, C2), and random access (RA)

With random access (RA), parameter randomAccessPeriod is set to 32, and parameters interPredictionEnabled and globalMotionEnabled are set to 1.

## Parameters for trisoup geometry coding evaluation

The following parameters define the codec configuration to be used in evaluation of Trisoup geometry.

* trisoupQuantizationBits=2
* trisoupFineRayTracingEnabled=1
* trisoupImprovedEncoderEnabled=1
* safeTrisoupPartitionning=0
* sliceMaxPointsTrisoup=5000000
* sliceMaxPoints=4000000
* sliceMinPoints=2000000

### Lossy geometry (Condition C2)

For all sequences the 4 rate points R4, R3, R2 and R1 shall be evaluated.

The trisoupHaloEnabled is set equal to 1 by default, but is set equal to 0 with ‘ULB\_Unicorn\_vox13’ and ‘ULB\_Unicorn\_vox20’ sequences.

The positionQuantizationScale parameter is set according to the following table. For a given test sequence, the same value is used for all rate points.

|  |  |  |
| --- | --- | --- |
| Test material filename | testDepth | positionQuantizationScale |
| 8i VFB – Long\_dress | 10 | 1 |
| 8i VFB – Loot | 10 | 1 |
| 8i VFB – Red\_and\_Black | 10 | 1 |
| 8i VFB – Soldier | 10 | 1 |
| basketball\_player\_vox11 | 11 | 1 |
| dancer\_vox11 | 11 | 1 |
| Queen n | 10 | 1 |

The trisoupNodeSizeLog2 and trisoupCentroidResidualEnabled parameters are set according to the following table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Rate point | R4 | R3 | R2 | R1 |
| trisoupNodeSizeLog2 | 2 | 3 | 4 | 5 |
| trisoupCentroidResidualEnabled | 0 | 1 | 1 | 1 |

## Parameters for attributes coding

Attributes coding evaluation of GeS-TM shall be limited to RAHT attributes coding.

The same parameters as TMC13 for RAHT shall be used for GeS-TM attribute coding evaluation.

# References

1. Requirements, “Call for Proposals for Point Cloud Coding V2,” ISO/IEC JTC1/SC29/WG11, 118th MPEG meeting, Hobart, AU, Tech. Rep. N16763, Apr. 2017.
2. 3DG, “PCC Requirements,” ISO/IEC JTC1/SC29/WG11, 121st MPEG meeting, Gwangju, KOR, Tech. Rep. N17353, Jan. 2018.
3. “G-PCC performance evaluation and anchor results,” ISO/IEC JTC1/SC29/WG7, 140th MPEG meeting, Mainz, Tech. Rep. N00421, October 2022.
4. “G-PCC Test Model v21,” ISO/IEC JTC1/SC29/WG7, 141th MPEG meeting, Online, Tech. Rep. N00502, Jan. 2023.
5. “Test model for geometry-based solid point cloud – GsS TM 1.0”, ISO/IEC JTC1/SC29/WG7, 141th MPEG meeting, Online, Tech. Rep. N00558, Jan. 2023.

# Objective Evaluation Metrics & Usage of Metric Software

## A.1 Geometric Distortions

Let and denote the original and the compressed point cloud, respectively. Consider evaluating the compression errors, denoted as in point cloud relative to reference point cloud. The steps to compute both point-to-point error (D1) and point-to-plane error (D2) for geometric errors are summarized in the following and illustrated in the below figure.

For each point in point cloud, *i.e.*, the black point in the figure, identify a corresponding point in point cloud, *i.e.*, the red point in the figure. Nearest neighbour is used to locate the corresponding point. In particular, a KD-tree search is used to perform the nearest neighbour search in order to reduce the computation complexity.

### A.1.1 Computing D1

Determine an error vector by connecting the identified point in reference point cloud  to point in point cloud . The length of the error vector is the point-to-point error, *i.e.*,

|  |  |  |
| --- | --- | --- |
|  |  | (A-1) |

Based on the point-to-point distances for all points , the point-to-point error (D1) for the whole point cloud, withas the number of points in point cloud, is defined as:

|  |  |  |
| --- | --- | --- |
|  |  | (A-2) |

For near-lossless geometry encoding, the maximum point-to-point error, denoted , should be considered instead:

|  |  |  |
| --- | --- | --- |
|  |  | (A-3) |

### A.1.2 Computing D2

Project the error vector along the normal direction and get a new error vector. In this way, the point-to-plane error is computed as,

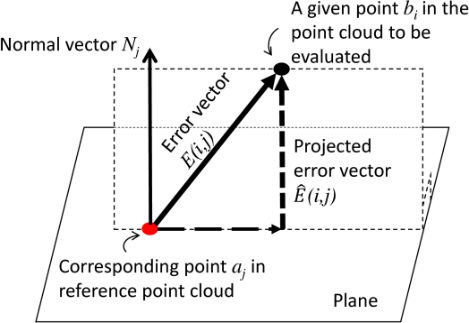
|  |  |  |
| --- | --- | --- |
|  | . | (A-4) |

The point-to-plane error (D2) for the whole point cloud is then defined as,

|  |  |  |
| --- | --- | --- |
|  |  | (A-5) |

For near-lossless geometry encoding, the maximum plane-to-plane error, denoted , should be considered instead:

|  |  |  |
| --- | --- | --- |
|  | . | (A-6) |

  
Figure – Illustration of point-to-point distance (D1) and point-to-plane distance (D2)

### A.1.3 PSNR Calculation

For reporting distortion values, the PSNR is defined as the peak signal over the symmetric distortion, i.e. for geometry distortions D1 or D2 computed as:

|  |  |  |
| --- | --- | --- |
|  |  | (A-7) |

where is the peak constant value defined for each reference point cloud as specified in Table 2, and is the mean squared point-to-point (D1) or point-to-plane (D2) error. For dynamic content, the peak value is unchanged over the frames of a sequence.

Note that the metric software dynamically determines the intrinsic resolution and uses it as normalizer if it is not specified in the command line (option -r).

## A.2 Attribute Distortions

For lossy attribute coding, the attribute PSNR value is computed as:

|  |  |  |
| --- | --- | --- |
|  |  | (A-8) |

For colour attributes, the MSE for each of the three colour components is calculated. A conversion from RGB space to ITU-R BT.709, since *Y′CbCr* spaces correlate better with human perception. A symmetric computation of the distortion is utilized, in the same way as is done for geometric distortions. The maximum distortion between the two passes is selected as the final distortion. Since the colour attributes for all test data have a bit depth of 8 bits per point, the peak value p for PSNR calculation is 255.

For reflectance attributes, the MSE for a single component is calculated. Since the reflectance attribute for all test data has a bit depth of 16 bits per point, the peak value p for PSNR calculation is 65535.

For near-lossless coding, the maximum error should be considered instead of MSE

## A.3 Metric Software Usage

This is the specified command line to recreate the objective distortion metrics for any lossless or lossy test condition response based on this CTC:

./pc\_error --fileA=pointcloudOrg.ply --fileB=pointcloudDec.ply \

--inputNorm=normalOrg.ply --resolution=<peak value> \

--color=1 --neighborsProc=1 --dropdups=2 --averageNormals=0

For conditions 3.Y and 3.Z (near-lossless), the modified command line is:

./pc\_error --fileA=pointcloudOrg.ply --fileB=pointcloudDec.ply \

--inputNorm=normalOrg.ply --resolution=<peak value> \

--color=1 --neighborsProc=1 --dropdups=2 --averageNormals=0 -h

These command lines will produce D1, D2 as well as color and reflectance distortion metrics, using an imported intrinsic resolution for PSNR computation rather than an internally determined intrinsic resolution. The option --dropdups=2 indicates that duplicate points are averaged and reports the number of points with the same coordinates. The option --neighborsProc=1 indicates, for the color metrics, that neighbouring points at the same minimum distance are averaged using equal weights. The option -h indicates the use of the maximum error (Hausdorff distance).

Further example command lines to use the evaluation metric tool are provided below.

./pc\_error --fileA=pointcloud1.ply

This will load the point cloud and report nearest neighbour distances – the intrinsic resolution to be used for PSNR computation.

./pc\_error --fileA=pointcloudOrg.ply --fileB=pointcloudDec.ply

This will produce D1.

./pc\_error --fileA=pointcloudOrg.ply --fileB=pointcloudDec.ply \

--inputNorm=normalOrg.ply

This will produce both D1 and D2. The normal is provided in normalOrg.ply for the original point cloud. It could be the same as pointcloudOrg.ply.

./pc\_error --fileA=pointcloudOrg.ply --fileB=pointcloudDec.ply \

--inputNorm=normalOrg.ply --color=1

This will produce D1, D2, as well as the color distortion metric.

./pc\_error --fileA=pointcloudOrg.ply --fileB=pointcloudDec.ply \

--inputNorm=normalOrg.ply --color=1 --resolution=<peak value>

This will produce D1, D2 as well as color distortion metric, using an imported peak value for PSNR computation rather than an internally determined peak value.