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# Introduction

While so far the most common way of representing the visual component of the world has been to take the output of a camera, compress it for transmission and storage using one of the MPEG video coding standards and eventually decode it and present it on 2D displays, there are now more and more devices that capture and present 3D representations of the world.

A point cloud is defined as a multi-set of points where a point is described by its 3D position with (x,y,z) coordinates(e.g., where x, y, and z have finite (or fixed) precision and dynamic range) and (optionally) a set of scalar/vector attributes. Typically, each point in a cloud has the same number of attributes attached to it. Point clouds can be used to reconstruct an object or a scene as a composition of such points. Point clouds can be captured using multiple cameras and depth sensors in various setups and may be made up of thousands up to billions of points in order to represent realistically reconstructed scenes.

As compression technologies are needed to reduce the amount of data required to represent a point cloud, MPEG is developing a Point Cloud Compression standard targeting for use in real-time communications, applications such as GIS, CAD, and cultural heritage. Given the above applications, MPEG has identified three categories of PCC: static point cloud compression (Category 1), dynamic point cloud compression (Category 2), and dynamically acquired/fused point cloud compression (Category 3).

# Note

*In reading this document, the reader is advised to take an attention to the usage of the words: ‘shall’ and ‘should’. Whenever used, the term ‘shall’ indicates that it is a mandatory statement. Whenever used, the term ‘should’ indicates that it is not mandatory, but desirable.*

# Requirements for Point Cloud Compression

This document presents the requirements for MPEG Point Cloud Compression. The requirements capture the use cases defined for PCC in MPEG [1], but are not limited to these use cases only.

## 3D Point Cloud Representation

Requirement

MPEG PCC shall provide means for encoding and decoding 3D point clouds.

Specification

The 3D point cloud representation shall support:

1. 3D positions: the (X, Y, Z) coordinates with a specification of its precision and dynamic range.
2. Pre-defined attributes: the attributes associated with each 3D position including colour, reflectance, normal vectors and transparency.
3. Generic (i.e., user-defined) attributes per 3D position
4. View-dependent attributes per 3D position
5. Time-varying point clouds: point clouds captured or represented with timed information.

## 3D Point Cloud Compression

Requirement

MPEG PCC shall provide means for efficient compression for storage, streaming or downloading of 3D point clouds. The compression shall encompass lossless, near-lossless and lossy.

Specification

MPEG PCC shall support:

1. Lossy compression: parameter control of the bitrate shall be supported.
2. Lossless geometry compression: the reconstructed position shall be mathematically identical to the original. The number of points reconstructed from the compressed point cloud is the same as the original. The reordering of points during compression is permissible.
3. Lossless attribute compression: the reconstructed attributes shall be mathematically identical to the original. The number of points reconstructed from the compressed point cloud is the same as the original. The reordering of points during compression is permissible.
4. Near-lossless geometry compression: The number of points after compression remains the same as the original, but the point locations after compression may not be mathematically identical, but the error between the original and compressed points is always less than the given error margin.
5. Near-lossless attribute compression: The number of points after compression remains the same as the original, but the point attributes after compression may not be mathematically identical, but the error between the original and compressed attributes is always less than the given error margin.
6. Temporal variations (e.g., dependency among temporal frames) of point clouds shall be supported.
7. Low latency: Encode plus decode as low as one point cloud frame duration shall be supported. For some applications, an even lower latency should be supported.
8. Low complexity: The complexity shall allow for feasible implementation of encoding and decoding within the constraints of the available technology at the expected time of usage.
9. Temporal scalability: The dependency of frames shall be structured such that some frames can be dropped from the bitstream.
10. Spatial scalability: The compressed bitstream shall be structured with more than one layer to decode the points of the current layer predicted from the points from the lower layer(s) which provides a coarse approximation (i.e., a lower number of points) of the entire point cloud.
11. Region-based spatial scalability: The compressed bitstream shall be structured with more than one layer such that certain regions of interest may have a higher density with additional layers; where the layers may be predicted from the lower layer(s).
12. Quality scalability: A point cloud shall be coded at a single spatial resolution but at different qualities (or bit depths). The data and decoded samples of lower qualities may be used to predict data or samples of higher qualities to reduce the bit rate to code the higher qualities.
13. Spatial random access: it shall be possible to decode the point-cloud corresponding to a region without having to decode the entire bitstream.
14. Temporal random access shall be possible.
15. Error resilience: it shall be possible to cope with packet loss without having to retransmit the entire point cloud.
16. Parallel encoding and decoding: The design should support parallel processing implementation with low cost in terms of bitrate overhead.

# Annex – Supported PCC Requirements per Category

As of the 121st meeting, MPEG PCC supports the requirements in the following subsections. All the requirements except for ‘not-applicable’ cases are expected to be supported during the PCC standardization.

## Point cloud representation requirements per category

Table 1 summarizes the currently supported point cloud representation requirements specified in Section 3.1, per category.

Table 1 – Current status of supported requirements of Point Cloud Representation per Category

|  |  |  |  |
| --- | --- | --- | --- |
| Requirements | Category 1 | Category 2 | Category 3 |
| a) 3D positions | 🗸 | 🗸 | 🗸 |
| b) Pre-defined attributes | 🗸 (colors) | 🗸 (colors) | 🗸  (colors, reflectance) |
| c) Generic attributes | 🗴 | 🗴 | 🗴 |
| d) View-dependent attributes | 🗴 | 🗴 | 🗴 |
| e) Time-varying | - | 🗸 | 🗴 |

(‘🗸’ = Supported, ‘🗴’ = Not supported yet, ‘-’ = Not applicable)

## Point cloud compression requirements per category

Table 2 summarizes the currently supported point cloud compression requirements, specified in Section 3.2, per category.

Table 2 – Current status of supported requirements of Point Cloud Compression per Category

|  |  |  |  |
| --- | --- | --- | --- |
| Requirements | Category 1 | Category 2 | Category 3 |
| a) Lossy compression | 🗸 | 🗸 | 🗸 |
| b) Lossless geometry compression | 🗸 | 🗸 | 🗸 |
| c) Lossless attribute compression | 🗴 | 🗸 | 🗸 |
| d) Near-lossless geometry compression | 🗸 | 🗸 | 🗸 |
| e) Near-lossless attribute compression | 🗴 | 🗸 | 🗸 |
| f) Temporal variations | - | 🗸 | 🗸 |
| g) Low latency | 🗸 | 🗸 | 🗸 |
| h) Low complexity | 🗸 | 🗸 | 🗸 |
| i) Temporal scalability | - | 🗸 | 🗸 |
| j) Spatial scalability | 🗴 | 🗴 | 🗴 |
| k) Region-based scalability | 🗴 | 🗴 | 🗴 |
| l) Quality scalability | 🗴 | 🗴 | 🗴 |
| m) Spatial random access | 🗴 | 🗴 | 🗴 |
| n) Temporal random access | - | 🗸 | 🗴 |
| o) Error resilience | 🗴 | 🗸 | 🗴 |
| p) Parallel encoding and decoding | 🗴 | 🗴 | 🗴 |

(‘🗸’ = Supported, ‘🗴’ = Not supported yet, ‘-’ = Not applicable)

# References

[1] n16331 Use Cases for Point Cloud Compression ISO/JCT SC29 WG11 Geneva June 2016