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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html. In the IEC, see www.iec.ch/understanding-standards.

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A list of all parts in the ISO/IEC 23090 series can be found on the ISO and IEC websites.

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Introduction

Advancements in 3D capturing and rendering technologies are enabling new applications and services in the fields of assisted and autonomous driving, cartography, cultural heritage, industrial processes, immersive real-time communication, and virtual/augmented/mixed reality (VR/AR/MR) content creation, transmission and communication. Point clouds have arisen as one of the main representations for such applications. A point cloud frame consists of a set of 3D points. Every point, in addition to having a 3D position, may also be associated with numerous other attributes such as colour, transparency, reflectance, timestamp, surface normal and classification. Such representations require a large amount of data, which can be costly in terms of storage and transmission. This document provides the method for efficiently compressing point cloud representations.

The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) draw attention to the fact that it is claimed that compliance with this document may involve the use of a patent.

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Information technology — Coded representation of immersive media —

Part 9:
Geometry-based point cloud compression

1 Scope

This document specifies geometry-based point cloud compression.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

RECOMMENDATION ITU-T , T.35, Procedure for the allocation of ITU-T defined codes for non-standard facilities

Rec. ITU-T X.690 | ISO/IEC 8825-1, *Information technology — ASN.1 encoding rules — Part 1: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)*

Rec. ITU-T X.660 | ISO/IEC 9834-1, *Information technology — Procedures for the operation of object identifier registration authorities: General procedures and top arcs of the international object identifier tree — Part 1:*

Rec. ITU-T X.667 | ISO/IEC 9834-8, *Information technology — Procedures for the operation of object identifier registration authorities — Part 8: Generation of universally unique identifiers (UUIDs) and their use in object identifiers*

ISO/IEC 23091-2, *Information technology — Coding-independent code points — Part 2: Video*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 General terms

3.1.1
point
fundamental element of a *point cloud* (3.1.2) comprising a position specified as *Cartesian coordinates* (3.1.8) and zero or more *attributes* (3.1.19)

3.1.2
point cloud
unordered list of *points* (3.1.1)

3.1.3
point cloud sequence
sequence of one or more *point clouds* (3.1.2)

3.1.4
point cloud frame
point cloud (3.1.2) in a *point cloud sequence* (3.1.3)

3.1.5
coded point cloud frame
coded representation of a *point cloud frame* (3.1.4)

3.1.6
canonical point order
order of *points* (3.1.1) decoded from a *slice* (3.1.21) according to the decoding processes

Note 1 to entry: The decoding processes are specified in Clause 9.

3.1.7
bounding box
axis-aligned cuboid defining a spatial region that bounds a set of *points* (3.1.1)

3.1.8
Cartesian coordinates
three scalar multiples of respective orthogonal *XYZ* (3.1.11) unit vectors with finite precision and bounds that specify a position relative to a fixed reference

3.1.9
angular coordinates
position specified as the radial distance ρ from the V axis, an azimuth angle φ in the S-T plane and an indexed elevation

3.1.10
attribute coordinates
STV (3.1.12) or scaled *RPI* (3.1.13) point coordinates used to code an *attribute* (3.1.19)

3.1.11
XYZ
XYZ axes
X, Y and Z axes, in that order, used to represent *Cartesian coordinates* (3.1.8)

3.1.12
STV
STV axes
S, T and V axes, in that order, that are a sequence-dependent permutation of the *XYZ axes* (3.1.11); used to represent the coded *geometry* (3.1.18)

3.1.13
RPI
RPI axes
R, P and I axes, in that order, used to represent *angular coordinates* (3.1.9)

3.1.14
sequence coordinate system
scaled and translated application-specific coordinate system that applies to an entire coded *point cloud sequence* (3.1.3) and in which all *points* (3.1.1) have non-negative fixed-point coordinates

3.1.15
coding coordinate system
scaled *sequence coordinate system* (3.1.14) that applies to an entire coded *point cloud sequence* (3.1.3) and in which all *points* (3.1.1) have non-negative integer coordinates

3.1.16
slice coordinate system
translated *coding coordinate system* (3.1.15) that applies to a single *slice* (3.1.21) and in which all *points* (3.1.1) in the slice have non-negative integer coordinates

3.1.17
beam
sampler of point positions using *angular coordinates* (3.1.9) by rays cast with a fixed elevation and from a point on and rotating around the V axis at the angular origin

3.1.18
geometry
point positions (3.4.1) associated with a set of *points* (3.1.1)

3.1.19
attribute
scalar or vector property associated with each *point* (3.1.1) in a *point cloud* (3.1.2)

EXAMPLE Colour, reflectance, frame index.

3.1.20
position
<bit> bit in a binary string or value, representing the factor 2^{position}

EXAMPLE The LSB has bit position 0.

3.1.21
slice
geometry (3.1.18) and *attributes* (3.1.19) for part of, or an entire, *coded point cloud frame* (3.1.5)

Note 1 to entry: the *bounding boxes* (3.1.7) of any two slices can intersect.

3.1.22
tile
set of *slices* (3.1.21) identified by a common slice_tag *syntax element* (3.2.16) value whose *geometry* (3.1.18) should be contained within a *bounding box* (3.1.7) specified in a tile inventory *data unit* (3.2.13)

3.1.23
Morton code
non-negative integer obtained by interleaving the bits of three integers

3.1.24
Morton order
order of elements according to their *Morton code* (3.1.23)

3.1.25
sparse array
array with fewer set elements than total addressable elements

Note 1 to entry: Unset elements can have an inferred value when accessed.

3.2 Terms related to high-level syntax and entropy coding

3.2.1
ASN.1
abstract syntax notation one
notation specified by Rec. ITU-T X.680 | ISO/IEC 8824-1 that is used for the definition of data types, values and constraints on data types

3.2.2
bin
binary symbol (bit) of the *binarized* (3.2.3) representation of a *syntax element*'s (3.2.16) value

3.2.3
binarization
specification of a *syntax element*'s (3.2.16) value as a sequence of *bins* (3.2.2)

3.2.4
bypass
<contextual probability model> static, equiprobable probability model

3.2.5
bypass symbol
bypass-contextualized (3.2.4) *bin* (3.2.2)

3.2.6
bypass stream
sequence of *bypass symbols* (3.2.5) that are not encoded in an arithmetic-coded *bitstream* (3.2.7)

3.2.7
bitstream
<data> sequence of bits

3.2.8
bitstream
<coded sequence> sequence of bits, in the form of encapsulated *data units* (3.2.13), that represents a coded *point cloud sequence* (3.1.3)

3.2.9
set bit
bit with the value 1

3.2.10
unset bit
bit with the value 0

3.2.11
byte
sequence of 8 bits, typeset with the most significant bit on the left and the least significant bit on the right.

Note 1 to entry: When represented in a bitstream, the most significant bit of a byte is first.

3.2.12
byte aligned
bitstream (3.2.7) position that is an integer multiple of eight bits from the position of the first bit in the bitstream

3.2.13
data unit
DU
sequence of *bytes* (3.2.11) conveying a single *syntax structure* (3.2.17) of known length

3.2.14
data unit header
parameters, located from the start of a *data unit* (3.2.13)

3.2.15
data unit footer
parameters, located from the end of a *data unit* (3.2.13)

3.2.16
syntax element
element of data represented in the *bitstream* (3.2.7)

3.2.17
syntax structure
zero or more *syntax elements* (3.2.16) present together in the *bitstream* (3.2.7) in a specified order

3.2.18
parameter set
collection of parameters that apply when activated

3.2.19
sequence parameter set
SPS
parameters for an entire coded *point cloud sequence* (3.1.3), conveyed by an SPS *data unit* (3.2.13) and activated when referenced by a *geometry* (3.1.18) data unit

3.2.20
geometry parameter set
GPS
parameters for the coding of *slice* (3.1.21) *geometry* (3.1.18), conveyed by a GPS *data unit* (3.2.13) and activated when referenced by a geometry data unit

3.2.21
attribute parameter set
APS
parameters for the coding of a *slice* (3.1.21) *attribute* (3.1.19), conveyed by an APS *data unit* (3.2.13) and activated when referenced by an attribute data unit

3.2.22
object identifier
OID
<ASN.1> ordered list of primary integer values from the root of the *international object identifier tree* (3.2.23) to a node, which unambiguously identifies that node

[SOURCE: Rec. ITU-T X.660 | ISO/IEC 9834-1:2012, 3.5.11, modified — The abbreviated term "OID" and the domain "<ASN.1>" have been added.]

3.2.23
international object identifier tree
tree whose root corresponds to Rec. ITU-T X.660 | ISO/IEC 9834-1 and whose nodes correspond to *registration authorities* (3.2.25) responsible for allocating arcs from a *parent node* (3.3.10)

[SOURCE: Rec. ITU-T X.660 | ISO/IEC 9834-1:2012, 3.5.5]

3.2.24
registration
<object identifier> assignment of an unambiguous name to an object in a way which makes the assignment available to interested parties

[SOURCE: Rec. ITU-T X.660 | ISO/IEC 9834-1:2012, 3.5.16, modified — The domain "<object identifier>" has been added.]

3.2.25
registration authority
<international object identifier tree> entity such as an organization, a standard or an automated facility that performs *registration* (3.2.24) of one or more types of objects

[SOURCE: Rec. ITU-T X.660 | ISO/IEC 9834-1, 3.5.17, modified — The domain "<international object identifier tree>" has been added.]

3.2.26
application specific
defined by an application or an application standard

3.2.27
unspecified
having no specified meaning in this document and will not have a specified meaning in future editions of this document

Note 1 to entry: It is used to specify values of a particular *syntax element* (3.2.16).

3.3 Terms related to tree structure

3.3.1
tree
recursive structure of *nodes* (3.3.7) without loops and containing a single *root node* (3.3.5)

3.3.2
top
<tree> *tree level* (3.3.4) with a *depth* (3.3.8) of 0, consisting of the *root node* (3.3.5)

3.3.3
bottom
<tree> *tree level* (3.3.4) with the greatest *depth* (3.3.8)

3.3.4
tree level
set of *nodes* (3.3.7) at the same *depth* (3.3.8) in a *tree* (3.3.1)

3.3.5
root node
node (3.3.7) without a *parent node* (3.3.10)

3.3.6
leaf node
terminal *node* (3.3.7) without any *child nodes* (3.3.9)

3.3.7
node
element of a *tree* (3.3.1)

3.3.8
depth
<node> number of descendent hops from the *root node* (3.3.5) to a *node* (3.3.7)

3.3.9
child node
direct descendent of a *node* (3.3.7)

3.3.10
parent node
direct ancestor of a *node* (3.3.7)

3.3.11
grandparent node
direct ancestor of a *node*'s (3.3.7) *parent node* (3.3.10)

3.3.12
great-grandparent node
direct ancestor of a *node*'s (3.3.7) *grandparent node* (3.3.11)

3.3.13
sibling nodes
nodes (3.3.7) that are *child nodes* (3.3.9) of the same *parent node* (3.3.10)

3.3.14
subtree
part of a *tree* (3.3.1) comprising a *subtree root node* (3.3.15) and all its descendents over all subsequent *tree levels* (3.3.4)

3.3.15
subtree root node
single *node* (3.3.7) of a *subtree* (3.3.14) from which all other nodes in the same subtree are descendents

3.4 Terms related to geometry coding

3.4.1
position
<point> three-dimensional coordinates of a *point* (3.1.1)

3.4.2
occupancy tree
eight-ary *tree* (3.3.1) of *occupancy tree nodes* (3.4.4) representing the *geometry* (3.1.18) of a *slice* (3.1.21)

3.4.3
predictive tree
tree (3.3.1) of *predictive tree nodes* (3.4.5) representing the *geometry* (3.1.18) of a *slice* (3.1.21)

3.4.4
occupancy tree node
node (3.3.7) of an *occupancy tree* (3.4.2) representing a sub-volume of the 3D space (or volume) containing the *point cloud* (3.1.2)

3.4.5
predictive tree node
node (3.3.7) of a *predictive tree* (3.4.3) representing a single *position* (3.4.1) for one or more *points* (3.1.1)

3.4.6
direct node
terminal *occupancy tree node* (3.4.4) that codes one or more *point positions* (3.4.1)

3.4.7
occupancy bitmap
8-bit bitmap for an *occupancy tree node* (3.4.4) whose bits indicate the existence of *child nodes* (3.3.9) at particular locations in the next *tree level* (3.3.4)

3.4.8
occupied neighbourhood pattern
pattern that indicates the existence and arrangement of the six possible *occupancy tree nodes* (3.4.4) that share faces with a central node

3.5 Terms related to attribute coding

3.5.1
primary attribute component
first, or only, *attribute* (3.1.19) component, identified by the index 0

3.5.2
secondary attribute component
attribute (3.1.19) component other than the first component, identified by an index greater than 0