DRAFT International Standard

ISO/IEC DIS 23090-38

Information technology — Coded representation of immersive media —

Part 38: Enhanced geometry-based point cloud compression

Technologies de l'information — Représentation codée de média immersifs —

Partie 38: Compression de nuage de points améliorée basée sur la géométrie

ICS: 35.040.40

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

Secretariat: **JISC**

Voting begins on:
2025-10-27

Voting terminates on:
2026-01-19

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Published in Switzerland

Contents

Foreword ix

Introduction x

1 Scope 1

2 Normative references 1

3 Terms and definitions 1
3.1 General terms 1
3.2 High-level syntax and entropy coding terms 5
3.3 Tree structure terms 7
3.4 Geometry coding terms 8
3.5 Attribute coding terms 10
3.6 Fine granularity slices terms 10

4 Abbreviated terms 11
4.1 Acronyms 11
4.2 Mnemonics 11

5 Conventions 12
5.1 General 12
5.2 Symbolic names 12
5.3 Numerical representation 13
5.4 Arithmetic operators 13
5.5 Logical operators 13
5.6 Relational operators 13
5.7 Bit-wise operators 13
5.8 Assignment operators 14
5.9 Range notation 14
5.10 Mathematical functions 14
5.10.1 General 14
5.10.2 IntAtan2 15
5.10.3 IntCos and IntSin 16
5.10.4 IntCosRad and IntSinRad 17
5.10.5 IntSqrt 17
5.10.6 IntRecipSqrt 18
5.10.7 IntRecip 19
5.10.8 Div 19
5.10.9 Morton 19
5.10.10 ScaledMorton 20
5.10.11 FromMorton 20
5.11 Order of operation precedence 21
5.12 Named expressions 21
5.12.1 General 21
5.12.2 Scope 22
5.12.3 Arguments of named expressions 22
5.12.4 Sub-expressions 23
5.12.5 Definitions with multiple statements 23
5.12.6 Textual definitions 23
5.13 Variables, syntax elements and tables 23

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6 Point cloud format and relationship to coded and output representations 24
6.1 General format 24
6.2 Attributes 24
6.2.1 General 24
6.2.2 Colour 24
6.2.3 Opacity 25
6.2.4 Reflectance 25
6.2.5 Normal vector 25
6.2.6 Material identifier 25
6.2.7 Frame number/index 25
6.2.8 User defined attributes 26
6.3 Codec-derived attributes 26
6.3.1 General 26
6.3.2 Slice identifier 26
6.3.3 Slice tag 26
6.3.4 Canonical point order 26
6.3.5 Point Morton order 26
6.4 Coded point cloud format 27
6.4.1 Sequence coordinate system 27
6.4.2 Coding coordinate system 28
6.4.3 Coded point cloud sequence 29
6.4.4 Coded point cloud frame 29
6.4.5 Slice of a coded point cloud frame 29
6.4.6 Repetition of slices 30
6.4.7 Relationship between tiles and slices 30
6.4.8 Parameter sets 31
6.5 Output point cloud format 32
6.5.1 General 32
6.5.2 Coordinate system 32
6.5.3 Fixed-point conformance output 32
6.5.4 Attributes 32
6.5.5 Output point cloud sequence 32
6.5.6 Output point cloud frame 32

7 Syntax and semantics 33
7.1 Method of specifying syntax in tabular form 33
7.2 Specification of syntax functions and descriptors 34
7.3 Syntax in tabular form 35
7.3.1 General 35
7.3.2 Parameter sets, ancillary data and byte alignment 35
7.3.3 Geometry data unit 45
7.3.4 Attribute data unit 55
7.3.5 Defaulted attribute data unit syntax 58
7.4 Semantics 59
7.4.1 General 59
7.4.2 Parameter sets, ancillary data and byte alignment 59
7.4.3 Geometry data unit 78
7.4.4 Attribute data unit 80
7.4.5 Defaulted attribute data unit semantics 81

8 Decoding process 82
8.1 General decoding process 82

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8.2 Frame decoding processes 82
8.2.1 General 82
8.2.2 Frame counter 82
8.2.3 At the end of a frame 82
8.3 Slice decoding processes 85
8.3.1 General 85
8.3.2 State variables 85
8.3.3 Geometry decoding process 85
8.3.4 Default attribute values 85
8.3.5 Attribute decoding process 85
8.3.6 At the end of a slice 86
8.3.7 Update of inter prediction buffer 86

9 Slice geometry 87
9.1 General 87
9.2 Occupancy tree 87
9.2.1 General 87
9.2.2 Coded occupancy tree 88
9.2.3 Occupancy tree syntax element semantics 90
9.2.4 Node dimensions per tree level 91
9.2.5 State representation 91
9.2.6 Occupancy tree node coding 91
9.2.7 Occupied neighbourhood patterns 98
9.2.8 Neighbourhood-permuted node occupancy bitmap 113
9.2.9 Dictionary coding of occupancy_byte 114
9.2.10 Bitwise occupancy coding 119
9.2.11 Planar occupancy coding 128
9.2.12 Direct nodes 140
9.2.13 Angular coding 145
9.2.14 Subtree scaling 157
9.2.15 Reference frame generation 162
9.3 Predictive tree 165
9.3.1 General 165
9.3.2 Syntax element semantics 166
9.3.3 Tree traversal for reconstruction of point positions 168
9.3.4 Reconstruction of point coordinates 175
9.4 TriSoup 178
9.4.1 General 178
9.4.2 Syntax element semantics 180
9.4.3 TriSoup decoding process 185

10 Slice attributes 208
10.1 General 208
10.2 Point coordinates 208
10.2.1 General 208
10.2.2 Conversion to scaled angular coordinates 209
10.3 Syntax element semantics 209
10.4 Raw attribute decoding 210
10.5 Attribute decoding using the region-adaptive hierarchical transform 210
10.5.1 General 210
10.5.2 Transform tree 211
10.5.3 Coefficient order 214

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10.5.4 Coefficient scaling **216**
10.5.5 Transform domain prediction **218**
10.5.6 Sample domain prediction and last component prediction **229**
10.5.7 Inverse transform **233**
10.5.8 Reconstructed attribute values **236**
10.6 Attribute decoding using levels of detail **237**
10.6.1 General **237**
10.6.2 Syntax element semantics **238**
10.6.3 Reconstruction process **238**
10.6.4 State variables **238**
10.6.5 Levels of detail **239**
10.6.6 Predictor search **246**
10.6.7 Reconstruction of attribute values **258**
10.6.8 Prediction mode coding **259**
10.6.9 Scaling **261**
10.6.10 Coefficient prediction **261**
10.6.11 Transform coefficient weights **262**
10.6.12 Transform **263**
10.6.13 Point quantization weights **264**
10.7 Attribute quantization parameters **264**
10.7.1 Syntax element semantics **264**
10.7.2 Per-point regional QP offset **266**
10.7.3 Attribute coefficient QP **266**
10.7.4 Definition of *AttrQstep* **266**
10.8 Reference slice generation for attribute **266**
10.8.1 General **266**
10.8.2 Reconstructed frame generation **267**
10.8.3 Reference frame generation **267**
10.8.4 Reference slice generation **268**

11 Parsing process **269**
11.1 General **269**
11.2 Data unit buffer **272**
11.2.1 General **272**
11.2.2 State **272**
11.2.3 Initialization at the start of parsing a data unit **272**
11.2.4 Initialization at the start of parsing a geometry data unit footer **272**
11.2.5 Definition of *DuNextBit* **272**
11.3 Chunked bytestream parsing **273**
11.3.1 General **273**
11.3.2 Chunk syntax **273**
11.3.3 Chunk semantics **273**
11.3.4 State **274**
11.3.5 Span of chunked bytestream data within a data unit **274**
11.3.6 The chunk buffer **274**
11.3.7 State update at the start of every CBS **274**
11.3.8 Unpacking a single chunk **274**
11.3.9 Definition of *ChunkNextAeBit* **275**
11.3.10 Definition of *ChunkNextBpBit* **275**
11.3.11 Boundary between spliced chunked bytestreams **275**
11.3.12 Location of chunked bytestream boundaries **276**

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11.4 General inverse binarization processes **277**
11.4.1 Parsing unsigned fixed-length codes (FL) **277**
11.4.2 Parsing signed fixed-length codes (FL+S) **277**
11.4.3 Parsing *k*-th order exp-Golomb codes (EGk) **277**
11.4.4 Parsing concatenated truncated unary and *k*-th order exp-Golomb codes (TU+EGk) **277**
11.4.5 Parsing truncated unary codes (TU) **278**
11.4.6 Mapping process for signed codes **278**
11.4.7 Parsing ASN.1 object identifiers **278**
11.5 CABAC parsing processes **279**
11.5.1 Initialization **279**
11.5.2 Definition of *AeReadBin* **279**
11.5.3 Contextual probability models **279**
11.5.4 Arithmetic decoding engine **286**
11.6 Parsing state memorization and restoration **288**
11.6.1 General **288**
11.6.2 Geometry data units **288**
11.6.3 Attribute data units **289**
11.6.4 Defaulted attribute data units **289**

12 OBUF parsing process **289**
12.1 General **289**
12.2 Creation of an OBUF instance **289**
12.2.1 Creation and initialization of OBUF trees **290**
12.2.2 Creation and initialization of an array of OBUF ACPMs **291**
12.3 Creation of a buffer of OBUF tree leaves **291**
12.4 Call and update of an OBUF instance **292**
12.4.1 Decode and update according to OBUF trees **292**
12.4.2 Decode and update according to an element of the buffer of OBUF tree leaves **294**
12.5 Decode of a bin based on an OBUF ACPM **294**
12.5.1 Probability correction based on probability bounds **295**
12.5.2 Decoding of a bin using CABAC **295**

Annex A (normative) Profiles and levels **296**
A.1 Permitted ranges for syntax elements **296**

Annex B (normative) Type-length-value encapsulated bytestream format **302**
B.1 General **302**
B.2 Syntax and semantics **302**
B.2.1 Syntax **302**
B.2.2 Semantics **302**
B.3 Parsing process **303**

Annex C (informative) Arithmetic encoding engine **304**
C.1 General **304**
C.2 State variables **304**
C.3 Initial state **304**
C.4 Encoding process for a single binary symbol **304**
C.5 Arithmetic encoder state renormalization process **305**
C.6 Arithmetic encoding engine termination process **305**

Annex D (normative) Partial decoding and spatial scalability **307**
D.1 General **307**
D.2 Partial slice geometry **307**

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D.2.1 General ... 307
D.2.2 Selection of partial point positions ... 307
D.2.3 Partial point positions ... 308
D.2.4 Output points ... 308
D.3 Partial attribute decoding ... 308
D.3.1 General ... 308
D.3.2 The finest detail level ... 308

Annex E (normative) Fine granularity slices ... 309
E.1 General ... 309
E.2 Coded point cloud format ... 309
E.2.1 Fine granularity slices ... 309
E.2.2 Layer-group structure ... 309
E.3 Syntax and semantics for fine granularity slices ... 311
E.3.1 Syntax in tabular form ... 311
E.3.2 Semantics ... 316
E.4 Decoding process ... 323
E.4.1 General ... 323
E.4.2 Fine granularity slice decoding process ... 323
E.5 Fine granularity slice geometry ... 325
E.5.1 General ... 325
E.5.2 Partial tree of occupancy tree ... 326
E.6 Fine granularity slice attributes ... 329
E.6.1 General ... 329
E.6.2 Point coordinates ... 330
E.6.3 Raw attribute decoding ... 330
E.6.4 Attribute decoding using levels of detail ... 330
E.6.5 Parent FGS generation for attributes ... 336
E.7 Parsing process ... 337
E.7.1 General ... 337
E.7.2 Data unit buffer ... 337
E.7.3 CABAC parsing processes ... 337
E.7.4 Parsing state memorization and restoration ... 338
E.8 Partial decoding ... 340
E.8.1 General ... 340
E.8.2 Partial density decoding ... 340

Bibliography ... 342

Index of named expressions and variables ... 343

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*.

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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.

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Information technology — Coded representation of immersive media —

Part 38:
Enhanced geometry-based point cloud compression

1 Scope

This document specifies enhanced 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

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

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

ISO/IEC 9834-8 (Rec. ITU-T X.667), 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 terminological databases for use in standardization at the following addresses:

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

— IEC Electropedia: available at http://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* (3.1.9) and zero or more *attributes* (3.1.20)

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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
reference point cloud frame
a coded point cloud frame (3.1.5) which contains points (3.1.1) that may be used for inter prediction (3.1.28) in the decoding process of subsequent point cloud frames (3.1.4) in decoding order

3.1.7
canonical point order
canonical decoding order
order of *points* (3.1.1) decoded from a *slice* (3.1.22) according to the decoding and parsing processes specified in this document

3.1.8
bounding box
axis-aligned cuboid defining a spatial region that bounds a set of *points* (3.1.1)

3.1.9
coordinates
<Cartesian> three scalar multiples of respective orthogonal *XYZ* (3.1.12) unit vectors with finite precision and bounds that specify a position relative to a fixed reference

3.1.10
coordinates
<angular> a position specified as the radial distance ρ from the V axis, an azimuth angle φ in the S-T plane and an indexed elevation

3.1.11
coordinates
<attribute> either *STV* (3.1.13) or scaled *RPI* (3.1.14) point coordinates used to code an attribute

3.1.12
XYZ (axes)
X, Y and Z axes, in that order, used to represent *Cartesian coordinates* (3.1.9)

3.1.13
STV (axes)
S, T and V axes, in that order, that are a sequence-dependent permutation of the *XYZ axes* (3.1.12); used to represent the coded *geometry* (3.1.19)

3.1.14
RPI (axes)
R, P and I axes, in that order, used to represent *angular coordinates* (3.1.10)

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3.1.15
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

3.1.16
coding coordinate system
scaled *sequence coordinate system* (3.1.15) that applies for an entire coded *point cloud sequence* (3.1.3), and in which all *points* (3.1.1) have non-negative integer coordinates

3.1.17
slice coordinate system
translated *coding coordinate system* (3.1.16) that applies for a single *slice* (3.1.22), and in which all *points* (3.1.1) in the *slice* have non-negative integer coordinates

3.1.18
beam
sampler of point positions using angular coordinates by rays cast with a fixed elevation and from a point on and rotating around the V axis at the angular origin

3.1.19
geometry
point positions (3.4.1) associated with a set of *points* (3.1.1)

3.1.20
attribute
scalar or vector property associated with each *point* (3.1.1) in a *point cloud* (3.1.2)

EXAMPLE Colour, reflectance, frame index, etc.

3.1.21
position
<bit> bit in a binary string or value, representing the factor $2^{position}$

EXAMPLE The LSB has bit position 0.

3.1.22
slice
geometry and attributes for part of, or an entire, *coded point cloud frame* (3.1.5)

Note 1 to entry: the bounding boxes of any two slices can intersect.

3.1.23
tile
set of *slices* (3.1.22) identified by a common slice_tag *syntax element* value (3.2.15) whose *geometry* (3.1.19) should be contained within a *bounding box* (3.1.8) specified in a tile inventory data unit

3.1.24
prediction
an embodiment of the *prediction process* (3.1.25)

3.1.25
prediction process
the use of a *predictor* (3.1.26) to provide an estimate of the data element currently being decoded

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3.1.26
predictor
a combination of specified values or previously decoded data elements used in the decoding process of subsequent data elements

3.1.27
intra prediction
a *prediction* (3.1.24) derived from only data elements (e.g., *point positions* (3.4.1) or *attributes* (3.1.20)) of the same decoded *slice* (3.1.22)

3.1.28
inter prediction
a *prediction* (3.1.24) derived in a manner that is dependent on data elements (e.g., *point positions* (3.4.1) or *attributes*(3.1.20)) of one or more *reference point cloud frames* (3.1.6)

3.1.29
uni-prediction
an inter *prediction* (3.1.28) derived in a manner that is dependent on data elements (e.g., *point positions* (3.4.1) or *attributes*(3.1.20)) of one *reference point cloud frame* (3.1.6)

3.1.30
bi-prediction
an inter *prediction* (3.1.28) derived in a manner that is dependent on data elements (e.g., *point positions* (3.4.1) or *attributes*(3.1.20)) of two *reference point cloud frames* (3.1.6)

3.1.31
I-slice
intra slice
a *slice* (3.1.22) that is decoded using *intra prediction* (3.1.27) without referring to a *reference point cloud frame* (3.1.6)

3.1.32
reference slice
a coded *slice* (3.1.22) which contains points (3.1.1) that may be used for inter prediction (3.1.28) in the decoding process of subsequent *slices* (3.1.22) in decoding order

3.1.33
I-frame
intra frame
a *point cloud frame* (3.1.4) that is decoded using *intra prediction* (3.1.27) without referring to a *reference point cloud frame* (3.1.6)

3.1.34
P-frame
predictive frame
a *point cloud frame* (3.1.4) that is decoded using *intra prediction* (3.1.27) or *inter prediction* (3.1.28) from at most one *reference point cloud frame* (3.1.6)

3.1.35
B-frame
bi-predictive frame
a *point cloud frame* (3.1.4) that is decoded using *intra prediction* (3.1.27) or *inter prediction* (3.1.28) from at most two *reference point cloud frames* (3.1.6)

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3.1.36
Morton code
non-negative integer obtained by interleaving the bits of three integers

3.1.37
Morton order
elements ordered according to their *Morton code* (3.1.36)

3.1.38
sparse array
array with fewer set elements than total addressable elements; unset elements can have an inferred value when accessed

3.1.39
temporal ID
An identifier associated with a point cloud frame which may be used to support temporal scalability.

3.2 High-level syntax and entropy coding terms

3.2.1
ASN.1
abstract syntax notation one
notation specified by Rec. ITU-T X.660 | ISO/IEC 9834-1 that is used for the definition of data types, values and constraints on data types

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

3.2.2
bin
binary symbol (bit) of the *binarized* (3.2.3) representation of a *syntax element* value (3.2.15)

3.2.3
binarization
specification of a *syntax element*'s value (3.2.15) as a sequence of *bins* (3.2.2)

3.2.4
bypass
<symbol> a static, equiprobable probability model

3.2.5
bypass
<stream> *bypass symbols* (3.2.4) that are not encoded in an arithmetic-coded *bitstream* (3.2.6)

3.2.6
bitstream
<data> sequence of bits

3.2.7
bitstream
<coded sequence> sequence of bits, in the form of encapsulated *data units* (3.2.12), that represents a coded *point cloud sequence* (3.1.3)

3.2.8
set bit
bit with the value 1

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3.2.9
unset bit
bit with the value 0

3.2.10
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.

3.2.11
byte aligned
bitstream (3.2.6) position that is an integer multiple of eight bits from the position of the first bit in the bitstream

3.2.12
data unit
DU
sequence of *bytes* (3.2.10) conveying a single *syntax structure* (3.2.16) of known length

3.2.13
data unit header
parameters, located from the start of a *data unit* (3.2.12)

3.2.14
data unit footer
parameters, located from the end of a *data unit* (3.2.12)

3.2.15
syntax element
element of data represented in the *bitstream* (3.2.6)

3.2.16
syntax structure
zero or more *syntax elements* (3.2.15) present together in the *bitstream* (3.2.6) in a specified order

3.2.17
parameter set
collection of parameters that apply when activated

3.2.18
sequence parameter set
SPS
parameters for an entire coded *point cloud sequence* (3.1.3), conveyed by an SPS *data unit* (3.2.12) and activated when referenced by a geometry data unit

3.2.19
geometry parameter set
GPS
parameters for the coding of *slice* (3.1.22) geometry, conveyed by a GPS *data unit* (3.2.12) and activated when referenced by a geometry data unit

3.2.20
attribute parameter set
APS
parameters for the coding of a *slice* (3.1.22) attribute, conveyed by an APS *data unit* (3.2.12) and activated when referenced by an attribute data unit

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3.2.21
object identifier
OID
<ASN.1> ordered list of primary integer values from the root of the *international object identifier tree* (3.2.22) to a node, which unambiguously identifies that node

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

3.2.22
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* (3.2.24) responsible for allocating arcs from a parent node

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

3.2.23
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]

3.2.24
registration authority
<international object identifier tree> an entity such as an organization, a standard or an automated facility that performs *registration* (3.2.23) of one or more types of objects

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

3.2.25
application specific
defined by an application or an application standard

3.2.26
unspecified
when used in subclauses specifying values of a particular *syntax element*, indicates that the values have no specified meaning in this document and will not have a specified meaning in future versions of this document

3.3 Tree structure terms

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 *depth* of 0 (3.3.8), 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)

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3.3.5
root node
<tree> *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
<tree> 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
root node
<subtree> single *node* (3.3.7) of a *subtree* (3.3.14) from which all other nodes in the same subtree are descendents

3.3.16
TriSoup node
occupied *leaf node* (3.3.6) of an *occupancy tree* (3.4.2) representing a sub-volume of the 3D space (or volume) containing at least one point of the *point cloud* (3.1.2)

3.4 Geometry coding terms

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

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3.4.2
occupancy tree
eight-ary *tree* (3.3.1) of *occupancy tree nodes* (3.4.4) representing the *geometry* (3.1.19) of a *slice* (3.1.22)

3.4.3
predictive tree
tree (3.3.1) of *predictive tree nodes* (3.4.5) representing the *geometry* (3.1.19) of a *slice* (3.1.22)

3.4.4
node
<occupancy tree> *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
node
<predictive tree> *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
<occupancy tree> terminal *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
indicates the existence and arrangement of the six possible occupancy tree *nodes* (3.4.4) that share faces with a central node

3.4.9
TriSoup
representation of the geometry of the *point cloud* (3.1.2) in a *TriSoup node* (3.3.163.1.1) by a set of triangles

3.4.10
TriSoup edge
any edge belonging to a cuboid volume associated with a *TriSoup node* (3.3.16)

3.4.11
TriSoup edge vertex
a *TriSoup vertex* (3.4.13) located on a *TriSoup edge* (3.4.10)

3.4.12
TriSoup face vertex
a *TriSoup vertex* (3.4.13) located on a face shared by two adjacent *TriSoup* nodes (3.3.16)

3.4.13
TriSoup vertex
a vertex of *TriSoup triangle* (3.4.14) including *TriSoup edge vertex* (3.4.11) and *TriSoup face vertex* (3.4.12)

3.4.14
TriSoup triangle
a triangle belonging to a *TriSoup node* (3.3.163.1.1) and whose vertex are defined from the *TriSoup vertices* (3.4.13) belonging to the cuboid volume associated with said TriSoup node

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3.4.15
voxelization (of a TriSoup triangle)
process of transforming a *TriSoup* triangle (3.4.14) into a set of points (3.1.1)

3.4.16
lexicographical order
an ordering of multi-dimensional data in which elements are compared sequentially from the first to the last dimension. The comparison proceeds by evaluating the first elements of each data item; if they differ, the order is determined by these values. If the first elements are equal, the second elements are compared, and this process continues until a difference is found or all elements have been compared.

3.5 Attribute coding terms

3.5.1
primary attribute component
first, or only, attribute component, identified by the index 0

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

3.5.3
detail level
set of *points* (3.1.1) that represent a subsampled version of the slice *geometry* (3.1.19)

3.5.4
refinement list
set of *points* (3.1.1) present in one *detail level* (3.5.3) that are not present in the next coarsest *detail level*

3.5.5
refinement point
point (3.1.1) in a *refinement list* (3.5.4)

3.5.6
predictor set
set of neighbouring *points* (3.1.1) from which an *attribute* (3.1.20) value is predicted

3.6 Fine granularity slices terms

3.6.1
fine granularity slices
a subset of a slice which carries a geometry or an attribute of a subgroup (3.6.3) in a layer-group (3.6.2)

3.6.2
layer-group
a group of consecutive tree levels (3.3.4) of an occupancy tree (3.4.2)

3.6.3
subgroup
a spatial subset of a layer-group (3.6.2) where the bounding box of a subgroup does not overlap with other subgroups in the same layer-group

3.6.4
root layer-group
a layer-group (3.6.2) which contains a root node (3.3.5) of the occupancy tree (3.4.2)

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3.6.5
parent subgroup
a layer-group (3.6.2) which contains a root node (3.3.5) of the occupancy tree (3.4.2)

3.6.6
child subgroup
a subgroup (3.6.3) in a layer-group (3.6.2) adjacent to the maximum depth of the current subgroup, where the bounding box of the child subgroup is a subset of the bounding box of the current subgroup

4 Abbreviated terms

4.1 Acronyms

APS	Attribute parameter set
ADU	Attribute data unit
CBS	Chunked bytestream
CPM	Contextual probability model
DADU	Dependent attribute data unit
DGDU	Dependent geometry data unit
DU	Data unit
FBDU	Frame boundary marker data unit
FGS	Fine granularity slice
FSAP	Frame-specific attribute properties
GDU	Geometry data unit
GOF	Group of frames
GPS	Geometry parameter set
G-PCC	Geometry-based point cloud compression
LoD	Level(s) of detail
LSB	Least significant bit
MSB	Most significant bit
NA	Not applicable
QP	Quantization parameter
RAHT	Region adaptive hierarchical transform
SPS	Sequence parameter set

4.2 Mnemonics

EGk	Exponential Golomb code of order k
FL	Fixed-length code
FL+S	Fixed-length code plus conditional sign bit
TU	Truncated unary code

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