JT File Format Reference
Version 9.5
Rev-A

Acknowledgments

Documents of this type typically require many hands both to author, and to ensure their correctness. However, if one single person can be identified most responsible for bringing this specification document into existence, it is Gary Lance. He authored the JT v8.1 Specification almost single-handedly over the course of four months in 2006, beginning with no knowledge of the DirectModel toolkit from which the JT format springs. This document owes much to the considerable efforts and high standards of quality Gary brought to that first version.

Equally required of documents of this type, come the inevitable erratum or two. Paul Kitchen, of Wilcox Associates, Inc. a Hexagon Metrology Company, is due special thanks for his patient, diligent, and even enthusiastic work with the authors in finding and correcting several bugs in the original JT v8.1 reference document. To our knowledge, Paul is the first outside developer to correctly read all data entities documented in the JT v8.1 specification.

This updated JT Version 9.5 document was written by the JT Format and DirectModel team's developers themselves: Michael Carter, Jianbing Huang, Sashank Ganti, Jeremy Bennett, and Bo Xu.

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1 Siemens JT Data Format Reference Intellectual Property License Terms

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2 Scope

This reference defines the syntax and semantics of the JT Version 9.5 file format.

The JT format is an industry focused, high-performance, lightweight, flexible file format for capturing and repurposing 3D Product Definition data that enables collaboration, validation and visualization throughout the extended enterprise. JT format is the de-facto standard 3D Visualization format in the automotive industry, and the single most dominant 3D visualization format in Aerospace, Heavy Equipment and other mechanical CAD domains.

The JT format is both robust, and streamable, and contains best-in-class compression for compact and efficient representation. The JT format was designed to be easily integrated into enterprise translation solutions, producing a single set of 3D digital assets that support a full range of downstream processes from lightweight web-based viewing to full product digital mockups.

At its core the JT format is a scene graph with CAD specific node and attributes support. Facet information (triangles), is stored with sophisticated geometry compression techniques. Visual attributes such as lights, textures, materials and shaders (Cg and OGLSL) are supported. Product and Manufacturing Information (PMI), Precise Part definitions (B-Rep) and Metadata as well as a variety of representation configurations are supported by the format. The JT format is also structured to enable support for various delivery methods including asynchronous streaming of content.

Some of the highlights of the JT format include:

- Built-in support for assemblies, sub-assemblies and part constructs
- Flexible partitioning scheme, supporting single or multiple files
- B-Rep, including integrated support for industry standard Parasolid® (XT) format
- Product Manufacturing Information in support of paperless manufacturing initiatives
- Precise and imprecise wireframe
- Discrete purpose-built Levels of Detail
- Wire harness information
- Triangle sets, Polygon sets, Point sets, Line sets and Implicit Primitive sets (cylinder, cone, sphere, etc…)
- Full array of visual attributes: Materials, Textures, Lights, Shaders
- Hierarchical Bounding Box and Bounding Spheres
- Advanced data compression that allows producers of JT files to fine tune the tradeoff between compression ratio and fidelity of the data.

Beyond the data contents description of the JT Format, the overall physical structure/organization of the format is also designed to support operations such as:

Offline optimizations of the data contents

- File granularity and flexibility optimized to meet the needs of Enterprise Data Translation Solutions

Asynchronous streaming of content

- Viewing optimizations such as view frustum and occlusion culling and fixed-framerate display modes.

Layers, and Layer Filters.

Along with the pure syntactical definition of the JT Format, there is also series of conventions which although not required to have a reference compliant JT file, have become commonplace within JT format translators. These conventions have been documented in the “Best Practices” section of this JT format reference.

This JT format reference does not specifically address implementation of, nor define, a run-time architecture for viewing and/or processing JT data. This is because although the JT format is closely aligned with a run-time data representation for fast and efficient loading/unloading of data, no interaction behavior is defined within the format itself, either in the form of specific viewer controls, viewport information, animation behavior or other event-based interactivity. This exclusion of interaction behavior from the JT format makes the format more easily reusable for dissimilar application interoperation and also facilitates incremental update, without losing downstream authored data, as the original CAD asset revises.

2.1 What’s New in This Revision

Revision A

This specification is based on the Version 8.1 Rev D specification, but with major changes to all sections, and as such is a completely new, standalone document.

3 References and Additional Information

[1] *JT Open Program* (http://www.jtopen.com) --- A program to help members leverage the benefits of open collaboration across the extended enterprise through the adoption of the JT format, a technology that makes it possible to view and share product information throughout the product lifecycle. Membership in the JT Open Program provides access to the JT Open Toolkit library, which among other things, provides read and write access to JT data and enforces certain JT conventions to ensure data compatibility with other JT-enabled applications.

[2] *JT2Go download* (http://www.jt2go.com) --- JT2Go is the no-charge 3D JT viewer from Siemens. JT2Go puts 3D data at your fingertips by allowing anyone to download the no-charge viewer. JT2Go also allows anyone to embed 3D JT data directly into Microsoft Office documents. JT2Go offers full 3D interactivity on parts, assemblies, and even 2D drawings (CGM & TIF).

[3] *Siemens: PLM Components: Parasolid: XT Pipeline* (http://www.ugs.com/products/open/parasolid/pipeline.shtml) --- This web page provides information on the Parasolid precise boundary representation format (XT) and how this XT format fits within the Siemens vision of seamless exchange of digital product models across enterprises, between different disciplines, using their PLM applications of choice.

[4] *OpenGL Programming Guide : The official guide to learning OpenGL Version 2*, Fifth Edition, by OpenGL Architecture Review Board, Dave Shreiner, Mason Woo, Jackie Neider, and Tom Davis (Addison-Wesley 2005) --- This book gives in-depth explanation of the OpenGL Specification and will provide further insight into the significance of some of the data (e.g. Materials, Textures) that can exist in a JT file. Information in this book may also serve as a guide for how one could process the data contained in a JT file to produce/render an image on the screen.

[5] Michael Deering, *Geometry Compression*, Computer Graphics, Proceedings SIGGRAPH '95, August 1995, pp. 13-20.

[6] Michael Deering, Craig Gotsman, Stefan Gumhold, Jarek Rossignac, and Gabriel Taubin, *3D Geometry Compression*, Course Notes for SIGGRAPH 2000, July 25, 2000.

[7] *OpenGL Shading Language Specification* (http://www.opengl.org/documentation/glsl/) --- OpenGL Shading Language (GLSL) as defined by the OpenGL Architectural Review Board, the governing body of OpenGL.

[8] *Cg Toolkit Users Manual* (http://developer.nvidia.com/object/cg_users_manual.html) --- Explains everything you need to learn and use the Cg language as well as the Cg runtime library.

[9] *The Cg Tutorial: The Definitive Guide to Programmable Real-Time Graphics,* Randima Fernando and Mark J. Kilgard, nVIDIA Corporation, Addison Wesley Publishing Company, April 2003

[10] K. Weiler. *Topological Structures for Geometric Modeling*, PhD thesis, Rensselaer Polytechnic Institute, Troy, NY, 1986.

[11] C. M. Hoffmann. *Geometric and Solid Modeling: An Introduction*. Morgan Kaufmann Publishers, Inc., San Mateo, California, 1989.

[12] Les Piegl and Wayne Tiller, *The NURBS Book*, Springer-Verlag, 1997.

[13] *Planetmath.org - Huffman Coding* (http://planetmath.org/encyclopedia/HuffmanCoding.html) --- This web page provides a technical overview of Huffman coding which is one form of data encoding used within the JT format.

[14] Michael Schindler, *Practical Huffman Coding* (http://www.compressconsult.com/huffman/#encoding) --- This web page provides some coding hints for implementing Huffman coding which is one form of data encoding used within the JT format.

[15] Glen G. Langdon Jr., *An Introduction to Arithmetic Coding*, IBM Journal of Research and Development, Volume 28, Number 2, March 1984, pp. 135-149.

[16] Paul G. Howard and Jeffrey Scott Vitter, *Practical Implementation of Arithmetic Coding. Image and Text Compression*, ed. J. A. Storer, Kluwer Academic Publishers, April 1992, pp. 85-112.

[17] zlib.net (http://www.zlib.net/) --- This web page provides (either directly or through links) complete detailed information on ZLIB compression including frequently asked questions, technical documentation, source code downloads, etc.

[18] Andrei Khodakovsky, Pierre Alliez, Mathieu Desbrun, and Peter Schröder, *Near-Optimal Connectivity Encoding of 2-Manifold Polygon Meshes*, Graphical Models, Vol. 64, No. 3-4, Pages: 147 - 168, 2002.

[19] B. Schneier, *Description of a New Variable-Length Key, 64-Bit Block Cipher (Blowfish)*, Fast Software Encryption, Cambridge Security Workshop Proceedings (December 1993), Springer-Verlag, 1994, pp. 191-204.

4 Definitions

4.1 Terms

It is assumed that readers of this document are familiar with concepts in the area of computer graphics and solid modeling. The intention of this section is not to provide comprehensive definitions, but is to provide a short introduction and clarification of the usage of terms within this document.

Assembly	A related collection of *model* parts, represented in a JT format logical scene graph as a logical graph branch
Attribute	Objects associated with nodes in a *logical scene graph* and specifying one of several appearances, positioning, or rendering characteristics of a *shape*.
Boundary Representation	A solid model representation where the solid volume is specified by its surface boundary (both its geometric and topological boundaries).
CodeText	A collection of data in encoded form.
Directed Acyclic Graph	A *graph* is a set of nodes, and a set of edges connecting the nodes in a tree like structure. A *directed graph* is one in which every edge has a direction such that edge (u,v), connecting node-u with node-v, is different from edge (v,u). A *Directed Acyclic Graph* is a directed graph with no cycles; where a cycle is a path (sequence of edges) from a node to itself. So with a *Directed Acyclic Graph* there is no path that can be followed within the graph such that the first node in the path is the same as the last node in the path.
JT Enabled Application	Application which supports reading and/or writing reference compliant JT Format files.
Level of Detail	One alternative graphical representation for some *model* component (e.g. part).
Logical Scene Graph	A *scene graph* representing the logical organization of a *model*. Contains *shapes* and *attributes* representing the *model's* physical

	components, *properties* identifying arbitrary metadata (e.g. names, semantic roles) of those components, and a hierarchical structure expressing the component relationships.
Mipmap	A reduced resolution version of a texture map. Mipmaps are used to texture a geometric primitive whose screen resolution differs from the resolution of the source texture map originally applied to the primitive.
Model	Representation, in JT format, of a physical or virtual product, part, assembly; or collections of such objects.
Parasolid XT Format	Parasolid boundary representation format
Product and Manufacturing Information	Collection of information created on a 3D/2D CAD Model to completely document the product with respect to design, manufacturing, inspection, etc. This may includes data such as: Dimensions (tolerances for each dimension) Geometric tolerances of feature (datums, feature control frames) Manufacturing information (surface finish, welding notations) Inspection information (key locations points) Assembly instructions Product information (materials, suppliers, part numbers)
Property	An object associated with a logical scene graph node and identifying arbitrary application or enterprise specific information (meta-data) related to that node.
Quantize	Constrain something to a discrete set of values, such as an integer or integral multiplier of a common factor, rather than a continuous set of values, such as a real number.
Scene Graph	In the context of the JT format, a scene graph is a *directed acyclic graph* that arranges the logical and often (but not necessarily) spatial representation of a graphical scene.
Shader	A user-definable program, expressed directly in a target assembly language, or in high-level form to be compiled. A shader program replaces a portion of the otherwise fixed-functionality graphics pipeline with some user-defined function. At present, hardware manufacturers have made it possible to run a shader for each vertex that is processed or each pixel that is rendered.
Streaming	In the context of the JT format, streaming refers to both: Loading from disk based medium only the portions of data that are required by the user to perform the tasks at hand. The motivation being to more efficiently manage system memory. Transfer of data in a stream of packets, over the internet on an on-demand basis, where the data is interpreted in real-time by the application as the data packets arrive. The motivation being that the user can begin using or interacting with the data almost immediately - no waiting for the entire data file(s) to be transferred before beginning The desired end result of both being to *deliver only the JT data that the user needs, where the user needs it, when the user needs it.* A

	“just-in-time” approach to delivering JT format product data.
Shape	A logical scene graph leaf node containing or referencing the geometric shape definition data (e.g. vertices, polygons, normals, etc.) of a model component.
Texture Channel	A Texture Unit plus the *texture environment*. In OpenGL® terms, Texture Channel basically controls “glActiveTexture” [4]
Texture Object	JT format meaning is the same as in OpenGL [4] “A named cache that stores texture data, such as the image array, associated mipmaps, and associated texture parameter values: width, height, border width, internal format, resolution of components, minification and magnification filters, wrapping modes, border color, and texture priority.”
Texture Unit	JT format meaning is the same as in OpenGL [4], with the connotation that *texture parameters* go with the Texture Unit (through binding of a texture object) but *texture environment* (texturing function) does not.

4.2 Coordinate Systems

The data contained within a JT file is defined within one of the following coordinate systems. If not otherwise specified in a data field’s description, it should be assumed that the data is defined in Local Coordinate System.

Local Coordinate System (LCS). The coordinate system in which shape geometry is specified. It is the coordinate system used to specify the “raw” data with no transforms applied.

Node Coordinate System (NCS). Local coordinates transformed by any transforms specified as attributes at the node. The NCS is also often referred to as Model Coordinate System (MCS).

World Coordinate System (WCS). Node coordinates transformed by transforms inherited from a node’s parent (i.e. the coordinate system at the root of the graph).

View Coordinate System (VCS). World coordinates transformed by a view matrix.

5 Acronyms and Abbreviations

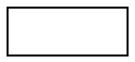
Abs	Absolute Value
BBox	Bounding Box
B-Rep	Boundary Representation
CAE	Computer Aided Engineering
Cg	C for Graphics
CODEC	Coder-Decoder
GD&T	Geometric Dimensioning and Tolerancing
GLSL	OpenGL Shader Language
GPU	Graphics Processing Unit
GUID	Globally Unique Identifier
HSV	Hue, Saturation, Value
HSVA	Hue, Saturation, Value, Alpha

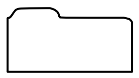
LCS	Local Coordinate System
LOD	Level of Detail
LsbFirst	Least Significant Byte First
LSG	Logical Scene Graph
Max	Maximum
MCS	Model Coordinate System
Min	Minimum
MsbFirst	Most Significant Byte First
N/A	Not Applicable
NCS	Node Coordinate System
PCS	Parameter Coordinate Space
PLM	Product Lifecycle Management
PMI	Product and Manufacturing Information
RGB	Red, Green, Blue
RGBA	Red, Green, Blue, Alpha
TOC	Table of Contents.
VPCS	Viewpoint Coordinate System
URL	Uniform Resource Locator
WCS	World Coordinate System

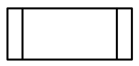
6 Notational Conventions

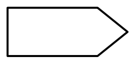
6.1 Diagrams and Field Descriptions

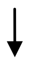
Symbolic diagrams are used to describe the structure of the JT file. The symbols used in these diagrams have the following meaning:


Rectangles represent a data field of one of the standard data types.


Folders represent a logical collection of one or more of the standard data types. This information is grouped for clarity and the basic data types that compose the group are detailed in following sections of the document.


Rectangles with extra lines at left and the right sides corners clipped off represent information logical stepsthat has been compressed.


Rectangles with the right side corners clipped off represent information that has been compressed.


Arrows convey the ordering of the information.

The format used to title the diagram symbols is dependent upon the symbol type as follows:

Diagram "rectangle box" (i.e. standard data types) symbols are titled using a format of "Data_Type : Field_Name." The Data_Type is an abbreviated data type symbol as defined in 6.2 Data Types. In the example below the Data_Type is "I32" (a signed 32 bit integer) and Field_Name is "Count."

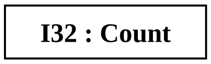


Diagram "folder" (i.e. logical data collections) symbols are simply titled with a collection name. In the example below the collection name is "Graph Elements."

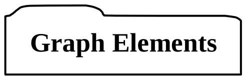


Diagram "rectangle box with lines at left and right sides" are simply titled with a logic step name. In the example below the logic step name is "Recover First Shell Indices".

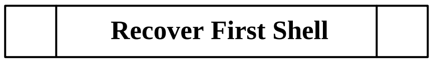
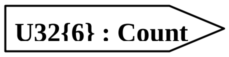


Diagram "rectangle box with clipped right side corners" (i.e. compressed/encoded data fields) are titled using one of the following three formats:

Data Type; followed by open brace "{", number of bits used to store value, closed brace "}", and a colon ":"; followed by the Field Name. This format for titling the diagram symbol indicates that the data is compressed but not encoded. The compression is achieved by using only a portion of the total bit range of the data type to store the value (e.g. if a count value can never be larger than the value "63" then only 6 bits are needed to store all possible count values). In the example below the Data Type is "U32", "6" bits are used to store the value, and Field Name is "Count"



Data Type followed by open brace "{", compressed data packet type, ",", Predictor Type, closed brace "}", and a colon ":"; followed by the field name. This format for titling the diagram indicates that a vector of "Data Type" data (i.e. *primal* values) is ran through "Predictor Type" algorithm and the resulting output array of *residual* values is then compressed and encoded into a series of symbols using one of the two supported compressed data packet types.

The two supported compressed data packet types are:

Int32CDP – The Int32CDP (i.e. Int32 Compressed Data Packet) represents the format used to encode/compress a collection of data into a series of Int32 based symbols. A complete description for Int32 Compressed Data Packet can be found in 8.1.1 Int32 Compressed Data Packet.

Int32CDP2 – The Int32CDP2 (i.e.Int32 Compressed Data Packet Mk. 2) represents a second-generation version of the above compressed data packet, and sports a simplified and more compact file layout, and the ability to more efficiently encode clustered data and bitfields. A complete description for Int32 Compressed Data Packet Mk. 2 can be found in 8.1.2 Int32 Compressed Data Packet Mk. 2.

Float64CDP – The Float64CDP (i.e. Float64 Compressed Data Packet) represents the format used to encode/compress a collection of data into a series of Float64 based symbols. A complete description for Float64 Compressed Data Packet can be found in 8.1.3 Float64 Compressed Data Packet.

The Int32 Compressed Data Packet type is used for compressing/encoding both "integer" and "float" (through quantization) data. While the Float64 Compressed Data Packet type is used for compressing/encoding "double" data.

In the example below the Data Type is "VecU32", Int32 Compressed Data Packet type is used, Lag1 Predictor Type is used, and Field Name is "First Shell Index."

VecU32{Int32CDP, Lag1} : First Shell

As mentioned above (with Predictor Type algorithm), the *primal* input data values are NOT always what is encoded/compressed. This is because the *primal* input data is first run through a Predictor Type algorithm, which produces an output array of residual values (i.e. difference from the predicted value), and this resulting output array of *residual* values is the data which is actually encoded/compressed. The JT format supports several Predictor Type algorithms and each use of Int32CDP or Float64CDP specifies, using the above described notation format, what Predictor Type algorithm is being used on the data. The JT format supported Predictor Type algorithms are as follows (note that a sample implementation of decoding the predictor *residual* values back into the *primal* values can be found in Appendix C: Decoding Algorithms – An Implementation):

Predictor Type	Description
Lag1	Predicts as last value
Lag2	Predicts as value before last
Stride1	Predicts using stride from last two values
Stride2	Predicts using stride from values 2 and 4 back

StripIndex	This is a completely empirical predictor. Looks at the values two back and four back in the stream, and uses the stride between these two values to predict the current value if and only if the stride lays between -8 and 8 *noninclusive*, else it predicts the value as the one two back plus two. In pseudo-code form the predicted values is computed as follows:
	`if(val2back - val4back < 8 && val2back - val4back > -8)`
	`      iPredicted = val2back + (val2back - val4back);`
	`else`
	`      iPredicted = val2back + 2;`

Ramp	Predict value “i” as values “i’s” index
Xor1	Predict as last, but use XOR instead of subtract to compute residual
Xor2	Predict as value before last, but use XOR instead of subtract to compute residual
NULL	No prediction applied

Each predictor type can be combined with additional processing steps, and in such case the predictor type is prefixed with “Combined:”. For example, “Combined:Lag1” means that predictor type “Lag1” is combined with additional preprocessing steps. Additional description about the processing steps is provided whenever such combined predictor is used.

“Data Type : Field Name” . This format for titling the diagram symbol indicates that the data is both compressed and encoded. The Data_Type is an abbreviated data type symbol as defined in 6.2 Data Types and usually represent a vector/array of data. How the data is compressed and encoded into the Data Type is indicated by a CODEC type and other information stored before the particular data in the file. In the example below the Data_Type is “VecU32” and Field_Name is “CodeText.”

VecU32 : CodeText

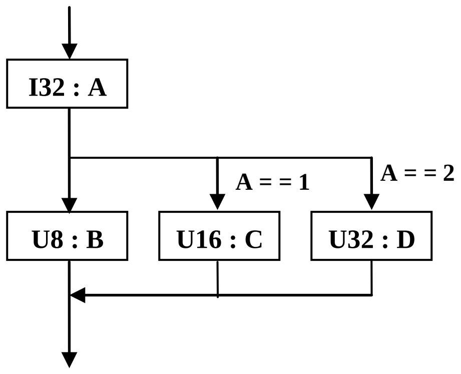
Note that for some JT file Segment Types there is ZLIB compression also applied to all bytes of element data stored in the segment. This ZLIB compression applied to all the segment’s data is not indicated in the diagrams through the use of "rectangle box with clipped right side corners". Instead, one must examine information stored with the first Element in the file segment to determine if ZLIB compression is applied to all data in the segment. A complete description of the JT format data compression and encoding can be found in 7.1.3 Data Segment and 8 Data Compression and Encoding.

Following each data collection diagram is detailed descriptions for each entry in the data diagram.

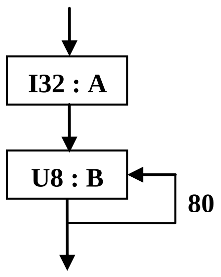
For rectangles this detail includes the abbreviated data type symbol, field name, verbal data description, and compression technique/algorithm where appropriate. If the data field is documented as a collection of flags, then the field is to be treated as a bit mask where the bit mask is formed by combining the flags using the binary OR operator. Each bits usage is documented, and bit ON indicates flag value is TRUE and bit OFF indicates flag value is FALSE. Any undocumented bits are reserved.

For folders (i.e. data collections), if the collection is not detailed under a sub-section of the particular document section referencing the data collection, then a comment is included following the diagram indicating where in the document the particular data collection is detailed.

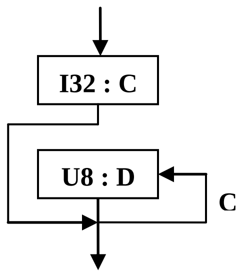
If an arrow appears with a branch in its shaft, then there are two or more options for data to be stored in the file. Which data is stored will depend on information previously read from the file. The following example shows data field A followed by (depending on value of A) either data field B, C, or D.



In cases where the same data type repeats, a loop construct is used where the number of iterations appears next to the loop line. There are two forms of this loop construct. The first form is used when the number of iterations is not controlled by some previous read count value. Instead the number of iterations is either a hard coded count (e.g. always 80 characters) or is indicated by some end-of-list marker in the data itself (thus the count is always minimum of 1). This first form of the loop construct looks as follows:



The second form of this loop construct is used when the number of iterations is based on data (e.g. count) previously read from the file. In this case it is valid for there to be zero data iterations (zero count). This second from of the loop construct looks as follows (data field D is repeated C value times).



6.2 Data Types

The data types that can occur in the JT binary files are listed in the following two tables.

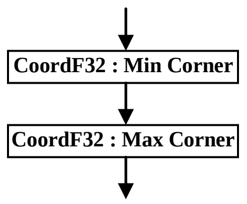
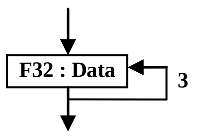
Table 1: Basic Data Types lists the basic/standard data types which can occur in JT file.

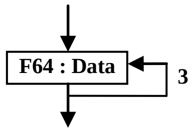
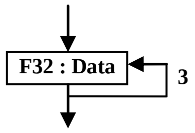
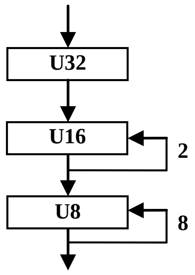
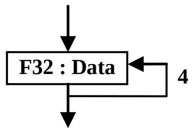
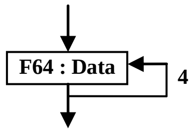
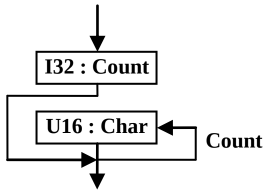
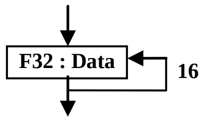
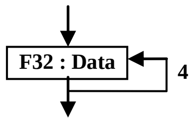
Table 1: Basic Data Types

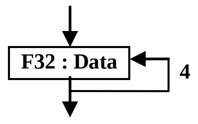
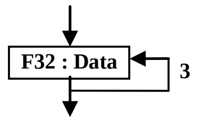
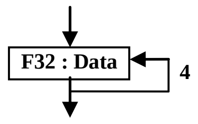
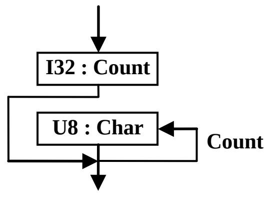
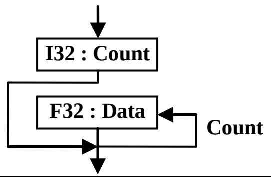
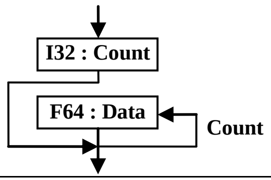
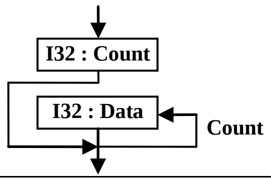
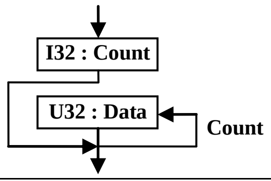
Type	Description
UChar	An unsigned 8-bit byte.
U8	An unsigned 8-bit integer value.
U16	An unsigned 16-bit integer value.
U32	An unsigned 32-bit integer value.
U64	An unsigned 64-bit integer value.
I16	A signed two’s complement 16-bit integer value.
I32	A signed two’s complement 32-bit integer value.
I64	A signed two's complement 64-bit integer value.
F32	An IEEE 32-bit floating point number.
F64	An IEEE 64-bit double precision floating point number

Table 2: Composite Data Types lists some composite data types which are used to represent some frequently occurring groupings of the basic data types (e.g. Vector, RGBA color). The composite data types are defined in this reference simply for convenience/brevity in describing the JT file contents.

Table 2: Composite Data Types

Type	Description	Symbolic Diagram
BBoxF32	The BBoxF32 type defines a bounding box using two CoordF32 types to store the XYZ coordinates for the bounding box minimum and maximum corner points.	
CoordF32	The CoordF32 type defines X, Y, Z coordinate values. So a CoordF32 is made up of three F32 base types.	

Type	Description	Symbolic Diagram
CoordF64	The CoordF64 type defines X, Y, Z coordinate values. So a CoordF64 is made up of three F64 base types.	
DirF32	The DirF32 type defines X, Y, Z components of a direction vector. So a DirF32 is made up of three F32 base types.	
GUID	The GUID type is a 16 byte (128-bit) number. GUID is stored/written to the JT file using a four-byte word (U32), 2 two-byte words (U16), and 8 one-byte words (U8) such as: {3F2504E0-4F89-11D3-9A-0C-03-05-E8-2C-33-01} In the JT format GUIDs are used as unique identifiers (e.g. Data Segment ID, Object Type ID, etc.)	
HCoordF32	The HCoordF32 type defines X, Y, Z, W homogeneous coordinate values. So an HCoordF32 is made up of four F32 base types.	
HCoordF64	The HCoordF64 type defines X, Y, Z, W homogeneous coordinate values. So an HCoordF64 is made up of four F64 base types	
MbString	The MbString type starts with an I32 that defines the number of characters (NumChar) the string contains. The number of bytes of character data is "2 * NumChar" (i.e. the strings are written out as multi-byte characters where each character is U16 size).	
Mx4F32	Defines a 4-by-4 matrix of F32 values for a total of 16 F32 values. The values are stored in row major order (right most subscript, column varies fastest), that is, the first 4 elements form the first row of the matrix.	
PlaneF32	The PlaneF32 type defines a geometric Plane using the General Form of the plane equation (Ax + By + Cz + D = 0). The PlaneF32 type is made up of four F32 base types where the first three F32 define the plane unit normal vector (A, B, C) and the last F32 defines the negated perpendicular distance (D), along normal vector, from the origin to the plane.	
Quaternion	The Quaternion type defines a 3-dimensional orientation (no translation) in quaternion linear combination form (a + b***i*** + c***j*** + d***k***) where the four scalar values (a, b, c, d) are associated with the 4 dimensions of a quaternion (1 real dimension, and 3 imaginary dimensions). So the Quaternion type is made up of	

Type	Description	Symbolic Diagram
	four F32 base types.	
RGB	The RGB type defines a color composed of Red, Green, Blue components, each of which is a F32. So a RGB type is made up of three F32 base types. The Red, Green, Blue color values typically range from 0.0 to 1.0.	
RGBA	The RGBA type defines a color composed of Red, Green, Blue, Alpha components, each of which is a F32. So a RGBA type is made up of four F32 base types. The Red, Green, Blue color values typically range from 0.0 to 1.0. The Alpha value ranges from 0.0 to 1.0 where 1.0 indicates completely opaque.	
String	The String type starts with an I32 that defines the number of characters (NumChar) the string contains. The number of bytes of character data is "NumChar" (i.e. the strings are written out as single-byte characters where each character is U8 size).	
VecF32	The VecF32 type defines a vector/array of F32 base type. The type starts with an I32 that defines the count of following F32 base type data. So a VecF32 is made up of one I32 followed by that number of F32. Note that it is valid for the I32 count number to be equal to "0", indicating no following F32.	
VecF64	The VecF64 type defines a vector/array of F64 base type. The type starts with an I32 that defines the count of following F64 base type data. So a VecF64 is made up of one I32 followed by that number of F64. Note that it is valid for the I32 count number to be equal to "0", indicating no following F64.	
VecI32	The VecI32 type defines a vector/array of I32 base type. The type starts with an I32 that defines the count of following I32 base type data. So a VecI32 is made up of one I32 followed by that number of I32. Note that it is valid for the I32 count number to be equal to "0", indicating no following I32.	
VecU32	The VecU32 type defines a vector/array of U32 base type. The type starts with an I32 that defines the count of following U32 base type data. So a VecU32 is made up of one I32 followed by that number of U32. Note that it is valid for the I32 count number to be equal to "0", indicating no following U32.	

7 File Format

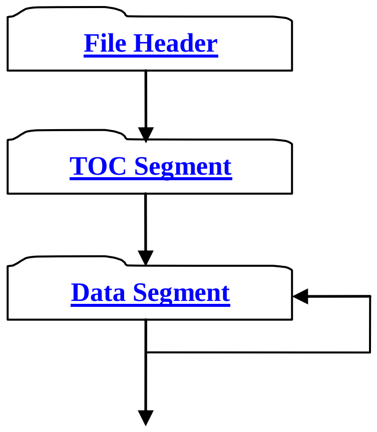
All objects represented in the JT format are assigned an "object identifier" (e.g. see 7.2.1.1.1.1.1 Base Node Data, or 7.2.1.1.2.1.1 Base Attribute Data) and all references from one object to another object are represented in the JT format using the referenced object's "object identifier". It is the responsibility of JT format readers/writers to maintain the integrity of these object references by doing appropriate pointer unswizzling/swizzling as JT format data is read into memory or written out to disk. Where “pointer swizzling” refers to the process of converting references based on object identifiers into direct memory pointer references and “pointer unswizzling” is the reverse operation (i.e. replacing references based on memory pointers with object identifier references).

7.1 File Structure

A JT file is structured as a sequence of blocks/segments. The File Header block is always the first block of data in the file. The File Header is followed (in no particular order) by a TOC Segment and a series of other Data Segments. The one Data Segment which must always exist to have a reference compliant JT file is the 7.2.1 LSG Segment.

The TOC Segment is located within the file using data stored in the File Header. Within the TOC Segment is information that locates all other Data Segments within the file. Although there are no JT format compliance rules about where the TOC Segment must be located within the file, in practice the TOC Segment is typically located either immediately following the File header (as shown in the below Figure) or at the very end of the file following all other Data Segments.

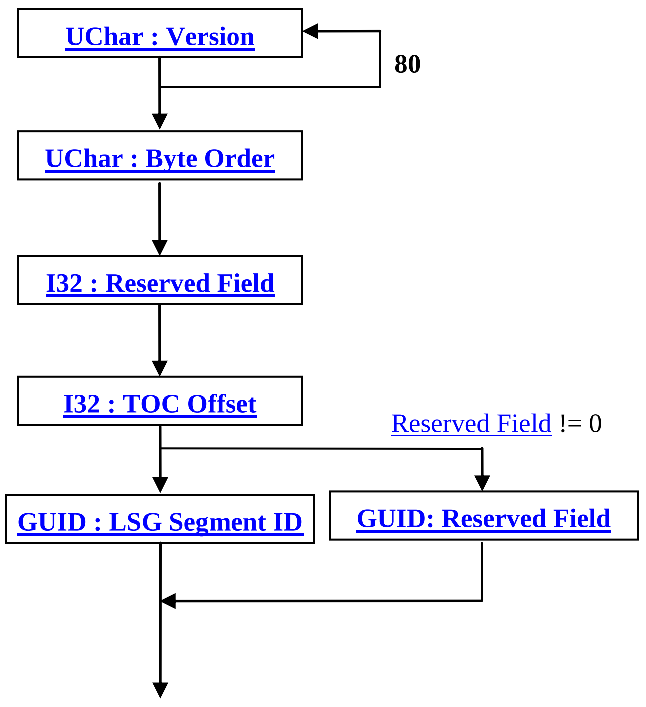
Figure 1: JT File Structure



7.1.1 File Header

The File Header is always the first block of data in a JT file. The File Header contains information about the JT file version and TOC location, which Loaders use to determine how to read the file. The exact contents of the File Header are as follows:

Figure 2: File Header data collection



UChar : Version

An 80-character version string defining the version of the file format used to write this file. The Version string has the following format:

Version ***M.n Comment***

Where ***M*** is replaced by the major version number, ***n*** is replaced by the minor version number, and ***Comment*** provides other unspecified reserved information. The string with the following format is commonly used as ***Comment*** to indicate the DM library version that was used to write this JT file:

DM ***Maj.Min.Qrm.Irm***

Where ***Maj***, ***Min***, ***Qrm***, and ***Irm*** are replaced by the major, minor, QRM, and IRM numbers respectively.

The version string is padded with spaces to a length of 75 ASCII characters and then the final five characters must be filled with the following linefeed and carriage return character combination (shown using c-style syntax):

```
Version[75] = ' '
Version[76] = '\n'
Version[77] = '\r'
Version[78] = '\n'
Version[79] = ' '
```

These final 5 characters (shown above and referred to as ASCII/binary translation detection bytes) can be used by JT file readers to validate that the JT files has not been corrupted by ASCII mode FTP transfers. For a JT Version 9.5 file written by DM library version 7.3.4.0 this string will look as follows:

"Version 9.5 JT DM 7.3.4.0   \n\r\n "

UChar : Byte Order

Defines the file byte order and thus can be used by the loader to determine if there is a mismatch (thus byte swapping required) between the file byte order and the machine (on which the loader is being run) byte order. Valid values for Byte Order are:

0 – Least Significant byte first (LsbFirst)

1 – Most Significant byte first (MsbFirst)

I32 : Reserved Field

Must have the value 0.

I32 : TOC Offset

Defines the byte offset from the top of the file to the start of the TOC Segment.

GUID : LSG Segment ID

LSG Segment ID specifies the globally unique identifier for the Logical Scene Graph Data Segment in the file. This ID along with the information in the TOC Segment can be used to locate the start of LSG Data Segment in the file. This ID is needed because without it a loader would have no way of knowing the location of the root LSG Data Segment. All other Data Segments must be accessible from the root LSG Data Segment.

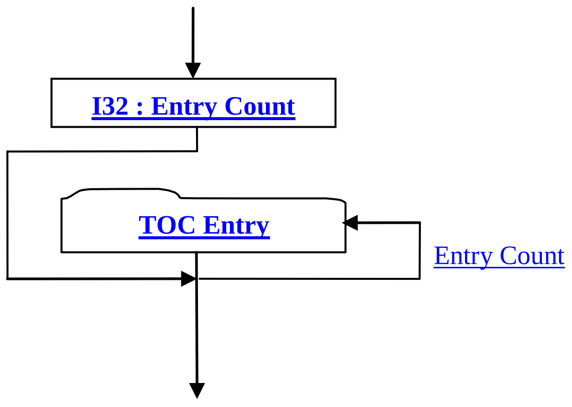
GUID: Reserved Field

Reserved Field is a data field reserved for future JT format expansion

7.1.2 TOC Segment

The TOC Segment contains information identifying and locating all individually addressable Data Segments within the file. A TOC Segment is always required to exist somewhere within a JT file. The actual location of the TOC Segment within the file is specified by the File Header segment's "TOC Offset" field. The TOC Segment contains one TOC Entry for each individually addressable Data Segment in the file.

Figure 3: TOC Segment data collection



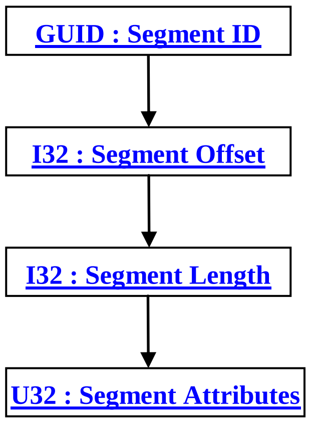
I32 : Entry Count

Entry Count is the number of entries in the TOC.

7.1.2.1 TOC Entry

Each TOC Entry represents a Data Segment within the JT File. The essential function of a TOC Entry is to map a Segment ID to an absolute byte offset within the file.

Figure 4: TOC Entry data collection



GUID : Segment ID

Segment ID is the globally unique identifier for the segment.

I32 : Segment Offset

Segment Offset defines the byte offset from the top of the file to start of the segment.

I32 : Segment Length

Segment Length is the total size of the segment in bytes.

U32 : Segment Attributes

Segment Attributes is a collection of segment information encoded within a single U32 using the following bit allocation.

Bits 0 - 23	Reserved for future use.
Bits 24 - 31	Segment type. Complete list of Segment types can be found in Table 3: Segment Types.

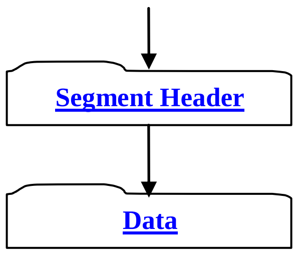
7.1.3 Data Segment

All data stored in a JT file must be defined within a Data Segment. Data Segments are “typed” based on the general classification of data they contain. See Segment Type field description below for a complete list of the segment types.

Beyond specific data field compression/encoding, some Data Segment types also have a ZLIB compression conditionally applied to all the Data bytes of information persisted within the segment. Whether ZLIB compression is conditionally applied to a segment’s Data bytes of information is indicated by information stored with the first “Element” in the segment. Also Table 3: Segment Types has a column indicating whether the Segment Type may have ZLIB compression applied to its Data bytes.

All Data Segments have the same basic structure.

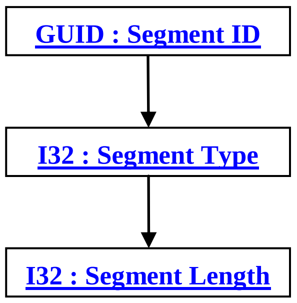
Figure 5: Data Segment data collection



7.1.3.1 Segment Header

Segment Header contains information that determines how the remainder of the Segment is interpreted by the loader.

Figure 6: Segment Header data collection



GUID : Segment ID

Global Unique Identifier for the segment.

I32 : Segment Type

Segment Type defines a broad classification of the segment contents. For example, a Segment Type of “1” denotes that the segment contains Logical Scene Graph material; “2” denotes contents of a B-Rep, etc.

The complete list of segment types is as follows. The column labeled "ZLIB Applied?" denotes whether ZLIB compression is conditionally applied to the entirety of the segment's Data payload.

Table 3: Segment Types

Type	Data Contents	ZLIB Applied?
1	Logical Scene Graph	Yes
2	JT B-Rep	Yes
3	PMI Data	Yes
4	Meta Data	Yes
6	Shape	No
7	Shape LOD0	No
8	Shape LOD1	No
9	Shape LOD2	No
10	Shape LOD3	No
11	Shape LOD4	No
12	Shape LOD5	No
13	Shape LOD6	No
14	Shape LOD7	No
15	Shape LOD8	No

Type	Data Contents	ZLIB Applied?
16	Shape LOD9	No
17	XT B-Rep	Yes
18	Wireframe Representation	Yes
20	ULP	Yes
24	LWPA	Yes

Note: Segment Types 7-16 all identify the contents as LOD Shape data, where the increasing type number is intended to convey some notion of how high an LOD the specific shape segment represents. The lower the type in this 7-16 range the more detailed the Shape LOD (i.e. Segment Type 7 is the most detailed Shape LOD Segment). For the rare case when there are more than 10 LODs, LOD9 and greater are all assigned Segment Type 16.

Note: The more generic Shape Segment type (i.e. Segment Type 6) is used when the Shape Segment has one or more of the following characteristics:

- Not a descendant of an LOD node,
- Is referenced by (i.e. is a child of) more than one LOD node,
- Shape has its own built-in LODs, and
- No way to determine what LOD a Shape Segment represents.

I32 : Segment Length

Segment Length is the total size of the segment in bytes. This length value includes all segment Data bytes plus the Segment Header bytes (i.e. it is the size of the complete segment) and should be equal to the length value stored with this segment's TOC Entry.

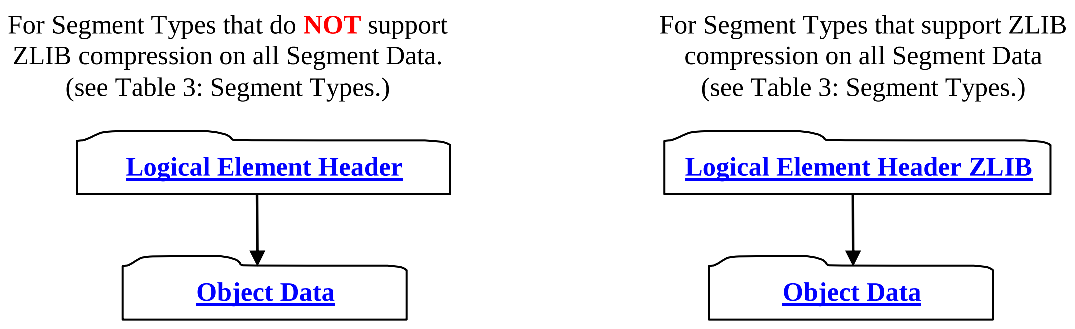
7.1.3.2 Data

The interpretation of the Data section depends on the Segment Type. See 7.2 Data Segments for complete description for all Data Segment that may be contained in a JT file.

Although the Data section is Segment Type dependent there is a common structure which often occurs within the Data section. This structure is a list or multiple lists of Elements where each Element has the same basic structure which consists of some fixed length header information describing the type of object contained in the Element, followed by some variable length object type specific data.

Individual data fields of an Element data collection (and its children data collections) may have advanced compression/encoding applied to them as indicated through compression related data values stored as part of the particular Element's storage format. In addition, another level of compression (i.e. ZLIB compression) may be conditionally applied to all bytes of information stored for all Elements within a particular Segment. Not all Segment types support ZLIB compression on all Segment data as indicated in Table 3: Segment Types. If a particular file Segment is of the type which supports ZLIB compression on all the Segment data, whether this compression is applied or not is indicated by data values stored in the Logical Element Header ZLIB data collection of the first Element within the Segment. An in-depth description of JT file compression/encoding techniques can be found in 8 Data Compression and Encoding.

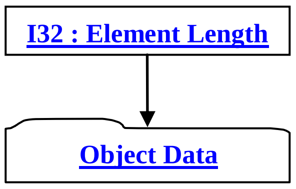
Figure 7: Data collection


For Segment Types that do NOT support ZLIB compression on all Segment Data. (see Table 3: Segment Types.)
Logical Element Header
Object Data
For Segment Types that support ZLIB compression on all Segment Data (see Table 3: Segment Types.)
Logical Element Header ZLIB
Object Data

7.1.3.2.1 Logical Element Header

Logical Element Header contains data defining the length in bytes of the Element along with the Element Header.

Figure 8: Logical Element Header data collection



Complete description for Logical Element Header can be found in 7.1.3.2.2 Element Header.

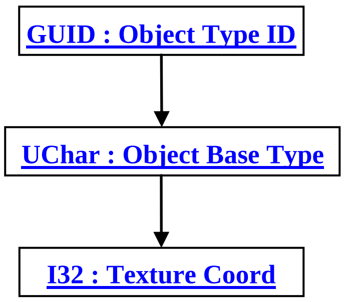
I32 : Element Length

Element Length is the total length in bytes of the element Object Data.

7.1.3.2.2 Element Header

Element Header contains data describing the object type contained in the Element.

Figure 9: Element Header data collection



GUID : Object Type ID

Object Type ID is the globally unique identifier for the object type. A complete list of the assigned GUID for all object types stored in a JT file can be found in Appendix A: Object Type Identifiers.

UChar : Object Base Type

Object Base Type identifies the base object type. This is useful when an unknown element type is encountered and thus the best the loader can do is to read the known Object Base Type data bytes (base type object data is always written first) and then skip (read pass) the bytes of unknown data using knowledge of number of bytes encompassing the Object Base Type data and the unknown types Length field. If the Object Base Type is unknown then the loader should simply skip (read pass) Element Length number of bytes.

Valid Object Base Types include the following:

Table 4: Object Base Types

Base Type	Description	Base Type's Data Format
255	Unknown Graph Node Object	none
0	Base Graph Node Object	7.2.1.1.1.1.1 Base Node Data
1	Group Graph Node Object	7.2.1.1.1.3.1Group Node Data
2	Shape Graph Node Object	7.2.1.1.1.10.1.1 Base Shape Data
3	Base Attribute Object	7.2.1.1.2.1.1 Base Attribute Data
4	Shape LOD	none

Base Type	Description	Base Type's Data Format
5	Base Property Object	7.2.1.2.1.1 Base Property Atom Data
6	JT Object Reference Object	7.2.1.2.5 JT Object Reference Property Atom Element without the Logical Element Header ZLIB data collection.
8	JT Late Loaded Property Object	0 Late Loaded Property Atom Element without the Logical Element Header ZLIB data collection.
9	JtBase (none)	none

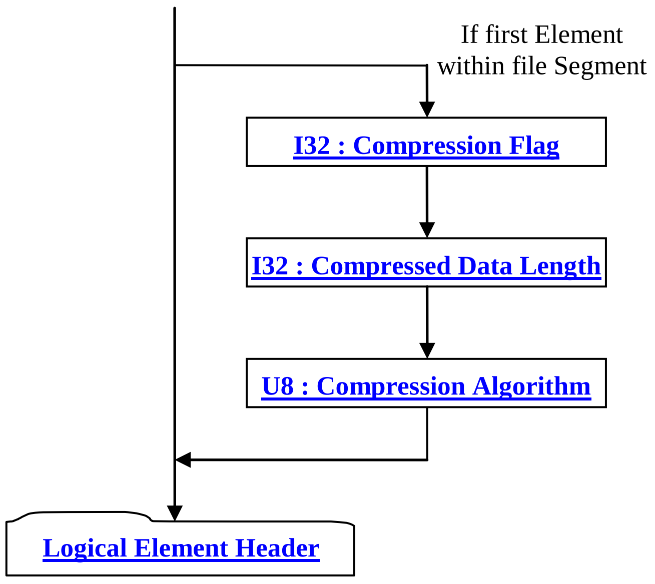
I32 : Object ID

Object ID is the identifier for this Object. Other objects referencing this particular object do so using the Object ID.

7.1.3.2.3 Logical Element Header ZLIB

Logical Element Header ZLIB data collection is the format of Element Header data used by all Elements within Segment Types that support ZLIB compression on all data in the Segment. See Table 3: Segment Types for information on whether a particular Segment Type supports ZLIB compression on all data in the Segment.

Figure 10: Logical Element Header ZLIB data collection


If first Element within file Segment
I32 : Compression Flag
I32 : Compressed Data Length
U8 : Compression Algorithm
Logical Element Header

Complete description for Logical Element Header can be found in 7.1.3.2.1 Logical Element Header. Note that if Compression Flag indicates that ZLIB compression is ON for all element data in the Segment, then the Logical Element Header data collection is also compressed accordingly.

I32 : Compression Flag

Compression Flag is a flag indicating whether ZLIB compression is ON/OFF for all data elements in the file Segment. Valid values include the following:

= 2	ZLIB compression is ON
!= 2	ZLIB compression is OFF.

I32 : Compressed Data Length

Compressed Data Length specifies the compressed data length in number of bytes. Note that data field Compression Algorithm is included in this count.

U8 : Compression Algorithm

Compression Algorithm specifies the compression algorithm applied to all data in the Segment. Valid values include the following:

= 1	No compression
= 2	ZLIB compression

7.1.3.2.4 Object Data

The interpretation of the Object Data section depends upon the Object Type ID stored in the Logical Element Header (see 7.1.3.2.1 Logical Element Header).

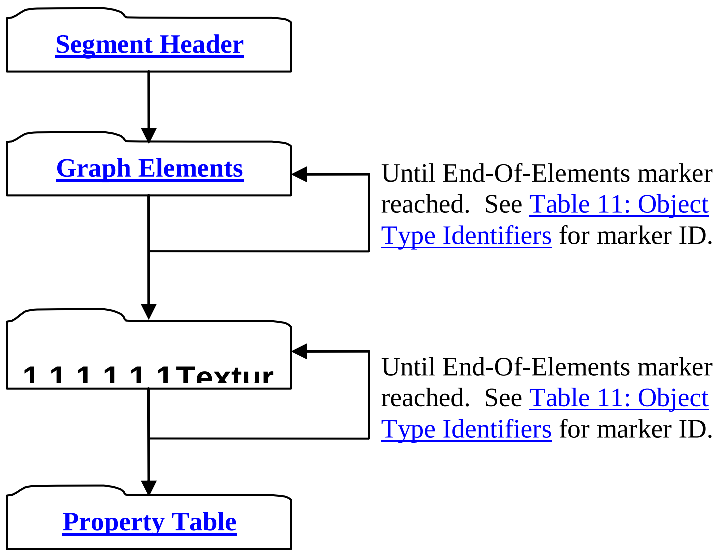
7.2 Data Segments

7.2.1 LSG Segment

LSG Segment contains a collection of objects (i.e. Elements) connected through directed references to form a directed acyclic graph structure (i.e. the LSG). The LSG is the graphical description of the model and contains graphics shapes and attributes representing the model's physical components, properties identifying arbitrary metadata (e.g. names, semantic roles) of those components, and a hierarchical structure expressing the component relationships. The "directed" nature of the LSG references implies that there is by default "state/attribute" inheritance from ancestor to descendant (i.e. predecessor to successor). It is the responsibility of the loader to insure that the acyclic property of the resulting LSG is maintained.

The first Graph Element in a LSG Segment should always be a Partition Node. The LSG Segment type supports ZLIB compression on all element data, so all elements in LSG Segment use the Logical Element Header ZLIB form of element header data.

Figure 11: LSG Segment data collection


Segment Header
Graph Elements
Until End-Of-Elements marker reached. See Table 11: Object Type Identifiers for marker ID.
1 1 1 1 1 1 Textur
Until End-Of-Elements marker reached. See Table 11: Object Type Identifiers for marker ID.
Property Table

Complete description for Segment Header can be found in 7.1.3.1Segment Header.

7.2.1.1 Graph Elements

Graph Elements form the backbone of the LSG directed acyclic graph structure and in doing so serve as the JT model's fundamental description. There are two general classifications of Graph elements, Node Elements and Attribute Elements.

Node Elements are nodes in the LSG and in general can be categorized as either an internal or leaf node. The leaf nodes are typically shape nodes used to represent a model's physical components and as such either contain or reference some graphical representation or geometry. The internal nodes define the hierarchical organization of the leaf nodes, forming both spatial and logical model relationships, and often contain or reference information (e.g. Attribute Elements) that is inherited down the LSG to all descendant nodes.

Attribute Elements represent graphical data (like appearance characteristics (e.g. color), or positional transformations) that can be attached to a node, and inherit down the LSG.

Each of these general Graph Element classifications (i.e. Node/Attribute Elements) is sub-typed into specific/concrete types based on data content and implied specialized behavior. The following sub-sections describe each of the Node and Attribute Element types.

7.2.1.1.1 Node Elements

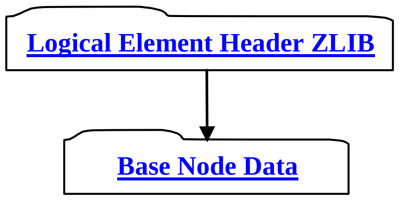
Node Elements represent the relationships of a model's components. The model's component hierarchy is formed via certain types of Node Elements containing collections of references to other Node Elements who in turn may reference other collections of Node Elements. Node Elements are also the holders (either directly or indirectly) of geometric shape, properties, and other information defining a model's components and representations.

7.2.1.1.1.1 Base Node Element

Object Type ID: 0x10dd1035, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Base Node Element represents the simplest form of a node that can exist within the LSG. The Base Node Element has no implied LSG semantic behavior nor can it contain any children nodes.

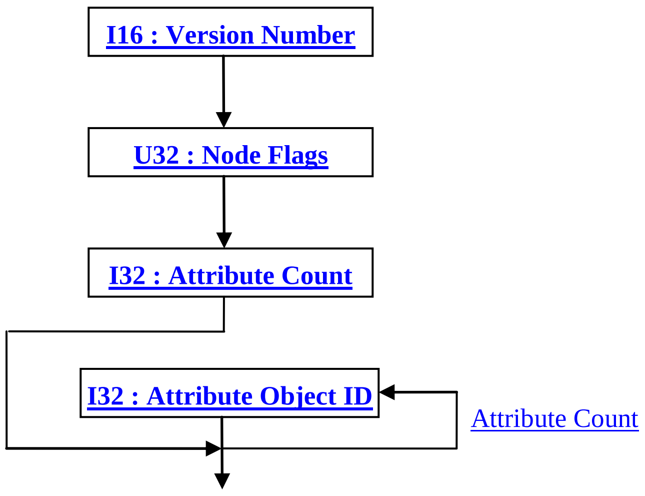
Figure 12: Base Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

7.2.1.1.1.1.1 Base Node Data

Figure 13: Base Node Data collection



I16 : Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for Base Node Data.

U32 : Node Flags

Node Flags is a collection of flags. The flags are combined using the binary OR operator. These flags store various state information of the node object. All undocumented bits are reserved.

0x00000001	Ignore Flag = 0 – Algorithms traversing the LSG structure should include/process this node. = 1 – Algorithms traversing the LSG structure should skip the whole subgraph rooted at this node. Essentially the traversal should be pruned.

I32 : Attribute Count

Attribute Count indicates the number of Attribute Objects referenced by this Node Object. A node may have zero Attribute Object references.

I32 : Attribute Object ID

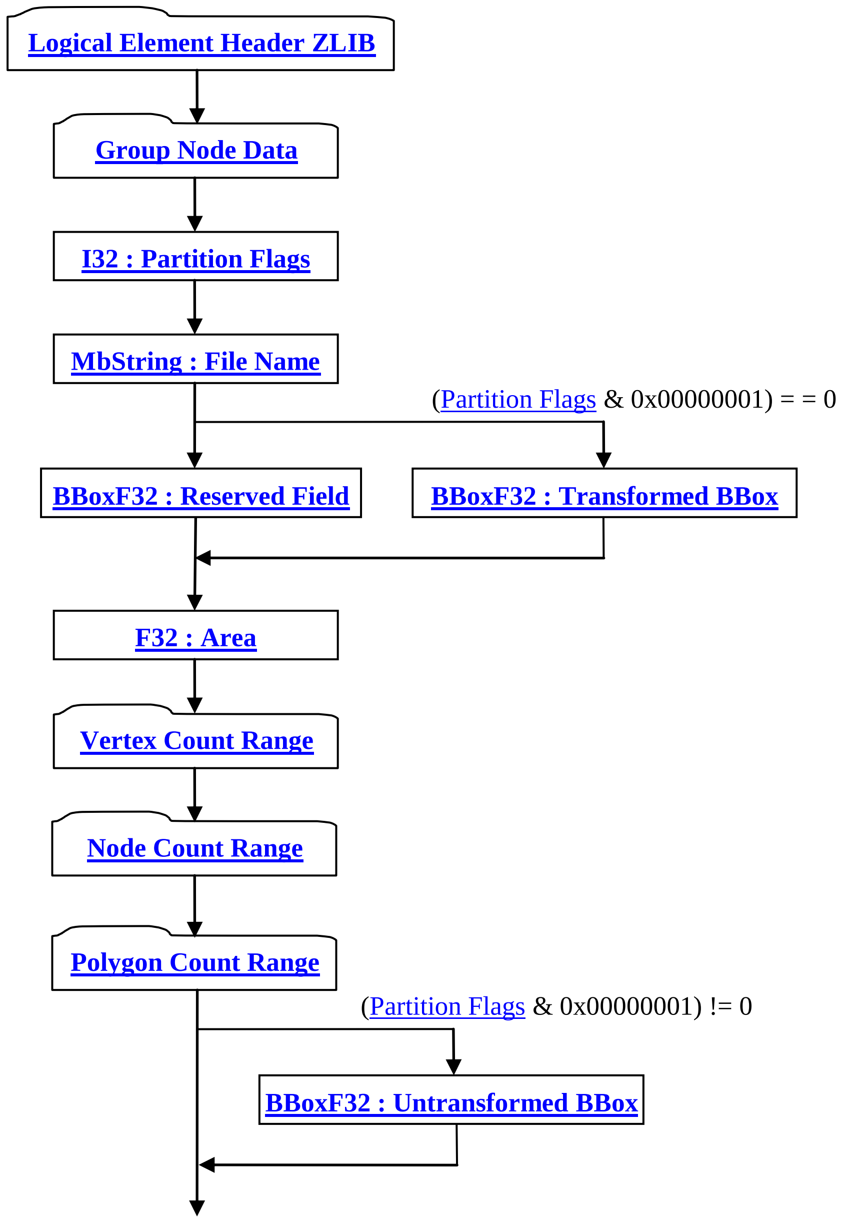
Attribute Object ID is the identifier for a referenced Attribute Object.

7.2.1.1.1.2 Partition Node Element

Object Type ID: 0x10dd103e, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

A Partition Node represents an external JT file reference and provides a means to partition a model into multiple physical JT files (e.g. separate JT file per part in an assembly). When the referenced JT file is opened, the Partition Node's children are really the children of the LSG root node for the underlying JT file. Usage of Partition Nodes in LSG also aids in supporting JT file loader/reader "best practice" of late loading data (i.e. can delay opening and loading the externally referenced JT file until the data is needed).

Figure 14: Partition Node Element data collection


Logical Element Header ZLIB
Group Node Data
I32 : Partition Flags
MbString : File Name
(Partition Flags & 0x00000001) = = 0
BBoxF32 : Reserved Field
BBoxF32 : Transformed BBox
F32 : Area
Vertex Count Range
Node Count Range
Polygon Count Range
(Partition Flags & 0x00000001) != 0
BBoxF32 : Untransformed BBox

Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Group Node Data can be found in 7.2.1.1.1.3.1Group Node Data.

I32 : Partition Flags

Partition Flags is a collection of flags. The flags are combined using the binary OR operator. These flags store various state information of the Partition Node Object such as indicating the presence of optional data. All undocumented bits are reserved.

0x00000001	Untransformed bounding box is written.

MbString : File Name

File Name is the relative path portion of the Partition's file location. Where "relative path" should be interpreted to mean the string contains the file name along with any additional path information that locates the partition JT file relative to the location of the referencing JT file

BBoxF32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion

BBoxF32 : Transformed BBox

The Transformed BBox is an NCS axis aligned bounding box and represents the transformed geometry extents for all geometry contained in the Partition Node. This bounding box information may be used by a renderer of JT data to determine whether to load the data contained within the Partition node (i.e. is any part of the bounding box within the view frustum).

F32 : Area

Area is the total surface area for this node and all of its descendents. This value is stored in NCS coordinate space (i.e. values scaled by NCS scaling).

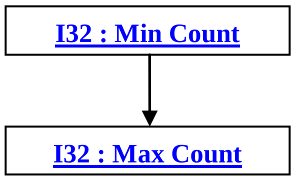
BBoxF32 : Untransformed BBox

The Untransformed BBox is only present if Bit 0x00000001 of Partition Flags data field is ON. The Untransformed BBox is an LCS axis-aligned bounding box and represents the untransformed geometry extents for all geometry contained in the Partition Node. This bounding box information may be used by a renderer of JT data to determine whether to load the data contained within the Partition node (i.e. is any part of the bounding box within the view frustum).

7.2.1.1.1.2.1 Vertex Count Range

Vertex Count Range is the aggregate minimum and maximum vertex count for all descendants of the Partition Node. There is a minimum and maximum value to accommodate descendant branches having LOD nodes, which encompass a range of count values within the branch, and to accommodate nodes that can themselves generate varying representations. The minimum value represents the least vertex count that can be achieved by the Partition Node's descendants. The maximum value represents the greatest vertex count that can be achieved by the Partition Node's descendants.

Figure 15: Vertex Count Range data collection



I32 : Min Count

Min Count is the least vertex count that can be achieved by the Partition Node's descendants.

I32 : Max Count

Max Count is the maximum vertex count that can be achieved by the Partition Node's descendants.

7.2.1.1.1.2.2 Node Count Range

Node Count Range is the aggregate minimum and maximum count of all node descendants of the Partition Node. There is a minimum and maximum value to accommodate descendant branches having LOD nodes, which encompass a range of descendant node count values within the branch. The minimum value represents the least node count that can be achieved by the Partition Node's descendants. The maximum value represents the greatest node count that can be achieved by the Partition Node's descendants.

The data format for Node Count Range is the same as that described in 7.2.1.1.1.2.1Vertex Count Range.

7.2.1.1.1.2.3 Polygon Count Range

Polygon Count Range is the aggregate minimum and maximum polygon count for all descendants of the Partition Node. There is a minimum and maximum value to accommodate descendant branches having LOD nodes, which encompass a range of count values within the branch, and to accommodate nodes that can themselves generate varying representations. The minimum value represents the least polygon count that can be achieved by the Partition Node's descendants. The maximum value represents the greatest polygon count that can be achieved by the Partition Node's descendants.

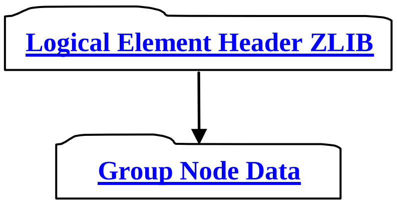
The data format for Polygon Count Range is the same as that described in 7.2.1.1.1.2.1Vertex Count Range.

7.2.1.1.1.3 Group Node Element

Object Type ID: 0x10dd101b, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Group Nodes contain an ordered list of references to other nodes, called the group's *children*. Group nodes may contain zero or more children; the children may be of any node type. Group nodes may not contain references to themselves or their ancestors.

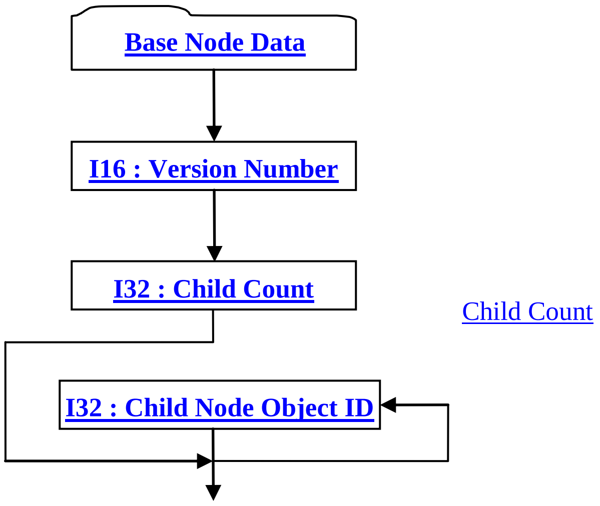
Figure 16: Group Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

7.2.1.1.1.3.1 Group Node Data

Figure 17: Group Node Data collection



Complete description for Base Node Data can be found in 7.2.1.1.1.1.1Base Node Data.

I16 : Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for Group Node Data.

I32 : Child Count

Child Count indicates the number of child nodes for this Group Node Object. A node may have zero children.

I32 : Child Node Object ID

Child Node Object ID is the identifier for the referenced Node Object.

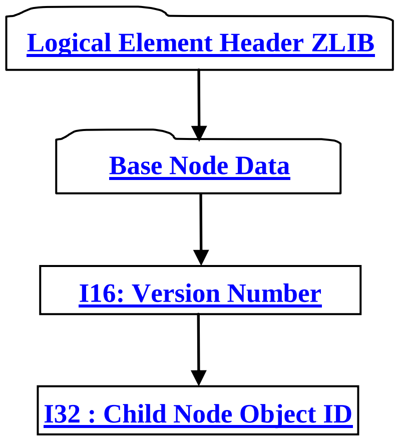
7.2.1.1.1.4 Instance Node Element

Object Type ID: 0x10dd102a, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

An Instance Node contains a single reference to another node. Their purpose is to allow sharing of nodes and assignment of instance-specific attributes for the instanced node. Instance Nodes may not contain references to themselves or their ancestors.

For example, a Group Node could use Instance Nodes to instance the same Shape Node several times, applying different material properties and matrix transformations to each instance. Note that this could also be done by using Group Nodes instead of Instance Nodes, but Instance Nodes require fewer resources.

Figure 18: Instance Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Node Data can be found in 7.2.1.1.1.1.1Base Node Data.

I16: Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for Instance Node Element.

I32 : Child Node Object ID

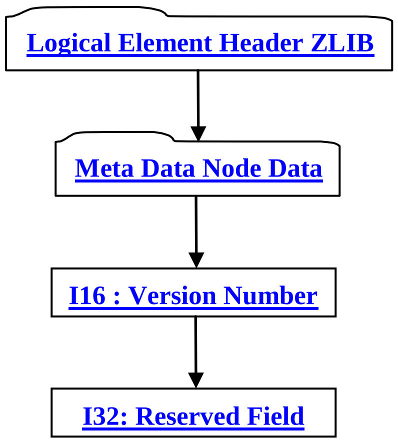
Child Node Object ID is the identifier for the instanced Node Object.

7.2.1.1.1.5 Part Node Element

Object Type ID: 0xce357244, 0x38fb, 0x11d1, 0xa5, 0x6, 0x0, 0x60, 0x97, 0xbd, 0xc6, 0xe1

A Part Node Element represents the root node for a particular Part within a LSG structure. Every unique Part represented within a LSG structure should have a corresponding Part Node Element. A Part Node Element typically references (using Late Loaded Property Atoms) additional Part specific geometric data and/or properties (e.g. B-Rep data, PMI data).

Figure 19: Part Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Meta Data Node Data can be found in 7.2.1.1.1.6.1Meta Data Node Data.

I16 : Version Number

Version Number is the version identifier for this node. Version number “0x0001” is currently the only valid value for Part nodes.

I32: Reserved Field

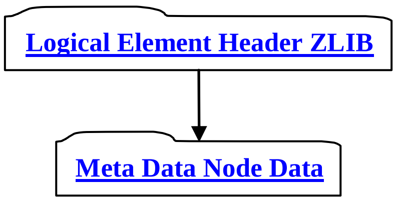
Reserved Field is a data field reserved for future JT format expansion

7.2.1.1.1.6 Meta Data Node Element

Object Type ID: 0xce357245, 0x38fb, 0x11d1, 0xa5, 0x6, 0x0, 0x60, 0x97, 0xbd, 0xc6, 0xe1

The Meta Data Node Element is a node type used for storing references to specific “late loaded” meta-data (e.g. properties, PMI). The referenced meta-data is stored in a separate addressable segment of the JT File (see 7.2.6 Meta Data Segment) and thus the use of this Meta Data Node Element is in support of the JT file loader/reader “best practice” of late loading data (i.e. storing the referenced meta-data in separate addressable segment of the JT file allows a JT file loader/reader to ignore this node’s meta-data on initial load and instead late-load the node’s meta-data upon demand so that the associated meta-data does not consume memory until needed).

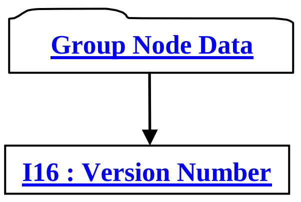
Figure 20: Meta Data Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

7.2.1.1.1.6.1 Meta Data Node Data

Figure 21: Meta Data Node Data collection



Complete description for Group Node Data can be found in 7.2.1.1.1.3.1Group Node Data.

I16 : Version Number

Version Number is the version identifier for this data. Version number “0x0001” is currently the only valid value for Meta Data Node Data.

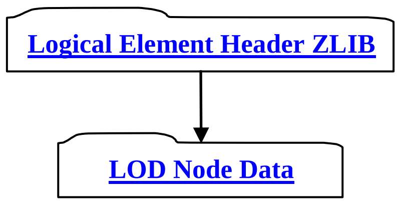
7.2.1.1.1.7 LOD Node Element

Object Type ID: 0x10dd102c, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

An LOD Node holds a list of alternate representations. The list is represented as the children of a base group node, however, there are no implicit semantics associated with the ordering. Traversers of LSG may apply semantics to the ordering as part of alternative representation selection.

Each alternative representation could be a sub-assembly where the alternative representation is a group node with an assembly of children.

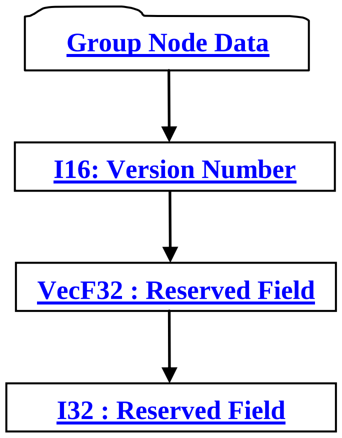
Figure 22: LOD Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

7.2.1.1.1.7.1 LOD Node Data

Figure 23: LOD Node Data collection



Complete description for Group Node Data can be found in 7.2.1.1.1.3.1Group Node Data.

I16: Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for LOD Node Data.

VecF32 : Reserved Field

Reserved Field is a vector data field reserved for future JT format expansion.

I32 : Reserved Field

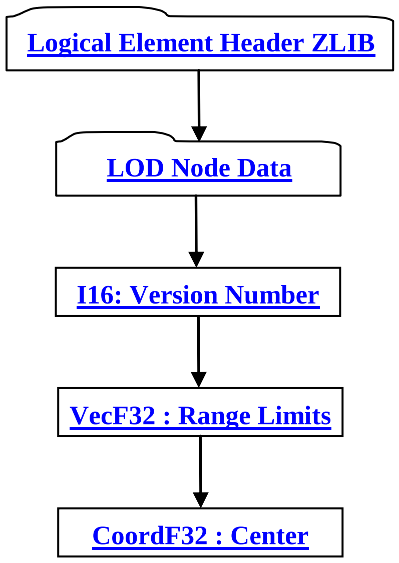
Reserved Field is a data field reserved for future JT format expansion.

7.2.1.1.1.8 Range LOD Node Element

Object Type ID: 0x10dd104c, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Range LOD Nodes hold a list of alternate representations and the ranges over which those representations are appropriate. Range Limits indicate the distance between a specified center point and the eye point, within which the corresponding alternate representation is appropriate. Traversers of LSG consult these range limit values when making an alternative representation selection.

Figure 24: Range LOD Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for LOD Node Data can be found in 7.2.1.1.1.7.1 LOD Node Data

I16: Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for Range LOD Node Data.

VecF32 : Range Limits

Range Limits indicate the WCS distance between a specified center point and the eye point, within which the corresponding alternate representation is appropriate. It is not required that the count of range limits is equivalent to the number of alternative representations. These values are considered "soft values" in that loaders/viewers of JT data are free to throw these values away and compute new values based on their desired LOD selection semantics.

Best practices suggest that LSG traversers apply the following strategy, at Range LOD Nodes, when making alternative representation selection decisions based on Range Limits: The first alternate representation is valid when the distance between the center and the eye point is less than or equal to the first range limit (and when no range limits are specified). The second alternate representation is valid when the distance is greater than the first limit and less than or equal to the second limit, and so on. The last alternate representation is valid for all distances greater than the last specified limit.

CoordF32 : Center

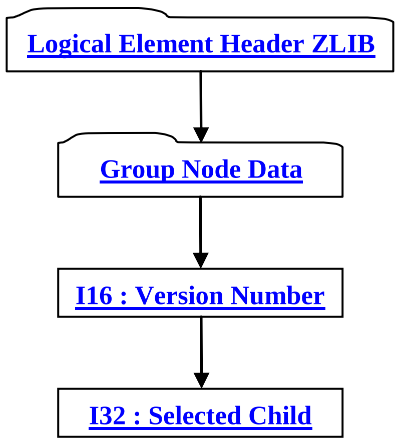
Center specifies the X,Y,Z coordinates for the NCS center point upon which alternative representation selection eye distance computations are based. Typically this location is the center of the highest-detail alternative representation. These values are considered "soft values" in that loaders/viewers of JT data are free to throw these values away and compute new values based on their desired LOD selection semantics

7.2.1.1.1.9 Switch Node Element

Object Type ID: 0x10dd10f3, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

The Switch Node is very much like a Group Node in that it contains an ordered list of references to other nodes, called the *children* nodes. The difference is that a Switch Node also contains additional data indicating which child (one or none) a LSG traverser should process/traverse.

Figure 25: Switch Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Group Node Data can be found in 7.2.1.1.1.3.1Group Node Data.

I16 : Version Number

Version Number is the version identifier for this node. Version number “0x0001” is currently the only valid value for Switch nodes.

I32 : Selected Child

Selected Child is the index for the selected child node. Valid Selected Child values reside within the following range: “-1 < Selected Child < Child Count”. Where “-1” indicates that no child is to be selected and “Child Count” is the data field value from 7.2.1.1.1.3.1Group Node Data.

7.2.1.1.1.10 Shape Node Elements

Shape Node Elements are “leaf” nodes within the LSG structure and contain or reference the geometric shape definition data (e.g. vertices, polygons, normals, etc.).

Typically Shape Node Elements do not directly contain the actual geometric shape definition data, but instead reference (using Late Loaded Property Atoms) Shape LOD Segments within the file for the actual geometric shape definition data. Storing the geometric shape definition data within separate independently addressable data segments in the JT file, allows a JT file reader to be structured to support the “best practice” of delaying the loading/reading of associated data until it is actually needed. Complete descriptions for Late Loaded Property Atom Elements and Shape LOD Segments can be found in 0 Late Loaded Property Atom Element and 7.2.2 Shape LOD Segment respectively.

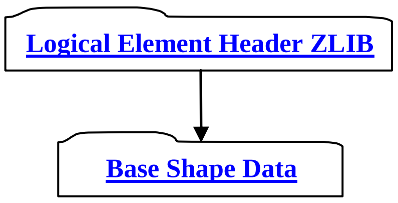
There are several types of Shape Node Elements which the JT format supports. The following sub-sections document the various Shape Node Element types.

7.2.1.1.1.10.1 Base Shape Node Element

Object Type ID: 0x10dd1059, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Base Shape Node Element represents the simplest form of a shape node that can exist within the LSG.

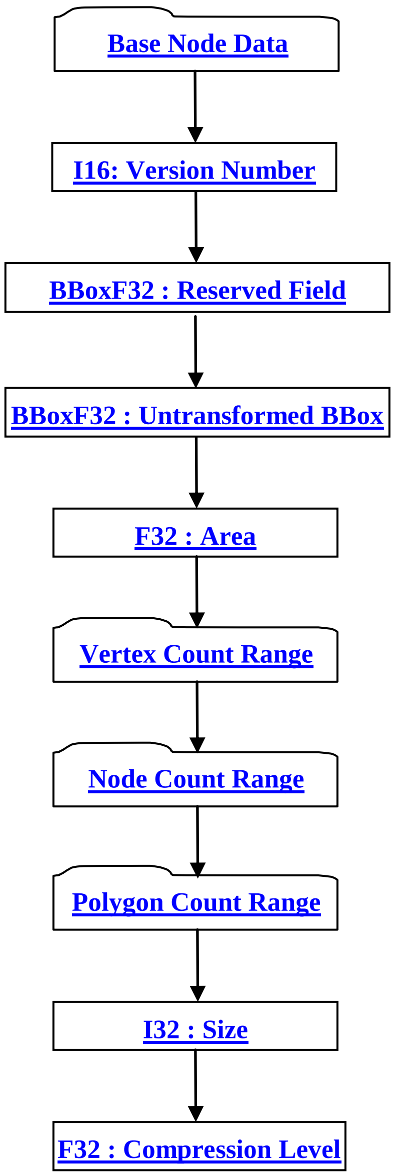
Figure 26: Base Shape Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

7.2.1.1.1.10.1.1 Base Shape Data

Figure 27: Base Shape Data collection



Complete description for Base Node Data can be found in 7.2.1.1.1.1.1Base Node Data

I16: Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for Base Shape Data.

BBoxF32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

BBoxF32 : Untransformed BBox

The Untransformed BBox is an axis-aligned LCS bounding box and represents the untransformed geometry extents for all geometry contained in the Shape Node.

F32 : Area

Area is the total surface area for this node and all of its descendents. This value is stored in NCS coordinate space (i.e. values scaled by NCS scaling).

I32 : Size

Size specifies the in memory length in bytes of the associated/referenced Shape LOD Element. This Size value has no relevancy to the on-disk (JT File) size of the associated/referenced Shape LOD Element. A value of zero indicates that the in memory size is unknown. See 7.2.2.1Shape LOD Element for complete description of Shape LOD Elements. JT file loaders/readers can leverage this Size value during late load processing to help pre-determine if there is sufficient memory to load the Shape LOD Element.

F32 : Compression Level

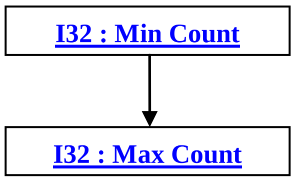
Compression Level specifies the qualitative compression level applied to the associated/referenced Shape LOD Element. See 7.2.2.1Shape LOD Element for complete description of Shape LOD Elements. This compression level value is a qualitative representation of the compression applied to the Shape LOD Element. The absolute compression (derived from this qualitative level) applied to the Shape LOD Element is physically represented in the JT format by other data stored with both the Shape Node and the Shape LOD Element (e.g. 7.2.1.1.1.10.2.1.1Quantization Parameters), and thus it's not necessary to understand how to map this qualitative value to absolute compression values in order to uncompress/decode the data

= 0.0	"Lossless" compression used.
= 0.1	"Minimally Lossy" compression used. This setting generally results in modest compression ratios with little if any visual difference when compared to the same images rendered from "Lossless" compressed Shape LOD Element.
= 0.5	"Moderate Lossy" compression used. The setting results in more data loss than "Minimally Lossy" and thus higher compression ratio is obtained. Some visual difference will likely be noticeable when compared to the same images rendered from "Lossless" compressed Shape LOD Element.
= 1.0	"Aggressive Lossy" compression used. With this setting as much data as possible will be thrown away, resulting in highest compression ratio, while still maintaining a modestly useable representation of the underlying data. Visual differences may be evident when compared to the same images rendered from "Lossless" compressed Shape LOD Element.

7.2.1.1.1.10.1.1.1 Vertex Count Range

Vertex Count Range is the aggregate minimum and maximum vertex count for this Shape Node. There is a minimum and maximum value to accommodate shape types that can themselves generate varying representations. The minimum value represents the least vertex count that can be achieved by the Shape Node. The maximum value represents the greatest vertex count that can be achieved by the Shape Node.

Figure 28: Vertex Count Range data collection



I32 : Min Count

Min Count is the least vertex count that can be achieved by this Shape Node.

I32 : Max Count

Max Count is the maximum vertex count that can be achieved by this Shape Node. A value of "-1" indicates maximum vertex count is unknown.

7.2.1.1.1.10.1.1.2 Node Count Range

Node Count Range is the aggregate minimum and maximum count of all node descendants of the Shape Node. The minimum value represents the least node count that can be achieved by the Shape Node's descendants. The maximum value represents the greatest node count that can be achieved by Shape Node's descendants. For Shape Nodes the minimum and maximum count values should always be equal to "1".

The data format for Node Count Range is the same as that described in 7.2.1.1.1.10.1.1.1Vertex Count Range.

7.2.1.1.1.10.1.1.3 Polygon Count Range

Polygon Count Range is the aggregate minimum and maximum polygon count for this Shape Node. There is a minimum and maximum value to accommodate shape types that can themselves generate varying representations. The minimum value represents the least polygon count that can be achieved by the Shape Node. The maximum value represents the greatest polygon count that can be achieved by the Shape Node.

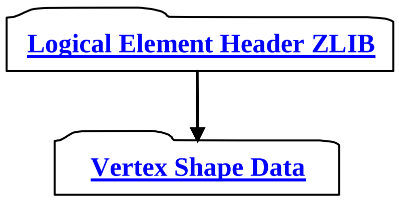
The data format for Polygon Count Range is the same as that described in 7.2.1.1.1.10.1.1.1Vertex Count Range.

7.2.1.1.1.10.2 Vertex Shape Node Element

Object Type ID: 0x10dd107f, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Vertex Shape Node Element represents shapes defined by collections of vertices.

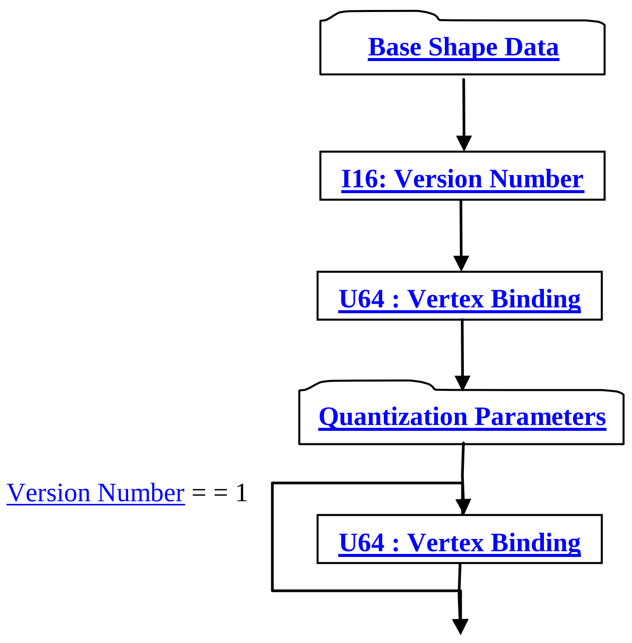
Figure 29: Vertex Shape Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

7.2.1.1.1.10.2.1 Vertex Shape Data

Figure 30: Vertex Shape Data collection



Complete description for Base Shape Data can be found in 7.2.1.1.1.10.1.1 Base Shape Data.

I16: Version Number

Version Number is the version identifier for this node. Version number "0x0002" is currently the highest valid value for Vertex Shape Data.

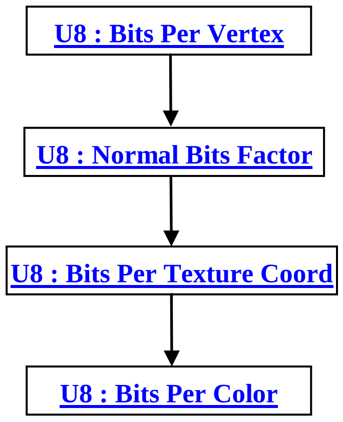
U64 : Vertex Binding

Vertex Bindings is a collection of normal, texture coordinate, and color binding information encoded within a single U64. All undocumented bits are reserved. For more information see Vertex Shape LOD Data U64 : Vertex Bindings.

7.2.1.1.1.10.2.1.1 Quantization Parameters

Quantization Parameters specifies for each shape data type grouping (i.e. Vertex, Normal, Texture Coordinates, Color) the number of quantization bits used for given qualitative compression level. Although these Quantization Parameters values are saved in the associated/referenced Shape LOD Element, they are also saved here so that a JT File loader/reader does not have to load the Shape LOD Element in order to determine the Shape quantization level. See 7.2.2.1Shape LOD Element for complete description of Shape LOD Elements.

Figure 31: Quantization Parameters data collection



U8 : Bits Per Vertex

Bits Per Vertex specifies the number of quantization bits per vertex coordinate component. Value must be within range [0:24] inclusive.

U8 : Normal Bits Factor

Normal Bits Factor is a parameter used to calculate the number of quantization bits for normal vectors. Value must be within range [0:13] inclusive . The actual number of quantization bits per normal is computed using this factor and the following formula: "BitsPerNormal = 6 + 2 * Normal Bits Factor"

U8 : Bits Per Texture Coord

Bits Per Texture Coord specifies the number of quantization bits per texture coordinate component. Value must be within range [0:24] inclusive.

U8 : Bits Per Color

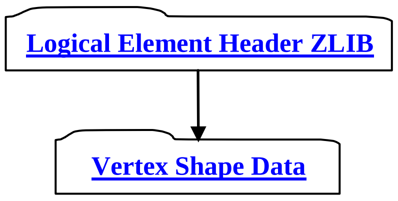
Bits Per Color specifies the number of quantization bits per color component. Value must be within range [0:24] inclusive.

7.2.1.1.1.10.3 Tri-Strip Set Shape Node Element

Object Type ID: 0x10dd1077, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

A Tri-Strip Set Shape Node Element defines a collection of independent and unconnected triangle strips. Each strip constitutes one primitive of the set and is defined by one list of vertex coordinates.

Figure 32: Tri-Strip Set Shape Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

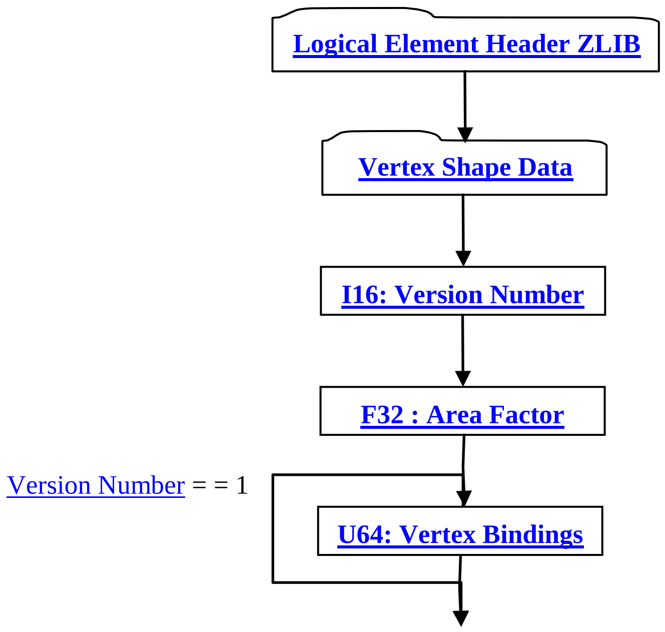
Complete description for Vertex Shape Data can be found in 7.2.1.1.1.10.2.1Vertex Shape Data.

7.2.1.1.1.10.4 Polyline Set Shape Node Element

Object Type ID: 0x10dd1046, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

A Polyline Set Shape Node Element defines a collection of independent and unconnected polylines. Each polyline constitutes one primitive of the set and is defined by one list of vertex coordinates.

Figure 33: Polyline Set Shape Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Vertex Shape Data can be found in 7.2.1.1.1.10.2.1Vertex Shape Data.

I16: Version Number

Version Number is the version identifier for this node. Version number "0x0002" is currently the highest valid value for Polyline Set Shape Data.

F32 : Area Factor

Area Factor specifies a multiplier factor applied to a Polyline Set computed surface area. In JT data viewer applications there may be LOD selection semantics that are based on screen coverage calculations. The so-called "surface area" of a polyline is computed as if each line segment were a square. This Area Factor turns each edge into a narrow rectangle. Valid Area Factor values lie in the range (0,1].

U64: Vertex Bindings

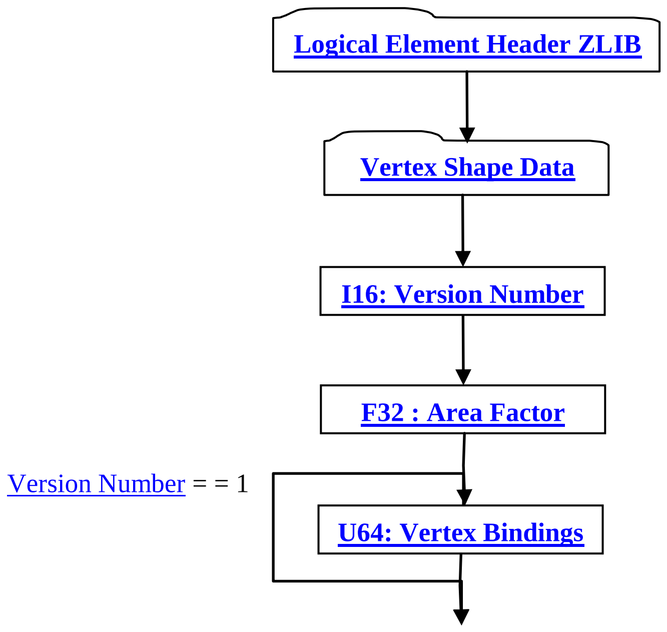
Vertex Bindings is a collection of normal, texture coordinate, and color binding information encoded within a single U64. All undocumented bits are reserved. For more information see Vertex Shape LOD Data U64 : Vertex Bindings.

7.2.1.1.1.10.5 Point Set Shape Node Element

Object Type ID: 0x98134716, 0x0010, 0x0818, 0x19, 0x98, 0x08, 0x00, 0x09, 0x83, 0x5d, 0x5a

A Point Set Shape Node Element defines a collection of independent and unconnected points. Each point constitutes one primitive of the set and is defined by one vertex coordinate.

Figure 34: Point Set Shape Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Vertex Shape Data can be found in 7.2.1.1.1.10.2.1Vertex Shape Data.

I16: Version Number

Version Number is the version identifier for this node. Version number "0x0002" is currently the highest valid value for Point Set Shape Data.

F32 : Area Factor

Area Factor specifies a multiplier factor applied to the Point Set computed surface area. In JT data viewer applications there may be LOD selection semantics that are based on screen coverage calculations. The computed "surface area" of a Point Set is equal to the larger (i.e. whichever is greater) of either the area of the Point Set's bounding box, or "1.0". Area Factor scales the result of this "surface area" computation..

U64: Vertex Bindings

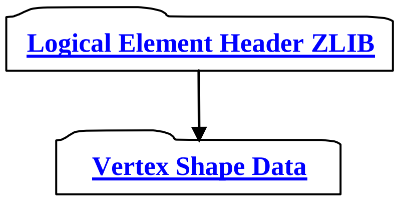
Vertex Bindings is a collection of normal, texture coordinate, and color binding information encoded within a single U64. All undocumented bits are reserved. For more information see Vertex Shape LOD Data U64 : Vertex Bindings.

7.2.1.1.1.10.6 Polygon Set Shape Node Element

Object Type ID: 0x10dd1048, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

A Polygon Set Shape Node Element defines a collection of independent and unconnected polygons. Each polygon constitutes one primitive of the set and is defined by one list of vertex coordinates.

Figure 35: Polygon Set Shape Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

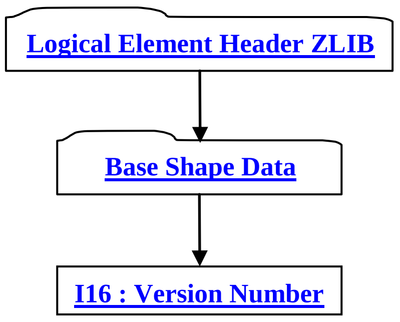
Complete description for Vertex Shape Data can be found in 7.2.1.1.1.10.2.1Vertex Shape Data.

7.2.1.1.1.10.7 NULL Shape Node Element

Object Type ID: 0xd239e7b6, 0xdd77, 0x4289, 0xa0, 0x7d, 0xb0, 0xee, 0x79, 0xf7, 0x94, 0x94

A NULL Shape Node Element defines a shape which has no direct geometric primitive representation (i.e. it is empty/NULL). NULL Shape Node Elements are often used as "proxy/placeholder" nodes within the serialized LSG when the actual Shape LOD data is run time generated (i.e. not persisted).

Figure 36: NULL Shape Node Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Shape Data can be found in 7.2.1.1.1.10.1.1 Base Shape Data.

I16 : Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for NULL Shape Node Element.

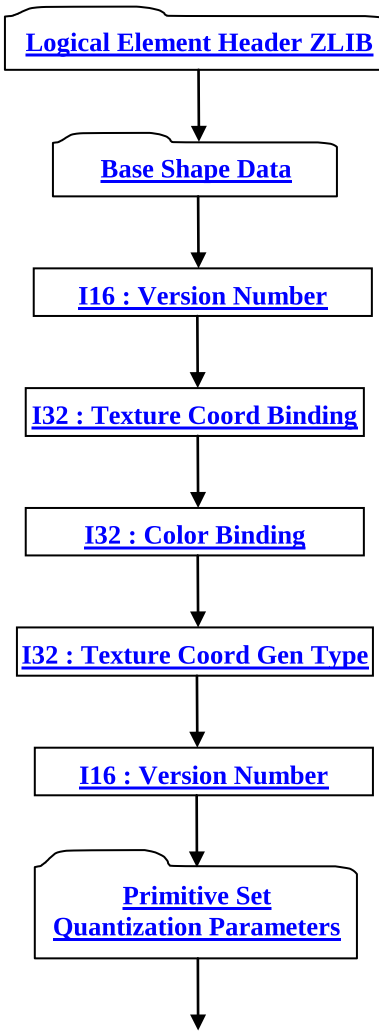
7.2.1.1.1.10.8 Primitive Set Shape Node Element

Object Type ID: 0xe40373c1, 0x1ad9, 0x11d3, 0x9d, 0xaf, 0x0, 0xa0, 0xc9, 0xc7, 0xdd, 0xc2

A Primitive Set Shape Node Element represents a list/set of primitive shapes (e.g. box, cylinder, sphere, etc.) who's LODs can be procedurally generated. "Procedurally generate" means that the raw geometric shape definition data (e.g. vertices, polygons, normals, etc) for LODs is not directly stored; instead some basic shape information is stored (e.g. sphere center and radius) from which LODs can be generated.

Primitive Set Shape Node Elements actually do not even directly contain this basic shape definition data, but instead reference (using Late Loaded Property Atoms) Primitive Set Shape Elements within the file for the actual basic shape definition data. Storing the basic shape definition data within separate independently addressable data segments in the JT file, allows a JT file reader to be structured to support the "best practice" of delaying the loading/reading of associated data until it is actually needed. Complete descriptions for Late Loaded Property Atom Elements and Primitive Set Shape Element can be found in 0 Late Loaded Property Atom Element and 7.2.2.2 Primitive Set Shape Element respectively.

Figure 37: Primitive Set Shape Node Element data collection


Logical Element Header ZLIB
Base Shape Data
I16 : Version Number
I32 : Texture Coord Binding
I32 : Color Binding
I32 : Texture Coord Gen Type
I16 : Version Number
Primitive Set Quantization Parameters

Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Shape Data can be found in 7.2.1.1.1.10.1.1 Base Shape Data.

I16 : Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for Primitive Set Shape Node Element.

I32 : Texture Coord Binding

Texture Coord Binding specifies how (at what granularity) texture coordinate data is supplied ("bound") for the shape in the associated/referenced Shape LOD Element. Valid values are as follows:

= 0	None. Shape has no texture coordinate data.
= 1	Per Vertex. Shape has texture coordinates for every vertex.

I32 : Color Binding

Color Binding specifies how (at what granularity) color data is supplied ("bound") for the shape in the associated/referenced Shape LOD Element. Valid values are the same as documented for Texture Coord Binding data field.

I16 : Version Number

Version Number is the version identifier for this element. The value of this Version Number indicates the format of data fields to follow.

= 0	Version 0 Format
= 1	Version 1 Format

I32 : Texture Coord Gen Type

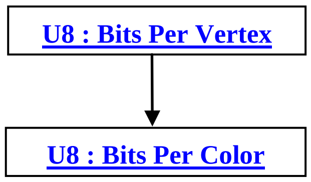
Texture Coord Gen Type specifies how texture coordinates are to be generated.

= 0	Single Tile…Indicates that a single copy of a texture image will be applied to significant primitive features (i.e. cube face, cylinder wall, end cap) no matter how eccentrically shaped.
= 1	Isotropic…Implies that multiple copies of a texture image may be mapped onto eccentric surfaces such that a mapped texel stays approximately square.

7.2.1.1.1.10.8.1 Primitive Set Quantization Parameters

Primitive Set Quantization Parameters specifies for the two shape data type grouping (i.e. Vertex, Color) the number of quantization bits used for given qualitative compression level. Although these Quantization Parameters values are saved in the associated/referenced Shape LOD Element, they are also saved here so that a JT File loader/reader does not have to load the Shape LOD Element in order to determine the Shape quantization level. See 7.2.2.1Shape LOD Element for complete description of Shape LOD Elements.

Figure 38: Primitive Set Quantization Parameters data collection



U8 : Bits Per Vertex

Bits Per Vertex specifies the number of quantization bits per vertex coordinate component. Value must be within range [0:24] inclusive.

U8 : Bits Per Color

Bits Per Color specifies the number of quantization bits per color component. Value must be within range [0:24] inclusive.

7.2.1.1.2 Attribute Elements

Attribute Elements (e.g. color, texture, material, lights, etc.) are placed in LSG as objects associated with nodes. Attribute Elements are not nodes themselves, but can be associated with any node.

For applications producing or consuming JT format data, it is important that the JT format semantics of how attributes are meant to be applied and accumulated down the LSG are followed. If not followed, then consistency between the applications in terms of 3D positioning and rendering of LSG model data will not be achieved.

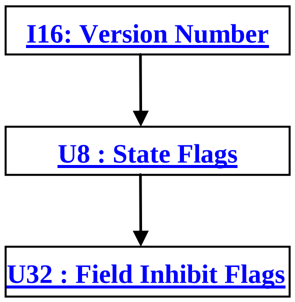
To that end each attribute type defines its own application and accumulation semantics, but in general attributes at lower levels in the LSG take precedence and replace or accumulate with attributes set at higher levels. Nodes without associated attributes inherit those of their parents. Attributes inherit only from their parents, thus a node's attributes do not affect that node's siblings. The root of a partition inherits the attributes in effect at the referring partition node.

Attributes can be declared "final" (see 7.2.1.1.2.1.1Base Attribute Data), which terminates accumulation of that attribute type at that attribute and propagates the accumulated values there to all descendants of the associated node. Descendants can explicitly do a one-shot override of "final" using the attribute "force" flag (see 7.2.1.1.2.1.1Base Attribute Data), but do not by default. Note that "force" does not turn OFF "final" – it is simply a one-shot override of "final" for the specific attribute marked as "forcing." An analogy for this "force" and "final" interaction is that "final" is a back-door in the attribute accumulation semantics, and that "force" is a doggy-door in the back-door!

7.2.1.1.2.1 Common Attribute Data Containers

7.2.1.1.2.1.1 Base Attribute Data

Figure 39: Base Attribute Data collection



I16: Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for Base Shape Data.

U8 : State Flags

State Flags is a collection of flags. The flags are combined using the binary OR operator and store various state information for Attribute Elements; such as indicating that the attributes accumulation is final. All undocumented bits are reserved.

0x01	Accumulation Final flag. Provides a means to terminate a particular attribute type's accumulation at any node of the LSG and thereby force all descendants to have that value of the attribute. = 0 – Accumulation is to occur normally = 1 – Accumulation is "final"
0x02	Accumulation Force flag. Provides a way to assign nodes in LSG, attributes that must not be overridden by ancestors. = 0 – Accumulation of this attribute obeys ancestor's Final flag setting. = 1 – Accumulation of this attribute is forced (overrides ancestor's Final flag setting)
0x04	Accumulation Ignore Flag. Provides a way to indicate that the attribute is to be ignored (not accumulated). = 0 – Attribute is to be accumulated normally (subject to values of Force/Final flags) = 1 – Attribute is to be ignored.
0x08	Attribute Persistable Flag.

	Provides a way to indicate that the attribute is to be persistable to a JT file. = 0 – Attribute is to be non-persistable. = 1 – Attribute is to be persistable.

U32 : Field Inhibit Flags

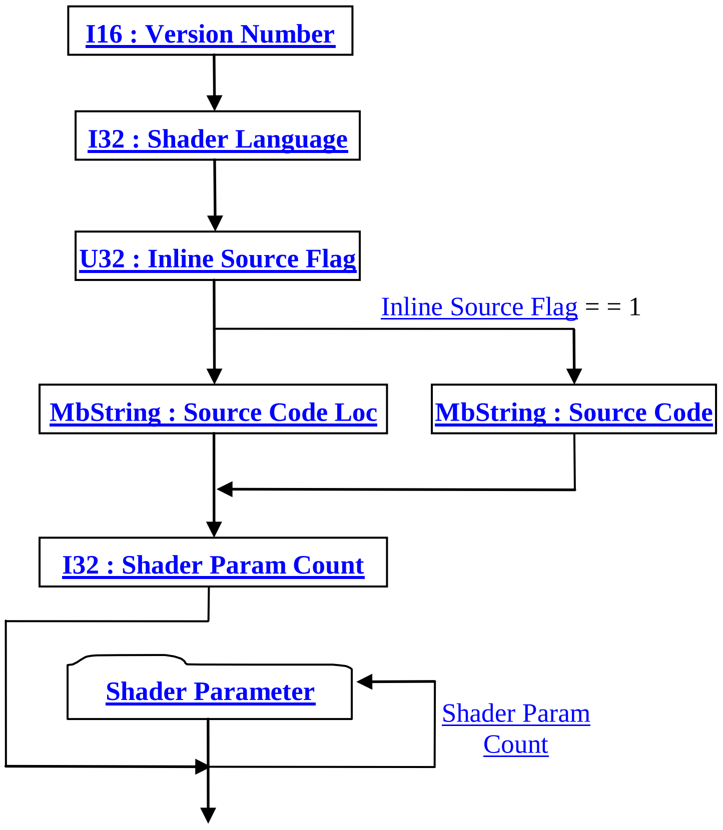
Field Inhibit Flags is a collection of flags. The flags are combined using the binary OR operator and store the per attribute value accumulation flag. Each value present in an Attribute Element is given a field number ranging from 0 to 31. If the field's corresponding bit in Inhibit Flags is set, then the field should not participate in attribute accumulation. All bits are reserved.

See each particular Attribute Element (e.g. Material Attribute Element) for a description of bit field assignments for each attribute value.

7.2.1.1.2.1.2 Base Shader Data

The JT v9 file format is able to represent vertex- and fragment shader programs in GLSL source code form together with parameter bindings for both. The shader source code can be specified inline directly in the JT file, or as a filename containing the shader source code.

Figure 40: Base Shader Data collection



I16 : Version Number

Version Number is the version identifier for this data collection. Version number "0x0001" is currently the only valid value.

I32 : Shader Language

Shader Language specifies the Shader program language. JT v9.5 only supports the GLSL Shading Language.

= 0	None
= 2	GLSL ("GL Shading Language" as defined by the Architectural Review Board of OpenGL, the governing body of OpenGL [7]**.**

U32 : Inline Source Flag

Inline Source Flag specifies whether the shader's "source code" is stored within this JT file or in some other externally referenced file. Valid values include the following:

= 0	Source code stored in an externally referenced file.
= 1	Source code stored within this JT file.

MbString : Source Code

Source Code is the shader's source code in Shader Language programming language.

MbString : Source Code Loc

Source Code Loc specifies the file name for the external file containing the shader's source code.

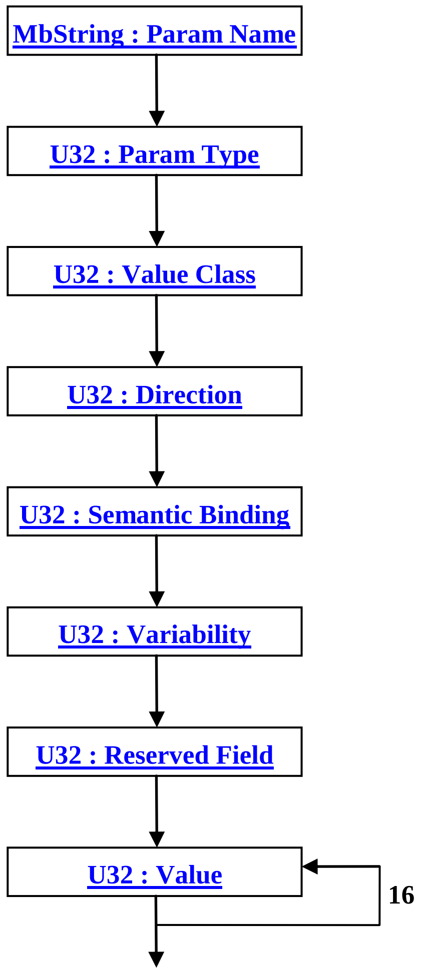
I32 : Shader Param Count

Shader Param Count specifies the number of shader parameters.

7.2.1.1.2.1.2.1 **Shader Parameter**

Shader Parameter data collection defines a Shader input and/or output parameter. A list of Shader Parameters represents the runtime linkage of the shader program into the GPU's data streams.

Figure 41: Shader Parameter data collection



MbString : Param Name

Param Name specifies the shader parameter name.

U32 : Param Type

Param Type specifies the shader parameter type. Valid types include the following:

= 0	Unknown
= 1	Boolean
= 2	Integer
= 3	Float
= 4	Vector of two Integer values.
= 5	Vector of three Integer values
= 6	Vector of four Integer values
= 7	Vector of two Float values
= 8	Vector of three Float values
= 9	Vector of four Float values
= 10	2 x 2 matrix of Float values
= 11	3 x 3 matrix of Float values
= 12	4 x 4 matrix of Float values

= 13	Texture Object/Unit number bound to current 1D texture sampler
= 14	Texture Object/Unit number bound to current 2D texture sampler
= 15	Texture Object/Unit number bound to current 3D texture sampler
= 16	Texture Object/Unit number bound to current rectangle map texture sampler
= 17	Texture Object/Unit number bound to current cube map texture sampler
= 18	Texture Object/Unit number bound to current 1D shadow map texture sampler
= 19	Texture Object/Unit number bound to current 2D shadow map texture sampler

U32 : Value Class

Value Class specifies the shader parameter "value class". Valid values include the following:

= 0	Unknown class
= 1	Immediate class.
= 2	Semantic class (i.e. Shader Parameter is implicitly tied/bound to a piece of OpenGL graphics system state (e.g. OpenGL ModelView matrix) or JT graphics system state (e.g. diffuse material color)). The actual graphics state that the parameter is bound to is indicated by value in Value data field.

U32 : Direction

Direction specifies whether the shader parameter is an input, output, or input/output parameter. Valid values include the following:

= 0	Unknown
= 1	Input parameter
= 2	Output parameter
= 3	Both an Input and an Output parameter.

U32 : Semantic Binding

Semantic Binding specifies the "per vertex input and/or output" or the "per fragment input and/or output" this shader parameter is associated with (i.e. bound to). Valid values, including their input/output applicability to vertex and fragment shaders, are as follows (note that N/A indicates 'Not Applicable"):

Value	Binding Description	Vertex Shader Applicability	Fragment Shader Applicability
= 0	Unknown		
= 1	None		
= 2	Position	Input/Output	Input
= 3	Normal	Input	N/A
= 4	Binormal	Input	N/A
= 5	Blend Indices	Input	N/A
= 6	Blend Weight	Input	N/A
= 7	Tangent	Input	N/A
= 8	Point Size	Input/Output	Input
= 10	Texture Coordinate 0	Input/Output	Input
= 11	Texture Coordinate 1	Input/Output	Input
= 12	Texture Coordinate 2	Input/Output	Input
= 13	Texture Coordinate 3	Input/Output	Input
= 14	Texture Coordinate 4	Input/Output	Input
= 15	Texture Coordinate 5	Input/Output	Input
= 16	Texture Coordinate 6	Input/Output	Input
= 17	Texture Coordinate 7	Input/Output	Input

Value	Binding Description	Vertex Shader Applicability	Fragment Shader Applicability
= 20	Fog Coordinate	Output	Input
= 21	Primary Color	Output	Input
= 22	Secondary Color	Output	Input
= 23	Primary Color	N/A	Output
= 24	Depth Value	N/A	Output

U32 : Variability

Variability specifies how often the value of the parameter is allowed to change. Valid values include the following:

= 0	Unknown
= 1	Constant (a parameter that takes on a single value and never changes)
= 2	Uniform (a parameter that may take on a different value each time the shader is invoked but remains the same for all vertices or fragments processed by the shader)
= 3	Varying (a parameter which may change with every vertex or fragment processed by the shader)

U32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

U32 : Value

Value specifies the shader parameter values treated as a U32 array of bytes. The maximum number of bytes required to store all possible Param Type and Value Class dependent values is 64 bytes and thus there are 16 U32 values stored. The interpretation of the Value data is Param Type and Value Class dependent as follows:

For "Immediate" Value Class parameters (i.e. Value Class = = 1), the interpretation of the Value data is dependent upon the Param Type value.

For "Semantic" Value Class parameters, the Value data is to be interpreted as a single U32 with all the possible values documented in Appendix B: Semantic Value Class Shader Parameter Values.

7.2.1.1.2.2 Material Attribute Element

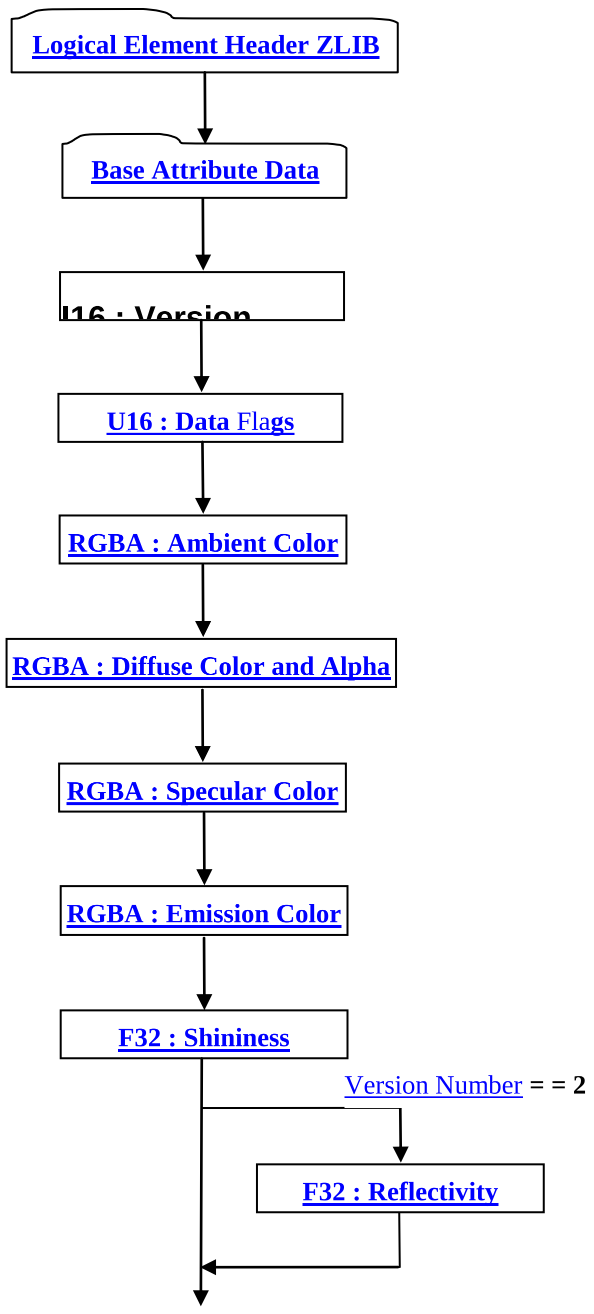
Object Type ID: 0x10dd1030, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Material Attribute Element defines the material properties of a object. JT format LSG traversal semantics state that material attributes accumulate down the LSG by replacement.

The Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments for the Material Attribute Element data fields, are as follows:

Field Inhibit Flag Bit	Data Field(s) Bit Applies To
0	Ambient Common RGB Value, Ambient Color
1	Diffuse Color and Alpha (Legacy)
2	Specular Common RGB Value, Specular Color
3	Emission Common RGB Value, Emission Color
4	Blending Flag, Source Blending Factor, Destination Blending Factor
5	Override Vertex Color Flag
6	Material Reflectivity
7	Diffuse Color
8	Diffuse Alpha

Figure 42: Material Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1Base Attribute Data.

I16 : Version Number

Version Number is the version identifier for this element. The value of this Version Number indicates the format of data fields to follow.

= 1	Version-1 Format

= 2	Version-2 Format

U16 : Data Flags

Data Flags is a collection of flags and factor data. The flags and factor data are combined using the binary OR operator. The flags store information to be used for interpreting how to read subsequent Material data fields. All undocumented bits are reserved.

0x0010	Blending Flag. Blending is a color combining operation in the graphics pipeline that happens just before writing a color to the framebuffer. If Blending is ON then incoming fragment RGBA color values are used (based on Source Blend Factor) and existing framebuffer's RGBA color values are used (based on Destination Blend Factor) to blend between the incoming fragment RGBA and the current frame buffer RGBA to arrive at a new RGBA color to write into the framebuffer. If Blending is OFF then incoming fragment RGBA color is written directly into framebuffer unmodified (i.e. completely overriding existing framebuffer RGBA color). Additional information on how one might leverage the Blending Flag and Blending Factors to render an image can be found in the references listed in section 3 References and Additional Information. = 0 – Blending OFF. = 1 – Blending ON
0x0020	Override Vertex Colors Flag. If ON, then a shape's per vertex colors are to be overridden by the accumulated Material color. = 0 – Override OFF = 1 – Override ON
0x07C0	Source Blend Factor (stored in bits 6 – 10 or in binary notation 0000011111000000). If Blending Flag enabled, this value indicates how the incoming fragment's (i.e. the source) RGBA color values are to be used to blend with the current framebuffer's (i.e. the destination) RGBA color values. Additional information on the interpretation of the Blending Factor values and how one might leverage them to render an image can be found in reference [4] listed in section 3 References and Additional Information. = 0 – Interpret same as OpenGL **GL_ZERO** Blending Factor = 1 – Interpret same as OpenGL **GL_ONE** Blending Factor = 2 – Interpret same as OpenGL **GL_DST_COLOR** Blending Factor = 3 – Interpret same as OpenGL **GL_SRC_COLOR** Blending Factor = 4 – Interpret same as OpenGL **GL_ONE_MINUS_DST_COLOR** Blending Factor = 5 – Interpret same as OpenGL **GL_ONE_MINUS_SRC_COLOR** Blending Factor = 6 – Interpret same as OpenGL **GL_SRC_ALPHA** Blending Factor = 7 – Interpret same as OpenGL **GL_ONE_MINUS_SRC_ALPHA** Blending Factor = 8 – Interpret same as OpenGL **GL_DST_ALPHA** Blending Factor = 9 – Interpret same as OpenGL **GL_ONE_MINUS_DST_ALPHA** Blending Factor = 10 – Interpret same as OpenGL **GL_SRC_ALPHA_SATURATE** Blending Factor
0xF800	Destination Blend Factor (stored in bits 11 – 15 or in binary notation 1111100000000000).). If Blending Flag enabled, this value indicates how the current framebuffer's (the destination) RGBA color values are to be used to blend with the incoming fragment's (the source) RGBA color values. Additional information on the interpretation of the Blending Factor values and how one might leverage them to render an image can be found in reference [4] listed in section 3 References and Additional Information. = 0 – Interpret same as OpenGL **GL_ZERO** Blending Factor = 1 – Interpret same as OpenGL **GL_ONE** Blending Factor = 2 – Interpret same as OpenGL **GL_DST_COLOR** Blending Factor

	= 3 – Interpret same as OpenGL **GL_SRC_COLOR** Blending Factor = 4 – Interpret same as OpenGL **GL_ONE_MINUS_DST_COLOR** Blending Factor = 5 – Interpret same as OpenGL **GL_ONE_MINUS_SRC_COLOR** Blending Factor = 6 – Interpret same as OpenGL **GL_SRC_ALPHA** Blending Factor = 7 – Interpret same as OpenGL **GL_ONE_MINUS_SRC_ALPHA** Blending Factor = 8 – Interpret same as OpenGL **GL_DST_ALPHA** Blending Factor = 9 – Interpret same as OpenGL **GL_ONE_MINUS_DST_ALPHA** Blending Factor = 10 – Interpret same as OpenGL **GL_SRC_ALPHA_SATURATE** Blending Factor

RGBA : Ambient Color

Ambient Color specifies the ambient red, green, blue, alpha color values of the material.

RGBA : Diffuse Color and Alpha

Diffuse Color and Alpha specify the diffuse red, green, blue color components, and alpha value of the material.

RGBA : Specular Color

Specular Color specifies the specular red, green, blue, alpha color values of the material.

RGBA : Emission Color

Emission Color specifies the emissive red, green, blue, alpha color values of the material.

F32 : Shininess

Shininess is the exponent associated with specular reflection and highlighting. Shininess controls the degree with which the specular highlight decays. Only values in the range [1,128] are valid.

F32 : Reflectivity

Reflectivity specifies the material reflectivity of the material. It represents the fraction of light reflected in the mirror direction by the material. Only values in the range [0.0, 1.0] are valid.

7.2.1.1.2.3Texture Image Attribute Element

Object Type ID: 0x10dd1073, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

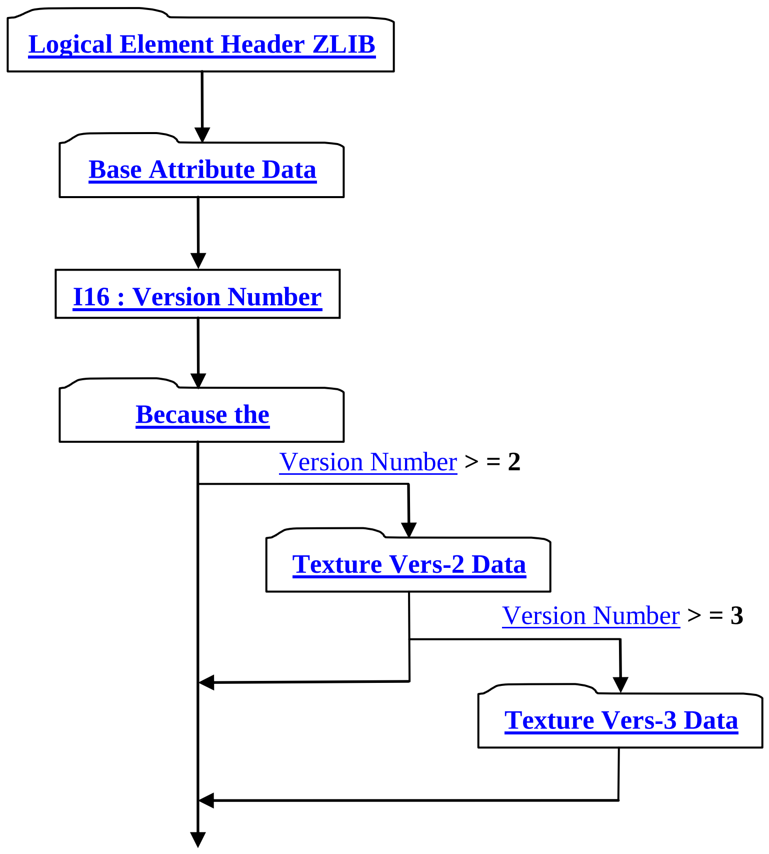
Texture Image Attribute Element defines a texture image and its mapping environment. JT format LSG traversal semantics state that texture image attributes accumulate down the LSG by replacement on a *per channel* basis. See below for more information on texture image channels.

Note that additional information on the interpretation of the various Texture Image Attribute Element data fields can be found in the OpenGL references listed in section 3 References and Additional Information.

The Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments for the Texture Image Attribute Element data fields, are as follows:

Field Inhibit Flag Bit	Data Field(s) Bit Applies To
0	I32 : Texture Type, Mipmap Image Texel Data, MbString : External Storage Name, Shared Image Flag
1	Border Mode, Border Color
2	Mipmap Minification Filter, Mipmap Magnification Filter
3	S-Dimen Wrap Mode, T-Dimen Wrap Mode, R-Dimen Wrap Mode
4	Blend Type, Blend Color
5	Texture Transform
6	Tex Coord Gen Mode, Tex Coord Reference Plane
8	Internal Compression Level

Figure 43: Texture Image Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1 Base Attribute Data.

Complete description for Texture Vers-1 Data can be found in 7.2.1.1.2.3.1 Texture Vers-1 Data.

Complete description for Texture Vers-2 Data can be found in 7.2.1.1.2.3.2 Texture Vers-2 Data.

Complete description for Texture Vers-3 Data can be found in 7.2.1.1.2.3.3 Texture Vers-3 Data.

I16 : Version Number

Version Number is the version identifier for this element. The value of this Version Number indicates the format of data fields to follow.

= 1	Version-1 Format
= 2	Version-2 Format
= 3	Version-3 Format

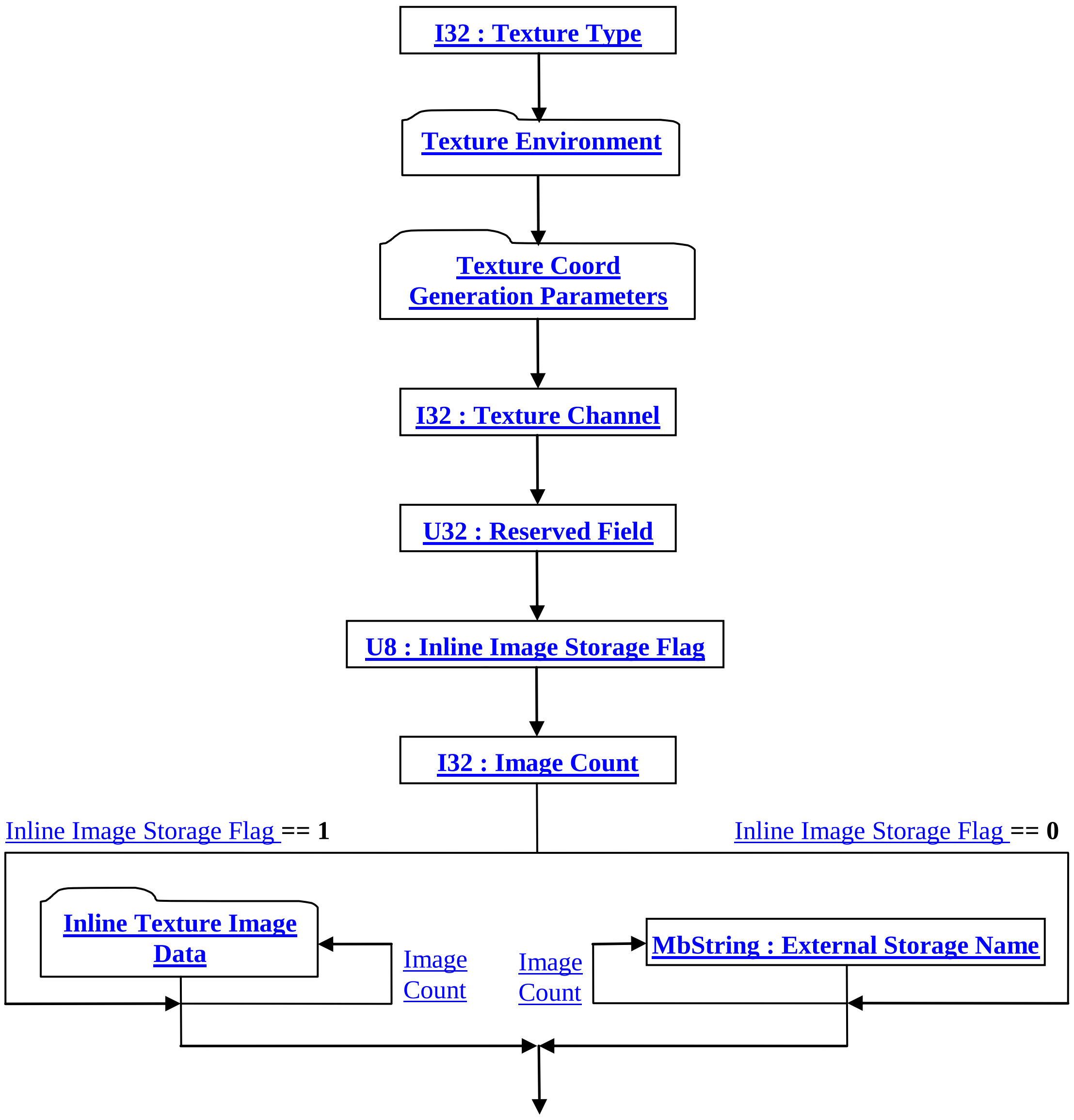
Because the 7.2.1.1.2.3Texture Image Attribute Element has undergone major upgrades during the lifetime of the JT v9 file format, the attribute has a complex version structure to be mindful of. Usually, when a data element in the JT file is versioned, it is for the purpose of merely adding a few pieces of new data onto the end of the existing data format. In this way, older viewers and readers of the JT file that do not yet know about higher local versions will naturally read the lower-numbered version blocks and ignore the higher-numbered ones they do not know how to read. This is sometimes the case with Texture Image Attribute Element, but sometimes not. Entirely new texture types with no analogous lower-level functionality have been added. In these cases, the most sensible thing for an older reader to do it to ignore the texture image entirely as if it were not even present in the JT file.

In order to support this sensible fallback mechanism, the following two general rules are followed: 1) a given texture image is written at the lowest version level that completely captures its contents, and 2) lower-order Texture Vers Data blocks are written with a "stub" texture.

7.2.1.1.2.3.1 Texture Vers-1 Data

Texture Vers-1 Data format is stored in JT file if the Texture Image Element is a vanilla/basic texture image (i.e. if texture does not use any advanced features as described in 7.2.1.1.2.3.2Texture Vers-2 Data and 7.2.1.1.2.3.3Texture Vers-3 Data). However, advanced textures *also* write a Texture Vers-1 Data block because of the need to be backward-compatible with older readers that may not understand Vers-2 and Vers-3 data.

Figure 44: Texture Vers-1 Data collection


I32 : Texture Type
Texture Environment
Texture Coord Generation Parameters
I32 : Texture Channel
U32 : Reserved Field
U8 : Inline Image Storage Flag
I32 : Image Count
Inline Image Storage Flag == 1
Inline Image Storage Flag == 0
Inline Texture Image Data
Image Count
Image Count
MbString : External Storage Name

Complete details for Texture Environment can be found in 7.2.1.1.2.3.1.1Texture Environment.

Complete details for Texture Coord Generation Parameters can be found in 7.2.1.1.2.3.1.2Texture Coord Generation Parameters.

Complete details for Inline Texture Image Data can be found in 7.2.1.1.2.3.1.3Inline Texture Image Data.

I32 : Texture Type

Texture Type specifies the type of texture.

= 0	None.
= 1	One-Dimensional. A one-dimensional texture has a height (T-Dimension) and depth (R-Dimension) equal to "1" and no top or bottom border.
= 2	Two-Dimensional. A two-dimensional texture has a depth (R-Dimension) equal to "1."
= 3	Three-Dimensional. A three-dimensional texture can be thought of as layers of two-dimensional sub image rectangles arranged in a sequence.
= 4	Bump Map. A bump map texture is a texture where the image texel data (e.g. RGB color values) represents surface normal XYZ components.
= 5	Cube Map. A cube map texture is a texture cube centered at the origin and formed by a set of six two-dimensional texture images.
= 6	Depth Map. A depth map texture is a texture where the image texel data represents depth values.

I32 : Texture Channel

Texture Channel specifies the texture channel number for the Texture Image Element. For purposes of multi-texturing, the JT concept of a texture channel corresponds to the OpenGL concept of a "texture unit." The Texture Channel value must be between 0 and 31 inclusive. Best practices suggest that renderer of JT data ignore all but channel-0 if the renderer does not support multi-textured geometry. Also for purposes of blending, renderer of JT data should assume that higher numbered texture channels "blend over" lower numbered ones.

U32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

U8 : Inline Image Storage Flag

Inline Image Storage Flag is a flag that indicates whether the texture image is stored within the JT File (i.e. inline) or in some other external file.

= 0	Texture image stored in an external file.
= 1	Texture image stored inline in this JT file.

I32 : Image Count

Image Count specifies the number of texture images. A "Cube Map" I32 : Texture Type must have six images while all other Texture Types should only have one image.

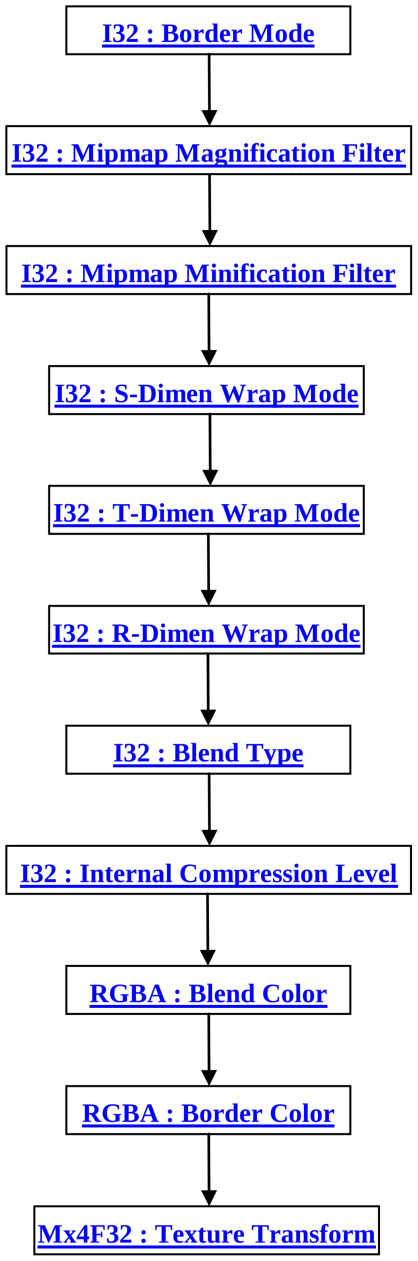
MbString : External Storage Name

External Storage Name is a string identifying the name of an external texture image storage. External Storage Name is only present if data field Inline Image Storage Flag equals "0." If present there will be data field Image Count number of External Storage Name instances. This External Storage Name string is a relative path based name for the texture image file. Where "relative path" should be interpreted to mean the string contains the file name along with any additional path information that locates the texture image file relative to the location of the referencing JT file.

7.2.1.1.2.3.1.1 Texture Environment

The Texture Environment is a collection of data defining various aspects of how a texture image is to be mapped/applied to a surface.

Figure 45: Texture Environment data collection



I32 : Border Mode

Border Mode specifies the texture border mode.

= 0	No border.
= 1	Constant Border Color. Indicates that the texture has a constant border color whose value is defined in data field Border Color.
= 2	Explicit. Indicates that a border texel ring is present in the texture image definition.

I32 : Mipmap Magnification Filter

Mipmap Magnification Filter specifies the texture filtering method to apply when a single pixel on screen maps to a tiny portion of a texel.

= 0	None.
= 1	Nearest. Texel with coordinates nearest the center of the pixel is used.
= 2	Linear. A weighted linear average of the 2 x 2 array of texels nearest to the center of the pixel is used. For one-dimensional texture is average of 2 texels. For three dimensional texel is 2 x 2 x 2 array.

I32 : Mipmap Minification Filter

Mipmap Minification Filter specifies the texture filtering method to apply when a single pixel on screen maps to a large collection of texels.

= 0	None.
= 1	Nearest. Texel with coordinates nearest the center of the pixel is used.
= 2	Linear. A weighted linear average of the 2 x 2 array of texels nearest to the center of the pixel is used. For one-dimensional texture is average of 2 texels. For three-dimensional texture is 2 x 2 x 2 array.
= 3	Nearest in Mipmap. Within an individual mipmap, the texel with coordinates nearest the center of the pixel is used.
= 4	Linear in Mipmap. Within an individual mipmap, a weighted linear average of the 2 x 2 array of texels nearest to the center of the pixel is used. For one-dimensional texture is average of 2 texels. For three-dimensional texture is 2 x 2 x 2 array
= 5	Nearest between Mipmaps. Within each of the adjacent two mipmaps, selects the texel with coordinates nearest the center of the pixel and then interpolates linearly between these two selected mipmap values.
= 6	Linear between Mipmaps. Within each of the two adjacent mipmaps, computes value based on a weighted linear average of the 2 x 2 array of texels nearest to the center of the pixel and then interpolates linearly between these two computed mipmap values.

I32 : S-Dimen Wrap Mode

S-Dimen Wrap Mode specifies the mode for handling texture coordinates S-Dimension values outside the range [0, 1].

= 0	None.
= 1	Clamp. Any values greater than 1.0 are set to 1.0; any values less than 0.0 are set to 0.0
= 2	Repeat Integer parts of the texture coordinates are ignored (i.e. retains only the fractional component o texture coordinates greater than 1.0 and only one-minus the fractional component of values less than zero). Resulting in copies of the texture map tiling the surface
= 3	Mirror Repeat. Like Repeat, except the surface tiles “flip-flop” resulting in an alternating mirror pattern of surface tiles.
= 4	Clamp to Edge. Border is always ignored and instead texel at or near the edge is chosen for coordinates outside the range [0, 1]. Whether the exact nearest edge texel or some average of the nearest edge texels is used is dependent upon the mipmap filtering value.
= 5	Clamp to Border. Nearest border texel is chosen for coordinates outside the range [0, 1]. Whether the exact nearest border texel or some average of the nearest border texels is used is dependent upon the mipmap filtering value.

I32 : T-Dimen Wrap Mode

T-Dimen Wrap Mode specifies the mode for handling texture coordinates T-Dimension values outside the range [0, 1]. Same mode values as documented for S-Dimen Wrap Mode.

I32 : R-Dimen Wrap Mode

R-Dimen Wrap Mode specifies the mode for handling texture coordinates R-Dimension values outside the range [0, 1]. Same mode values as documented for S-Dimen Wrap Mode.

I32 : Blend Type

Blend Type contains information indicating how the values in the texture map are to be modulated/combined/blended with the original color of the surface or some other alternative color to compute the final color to be painted on the surface. Additional information on the interpretation of the Blend Type values and how one might leverage them to render an image can be found in reference [4] listed in section 3 References and Additional Information.

= 0	None.
= 1	Decal. Interpret same as OpenGL **GL_DECAL** environment mode.
= 2	Modulate. Interpret same as OpenGL **GL_MODULATE** environment mode.
= 3	Replace. Interpret same as OpenGL **GL_REPLACE** environment mode.
= 4	Blend. Interpret same as OpenGL **GL_BLEND** environment mode.
= 5	Add. Interpret same as OpenGL **GL_ADD** environment mode.
= 6	Combine. Interpret same as OpenGL **GL_COMBINE** environment mode.

I32 : Internal Compression Level

Internal Compression Level specifies a data compression hint/recommendation that a JT file loader is free to follow for internally (in memory) storing texel data. This setting does not affect how image texel data is actually stored in JT files or other externally referenced files.

= 0	None. No compression of texel data.
= 1	Conservative. Lossless compression of texel data.
= 2	Moderate. Texel components truncated to 8-bits each.
= 3	Aggressive. Texel components truncates to 4-bits each (or 5 bits for RGB images).

RGBA : Blend Color

Blend Color specifies the color to be used for the "Blend" mode of Blend Type operations.

RGBA : Border Color

Border Color specifies the constant border color to use for "Clamp to Border" style wrap modes when the texture itself does not have a border.

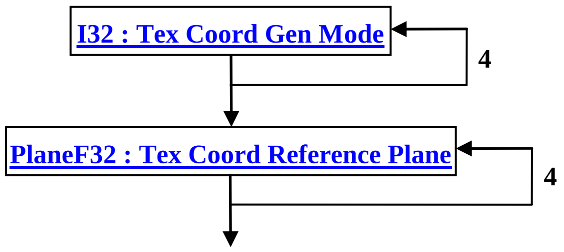
Mx4F32 : Texture Transform

Texture Transform defines the texture coordinate transformation matrix. A renderer of JT data would typically apply this transform to texture coordinates prior to applying the texture.

7.2.1.1.2.3.1.2 **Texture Coord Generation Parameters**

Texture Coord Generation Parameters contains information indicating if and how texture coordinate components should be automatically generated for each of the 4 components (S, T, R, Q) of a texture coordinate.

Figure 46: Texture Coord Generation Parameters data collection



I32 : Tex Coord Gen Mode

Tex Coord Gen Mode specifies the texture coordinate generation mode for each component (S, T, R, Q) of texture coordinate. There are four mode values stored, one for each component of texture coordinate. The mode values are stored in S, T, R, Q order.

= 0	None. No texture coordinates automatically generated.
= 1	Model Coordinate System Linear. Texture coordinates computed as a distance from a reference plane specified in model coordinates.
= 2	View Coordinate System Linear. Texture coordinates computed as a distance from a reference plane specified in view coordinates.
= 3	Sphere Map. Texture coordinates generated based on spherical environment mapping.
= 4	Reflection Map. Texture coordinates generated based on cubic environment mapping.
= 5	Normal Map. Texture coordinates computed/set by copying vertex normal in view coordinates to S, T, R.

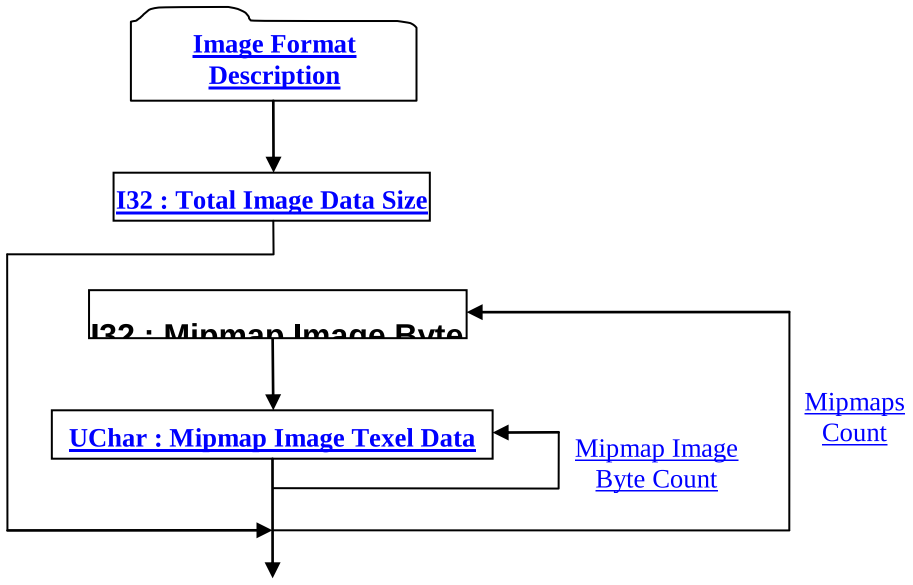
PlaneF32 : Tex Coord Reference Plane

Reference Plane specifies the reference plane used for "Model Coordinate System Linear" and "View Coordinate System Linear" texture coordinate generation modes. There are four Reference Planes stored, one for each component of texture coordinate. The Reference Planes are stored in S, T, R, Q order. Even if a components "Tex Coord Gen Mode" is one that does not require a reference plane, dummy reference planes are still stored in JT file.

7.2.1.1.2.3.1.3 Inline Texture Image Data

Inline Texture Image Data is a collection of data defining the texture format properties and image texel data for one texture image. Inline Texture Image Data is only present if data field Inline Image Storage Flag equals "1." If present there will be data field Image Count number of Inline Texture Image Data instances.

Figure 47: Inline Texture Image Data collection



Complete description for Image Format Description can be found in 7.2.1.1.2.3.1.3.1Image Format Description.

I32 : Total Image Data Size

Total Image Data Size specifies the total length, in bytes, of the on-disk representation for all mipmap images. This byte total does not include the I32 : Mipmap Image Byte Count

data field storage (4 bytes per) for each mipmap.

I32 : Mipmap Image Byte Count

Mipmap Image Byte Count specifies the length, in bytes, of the on-disk representation of the next mipmap image.

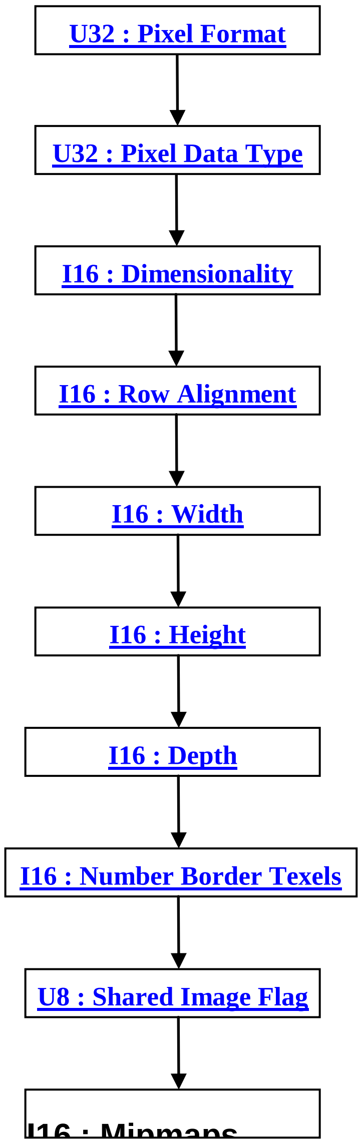
UChar : Mipmap Image Texel Data

Mipmap Image Texel Data is the mipmap's block of image data. The length of this field in bytes is specified by the value of data field Mipmap Image Byte Count.

7.2.1.1.2.3.1.3.1 Image Format Description

The Image Format Description is a collection of data defining the pixel format, data type, size, and other miscellaneous characteristics of the texel image data.

Figure 48: Image Format Description data collection



U32 : Pixel Format

Pixel format specifies the format of the texture image pixel data. Depending on the format, anywhere from one to four elements of data exists per texel.

= 0	No format specified. Texture mapping is not applied.
= 1	RGB: A red color component followed by green and blue color components
= 2	RGBA: A red color component followed by green, blue, and alpha color components
= 3	LUM: A single luminance component
= 4	LUMA: A luminance component followed by an alpha color component.
= 5	A single stencil index.
= 6	A single depth component
= 7	A single red color component
= 8	A single green color component
= 9	A single blue color component

= 10	A single alpha color component
= 11	A blue color component, followed by green and red color components
= 12	A blue color component, followed by green , red, and alpha color components
= 13	A depth component, followed by a stencil component

U32 : Pixel Data Type

Pixel Data Type specifies the data type used to store the per texel data. If the Pixel Format represents a multi component value (e.g. red, green, blue) then each value requires the Pixel Data Type number of bytes of storage (e.g. a Pixel Format Type of "1" with Pixel Data Type of "3" would require 3 bytes of storage for each texel).

= 0	No type specified. Texture mapping is not applied.
= 1	Signed 8-bit integer
= 2	Single-precision 32-bit floating point
= 3	Unsigned 8-bit integer
= 4	Single bits in unsigned 8-bit integers
= 5	Unsigned 16-bit integer
= 6	Signed 16-bit integer
= 7	Unsigned 32-bit integer
= 8	Signed 32-bit integer
= 9	16-bit floating point according to IEEE-754 format (i.e. 1 sign bit, 5 exponent bits, 10 mantissa bits)

I16 : Dimensionality

Dimensionality specifies the number of dimensions the texture image has. Valid values include:

= 1	One-dimensional texture
= 2	Two-dimensional texture
= 3	Three-dimensional texture

I16 : Row Alignment

Row Alignment specifies the byte alignment for image data rows. This data field must have a value of 1, 2, 4, or 8. If set to 1 then all bytes are used (i.e. no bytes are wasted at end of row). If set to 2, then if necessary, an extra wasted byte(s) is/are stored at the end of the row so that the first byte of the next row has an address that is a multiple of 2 (multiple of four for Row Alignment equal 4 and multiple of 8 for row alignment equal 8). The actual formula (using C syntax) to determine number of bytes per row is as follows:

```
BytesPerRow =  (numBytesPerPixel * ImageWidth + RowAlignment – 1)  &  ~(RowAlignment – 1)
```

I16 : Width

Width specifies the width dimension (number of texel columns) of the texture image in number of pixels.

I16 : Height

Height specifies the height dimension (number of texel rows) of the texture image in number of pixels. Height is 1 for one-dimensional images.

I16 : Depth

Depth specifies the depth dimension (number of texel slices) of the texture image in number of pixels. Depth is 1 for one-dimensional and two-dimensional images.

I16 : Number Border Texels

Number Border Texels specifies the number of border texels in the texture image definition. Valid values are 0 and 1.

U8 : Shared Image Flag

Shared Image Flag is a flag indicating whether this texture image is shareable with other Texture Image Element attributes.

= 0	Image is not shareable with other Texture Image Elements.
= 1	Image is shareable with other Texture Image Elements.

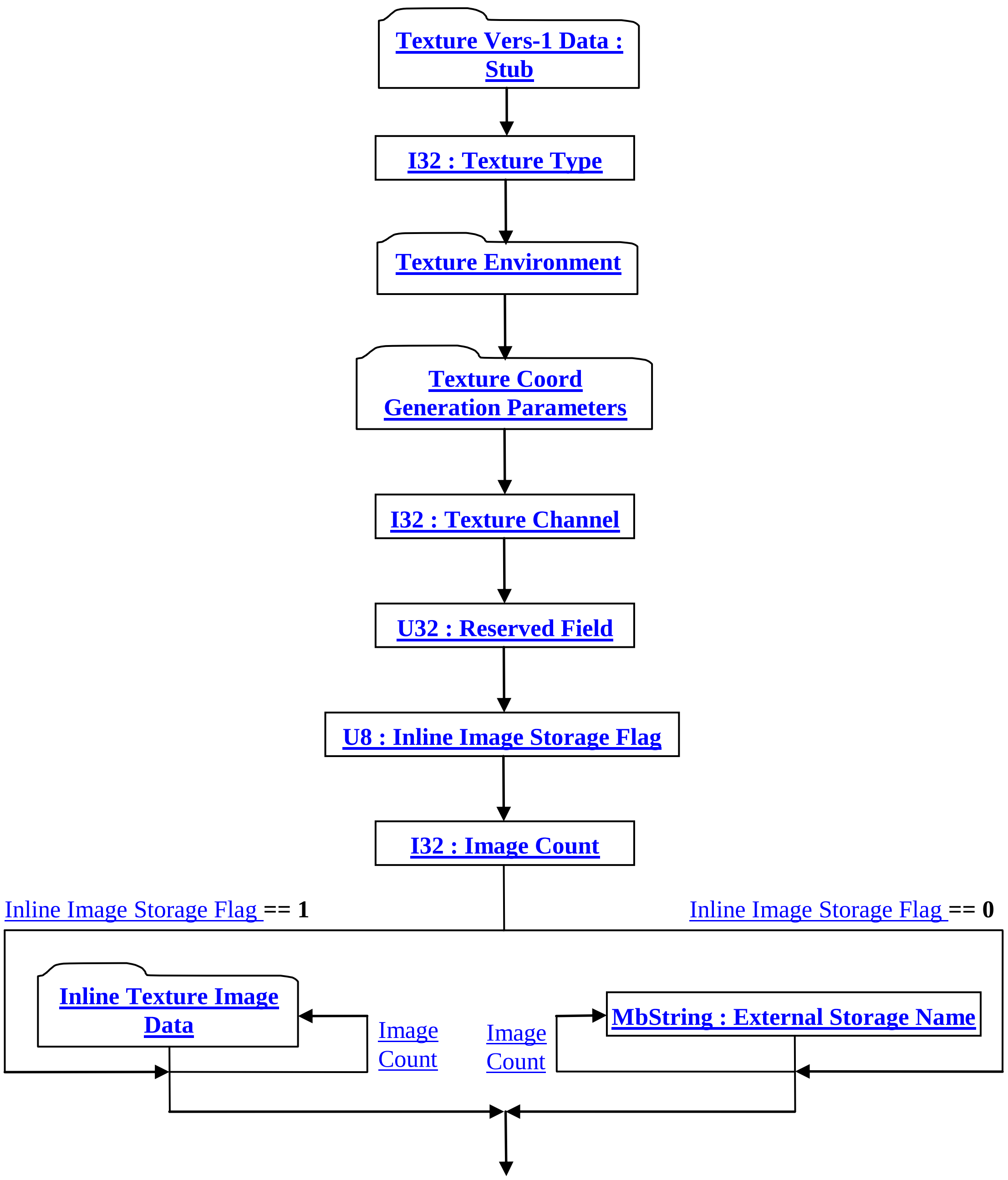
I16 : Mipmaps Count

Mipmaps Count specifies the number of mipmap images. A value of 1 indicates that no mipmaps are used. A value greater than 1 indicates that mipmaps are present all the way down to a 1-by-1 texel.

7.2.1.1.2.3.2 Texture Vers-2 Data

Texture Vers-2 Data collection supports texturing effects not representable in the Texture Vers-1 Data format (e.g. more precise texture types, automatic texture channel, etc.). Any Texture Image Attribute Element using the Texture Vers-2 Data format will contain a “degenerate” Texture Vers-1 Data block, where Image Count data field has a value of “0”.

Figure 49: Texture Vers-2 Data collection


Texture Vers-1 Data : Stub
I32 : Texture Type
Texture Environment
Texture Coord Generation Parameters
I32 : Texture Channel
U32 : Reserved Field
U8 : Inline Image Storage Flag
I32 : Image Count
Inline Image Storage Flag == 1
Inline Image Storage Flag == 0
Inline Texture Image Data
Image Count
Image Count
MbString : External Storage Name

Complete details for Texture Environment can be found in 7.2.1.1.2.3.1.1Texture Environment.

Complete details for Texture Coord Generation Parameters can be found in 7.2.1.1.2.3.1.2Texture Coord Generation Parameters.

Complete details for Inline Texture Image Data can be found in 7.2.1.1.2.3.1.3Inline Texture Image Data.

Texture Vers-1 Data : Stub

This is a dummy block written with its I32 : Texture Type field set to "None". This block is included so that older readers that do not understand Texture Vers-2 Data will read an "empty" texture.

I32 : Texture Type

Texture Type specifies the type of texture. There is a complete restructuring and redefinition of what a "texture type" implies in Texture Vers-2 Data. It is a much stronger concept now, that not only describes generally what the texture image contains, but also defines precisely what the texture is being used for. In the following list, "image" refers to an image texture, "pre-lit" indicates that the image texture is to be applied before lighting when rendering the object to which it is applied, and "post-lit" indicates that the image texture is to be applied after lighting. A gloss map is a pre-lit texture that applies itself to the specular material component of lighting instead of the diffuse component. A light map is an environment texture (texture at infinity surrounding the whole model) that serves as a source of illumination during shading calculations.

Texture Type	Description	Explicit Channel	Auto Channel
= 0	None.	N/A	N/A
= 1	One-Dimensional post-lit image texture.	Yes	No
= 2	Two-Dimensional post-lit image texture.	Yes	No
= 3	Three-Dimensional post-lit image texture.	Yes	No
= 4	Two-Dimensional 3-component tangent-space normal map.	No	Yes
= 5	Cube post-lit image texture.	Yes	No
= 7	Cube pre-lit image texture.	Yes	No
= 8	One-Dimensional pre-lit image texture.	Yes	No
= 9	Two-Dimensional pre-lit image texture.	Yes	No
= 10	Three-Dimensional pre-lit image texture.	Yes	No
= 11	Cube environment map.	No	Yes
= 12	One-Dimensional gloss map (specular) texture.	No	Yes
= 13	Two-Dimensional gloss map (specular) texture.	No	Yes
= 14	Three-Dimensional gloss map (specular) texture.	No	Yes
= 15	Cube gloss map (specular) texture.	No	Yes
= 16	Two-Dimensional 1-component bumpmap.	No	Yes
= 17	Two-Dimensional 3-component world-space normal map.	No	Yes
= 18	Two-Dimensional sphere environment map.	No	Yes
= 19	Two-Dimensional latitude/longitude environment map.	No	Yes
= 20	Two-Dimensional spherical diffuse light map.	No	Yes
= 21	Cube diffuse light map.	No	Yes
= 22	Two-Dimensional latitude/longitude diffuse light map.	No	Yes
= 23	Two-Dimensional spherical specular light map.	No	Yes
= 24	Cube specular light map.	No	Yes
= 25	Two-Dimensional latitude/longitude specular light map.	No	Yes

I32 : Texture Channel

Texture Channel specifies the texture channel number for the Texture Image Element. For purposes of multi-texturing, the JT concept of a texture channel corresponds to the OpenGL concept of a "texture unit." The Texture Channel value must be between -1 and 31 inclusive. The value -1 is accepted to denote a texture whose channel number is to be automatically assigned. This assignment will never displace another texture with an explicit texture channel assignment from its slot. Best practices suggest that renderer of JT data ignore all but channel-0 if the renderer does not support multi-textured geometry. Also for purposes of blending, any renderer of JT data should ensure that higher numbered texture channels "blend over" lower numbered ones.

Pre- and post-lit image textures must specify an explicit texture channel. All other texture types must specify -1 for their texture channel.

U32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

U8 : Inline Image Storage Flag

Inline Image Storage Flag is a flag that indicates whether the texture image is stored within the JT File (i.e. inline) or in some other external file.

= 0	Texture image stored in an external file.
= 1	Texture image stored inline in this JT file.

I32 : Image Count

Image Count specifies the number of texture images. A "Cube Map" I32 : Texture Type must have six images while all other Texture Types may only have one image.

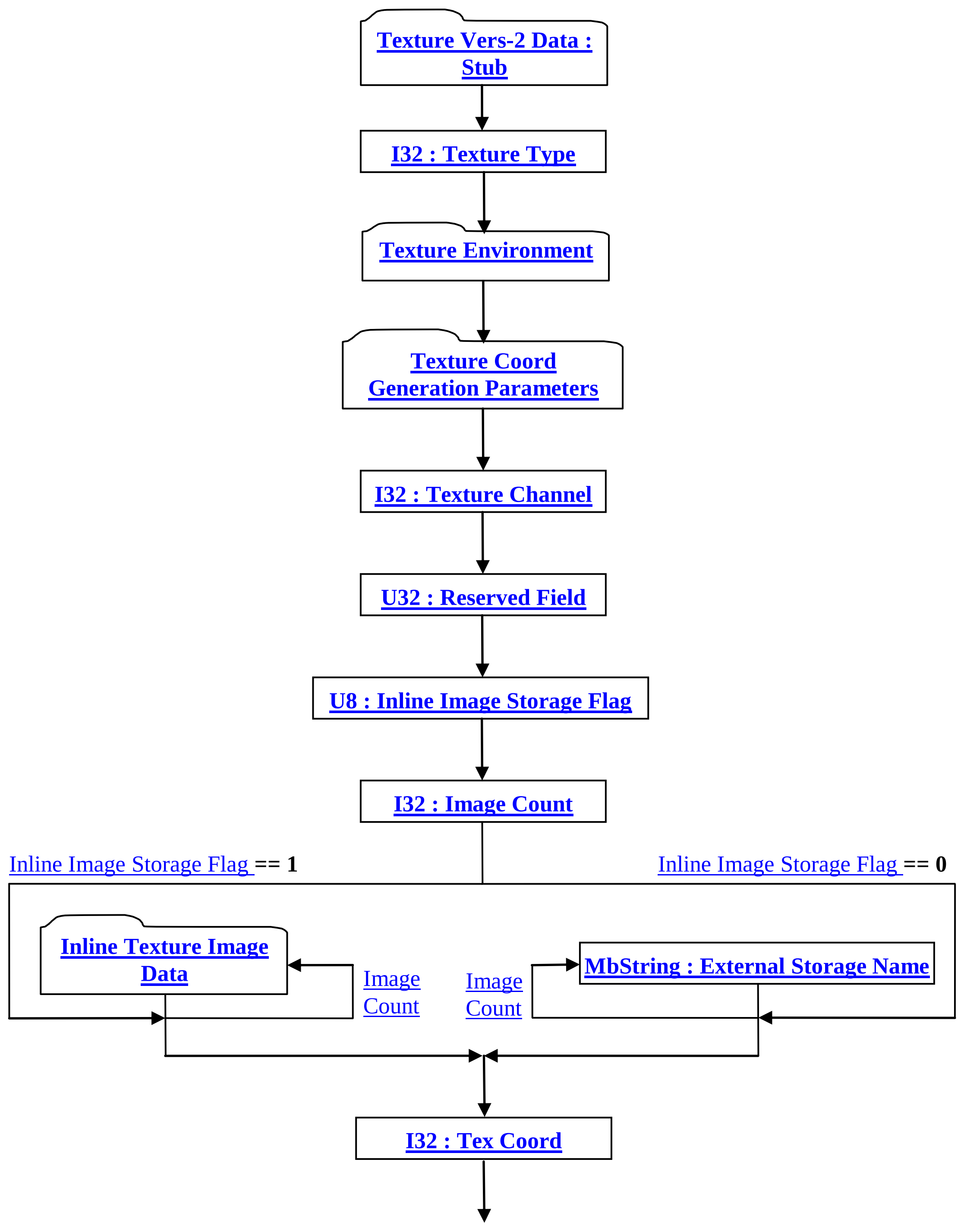
MbString : External Storage Name

External Storage Name is a string identifying the name of an external texture image storage. External Storage Name is only present if data field Inline Image Storage Flag equals 0. If present, there will be data field Image Count number of External Storage Name instances. This External Storage Name string is a relative path based name for the texture image file. Where "relative path" should be interpreted to mean the string contains the file name along with any additional path information that locates the texture image file relative to the location of the referencing JT file.

7.2.1.1.2.3.3 Texture Vers-3 Data

Texture Vers-3 Data collection supports texturing effects not representable in the Texture Vers-1 Data format or the Texture Vers-2 Data format (e.g. texture coordinate channel, separator texture type, and texture channel greater than 31). Any Texture Image Attribute Element using the Texture Vers-3 Data format will contain a "degenerate" Texture Vers-1 Data block, and a "degenerate" Texture Vers-2 Data block, where Image Count data field has a value of 0 and the Texture Type will be set to None.

Figure 50: Texture Vers-3 Data collection



Texture Vers-2 Data : Stub
I32 : Texture Type
Texture Environment
Texture Coord Generation Parameters
I32 : Texture Channel
U32 : Reserved Field
U8 : Inline Image Storage Flag
I32 : Image Count
Inline Image Storage Flag == 1
Inline Image Storage Flag == 0
Inline Texture Image Data
Image Count
Image Count
MbString : External Storage Name
I32 : Tex Coord

Complete details for Texture Environment can be found in 7.2.1.1.2.3.1.1Texture Environment.

Complete details for Texture Coord Generation Parameters can be found in 7.2.1.1.2.3.1.2Texture Coord Generation Parameters.

Complete details for Inline Texture Image Data can be found in 7.2.1.1.2.3.1.3Inline Texture Image Data.

Texture Vers-2 Data : Stub

This is a dummy block written with its I32 : Texture Type field set to "None". This block is included so that older readers that do not understand Texture Vers-3 Data will read an "empty" texture.

I32 : Texture Type

Texture Type specifies the type of texture. A new texture type, separator texture, is defined in Texture Vers-3 Data to support resetting the texture accumulation state mid-graph. Shadow maps and prefiltered light maps, however, are a general exception to this rule. In the following list, “image” refers to an image texture, “pre-lit” indicates that the image texture is to be applied before lighting when rendering the object to which it is applied, and “post-lit” indicates that the image texture is to be applied after lighting. A gloss map is a pre-lit texture that applies itself to the specular material component of lighting instead of the diffuse component. A light map is an environment texture (texture at infinity surrounding the whole model) that serves as a source of illumination during shading calculations.

Texture Type	Description	Explicit Channel	Auto Channel
= 0	None.	N/A	N/A
= 1	One-Dimensional post-lit image texture.	Yes	No
= 2	Two-Dimensional post-lit image texture.	Yes	No
= 3	Three-Dimensional post-lit image texture.	Yes	No
= 4	Two-Dimensional 3-component tangent-space normal map.	No	Yes
= 5	Cube post-lit image texture.	Yes	No
= 7	Cube pre-lit image texture.	Yes	No
= 8	One-Dimensional pre-lit image texture.	Yes	No
= 9	Two-Dimensional pre-lit image texture.	Yes	No
= 10	Three-Dimensional pre-lit image texture.	Yes	No
= 11	Cube environment map.	No	Yes
= 12	One-Dimensional gloss map (specular) texture.	No	Yes
= 13	Two-Dimensional gloss map (specular) texture.	No	Yes
= 14	Three-Dimensional gloss map (specular) texture.	No	Yes
= 15	Cube gloss map (specular) texture.	No	Yes
= 16	Two-Dimensional 1-component bumpmap.	No	Yes
= 17	Two-Dimensional 3-component world-space normal map.	No	Yes
= 18	Two-Dimensional sphere environment map.	No	Yes
= 19	Two-Dimensional latitude/longitude environment map.	No	Yes
= 20	Two-Dimensional spherical diffuse light map.	No	Yes
= 21	Cube diffuse light map.	No	Yes
= 22	Two-Dimensional latitude/longitude diffuse light map.	No	Yes
= 23	Two-Dimensional spherical specular light map.	No	Yes
= 24	Cube specular light map.	No	Yes
= 25	Two-Dimensional latitude/longitude specular light map.	No	Yes
=26	Resets texture state except shadow map and light maps.	N/A	N/A

I32 : Texture Channel

Texture Channel specifies the texture channel number for the Texture Image Element. For purposes of multi-texturing, the JT concept of a texture channel corresponds to the OpenGL concept of a “texture unit.” The Texture Channel value must be between -1 and 2,147,483,647 inclusive. The value -1 is accepted to denote a texture whose channel number is to be automatically assigned. This assignment will never displace another texture with an explicit texture channel assignment from its slot. Best practices suggest that renderer of JT data ignore all but channel-0 if the renderer does not support multi-textured geometry. Also for purposes of blending, any renderer of JT data should ensure that higher numbered texture channels “blend over” lower numbered ones.

Pre- and post-lit image textures must specify an explicit texture channel. All other texture types must specify -1 for their texture channel.

U32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

U8 : Inline Image Storage Flag

Inline Image Storage Flag is a flag that indicates whether the texture image is stored within the JT File (i.e. inline) or in some other external file.

= 0	Texture image stored in an external file.
= 1	Texture image stored inline in this JT file.

I32 : Image Count

Image Count specifies the number of texture images. A "Cube Map" I32 : Texture Type must have six images while all other Texture Types should only have one image.

MbString : External Storage Name

External Storage Name is a string identifying the name of an external texture image storage. External Storage Name is only present if data field Inline Image Storage Flag equals "0."   If present there will be data field Image Count number of External Storage Name instances. This External Storage Name string is a relative path based name for the texture image file. Where "relative path" should be interpreted to mean the string contains the file name along with any additional path information that locates the texture image file relative to the location of the referencing JT file.

I32 : Tex Coord Channel

Tex Coord Channel specifies the channel number for texture coordinate generation. Value must be within range [-1, 2147483647] inclusive.

7.2.1.1.2.4Draw Style Attribute Element

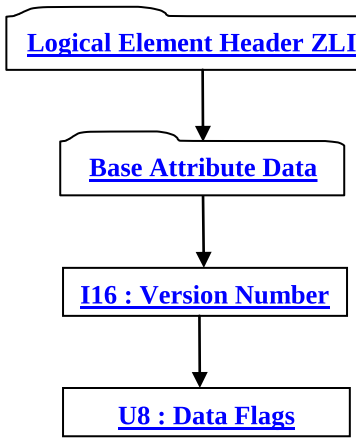
Object Type ID: 0x10dd1014, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Draw Style Attribute Element contains information defining various aspects of the graphics state/style that should be used for rendering associated geometry. JT format LSG traversal semantics state that draw style attributes accumulate down the LSG by replacement.

The Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments for the Draw Style Attribute Element data fields, are as follows:

Field Inhibit Flag Bit	Data Field(s) Bit Applies To
0	Two Sided Lighting Flag
1	Back-face Culling Flag
2	Outlined Polygons Flag
3	Lighting Enabled Flag
4	Flat Shading Flag
5	Separate Specular Flag

Figure 51: Draw Style Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1Base Attribute Data.

I16 : Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for Draw Style Attribute Element.

U8 : Data Flags

Data Flags is a collection of flags. The flags are combined using the binary OR operator and store various state settings for Draw Style Attribute Elements. All undocumented bits are reserved.

0x01	Back-face Culling Flag. Indicates if back-facing polygons should be discarded (culled). = 0 – Back-facing polygons not culled. = 1 – Back-facing polygons culled.
0x02	Two Sided Lighting Flag. Indicates if two sided lighting should be enabled to insure that polygons are illuminated on both sides. = 0 – Disable two sided lighting. = 1 – Enable two sided lighting.
0x04	Outlined Polygons Flag. Indicates if polygons should be draw as "wireframes" i.e. not filled. = 0 – Polygons drawn as filled. = 1 – Only polygon's outline drawn.
0x08	Lighting Enabled Flag. Indicates if lighting should be enabled. If lighting disabled, then renderer should perform no calculations concerning normals, light sources, material properties, etc. = 0 – Disable lighting. = 1 – Enable lighting.
0x10	Flat Shading Flag. Indicates if the geometry should be rendered with single color (flat shading) or with many different color (smooth/Gouraud) shading. = 0 – Disable flat shading (i.e. use smooth/Gouraud shading). = 1 – Enable flat shading.
0x20	Separate Specular Flag. Indicates if the application of the specular color should be delayed until after texturing. If

	no texture mapping then this flag setting is irrelevant. = 0 – Apply specular color contribution before texture mapping. = 1 – Apply specular color contribution after texture mapping.

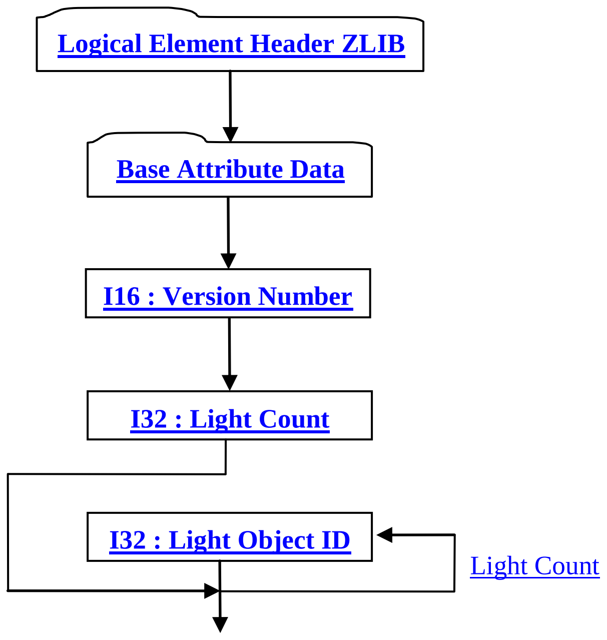
7.2.1.1.2.5 Light Set Attribute Element

Object Type ID: 0x10dd1096, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Light Set Attribute Element holds an unordered list of Lights. JT format LSG traversal semantics state that light set attributes accumulate down the LSG through addition of lights to an attribute list.

Light Set Attribute Element does not have any Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments.

Figure 52: Light Set Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1Base Attribute Data.

I16 : Version Number

Version Number is the version identifier for this element. Version number “0x0001” is currently the only valid value for Light Set Attribute Element.

I32 : Light Count

Light Count specifies the number of lights in the Light Set.

I32 : Light Object ID

Light Object ID is the identifier for a referenced Light Object.

7.2.1.1.2.6Infinite Light Attribute Element

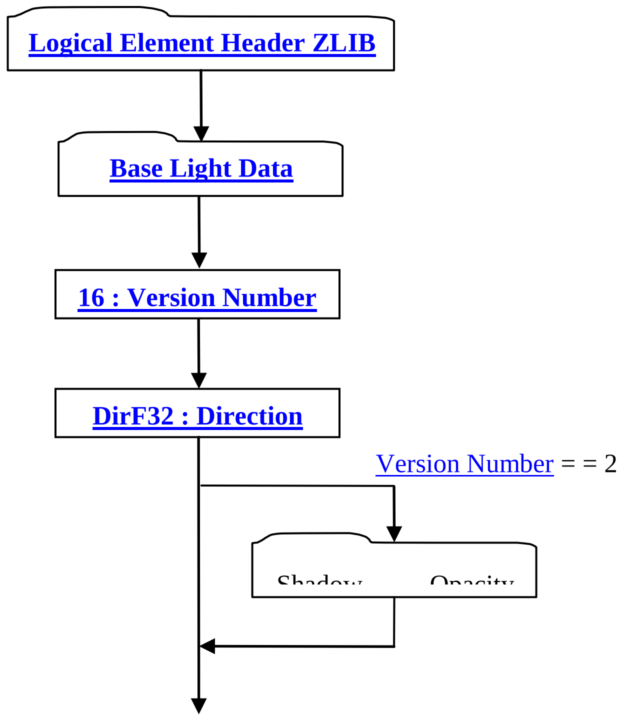
Object Type ID: 0x10dd1028, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Infinite Light Attribute Element specifies a light source emitting unattenuated light in a single direction from every point on an infinite plane. The infinite location indicates that the rays of light can be considered parallel by the time they reach an object.

JT format LSG traversal semantics state that infinite light attributes accumulate down the LSG through addition of lights to an attribute list.

Infinite Light Attribute Element does not have any Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments.

Figure 53: Infinite Light Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Light Data can be found in 7.2.1.1.2.6.1Base Light Data.

Complete description for Shadow Parameters can be found in 7.2.1.1.2.6.2 Shadow Parameters.

16 : Version Number

Version Number is the version identifier for this element. The value of this Version Number indicates the format of data fields to follow.

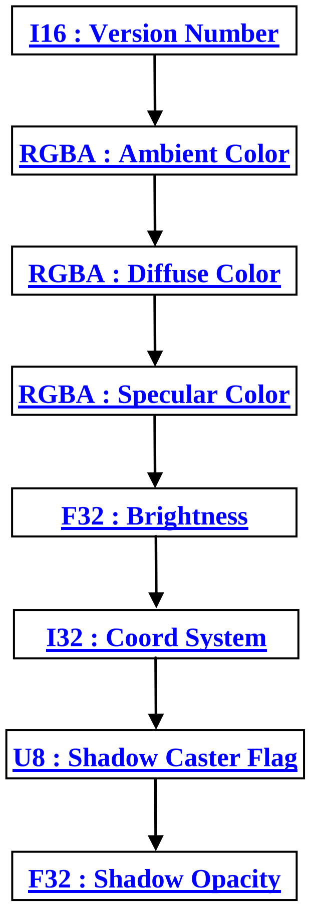
= 1	Version-1 Format
= 2	Version-2 Format

DirF32 : Direction

Direction specifies the direction the light is pointing in.

7.2.1.1.2.6.1 Base Light Data

Figure 54: Base Light Data collection



I16 : Version Number

Version number is the version identifier for this element. Version number “0x0001” is currently the only valid value for Base Light Data.

RGBA : Ambient Color

Ambient Color specifies the ambient red, green, blue, alpha color values of the light.

RGBA : Diffuse Color

Diffuse Color specifies the diffuse red, green, blue, alpha color values of the light.

RGBA : Specular Color

Specular Color specifies the specular red, green, blue, alpha color values of the light.

F32 : Brightness

Brightness specifies the Light brightness. The Brightness value must be greater than or equal to “-1”.

I32 : Coord System

Coord System specifies the coordinate space in which Light source is defined. Valid values include the following:

= 1	Viewpoint Coordinate System. Light source is to move together with the viewpoint
= 2	Model Coordinate System. Light source is affected by whatever model transforms that are current when the light source is encountered in LSG.
= 3	World Coordinate system. Light source is not affected by model transforms in the LSG.

U8 : Shadow Caster Flag

Shadow Caster Flag is a flag that indicates whether the light is a shadow caster or not.

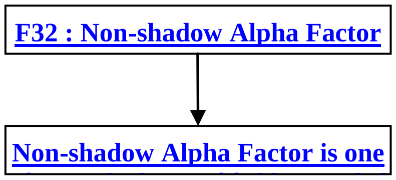
= 0	Light source is not a shadow caster.
= 1	Light source is a shadow caster.

F32 : Shadow Opacity

Shadow Opacity specifies the shadow opacity factor on Light source. Value must be within range [0.0, 1.0] inclusive. Shadow Opacity is intended to convey how dark a shadow cast by this light source are to be rendered. A value of 1.0 means that no light from this light source reaches a shadowed surface, resulting in a black shadow.

7.2.1.1.2.6.2 Shadow Parameters

Figure 55: Shadow Parameters data collection



F32 : Non-shadow Alpha Factor

Non-shadow Alpha Factor is one of a matched pair of fields intended to govern how a shadowing light source (one whose Shadow Caster Flag is set) casts "alpha light" into areas that it directly illuminates (i.e. are not in shadow). Those fragments directly lit by this light source will have their alpha values scaled by Non-shadow Alpha Factor. Non-shadow Alpha Factor value must lie on the range [0.0, 1.0] inclusive.

This field can be used to create "drop shadows" by setting its value to 0. The effect being that all geometry illuminated by the light source will be "burned away," leaving behind only those parts lying in shadow. Naturally, implementing this intended behavior implies extensive viewer support.

F32 : Shadow Alpha Factor

Shadow Alpha Factor is one of a matched pair of fields intended to govern how a shadowing light source (one whose Shadow Caster Flag is set) casts "alpha light" into areas that it does not illuminate (i.e. are in shadow). Those fragments in shadow from this light source will have their alpha values scaled by Shadow Alpha Factor. Shadow Alpha Factor value must lie on the range [0.0, 1.0] inclusive.

This field has the opposite effect of Non-shadow Alpha Factor. If set to a value of 0, for example, it will cause all geometry shadowed from the light source to be burned away, leaving behind only those parts directly illuminated by the light source. Naturally, implementing this intended behavior implies extensive viewer support.

7.2.1.1.2.7 Point Light Attribute Element

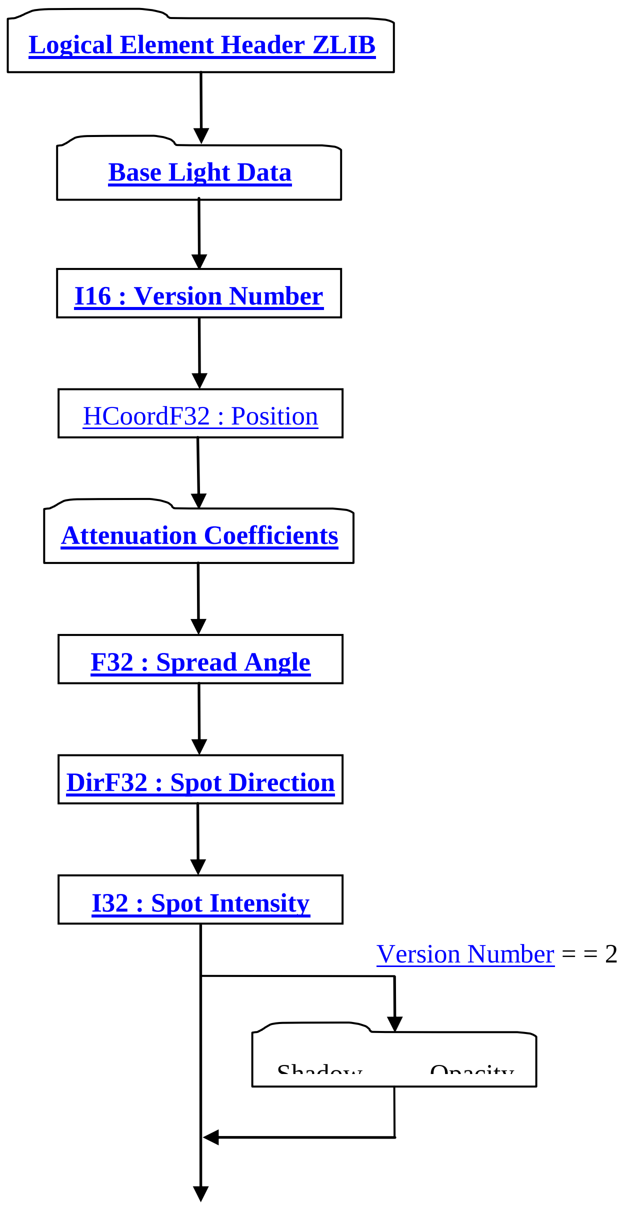
Object Type ID: 0x10dd1045, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Point Light Attribute Element specifies a light source emitting light from a specified position, along a specified direction, and with a specified spread angle

JT format LSG traversal semantics state that point light attributes accumulate down the LSG through addition of lights to an attribute list.

Point Light Attribute Element does not have any Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments.

Figure 56: Point Light Attribute ElementPoint Light Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Light Data can be found in 7.2.1.1.2.6.1 Base Light Data.

Complete description for Attenuation Coefficients can be found in 7.2.1.1.2.7.1Attenuation Coefficients.

Complete description for Shadow Parameters can be found in 7.2.1.1.2.6.2 Shadow Parameters.

I16 : Version Number

Version Number is the version identifier for this element. The value of this Version Number indicates the format of data fields to follow.

= 1	Version-1 Format
= 2	Version-2 Format

HCoordF32 : Position

Position specifies the light position in homogeneous coordinates.

F32 : Spread Angle

Spread Angle, as shown in Figure 57 below, specifies in degrees the half angle of the light cone. Valid Spread Angle values are clamped and interpreted as follows:

angle = = 180.0	Simple point light
0.0 >= angle <= 90.0	Spot Light

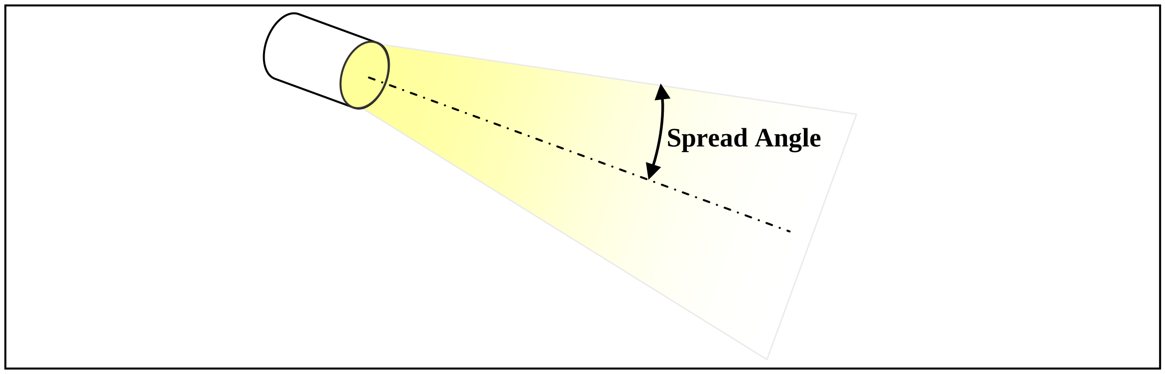


Figure 57: Spread Angle value with respect to the light cone

DirF32 : Spot Direction

Spot Direction specifies the direction the spot light is pointing in.

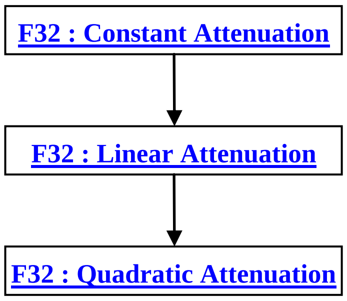
I32 : Spot Intensity

Spot Intensity specifies the intensity distribution of the light within the spot light cone. Spot Intensity is really a "spot exponent" in a lighting equation and indicates how focused the light is at the center. The larger the value, the more focused the light source. Only non-negative Spot intensity values are valid.

7.2.1.1.2.7.1 Attenuation Coefficients

Attenuation Coefficients data collection contains the coefficients for how light intensity decreases with distance.

Figure 58: Attenuation Coefficients data collection



F32 : Constant Attenuation

Constant Attenuation specifies the constant coefficient for how light intensity decreases with distance. Value must be greater than or equal to "0".

F32 : Linear Attenuation

Linear Attenuation specifies the linear coefficient for how light intensity decreases with distance. Value must be greater than or equal to "0".

F32 : Quadratic Attenuation

Quadratic Attenuation specifies the quadratic coefficient for how light intensity decreases with distance. Value must be greater than or equal to "0".

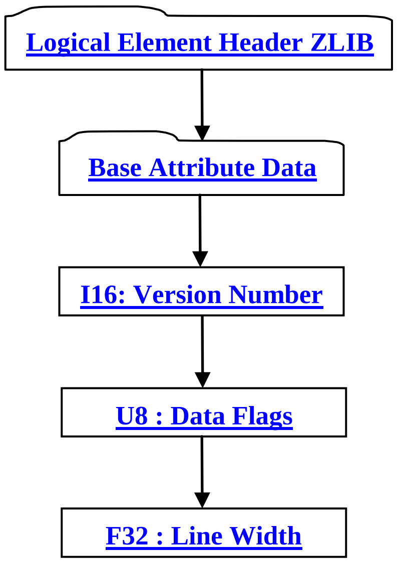
7.2.1.1.2.8Linestyle Attribute Element

Object Type ID: 0x10dd10c4, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Linestyle Attribute Element contains information defining the graphical properties to be used for rendering polylines. JT format LSG traversal semantics state that Linestyle attributes accumulate down the LSG by replacement.

Linestyle Attribute Element does not have any Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments.

Figure 59: Linestyle Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1Base Attribute Data.

I16: Version Number

Version Number is the version identifier for this node. Version number "0x0001" is currently the only valid value for Linestyle Attribute Element.

U8 : Data Flags

Data Flags is a collection of flags and line type data. The flags and line type data are combined using the binary OR operator and store various polyline rendering attributes. All undocumented bits are reserved.

0x0F	Line Type (stored in bits 0 – 3 or in binary notation 00001111) Line type specifies the polyline rendering stipple-pattern. = 0 - Solid ────────────────────── = 1 – Dash - = 2 – Dot ································· = 3 – Dash_Dot -·-·-·-·-·-·-·-·-·-·-·-·-·-·-·- = 4 – Dash_Dot_Dot —··—··—··—··—··—··—··—··— = 5 – Long_Dash — — — — — — — — — — — — — — — = 6 – Center_Dash —·—·—·—·—·—·—·—·—·—·—·—·— = 7 – Center_Dash_Dash —·—··—·—··—·—··—·—··—·—··—
0x10	Antialiasing Flag (stored in bit 4 or in binary notation 00010000) Indicates if antialiasing should be applied as part of rendering polylines. = 0 – Antialiasing disabled. = 1 – Antialiasing enabled.

F32 : Line Width

Line Width specifies the width in pixels that should be used for rendering polylines. The value of this field must be greater than 0.0.

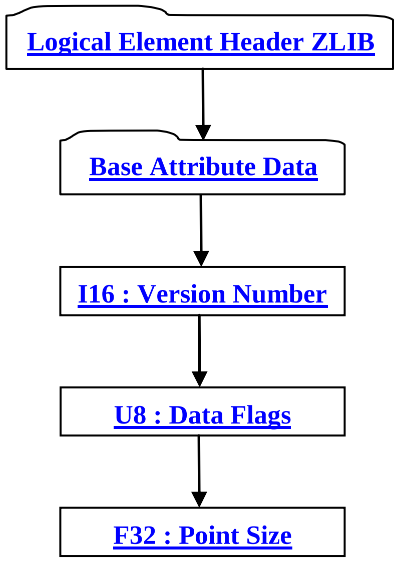
7.2.1.1.2.9Pointstyle Attribute Element

Object Type ID: 0x8d57c010, 0xe5cb, 0x11d4, 0x84, 0xe, 0x00, 0xa0, 0xd2, 0x18, 0x2f, 0x9d

Pointstyle Attribute Element contains information defining the graphical properties that should be used for rendering points. JT format LSG traversal semantics state that Pointstyle attributes accumulate down the LSG by replacement.

Pointstyle Attribute Element does not have any Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments.

Figure 60: Pointstyle Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1Base Attribute Data.

I16 : Version Number

Version Number is the version identifier for this element. Version number "0x0001" is currently the only valid value for Pointstyle Attribute Element.

U8 : Data Flags

Data Flags is a collection of flags and point type data. The flags and point type data are combined using the binary OR operator and store various point rendering attributes. All undocumented bits are reserved.

0x0F	Point Type (stored in bits 0 – 3 or in binary notation 00001111) These bits are reserved for future expansion of the format to support Point Types.
0x10	Antialiasing Flag (stored in bit 4 or in binary notation 00010000) Indicates if antialiasing should be applied as part of rendering points. = 0 – Antialiasing disabled. = 1 – Antialiasing enabled.

F32 : Point Size

Point Size specifies the size in pixels that should be used for rendering points. The value must be greater than 0.0.

7.2.1.1.2.10 Geometric Transform Attribute Element

Object Type ID: 0x10dd1083, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

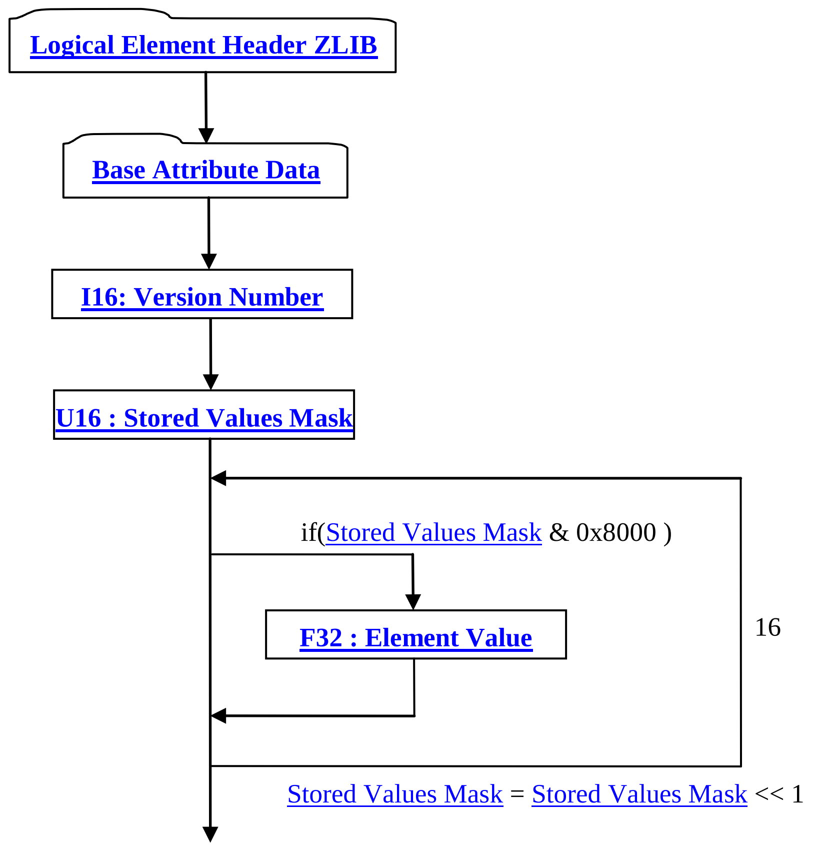
Geometric Transform Attribute Element contains a 4x4 homogeneous transformation matrix that positions the associated LSG node's coordinate system relative to its parent LSG node. JT format LSG traversal semantics state that geometric transform attributes accumulate down the LSG through matrix multiplication as follows:

$$p' = pAM$$

Where *p* is a point of the model, *p'* is the transformed point, *M* is the current modeling transformation matrix inherited from ancestor LSG nodes and previous Geometric Transform Attribute Element, and *A* is the transformation matrix of this Geometric Transform Attribute Element. The matrix is allowed to contain translation, rotation, and uniform- and non-uniform scaling factors, including negative scales. It is not allowed to contain shearing or projective components, or scaling factors of zero (which would make the matrix singular).

Geometric Transform Attribute Element does not have any Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments.

Figure 61: Geometric Transform Attribute Element data collection


Logical Element Header ZLIB
Base Attribute Data
I16: Version Number
U16 : Stored Values Mask
if(Stored Values Mask & 0x8000)
F32 : Element Value
16
Stored Values Mask = Stored Values Mask << 1

Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1Base Attribute Data.

I16: Version Number

Version Number is the version identifier for this node. Version number “0x0001” is currently the only valid value for Geometric Transform Attribute Element.

U16 : Stored Values Mask

Stored Values mask is a 16-bit mask where each bit is a flag indicating whether the corresponding element in the matrix is different from the identity matrix. Only elements which are different from the identity matrix are actually stored. The bits are assigned to matrix elements as follows:

Bit15	Bit14	Bit13	Bit12
Bit11	Bit10	Bit9	Bit8
Bit7	Bit6	Bit5	Bit4
Bit3	Bit2	Bit1	Bit0

The individual bit-flag values are interpreted as follows:

= 0	Value not stored (matrix value same as corresponding element in identity matrix)
= 1	Value stored

F32 : Element Value

Element Value specifies a particular matrix element value.

7.2.1.1.2.11 Shader Effects Attribute Element

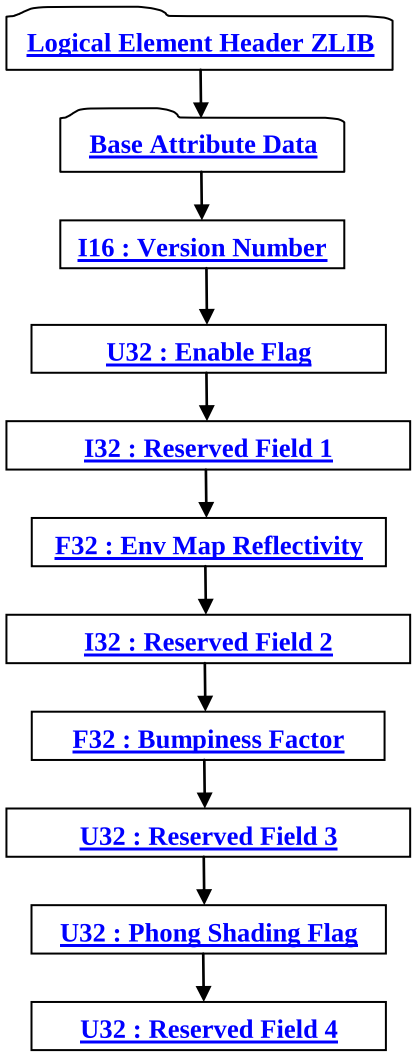
Object Type ID: 0xaa1b831d, 0x6e47, 0x4fee, 0xa8, 0x65, 0xcd, 0x7e, 0x1f, 0x2f, 0x39, 0xdb

Shader Effects Attribute Element contains information specifying "high-level" shader functionality (e.g. Phong shading, bump mapping, etc.) that should be used for rendering the geometry this attribute element is associated with.

JT format LSG traversal semantics state that shader effects attributes accumulate down the LSG by replacement.

Shader Effects Attribute Element does not have any Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments.

Figure 62: Shader Effects Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1Base Attribute Data.

I16 : Version Number

Version Number is the version identifier for this element. Version number "0x0001" is currently the only valid value.

U32 : Enable Flag

Enable Flag specifies whether this Shader Effects Attribute is enabled. Valid values include the following:

= 0	Shader Effects Attribute disabled
= 1	Shader Effects Attribute enabled

I32 : Reserved Field 1

Reserved Field 1 is a data field reserved for future JT format expansion

F32 : Env Map Reflectivity

Env Map Reflectivity specifies the fraction of the environment to be reflected (1 minus this fraction will show through form the underlying texture channel). Valid value must be in the range [0:1] inclusive.

I32 : Reserved Field 2

Reserved Field 2 is a data field reserved for future JT format expansion

F32 : Bumpiness Factor

Bumpiness Factor specifies the degree of "bumpiness", or the relative "height" of the bump map. Larger values make the bumps appear deep and more severe. Negative values invert the sense of the bump map, making the surface appear engraved, rather than embossed. This value only has an effect with tangent space bump maps.; it has no effect on the appearance of object space bump maps.

U32 : Reserved Field 3

Reserved Field 3 is a data field reserved for future JT format expansion

U32 : Phong Shading Flag

Phong Shading Flag specifies whether Phong Shading (i.e. per fragment lighting) is enabled. Valid values include the following:

= 0	Phong Shading disabled
= 1	Phong Shading enabled

U32 : Reserved Field 4

Reserved Field 4 is a data field reserved for future JT format expansion

7.2.1.1.2.12 Vertex Shader Attribute Element

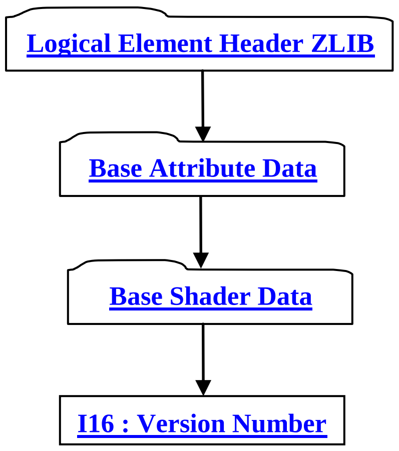
Object Type ID: 0x2798bcad, 0xe409, 0x47ad, 0xbd, 0x46, 0xb, 0x37, 0x1f, 0xd7, 0x5d, 0x61

Vertex Shader Attribute Element defines a per-vertex shader program in the GLSL shading language. A complete description of the GLSL shading language can be found in references listed within the 3 References and Additional Information section of this document.

JT format LSG traversal semantics state that vertex shader attributes accumulate down the LSG by replacement.

In general, a shader program is used to replace a portion of the otherwise fixed-function graphics pipeline with some user-defined functionality. Specifically a Vertex Shader program is a small user defined program to be run for each vertex that is sent to the GPU for processing. A Vertex shader can alter vertex positions and normals, generate texture coordinates, perform Gouraud per-vertex lighting, etc.

Figure 63: Vertex Shader Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1Base Attribute Data.

I16 : Version Number

Version Number is the version identifier for this element. Version number "0x0001" is currently the only valid value.

7.2.1.1.2.13 Fragment Shader Attribute Element

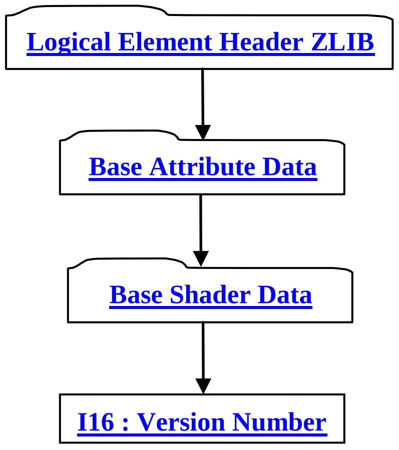
Object Type ID: 0xad8dccc2, 0x7a80, 0x456d, 0xb0, 0xd5, 0xdd, 0x3a, 0xb, 0x8d, 0x21, 0xe7

Fragment Shader Attribute Element defines a per-fragment shader program in the GLSL shading language. A complete description of the GLSL shading language can be found in references listed within the 3 References and Additional Information section of this document.

JT format LSG traversal semantics state that fragment shader attributes accumulate down the LSG by replacement; with the exception that if the new fragment shader attribute's shader language is not the same as current fragment shader attribute's shader language, then new fragment shader attribute is simply ignored.

In general, a shader program is used to replace a portion of the otherwise fixed-function graphics pipeline with some user-defined functionality. Specifically a Fragment Shader program is a small user defined program to be run for each fragment generated by the GPU hardware's scan-conversion logic. A fragment is a "proto-pixel" generated by triangle scan-conversion, but not let laid down into the frame buffer, where it will become an actual pixel. A Fragment Shader can support sophisticated effects like Phong shading, shadow mapping, bump mapping, reflection mapping, etc.

Figure 64: Fragment Shader Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1Base Attribute Data.

Complete description for Base Shader Data can be found in 7.2.1.1.2.1.2 Base Shader Data.

I16 : Version Number

Version Number is the version identifier for this element. Version number “0x0001” is currently the only valid value.

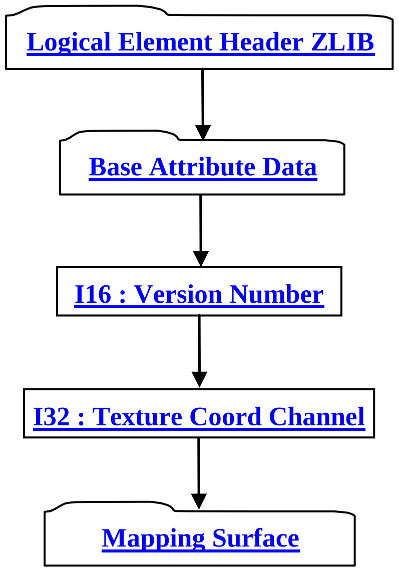
7.2.1.1.2.14 Texture Coordinate Generator Attribute Element

Object Type ID: 0xaa1b831d, 0x6e47, 0x4fee, 0xa8, 0x65, 0xcd, 0x7e, 0x1f, 0x2f, 0x39, 0xdc

Texture Coordinate Generator Attribute Element defines texture coordinate generation for texture mapping. Multiple texture coordinate generation at a given node is supported by way of the “texture coordinate channel” concept. JT format LSG traversal semantics state that Texture Coordinate Generator attributes accumulate down the LSG by replacement on a per-channel basis.

Texture Coordinate Generator Attribute Element does not have any Field Inhibit flag (see 7.2.1.1.2.1.1Base Attribute Data) bit assignments.

Figure 65: Texture Coordinate Generator Attribute Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Attribute Data can be found in 7.2.1.1.2.1.1Base Attribute Data.

Complete description for Mapping Surface can be found in 7.2.1.1.2.14.1Mapping Surface.

I16 : Version Number

Version Number is the version identifier for this element. Version number "0x0001" is currently the only valid value.

I32 : Texture Coord Channel

Tex Coord Channel specifies the channel number for texture coordinate generation. Value must be within range [0, 2147483647] inclusive. This number is intended to match up with the I32 : Tex Coord Channel field on Texture Image Attribute Element in order to associate a specific Texture Coordinate Generator with a Specific Texture Image.

7.2.1.1.2.14.1 Mapping Surface

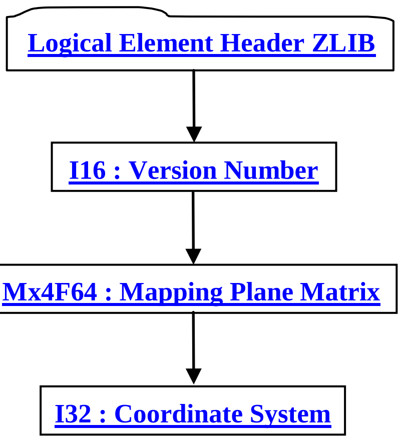
Mapping Surface defines the mapping surface for texture coordinate generation. Four kinds of mapping surfaces, Mapping Plane Element, Mapping Cylinder Element, Mapping Sphere Element, and Mapping TriPlanar Element, are defined to support texture coordinate generation.

7.2.1.1.2.14.1.1 Mapping Plane Element

Object Type ID: 0xa3cfb921, 0xbdeb, 0x48d7, 0xb3, 0x96, 0x8b, 0x8d, 0xe, 0xf4, 0x85, 0xa0

Mapping Plane Element defines the mapping plane for texture coordinate generation.

Figure 66: Mapping Plane Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

I16 : Version Number

Version Number is the version identifier for this element. Version number "0x0001" is currently the only valid value.

Mx4F64 : Mapping Plane Matrix

Mx4F64 : Mapping Plane Matrix specifies the transformation matrix and mapping parameters for the mapping plane. The transformation matrix defines the mapping coordinate system transformed from I32 : Coordinate System. The mapping parameters specifies the width and height of the mapping plane. The mapping plane is defined in the + xy-plane of the mapping coordinate system. In the mapping process, the geometry vertex coordinates in Model Coordinate System are transformed to the mapping coordinate system at first, and then the transformed vertex coordinates are mapped to texture coordinates as following:

s-coordinate = x-coordinate of the transformed vertex / the width of the mapping plane
t-coordinate = y-coordinate of the transformed vertex / the height of the mapping plane

I32 : Coordinate System

Coordinate system specifies the coordinate space in which mapping plane is defined. Valid values include the following

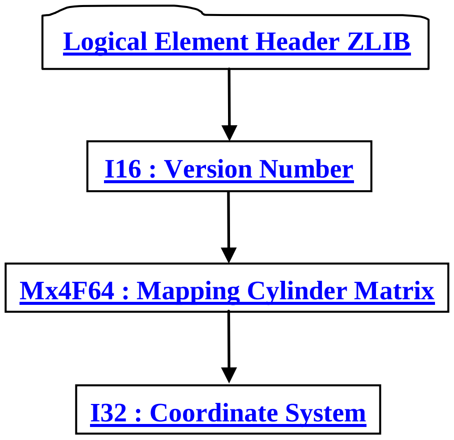
= 0	Undefined Coordinate System.
= 1	Viewpoint Coordinate System. Mapping plane is to move together with the viewpoint.
= 2	Model Coordinate System. Mapping plane is affected by whatever model transforms that are current when the mapping plane is encountered in LSG.
= 3	World Coordinate system. Mapping plane is not affected by model transforms in the LSG.

7.2.1.1.2.14.1.2 Mapping Cylinder Element

Object Type ID: 0x3e70739d, 0x8cb0, 0x41ef, 0x84, 0x5c, 0xa1, 0x98, 0xd4, 0x0, 0x3b, 0x3f

Mapping Cylinder Element defines the mapping cylinder for texture coordinate generation.

Figure 67: Mapping Cylinder Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

I16 : Version Number

Version Number is the version identifier for this element. Version number "0x0001" is currently the only valid value.

Mx4F64 : Mapping Cylinder Matrix

Mx4F64 : Mapping Cylinder Matrix specifies the transformation matrix and mapping parameters for the mapping cylinder. The transformation matrix defines the mapping coordinate system transformed from I32 : Coordinate System. The mapping parameters specifies the horizontal sweep angle and height of the mapping cylinder. The mapping cylinder's axis is parallel to the z-axis of the mapping coordinate system, and the horizontal sweep angle starts from the +x-axis in a counter clockwise direction. In the mapping process, the geometry vertex coordinates in Model Coordinate System are transformed to the mapping coordinate system at first, and then the transformed vertex coordinates are mapped to texture coordinates as following:

s-coordinate = the horizontal sweep angle of the vertex / the horizontal sweep angle of the mapping cylinder
t-coordinate = the z-coordinate of the vertex / height of the mapping cylinder

Mapping Cylinder Element implements the strategy to handle texture coordinates who cross the seam of the texture in the mapping process.

I32 : Coordinate System

Coordinate system specifies the coordinate space in which mapping cylinder is defined. Valid values include the following

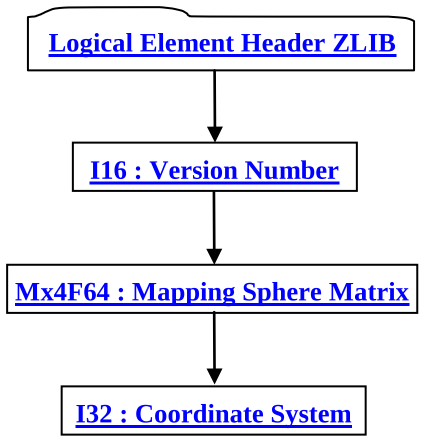
= 0	Undefined Coordinate System.
= 1	Viewpoint Coordinate System. Mapping cylinder is to move together with the viewpoint.
= 2	Model Coordinate System. Mapping cylinder is affected by whatever model transforms that are current when the mapping cylinder is encountered in LSG.
= 3	World Coordinate system. Mapping cylinder is not affected by model transforms in the LSG.

7.2.1.1.2.14.1.3 Mapping Sphere Element

Object Type ID: 0x72475fd1, 0x2823, 0x4219, 0xa0, 0x6c, 0xd9, 0xe6, 0xe3, 0x9a, 0x45, 0xc1

Mapping Sphere Element defines the mapping sphere for texture coordinate generation.

Figure 68: Mapping Sphere Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

I16 : Version Number

Version Number is the version identifier for this element. Version number "0x0001" is currently the only valid value.

Mx4F64 : Mapping Sphere Matrix

Mx4F64 : Mapping Sphere Matrix specifies the transformation matrix and mapping parameters of the mapping sphere. The transformation matrix defines the mapping coordinate system transformed from I32 : Coordinate System. The mapping parameters specify the horizontal sweep angle and vertical sweep angle of the mapping sphere. The mapping sphere's center is at the origin of the mapping coordinate system, and the poles of the sphere are parallel to the z-axis of the coordinate system. The horizontal sweep angle starts from the +x-axis in a counter clockwise direction, and the vertical sweep angle is from the +z-axis to the –z-axis. In the mapping process, the geometric vertex coordinates in Model Coordinate System are transformed to the mapping coordinate system at first, and then the transformed vertex coordinates are mapped to texture coordinates as following:

s-coordinate = the horizontal sweep angle of the vertex / the horizontal sweep angle of the mapping sphere
t-coordinate = the vertical sweep angle of the vertex / the vertical sweep angle of the mapping sphere

Mapping Sphere Element implements the strategy to handle texture coordinates who cross the seam of the texture in the mapping process.

I32 : Coordinate System

Coordinate system specifies the coordinate space in which mapping sphere is defined. Valid values include the following

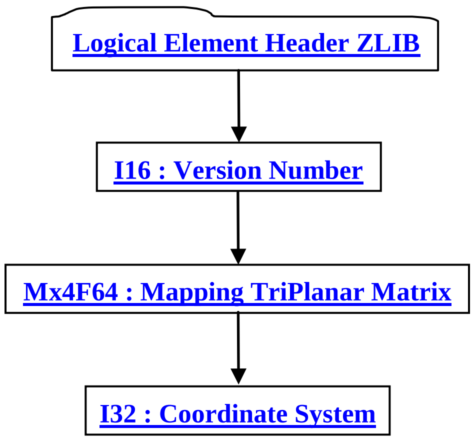
= 0	Undefined Coordinate System.
= 1	Viewpoint Coordinate System. Mapping sphere is to move together with the viewpoint.
= 2	Model Coordinate System. Mapping sphere is affected by whatever model transforms that are current when the mapping sphere is encountered in LSG.
= 3	World Coordinate system. Mapping sphere is not affected by model transforms in the LSG.

7.2.1.1.2.14.1.4 Mapping TriPlanar Element

Object Type ID: 0x92f5b094, 0x6499, 0x4d2d, 0x92, 0xaa, 0x60, 0xd0, 0x5a, 0x44, 0x32, 0xcf

Mapping TriPlanar Element defines the mapping triplanar surface for texture coordinate generation.

Figure 69: Mapping TriPlanar Element data collection


Logical Element Header ZLIB
I16 : Version Number
Mx4F64 : Mapping TriPlanar Matrix
I32 : Coordinate System

Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

I16 : Version Number

Version Number is the version identifier for this element. Version number “0x0001” is currently the only valid value.

Mx4F64 : Mapping TriPlanar Matrix

Mx4F64 : Mapping TriPlanar Matrix specifies the transformation matrix and mapping parameter for the mapping triplanar. The transformation matrix defines the mapping coordinate system transformed from I32 : Coordinate System. The mapping parameter specifies the planar length of the triplanar. The left bottom corner of the triplanar is located at the origin of the mapping coordinate system, and the three planes are in the + xy-plane, + yz-plane, and + xz-plane respectively. In the mapping process, the geometry vertex coordinates in Model Coordinate System are transformed to the mapping coordinate system at first, and then the transformed vertex coordinates are projected to the corresponding plane based on the maximum component of its normals, and at last the projected vertex coordinates are mapped to texture coordinates as following:

s-coordinate = the first-coordinate of the projected vertex / the planar length of the triplanar
t-coordinate = the second-coordinate of the projected vertex / the planar length of the triplanar

I32 : Coordinate System

Coordinate system specifies the coordinate space in which mapping triplanar surface is defined. Valid values include the following

= 0	Undefined Coordinate System.
= 1	Viewpoint Coordinate System. Mapping triplanar surface is to move together with the viewpoint.
= 2	Model Coordinate System. Mapping triplanar surface is affected by whatever model transforms that are current when the mapping triplanar surface is encountered in LSG.
= 3	World Coordinate system. Mapping triplanar surface is not affected by model transforms in the LSG.

7.2.1.2 Property Atom Elements

Property Atom Elements are meta-data objects associated with nodes or Attributes. Property Atom Elements are not nodes or attributes themselves, but can be associated with any node or Attribute to maintain arbitrary application- or enterprise information (meta-data) pertaining to that node or Attribute. Each Node Element or Attribute Element in an LSG may hold zero or more Property Atom Elements and this relationship information is stored within 7.2.1.3 Property Table section of a JT file.

An individual property is specified as a *key/value* Property Atom Element pair, where the *key* identifies the type and meaning of the *value*. The JT format supports many different Property Atom Element key/value object types. The different Property Atom Element key/value object types are documented in the following subsections.

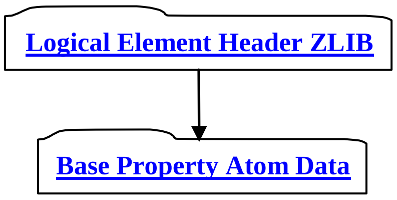
Some "Best Practices" for placing application or enterprise properties/meta-data on Nodes in JT files can be found in 9.6 Metadata Conventions section of this reference.

7.2.1.2.1 Base Property Atom Element

Object Type ID: 0x10dd104b, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Base Property Atom Element represents the simplest form of a property that can exist within the LSG and has no type specific value data associated with it.

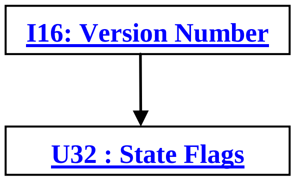
Figure 70: Base Property Atom Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

7.2.1.2.1.1 Base Property Atom Data

Figure 71: Base Property Atom Data collection



I16: Version Number

Version Number is the version identifier for this data collection. Version number "0x0001" is currently the only valid value for Base Property Atom Data.

U32 : State Flags

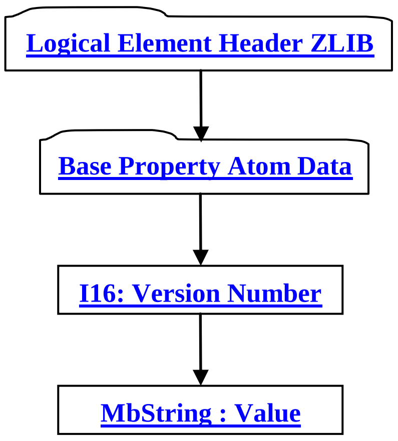
State Flags is a collection of flags. The flags are combined using the binary OR operator and store various state information for property atoms. Bits 0 – 7 are freely available for an application to store whatever property atom information desired. All other bits are reserved for future expansion of the file format.

7.2.1.2.2 String Property Atom Element

Object Type ID: 0x10dd106e, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

String Property Atom Element represents a character string property atom.

Figure 72: String Property Atom Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Property Atom Data can be found in 7.2.1.2.1.1Base Property Atom Data.

I16: Version Number

Version Number is the version identifier for this data collection. Version number “0x0001” is currently the only valid value for String Property Atom Element.

MbString : Value

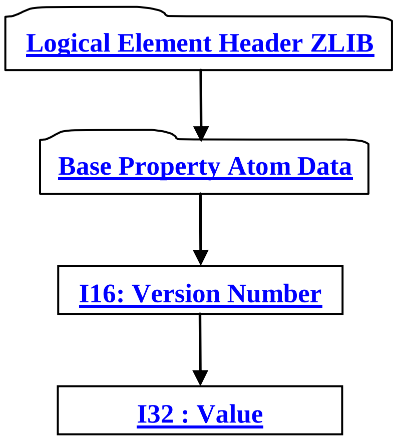
Value contains the character string value for this property atom.

7.2.1.2.3 Integer Property Atom Element

Object Type ID: 0x10dd102b, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Integer Property Atom Element represents a property atom whose value is of I32 data type.

Figure 73: Integer Property Atom Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Property Atom Data can be found in 7.2.1.2.1.1Base Property Atom Data.

I16: Version Number

Version Number is the version identifier for this data collection. Version number "0x0001" is currently the only valid value for Integer Property Atom Element.

I32 : Value

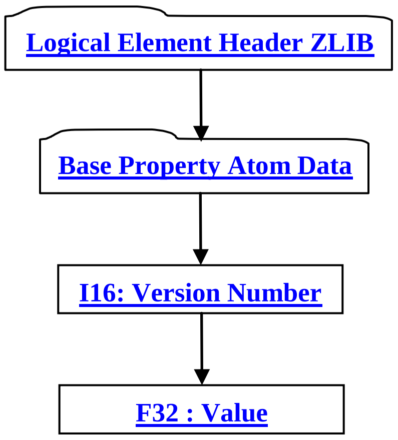
Value contains the integer value for this property atom.

7.2.1.2.4 Floating Point Property Atom Element

Object Type ID: 0x10dd1019, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Floating Point Property Atom Element represents a property atom whose value is of F32 data type.

Figure 74: Floating Point Property Atom Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Property Atom Data can be found in 7.2.1.2.1.1Base Property Atom Data.

I16: Version Number

Version Number is the version identifier for this data collection. Version number "0x0001" is currently the only valid value.

F32 : Value

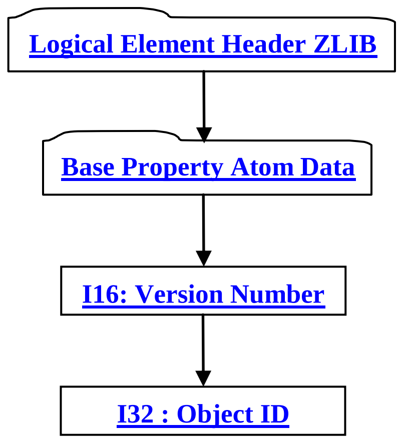
Value contains the floating point value for this property atom.

7.2.1.2.5 JT Object Reference Property Atom Element

Object Type ID: 0x10dd1004, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

JT Object Reference Property Atom Element represents a property atom whose value is an object ID for another object within the JT file.

Figure 75: JT Object Reference Property Atom Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Property Atom Data can be found in 7.2.1.2.1.1Base Property Atom Data.

I16: Version Number

Version Number is the version identifier for this data collection. Version number "0x0001" is currently the only valid value.

I32 : Object ID

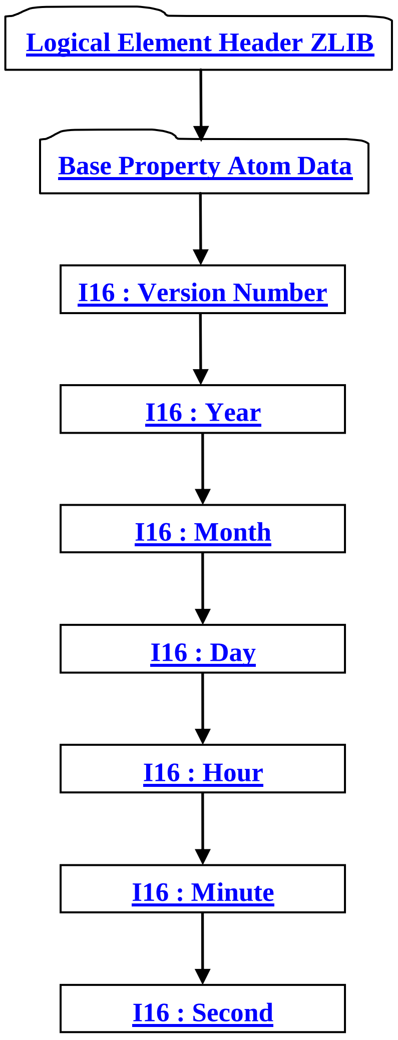
Object ID specifies the identifier within the JT file for the referenced object.

7.2.1.2.6 Date Property Atom Element

Object Type ID: 0xce357246, 0x38fb, 0x11d1, 0xa5, 0x6, 0x0, 0x60, 0x97, 0xbd, 0xc6, 0xe1

Date Property Atom Element represents a property atom whose value is a "date".

Figure 76: Date Property Atom Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Property Atom Data can be found in 7.2.1.2.1.1Base Property Atom Data.

I16 : Version Number

Version Number is the version identifier for this data collection. Version number "0x0001" is currently the only valid value for Late Loaded Property Atom Element.

I16 : Year

Year specifies the date year value. Valid values are [1900, 2999] inclusive.

I16 : Month

Month specifies the date month value. Valid values are [0, 11] inclusive.

I16 : Day

Day specifies the date day value. Valid values are [1, 31] inclusive.

I16 : Hour

Hour specifies the date hour value. Valid values are [0, 23] inclusive.

I16 : Minute

Minute specifies the date minute value. Valid values are [0, 59] inclusive.

I16 : Second

Second specifies the date Second value. Valid values are [0, 59] inclusive.

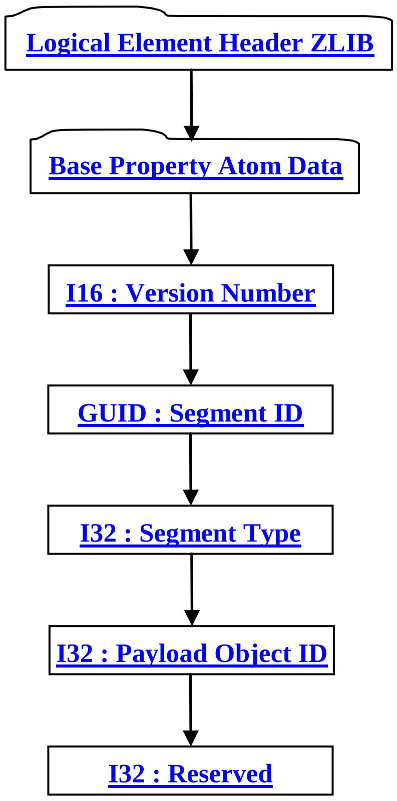
7.2.1.2.7 Late Loaded Property Atom Element

Object Type ID: 0xe0b05be5, 0xfbbd, 0x11d1, 0xa3, 0xa7, 0x00, 0xaa, 0x00, 0xd1, 0x09, 0x54

Late Loaded Property Atom Element is a property atom type used to reference an associated piece of atomic data in a separate addressable segment of the JT file. The "Late Loaded" connotation derives from the associated data being stored in a separate addressable segment of the JT file, and thus a JT file reader can be structured to support the "best practice" of delaying the loading/reading of the associated data until it is actually needed.

Late Loaded Property Atom Elements are used to store a variety of data, including, but not limited to, Shape LOD Segments and B-Rep Segments (see 7.2.2 Shape LOD Element and 7.2.3 JT B-Rep Segment).

Figure 77: Late Loaded Property Atom Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Property Atom Data can be found in 7.2.1.2.1.1Base Property Atom Data.

I16 : Version Number

Version Number is the version identifier for this data collection. Version number "0x0001" is currently the only valid value for Late Loaded Property Atom Element.

GUID : Segment ID

Segment ID is the globally unique identifier for the associated data segment in the JT file. See 7.1.2 TOC Segment for additional information on how this Segment ID can be used in conjunction with the file TOC Entries to locate the associated data in the JT file.

The complete list of segment types can be found in Table 3: Segment Types.

I32 : Segment Type

Segment Type defines a broad classification of the associated data segment contents. For example, a Segment Type of "1" denotes that the segment contains Logical Scene Graph material; "2" denotes contents of a B-Rep, etc.

I32 : Payload Object ID

Object ID is the identifier for the payload. Other objects referencing this particular payload will do so using the Object ID.

I32 : Reserved

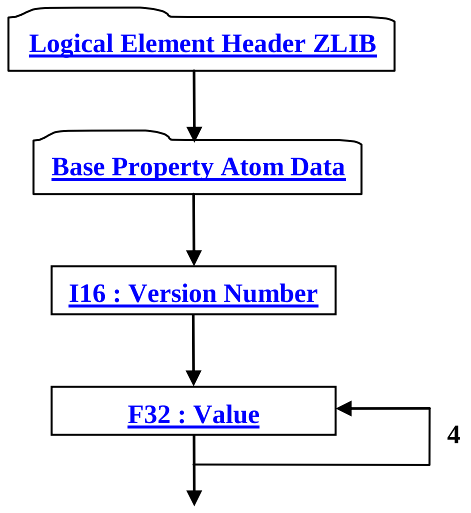
Reserved data field that is guaranteed to always be greater than or equal to 1

7.2.1.2.8 Vector4f Property Atom Element

Object Type ID: 0x2e7db4be, 0xc71a, 0x4b18, 0x9d, 0x7, 0xc7, 0x22, 0x7e, 0x9f, 0xef, 0x76

Vector4f Property Atom Element represents a property atom whose value is of VecF32 data type with the length to be equal to 4 .

Figure 78: Vector4f Property Atom Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

Complete description for Base Property Atom Data can be found in 7.2.1.2.1.1Base Property Atom Data.

I16 : Version Number

Version Number is the version identifier for this data collection. Version number "0x0001" is currently the only valid value for Late Loaded Property Atom Element.

F32 : Value

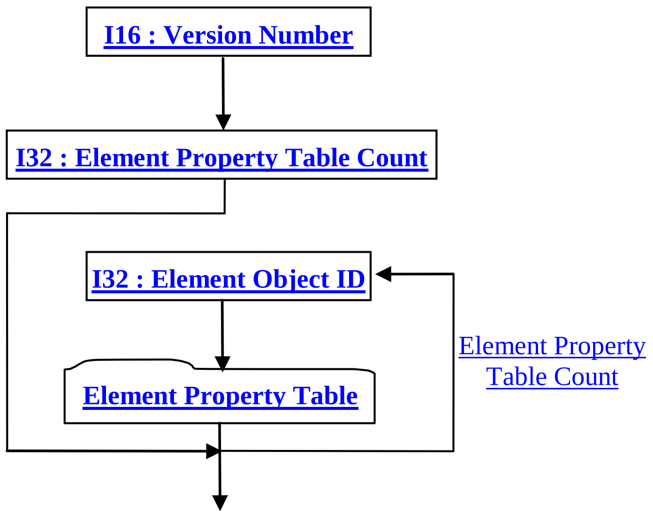
Value contains the floating point value for this property atom

7.2.1.3 Property Table

The Property Table is where the data connecting Node Elements and Attribute Elements with their associated Properties is stored. The Property Table contains an Element Property Table for each element in the JT File which has associated Properties. An Element Property Table is a list of key/value Property Atom Element pairs for all Properties associated with a particular Node Element Object or Attribute Element Object.

For a reference compliant JT File all Node Elements, Attribute Elements, and Property Atom Elements contained in a JT file should have been read by the time a JT file reader reaches the Property Table section of the file. This means that all Node Objects, Attribute Objects, and Property Atom Objects referenced in the Property Table (through Object IDs), should have already been read, and if not, then the file is corrupt (i.e. not reference compliant).

Figure 79: Property Table data collection



I16 : Version Number

Version Number is the version identifier for this Property Table. Version number "0x0001" is currently the only valid value.

I32 : Element Property Table Count

Element Property Table Count specifies the number of Element Property Tables to follow. This value is equivalent to the total number of Node Elements (see 7.2.1.1.1Node Elements) and Attribute Elements (see 7.2.1.1.2 Attribute Elements) that have associated Property Atom Elements (see 7.2.1.2 Property Atom Elements).

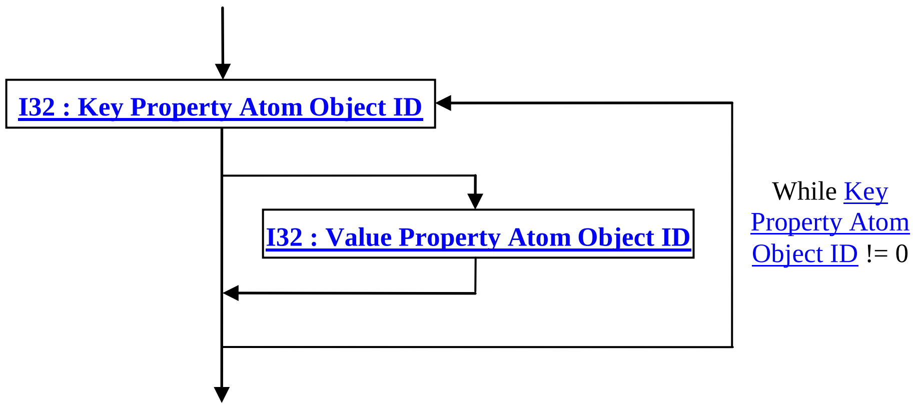
I32 : Element Object ID

Element Object ID is the identifier for the Node Element object (see 7.2.1.1.1Node Elements) or the Attribute Element object (see 7.2.1.1.2Attribute Elements) that the following Element Property Table is for (i.e. Node Element or Attribute Element that all properties in the following Element Property Table are associated with).

7.2.1.3.1 Element Property Table

The Element Property Table is a list of key/value Property Atom Element pairs for all properties associated with a particular Node Element Object or Attribute Element Object. The list is terminated by a "0" value for Key Property Atom Object ID.

Figure 80: Element Property Table data collection



I32 : Key Property Atom Object ID
I32 : Value Property Atom Object ID
While Key Property Atom Object ID != 0

I32 : Key Property Atom Object ID

Key Property Atom Object ID is the identifier for the Property Atom Element object (see 7.2.1.2 Property Atom Elements) representing the "key" part of the property key/value pair. A value of "0" indicates the end of the Node Property Table.

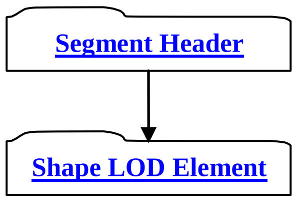
I32 : Value Property Atom Object ID

Value Property Atom Object ID is the identifier for the Property Atom Element object (see 7.2.1.2 Property Atom Elements) representing the "value" part of the property key/value pair. A value is not stored if Key Property Atom Object ID has a value of "0".

7.2.2 Shape LOD Segment

Shape LOD Segment contains an Element that defines the geometric shape definition data (e.g. vertices, polygons, normals, etc) for a particular shape Level Of Detail or alternative representation. Shape LOD Segments are typically referenced by Shape Node Elements using Late Loaded Property Atom Elements (see 7.2.1.1.1.10 Shape Node Elements and 0 Late Loaded Property Atom Element respectively).

Figure 81: Shape LOD Segment data collection



Complete description for Segment Header can be found in 7.1.3.1Segment Header.

7.2.2.1 Shape LOD Element

A Shape LOD Element is the holder/container of the geometric shape definition data (e.g. vertices, polygons, normals, etc.) for a single LOD. Much of the "heavyweight" data contained within a Shape LOD Element may be optionally compressed and/or encoded. The compression and/or encoding state is indicated through other data stored in each Shape LOD Element.

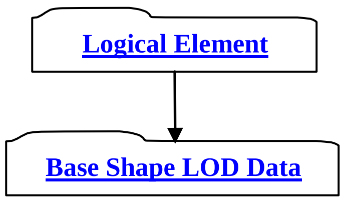
There are several types of Shape LOD Elements which the JT format supports. The following sub-sections document the various Shape LOD Element types.

7.2.2.1.1 Base Shape LOD Element

Object Type ID: 0x10dd10a4, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Base Shape LOD Element serves as the underlying representation for all LODs.

Figure 82: Base Shape LOD Element data collection



Complete description for Logical Element Header can be found in 7.1.3.2.1Logical Element Header.

7.2.2.1.1.1Base Shape LOD Data

Base shape LOD data contains the common items to all shape LODs.

Figure 83: Base Shape LOD Data collection

I16 : Version Number

I16 : Version Number

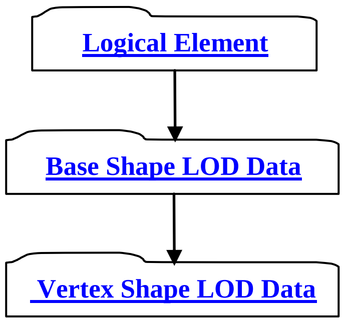
Version Number is the version identifier for this Base Shape LOD Data. Version number “0x0001” is currently the only valid value.

7.2.2.1.2 Vertex Shape LOD Element

Object Type ID: 0x10dd10b0, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

Vertex Shape LOD Element represents LODs defined by collections of vertices.

Figure 84: Vertex Shape LOD Element data collection



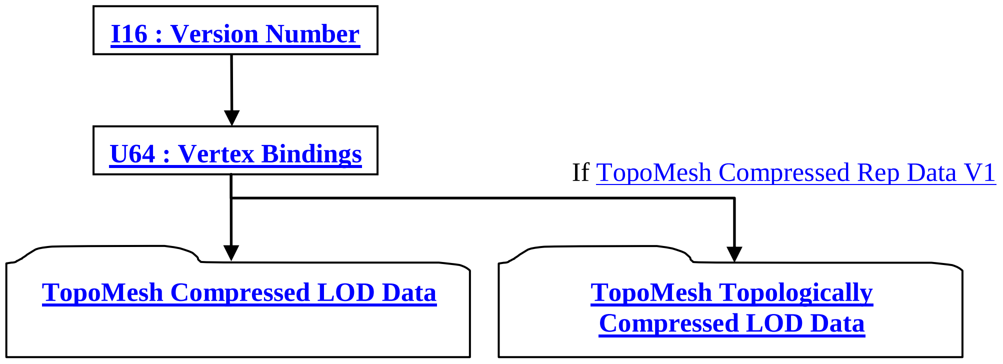
Complete description for Logical Element Header can be found in 7.1.3.2.1Logical Element Header.

7.2.2.1.2.1 Vertex Shape LOD Data

Vertex Shape LOD Data collection is an abstract container for geometric *primitives* such as triangle strips, line strips, or points, depending on the specific type of Vertex Shape. The set of primitives are further partitioned into so-called "face groups." The Vertex Shape LOD Data also contains the vertex attribute bindings and quantization settings used to store the vertex records referenced by the primitives.

One use for face groups is to establish a correspondence between Brep faces and their triangle representation. A convention for mapping JTBrep and XTBrep faces to face groups is described in section 9.10 Brep Face Group Associations.

Figure 85: Vertex Shape LOD Data collection


I16 : Version Number
U64 : Vertex Bindings
If TopoMesh Compressed Rep Data V1
TopoMesh Compressed LOD Data
TopoMesh Topologically Compressed LOD Data

Complete description for TopoMesh Compressed LOD Data and TopoMesh Topologically Compressed LOD Data can be found in 7.2.2.1.2.3 TopoMesh Compressed LOD Data and 7.2.2.1.2.4 TopoMesh Topologically Compressed LOD Data.

I16 : Version Number

Version Number is the version identifier for this Vertex Shape LOD Data. Version number "0x0001" is currently the only valid value.

U64 : Vertex Bindings

Binding Attributes is a collection of normal, texture coordinate, and color binding information encoded within a single U64 using the following bit allocation. All undocumented bits are reserved.

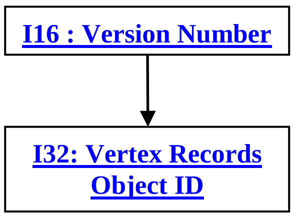
Bits 1-3	Vertex Coordinate Binding. The Vertex Coordinate Binding denotes per vertex coordinate field data is present when one of the bits is set. Bit 1 - 2 Component Vertex Coordinates Bit 2 - 3 Component Vertex Coordinates Bit 3 - 4 Component Vertex Coordinates
Bit 4	Normal Binding. The Normal Binding denotes per vertex normal field data is present when the bit is set. Normal field data is always stored in 3 Component Normals when present.
Bits 5 -6	Color Binding. The Color Binding denotes per vertex color field data is present when one of the bits is set. Bit 5 - 3 Component Colors Bit 6 - 4 Component Color
Bit 7	Vertex Flag Binding. The Vertex Flag Binding denotes the per vertex flag field is present on the shape when the bit is set.
Bits 9-12	Texture Coordinate 0 Binding. The Texture Coordinate 0 binding denotes per vertex texture coordinates field data is present when one of the bits is set: Bit 9 - 1 Component Texture Coordinates Bit 10 - 2 Component Texture Coordinates Bit 11 - 3 Component Texture Coordinates Bit 12 - 4 Component Texture Coordinates
Bits 13-16	Texture Coordinate 1 Binding. The Texture Coordinate 1 binding denotes per vertex texture coordinates field data is present when one of the bits is set: Bit 13 - 1 Component Texture Coordinates Bit 14 - 2 Component Texture Coordinates Bit 15 - 3 Component Texture Coordinates Bit 16 - 4 Component Texture Coordinates
Bits 17-20	Texture Coordinate 2 Binding. The Texture Coordinate 2 binding denotes per vertex texture coordinates field data is present when one of the bits is set:

	Bit 17 - 1 Component Texture Coordinates Bit 18 - 2 Component Texture Coordinates Bit 19 - 3 Component Texture Coordinates Bit 20 - 4 Component Texture Coordinates
Bits 21-24	Texture Coordinate 3 Binding. The Texture Coordinate 3 binding denotes per vertex texture coordinates field data is present when one of the bits is set: Bit 21 - 1 Component Texture Coordinates Bit 22 - 2 Component Texture Coordinates Bit 23 - 3 Component Texture Coordinates Bit 24 - 4 Component Texture Coordinates
Bits 25-28	Texture Coordinate 4 Binding. The Texture Coordinate 4 binding denotes per vertex texture coordinates field data is present when one of the bits is set: Bit 25 - 1 Component Texture Coordinates Bit 26 - 2 Component Texture Coordinates Bit 27 - 3 Component Texture Coordinates Bit 28 - 4 Component Texture Coordinates
Bits 29-32	Texture Coordinate 5 Binding. The Texture Coordinate 5 binding denotes per vertex texture coordinates field data is present when one of the bits is set: Bit 29 - 1 Component Texture Coordinates Bit 30 - 2 Component Texture Coordinates Bit 31 - 3 Component Texture Coordinates Bit 32 - 4 Component Texture Coordinates
Bits 33-36	Texture Coordinate 6 Binding. The Texture Coordinate 6 binding denotes per vertex texture coordinates field data is present when one of the bits is set: Bit 33 - 1 Component Texture Coordinates Bit 34 - 2 Component Texture Coordinates Bit 35 - 3 Component Texture Coordinates Bit 36 - 4 Component Texture Coordinates
Bits 37-40	Texture Coordinate 7 Binding. The Texture Coordinate 7 binding denotes per vertex texture coordinates field data is present when one of the bits is set: Bit 37 - 1 Component Texture Coordinates Bit 38 - 2 Component Texture Coordinates Bit 39 - 3 Component Texture Coordinates Bit 40 - 4 Component Texture Coordinates
Bit 64	Auxiliary Vertex Field Binding. The Auxiliary Vertex Field Binding denotes per vertex auxiliary field data is present on the shape when the bit is set.

7.2.2.1.2.2 TopoMesh LOD Data

TopoMesh LOD Data collection contains the common items to all TopoMesh LOD elements.

Figure 86: TopoMesh LOD Data collection



I16 : Version Number

Version Number is the version identifier for this TopoMesh LOD Data. Version number "0x0001" and "0x0002" are currently the only valid values.

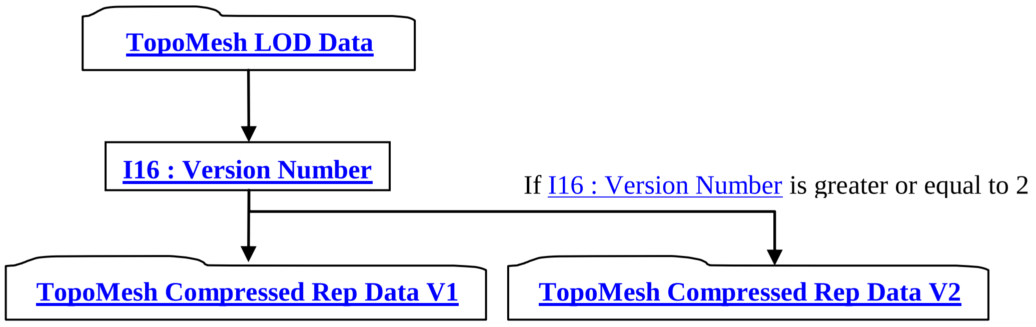
I32: Vertex Records Object ID

Vertex Records Object ID is the identifier for the vertex records associated with this Object. Other objects referencing these vertex records will do so using this Object ID.

7.2.2.1.2.3 TopoMesh Compressed LOD Data

TopoMesh Compressed LOD Data collection contains the common items to all TopoMesh Compressed LOD data elements.

Figure 87: TopoMesh LOD Data collection


TopoMesh LOD Data
I16 : Version Number
If I16 : Version Number is greater or equal to 2
TopoMesh Compressed Rep Data V1
TopoMesh Compressed Rep Data V2

Complete description for TopoMesh LOD Data, TopoMesh Compressed Rep Data V1, and TopoMesh Compressed Rep Data V2 can be found in 7.2.2.1.2.2 TopoMesh LOD Data, 7.2.2.1.2.7 TopoMesh Compressed Rep Data V1, and 7.2.2.1.2.8 TopoMesh Compressed Rep Data V2.

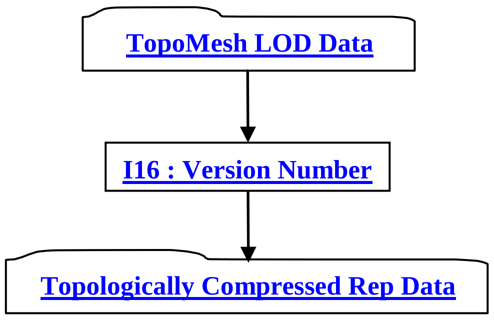
I16 : Version Number

Version Number is the version identifier for this TopoMesh LOD Data. Version number “0x0001” and "0x0002" are currently the only valid values.

7.2.2.1.2.4 TopoMesh Topologically Compressed LOD Data

TopoMesh Topologically Compressed LOD Data collection contains the common items to all TopoMesh Topologically Compressed LOD data elements.

Figure 88: TopoMesh Topologically Compressed LOD Data collection



Complete description for TopoMesh LOD Data and Topologically Compressed Rep Data can be found in 7.2.2.1.2.2 TopoMesh LOD Data and 7.2.2.1.2.5 Topologically Compressed Rep Data.

I16 : Version Number

Version Number is the version identifier for this TopoMesh Topologically Compressed LOD Data. Version number “0x0001” and “0x0002” are currently the only valid values.

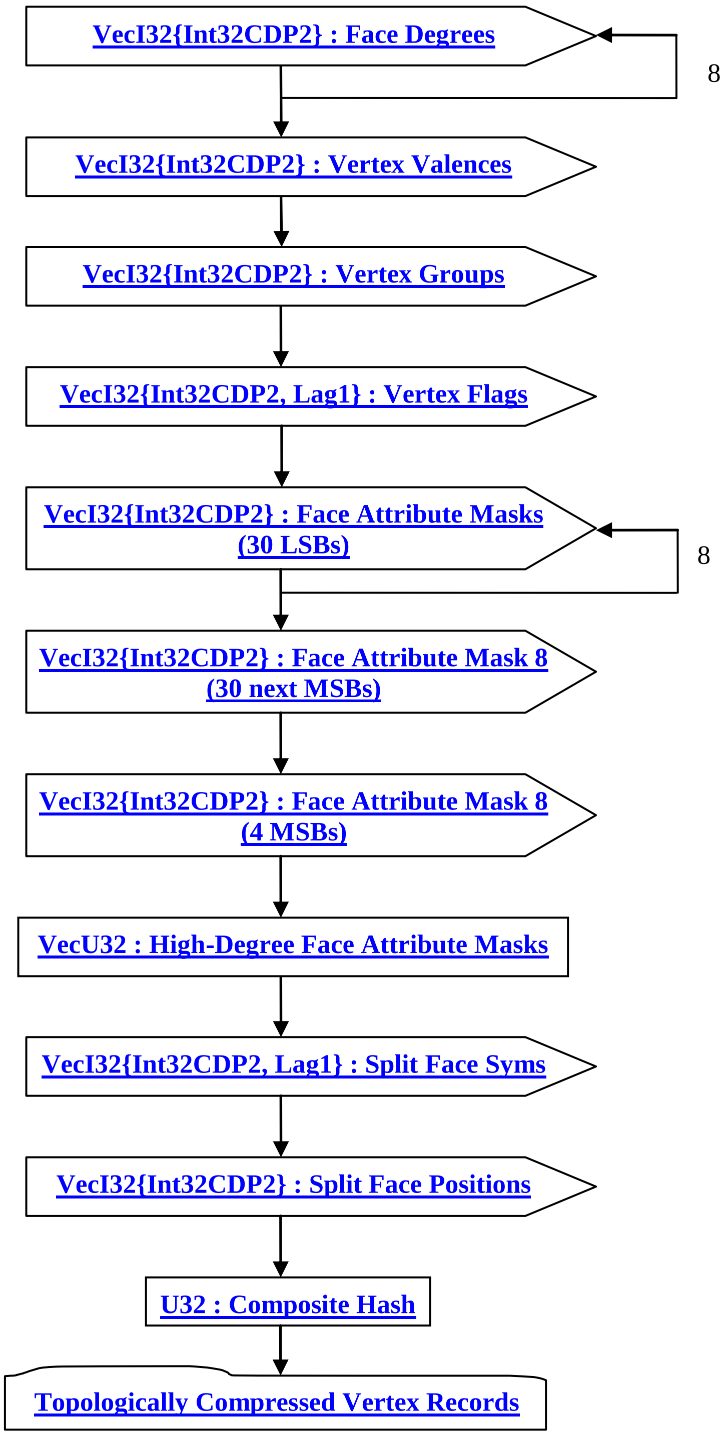
7.2.2.1.2.5 Topologically Compressed Rep Data

JT v9 represents triangle strip data very differently than it does in the JT v8 format. The new scheme stores the triangles from a TriStripSet as a topologically-connected triangle mesh. Even though *more* information is stored to the JT file, the additional structure provided by storing the full topological adjacency information actually provides a handsome reduction in the number of bytes needed to encode the triangles. More importantly, however, the topological information aids us in a more significant respect -- that of only storing the *unique* vertex records used by the TriStripSet. Combined, these two effects reduce the typical storage footprint of TriStripSet data by approximately half relative to the JT v8 format.

The tristrip information itself is no longer stored in the JT file -- only the triangles themselves. The reader is expected to re-tristrip (or not) as it sees fit, as tristrips may no longer provide a performance advantage during rendering. There may, however, remain some memory savings for tristripping, and so the decision to tristrip is left to the user.

To begin the decoding process, first read the compressed data fields shown in Figure 89. These fields provide all the information necessary to reconstruct the per face-group organized sets of triangles. The first 22 fields represent the topological information, and the remaining fields constitute the set of unique vertex records to be used. The next step is to run the topological decoder algorithm detailed in Appendix E: Polygon Mesh Topology Coder on this data to reconstruct the topologically connected representation of the triangle mesh in a so-called "dual VFMesh." The triangles in this heavy-weight data structure can then be exported to a lighter-weight form, and the dual VFMesh discarded if desired.

Figure 89: Topologically Compressed Rep Data Collection


VecI32{Int32CDP2} : Face Degrees
8
VecI32{Int32CDP2} : Vertex Valences
VecI32{Int32CDP2} : Vertex Groups
VecI32{Int32CDP2, Lag1} : Vertex Flags
VecI32{Int32CDP2} : Face Attribute Masks (30 LSBs)
8
VecI32{Int32CDP2} : Face Attribute Mask 8 (30 next MSBs)
VecI32{Int32CDP2} : Face Attribute Mask 8 (4 MSBs)
VecU32 : High-Degree Face Attribute Masks
VecI32{Int32CDP2, Lag1} : Split Face Syms
VecI32{Int32CDP2} : Split Face Positions
U32 : Composite Hash
Topologically Compressed Vertex Records

VecI32{Int32CDP2} : Face Degrees

Similarly to the way valences are encoded, the topology encoder emits the *degree* (number of incident vertices) of each face *in the order they were visited*. The number of face degrees in this array is equal to the number of faces in the mesh.

VecI32{Int32CDP2} : Vertex Valences

As the coder visits each vertex in the mesh, it emits the *valence* (number of incident faces) of each vertex. These valences are collect *in the order they were visited* into this array. The number of valences in this array is equal to the number of (topological) vertices in the mesh.

VecI32{Int32CDP2} : Vertex Groups

This array is parallel to the Vertex Valences array above. As the coder emits the valence of each vertex, it also emits the face group number to which the dual vertex belongs into this array.

VecI32{Int32CDP2, Lag1} : Vertex Flags

This array is also parallel to the Vertex Valences array, and contains a value of 0 when the dual face was present in the original triangle mesh, and a value of 1 if the dual face is a *cover face* that was added to artificially close the original mesh.

VecI32{Int32CDP2} : Face Attribute Masks (30 LSBs)

This field is written 8 times – once for each of the 8 context groups listed above – and encodes the face attribute bit vector associated with a single face.

VecI32{Int32CDP2} : Face Attribute Mask 8 (30 next MSBs)

This field encodes the next 30 most significant bits of the 8th context group of face attribute bit vectors.

VecI32{Int32CDP2} : Face Attribute Mask 8 (4 MSBs)

This field encodes the 4 most significant bits of the 8th context group of face attribute bit vectors, rounding out its full 64-bit width.

VecU32 : High-Degree Face Attribute Masks

This field encodes all remaining face attribute bit vectors, adjoined end-to-end, and encoded as a single array of unsigned integers.

VecI32{Int32CDP2, Lag1} : Split Face Syms

Encodes the list of “split face” ID numbers in the order the coder encountered them.

VecI32{Int32CDP2} : Split Face Positions

Encodes the list of “split face” positions in the active vertex queue in the order the code encountered them.

U32 : Composite Hash

This field is a hash value computed on all of the above data using the hash function described in Appendix D: . It is written into the JT file so that a reader can perform the same hash on the above data and compare against this value in order to guarantee that it has read and decoded correct data from the JT file. It is *highly* encouraged that all readers perform this check, as even a single bit error in the topology information above can have catastrophic consequences on the topology decoder and the resulting mesh. Any writers are *required* to write this field using the method provided so that other readers may validate the data they read.

```
UInt32 uHash        = 0;
UInt32 anDegSyms[8] = {0},
       nValSyms = 0,
       nVGrpSyms = 0,
       nVtxFlags = 0,
       anAttrMasks[8] = {0},
       nLrgAttrMasks = 0,
       nSplitVtxSyms = 0,
       nSplitVtxPos = 0;
VecI32 vFaceDegreeSymbols[8], vviValenceSymbols, vFaceGroupSyms,
       vvuAttrMasks[8], viSplitVtxSyms, viSplitVtxPos;
VecI16 vFaceFlags;
VecU32 vuTmp, vuAttrMasksLrg;
...
for (i=0 ; i<8 ;i++)
```

```
  uHash = hash32((UInt32*) vFaceDegreeSymbols[i].ptr(), anDegSyms[i], uHash );
uHash = hash32((UInt32*) vviValenceSymbols.ptr(), nValSyms, uHash );
uHash = hash32((UInt32*)vVtxGroupSyms.ptr(), nVGrpSyms, uHash );
uHash = hash16((UInt16*)vVtxFlags.ptr(), nFlags, uHash );
for (i=0 ; i<7 ;i++)
  uHash = hash32((UInt32*)vvuAttrMasks[i].ptr(), anAttrMasks[i], uHash );
vuTmp = vvuAttrMasks[7] & 0x3fffffff;  // Lower 30 bits of each element
uHash = hash32(vuTmp.ptr(), anAttrMasks[7], uHash );
vuTmp = (vvuAttrMasks[7] >> 30) & 0x3fffffff; // Next 30 bits of each element
uHash = hash32(vuTmp.ptr(), anAttrMasks[7], uHash );
vuTmp = (vvuAttrMasks[7] >> 60) & 0x0f; // Upper 4 bits of each element
uHash = hash32(vuTmp.ptr(), anAttrMasks[7], uHash );
uHash = hash32(vuAttrMasksLrg.ptr(), nLrgAttrMasks, uHash );
uHash = hash32((UInt32*)viSplitVtxSyms.ptr(), nSplitVtxSyms, uHash );
uHash = hash32((UInt32*)viSplitVtxPos.ptr(), nSplitVtxPos, uHash );
```

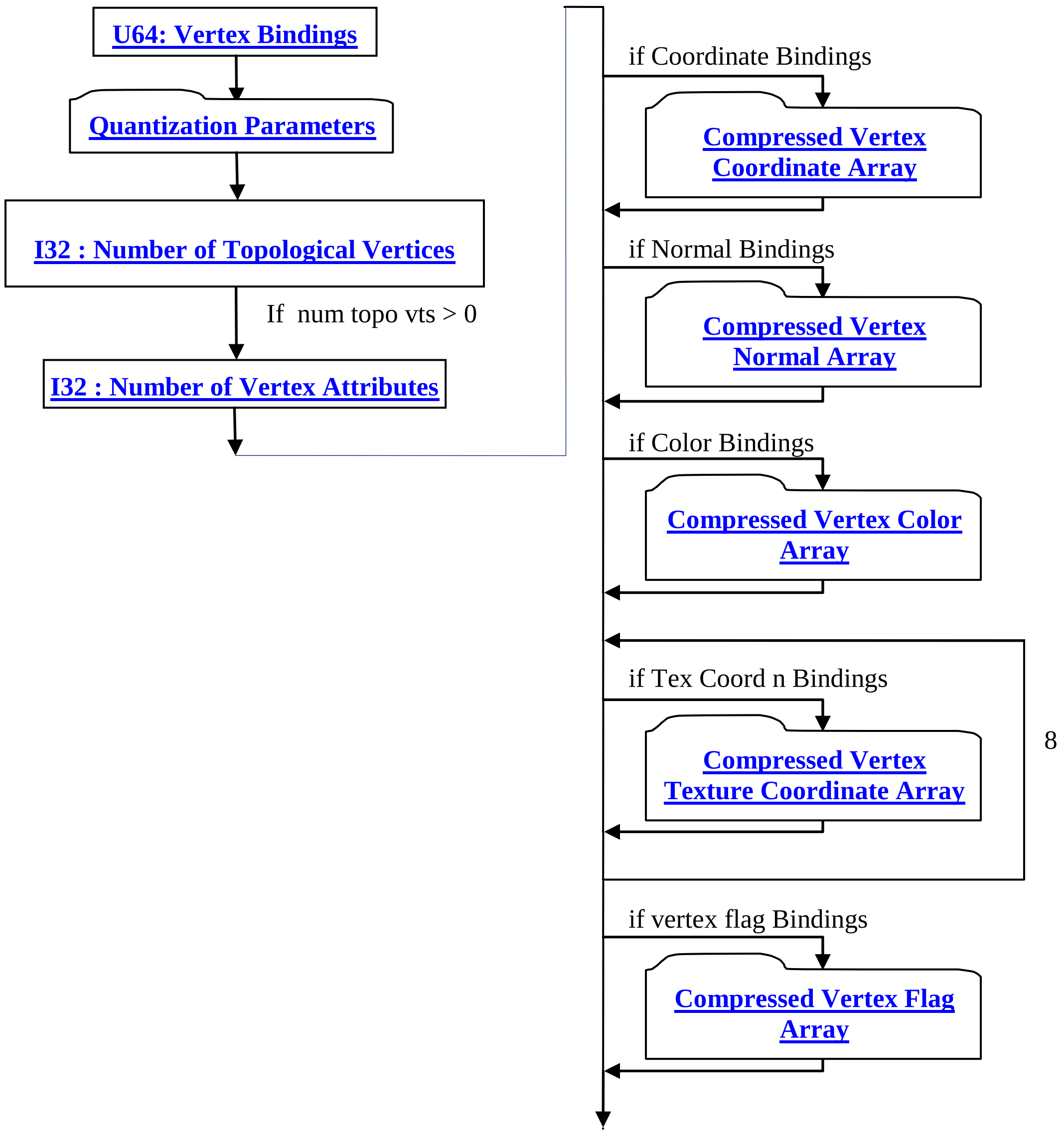
7.2.2.1.2.6 Topologically Compressed Vertex Records

Documented here is the format of the vertex data written by the topological encoder from Appendix E: . Some additional explanation is necessary, however, because only the *unique* vertex coordinates are written to the JT file, while the remaining vertex attributes (normals, colors, texture coordinates, vertex flags) may not be unique.

Vertex coordinates are written to the file in the order that they were visited by the topology encoder. Note that this means that the number of vertex coordinates written is equal to the number of topological vertices in the mesh (i.e. all vertex coordinates are unique).

By contrast one set of vertex attribute records is written to the file corresponding to each 1 bit across all encoded dual Face Attribute Masks. The vertex attribute records are written in the order that the topology encoder visited them. The reader must then use the topology decoder's output to correctly associate each vertex attribute record to the correct vertex coordinate using the dual Face Attribute Masks.

Figure 90: Topologically Compressed Vertex Records data collection


U64: Vertex Bindings
Quantization Parameters
I32 : Number of Topological Vertices
If num topo vts > 0
I32 : Number of Vertex Attributes
if Coordinate Bindings
Compressed Vertex Coordinate Array
if Normal Bindings
Compressed Vertex Normal Array
if Color Bindings
Compressed Vertex Color Array
if Tex Coord n Bindings
Compressed Vertex Texture Coordinate Array
8
if vertex flag Bindings
Compressed Vertex Flag Array

U64: Vertex Bindings

Vertex Bindings is a collection of normal, texture coordinate, and color binding information encoded within a single U64. All undocumented bits are reserved. For more information see Vertex Shape LOD Data U64 : Vertex Bindings.

I32 : Number of Topological Vertices

This field is the number of topological vertices encoded by the topology encoder. This is the number of unique vertex coordinates that will be written in the later Compressed Vertex Coordinate Array field.

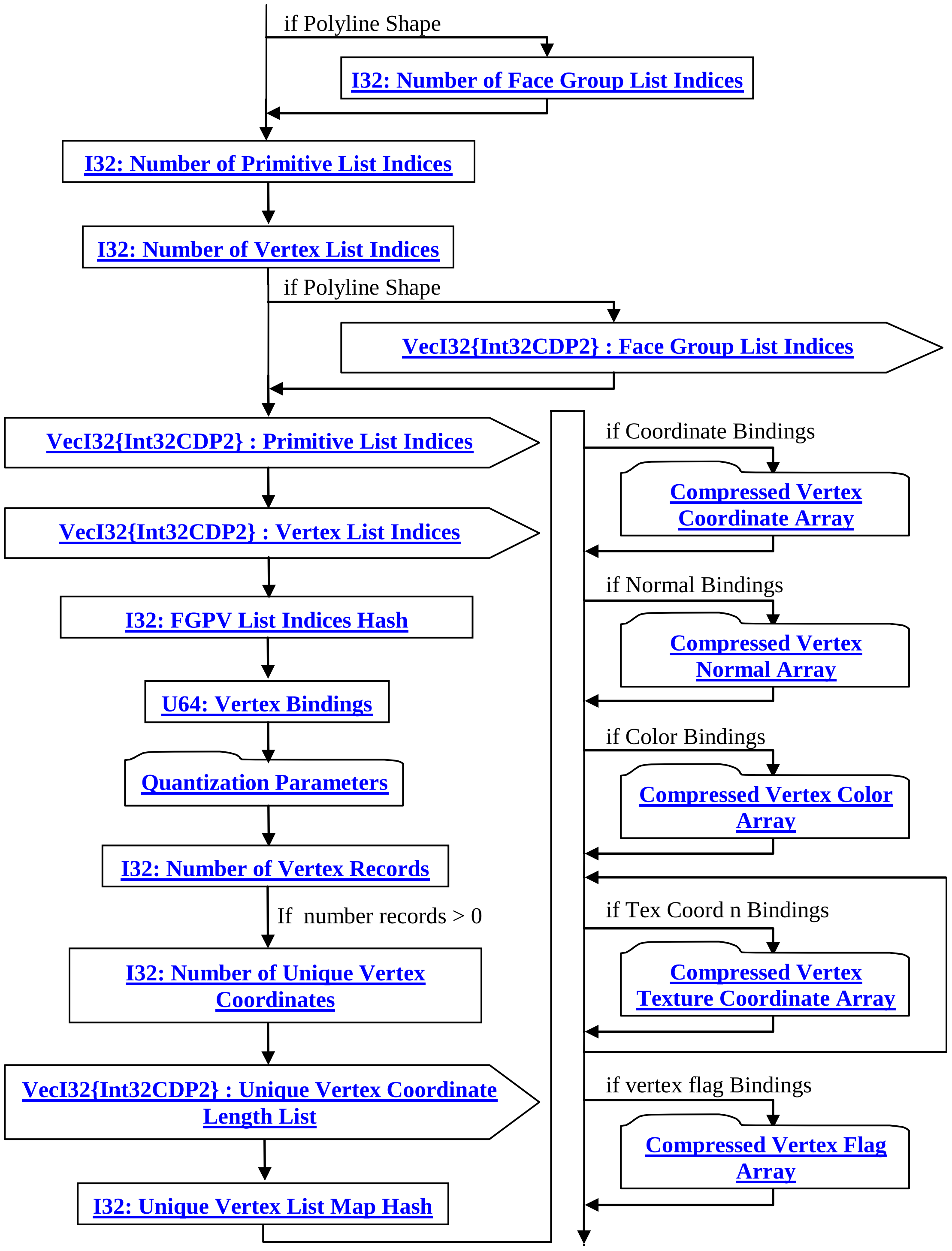
I32 : Number of Vertex Attributes

One set of vertex attribute records is written to the file corresponding to each 1 bit across all encoded dual Face Attribute Masks. The vertex attribute records are written in the order that the topology encoder visited them. The reader must then use the topology decoder's output to correctly associate each vertex attribute record to the correct vertex coordinate using the dual Face Attribute Masks.

7.2.2.1.2.7 TopoMesh Compressed Rep Data V1

TopoMesh Compressed Rep Data V1 contains the geometric shape definition data (e.g. vertices, colors, normals, etc.) in a lossy or lossless compressed formed.

Figure 91: TopoMesh Compressed Rep Data V1 data collection



if Polyline Shape
I32: Number of Face Group List Indices
I32: Number of Primitive List Indices
I32: Number of Vertex List Indices
if Polyline Shape
VecI32{Int32CDP2} : Face Group List Indices
VecI32{Int32CDP2} : Primitive List Indices
VecI32{Int32CDP2} : Vertex List Indices
I32: FGPV List Indices Hash
U64: Vertex Bindings
Quantization Parameters
I32: Number of Vertex Records
If number records > 0
I32: Number of Unique Vertex Coordinates
VecI32{Int32CDP2} : Unique Vertex Coordinate Length List
I32: Unique Vertex List Map Hash
if Coordinate Bindings
Compressed Vertex Coordinate Array
if Normal Bindings
Compressed Vertex Normal Array
if Color Bindings
Compressed Vertex Color Array
if Tex Coord n Bindings
Compressed Vertex Texture Coordinate Array
8
if vertex flag Bindings
Compressed Vertex Flag Array

Complete description for Quantization Parameters can be found in 7.2.1.1.1.10.2.1.1 Quantization Parameters.

I32: Number of Face Group List Indices

Number of Face Group List Indices.

I32: Number of Primitive List Indices

Number of Primitive List Indices.

I32: Number of Vertex List Indices

Number of Vertex List Indices.

VecI32{Int32CDP2} : Face Group List Indices

Face Group List Indices is a vector of indices into the uncompressed Raw Primitive Data marking the start/beginning of Faces. Face Group List Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP2} : Primitive List Indices

Primitive List Indices is a vector of indices into the uncompressed Raw Vertex Data marking the start/beginning of primitives. Primitive List Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP2} : Vertex List Indices

Vertex List Indices is a vector of indices (one per vertex) into the uncompressed/dequantized unique vertex data arrays (Vertex Coords, Vertex Normals, Vertex Texture Coords, Vertex Colors) identifying each Vertex's data (i.e. for each Vertex there is an index identifying the location within the unique arrays of the particular Vertex's data). The Compressed Vertex Index List uses the Int32 version of the CODEC to compress and encode data.

I32: FGPV List Indices Hash

The FGPV Hash is the combined hash value of the Face Group List Indices (if Polyline), Primitive List Indices, and Vertex List Indices. Refer to section 9.5 for a more detailed description on hashing.

```
UInt32 uHash    = 0;
UInt32 nFGIdx   = 0,
       nPrimIdx = 0,
       nVtxIdx  = 0;
vecI32 vFGIndices, vPrimIdices, vVertexIndices;
...
if (bLineStrip)
  uHash = hash32( (UInt32*)(&vFGIndices), nFGIdx+1, uHash );
uHash = hash32( (UInt32*)(& vPrimIdices), nPrimIdx+1, uHash );
uHash = hash32( (UInt32*)(& vVertexIndices), nVtxIdx  , uHash );
```

U64: Vertex Bindings

Vertex Bindings is a collection of normal, texture coordinate, and color binding information encoded within a single U64. All undocumented bits are reserved. For more information see Vertex Shape LOD Data U64 : Vertex Bindings.

I32: Number of Vertex Records

Number of vertex records.

I32: Number of Unique Vertex Coordinates

Number of unique vertex coordinates values in the Compressed Vertex Coordinate Array.

VecI32{Int32CDP2} : Unique Vertex Coordinate Length List

The Unique Vertex Length List contains the number of vertex records containing each of the unique vertex coordinates and should sum to the number of vertex records. When read in the Compressed Vertex Coordinate Array only contains a single value for each unique vertex coordinate value and is therefore parallel to the Unique Vertex Length List. In order to expand its coordinates into the vertex record space it unique coordinate value will need to be smeared out such that each unique vertex coordinate is repeated the number of times specified in the Unique Vertex Length List. The Compressed Vertex Normal, Color, Texture, and Flag Arrays do not require the same expansion.

I32: Unique Vertex List Map Hash

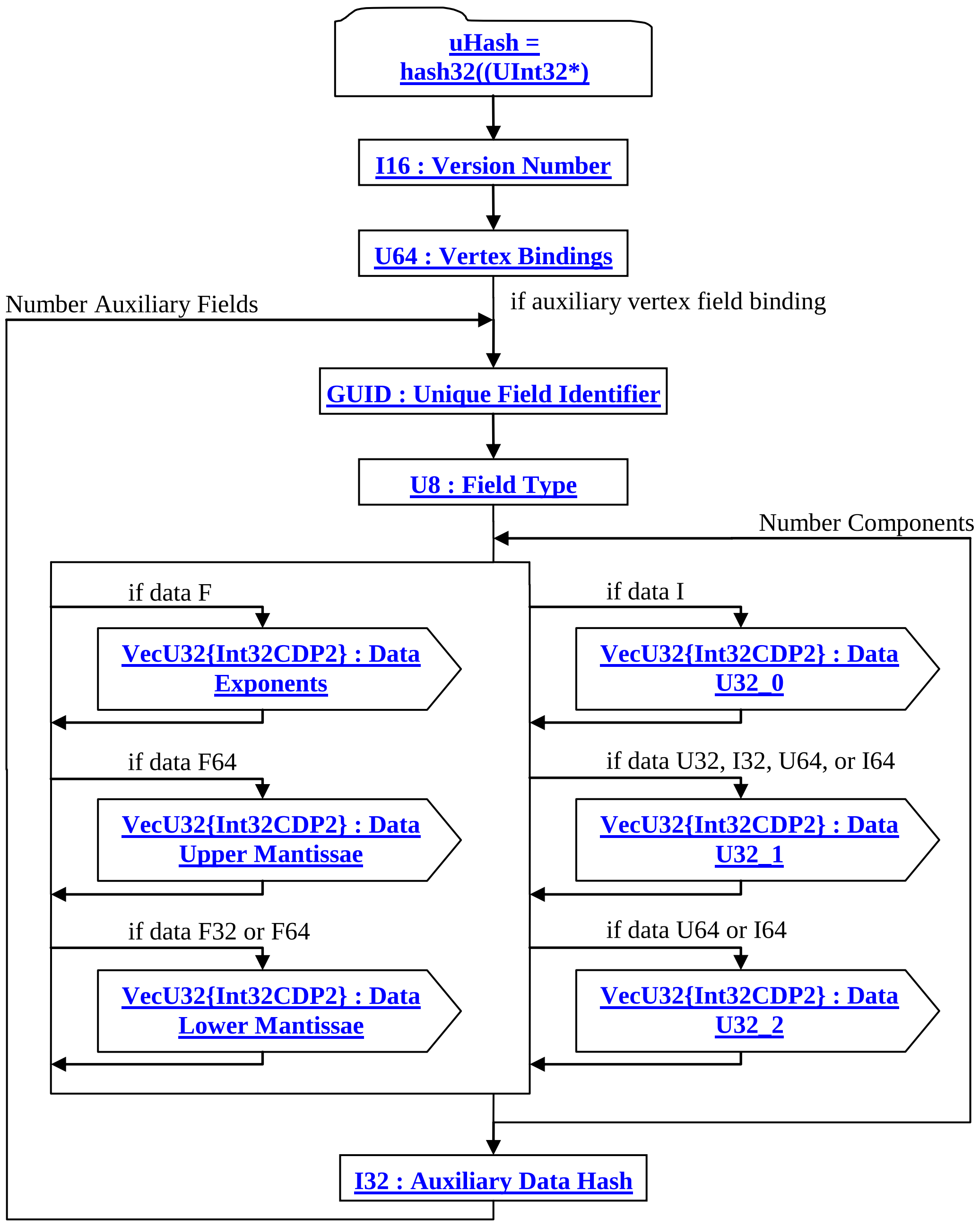
The Unique Vertex List Map Hash is the hash value of Unique Vertex Coordinate Length List. Refer to section 9.5 for a more detailed description on hashing.

```
UInt32 uHash    = 0;
UInt32 nUniqVtx = 0;
vecF32 vUniqVtxIndices;
...
uHash = hash32( (UInt32*)(&vUniqVtxIndices), nUniqVtx, uHash );
```

7.2.2.1.2.8 TopoMesh Compressed Rep Data V2

TopoMesh Compressed Rep Data V2 data contains additional geometric shape data (auxiliary vertex fields) that were not included in V1. Auxiliary fields are parallel to the existing vertex record information and contain additional information pertaining to each vertex.

Figure 92: TopoMesh Compressed Rep Data V2 data collection


uHash = hash32((UInt32*)
I16 : Version Number
U64 : Vertex Bindings
Number Auxiliary Fields
if auxiliary vertex field binding
GUID : Unique Field Identifier
U8 : Field Type
Number Components
if data F
VecU32{Int32CDP2} : Data Exponents
if data I
VecU32{Int32CDP2} : Data U32_0
if data F64
VecU32{Int32CDP2} : Data Upper Mantissae
if data U32, I32, U64, or I64
VecU32{Int32CDP2} : Data U32_1
if data F32 or F64
VecU32{Int32CDP2} : Data Lower Mantissae
if data U64 or I64
VecU32{Int32CDP2} : Data U32_2
I32 : Auxiliary Data Hash

Complete description for TopoMesh Compressed Rep Data V1 can be found in TopoMesh Compressed Rep Data V1.

I16 : Version Number

Version Number is the version identifier for this TopoMesh Compressed Rep Data V2. Version number "0x0001" is currently the only valid value.

U64 : Vertex Bindings

Vertex Bindings is a collection of normal, texture coordinate, and color binding information encoded within a single U64. All undocumented bits are reserved. For more information see Vertex Shape LOD Data U64 : Vertex Bindings.

GUID : Unique Field Identifier

Each Auxiliary Vertex Field is associated with Unique Field Identifier to denote the usage of the contained data. All Unique Field Identifiers are currently reserved. These identifiers are intended to be unique across all application domains, therefore any JT file producer wishing to "lock down" a Unique Field Identifier so that others can rely on its semantic identity should contact the JTOpen industry liaison to obtain them.

U8 : Field Type

Defines the number of components and type of data contained within the auxiliary field based upon the below table.

Type	Data	Components
1	U8	1
2	U8	2
3	U8	3
4	U8	4
5	I8	1
6	I8	2
7	I8	3
8	I8	4
9	U16	1
10	U16	2
11	U16	3
12	U16	4
13	I16	1
14	I16	2
15	I16	3
16	I16	4
17	U32	1
18	U32	2
19	U32	3
20	U32	4
21	I32	1
22	I32	2
23	I32	3

Type	Data	Components
24	I32	4
25	U64	1
26	U64	2
27	U64	3
28	U64	4
29	I64	1
30	I64	2
31	I64	3
32	I64	4
33	F32	1
34	F32	2
35	F32	3
36	F32	4
37	F32	2x2
38	F32	3x3
39	F32	4x4
40	F64	1
41	F64	2
42	F64	3
43	F64	4
44	F64	2x2
45	F64	3x3
46	F64	4x4

VecU32{Int32CDP2} : Data U32_0

Data U32_0 contains the low order bits from the data i'th data component for each vertex record in an U32 vector. For U8, I8, U16, and I16 data types this contains all bits. For U32, I32, U64, and I64 data types it contains bits 0 through 30. Data U32_0 uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Data U32_1

Data U32_1 contains the middle order bits from the data i'th data component for each vertex record in an U32 vector. For U32 and I32 data types it only contains bit 31. For U64 and U64 data types it contains bits 31 through 61. Data U32_1 uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Data U32_2

Data U32_2 contains the upper order bits from the data i'th data component for each vertex record in an U32 vector. For U64 and I64 data types it contains bits 62 and 63. Data U32_2 uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Data Lower Mantissae

Vertex Coord Components is a vector of lower bits of Floating Point Mantissae for all the i'th component values of a set of vertex coordinates. For F32 data type this contains all bits of the mantissa, however for F64 data type it only contains bits 0 through 30. Data Lower Mantissae uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Data Upper Mantissae

Vertex Coord Components is a vector of upper bits of the Floating Point Mantissae for all the i'th component values of a set of vertex coordinates. For the F64 data type it contains bits 31 though 51. Data Upper Mantissae uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Data Exponents

Vertex Coord Components is a vector of Floating Point Exponents and Sign for all the i'th component values of a set of vertex coordinates. Data Exponents uses the Int32 version of the CODEC to compress and encode data.

I32 : Auxiliary Data Hash

The Auxiliary Data Hash is the combined hash of auxiliary field data arrays. Refer to section 9.5 for a more detailed description on hashing.

```
UInt32 uHash    = 0;
UInt32 nVtxRec  = 0,
       nComp    = 0;
vecU32 vU32_0, vU32_1, vU32_2, vLMANT, vUMANT, vEXP;
...
if ( bU8 || bI8 | bU16 | bI16 ) {
  for ( int i=0 ; i<nComp ; i++ ) {
    uHash = hash32( &vU32_0[i], nVtxRec, uHash );
  }
} else if ( bU32 || bI32 ) {
  for ( int i=0 ; i<nComp ; i++ ) {
    uHash = hash32( &vU32_0[i], nVtxRec, uHash );
    uHash = hash32( &vU32_1[i], nVtxRec, uHash );
  }
} else if ( bU64 || bI64 ) {
  for ( int i=0 ; i<nComp ; i++ ) {
    uHash = hash32( &vU32_0[i], nVtxRec, uHash );
    uHash = hash32( &vU32_1[i], nVtxRec, uHash );
    uHash = hash32( &vU32_2[i], nVtxRec, uHash );
  }
} else if ( bF32 ) {
  for ( int i=0 ; i<nComp ; i++ ) {
    uHash = hash32( &vLMANT[i], nVtxRec, uHash );
    uHash = hash32( &vEXP[i], nVtxRec, uHash );
  }
} else {
  for ( int i=0 ; i<nComp ; i++ ) {
    uHash = hash32( &vLMANT[i], nVtxRec, uHash );
    uHash = hash32( &vUMANT[i], nVtxRec, uHash );
    uHash = hash32( &vEXP[i], nVtxRec, uHash );
  }
}
```

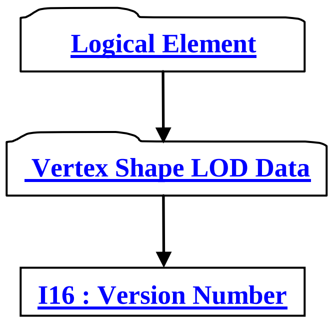
7.2.2.1.3 Tri-Strip Set Shape LOD Element

Object Type ID: 0x10dd10ab, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

A Tri-Strip Set Shape LOD Element contains the geometric shape definition data (e.g. vertices, polygons, normals, etc.) for a single LOD of a collection of independent and unconnected triangle strips. Each strip constitutes one primitive of the set and the ordering of the vertices in forming triangles, is the same as OpenGL’s triangle strip definition [4].

A Tri-Strip Set Shape LOD Element is typically referenced by a Tri-Strip Set Shape Node Element using Late Loaded Property Atom Elements (see 7.2.1.1.1.10.3 Tri-Strip Set Shape Node Element and 0 Late Loaded Property Atom ElementLate Loaded Property Atom Element respectively).

Figure 93: Tri-Strip Set Shape LOD Element data collection



Complete description for Logical Element Header can be found in 7.1.3.2.1Logical Element Header.

Complete description for Vertex Shape LOD Data can be found in 7.2.2.1.2.1 Vertex Shape LOD Data.

I16 : Version Number

Version Number is the version identifier for this Tri-Strip Set Shape LOD. Version number "0x0001" is currently the only valid value.

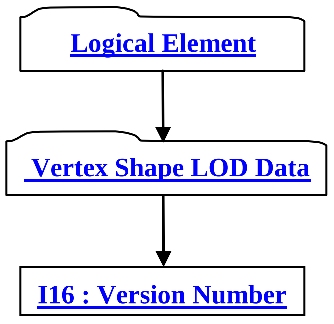
7.2.2.1.4 Polyline Set Shape LOD Element

Object Type ID: 0x10dd10a1, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

A Polyline Set Shape LOD Element contains the geometric shape definition data (e.g. vertices, normals, etc.) for a single LOD of a collection of independent and unconnected polylines. Each polyline constitutes one primitive of the set.

A Polyline Set Shape LOD Element is typically referenced by a Polyline Set Shape Node Element using Late Loaded Property Atom Elements (see 7.2.1.1.1.10.5 Polyline Set Shape Node Element and 0 Late Loaded Property Atom Element respectively).

Figure 94: Polyline Set Shape LOD Element data collection



Complete description for Logical Element Header can be found in 7.1.3.2.1Logical Element Header.

Complete description for Vertex Shape LOD Data can be found in 7.2.2.1.2.1 Vertex Shape LOD Data.

I16 : Version Number

Version Number is the version identifier for this Polyline Set Shape LOD. Version number "0x0001" is currently the only valid value.

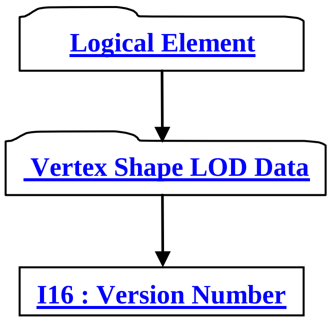
7.2.2.1.5 Point Set Shape LOD Element

Object Type ID: 0x98134716, 0x0011, 0x0818, 0x19, 0x98, 0x08, 0x00, 0x09, 0x83, 0x5d, 0x5a

A Point Set Shape LOD Element contains the geometric shape definition data (e.g. coordinates, normals, etc.) for a collection of independent and unconnected points. Each point constitutes one primitive of the set.

A Point Set Shape LOD Element is typically referenced by a Point Set Shape Node Element using Late Loaded Property Atom Elements (see 7.2.1.1.1.10.5 Point Set Shape Node Element and 0 Late Loaded Property Atom Element respectively).

Figure 95: Point Set Shape LOD Element data collection



Complete description for Logical Element Header can be found in 7.1.3.2.1Logical Element Header.

Complete description for Vertex Shape LOD Data can be found in 7.2.2.1.2.1 Vertex Shape LOD Data.

I16 : Version Number

Version Number is the version identifier for this Point Set Shape LOD. Version number “0x0001” is currently the only valid value.

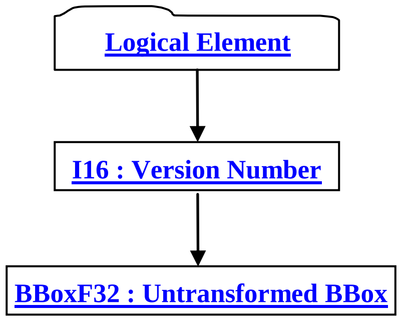
7.2.2.1.6 Null Shape LOD Element

Object Type ID: 0x3e637aed, 0x2a89, 0x41f8, 0xa9, 0xfd, 0x55, 0x37, 0x37, 0x3, 0x96, 0x82

A Null Shape LOD Element represents the pseudo geometric shape definition data for a NULL Shape Node Element. Although a NULL Shape Node Element has no real geometric primitive representation (i.e. is empty), its usage as a “proxy/placeholder” node within the LSG still supports the concept of having a defined bounding box and thus the existence of this Null Shape LOD Element type.

A Null Shape LOD Element is typically referenced by a NULL Shape Node Element using Late Loaded Property Atom Elements (see 7.2.1.1.1.10.7 NULL Shape Node Element and 7.2.1.2.7 Late Loaded Property Atom Element respectively).

Figure 96: Null Shape LOD Element data collection



Complete description for Logical Element Header can be found in 7.1.3.2.1 Logical Element Header.

I16 : Version Number

Version Number is the version identifier for this Null Shape LOD Element. Version number "0x0001" is currently the only valid value.

BBoxF32 : Untransformed BBox

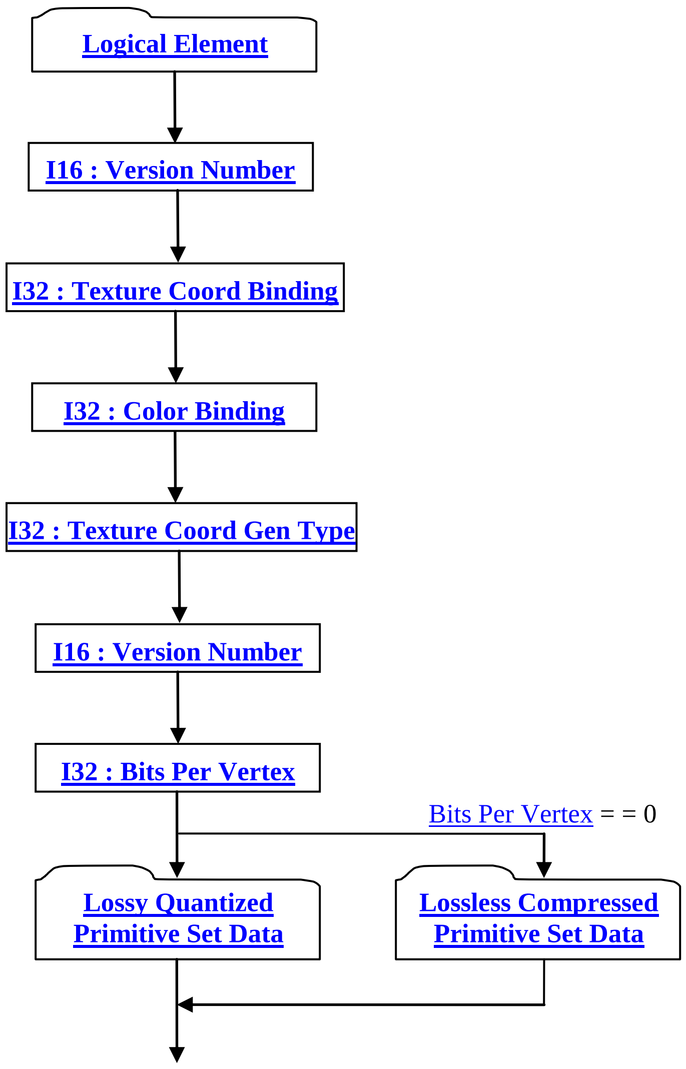
The Untransformed BBox is an axis-aligned LCS bounding box and represents the untransformed extents for this Null Shape LOD Element.

7.2.2.2 Primitive Set Shape Element

Object Type ID: 0xe40373c2, 0x1ad9, 0x11d3, 0x9d, 0xaf, 0x0, 0xa0, 0xc9, 0xc7, 0xdd, 0xc2

A Primitive Set Shape Element defines the minimum data necessary to procedurally generate LODs for a list of primitive shapes (e.g. box, cylinder, sphere, etc.). "Procedurally generate" means that the raw geometric shape definition data (e.g. vertices, polygons, normals, etc) for LODs is not directly stored; instead some basic shape information is stored (e.g. sphere center and radius) from which LODs can be generated.

Figure 97: Primitive Set Shape Element data collection


Logical Element
I16 : Version Number
I32 : Texture Coord Binding
I32 : Color Binding
I32 : Texture Coord Gen Type
I16 : Version Number
I32 : Bits Per Vertex
Bits Per Vertex = = 0
Lossy Quantized Primitive Set Data
Lossless Compressed Primitive Set Data

Complete description for Logical Element Header can be found in 7.1.3.2.1Logical Element Header.

I16 : Version Number

Version Number is the version identifier for this element. Only version number 0x0001 is valid for now

I32 : Texture Coord Binding

Texture Coord Binding specifies how (at what granularity) texture coordinate data is supplied ("bound") for the shape. Valid values are as follows:

= 0	None. Shape has no texture coordinate data.
= 1	Per Vertex. Shape has texture coordinates for every vertex.

I32 : Color Binding

Color Binding specifies how (at what granularity) color data is supplied ("bound") for the shape. Valid values are the same as documented for Texture Coord Binding data field.

I16 : Version Number

Version Number is the version identifier for this element. The value of this Version Number indicates the format of data fields to follow.

= 1	Version-1 Format
= 2	Version-2 Format

I32 : Bits Per Vertex

Bits Per Vertex specifies the number of quantization bits per vertex coordinate component. Value must be within range [0:32] inclusive.

I32 : Texture Coord Gen Type

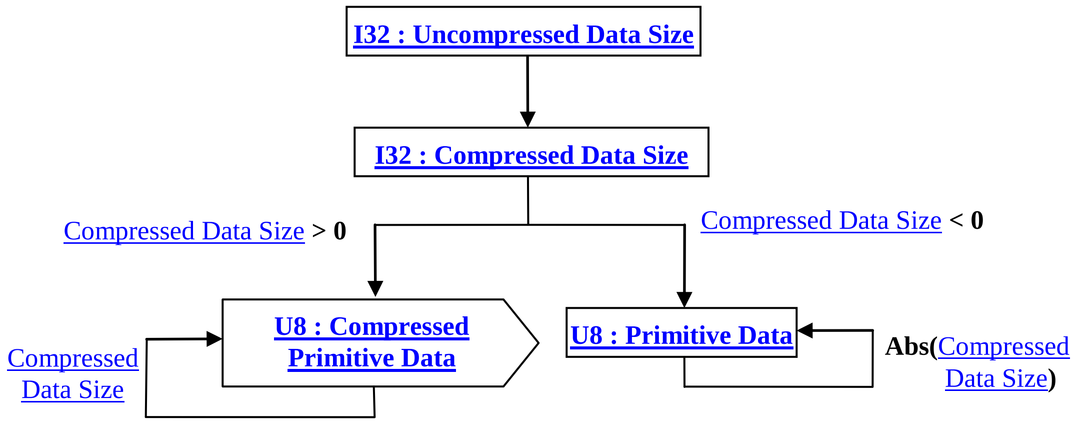
Texture Coord Gen Type specifies how texture coordinates are to be generated.

= 0	Single Tile…Indicates that a single copy of a texture image will be applied to significant primitive features (i.e. cube face, cylinder wall, end cap) no matter how eccentrically shaped.
= 1	Isotropic…Implies that multiple copies of a texture image may be mapped onto eccentric surfaces such that a mapped texel stays approximately square.

7.2.2.2.1 Lossless Compressed Primitive Set Data

The Lossless Compressed Primitive Set Data collection contains all the per-primitive information stored in a "lossless" compression format for all primitives in the Primitive Set. The Lossless Compressed Primitive Set Data collection is only present when the Bits Per Vertex data field equals "0" (see 7.2.2.2 Primitive Set Shape Element for complete description).

Figure 98: Lossless Compressed Primitive Set Data collection


I32 : Uncompressed Data Size
I32 : Compressed Data Size
Compressed Data Size > 0
Compressed Data Size < 0
U8 : Compressed Primitive Data
U8 : Primitive Data
Compressed Data Size
Abs(Compressed Data Size)

I32 : Uncompressed Data Size

Uncompressed Data size specifies the uncompressed size of Primitive Data or Compressed Primitive Data in bytes.

I32 : Compressed Data Size

Compressed Data Size specifies the compressed size of Primitive Data or Compressed Primitive Data in bytes. If the Compressed Data Size is negative, then the Compressed Primitive Data field is not present (i.e. data is not compressed) and the absolute value of Compressed Data Size should be equal to Uncompressed Data Size value.

U8 : Primitive Data

The Primitive Data field is a packed array of the raw per primitive data (i.e. reserved, params1, params2, params3, color, type) sequentially for all primitives in the set. The Primitive Data field is only present if Compressed Data Size value is less than zero.

The per primitive data is packed into Primitive Data array using an interleaved data schema/format as follows:

{[reserved], [params1], [params2], [params3], [color], [type]}, …, **for all primitives**

Where the data elements have the following size and meaning:

Element	Data Type	Description
reserved	I32	This is a field reserved for future expansion of the JT Format.
params1	CoordF32	Interpretation is Primitive Type specific (see below table)
params2	DirF32	Interpretation is Primitive Type specific (see below table)
params3	Quaternion	Interpretation is Primitive Type specific (see below table)
color	RGB	Red, Green, Blue color component values
type	I32	Primitive Type = 0 – Box = 1 – Cylinder = 2 – Pyramid = 3 – Sphere = 4 – Tri-Prism

Table 5: Primitive Set Primitive Data Elements

Given this format of the Primitive Data, and the previously read size fields, a reader can then implicitly compute the data stride (length of one primitive entry in Primitive Data), and number of primitives.

The interpretation of the three "params#" data fields is primitive type dependent as follows:

Primitive Type	params1			params2			params3			
	[0]	[1]	[2]	[0]	[1]	[2]	[0]	[1]	[2]	[3]
Box	min X	min Y	min Z	length X	length Y	length Z	orientation in Quaternion form			
Cylinder	base center X	base center Y	base center Z	spine X	spine Y	spine Z	radius 1	radius 2	N/A	N/A
Pyramid	base center X	base center Y	base center Z	length X	length Y	length Z	orientation in Quaternion form			
Sphere	center X	center Y	center Z	radius	N/A	N/A	N/A	N/A	N/A	N/A
Tri-Prism	bottom front X	bottom front Y	bottom front Z	length X (to right)	length Y (to back)	length Z (to top)	orientation in Quaternion form			

Table 6: Primitive Set "params#" Data Fields Interpretation

U8 : Compressed Primitive Data

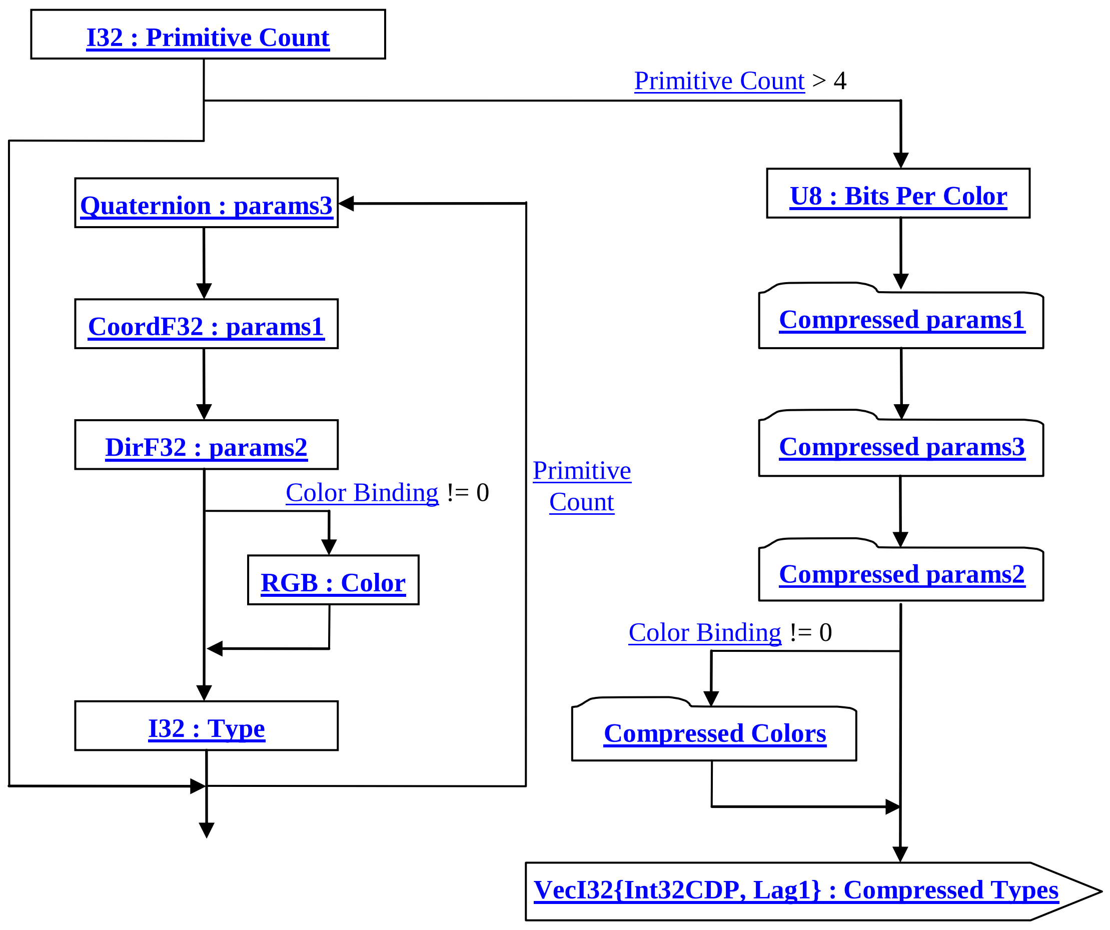
The Compressed Primitive Data field represents the same data as documented in Primitive Data field above except that the data is compressed using the general "ZLIB deflation compression" method. The Compressed Primitive Data field is only present if Compressed Data Size value is greater than zero. See 8 Data Compression and Encoding for more details on ZLIB compression and ZLIB library version used.

7.2.2.2.2 Lossy Quantized Primitive Set Data

The Lossy Quantized Primitive Set Data collection contains all the per-primitive information (i.e. reserved, params1, params2, params3, color, type) stored in a "lossy" encoding/compression format for all primitives in the Primitive Set. The Lossy Quantized Primitive Set Data collection is only present when the Bits Per Vertex data field is NOT equal to "0" (See 7.2.2.2 Primitive Set Shape Element for compete description).

The interpretation of the three per-primitive "params#" data fields is primitive type dependent. See Table 6: Primitive Set "params#" Data Fields Interpretation in 7.2.2.2.1 Lossless Compressed Primitive Set Data for per-primitive type description of the "params#" data fields.

Figure 99: Lossy Quantized Primitive Set Data collection



I32 : Primitive Count

Primitive Count specifies the number of primitives in the Primitive Set.

Quaternion : params3

Interpretation of params3 data field is primitive Type dependent. See Table 6: Primitive Set "params#" Data Fields Interpretation in 7.2.2.2.1 Lossless Compressed Primitive Set Data for per-primitive type description of the params3 data fields.

CoordF32 : params1

Interpretation of params1 data field is primitive Type dependent. See Table 6: Primitive Set "params#" Data Fields Interpretation in 7.2.2.2.1 Lossless Compressed Primitive Set Data for per-primitive type description of the params1 data fields.

DirF32 : params2

Interpretation of params1 data field is primitive Type dependent. See Table 6: Primitive Set "params#" Data Fields Interpretation in 7.2.2.2.1 Lossless Compressed Primitive Set Data for per-primitive type description of the params1 data fields.

RGB : Color

Color specifies the Red, Green Blue color components for the primitive. This data field is only present if previously read Color Binding (see 7.2.2.2 Primitive Set Shape Element) is not equal to "0".

I32 : Type

Type specifies the primitive type. See Table 5: Primitive Set Primitive Data Elements in 7.2.2.2.1 Lossless Compressed Primitive Set Data for valid primitive Type values.

U8 : Bits Per Color

Bits Per Color specifies the number of quantization bits per color component. Value must be within range [0:32] inclusive.

VecI32{Int32CDP, Lag1} : Compressed Types

The Compressed Types data field is a vector of Type data for all the primitives in the Primitive Set. Compressed Types uses the Int32 version of the CODEC to compress and encode data. In an uncompressed form the valid primitive Type vales are as documented in Table 5: Primitive Set Primitive Data Elements in 7.2.2.2.1 Lossless Compressed Primitive Set Data.

7.2.2.2.2.1 Compressed params1

Compressed params1 is the compressed representation of the *params1* data for all the primitives in the Primitive Set. Note that the interpretation of the uncompressed *params1* data is primitive Type dependent. See Table 6: Primitive Set "params#" Data Fields Interpretation in 7.2.2.2.1 Lossless Compressed Primitive Set Data for per-primitive type description of the *params1* data fields

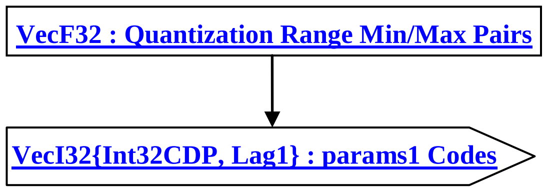
The *params1* data for all primitives in the Primitive Set is compressed/encoded on a per ordinate basis using a separate Uniform Quantizer (with Bits Per Vertex number of quantization bits) for each collection of ordinate values. Since *params1* is of type "CoordF32", it has three ordinate values (three F32 values), and thus three Uniform Quantizers (where a Uniform Quantizer is a scalar quantizer/encoder whose range is divided into levels of equal spacing). See 8 Data Compression and Encoding for more complete description of Uniform Quantizer.

The JT Format packs all the *params1* data for all primitives into a single array using an ordinate dependent order (as shown below) and then encodes each of the lists of ordinate values using a separate Uniform Quantizer per ordinate list.

```
{prim1 params1[0], prim2 params1[0],…primN params1[0],
 prim1 params1[1], prim2 params1[1],…primN params1[1],
 prim1 params1[2], prim2 params1[2],…primN params1[2]}
```

The result of the Uniform Quantizer encoding is a range min and max floating point value pairs for each ordinate value collection, and an integer array of *params1* quantization codes that corresponds to the above described "ordinate dependent order" packed array of *params1* data.

Figure 100: Compressed params1 data collection


VecF32 : Quantization Range Min/Max Pairs
VecI32{Int32CDP, Lag1} : params1 Codes

VecF32 : Quantization Range Min/Max Pairs

Quantization Range Min/Max Pairs is a vector of Uniform Quantizer range min/max value pairs. There must be a min/max pair for each ordinate value collection (i.e. each Uniform Quantizer). Thus the length of this vector is "2 * num_ordinates" (so vector length would be "6" for *params1* data).

VecI32{Int32CDP, Lag1} : params1 Codes

The params1 Codes data field is a vector of quantizer "codes" for the *params1* data of all the primitives in the Primitive Set. The params1Codes also uses the Int32 version of the CODEC to compress and encode data.

7.2.2.2.2.2 Compressed params3

Compressed params3 is the compressed representation of the *params3* data for all the primitives in the Primitive Set. Note that the interpretation of the uncompressed *param31* data is primitive Type dependent. See Table 6: Primitive Set “params#” Data Fields Interpretation in 7.2.2.2.1 Lossless Compressed Primitive Set Data for per-primitive type description of the *params3* data fields

The *params3* data for all primitives in the Primitive Set is compressed/encoded on a per ordinate basis using a separate Uniform Quantizer (with Bits Per Vertex number of quantization bits) for each collection of ordinate values. Since *params1* is of type “Quaternion”, it has four ordinate values (four F32 values), and thus four Uniform Quantizers (where a Uniform Quantizer is a scalar quantizer/encoder whose range is divided into levels of equal spacing). See 8 Data Compression and Encoding for more complete description of Uniform Quantizer.

The JT Format packs all the *params3* data for all primitives into a single array using an ordinate dependent order (as shown below) and then encodes each of the lists of ordinate values using a separate Uniform Quantizer per ordinate list.

```
{prim1 params3[0], prim2 params3[0],…primN params3[0],
 prim1 params3[1], prim2 params3[1],…primN params3[1],
 prim1 params3[2], prim2 params3[2],…primN params3[2],
 prim1 params3[3], prim2 params3[3],…primN params3[3]}
```

The result of the Uniform Quantizer encoding is a range min and max floating point value pairs for each ordinate value collection, and an integer array of *params3* quantization codes that corresponds to the above described “ordinate dependent order” packed array of *params3* data.

The storage format of Compressed params3 is exactly the same as that documented in Figure 100: Compressed params1 data collection.

7.2.2.2.2.3 Compressed params2

Compressed params2 is the compressed representation of the *params2* data for all the primitives in the Primitive Set. Note that the interpretation of the uncompressed *params2* data is primitive Type dependent. See Table 6: Primitive Set “params#” Data Fields Interpretation in 7.2.2.2.1 Lossless Compressed Primitive Set Data for per-primitive type description of the *params2* data fields

The *params2* data for all primitives in the Primitive Set is compressed/encoded on a per ordinate basis using a separate Uniform Quantizer (with Bits Per Vertex number of quantization bits) for each collection of ordinate values. Since *params2* is of type “DirF32”, it has three ordinate values (three F32 values), and thus three Uniform Quantizers (where a Uniform Quantizer is a scalar quantizer/encoder whose range is divided into levels of equal spacing). See 8 Data Compression and Encoding for more complete description of Uniform Quantizer.

The JT Format packs all the *params2* data for all primitives into a single array using an ordinate dependent order (as shown below) and then encodes each of the lists of ordinate values using a separate Uniform Quantizer per ordinate list.

```
{prim1 params2[0], prim2 params2[0],…primN params2[0],
 prim1 params2[1], prim2 params2[1],…primN params2[1],
 prim1 params2[2], prim2 params2[2],…primN params2[2]}
```

The result of the Uniform Quantizer encoding is a range min and max floating point value pairs for each ordinate value collection, and an integer array of *params2* quantization codes that corresponds to the above described “ordinate dependent order” packed array of *params2* data.

The storage format of Compressed params2 is exactly the same as that documented in Figure 100: Compressed params1 data collection.

7.2.2.2.2.4 Compressed Colors

Compressed Colors is the compressed representation of the *color* data for all the primitives in the Primitive Set. This data collection is only present if previously read Color Binding (see 7.2.2.2 Primitive Set Shape Element) is not equal to “0”.

The *color* data for all primitives in the Primitive Set is compressed/encoded on a per ordinate basis using a separate Uniform Quantizer (with Bits Per Color number of quantization bits) for each collection of ordinate values. Since *color* is of type

"RGB", it has three ordinate values (three F32 values), and thus three Uniform Quantizers (where a Uniform Quantizer is a scalar quantizer/encoder whose range is divided into levels of equal spacing). See 8 Data Compression and Encoding for more complete description of Uniform Quantizer.

The JT Format packs all the *color* data for all primitives into a single array using an ordinate dependent order (as shown below) and then encodes each of the lists of ordinate values using a separate Uniform Quantizer per ordinate list.

```
{prim1 color[0], prim2 color[0],…primN color[0],
 prim1 color[1], prim2 color[1],…primN color[1],
 prim1 color[2], prim2 color[2],…primN color[2]}
```

The result of the Uniform Quantizer encoding is a range min and max floating point value pairs for each ordinate value collection, and an integer array of *color* quantization codes that corresponds to the above described "ordinate dependent order" packed array of *color* data.

The storage format of Compressed Colors is exactly the same as that documented in Figure 100: Compressed params1 data collection.

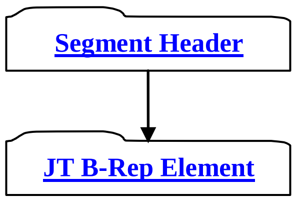
7.2.3 JT B-Rep Segment

JT B-Rep Segment contains an Element that defines the precise geometric Boundary Representation data for a particular Part in JT B-Rep format. Note that there is also another Boundary Representation format (i.e. XT B-Rep) supported by the JT file format within a different file Segment Type. Complete description for the XT B-Rep can be found in 7.2.4 XT B-Rep Segment.

JT B-Rep Segments are typically referenced by Part Node Elements (see 7.2.1.1.1.5Part Node Element) using Late Loaded Property Atom Elements (see 0Second specifies the date Second value. Valid values are [0, 59] inclusive.

Late Loaded Property Atom Element Late Loaded Property Atom Element). The JT B-Rep Segment type supports ZLIB compression on all element data, so all elements in JT B-Rep Segment use the Logical Element Header ZLIB form of element header data.

Figure 101: JT B-Rep Segment data collection



Complete description for Segment Header can be found in 7.1.3.1Segment Header.

7.2.3.1 JT B-Rep Element

Object Type ID: 0x873a70c0, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

JT B-Rep Element represents a particular Part's precise data in JT boundary representation format. Much of the "heavyweight" data contained within a JT B-Rep Element is compressed and/or encoded. The compression and/or encoding state is indicated through other data stored in each JT B-Rep Element.

Two important aspects of a Part are its geometry and its topology. The geometry describes the shape of a Part: this Surface is a plane, that Surface is a cylinder, this Curve is an arc, etc. The topology describes the connectivity of the Part: this Point is inside the Part, these Surfaces are next to each other, etc. The 0, 1, and 2 dimensional building blocks of geometry are Points, Curves, and Surfaces. The corresponding topological building blocks are Vertices, Edges, and Faces. Topology also uses Shells and Regions to conceptually divide up the three dimensional space.

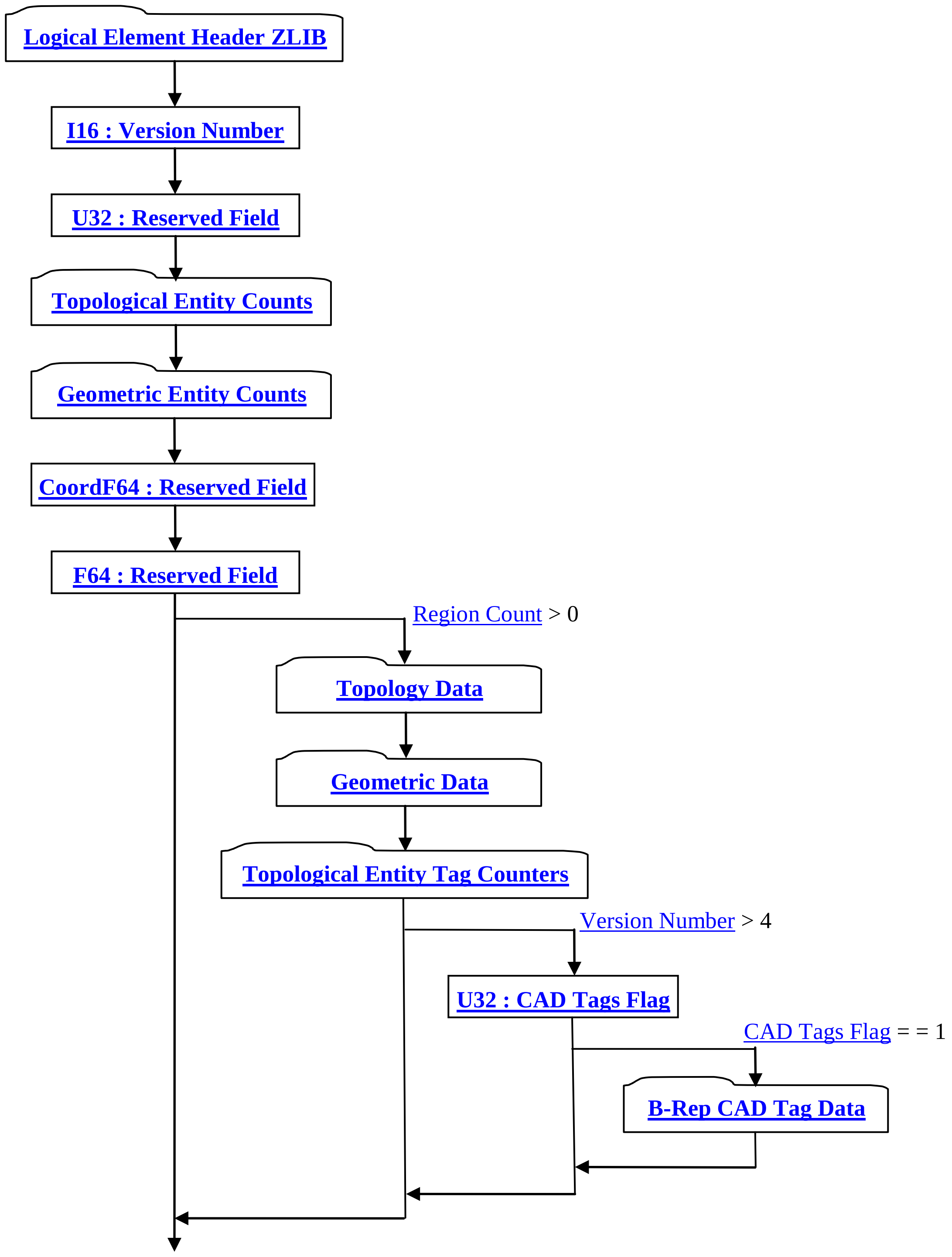
Parts may have the same topology, but wildly different geometry. Imagine the Surfaces of a Part being composed of rubber. The topology of the Part does not change as we deform the Part by bending or stretching the surfaces, as long as we do not cut or glue them (we call this a "nice" deformation). A Part's topology can be classified as being "manifold" or "non-manifold”; where “manifold” implies that the Part has the property that each Edge, excluding seams and poles, has exactly two faces using it.

Similarly, Parts may have nearly identical geometry but different topology. The topology of a Part depends on how the geometry is put together. A Part may be manifold or non-manifold simply depending on how the geometry is put together. In addition to describing connectivity in space, topology is used to describe areas of interest (active areas) on Surfaces. These active Surface areas are used in defining a complex Part. The areas are specified by oriented Loops and often referred to as trimmed Surfaces which are exactly the 2-dimensional topological building block called a Face.

Readers desiring/needing a more in-depth exploration of boundary representation theory in order to understand the significance/meaning of some of the JT B-Rep data fields are referred to references [10], [11] and [12] listed in 3 References and Additional Information section of this document.

Since the topology is a convenient way to describe or organize the Part, it is also convenient to store the geometry of the Part in the topological structures. The following sub-sections document the JT B-Rep format for storing the topology and geometry of a Part in a JT file.

Figure 102: JT B-Rep Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

I16 : Version Number

Version Number is the version identifier for this JT B-Rep Element. Only version number 0x0001 is currently defined.

U32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

CoordF64 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

F64 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

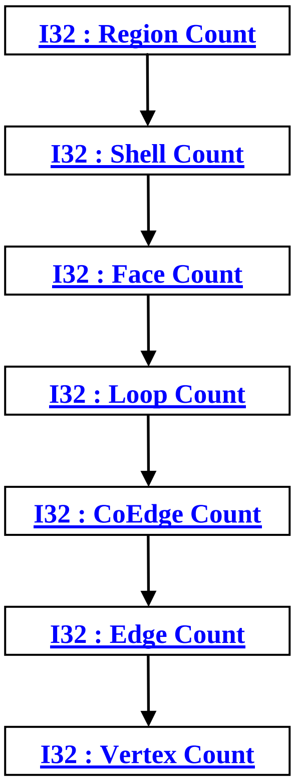
U32 : CAD Tags Flag

CAD Tags Flag is a flag indicating whether CAD Tag data exist for the JT B-Rep.

7.2.3.1.1 Topological Entity Counts

Topological Entity Counts data collection defines the counts for each of the various topological entities within a B-Rep.

Figure 103: Topological Entity Counts data collection



I32 : Region Count

Region Count indicates the number of topological region entities in the B-Rep.

I32 : Shell Count

Shell Count indicates the number of topological shell entities in the B-Rep

I32 : Face Count

Face Count indicates the number of topological face entities in the B-Rep

I32 : Loop Count

Loop Count indicates the number of topological loop entities in the B-Rep

I32 : CoEdge Count

CoEdge Count indicates the number of topological coedge entities in the B-Rep

I32 : Edge Count

Edge Count indicates the number of topological edge entities in the B-Rep

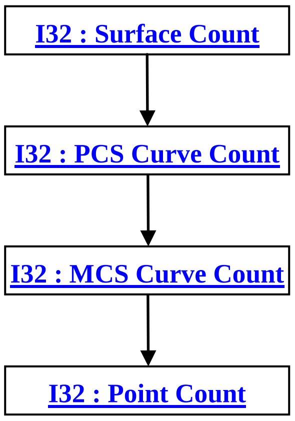
I32 : Vertex Count

Vertex Count indicates the number of topological vertex entities in the B-Rep

7.2.3.1.2 Geometric Entity Counts

Geometric Entity Counts data collection defines the counts for each of the various geometric entities within a B-Rep.

Figure 104: Geometric Entity Counts data collection



I32 : Surface Count

Surface Count indicates the number of distinct geometric surface entities in the B-Rep

I32 : PCS Curve Count

PCS Curve Count indicates the number of distinct geometric Parameter Coordinate Space curves (i.e. UV curve) entities in the B-Rep

I32 : MCS Curve Count

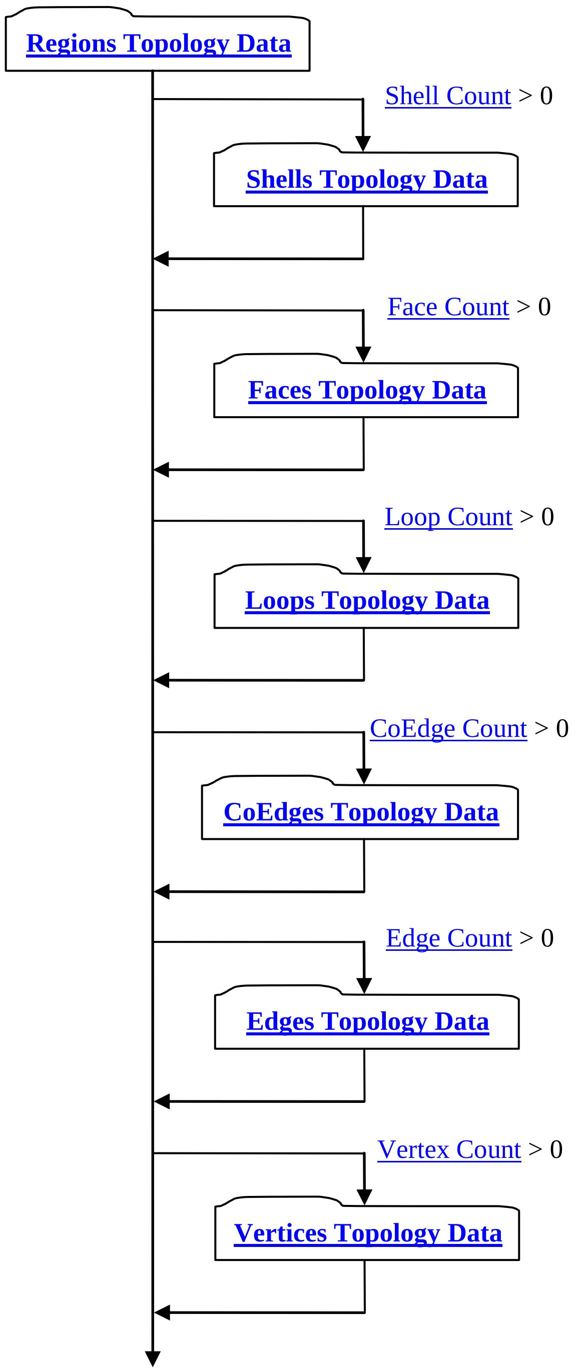
MCS Curve Count indicates the number of distinct geometric (Model Coordinate Space) curves (i.e. XYZ curve) entities in the B-Rep.

I32 : Point Count

Point Count indicates the number of distinct geometric point entities in the B-Rep.

7.2.3.1.3 Topology Data

Figure 105: Topology Data collection

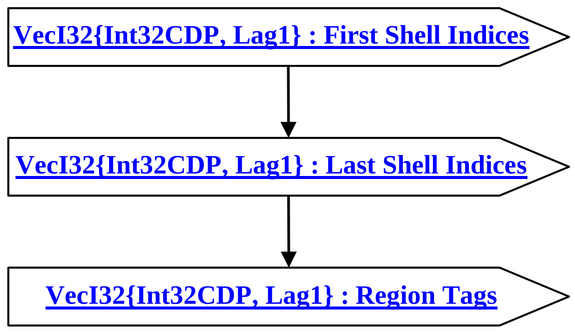


7.2.3.1.3.1 Regions Topology Data

Regions Topology Data defines the set of non-overlapping Shells comprising each Region. The volume of a Region is that volume lying inside each "anti-hole Shell" and outside each simply-contained "hole Shell" belonging to the particular Region. A Region is analogous to a dimensionally elevated face where Region corresponds to Face and Shell corresponds to Trim Loop.

Each Region's defining Shells are identified in a list of Shells by an index for both the first Shell and the last Shell in each Region (i.e. all Shells inclusive between the specified first and last Shell list index define the particular Region).

Figure 106: Regions Topology Data collection


VecI32{Int32CDP, Lag1} : First Shell Indices
VecI32{Int32CDP, Lag1} : Last Shell Indices
VecI32{Int32CDP, Lag1} : Region Tags

VecI32{Int32CDP, Lag1} : First Shell Indices

First Shell Indices is a vector of indices representing the index of the first Shell in each Region. First Shell Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Last Shell Indices

Last Shell Indices is a vector of indices representing the index of the last Shell in each Region. Last Shell Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Region Tags

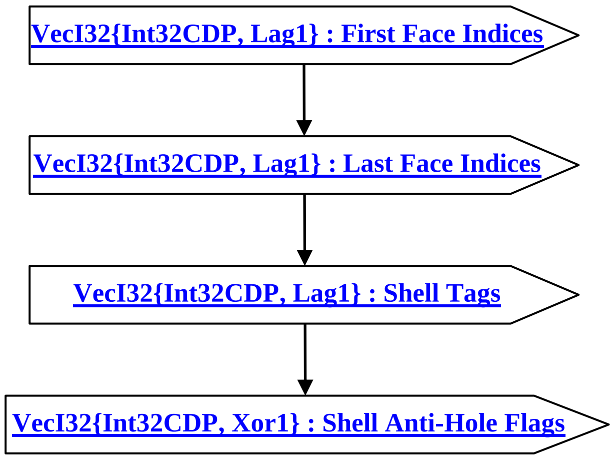
Each Region has an identifier tag. Region Tags is a vector of identifier tags for a set of Regions. Region Tags uses the Int32 version of the CODEC to compress and encode data.

7.2.3.1.3.2 Shells Topology Data

Shells Topology Data defines the set of topological adjacent Faces making up each Shell. A Shell's set of topological adjacent Faces define a single (usually closed) two manifold solid that in turn defines the boundary between the finite volume of space enclosed within the Shell and the infinite volume of space outside the Shell. Additional, each Shell has a flag that denotes whether the Shell refers to the finite interior volume (i.e. a "hole Shell") or the infinite exterior volume (i.e. an "anti-hole Shell").

Each Shell's defining Faces are identified in a list of Faces by an index for both the first Face and the last Face in each Shell (i.e. all Faces inclusive between the specified first and last Face list index define the particular Shell).

Figure 107: Shells Topology Data collection


VecI32{Int32CDP, Lag1} : First Face Indices
VecI32{Int32CDP, Lag1} : Last Face Indices
VecI32{Int32CDP, Lag1} : Shell Tags
VecI32{Int32CDP, Xor1} : Shell Anti-Hole Flags

VecI32{Int32CDP, Lag1} : First Face Indices

First Face Indices is a vector of indices representing the index of the first Face in each Shell. First Face Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Last Face Indices

Last Face Indices is a vector of indices representing the index of the last Face in each Shell. Last Face Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Shell Tags

Each Shell has an identifier tag. Shell Tags is a vector of identifier tags for a set of Shells. Shell Tags uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Xor1} : Shell Anti-Hole Flags

Each Shell has a flag identifying whether the Shell is an anti-hole Shell. Shell Anti-Hole Flags is a vector of anti-hole flags for a set of Shells.

In an uncompressed/decoded form the flag values have the following meaning:

= 0	Shell is not an anti-hole Shell
= 1	Shell is an anti-hole Shell

Shell Anti-Hole Flags uses the Int32 version of the CODEC to compress and encode data.

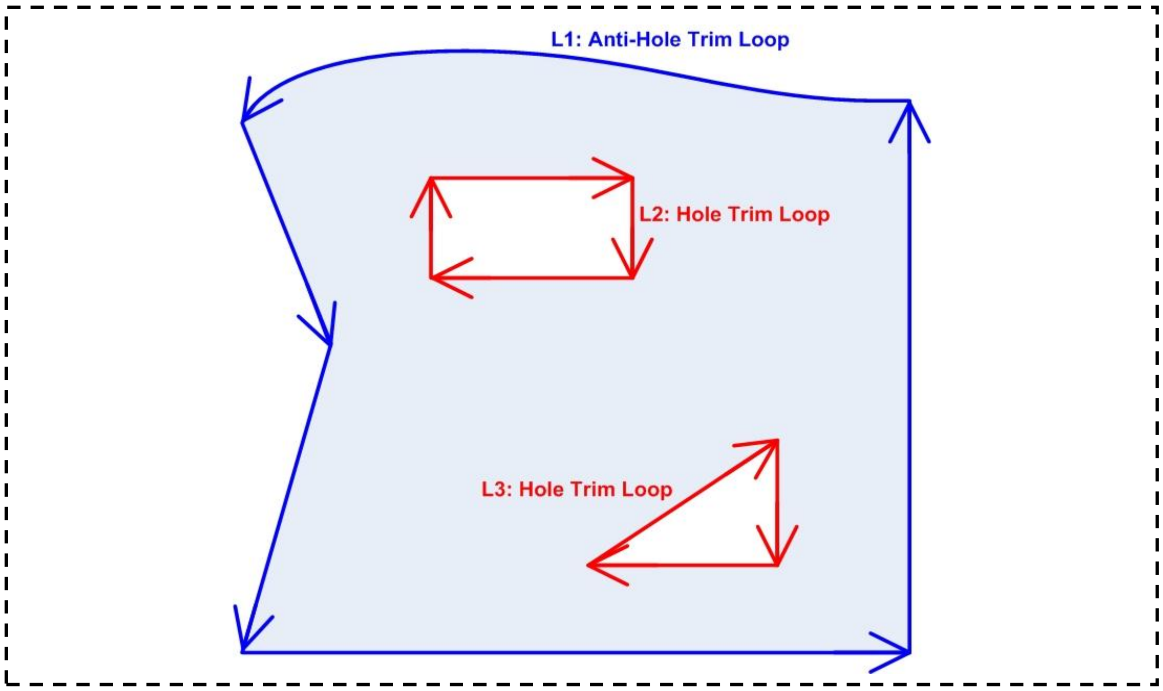
7.2.3.1.3.3 Faces Topology Data

A Face is a two-dimensional topological building block defined as the active (that portion to be used in the model) regions/areas of a Geometric Surface; where active regions/areas of a Geometric Surface are indicated using oriented Trim Loops. Faces Topology Data specifies the underlying Geometric Surface and Trim Loops making up each Face along with a “reverse normal” flag and identifier tag for each Face.

A Face must be trimmed with at least one “anti-hole” Trim Loop and zero or more “hole” Trim Loops. Thus the area of the Geometric Surface defined as the Face, is the area inside the “anti-hole” Trim Loops and outside each “hole” Trim Loop. No Trim Loops (“hole’ or “anti-hole”) may intersect/cross or be tangent at any point. “Anti-Hole” Trim Loops must be defined with a counter-clockwise orientation in the underlying surface's parameter space whereas “hole” Trim Loops must be defined with a clockwise orientation. With this Trim Loop orientation definition, as one traverses a Trim Loop of a Face, the material or “active region” is always to one’s left. Figure 108 gives an example in parameter space of proper trim loop definition and orientation (as indicated by the arrows on the loop’s CoEdges) for a face with two holes. “L1” represents the face “anti-hole”

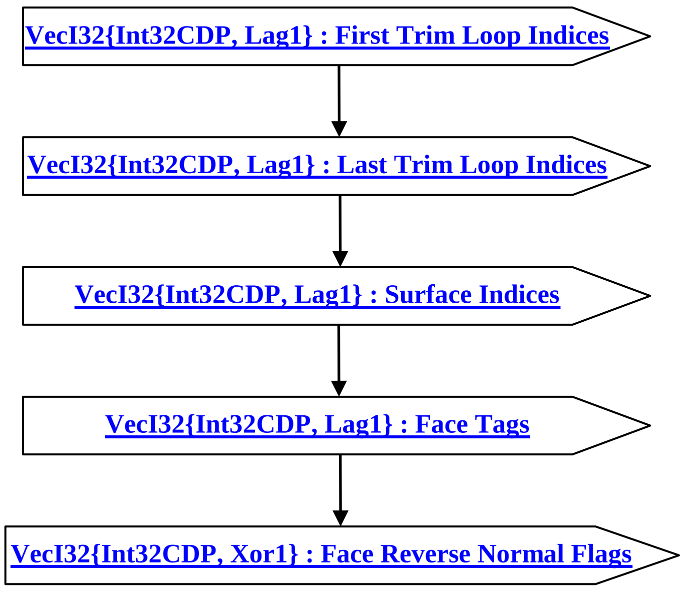
Trim Loop while "L2" and L3" represent the two "hole" Trim Loops. Note that each hole is always represented by a separate distinct "hole" Trim Loop.

Figure 108: Trim Loop example in parameter Space - One Face with 2 Holes



Each Face's underlying Geometric Surface is identified by an index into a list of Geometric Surfaces. Each Face's defining Trim Loops are identified in a list of trim Loops by an index for both the first Trim Loop and the last Trim Loop in each Face (i.e. all Trim Loops inclusive between the specified first and last Trim Loop list index define the particular Face).

Figure 109: Faces Topology Data collection


VecI32{Int32CDP, Lag1} : First Trim Loop Indices
VecI32{Int32CDP, Lag1} : Last Trim Loop Indices
VecI32{Int32CDP, Lag1} : Surface Indices
VecI32{Int32CDP, Lag1} : Face Tags
VecI32{Int32CDP, Xor1} : Face Reverse Normal Flags

VecI32{Int32CDP, Lag1} : First Trim Loop Indices

First Trim Loop Indices is a vector of indices representing the index of the first Trim Loop in each Face. First Trim Loop Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Last Trim Loop Indices

Last Trim Loop Indices is a vector of indices representing the index of the last Trim Loop in each Face. Last Trim Loop Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Surface Indices

Surface Indices is a vector of indices representing the index of the underlying Geometric Surface for each Face. Surface Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Face Tags

Each Face has an identifier tag. Face Tags is a vector of identifier tags for a set of Faces. Face Tags uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Xor1} : Face Reverse Normal Flags

Each Face has a flag identifying whether the Face’s normal(s) should be interpreted to point in the direction opposite of the usual U cross V normal (note that these flags do not imply any sort of parameter reversal, the flag only implies that the material is on the other side of the surface).

Face Reverse Normal Flags is a vector of reverse-normal flags for a set of Faces.

In an uncompressed/decoded form the flag values have the following meaning:

= 0	Face normal is not reversed
= 1	Face normal is reversed.

Face Reverse Normal Flags uses the Int32 version of the CODEC to compress and encode data.

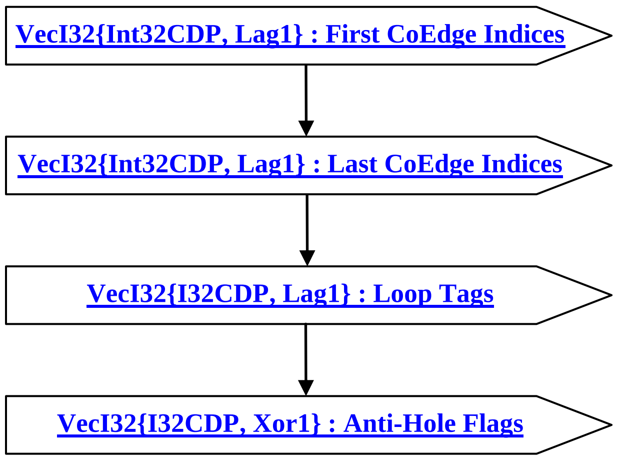
7.2.3.1.3.4 Loops Topology Data

A Loop (often called Trimming Loop) defines in parameter space a 1D boundary around which geometric surfaces are trimmed to form a Face. Loops Topology Data specifies the CoEdges making up each Loop along with an anti-hole flag and identifier tag for each Loop.

A Loop is composed of one or more CoEdges and the Loop must be closed and non-self-intersecting.

Each Loop’s defining CoEdges are identified in a list of CoEdges by an index for both the first CoEdge and the last CoEdge in each Loop (i.e. all CoEdges inclusive between the specified first and last CoEdge list index define the particular Loop).

Figure 110: Loops Topology Data collection


VecI32{Int32CDP, Lag1} : First CoEdge Indices
VecI32{Int32CDP, Lag1} : Last CoEdge Indices
VecI32{I32CDP, Lag1} : Loop Tags
VecI32{I32CDP, Xor1} : Anti-Hole Flags

VecI32{Int32CDP, Lag1} : First CoEdge Indices

First CoEdge Indices is a vector of indices representing the index of the first CoEdge in each Loop. First CoEdge Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Last CoEdge Indices

Last CoEdge Indices is a vector of indices representing the index of the last CoEdge in each Loop. Last CoEdge Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{I32CDP, Lag1} : Loop Tags

Each Loop has an identifier tag. Loop Tags is a vector of identifier tags for a set of Loops. Loop Tags uses the Int32 version of the CODEC to compress and encode data.

VecI32{I32CDP, Xor1} : Anti-Hole Flags

Each Loop has a flag identifying whether the Loop is an anti-hole Loop. Anti-Hole Flags is a vector of anti-hole flags for a set of Loops

In an uncompressed/decoded form the flag values have the following meaning:

= 0	Loop is not an anti-hole Loop
= 1	Loop is an anti-hole Loop

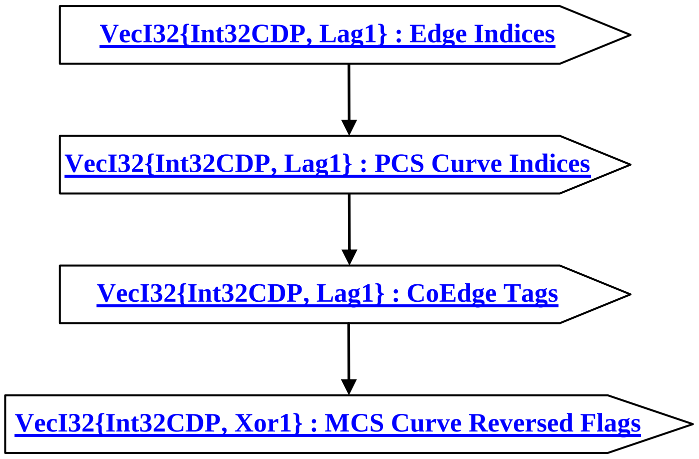
Anti-Hole Flags uses the Int32 version of the CODEC to compress and encode data.

7.2.3.1.3.5 CoEdges Topology Data

A CoEdge defines a parameter space edge trim Loop segment (i.e. the projection of an Edge into the parameter space of the Face). CoEdges Topology Data specifies the underlying Edge and PCS Curve making up each CoEdge along with a MCS curve reversed flag and tag for each CoEdge.

The “Co” portion of the CoEdge name derives from the manifold topology definition that each Edge has exactly two Faces containing it; thus a CoEdge defines one Face’s “use” of an Edge and the adjoining Face also has a CoEdge (“edge use” in some other terminologies) for the same underlying Edge. This sharing of the same underlying Edge by two adjoining Faces requires an “MCS Curve Reversed Flag” on each CoEdge to indicate the edge traversal direction (i.e. for a proper manifold topology definition each CoEdge must traverse the Edge in opposite directions).

Figure 111: CoEdges Topology Data collection


VecI32{Int32CDP, Lag1} : Edge Indices
VecI32{Int32CDP, Lag1} : PCS Curve Indices
VecI32{Int32CDP, Lag1} : CoEdge Tags
VecI32{Int32CDP, Xor1} : MCS Curve Reversed Flags

VecI32{Int32CDP, Lag1} : Edge Indices

Edge Indices is a vector of indices representing the index of the underlying Edge for each CoEdge. Edge Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : PCS Curve Indices

PCS Curve Indices is a vector of indices representing the index of the PCS Curve (UV Curve) for each CoEdge. PCS Curve Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : CoEdge Tags

Each CoEdge has an identifier tag. CoEdge Tags is a vector of identifier tags for a set of CoEdges. CoEdge Tags uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Xor1} : MCS Curve Reversed Flags

Each CoEdge has a flag indicating whether the directional sense of the associated Edge's MCS curve should be interpreted as opposite the direction its parameterization implies. MCS Curve Reversed Flags is a vector of reverse flags for a set of CoEdges.

In an uncompressed/decoded form the flag values have the following meaning:

= 0	Directional sense of associated edges MCS curve should not be interpreted as opposite the direction its parameterization implies.
= 1	Directional sense of associated edges MCS curve should be interpreted as opposite the direction its parameterization implies.

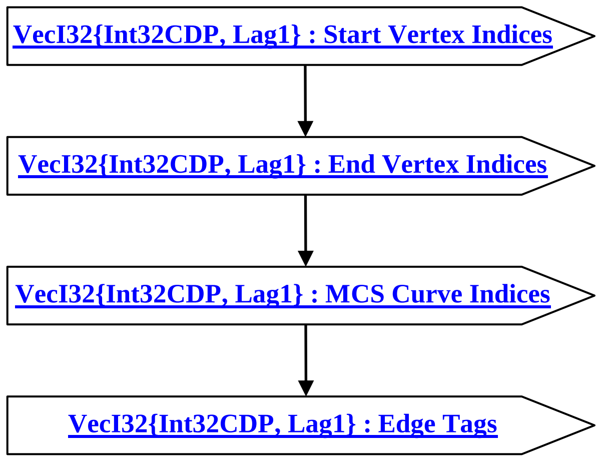
MCS Curve Reversed Flags uses the Int32 version of the CODEC to compress and encode data.

7.2.3.1.3.6 Edges Topology Data

An Edge defines a model space trim Loop segment. Edges Topology Data specifies the underlying MCS Curve and start and end Vertex making up each Edge along with an identification tag for each Edge.

If manifold topology, then two faces join at a single model Edge and thus an edge is shared/referenced by two CoEdges (one per Face).

Figure 112: Edges Topology Data collection


VecI32{Int32CDP, Lag1} : Start Vertex Indices
VecI32{Int32CDP, Lag1} : End Vertex Indices
VecI32{Int32CDP, Lag1} : MCS Curve Indices
VecI32{Int32CDP, Lag1} : Edge Tags

VecI32{Int32CDP, Lag1} : Start Vertex Indices

Start Vertex Indices is a vector of indices representing the index of the start Vertex in each Edge. Start Vertex Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : End Vertex Indices

End Vertex Indices is a vector of indices representing the index of the end Vertex in each Edge. End Vertex Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : MCS Curve Indices

MCS Curve Indices is a vector of indices representing the index of the MCS Curve (Model Space curve) for each Edge. MCS Curve Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Edge Tags

Each Edge has an identifier Tag. Edge Tags is a vector of identifier Tags for a set of Edges. Edge Tags uses the Int32 version of the CODEC to compress and encode data.

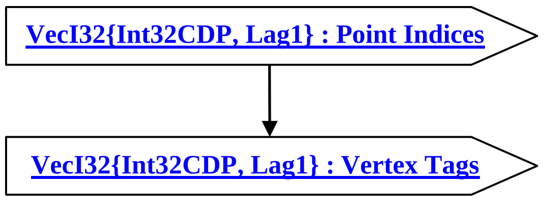
7.2.3.1.3.7 Vertices Topology Data

A Vertex is the simplest topological entity and is basically made up of a geometric Point. Vertices Topology Data specifies the underlying geometric Point making up each Vertex along with an identification tag for each Vertex.

The presence of Vertices Topology Data in a JT B-Rep topology definition is optional. Vertex data is optional because unlike most topological entities, no connectivity information is contained in a Vertex structure and Vertex data is also not necessary for performing operations such as tessellation or mass properties calculations.

A Vertex is usually shared/referenced by two or more Edges (e.g. if the corners of four rectangular Faces touches at a common point, this point is represented by a Vertex and is shared by four Edges).

Figure 113: Vertices Topology Data collection


VecI32{Int32CDP, Lag1} : Point Indices
VecI32{Int32CDP, Lag1} : Vertex Tags

VecI32{Int32CDP, Lag1} : Point Indices

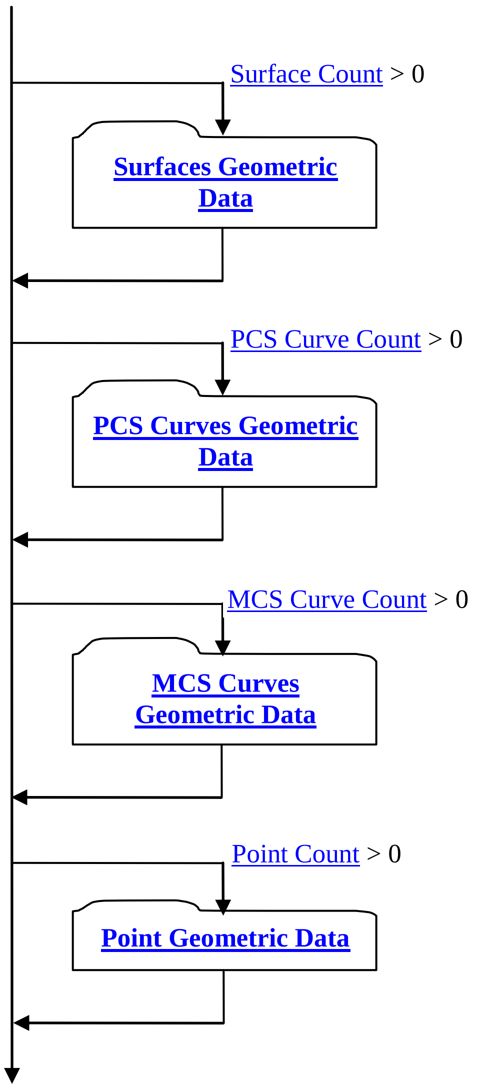
Point Indices is a vector of indices representing the index of the geometric point for each Vertex. Point Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Vertex Tags

Each Vertex has an identifier Tag. Vertex Tags is a vector of identifier Tags for a set of Vertices. Vertex Tags uses the Int32 version of the CODEC to compress and encode data.

7.2.3.1.4 Geometric Data

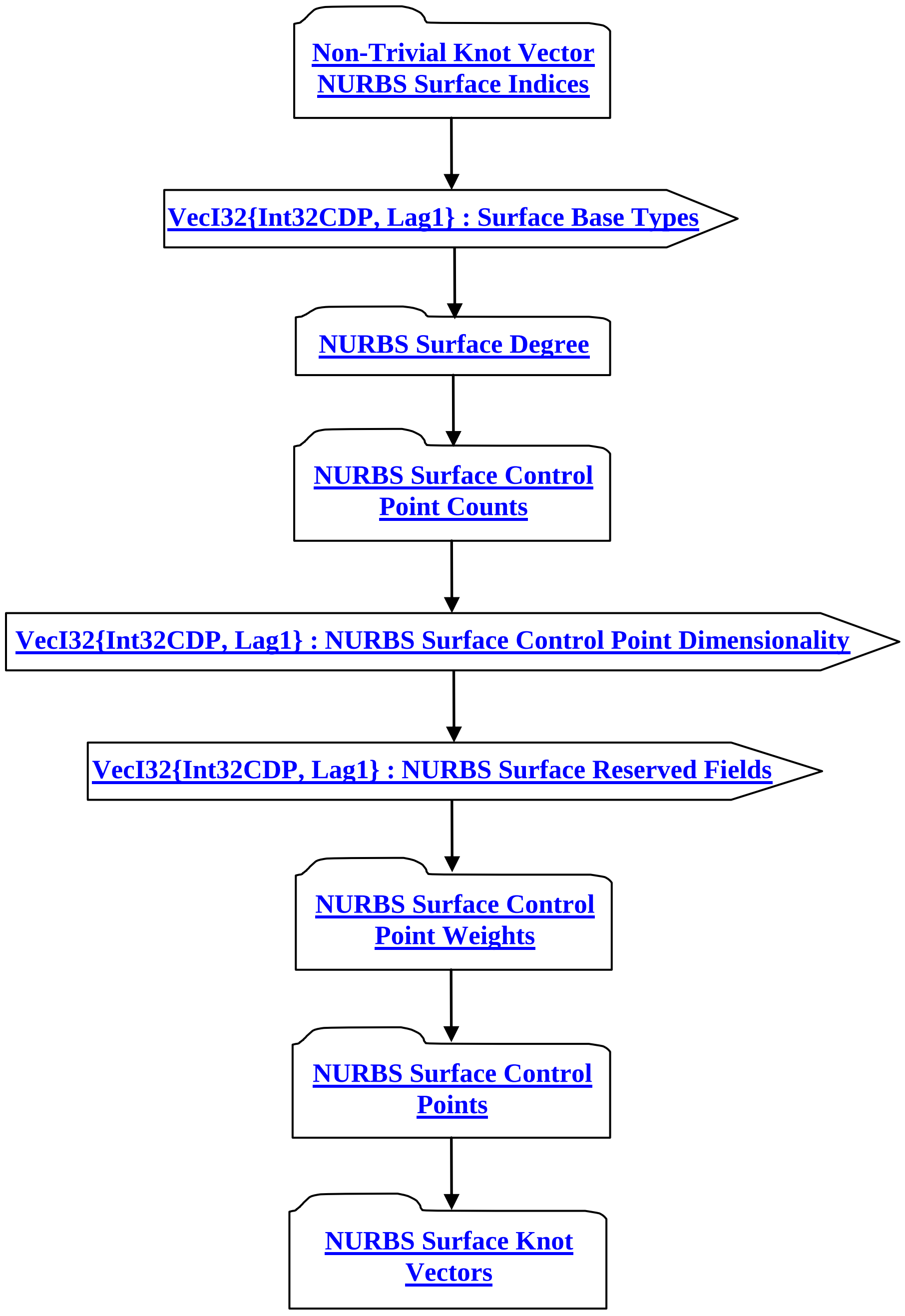
Figure 114: Geometric Data collection



7.2.3.1.4.1 Surfaces Geometric Data

Surfaces Geometric Data collection contains the JT B-Rep's geometric Surface data. Currently only NURBS Surface types are supported within a JT B-Rep. The count/number of Surfaces within a JT B-Rep is indicated by data field Surface Count documented in 7.2.3.1.2 Geometric Entity Counts.

Figure 115: Surfaces Geometric Data collection


Non-Trivial Knot Vector NURBS Surface Indices
VecI32{Int32CDP, Lag1} : Surface Base Types
NURBS Surface Degree
NURBS Surface Control Point Counts
VecI32{Int32CDP, Lag1} : NURBS Surface Control Point Dimensionality
VecI32{Int32CDP, Lag1} : NURBS Surface Reserved Fields
NURBS Surface Control Point Weights
NURBS Surface Control Points
NURBS Surface Knot Vectors

VecI32{Int32CDP, Lag1} : Surface Base Types

Each Surface is assigned a base type identifier. Surface Base Types is a vector of base type identifiers for each Surface in a list of Surfaces. Currently only NURBS Surface Base Type is supported, but a type identifier is still included in the specification to allow for future expansion of the JT Format to support other surface types within a JT B-Rep.

In an uncompressed/decoded form the Surface base type identifier values have the following meaning:

= 1	Surface is a NURBS surface

Surface Base Types uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : NURBS Surface Control Point Dimensionality

NURBS Surface Control Point Dimensionality is a vector of control point dimensionality values for each NURBS Surface in a list of Surfaces (i.e. there is a stored values for each NURBS Surface in the list).

In an uncompressed/decoded form dimensionality values have the following meaning:

= 3	Non-Rational (each control point has 3 coordinates)
= 4	Rational (each control point has 4 coordinates)

NURBS Surface Control Point Dimensionality uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : NURBS Surface Reserved Fields

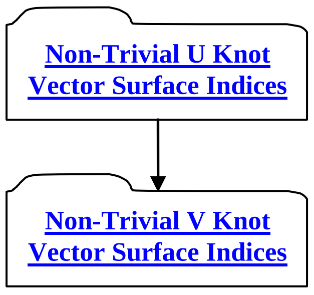
NURBS Surface Reserved Fields is a vector of data reserved for future expansion of the JT format. Each NURBS Surface in a list of Surfaces has one reserved data field entry in this NURBS Surface Reserved Fields vector. NURBS Surface Reserved Fields uses the Int32 version of the CODEC to compress and encode data

7.2.3.1.4.1.1 Non-Trivial Knot Vector NURBS Surface Indices

Non-Trivial Knot Vector NURBS Surface Indices data collection specifies for both U and V directions the Surface index identifiers (i.e. indices to particular NURBS Surfaces within a list of Surfaces) for all NURBS Surfaces containing non-trivial knot vectors. A description/definition for "non-trivial knot vector" can be found in 8.1.13 Compressed Entity List for Non-Trivial Knot Vector.

This Surface index data is stored in a compressed format.

Figure 116: Non-Trivial Knot Vector NURBS Surface Indices data collection

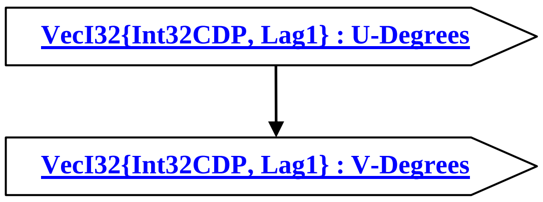

Non-Trivial U Knot Vector Surface Indices
Non-Trivial V Knot Vector Surface Indices

Both Non-Trivial U Knot Vector Surface Indices and Non-Trivial V Knot Vector Surface Indices have the same data format as that documented for data collection 8.1.13 Compressed Entity List for Non-Trivial Knot Vector.

7.2.3.1.4.1.2 NURBS Surface Degree

NURBS Surface Degree data collection defines the Surface degree in both U and V directions for each NURBS Surface in a list of Surfaces (i.e. there are stored values for each NURBS Surface in the list). This degree data for the list of Surfaces is stored in a compressed format.

Figure 117: NURBS Surface Degree data collection


VecI32{Int32CDP, Lag1} : U-Degrees
VecI32{Int32CDP, Lag1} : V-Degrees

VecI32{Int32CDP, Lag1} : U-Degrees

U-Degrees is a vector of Surface degree values in U direction for each NURBS Surface in a list of Surfaces. U-Degrees uses the Int32 version of the CODEC to compress and encode data.

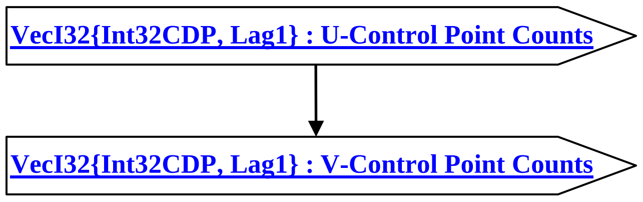
VecI32{Int32CDP, Lag1} : V-Degrees

V -Degrees is a vector of Surface degree values in V direction for each NURBS Surface in a list of Surfaces. V-Degrees uses the Int32 version of the CODEC to compress and encode data.

7.2.3.1.4.1.3 NURBS Surface Control Point Counts

NURBS Surface Control Point Counts defines the number of NURBS Surface control points for both U and V directions for each NURBS Surface in a list of Surfaces (i.e. there are stored values for each NURBS Surface in the list). The control point count data for the list of Surfaces in stored in a compressed format.

Figure 118: NURBS Surface Control Point Counts data collection


VecI32{Int32CDP, Lag1} : U-Control Point Counts
VecI32{Int32CDP, Lag1} : V-Control Point Counts

VecI32{Int32CDP, Lag1} : U-Control Point Counts

U-Control Point Counts is a vector of control point counts in U direction for each NURBS Surface in a list of Surfaces. U-Control Point Counts uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : V-Control Point Counts

V-Control Point Counts is a vector of control point counts in V direction for each NURBS Surface in a list of Surfaces. V-Control Point Counts uses the Int32 version of the CODEC to compress and encode data.

7.2.3.1.4.1.4 NURBS Surface Control Point Weights

NURBS Surface Control Point Weights data collection defines the Weight values for a conditional set of Control Points for a list of NURBS Surfaces. The storing of the Weight value for a particular Control Point is conditional, because if NURBS Surface Control Point Dimension is “non-rational” or the actual Control Point’s Weight value is “1”, then no Weight value is stored for the Control Point (i.e. Weight value can be inferred to be “1”).

The NURBS Surface Control Point Weights data is stored in a compressed format.

Figure 119: NURBS Surface Control Point Weights data collection

Compressed Control Point Weights Data

Complete description for Compressed Control Point Weights Data can be found in 8.1.14 Compressed Control Point Weights Data.

7.2.3.1.4.1.5 NURBS Surface Control Points

NURBS Surface Control Points is the compressed and/or encoded representation of the Control Point coordinates for each NURBS Surface in a list of Surfaces (i.e. there are stored values for each NURBS Surface in the list). Note that these are non-homogeneous coordinates (i.e. Control Point coordinates have been divided by the corresponding Control Point Weight values).

Figure 120: NURBS Surface Control Points data collection

VecF64{Float64CDP, NULL} : Control Points

VecF64{Float64CDP, NULL} : Control Points

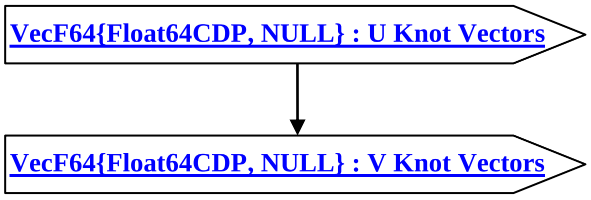
Control Points is a vector of Control Point coordinates for all the NURBS Surfaces in a list of Surfaces. All the NURBS Surfaces Control Point coordinates are cumulated into this single vector in the same order as the Surface appears in the Surface list (i.e. Surface-1 U Control Points, Surface-1 V Control Points, Surface-2 U Control Points, Surface-2 V Control Points, etc.). Control Points uses the Float64 version of the CODEC to compress and encode data in a “lossless” manner.

7.2.3.1.4.1.6 NURBS Surface Knot Vectors

NURBS Surface Knot Vectors defines the knot vectors for both U and V directions for each NURBS Surface having non-trivial knot vectors in a list of Surfaces (i.e. there are stored values for each non-trivial knot vector NURBS Surface in the list). The NURBS Surfaces for which knot vectors are stored (i.e. those containing non-trivial knot vectors) are identified in data collection Non-Trivial Knot Vector NURBS Surface Indices documented in 7.2.3.1.4.1.1 Non-Trivial Knot Vector NURBS Surface Indices.

The knot vector data for the list of Surfaces is stored in a compressed format.

Figure 121: NURBS Surface Knot Vectors data collection


VecF64{Float64CDP, NULL} : U Knot Vectors
VecF64{Float64CDP, NULL} : V Knot Vectors

VecF64{Float64CDP, NULL} : U Knot Vectors

U Knot Vectors is a list of knot vector values in U direction for each NURBS Surface having non-trivial knot vectors in a list of Surfaces. All these NURBS Surface U direction non-trivial knot vectors are cumulated into this single list in the same order as the Surface appears in the Surface list (i.e. Surface-N Non-Trivial U Knot Vector, Surface-M Non-Trivial U Knot Vector, etc.). U Knot Vectors uses the Float64 version of the CODEC to compress and encode data.

VecF64{Float64CDP, NULL} : V Knot Vectors

V Knot Vectors is a list of knot vector values in V direction for each NURBS Surface having non-trivial knot vectors in a list of Surfaces. All these NURBS Surface V direction non-trivial knot vectors are cumulated into this single list in the same order as the Surface appears in the Surface list (i.e. Surface-N Non-Trivial V Knot Vector, Surface-M Non-Trivial V Knot Vector, etc.). V Knot Vectors uses the Float64 version of the CODEC to compress and encode data.

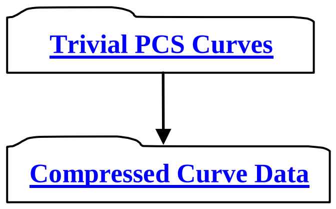
7.2.3.1.4.2 PCS Curves Geometric Data

PCS Curves Geometric Data collection contains the JT B-Rep's Parameter Coordinate Space geometric Curve data (i.e. UV Curve data). This geometric PCS Curve data is divided up into two collection types; one data collection for what are considered "Trivial" PCS curves and one data collection for compressed/encoded PCS NURBS Curve data.

"Trivial" PCS Curves are those UV Curves whose definition is such that the actual UV Curve definition can be derived from the parametric domain definition by storing a limited amount of descriptive data for each UV curve (i.e. do not have to store the complete NURBS UV Curve definition).

The count/number of PCS Curves within a JT B-Rep is indicated by data field PCS Curve Count documented in 7.2.3.1.2 Geometric Entity Counts.

Figure 122: PCS Curves Geometric Data collection

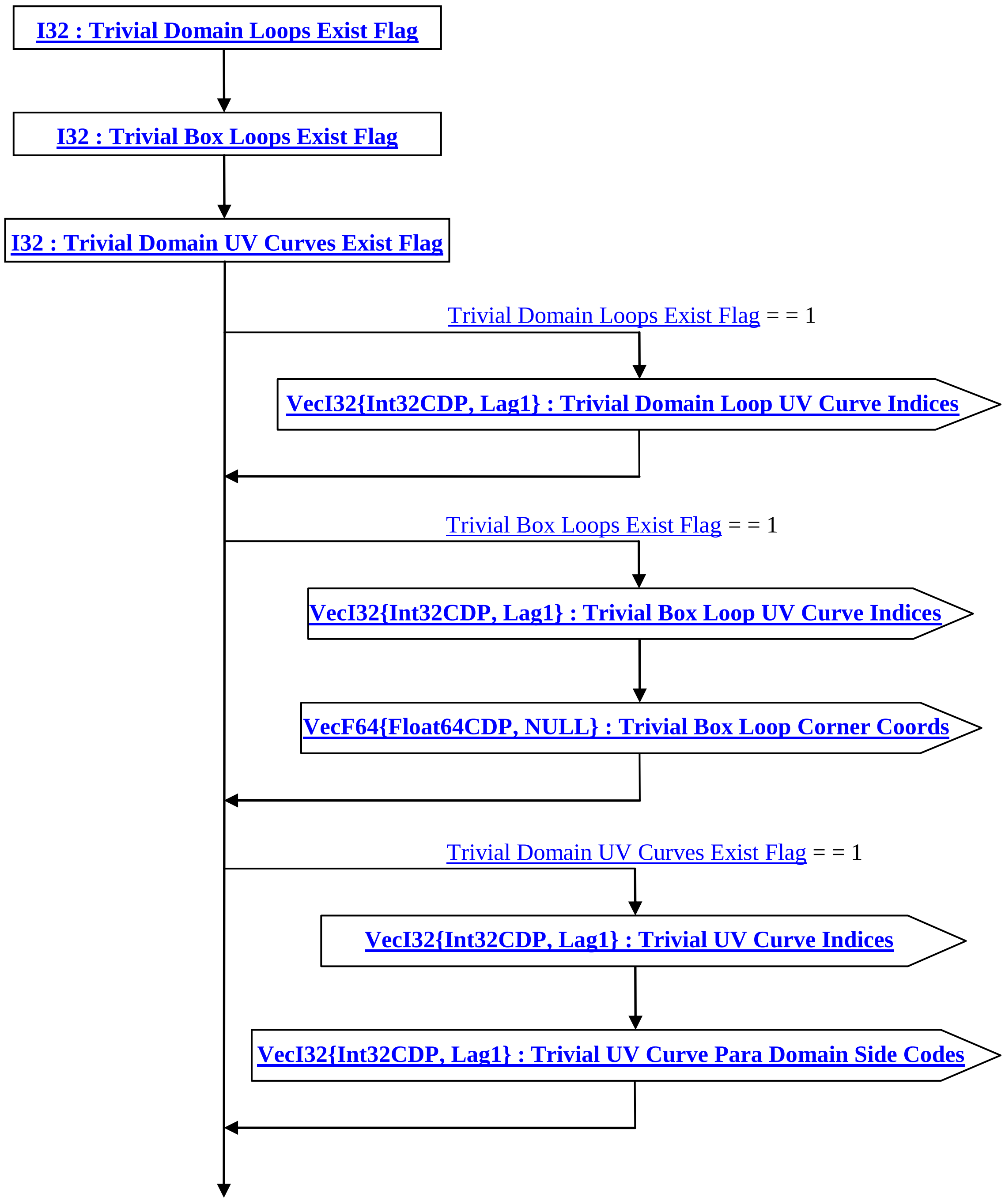


Complete description for Compressed Curve Data can be found in 8.1.15 Compressed Curve Data.

7.2.3.1.4.2.1 Trivial PCS Curves

Trivial PCS Curves data collection represents those UV curves whose definition is such (i.e. "trivial" enough) that the actual UV curve definition can be derived from the parametric domain definition by storing a limited amount of descriptive data for each UV curve (i.e. do not have to store the complete UV curve definition). These Trivial PCS Curves are grouped into three classifications (Trivial Domain Loop, Trivial Box Loop, or Trivial Domain UV Curve) and stored as described in the following sub-sections.

Figure 123: Trivial PCS Curves data collection


I32 : Trivial Domain Loops Exist Flag
I32 : Trivial Box Loops Exist Flag
I32 : Trivial Domain UV Curves Exist Flag
Trivial Domain Loops Exist Flag = = 1
VecI32{Int32CDP, Lag1} : Trivial Domain Loop UV Curve Indices
Trivial Box Loops Exist Flag = = 1
VecI32{Int32CDP, Lag1} : Trivial Box Loop UV Curve Indices
VecF64{Float64CDP, NULL} : Trivial Box Loop Corner Coords
Trivial Domain UV Curves Exist Flag = = 1
VecI32{Int32CDP, Lag1} : Trivial UV Curve Indices
VecI32{Int32CDP, Lag1} : Trivial UV Curve Para Domain Side Codes

I32 : Trivial Domain Loops Exist Flag

Trivial Domain Loops Exist Flag is a flag indicating whether "trivial" domain loops exist/follow. A Trivial Domain Loop is a Loop that encloses the entire parametric domain. (i.e. all UV Curves of the Loop span the entire length of the Surface parametric domain). Given this criteria a Trivial Domain Loop must always be made up of four Trivial Domain UV curves.

= 0	Trivial Domain Loops do not exist.

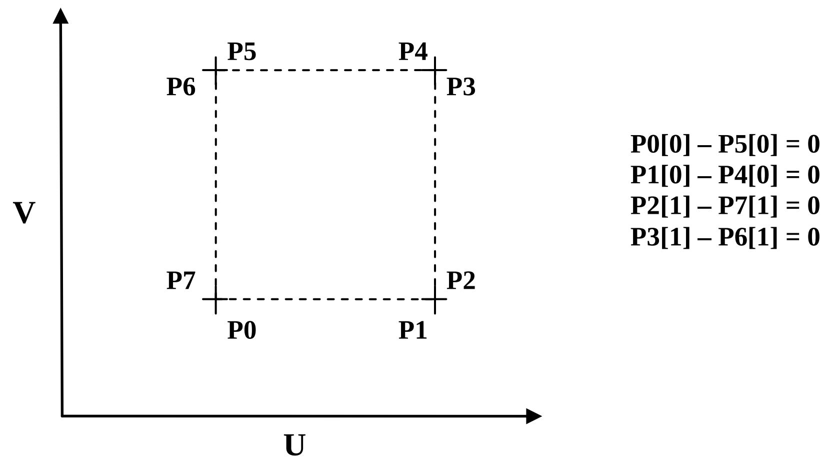
= 1	Trivial Domain Loops exist.

I32 : Trivial Box Loops Exist Flag

Trivial Box Loops Exist Flag is a flag indicating whether "trivial" box loops exist/follow. A trivial Box Loop is a Loop that forms a rectangle (i.e. corresponding curve end coordinates of opposite sides of the box are equal). Given this criteria a Trivial Box Loop must always be made up of four UV curves

= 0	Trivial Box Loops do not exist.
= 1	Trivial Box Loops exist.

"Equality of corresponding curve end coordinates of opposite sides of the box" is represented graphically as follows:



I32 : Trivial Domain UV Curves Exist Flag

Trivial Domain UV Curves Exist Flag is a flag indicating whether "trivial" domain UV curves (Loop CoEdges) exist/follow that are not part of a Trivial Domain Loop or Trivial Box Loop (i.e. a Loop contains some UV curves that span the entire length of the Surface parametric domain but not all the Loop UV curves meet this criteria and thus not captured as part of the Trivial Domain Loop data).

= 0	Trivial Domain UV Curves do not exist.
= 1	Trivial Domain UV Curves exist.

VecI32{Int32CDP, Lag1} : Trivial Domain Loop UV Curve Indices

Trivial Domain Loop UV Curve Indices is a vector of all UV curve indices that are part of a Trivial Domain Loop. Note that each Trivial Domain Loop is always made up of four UV curves (thus four UV curve indices per Loop). Trivial Domain Loop UV Curve Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Trivial Box Loop UV Curve Indices

Trivial Box Loop UV Curve Indices is a vector of all UV Curve indices that are part of a Trivial Box Loop. Note that each Trivial Box Loop is always made up of four UV Curves (thus four UV Curve indices per Loop). Trivial Box Loop UV Curve Indices uses the Int32 version of the CODEC to compress and encode data.

VecF64{Float64CDP, NULL} : Trivial Box Loop Corner Coords

Trivial Box Loop Corner Coords is a vector of box corner coordinates for all Trivial Box Loops (i.e. each Box Loop will store two box coroner coordinates). A Box Loop's set of "box corner coordinates" are the coordinates of the two min/max diagonally opposite corners of the box. Note that if the Box Loop is a "hole", then the max and min corners are the other ends of the respective box sides that contain the max and min corners. Trivial Box Loop Corner Coords uses the Float64 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Trivial UV Curve Indices

Trivial UV Curve Indices is a vector of all Loop UV Curve indices that are not part of a Trivial Domain Loop or Trivial Box Loop. Trivial UV Curve Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : Trivial UV Curve Para Domain Side Codes

Trivial UV Curve Para Domain Side Codes is a vector containing a "side code" for each Trivial UV Curve indicating which parametric domain side the UV Curve lies on.

In an uncompressed/decoded form the parametric domain side values have the following meaning:

= 0	Bottom side of parametric domain
= 1	Right side of parametric domain
= 2	Top side of parametric domain
= 3	Left side of parametric domain

Trivial UV Curve Para Domain Side Codes uses the Int32 version of the CODEC to compress and encode data.

7.2.3.1.4.3 MCS Curves Geometric Data

MCS Curves Geometric Data collection contains the JT B-Rep's Model Coordinate System geometric Curve data (i.e. XYZ Curve data). Currently only NURBS Curve types are supported within a JT B-Rep. The count/number of MCS Curves within a JT B-Rep is indicated by data field MCS Curve Count documented in 7.2.3.1.2 Geometric Entity Counts.

Figure 124: MCS Curves Geometric Data collection

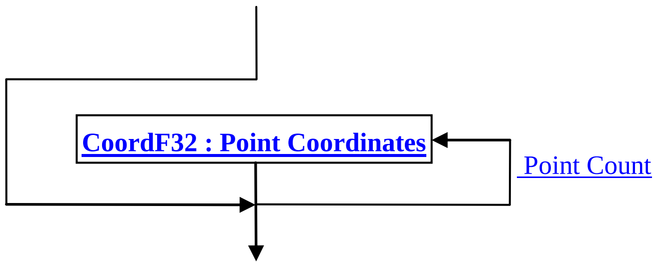
Compressed Curve Data

Complete description for Compressed Curve Data can be found in 8.1.15 Compressed Curve Data.

7.2.3.1.4.4 Point Geometric Data

Point Geometric Data collection contains the JT B-Rep's geometric Point data. Each Point is simply represented by a CoordF32 for the Point's coordinate components. The count/number of Points within a JT B-Rep is indicated by data field Point Count documented in 7.2.3.1.2 Geometric Entity Counts.

Figure 125: Point Geometric Data collection



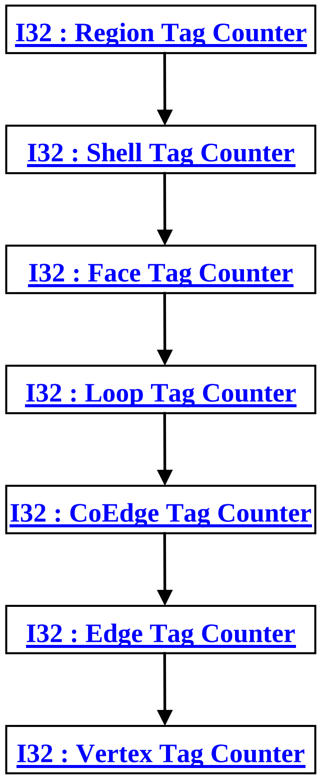
CoordF32 : Point Coordinates

Point Coordinates specifies the XYZ coordinate components for a Point.

7.2.3.1.5 Topological Entity Tag Counters

Topological Entity Tag Counters data collection specifies the next available “unique” tag value for each entity type in a JT B-Rep. These are rolling tag counters that are meant to be used for assigning a unique tag when a new entity is added to a JT B-Rep.

Figure 126: Topological Entity Tag Counters data collection



I32 : Region Tag Counter

Region tag Counter specifies the next available “unique’ tag value for Region entity.

I32 : Shell Tag Counter

Shell Tag Counter specifies the next available “unique’ tag value for Shell entity.

I32 : Face Tag Counter

Face Tag Counter specifies the next available “unique’ tag value for Face entity.

I32 : Loop Tag Counter

Loop Tag Counter specifies the next available “unique’ tag value for Loop entity.

I32 : CoEdge Tag Counter

CoEdge Tag Counter specifies the next available “unique’ tag value for CoEdge entity.

I32 : Edge Tag Counter

Edge Tag Counter specifies the next available “unique’ tag value for Edge entity.

I32 : Vertex Tag Counter

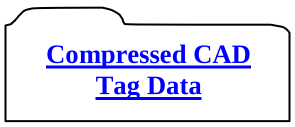
Vertex Tag Counter specifies the next available “unique’ tag value for Vertex entity.

7.2.3.1.6 B-Rep CAD Tag Data

The B-Rep CAD Tag Data collection contains the list of persistent IDs, as defined in the CAD System, to uniquely identify individual Faces and Edges in the JT B-Rep. The existence of this B-Rep CAD Tag Data collection is dependent upon the value of previously read data field CAD Tags Flag as documented in 7.2.3.1 JT B-Rep Element.

If B-Rep CAD Tag Data collection is present, there will be a CAD Tag for every Face and every Edge in the JT B-Rep and the list order will be Face CAD Tags followed by Edge CAD Tags. Therefore the total number of CAD Tags in the list should be equal to "Face Count + Edge Count" as documented in 7.2.3.1.1 Topological Entity Counts.

Figure 127: B-Rep CAD Tag Data collection



Complete description for Compressed CAD Tag Data can be found in 8.1.16 Compressed CAD Tag Data.

7.2.4 XT B-Rep Segment

XT B-Rep Segment contains an Element that defines the precise geometric Boundary Representation data for a particular Part in Parasolid boundary representation (XT) format. Note that there is also another Boundary Representation format (i.e. JT B-Rep) supported by the JT file format within a different file Segment Type. Complete description for the JT B-Rep can be found in 7.2.3 JT B-Rep Segment.

XT B-Rep Segments are typically referenced by Part Node Elements (see 7.2.1.1.1.5Part Node Element) using Late Loaded Property Atom Elements (see 0Second specifies the date Second value. Valid values are [0, 59] inclusive.

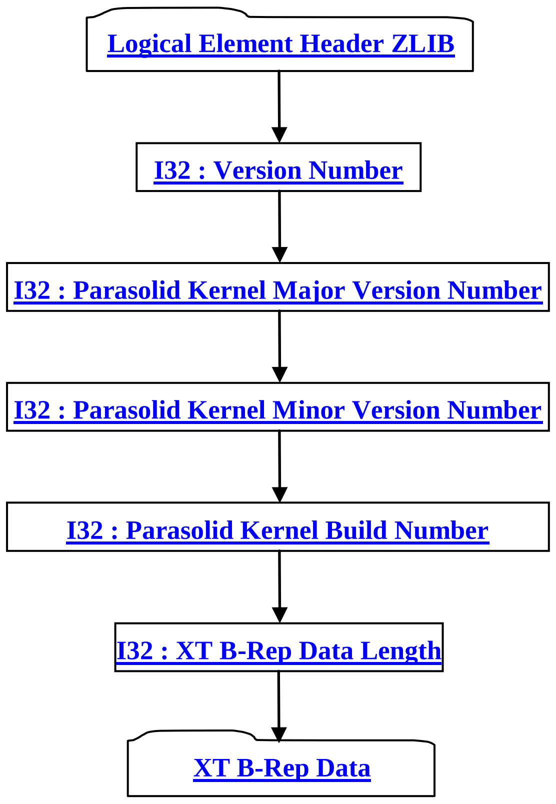
Late Loaded Property Atom Element). The XT B-Rep Segment type supports ZLIB compression on all element data, so all elements in XT B-Rep Segment use the Logical Element Header ZLIB form of element header data.

7.2.4.1 XT B-Rep Element

Object Type ID: 0x873a70e0, 0x2ac9, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

XT B-Rep Element represents a particular part's precise data in Parasolid boundary representations (XT) format.

Figure 128: XT B-Rep Element data collection


Logical Element Header ZLIB
I32 : Version Number
I32 : Parasolid Kernel Major Version Number
I32 : Parasolid Kernel Minor Version Number
I32 : Parasolid Kernel Build Number
I32 : XT B-Rep Data Length
XT B-Rep Data

Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

I32 : Version Number

Version Number is the version identifier for this XT B-Rep Element. Version number "2" is currently the only valid value for v9 JT files.

I32 : Parasolid Kernel Major Version Number

Parasolid Kernel Major Version Number specifies the major version number for the revision of Parasolid that wrote the XT B-Rep data into JT File.

I32 : Parasolid Kernel Minor Version Number

Parasolid Kernel Minor Version Number specifies the minor version number for the revision of Parasolid that wrote the XT B-Rep data into JT File.

I32 : Parasolid Kernel Build Number

Parasolid Kernel Build Number specifies the build number for the revision of Parasolid that wrote the XT B-Rep data into JT File.

I32 : XT B-Rep Data Length

XT B-Rep Data Length specifies the length in bytes of the XT B-Rep Data collection. A JT file loader/reader may use this information to compute the end position of the XT B-Rep Data within the JT file and thus skip (for whatever reason) reading the remaining XT B-Rep Data.

7.2.4.1.1 XT B-Rep Data

The XT B-Rep Data collection specifies the raw stream of bytes that Parasolid uses to represent a Part's B-Rep Body(s) in an external file. The XT B-Rep Data collection format in the JT file is exactly equivalent to the Parasolid XT "Neutral Binary" encoding format as written by the Parasolid "PK_PART_transmit" interface routine.

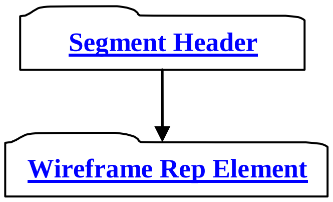
Complete documentation for the Parasolid XT "Neutral Binary" encoding format as written by "PK_PART_transmit" can be found in Appendix F: Parasolid XT Format Reference.

7.2.5 Wireframe Segment

Wireframe Segment contains an Element that defines the precise 3D wireframe data for a particular Part. A Wireframe Segment is typically referenced by a Part Node Element (see 7.2.1.1.1.5 Part Node Element) using a Second specifies the date Second value. Valid values are [0, 59] inclusive.

Late Loaded Property Atom Element (see 0 Late Loaded Property Atom Element). The Wireframe Segment type supports ZLIB compression on all element data, so all elements in Wireframe Segment use the Logical Element Header ZLIB form of element header data.

Figure 129: Wireframe Segment data collection



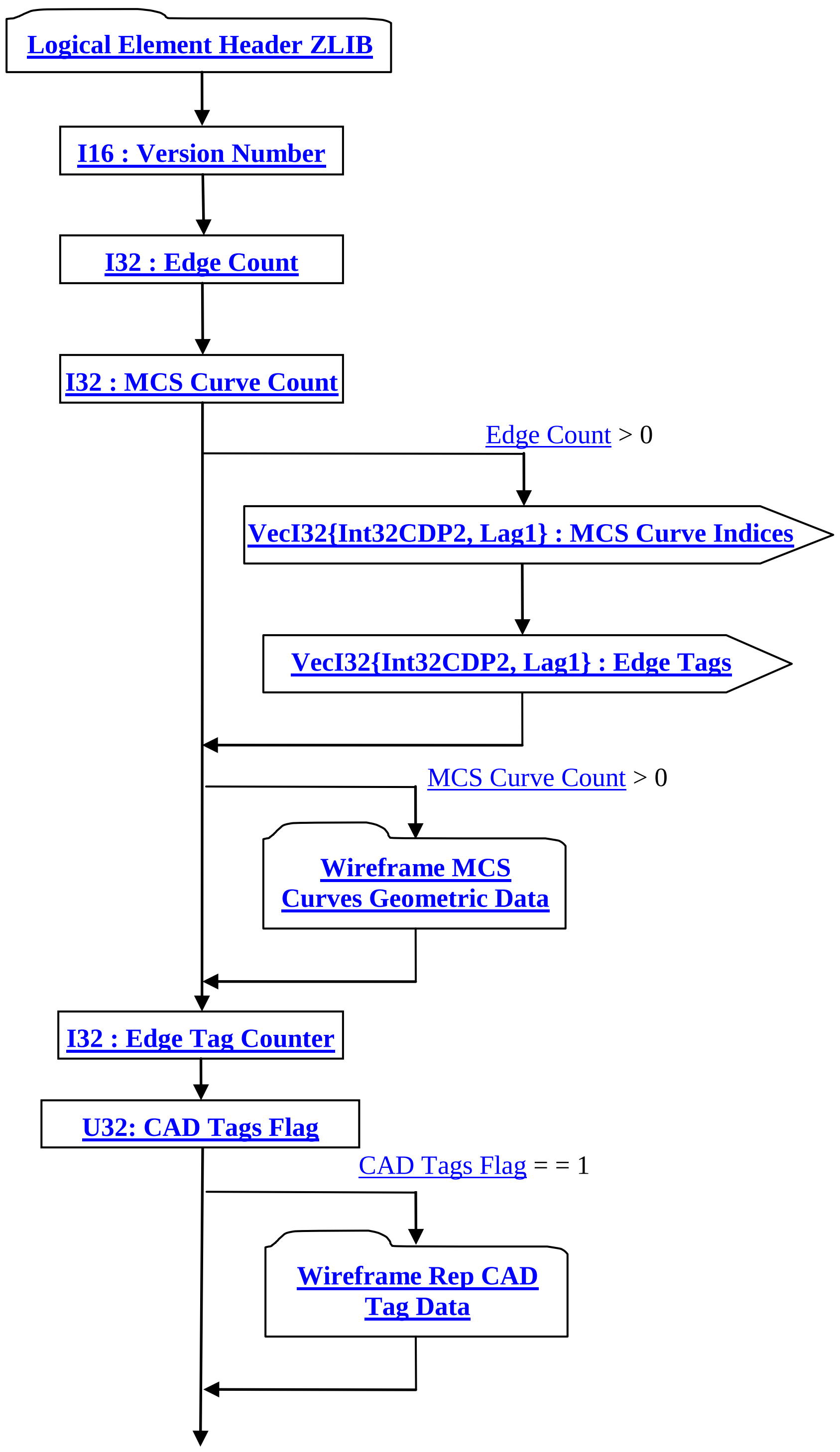
Complete description for Segment Header can be found in 7.1.3.1Segment Header.

7.2.5.1 Wireframe Rep Element

Object Type ID: 0x873a70d0, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97

A Wireframe Rep Element represents a particular Part's precise 3D wireframe data (e.g. reference curves, section curves). Much of the "heavyweight" data contained within a Wireframe Rep Element is compressed and/or encoded. The compression and/or encoding state is indicated through other data stored in each Wireframe Rep Element.

Figure 130: Wireframe Rep Element data collection



Logical Element Header ZLIB
I16 : Version Number
I32 : Edge Count
I32 : MCS Curve Count
Edge Count > 0
VecI32{Int32CDP2, Lag1} : MCS Curve Indices
VecI32{Int32CDP2, Lag1} : Edge Tags
MCS Curve Count > 0
Wireframe MCS Curves Geometric Data
I32 : Edge Tag Counter
U32: CAD Tags Flag
CAD Tags Flag = = 1
Wireframe Rep CAD Tag Data

Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

I16 : Version Number

Version Number is the version identifier for this JT Wireframe Rep Element. Version numbers “1” is currently supported.

I32 : Edge Count

Edge Count indicates the number of topological Edge entities in the Wireframe Rep

I32 : MCS Curve Count

MCS Curve Count indicates the number of distinct geometric (Model Coordinate Space) curves (i.e. XYZ curve) entities in the Wireframe Rep.

VecI32{Int32CDP2, Lag1} : MCS Curve Indices

MCS Curve Indices is a vector of indices representing the index of the MCS Curve (Model Space curve) for each Edge. MCS Curve Indices uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP2, Lag1} : Edge Tags

Each Edge has an identifier Tag. Edge Tags is a vector of identifier Tags for a set of Edges. Edge Tags uses the Int32 version of the CODEC to compress and encode data.

I32 : Edge Tag Counter

Edge Tag Counter specifies the next available "unique' tag value for Edge entity.

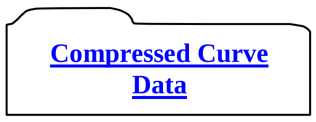
U32: CAD Tags Flag

CAD Tags Flag is a flag indicating whether CAD Tag data exist for the Wireframe Rep.

7.2.5.1.1 Wireframe MCS Curves Geometric Data

Wireframe MCS Curves Geometric Data collection contains the Wireframe Rep's Model Coordinate System geometric Curve data (i.e. XYZ Curve data). Currently only NURBS Curve types are supported within a Wireframe Rep. The count/number of MCS Curves within a Wireframe Rep is indicated by data field MCS Curve Count documented in 7.2.5.1 Wireframe Rep Element.

Figure 131: Wireframe MCS Curves Geometric Data collection



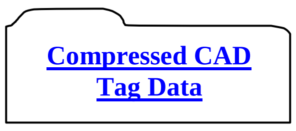
Complete description for Compressed Curve Data can be found in 8.1.15 Compressed Curve Data.

7.2.5.1.2 Wireframe Rep CAD Tag Data

The Wireframe Rep CAD Tag Data collection contains the list of persistent IDs, as defined in the CAD System, to uniquely identify individual Edges in the Wireframe Rep. The existence of this Wireframe Rep CAD Tag Data collection is dependent upon the value of previously read data field CAD Tags Flag as documented in 7.2.5.1 Wireframe Rep Element.

If Wireframe Rep CAD Tag Data collection is present, there will be a CAD Tag for every Edge in the Wireframe Rep. Therefore the total number of CAD Tags in the list should be equal to "Edge Count" as documented in 7.2.5.1 Wireframe Rep Element.

Figure 132: Wireframe Rep CAD Tag Data collection



Complete description for Compressed CAD Tag Data can be found in 8.1.16 Compressed CAD Tag Data.

7.2.6 Meta Data Segment

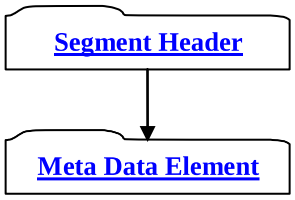
Meta Data Segments are used to store large collections of meta-data in separate addressable segments of the JT File. Storing meta-data in a separate addressable segment allows references (from within the JT file) to these segments to be constructed such that the meta-data can be late-loaded (i.e. JT file reader can be structured to support the "best practice" of delaying the loading/reading of the referenced meta-data segment until it is actually needed).

Meta Data Segments are typically referenced by Part Node Elements (see 7.2.1.1.1.5Part Node Element) using Late Loaded Property Atom Elements (see 0 Late Loaded Property Atom ElementSecond specifies the date Second value. Valid values are [0, 59] inclusive.

Late Loaded Property Atom Element).

The Meta Data Segment type supports ZLIB compression on all element data, so all elements in Meta Data Segment use the Logical Element Header ZLIB form of element header data.

Figure 133: Meta Data Segment data collection



Complete description for Segment Header can be found in 7.1.3.1 Segment Header.

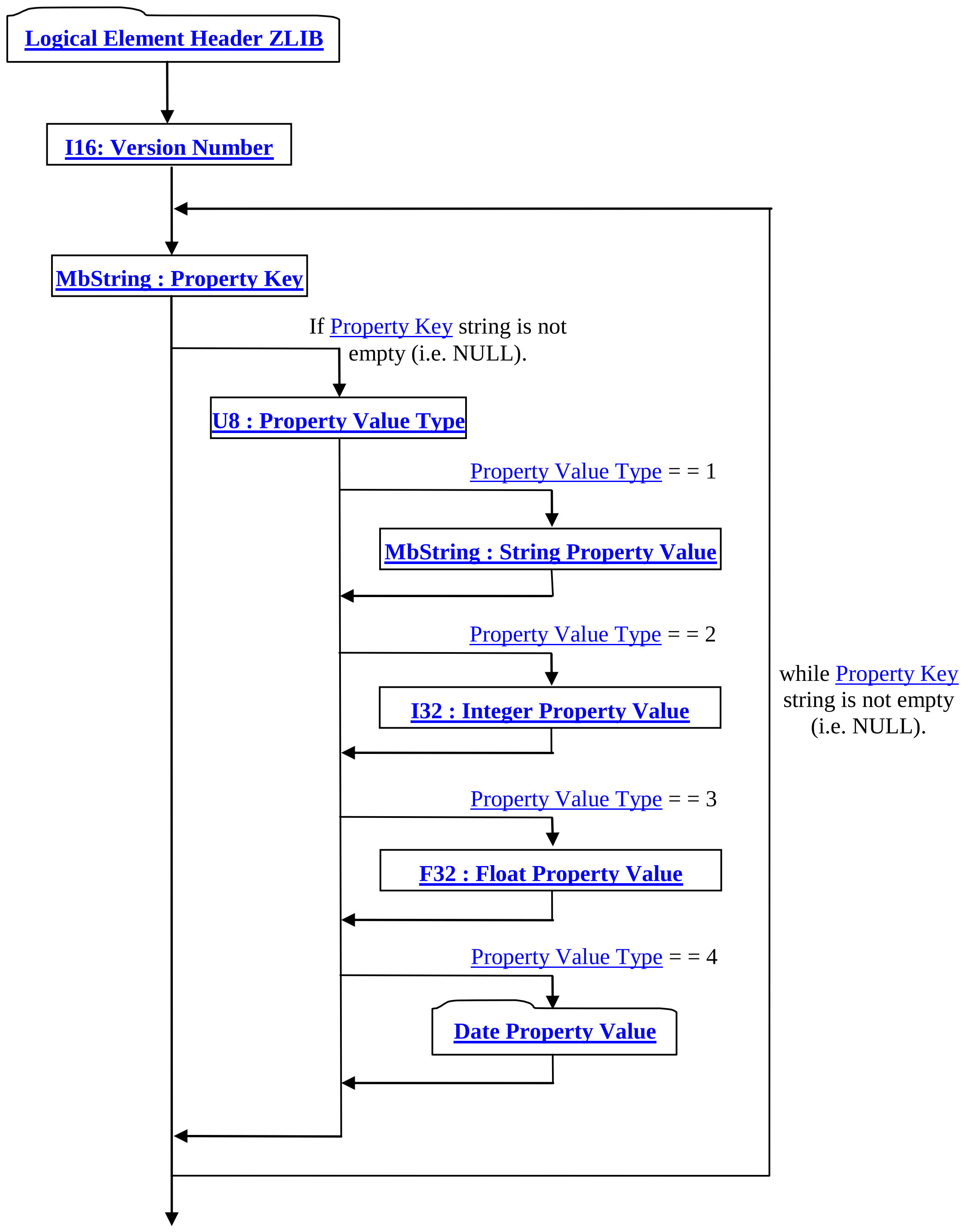
The following sub-sections document the various I32 : Texture Coord Channel types.

7.2.6.1 Property Proxy Meta Data Element

Object Type ID: 0xce357247, 0x38fb, 0x11d1, 0xa5, 0x6, 0x0, 0x60, 0x97, 0xbd, 0xc6, 0xe1

A Property Proxy Meta Data Element serves as a "proxy" for all meta-data properties associated with a particular Meta Data Node Element (see 7.2.1.1.1.6 Meta Data Node Element). The proxy is in the form of a list of key/value property pairs where the *key* identifies the type and meaning of the *value*. Although the property *key* is always in the form of a String data type, the *value* can be one of several data types.

Figure 134: Property Proxy Meta Data Element data collection


Logical Element Header ZLIB
I16: Version Number
MbString : Property Key
If Property Key string is not empty (i.e. NULL).
U8 : Property Value Type
Property Value Type = = 1
MbString : String Property Value
Property Value Type = = 2
I32 : Integer Property Value
Property Value Type = = 3
F32 : Float Property Value
Property Value Type = = 4
Date Property Value
while Property Key string is not empty (i.e. NULL).

Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

I16: Version Number

Version Number is the version identifier for this data collection. Version number "0x0001" is currently the only valid value.

MbString : Property Key

Property Key specifies the *key* string for the property.

U8 : Property Value Type

Property Value Type specifies the data type for the Property Value. If the type equals "0" then no Property Value is written. Valid types include the following:

= 0	Unknown
= 1	MbString data type value
= 2	I32 data type value
= 3	F32 data type value
= 4	Date value

MbString : String Property Value

String Property Value represents the property value when Property Value Type = = 1.

I32 : Integer Property Value

Integer Property Value represents the property value when Property Value Type = = 2.

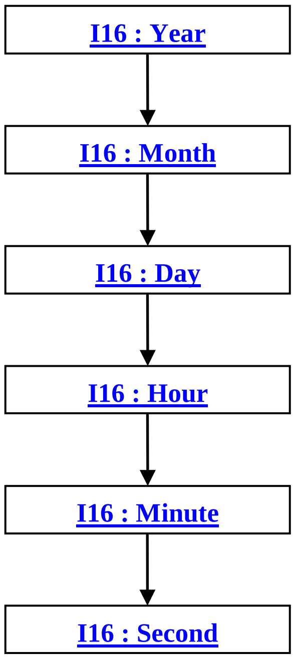
F32 : Float Property Value

Float Property Value represents the property value when Property Value Type = = 3.

7.2.6.1.1 Date Property Value

Date Property Value represents the property value when Property Value Type = = 4. Date Property Value data collection represents a date as a combination of year, month, day, hour, minute, and second data fields.

Figure 135: Date Property Value data collection



I16 : Year

Year specifies the date year value.

I16 : Month

Month specifies the date month value.

I16 : Day

Day specifies the date day value.

I16 : Hour

Hour specifies the date hour value.

I16 : Minute

Minute specifies the date minute value.

I16 : Second

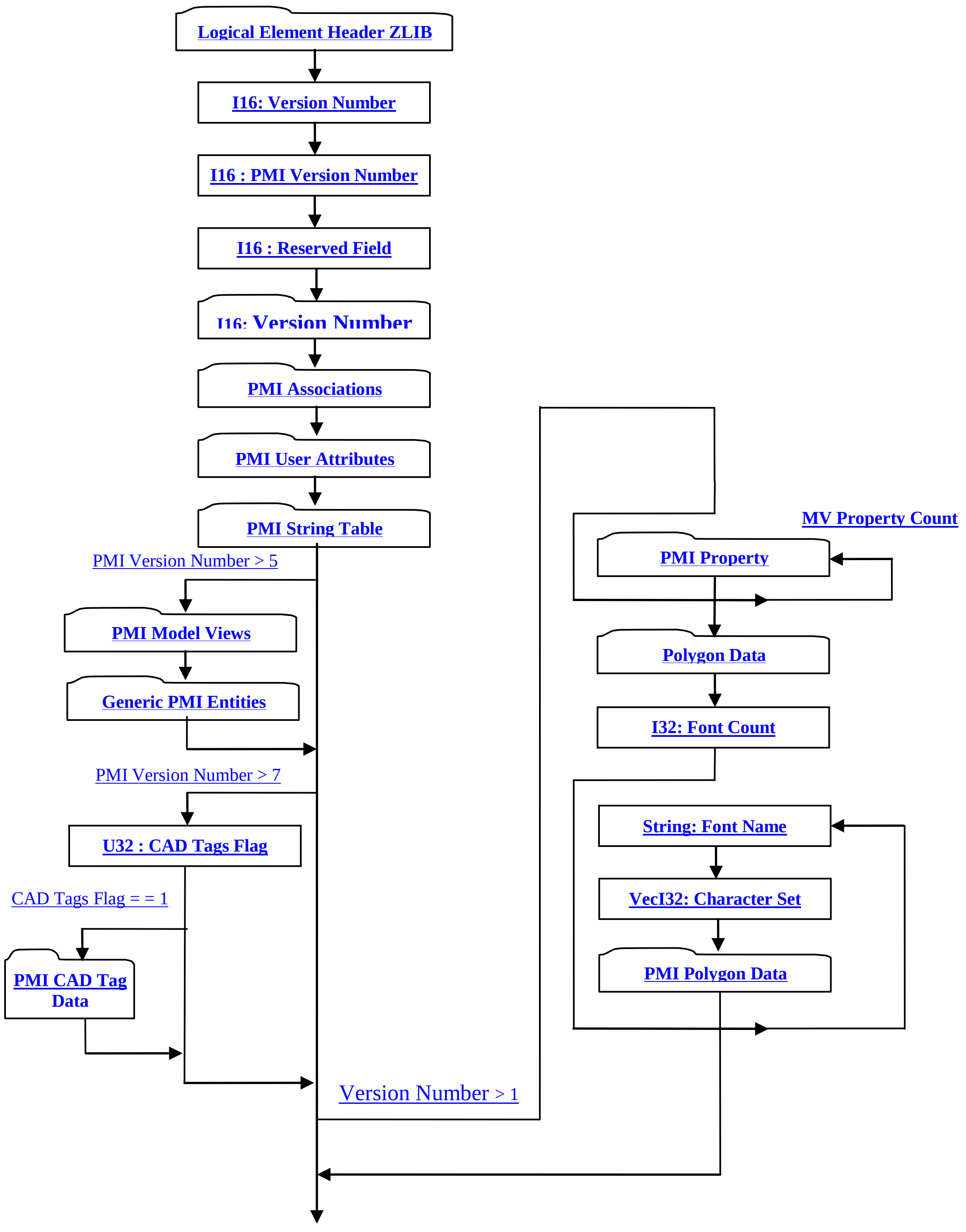
Second specifies the date Second value.

7.2.6.2 PMI Manager Meta Data Element

Object Type ID: 0xce357249, 0x38fb, 0x11d1, 0xa5, 0x6, 0x0, 0x60, 0x97, 0xbd, 0xc6, 0xe1

The PMI Manager Meta Data Element data collection is a type of I32 : Texture Coord Channel which contains the Product and Manufacturing Information for a part/assembly.

Figure 136: PMI Manager Meta Data Element data collection



Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

I16: Version Number

Version Number is the version identifier for this PMI Manager Element. Version numbers 0x0001 and 0x0002 are currently supported.

I16 : PMI Version Number

Version Number is the version identifier for the PMI. There are several PMI versions that must be supported for JT File format 8.1. This is because if an older JT File format containing PMI is read and then re-exported to JT File Format 8.1, the exported PMI data must be maintained in the version format originally read from the initial JT file (i.e. PMI data read from a JT File is not migrated to new version format when re-exported to another JT File format).

The valid PMI version numbers are as follows:

= 3	Version-3
= 4	Version-4
= 5	Version-5
= 6	Version-6
= 7	Version-7
= 8	Version-8

I16 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

U32 : CAD Tags Flag

CAD Tags Flag is a flag indicating whether CAD Tag data exist for the PMI.

I32: MV Property Count

Number of ModelViews in the PMI segment.

I32: Font Count

Number of sets of glyph definitions. Each set of glyphs represents a single font definition that consists of a name, a character set and polygonal glyph definition for each character in the set.

String: Font Name

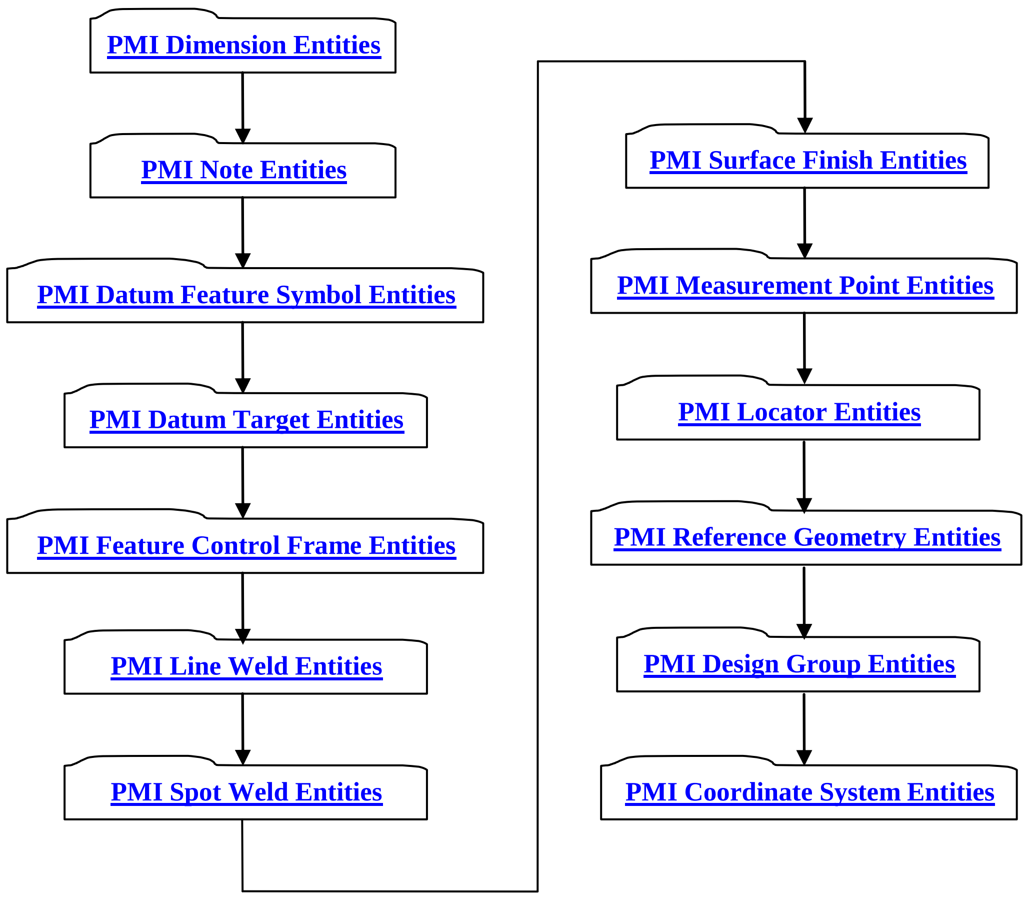
Font name specifies a representative name for the font set.

VecI32: Character Set

Integer identifiers for each character whose symbol is defined in the ensuing PolygonData segment.

7.2.6.2.1 PMI Entities

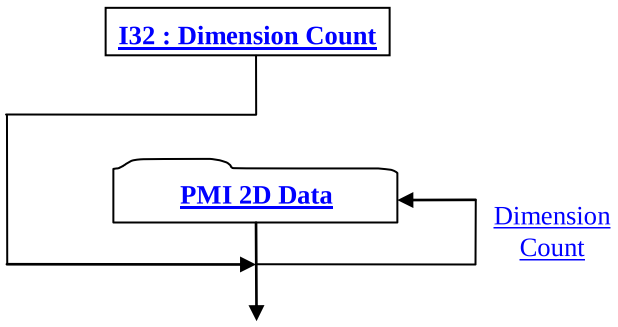
Figure 137: PMI Entities data collection


PMI Dimension Entities
PMI Note Entities
PMI Datum Feature Symbol Entities
PMI Datum Target Entities
PMI Feature Control Frame Entities
PMI Line Weld Entities
PMI Spot Weld Entities
PMI Surface Finish Entities
PMI Measurement Point Entities
PMI Locator Entities
PMI Reference Geometry Entities
PMI Design Group Entities
PMI Coordinate System Entities

7.2.6.2.1.1PMI Dimension Entities

The PMI Dimension Entities data collection defines data for a list of Dimensions.

Figure 138: PMI Dimension Entities data collection



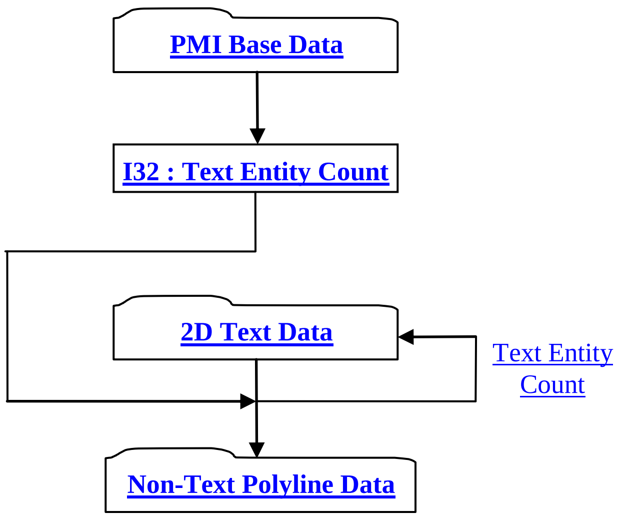
I32 : Dimension Count

Dimension Count specifies the number of Dimension entities.

7.2.6.2.1.1.1 PMI 2D Data

The PMI 2D Data collection defines a data format common to all 2D based PMI entities.

Figure 139: PMI 2D Data collection



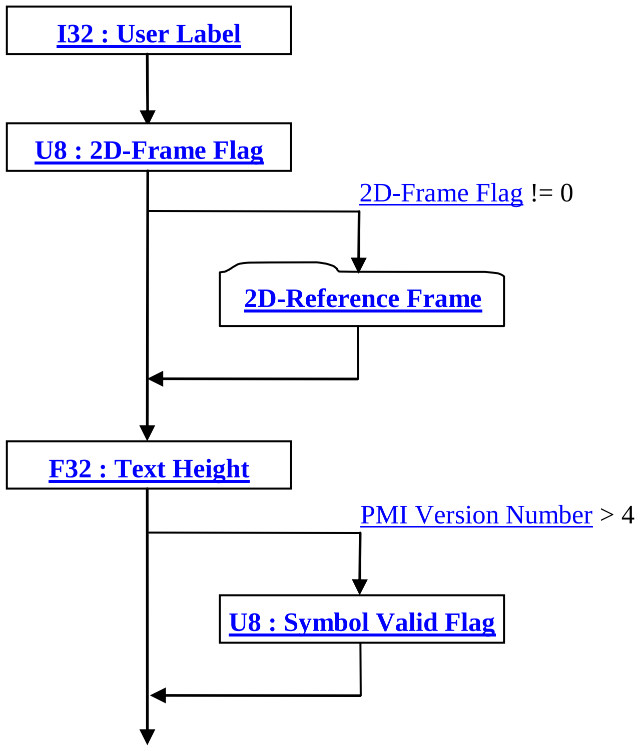
I32 : Text Entity Count

Text Entity Count specifies the number of Text entities in the particular PMI entity.

7.2.6.2.1.1.1.1 PMI Base Data

The PMI Base Data collection defines the basic/common data that every 2D and 3D PMI entity contains

Figure 140: PMI Base Data collection



I32 : User Label

User Label specifies the particular PMI entity identifier.

U8 : 2D-Frame Flag

2D-Frame Flag is a flag specifying whether 7.2.6.2.1.1.1.1.1 2D-Reference Frame data is stored. If 2D-Frame Flag has a non-zero value then 2D-Reference Frame data is included. If 2D-Frame Flag has a value of "2", then dummy (i.e. all zeros) 2D-Reference Frame data is written. The "2D-Frame Flag = = 2" case is used by 7.2.6.2.6 Generic PMI Entities because for Generic PMI Entities all the 7.2.6.2.1.1.1.3 Non-Text Polyline Data is already in 3D form (i.e. XYZ coordinate data).

F32 : Text Height

Text Height specifies the PMI text height in WCS.

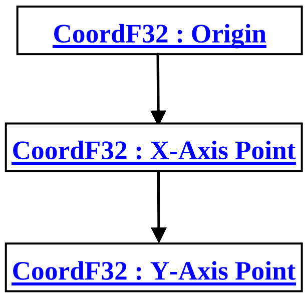
U8 : Symbol Valid Flag

Symbol Valid Flag is a flag specifying whether the particular PMI entity is valid. If Symbol Valid Flag has a non-zero value then PMI entity is valid. This flag is only stored if the Version Number as defined in 7.2.6.2PMI Manager Meta Data Element is greater than "4."

7.2.6.2.1.1.1.1.1 2D-Reference Frame

The 2D-Reference Frame data collection defines a reference frame (2D coordinate system) where the PMI entity is displayed in 3D space. All the PMI entity's 2D and 3D polyline data is assumed to lie on the defined plane.

Figure 141: 2D-Reference Frame data collection



CoordF32 : Origin

Origin defines the origin (min-corner) of the 2D coordinate system

CoordF32 : X-Axis Point

X-Axis Point defines a point along the X-Axis of the 2D coordinate system.

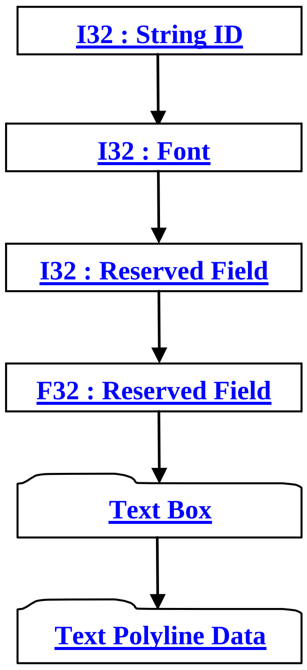
CoordF32 : Y-Axis Point

Y-Axis Point defines a point along the Y-Axis of the 2D coordinate system.

7.2.6.2.1.1.1.2 2D Text Data

The 2D Text Data collection defines a 2D text entity/primitive.

Figure 142: 2D Text Data collection



I32 : String ID

String ID specifies the identifier for the character string. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

I32 : Font

Font identifies the font to be used for this text. Valid values include the following:

= 1	Simplex
= 2	Din
= 3	Military
= 4	ISO
= 5	Lightline
= 6	IGES 1001
= 7	Century
= 8	IGES 1002
= 9	IGES 1003
= 101	Japanese JISX 0208 coded character set
= 102	Japanese Extended Unix Codes JISX 0208 coded character set
= 103	Chinese GB 2312.1980 Simplified coded character set
= 104	Korean KSC 5601 coded character set
= 105	Chinese Big5 Traditional coded character set

I32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

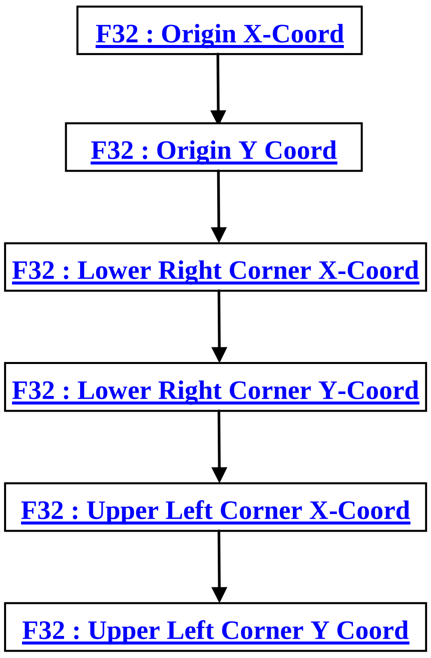
F32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

7.2.6.2.1.1.1.2.1 Text Box

The Text Box data collection specifies a 2D box that particular text fits within. All values are with respect to 2D-Reference Frame documented in 7.2.6.2.1.1.1.1.1 2D-Reference Frame.

Figure 143: Text Box data collection


F32 : Origin X-Coord
F32 : Origin Y Coord
F32 : Lower Right Corner X-Coord
F32 : Lower Right Corner Y-Coord
F32 : Upper Left Corner X-Coord
F32 : Upper Left Corner Y Coord

F32 : Origin X-Coord

Origin X-Coord defines the 2D X-coordinate of the text origin with respect to 2D-Reference Frame.

F32 : Origin Y Coord

Origin Y-Coord defines the 2D Y-coordinate of the text origin with respect to 2D-Reference Frame.

F32 : Lower Right Corner X-Coord

Lower Right Corner X-Coord defines the 2D X-coordinate of the lower right corner of the text with respect to 2D-Reference Frame.

F32 : Lower Right Corner Y-Coord

Lower Right Corner Y-Coord defines the 2D Y-coordinate of the lower right corner of the text with respect to 2D-Reference Frame.

F32 : Upper Left Corner X-Coord

Upper Left Corner X-Coord defines the 2D X-coordinate of the upper left corner of the text with respect to 2D-Reference Frame.

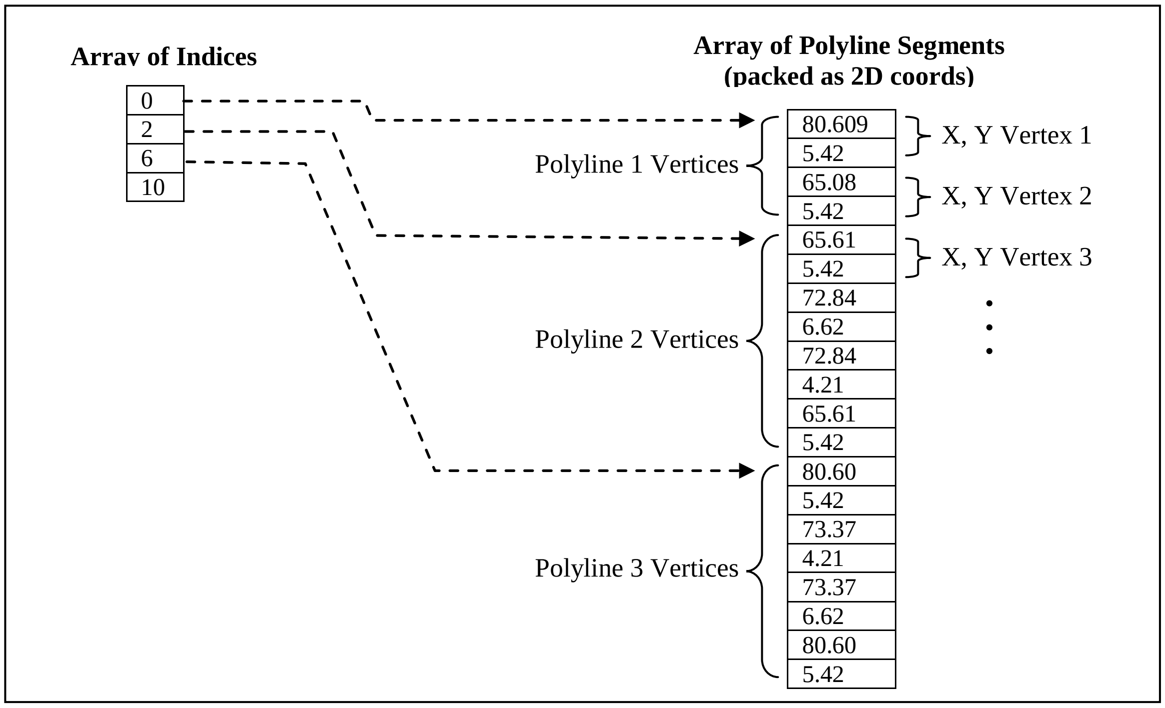
F32 : Upper Left Corner Y Coord

Upper Left Corner Y-Coord defines the 2D Y-coordinate of the upper left corner of the text with respect to 2D-Reference Frame.

7.2.6.2.1.1.1.2.2 Text Polyline Data

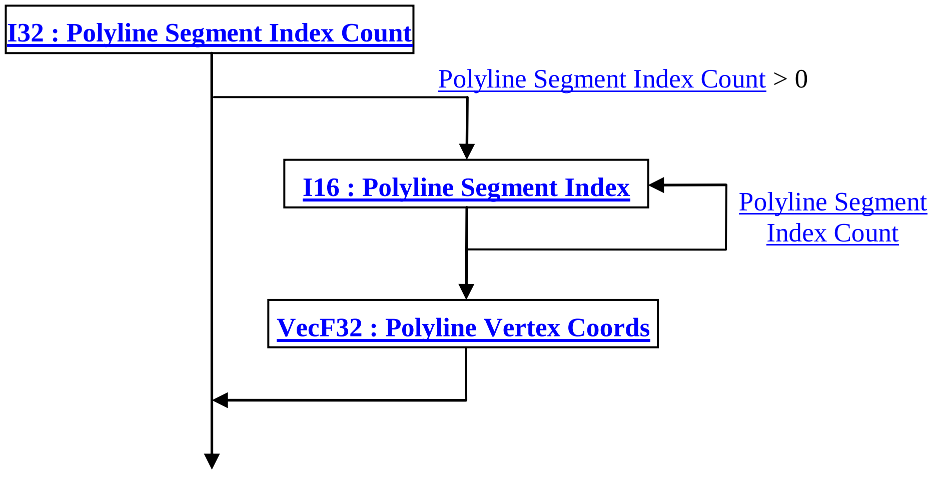
The Text Polyline Data collection defines any polyline segments which are part of the text representation. This existence of this polyline data is conditional (i.e. not all text has it) and is made up of an array of indices into an array of polyline segments packed as 2D vertex coordinates, specifying where each polyline segment begins and ends. Polylines are constructed from these arrays of data as follows:

Figure 144: Constructing Text Polylines from data arrays



This data is represented in JT file in the following format:

Figure 145: Text Polyline Data collection


I32 : Polyline Segment Index Count
Polyline Segment Index Count > 0
I16 : Polyline Segment Index
Polyline Segment Index Count
VecF32 : Polyline Vertex Coords

I32 : Polyline Segment Index Count

Polyline Segment Index Count specifies the number of polyline segment indices.

I16 : Polyline Segment Index

Polyline Segment Index is an index into the Polyline Vertex Coords array specifying where polyline segment begins or ends. This index is a vertex coordinate index so the absolute index into the Polyline Vertex Coords array is computed by multiplying the index value by “2” (i.e. for 2D coordinates).

VecF32 : Polyline Vertex Coords

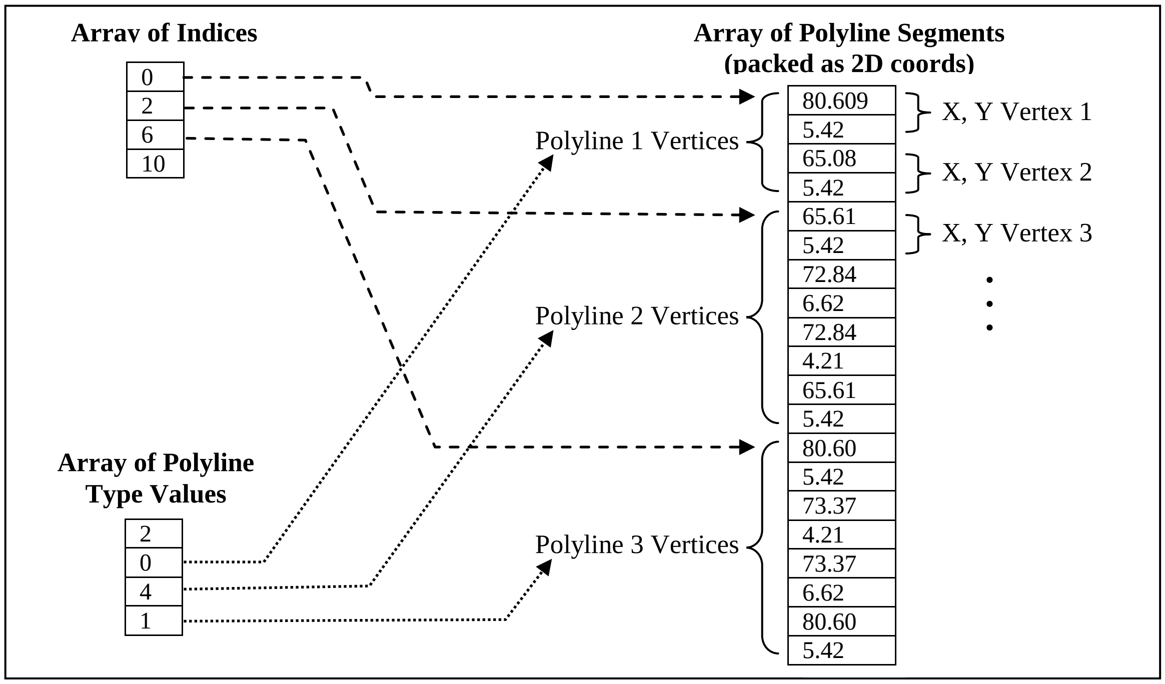
Polyline Vertex Coords is an array of polyline segments packed as 2D point coordinates. These 2D point coordinates are with respect to the 2D-Reference Frame documented in 7.2.6.2.1.1.1.1.1 2D-Reference Frame.

7.2.6.2.1.1.1.3 Non-Text Polyline Data

The Non-Text Polyline Data collection contains all the non-text polylines making up the particular PMI entity. Examples of non-text polylines include line attachments, text boxes, symbol box dividers, etc. The Non-Text Polyline Data collection is made up of an array of indices into an array of polyline segments packed as either 2D or 3D vertex coordinates, specifying where each polyline segment begins and ends. Whether vertex coordinates are 2D or 3D is dependent upon the PMI entity type using this data collection. If it is a 7.2.6.2.6 Generic PMI Entities type then the packed coordinate data is 3D; for all other PMI entity types the packed coordinate data is 2D. Also for Version Number, as defined in 7.2.6.2 PMI Manager Meta Data Element, greater than “4” an array of values that sequentially specify the polyline type in the polyline segments array is included.

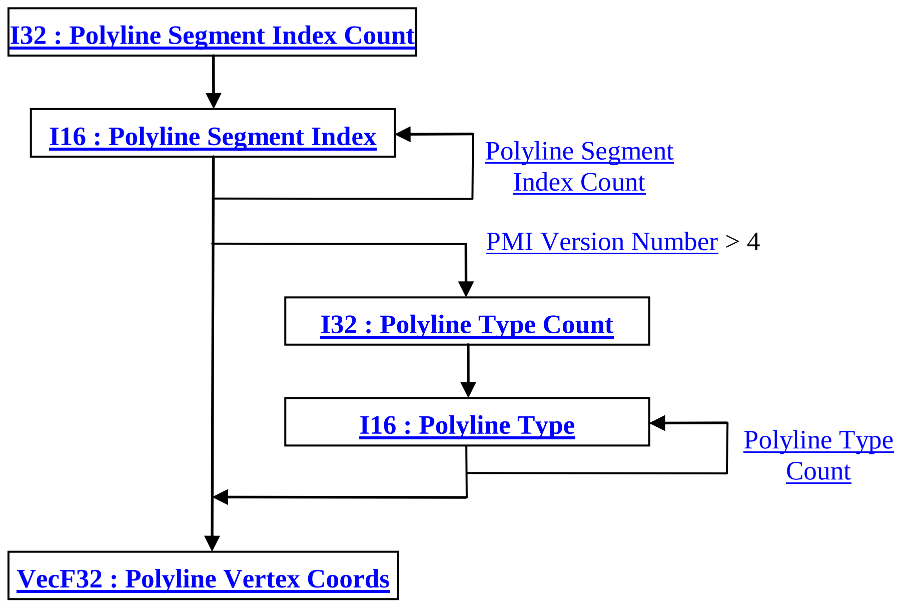
Figure 146 below shows how Polylines are constructed from these arrays of data for the packed 2D coordinates case. The packed 3D coordinates case is interpreted the same except that the coordinates array includes a Z component and is thus packed as “[XYZ][XYZ][XYZ]…”

Figure 146: Constructing Non-Text Polylines from packed 2D data arrays



This data is represented in the JT format as follows:

Figure 147: Non-Text Polyline Data collection


I32 : Polyline Segment Index Count
I16 : Polyline Segment Index
Polyline Segment Index Count
PMI Version Number > 4
I32 : Polyline Type Count
I16 : Polyline Type
Polyline Type Count
VecF32 : Polyline Vertex Coords

I32 : Polyline Segment Index Count

Polyline Segment Index Count specifies the number of polyline segment indices.

I16 : Polyline Segment Index

Polyline Segment Index is an index into the Polyline Vertex Coords array specifying where polyline segment begins or ends. This index is a vertex/coordinate index so the absolute index into the Polyline Vertex Coords array is computed by multiplying the index value by "2" (i.e. for 2D coordinates).

I32 : Polyline Type Count

Polyline Type Count specifies the number of polyline type values.

I16 : Polyline Type

Polyline Type specifies the type of polyline segment in Polyline Vertex Coords array. See Figure 146: Constructing Non-Text Polylines from packed 2D data arrays for interpretation of this array of type values relative to the defined polylines. Valid values include the following:

= 0	General line
= 1	General arrow
= 2	General circle
= 3	General arc
= 4	Extended line 1
= 5	Extended line 2
= 6	Extended arc
= 7	Extended circle
= 8	Text line (used in text boxes and symbol box dividers)
= 9	Text string

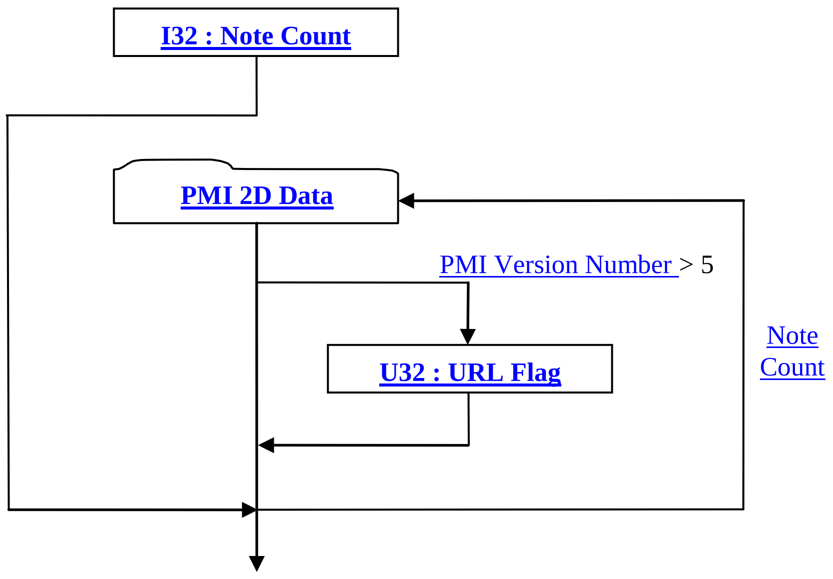
VecF32 : Polyline Vertex Coords

Polyline Vertex Coords is an array of polyline segments packed as 2D point coordinates. These 2D point coordinates are with respect to the 2D-Reference Frame documented in 7.2.6.2.1.1.1.1.1 2D-Reference Frame.

7.2.6.2.1.2 PMI Note Entities

The PMI Note Entities data collection defines data for a list of Notes. Notes are used to connect textual information to specific Part entities.

Figure 148: PMI Note Entities data collection



Complete description for PMI 2D Data can be found in 7.2.6.2.1.1.1 PMI 2D Data.

I32 : Note Count

Note Count specifies the number of Note entities.

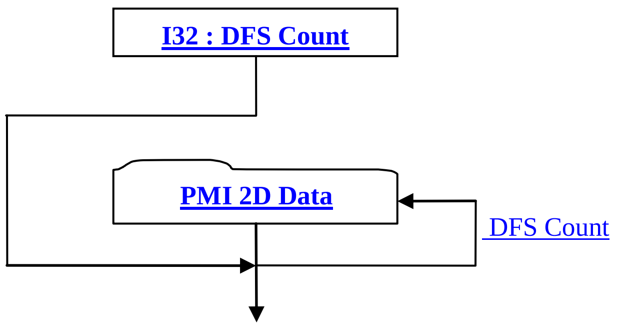
U32 : URL Flag

URL Flag specifies whether Note is an URL. This data field is only present if Version Number, as defined in 7.2.6.2 PMI Manager Meta Data Element, is greater than “5”. The URL is the actual text of the note as specified in PMI 2D Data.

7.2.6.2.1.3 PMI Datum Feature Symbol Entities

The PMI Datum Feature Symbol Entities data collection defines data for a list of Datum Feature Symbols. A Datum Feature Symbol is a Geometric Dimensioning and Tolerancing (GD&T) symbol that provides a “label” for a part feature which is referenced by a Feature Control Frame.

Figure 149: PMI Datum Feature Symbol Entities data collection



Complete description for PMI 2D Data can be found in 7.2.6.2.1.1.1 PMI 2D Data.

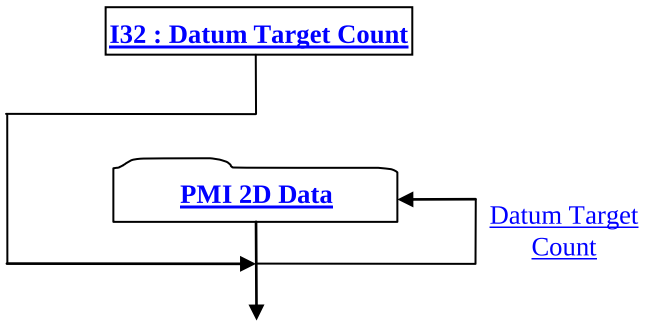
I32 : DFS Count

DFS Count specifies the number of Datum Feature Symbol entities.

7.2.6.2.1.4 PMI Datum Target Entities

The PMI Datum Target Entities data collection defines data for a list of Datum Targets. A Datum Target is a Geometric Dimensioning and Tolerancing (GD&T) symbol that specifies a point, a line, or an area on a part to define a "datum" for manufacturing and inspection operations.

Figure 150: PMI Datum Target Entities data collection



Complete description for PMI 2D Data can be found in 7.2.6.2.1.1.1 PMI 2D Data.

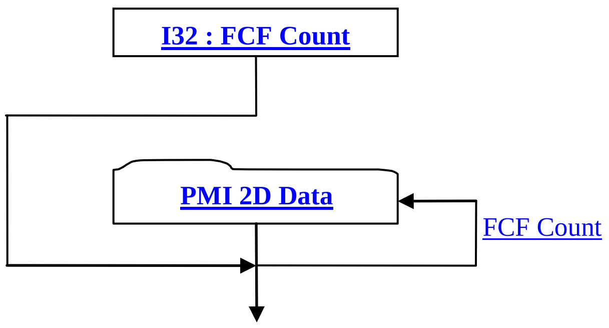
I32 : Datum Target Count

Datum Target Count specifies the number of Datum Target entities.

7.2.6.2.1.5 PMI Feature Control Frame Entities

The PMI Feature Control Frame Entities data collection defines data for a list of Feature Control Frames. A Feature Control Frame is a Geometric Dimensioning and Tolerancing (GD&T) symbol used for expressing the geometric characteristics, form tolerance, runout or location tolerance, and relationships between the geometric features of a part. If necessary, Datum Feature and/or Datum Target references may be included in the Feature Control Frame symbol.

Figure 151: PMI Feature Control Frame Entities data collection



Complete description for PMI 2D Data can be found in 7.2.6.2.1.1.1 PMI 2D Data.

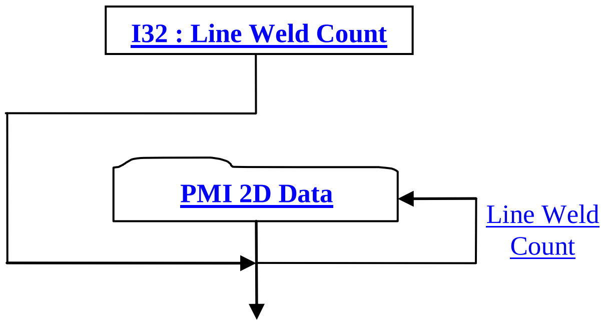
I32 : FCF Count

FCF Count specifies the number of Feature Control Frame entities.

7.2.6.2.1.6 PMI Line Weld Entities

The PMI Line Weld Entities data collection defines data for a list of Line Weld symbols. A Line Weld symbol describes the specifications for welding a joint.

Figure 152: PMI Line Weld Entities data collection



Complete description for PMI 2D Data can be found in 7.2.6.2.1.1.1 PMI 2D Data.

I32 : Line Weld Count

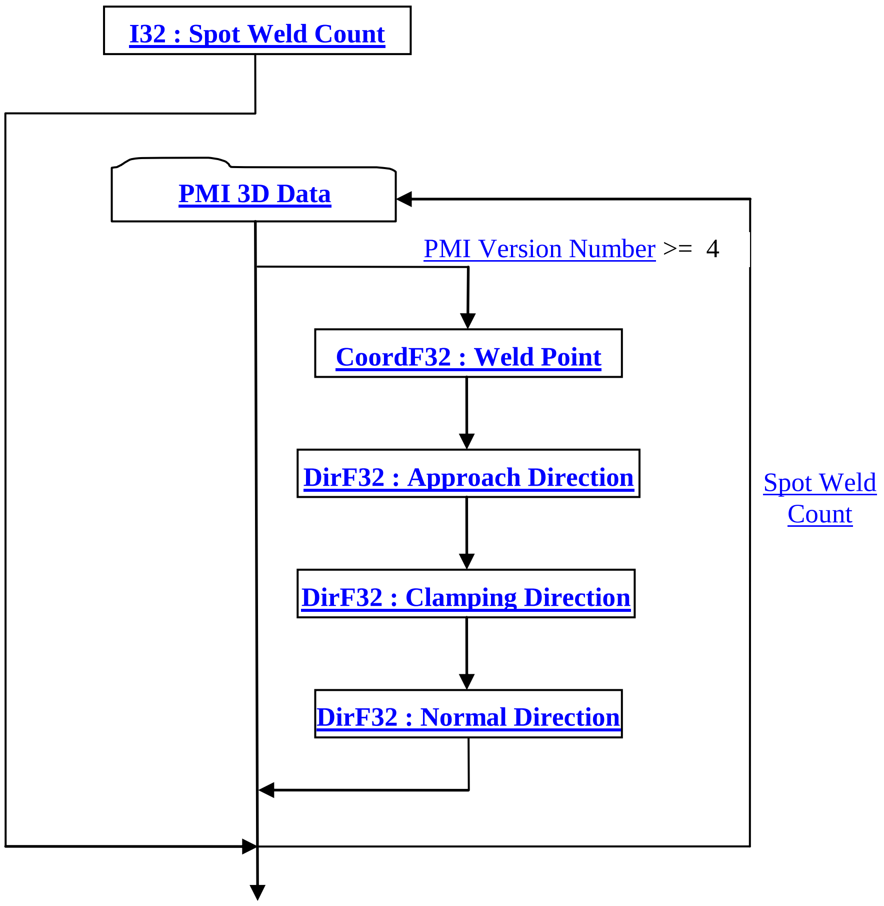
Line Weld Count specifies the number of Line Weld entities.

7.2.6.2.1.7 PMI Spot Weld Entities

The PMI Spot Weld Entities data collection defines data for a list of Spot Weld Symbols. Spot Weld symbols describe the specifications for welding sheet metal.

Several data fields of the PMI Spot Weld Entities data collection are only present if Version Number, as defined in 7.2.6.2PMI Manager Meta Data Element, is greater than or equal to “4”.

Figure 153: PMI Spot Weld Entities data collection



I32 : Spot Weld Count

Spot Weld Count specifies the number of Spot Weld entities.

CoordF32 : Weld Point

Weld Point specifies the coordinates of the weld point.

DirF32 : Approach Direction

Approach Direction specifies the components of the direction vector from which the weld gun approaches the part.

DirF32 : Clamping Direction

Clamping Direction specifies the components of the clamping force direction vector.

DirF32 : Normal Direction

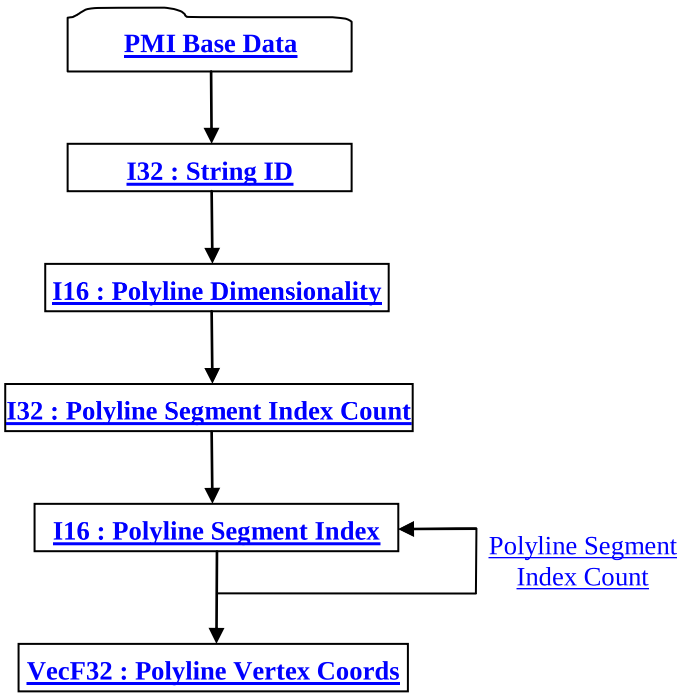
Normal Direction specifies the components of the direction vector normal to the actual spot weld.

7.2.6.2.1.7.1 PMI 3D Data

The PMI 3D Data collection defines a data format common to all 3D based PMI entities.

Along with the PMI Base Data and String identifier, this data collection also includes non-text polyline data defined by an array of indices into an array of polyline segments packed as 2D/3D vertex coordinates, specifying where each polyline segment begins and ends. How polylines are constructed from this index array and packed vertex coordinates array is the same as that illustrated in Figure 144 of 7.2.6.2.1.1.1.2.2 Text Polyline Data.

Figure 154: PMI 3D Data collection


PMI Base Data
I32 : String ID
I16 : Polyline Dimensionality
I32 : Polyline Segment Index Count
I16 : Polyline Segment Index
Polyline Segment Index Count
VecF32 : Polyline Vertex Coords

Complete description for PMI Base Data can be found in 7.2.6.2.1.1.1.1 PMI Base Data.

I32 : String ID

String ID specifies the identifier for the character string. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

I16 : Polyline Dimensionality

Polyline Dimensionality specifies the dimensionality of the polyline coordinates packed in Polyline Vertex Coords. Valid values include the following:

= 2	Indicates 2-dimensioanl (xyxy…) data packing..
= 3	Indicates 3-dimensional (xyzxyz…) data packing.

I32 : Polyline Segment Index Count

Polyline Segment Index Count specifies the number of polyline segment indices.

I16 : Polyline Segment Index

Polyline Segment Index is an index into the Polyline Vertex Coords array specifying where polyline segment begins or ends. This index is a vertex coordinate index so the absolute index into the Polyline Vertex Coords array is computed by multiplying the index value by Polyline Dimensionality.

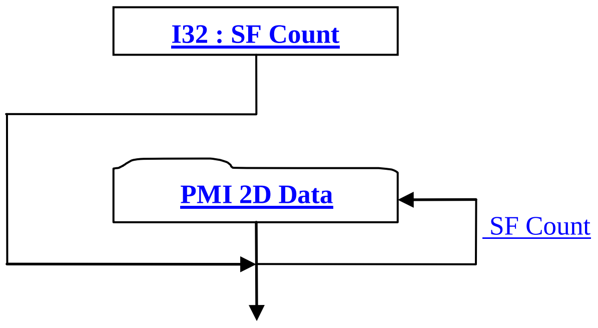
VecF32 : Polyline Vertex Coords

Polyline Vertex Coords is an array of polyline segments packed as Polyline Dimensionality point coordinates.

7.2.6.2.1.8 PMI Surface Finish Entities

The PMI Surface Finish Entities data collection defines data for a list of Surface Finish symbols. Surface Finish symbols indicate surface quality and generally are only specified where finish quality affects function (e.g. bearings, pistons, gears).

Figure 155: PMI Surface Finish Entities data collection



Complete description for PMI 2D Data can be found in 7.2.6.2.1.1.1 PMI 2D Data.

I32 : SF Count

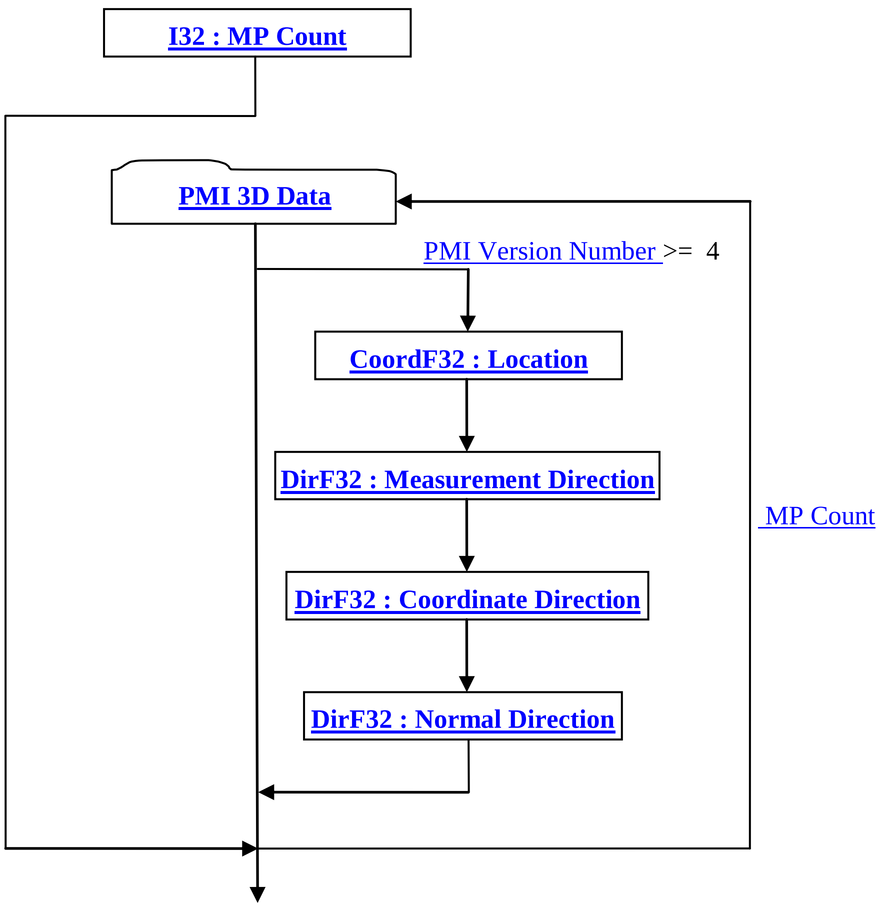
SF Count specifies the number of Surface Finish symbol entities.

7.2.6.2.1.9 PMI Measurement Point Entities

The PMI Measurement Point Entities data collection defines data for a list of Measurement Point symbols. Measurement Points are predefined locations (i.e. geometric entities or theoretical, but measurable points, such as surface locations) which are measured on manufactured parts to verify the accuracy of the manufacturing process.

Several data fields of the PMI Measurement Point Entities data collection are only present if Version Number, as defined in 7.2.6.2PMI Manager Meta Data Element, is greater than or equal to “4”.

Figure 156: PMI Measurement Point Entities data collection


I32 : MP Count
PMI 3D Data
PMI Version Number >= 4
CoordF32 : Location
DirF32 : Measurement Direction
DirF32 : Coordinate Direction
DirF32 : Normal Direction
MP Count

Complete description for PMI 3D Data can be found in 7.2.6.2.1.7.1 PMI 3D Data.

I32 : MP Count

MP Count specifies the number of Measurement Point entities.

CoordF32 : Location

Location specifies the coordinates of the Measurement Point.

DirF32 : Measurement Direction

Measurement Direction specifies the components of the direction vector from which a CCM (Coordinate Measuring Machine) approaches when taking a measurement.

DirF32 : Coordinate Direction

Coordinate Direction specifies the components of the direction vector another Measurement Point on a mating part would like to align with a Measurement Point on the first part.

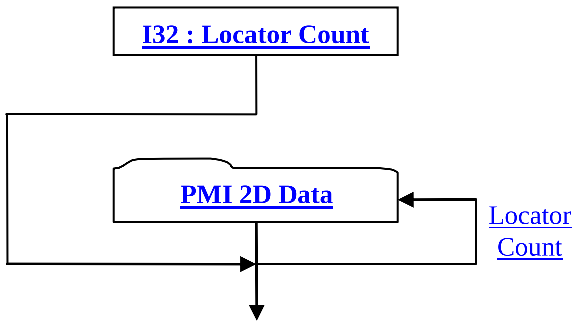
DirF32 : Normal Direction

Normal Direction specifies the components of the direction vector normal to the actual Measurement Point.

7.2.6.2.1.10 PMI Locator Entities

The PMI Locator Entities data collection defines data for a list of Locator symbols. Locator symbols are used to accurately locate components with respect to each other and the manufacturing tooling.

Figure 157: PMI Locator Entities data collection



Complete description for PMI 2D Data can be found in 7.2.6.2.1.1.1 PMI 2D Data.

I32 : Locator Count

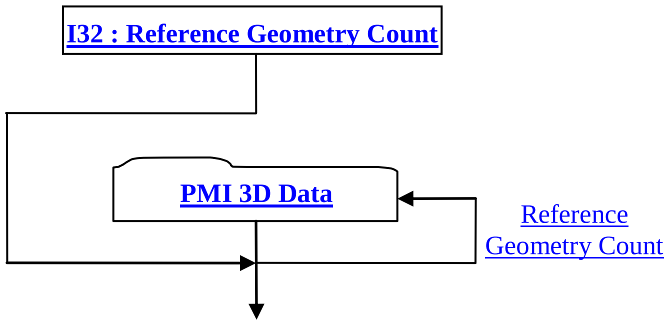
Locator Count specifies the number of Locator symbol entities.

7.2.6.2.1.11 PMI Reference Geometry Entities

The PMI Reference Geometry Entities data collection defines data for a list of Reference Geometry. Reference Geometry can be thought of as user-definable datums, which are positioned relative to the topology of an existing entity. Each reference geometry type (point, polyline, polygon) can be implicitly determined by the value of Polyline Segment Index[1] (see 7.2.6.2.1.7.1 PMI 3D Data) as follows:

Polyline Segment Index[1]	Implied Reference Geometry Type
= = 1	Point
= = 2	Polyline
> 2	Polygon

Figure 158: PMI Reference Geometry Entities data collection



Complete description for PMI 3D Data can be found in 7.2.6.2.1.7.1 PMI 3D Data.

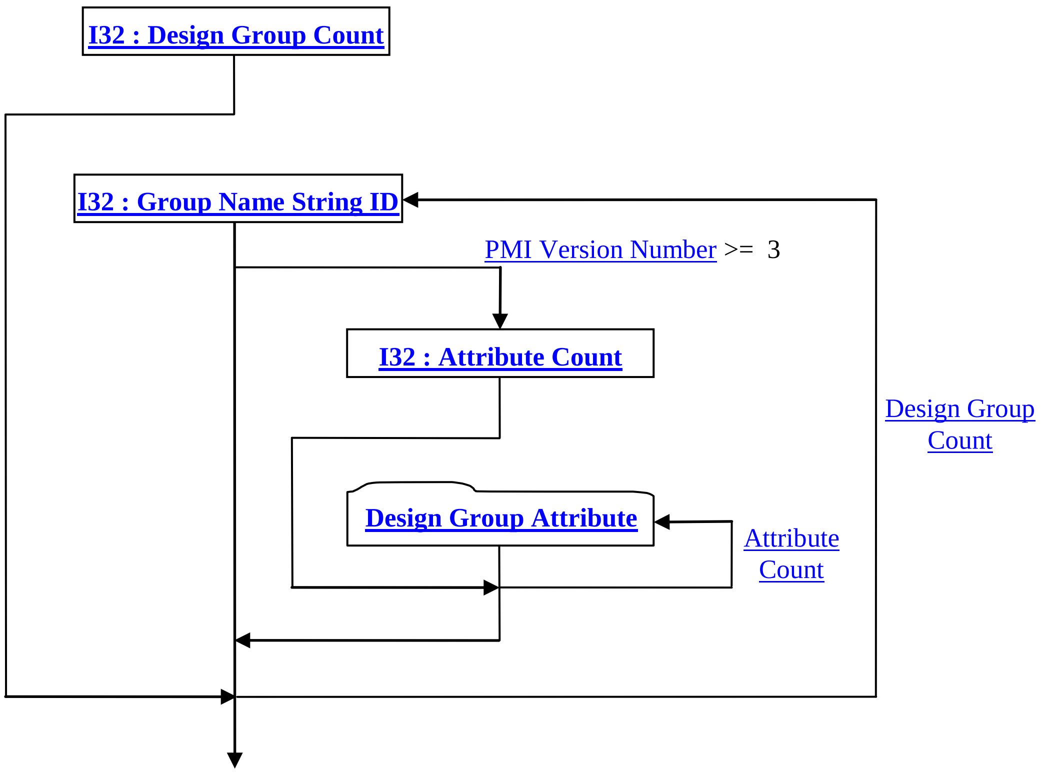
I32 : Reference Geometry Count

Reference Geometry Count specifies the number of Reference Geometry entities.

7.2.6.2.1.12 PMI Design Group Entities

The PMI Design Group Entities data collection defines data for a list of Design Groups. Design Groups are collections of PMI created to organize a model into smaller subsets of information. This organization is achieved via PMI Associations (see 7.2.6.2.2 PMI Associations), where specific PMI entities are associated as "destinations" to a "source" PMI Design Group.

Figure 159: PMI Design Group Entities data collection



I32 : Design Group Count

Design Group Count specifies the number of Design Group entities.

I32 : Group Name String ID

Group Name String ID specifies the identifier for the group name character string. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

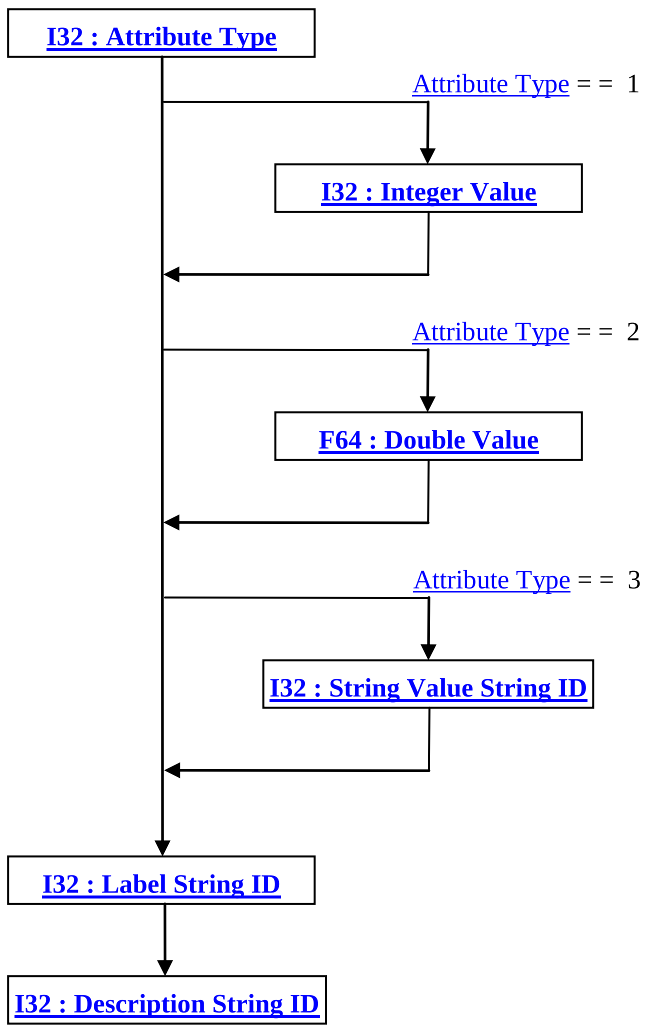
I32 : Attribute Count

Attribute Count specifies the number of Design Group Attribute data collections

7.2.6.2.1.12.1 Design Group Attribute

The Design Group Attribute data collection defines a group property/attribute.

Figure 160: Design Group Attribute data collection



I32 : Attribute Type

Attribute Type specifies the attribute type. Valid types include the following:

= 1	Integer
= 2	Double
= 3	String

I32 : Integer Value

Integer Value specifies the value for "integer" Attribute Types.

F64 : Double Value

Double Value specifies the value for "double" Attribute Types.

I32 : String Value String ID

String Value String ID specifies the string identifier value for "string" Attribute Types. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

I32 : Label String ID

Label String ID specifies the string identifier for the attribute label. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

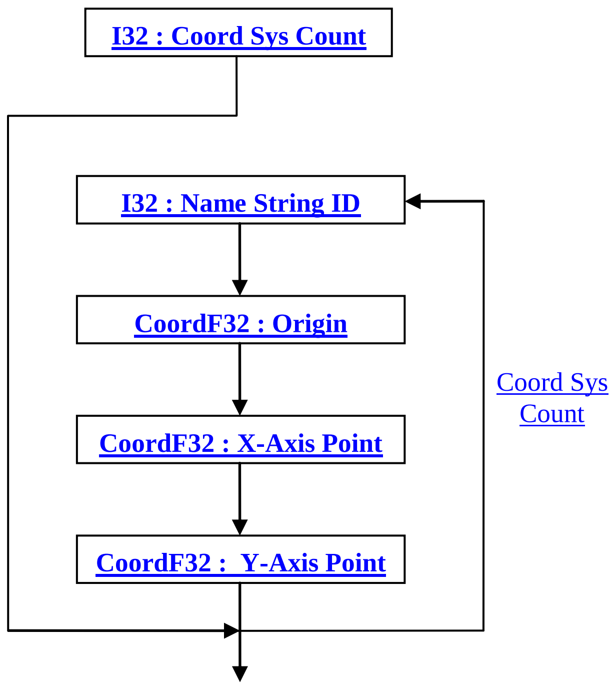
I32 : Description String ID

Description String ID specifies the string identifier for the attribute description. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

7.2.6.2.1.13 PMI Coordinate System Entities

The PMI Coordinate System Entities data collection defines data for a list of Coordinate Systems.

Figure 161: PMI Coordinate System Entities data collection



I32 : Coord Sys Count

Coord Sys Count specifies the number of Coordinate System entities.

I32 : Name String ID

Name String ID specifies the string identifier for the Coordinate System name. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

CoordF32 : Origin

Origin defines the origin of the coordinate system.

CoordF32 : X-Axis Point

X-Axis Point defines a point along the X-Axis of the coordinate system.

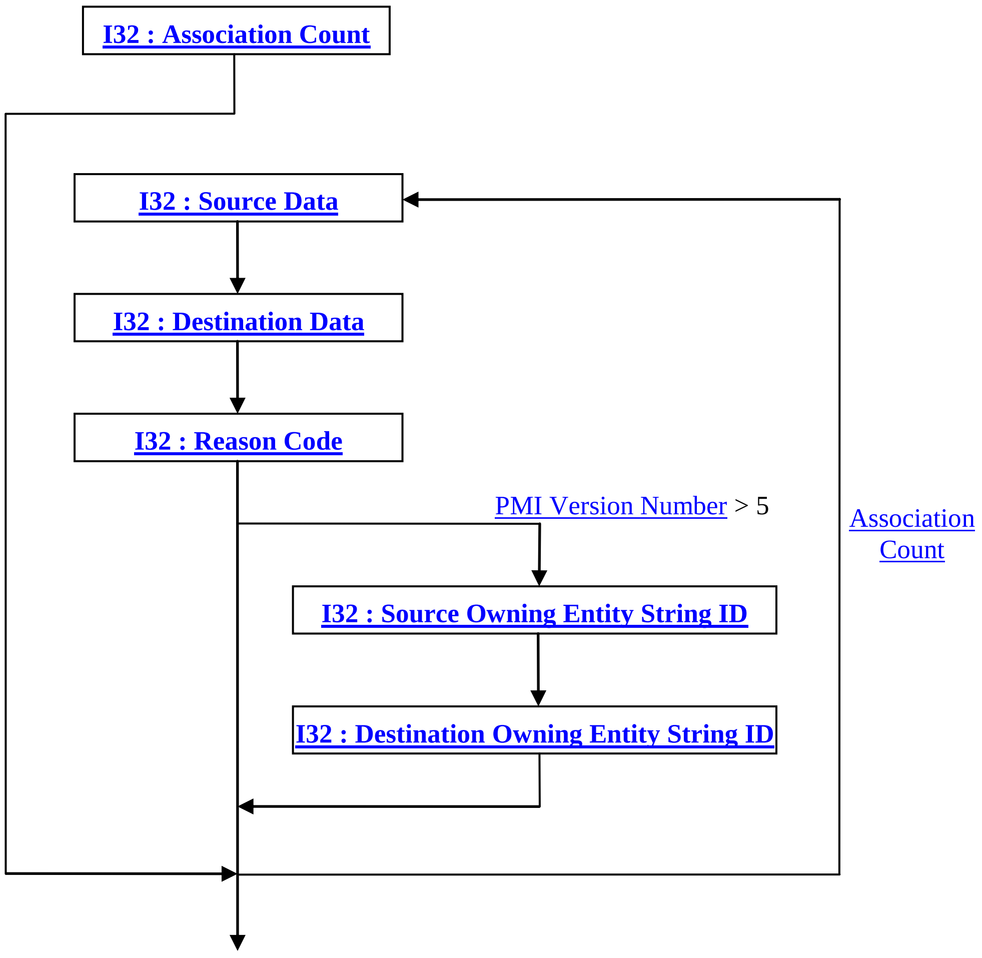
CoordF32 : Y-Axis Point

Y-Axis Point defines a point along the Y-Axis of the coordinate system.

7.2.6.2.2 PMI Associations

The PMI Associations data collection defines data for a list of associations. An association defines a link ("relationship") between two PMI, B-Rep, or Wireframe Rep entities where one entity is defined as the "source" and the other entity is defined as the "destination".

Figure 162: PMI Associations data collection



I32 : Association Count

Association Count specifies the number of associations.

I32 : Source Data

Source Data is a collection of source entity information encoded/packed within a single I32 using the following bit allocation. All undocumented bits are reserved.

Bits 0 - 23	Source Entity Identifier. The interpretation of this identifier data is dependent upon the value of Bit 31 documented below.
Bits 24 -30	Source Entity PMI or B-Rep type. Valid types include the following: = 0 PMI - Dimension = 1 PMI - Note = 2 PMI - Datum Feature Symbol = 3 PMI - Datum Target = 4 PMI - Feature Control Frame = 5 PMI - Line Weld = 6 PMI - Spot Weld = 7 PMI - Measurement Point = 8 PMI - Surface Finish = 9 PMI - Locator Designator = 10 PMI - Reference Geometry = 11 PMI - Coordinate System = 12 PMI - Design Group = 13 PMI - User Attribute = 14 B-Rep - Vertex = 15 B-Rep - Edge = 16 B-Rep - Face = 17 PMI - Model View = 18 PMI - Generic = 19 Wireframe Rep - Edge = 20 PMI - Unspecified type = 21 Part Instance
Bit 31	Indirect Identifier Flag = 0 – Value in Bits 0-23 is not the actual CAD identifier, instead Bits 0-23 is an index into the source type's PMI array or index of the edge/face in B-Rep or Wireframe Rep for the source entity. = 1 – Value in Bits 0-23 is not the actual CAD identifier; instead Bits 0-23 is an index into the list of CAD Tags (as documented in 7.2.6.2.7 PMI CAD Tag Data) identifying the CAD Tag belonging to the particular source entity.

I32 : Destination Data

Destination Data is a collection of destination entity information encoded/packed within a single I32. The encoding schema and interpretation of this data is the same as that documented in Source Data.

I32 : Reason Code

Reason Code specifies the "reason" for the association. Valid Reason Codes include the following:

= 0	Association is to the primary entity being dimensioned
= 1	Association is to the secondary entity being dimensioned
= 2	Association is to the dimension plane
= 5	Association is to the entity used to specify the Z-Axis of a coordinate system
= 10	Association is to an entity "associated" to or "included in" a PMI symbol
= 11	Association is to an entity used to "attach" a PMI symbol.
= 12	Association is to first entity used to “attach” a PMI symbol
= 13	Association is to second entity used to “attach” a PMI symbol
= 14	Specifying PMI grouping, source is PMI/B-Rep entity and destination is design group.
= 15	Association is to a weld line entity
= 16	Association is to a “hot spot”
= 17	Association is to a child in a PMI stack
= 72	Association is for PMI miscellaneous relation.
= 73	Association is for PMI related entity.
= 98	Association is to show the PMI when associated Model View is selected. Source is the PMI, and destination is Model View.
= 99	Association is to show/select PMI B, if showing/selecting PMI A. Source is PMI A, and destination is PMI B. This is different from an “attached” PMI , where the convention is to show the PMI visibly linked to one another.
= 100	Association is to show all parts except the associated part instance. Source is the part instance, and destination is Model View

I32 : Source Owning Entity String ID

Source Owning Entity String ID specifies the string identifier for the string which contains the unique CAD identifier of the component (part or assembly) that owns the source PMI or B-Rep entity. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of “-1” indicates no string and implies that the entity is to be found on the current node‘s PMI/B-Rep/Wireframe-Rep segment. It is valid for the source owning entity to be the same as the destination owning entity (i.e. an association between two PMI or B-Rep entities in the same part/assembly). This data field is only present if Version Number, as defined in 7.2.6.2 PMI Manager Meta Data Element, is greater than “5”.

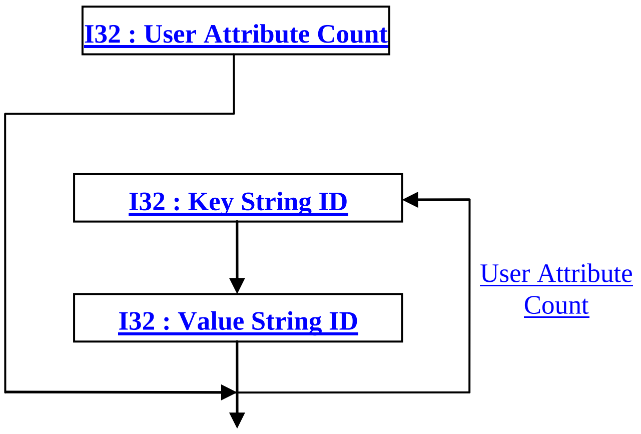
I32 : Destination Owning Entity String ID

Destination Owning Entity String ID specifies the string identifier for the string which contains the unique CAD identifier of the component (part or assembly) that owns the destination PMI or B-Rep entity. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of “-1” indicates no string and implies that the entity is to be found on the current node‘s PMI/B-Rep/Wireframe-Rep segment. It is valid for the source owning entity to be the same as the destination owning entity (i.e. an association between two PMI or B-Rep entities in the same part/assembly). This data field is only present if Version Number, as defined in 7.2.6.2 PMI Manager Meta Data Element, is greater than “5”.

7.2.6.2.3 PMI User Attributes

The PMI User Attributes collection defines data for a list of user attributes. PMI User Attributes are used to add attribute data to a part/assembly. Each user attribute is composed of key/value pair of strings.

Figure 163: PMI User Attributes data collection



I32 : User Attribute Count

User Attribute Count specifies the number of user attributes.

I32 : Key String ID

Key String ID specifies the string identifier for the user attribute key. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

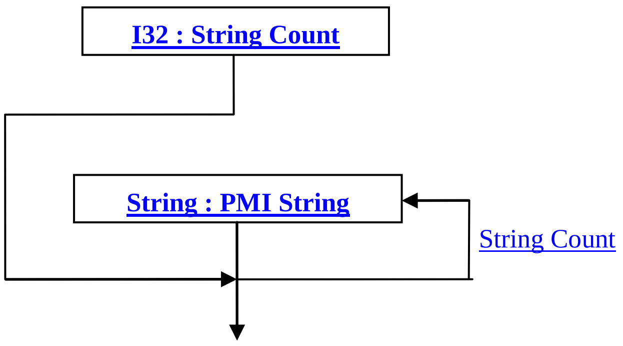
I32 : Value String ID

Value String ID specifies the string identifier for the user attribute value. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

7.2.6.2.4 PMI String Table

The PMI String Table data collection defines data for a list of character strings and serves as a central repository for all character strings used by other PMI Entities within the same PMI Manager Meta Data Element. PMI Entities reference into this list/array of character strings to define usage of a particular character string using a simple list/array "index" (i.e. String ID).

Figure 164: PMI String Table data collection



I32 : String Count

String Count specifies the number of character strings in the string table.

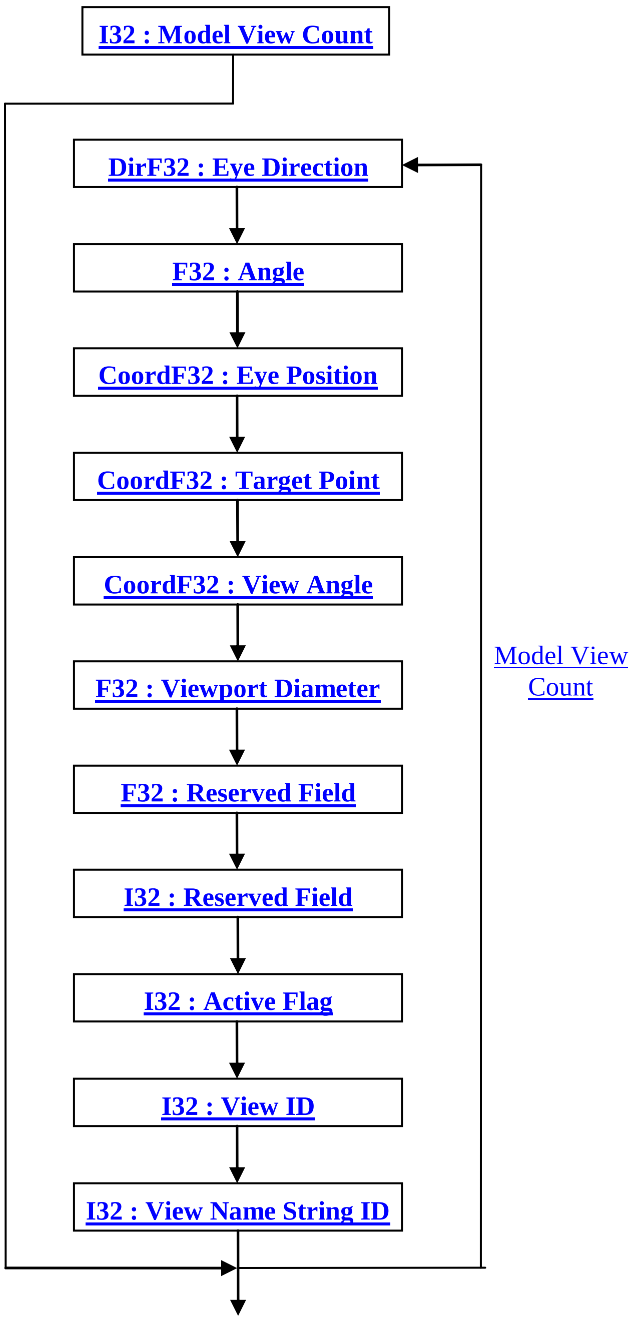
String : PMI String

PMI String specifies the character string.

7.2.6.2.5 PMI Model Views

The PMI Model Views data collection defines data for a list of Model Views. A fully annotated part/assembly may contain so much PMI information, that it becomes very difficult to interpret the design intent when viewing a 3D Model (with PMI visible) of the part/assembly. Model Views provide a means to capture and organize PMI information about a 3D model so that the design intent can be clearly interpreted and communicated to others in later stages of the Product Lifecycle Management (PLM) process (e.g. manufacturing, inspection, assembly). This organization is achieved via PMI Associations (see 7.2.6.2.2 PMI Associations), where specific PMI entities are associated as "destinations" to a "source" PMI Model View.

Figure 165: PMI Model Views data collection



I32 : Model View Count

Model View Count specifies the number of Model Views.

DirF32 : Eye Direction

Eye Direction specifies the camera direction vector.

F32 : Angle

Angle specifies the camera rotation angle (in degrees where positive is counter-clockwise) about the Eye Direction. So this Angle in combination with the Eye Direction is equivalent to specifying a rotation using axis-angle representation.

CoordF32 : Eye Position

Eye Position specifies the WCS coordinates of the eye/camera "look from" position.

CoordF32 : Target Point

Target Point specifies the WCS coordinates of the eye/camera "look at" position.

CoordF32 : View Angle

View angle specifies the X, Y, Z rotation angles (in degrees) of the model's axis. The rotations are defined with respect to an initial orientation where the model's axis are aligned with the screen's axis (i.e. +X axis points to right, +Y axis points up, +Z axis points out at you).

F32 : Viewport Diameter

Viewport Diameter specifies the diameter in WCS coordinates of the largest possible circle that could be inscribed within viewport. If a large diameter value is specified, the model appears very small in relation to the viewport; whereas if a small diameter value is specified a close-up ("zoomed-in)" view of the model results.

F32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

I32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion

I32 : Active Flag

Active Flag is a flag specifying whether this Model View is the "active" view. Valid values include the following:

= 0	Is not the active Model View.
= 1	Is the active Model View

I32 : View ID

View ID specifies the Model View unique identifier.

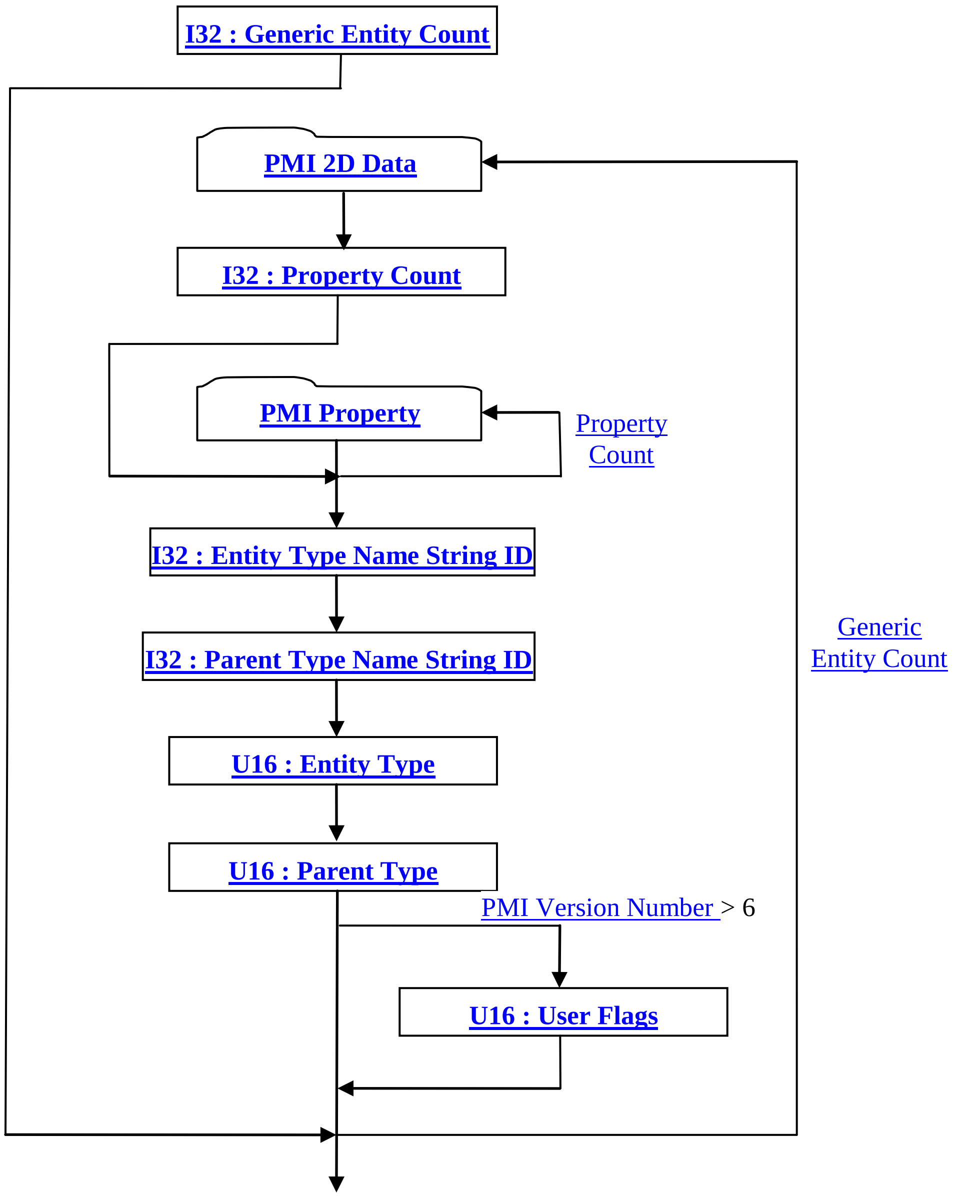
I32 : View Name String ID

View Name String ID specifies the string identifier for the Model View's name. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

7.2.6.2.6 Generic PMI Entities

The Generic PMI Entities data collection provides a "generic" format for defining various PMI entity types, including user defined types. The generic format defines the data making up the PMI Entity through a combination of the PMI 2D Data collection and a list of PMI Property data collections.

Figure 166: Generic PMI Entities data collection



Complete description for PMI 2D Data can be found in 7.2.6.2.1.1.1 PMI 2D Data.

I32 : Generic Entity Count

Generic Entity Count specifies the number of Generic PMI Entities.

I32 : Property Count

Property Count specifies the number of PMI Properties.

I32 : Entity Type Name String ID

Entity Type Name String ID specifies the string identifier for the name of the Generic PMI Entity Type. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

I32 : Parent Type Name String ID

Parent Type Name String ID specifies the string identifier for the name of the parent Generic PMI Entity Type. This identifier is an index to a particular character string in the PMI String Table as defined in 7.2.6.2.4 PMI String Table. An identifier value of "-1" indicates no string.

U16 : Entity Type

Entity Type specifies the Generic PMI Entity Type. The valid Entity Type values (in hexadecimal format) are documented in the following table. Note that for "user defined" Generic PMI Entities a hexadecimal value of "0x0114" (as documented in table below) should be used.

0x0001	PMI (generally only used as a Parent Type)
0x0002	Weld
0x0004	Spot Weld
0x0008	Line Weld
0x0010	Groove Weld
0x0011	Fillet Weld
0x0012	Slot Weld
0x0014	Edge Weld
0x0018	Arc Spot Weld
0x0020	Resistance Spot Weld
0x0021	Resistance Seam Weld
0x0022	Structural Adhesive Bead Shaped
0x0024	Structural Adhesive Tape Shaped
0x0028	Structural Adhesive Dollop Shaped
0x0040	Mechanical Clinch Connector
0x0041	Surface Finish
0x0042	Measurement Point
0x0044	Datum Locator
0x0048	Certification Point
0x0080	Geometric Dimensioning and Tolerancing
0x0081	Feature Control Frame
0x0082	Dimension
0x0084	Datum Feature Symbol
0x0088	Datum Target
0x0100	Note
0x0101	Face Attribute Note
0x0102	Model View Label Note
0x0104	Coordinate System

0x0108	Reference Geometry
0x0110	Reference Point
0x0111	Reference Axis
0x0112	Reference Plane
0x0114	User Defined
0x0118	Measurement Locator
0x0120	Datum Point
0x0121	Surface Vector Measurement Point
0x0122	Hole Vector Measurement Point
0x0124	Trimmed Sheet Vector Measurement Point
0x0128	Hem Vector Measurement Point

U16 : Parent Type

Parent Type specifies the parent Generic PMI Entity Type. The valid Parent Type values are the same as that documented above for Entity Type. The Parent Type is used to create a class hierarchy of PMI when presenting the PMI contents from a JT file.

U16 : User Flags

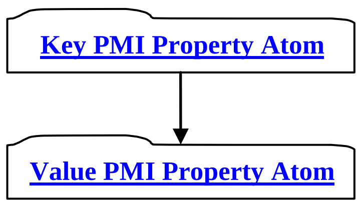
User Flags is a collection of flags. The flags are combined using the binary OR operator and store various state information for the Generic PMI Entity. All undocumented bits are reserved.

0x0001	Show PMI Entity "flat to screen only" flag = 0 – Allow PMI display plane to rotate with model. = 1 – Display PMI entity in the plane of the screen, so that it does not rotate with model.

7.2.6.2.6.1 PMI Property

A PMI Property data collection consists of a key/value pair and is used to describe attributes of Generic PMI Entity or other specific data.

Figure 167: PMI Property data collection



Both Key PMI Property Atom and Value PMI Property Atom have the same format as that documented in 7.2.6.2.6.1.1 PMI Property Atom.

Although there is no reference compliant requirements for what the PMI Property key/value pairs must be for each Generic PMI Entity type, there are some common PMI Property keys and corresponding value formats that appear in JT File. The below table documents these common PMI Property keys (i.e. the keys encoded string value) and what the format of the value data is in the values encoded string (see 7.2.6.2.6.1.1 PMI Property Atom for an explanation of what is meant by "encoded string value" for the "key" and "value" data).

Table 7: Common Property Keys and Their Value Encoding formats

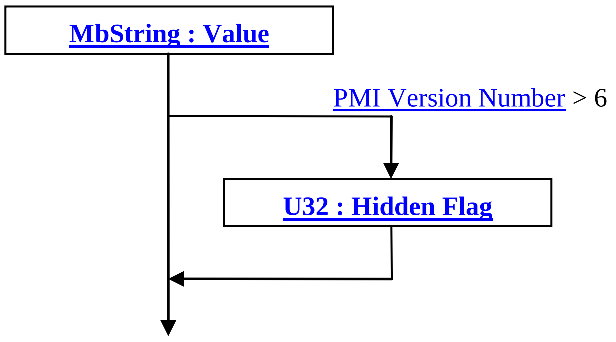
"Key" Property Atom Value String	"Value" Property Atom Value String Encoding Format	Decoding Notes
"PMI_PROP_ANCHOR_POINT"	"Px Py Pz"	Each Px, Py, Pz is a F32 value using "%f" format
"PMI_PROP_NOTE_HAS_URL"	"0" or "1"	0 = = False; 1 = = True
"PMI_PROP_NORMAL_DIR"	"Dx Dy Dz"	Each Dx, Dy, Dz is a F32 value using "%f" format
"PMI_PROP_APPROACH_DIR"	"Dx Dy Dz"	Each Dx, Dy, Dz is a F32 value using "%f" format
"PMI_PROP_CLAMPING_DIR"	"Dx Dy Dz"	Each Dx, Dy, Dz is a F32 value using "%f" format
"PMI_PROP_MEAS_DIR"	"Dx Dy Dz"	Each Dx, Dy, Dz is a F32 value using "%f" format
"PMI_PROP_COORD_DIR"	"Dx Dy Dz"	Each Dx, Dy, Dz is a F32 value using "%f" format
"PMI_PROP_MEAS_LEVEL"	"#"	Integer representing level number
"PMITextForegroundColor"	"#"	Hexadecimal integer representing RGB color where value has "0x00bbggrr" form. The low-order byte contains a value for the relative intensity of red; the second byte contains a value for the relative intensity of green; and the third byte contains a value for the relative intensity of blue. The high-order byte must be zero. The maximum value for a single byte is 0xFF (i.e. intensity value is in the range [0:255]).
"PMITextBackgroundColor"	"#"	Same as "PMITextForegroundColor"
"PMITextBackgroundOpacity"	"#"	Unsigned decimal integer representing opacity percentage. Actual opacity is: decoded# / 100.0
"PMITextShowBorder"	"#"	Unsigned decimal integer: 0 = = False; 1 = = True
"PMITextSize"	"#"	Unsigned decimal integer representing text size in units of pixels.
"PMITextInPlane"	"#"	Unsigned decimal integer: 0 = = False; 1 = = True where "1" indicates that text should be displayed in the plane of the entity so that it rotates with view.
"PMIGeometryColor"	"#"	Same as "PMITextForegroundColor"
"PMIGeometryWidth"	"#"	Unsigned decimal integer representing line width in units of pixels.
CLIP_NORMAL	"#,#,#"	Used for Entity Type = "0x0114" and Entity Type Name String = "Section" to specify the normal to the clipping plane. The clipping normal points toward the piece of the model that will be clipped away. Each # is a F64 value using "%lf" format.
CLIP_POSITION	"#,#,#"	Used for Entity Type = "0x0114" and Entity Type Name String = "Section" to specify one point on the clipping plane. Each # is a F64 value using "%lf" format.

"Key" Property Atom Value String	"Value" Property Atom Value String Encoding Format	Decoding Notes
TRANSFORMATION_MATRIX	"#,#,#,#,#,#,#,#, #,#,#,#,#,#,#,#"	Used for Entity Type = "0x0114" and Entity Type Name String = "Part Transform" to specify a transformation matrix. Each # is a F32 value using "%f" format.

7.2.6.2.6.1.1 PMI Property Atom

PMI Property Atom data collection represents the data format for both the key and value data of a PMI Property key/value pair.

Figure 168: PMI Property Atom data collection



MbString : Value

Value specifies the property atom value encoded into a String. See Table 7: Common Property Keys and Their Value Encoding formats above for encoding formats of the Value string.

U32 : Hidden Flag

Hidden Flag specifies if the property is "hidden" or not. A JT file reader could use this flag to control whether read properties should be exposed to the end user of the application reading the JT file. Valid values include the following:

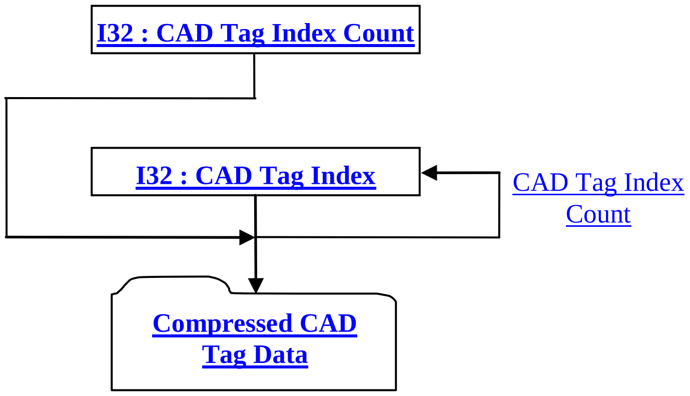
= 0	Property is not hidden.
= 1	Property is hidden.

7.2.6.2.7 PMI CAD Tag Data

The PMI CAD Tag Data collection contains the list of persistent IDs, as defined in the CAD System, to uniquely identify individual PMI entities. The existence of this PMI CAD Tag Data collection is dependent upon the value of previously read data field CAD Tags Flag as documented in 7.2.6.2 PMI Manager Meta Data Element.

If PMI CAD Tag Data collection is present, there will be a CAD Tag for each PMI entity as specified by the below documented CAD Tag Index Count formula.

Figure 169: PMI CAD Tag Data collection



Complete description for Compressed CAD Tag Data can be found in 8.1.16 Compressed CAD Tag Data.

I32 : CAD Tag Index Count

CAD Tag Index Count specifies the total number of CAD Tag indices. This value must be equal to the summation of the previously read count values for all the PMI entities supporting CAD Tags. The formula is the sum of the following:

- Line Weld Count
- Spot Weld Count
- SF Count
- MP Count
- Reference Geometry Count
- Datum Target Count
- FCF Count
- Locator Count
- Dimension Count
- DFS Count
- Note Count
- Model View Count
- Design Group Count
- Coord Sys Count
- Generic Entity Count

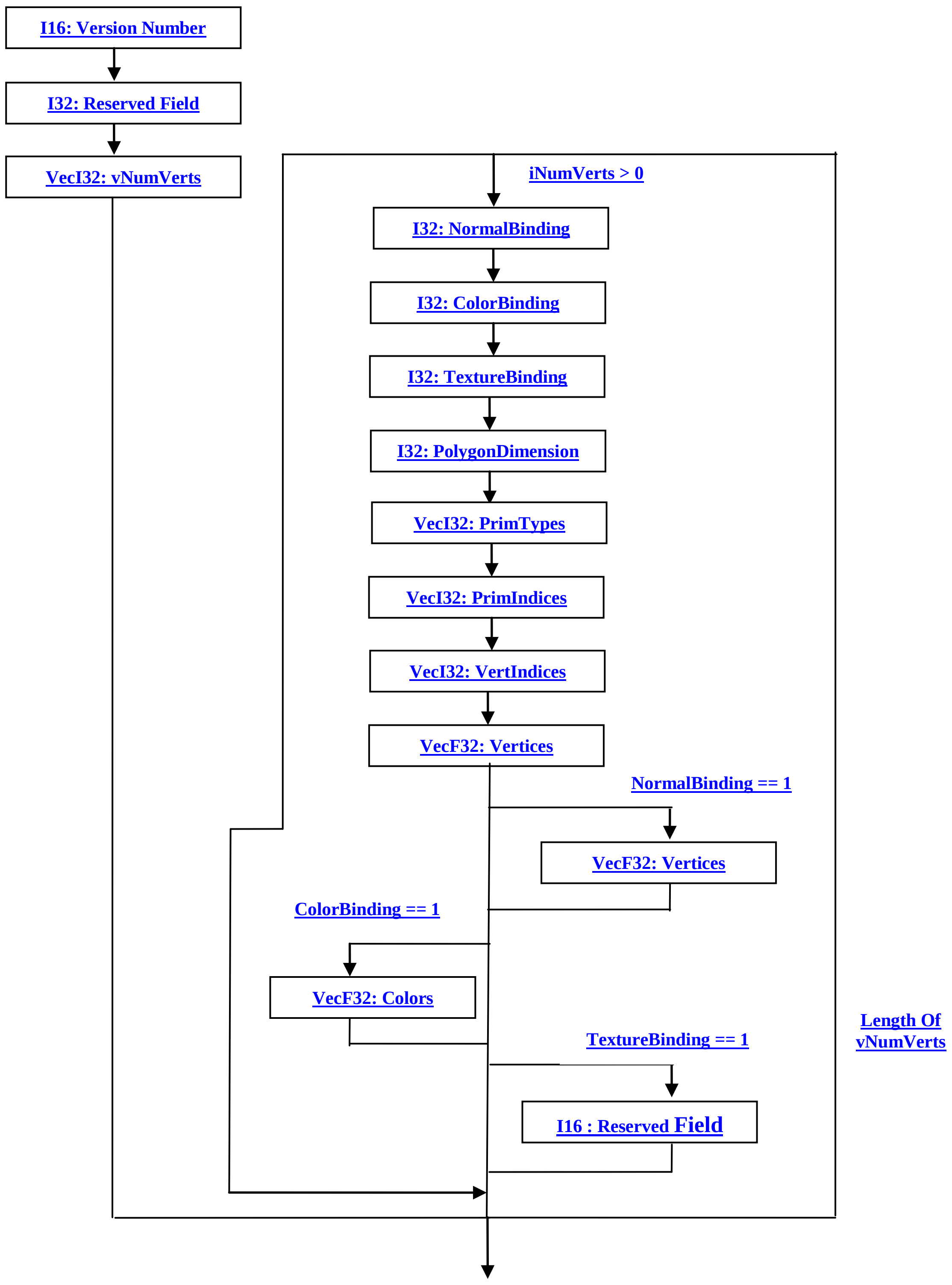
I32 : CAD Tag Index

CAD Tag Index specifies an index into a list of CAD Tags, identifying the CAD Tag belonging to a particular PMI entity. There will be a total of CAD Tag Index Count number of CAD Tag Indices and the order of the indices will be as defined by the above documented CAD Tag Index Count formula (i.e. Line Weld CAD Tag Indices are first, followed by the Spot Weld CAD Tag Indices, followed by the Surface Finish CAD Tag Indices, etc.)

7.2.6.2.8 PMI Polygon Data

The PMI Polygon Data collection contains a list of vertices classified as polygonal primitives. Its composition is shown in the figure 177. Each block of PMI PolygonData contains a list of 0 or more PolygonData elements. Empty PolygonData elements are written with 0 vertices and no additional fields.

Figure 170: PMI Polygon Data



I16: Version Number

Version number is the version identifier for this PMI Polygon Data Element. V9.5 format only supports version 1 of the PMI Polygon data

I32: Reserved Field

Reserved Field is a data field reserved for future JT format expansion

VecI32: vNumVerts

An integer vector used to record the number of vertices in each polygon data element. The length of this vector is equal to the number of PolygonData elements written in this block of PMI PolygonData. The presence of additional data fields in each PolygonData element is hinged upon that element having more than 0 vertices recorded in this vector.

Retrieve next vertCount from vNumVerts

If the next element in the vNumVerts vector is non-zero, proceed to read other fields that make up a single PMI PolygonData element. Otherwise, skip reading more data for this element and loop back to seek the next element in the vector.

iNumVerts

Number of vertices for the i^{th} PolygonData element.

Length Of vNumVerts

Number of Polygon Data elements.

I32: NormalBinding

A Boolean value that indicates if there are normals present along with the list of coordinates at each vertex.

I32: ColorBinding

A Boolean value that indicates if there are colors present along with the list of coordinates at each vertex.

I32: TextureBinding

A Boolean value that indicates if there are Texture Coordinates present along with the list of coordinates at each vertex.

I32: PolygonDimension

Indicates the dimension of vertex coordinates.

VecI32: PrimTypes

An array indicating the type of each of the primitive stored in the PrimIndices array. Adjacent numbers in the array form tuples of the form [PrimIndex, PrimType]. All primitives to the left of the PrimIndex are of type PrimType unless they are already to the left of an earlier PrimIndex in this array.

VecI32: PrimIndices

Indices of vertices that form a single primitive. The difference between two adjacent values in this array determines the length of the primitive. An extra element is stored at the end of this array to identify the length of the last primitive. Values in this array are indices into the VertIndices array.

VecI32: VertIndices

An array of indices into the Vertices array. This index array eliminates the need to duplicate floating point vertices that are shared by multiple primitives.

VecF32: Vertices

The list of vertex coordinates. Each vertex is made of PolygonDimension coordinates. The length of this list is equal to number of vertices multiplied by PolygonDimension.

VecF32: Normals

An optional list of Normals for each vertex. Presence of this list is indicated by the NormalBinding flag. Each normal consists of PolygonDimension components. The size of this list is equal to number of vertices multiplied by PolygonDimension.

VecF32: Colors

An optional list of Colors for each vertex. Presence of this list is indicated by the ColorBinding flag. Each color consists of PolygonDimension components. The size of this list is equal to number of vertices multiplied by PolygonDimension.

VecF32: Texture Coords

An optional list of Texture coordinates for each vertex. Presence of this list is indicated by the TexCoordBinding flag. Each TexCoord consists of 2 components. The size of this list is equal to number of vertices multiplied by 2.

7.2.7 PMI Data Segment

The PMI Manager Meta Data Element (as documented in 7.2.6.2 PMI Manager Meta Data Element) can sometimes also be represented in a PMI Data Segment. This can occur when a pre JT 8 version file is migrated to JT 9.5 version file. So from a parsing point of view a PMI Data Segment should be treated exactly the same as a 7.2.6 Meta Data Segment.

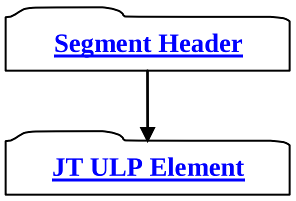
7.2.8 JT ULP Segment

JT ULP Segment contains an Element that defines the semi-precise geometric Boundary Representation data for a particular Part in JT ULP format. Note that there is also two other Boundary Representation formats (i.e. JT B-Rep and XT B-Rep) supported by the JT file format within a different file Segment Type. Complete description for the JT B-Rep and the XT B-Rep can be found in 7.2.3 JT B-Rep Segment and

7.2.4 XT B-Rep Segment respectively.

JT ULP Segments are typically referenced by Part Node Elements (see 7.2.1.1.1.5Part Node Element) using Late Loaded Property Atom Elements (see 0 Late Loaded Property Atom Element). The JT ULP Segment type supports ZLIB compression on all element data, so all elements in JT ULP Segment use the Logical Element Header ZLIB form of element header data.

Figure 171: JT ULP Segment data collection



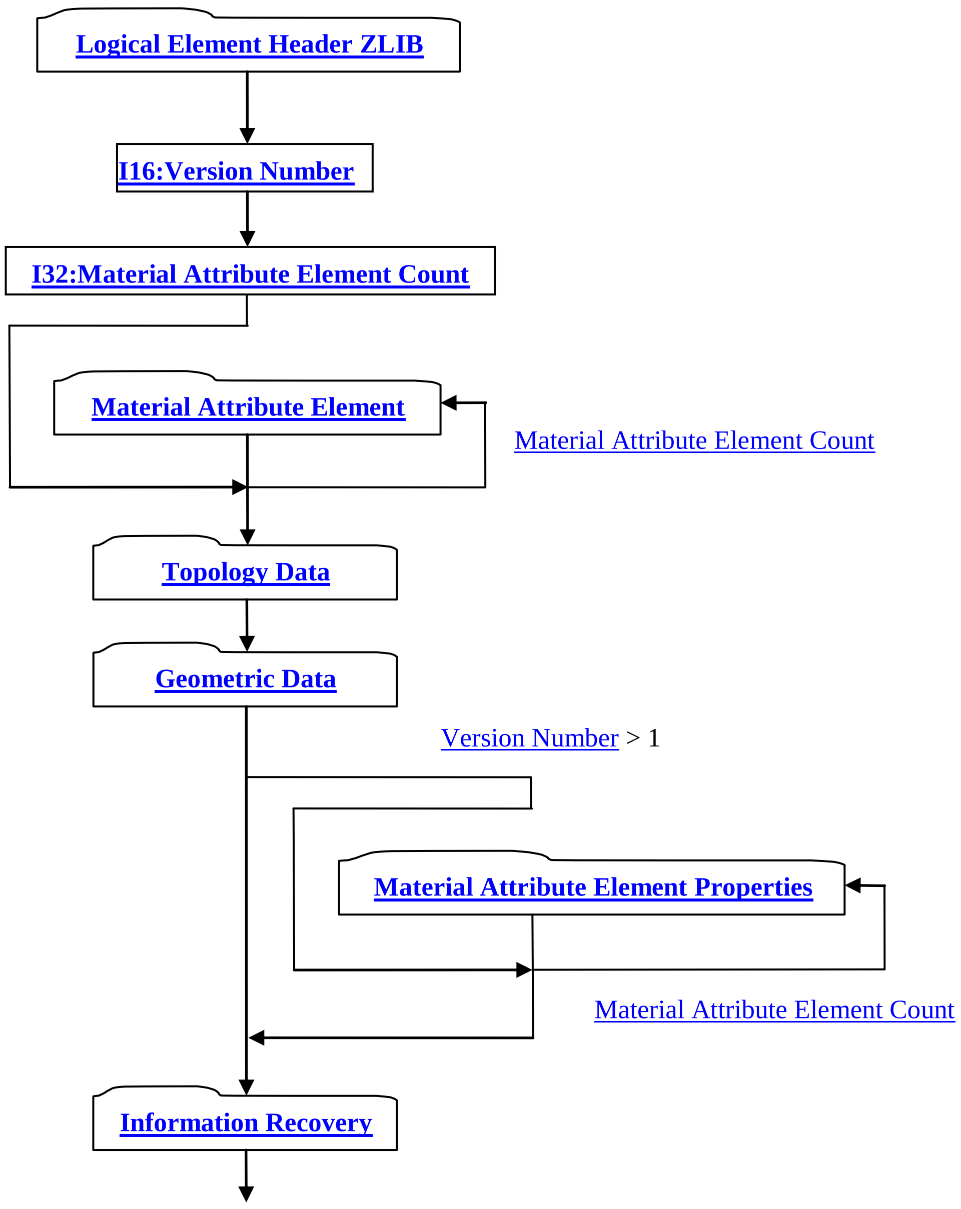
Complete description for Segment Header can be found in 7.1.3.1Segment Header.

7.2.8.1 JT ULP Element

Object Type ID: 0xf338a4af, 0xd7d2, 0x41c5, 0xbc, 0xf2, 0xc5, 0x5a, 0x88, 0xb2, 0x1e, 0x73

JT ULP Element represents a particular Part's ultra-lightweight semi-precise B-Rep data. Like JT B-Rep Element or XT B-Rep Element, JT ULP Element contains all the topological and geometric information that describes the shape of a part. The difference is that the size of JT ULP Element is typically around 10% of a typical JT file with B-Rep and LODs, and this is achieved by sophisticated compression techniques. In addition, JT ULP Element is semi-precise meaning that its geometric description is not as precise as either JT B-Rep Element or XT B-Rep Element. The precision loss of JT ULP Element, however, is carefully controlled to be equal to or better than 0.01% of the part size or 0.1mm, whichever is smaller.

Figure 172: JT ULP Element data collection


Logical Element Header ZLIB
I16:Version Number
I32:Material Attribute Element Count
Material Attribute Element
Material Attribute Element Count
Topology Data
Geometric Data
Version Number > 1
Material Attribute Element Properties
Material Attribute Element Count
Information Recovery

Complete description for Logical Element Header ZLIB can be found in 7.1.3.2.3 Logical Element Header ZLIB.

I16:Version Number

Version Number is the version identifier for this JT ULP Element. Version numbers "1" and "2" are currently supported.

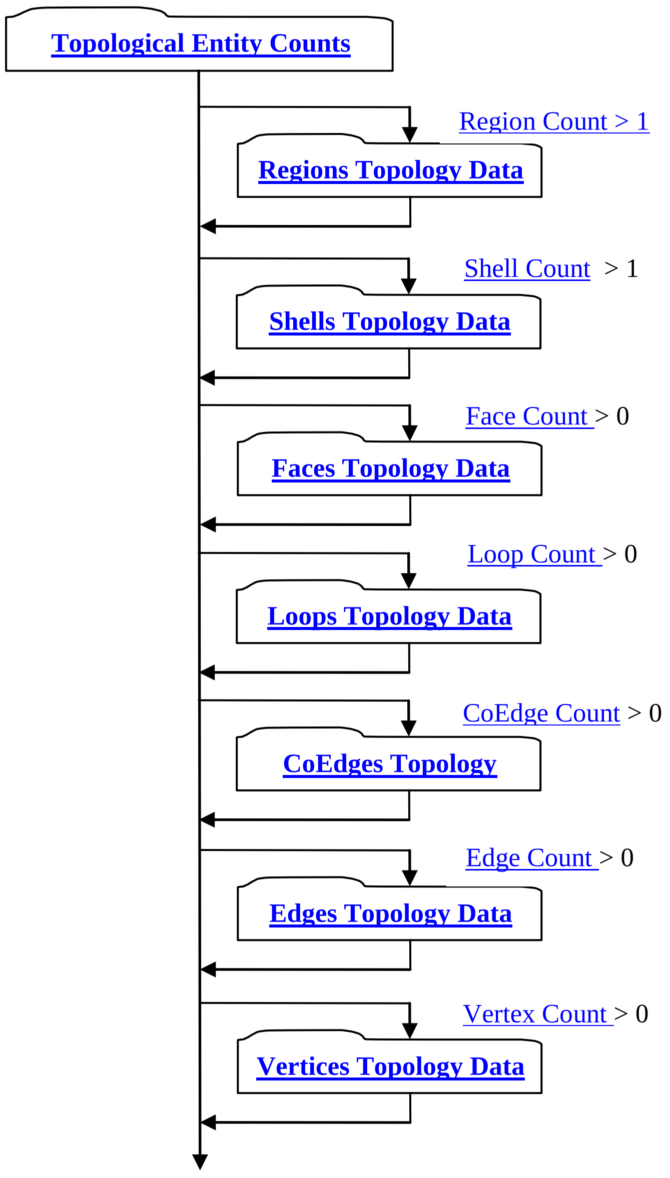
I32:Material Attribute Element Count

Material Attribute Element Count is the number of material attribute elements.

Complete description for Material Attribute Element can be found in 7.2.1.1.2.2 Material Attribute Element.

7.2.8.1.1 Topology Data

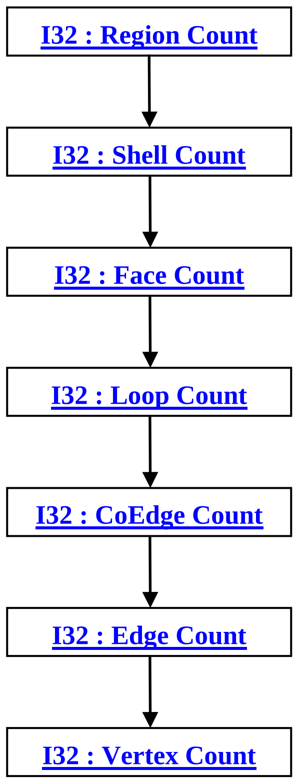
Figure 173: Topology Data collection



7.2.8.1.1.1 Topological Entity Counts

Topological Entity Counts data collection defines the counts for each of the various topological entities within a ULP.

Figure 174: Topological Entity Counts data collection



I32 : Region Count

Region Count indicates the number of topological region entities in the ULP.

I32 : Shell Count

Shell Count indicates the number of topological shell entities in the ULP.

I32 : Face Count

Face Count indicates the number of topological face entities in the ULP.

I32 : Loop Count

Loop Count indicates the number of topological loop entities in the ULP.

I32 : CoEdge Count

CoEdge Count indicates the number of topological coedge entities in the ULP.

I32 : Edge Count

Edge Count indicates the number of topological edge entities in the ULP.

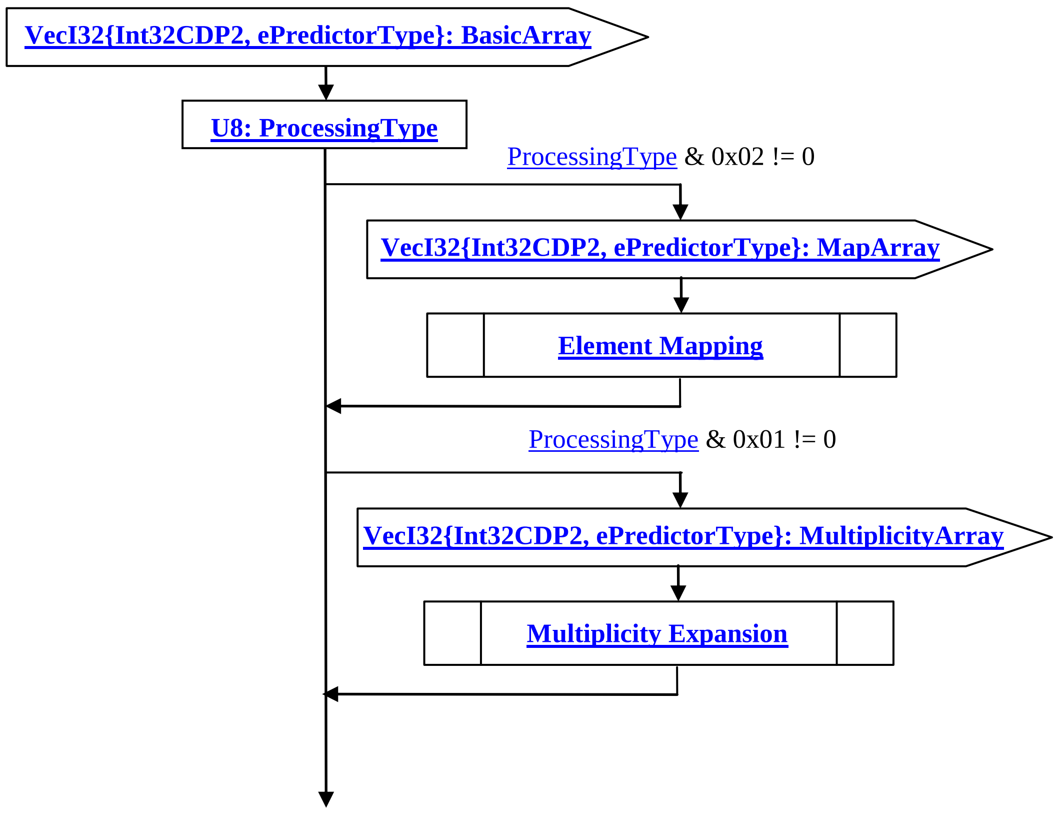
I32 : Vertex Count

Vertex Count indicates the number of topological vertex entities in the ULP.

7.2.8.1.1.2 Combined Predictor Type

A predictor type may be combined with additional processing. When Combined Predictor Type is used, the additional processing step is encoded. For example, combined predictor type *Combined:NULL* means that the data collection follows the logical diagram in Figure 175 with ePredictorType set to be NULL.

Figure 175: Combined Predictor Type data collection


VecI32{Int32CDP2, ePredictorType}: BasicArray
U8: ProcessingType
ProcessingType & 0x02 != 0
VecI32{Int32CDP2, ePredictorType}: MapArray
Element Mapping
ProcessingType & 0x01 != 0
VecI32{Int32CDP2, ePredictorType}: MultiplicityArray
Multiplicity Expansion

VecI32{Int32CDP2, ePredictorType}: BasicArray

BasicArray is an integer array, compressed and encoded using the Int32 version of second generation CODEC.

U8: ProcessingType

Two bits of this value are currently used. If bit 0x02 is set, then the integer array is a list of elements with unique values and Element Mapping step is needed to recover the original values. If bit 0x01 is set, then the some elements in the integer array may be repeated, and Multiplicity Expansion is used to recover the original values.

VecI32{Int32CDP2, ePredictorType}: MapArray

MapArray is an integer array, where each element represents the index mapping information. MapArray is compressed and encoded using the Int32 version of second generation CODEC.

Element Mapping

Element Mapping recovers the original array from BasicArray and MapArray, using relationship $OriginalArray[i] = BasicArray[MapArray[i]]$. After Element Mapping, the value of $BasicArray$ is updated with $OriginalArray$.

VecI32{Int32CDP2, ePredictorType}: MultiplicityArray

MultiplicityArray is an integer array, where each element represents the multiplicity of each element in BasicArray. MultiplicityArray is compressed and encoded using the Int32 version of second generation CODEC.

Multiplicity Expansion

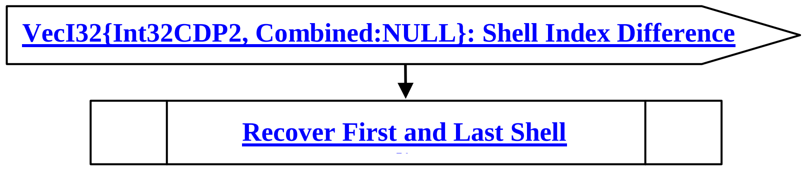
Multiplicity Expansion recovers the original array from BasicArray and MultiplicityArray. The original array is an expansion of the BasicArray. If the corresponding multiplicity value is greater than 1, the element in BasicArray is contiguously repeated in the original array according to multiplicity value.

7.2.8.1.1.3 Regions Topology Data

Regions Topology Data defines the disjoint set of non-overlapping Shells making up each Region. Each Region is defined by one or more non-overlapping Shells. The volume of a Region is that volume lying inside each “anti-hole Shell” and outside each simply-contained “hole Shell” belonging to the particular Region. A Region is analogous to a dimensionally elevated face where Region corresponds to Face and Shell corresponds to Trim Loop.

Each Region’s defining Shells are identified in a list of Shells by an index for both the first Shell and the last Shell in each Region (i.e. all Shells inclusive between the specified first and last Shell list index define the particular Region). In addition, the indices of all the shells in a single Region are contiguous. The first shell index of the first region is 0, and the first shell index of other regions is one greater than the last shell index of the previous region. Therefore only the number of shells of each region is stored. In the special case when the number of regions is 1, no information needs be stored since its last Shell index is known to be Shell Count-1.

Figure 176: Regions Topology Data collection


VecI32{Int32CDP2, Combined:NULL}: Shell Index Difference
Recover First and Last Shell

VecI32{Int32CDP2, Combined:NULL}: Shell Index Difference

Shell Index Difference is a vector of indices representing the integer value by subtracting first shell index from last shell index in each region, encoded using Combined Predictor Type. Shell Index Difference is compressed and encoded using the Int32 version of second generation CODEC.

Recover First and Last Shell Indices

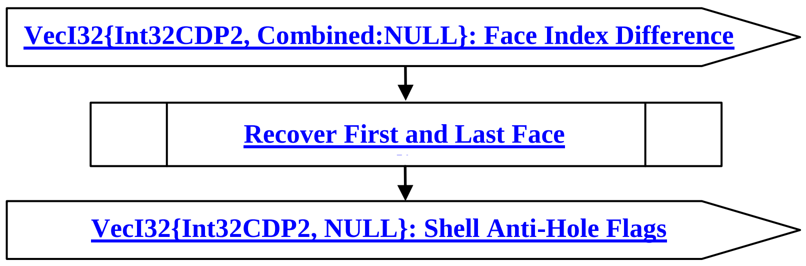
The first shell index of the first region is 0, and the last shell index of the first region is element 0 of Shell Index Difference. The first shell index of region $k, k \geq 1$ equals to the last shell index of region $k-1$ plus 1. The last shell index of region $k, k \geq 1$ equals to the first shell index of region k plus element k of Shell Index Difference array.

7.2.8.1.1.4 Shells Topology Data

Shells Topology Data defines the set of topological adjacent Faces making up each Shell. A Shell’s set of topological adjacent Faces define a single (usually closed) two manifold solid that in turn defines the boundary between the finite volume of space enclosed within the Shell and the infinite volume of space outside the Shell. In addition, each Shell has a flag that denotes whether the Shell refers to the finite interior volume (i.e. a “hole Shell”) or the infinite exterior volume (i.e. an “anti-hole Shell”).

Each Shell’s defining Faces are identified in a list of Faces by an index for both the first Face and the last Face in each Shell (i.e. all Faces inclusive between the specified first and last Face list index define the particular Shell). In addition, the indices of all the faces in a single Shell are contiguous. The first face index of the first shell is 0, and the first face index of other shells is one greater than the last face index of the previous shell. Therefore only the number of faces of each shell is stored. In the special case when the number of shells is 1, no information needs be stored since its last face index is known to be Face Count-1.

Figure 177: Shells Topology Data collection


VecI32{Int32CDP2, Combined:NULL}: Face Index Difference
Recover First and Last Face
VecI32{Int32CDP2, NULL}: Shell Anti-Hole Flags

VecI32{Int32CDP2, Combined:NULL}: Face Index Difference

Face Index Difference is a vector of indices representing the integer value by subtracting first face index from last face index in each shell, encoded using Combined Predictor Type. Face Index Difference is compressed and encoded using the Int32 version of second generation CODEC.

Recover First and Last Face Indices

The first face index of the first shell is 0, and the last face index of the first shell is element 0 of Face Index Difference. The first face index of shell $k, k \geq 1$ equals to the last face index of shell $k - 1$ plus 1. The last face index of shell $k, k \geq 1$ equals to the first face index of shell k plus element k of Face Index Difference array.

VecI32{Int32CDP2, NULL}: Shell Anti-Hole Flags

Each Shell has a flag identifying whether the Shell is an anti-hole Shell. Shell Anti-Hole Flags is a vector of anti-hole flags for a set of Shells.

In an uncompressed/decoded form the flag values have the following meaning:

= 0	Shell is not an anti-hole Shell
= 1	Shell is an anti-hole Shell

Shell Anti-Hole Flags uses the Int32 version of the CODEC to compress and encode data.

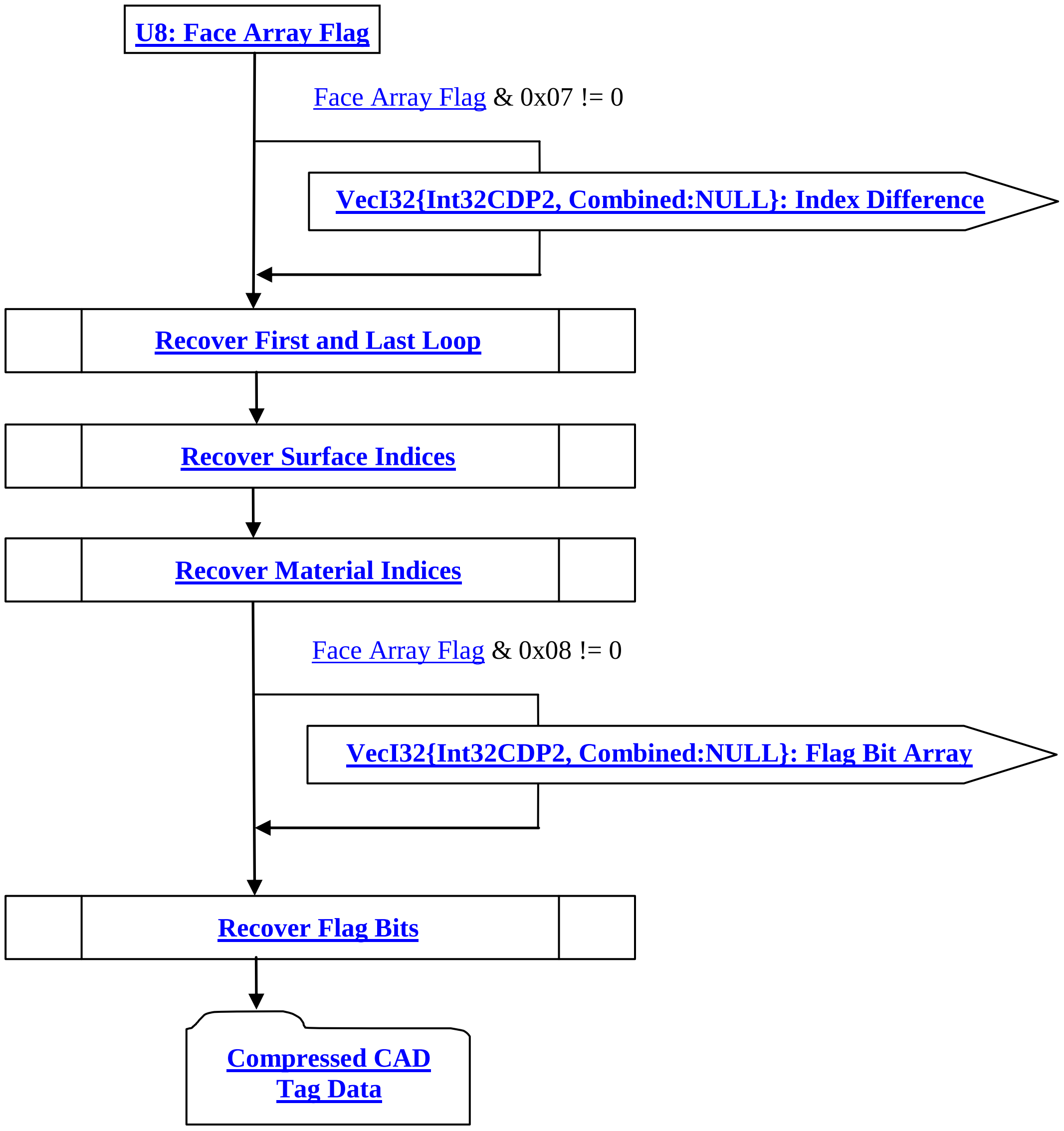
7.2.8.1.1.5 Faces Topology Data

A Face must be trimmed with at least one "anti-hole" Trim Loop and may be trimmed with one or more "hole" Trim Loops. The complete description of face and its relation to the trim loops can be found in 7.2.3.1.3.3 Faces Topology Data.

Each Face's defining Trim Loops are identified in a list of trim Loops by an index for both the first Trim Loop and the last Trim Loop in each Face (i.e. all Trim Loops inclusive between the specified first and last Trim Loop list index define the particular Face). In addition, the indices of all the loops in a single Face are contiguous. The first loop index of the first face is 0, and the first loop index of other faces is one greater than the last loop index of the previous face. Therefore only the number of loops of each face is stored. In the special case when the number of faces is 1, no information needs be stored since its last loop index is known to be Loop Count-1.

Each Face's underlying Geometric Surface is identified by an index into a list of Geometric Surfaces. Each face's material is identified by an index into the list of Material Attribute Elements.

Figure 178: Faces Topology Data collection



U8: Face Array Flag
Face Array Flag & 0x07 != 0
VecI32{Int32CDP2, Combined:NULL}: Index Difference
Recover First and Last Loop
Recover Surface Indices
Recover Material Indices
Face Array Flag & 0x08 != 0
VecI32{Int32CDP2, Combined:NULL}: Flag Bit Array
Recover Flag Bits
Compressed CAD Tag Data

U8: Face Array Flag

Face Array Flag indicates which arrays of face topology data are not trivial and therefore encoded.

VecI32{Int32CDP2, Combined:NULL}: Index Difference Array

Index Difference Array is a combined vector of indices encoded using Int32 version of CODEC and Combined Predictor Type, with its content decided by the value of Face Array Flag. If Face Array Flag has bit 0x01 set, then the vector of integer values obtained by subtracting first loop index from last loop index in each face is appended to the end of Index Difference Array. If Face Array Flag has bit 0x02 set, then the vector of integer values obtained by subtracting surface index from face index in each face is appended to the end of Index Difference Array. If Face Array Flag has bit 0x04 set, then the vector of integer values representing the material index of each face is appended to the end of Index Difference Array.

Recover First and Last Loop Indices

The first loop index of the first face is 0, and the last loop index of the first face is element 0 of Index Difference Array if the array is encoded, or 0 if bit 0x01 of Face Array Flag is not set. The first loop index of face $k, k \geq 1$ equals to the last loop index of face $k - 1$ plus 1. The last loop index of face $k, k \geq 1$ equals to the first loop index of face k plus element k of Index Difference Array, or 0 if bit 0x01 of Face Array Flag is not set.

Recover Surface Indices

The surface index of each face equals to the face index if bit 0x02 of Face Array Flag is not set. Otherwise the surface index of face k is obtained by substracting element $k + offset$ of Index Difference Array from face index k, where $offset$ is equal to Face Count if bit 0x01 of Face Array Flag is set and 0 if the bit is not set.

Recover Material Indices

The material index of each face equals to 0 if bit 0x04 of Face Array Flag is not set. Otherwise the material index of face k equals to the element $k + offset$ of Index Difference Array, where $offset$ is equal to twice of Face Count if both bit 0x01 and bit 0x02 of Face Array Flag are set, is equal to Face Count if either bit 0x01 or bit 0x02 of Face Array Flag is set, and is equal to 0 if neither bit is set.

VecI32{Int32CDP2, Combined:NULL}: Flag Bit Array

Only the lower 24 bits of the four integer indices, namely first loop index, last loop index, surface index, and material index, are used as integer identifiers. The other bits of these integers are either used to encode additional information, or reserved for future usage.

	24	25	26	27	28	29	30	31
First Loop Index	Surface Type			U Knot Type		V Knot Type		isNormalReversed
Last Loop Index	isIsolated	Reserved						
Surface Index	Reserved							
Material Index	Reserved							

Each element of Flag Bit Array is a 32 bit integer obtained by combining all 32 flag bits from four different integers. More specifically:

- Bits 0~7 of Flag Bit Array are equal to bits 24~31 of First Loop Index
- Bits 8~15 of Flag Bit Array are equal to bits 24~31 of Last Loop Index
- Bits 16~23 of Flag Bit Array are equal to bits 24~31 of Surface Index
- Bits 24~31 of Flag Bit Array are equal to bits 24~31 of Material Index

Supported Surface Type

In an uncompressed/decoded form, the supported surface types are listed below.

0	Nurbs
1	Plane
2	Cylinder
3	Cone
4	Sphere
5	Torus
6	Reserved
7	Reserved

Supported Knot Type

In an uncompressed/decoded form, the supported knot types are listed below. The knot type of the underlying surface along both U and V parameter directions are encoded.

0	No Pattern
1	No knot value in between the clamped end knots
2	All knot values in between the end knots increase with an even interval
3	All knot values in between the end knots repeat exactly once, and the distinct values increase with an even interval

In an uncompressed/decoded form, the Face Reverse Normal Flag has the following meaning:

= 0	Face normal is not reversed
= 1	Face normal is reversed.

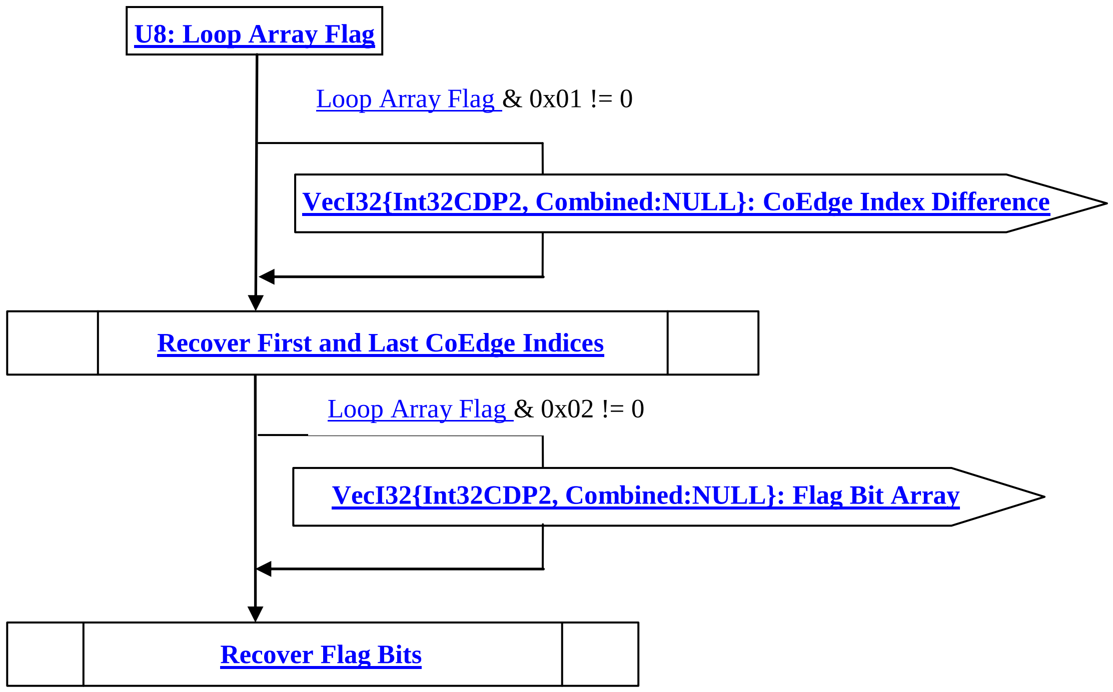
Recover Flag Bits

If Face Array Flag & 0x08 is equal to 0, then each element in Flag Bit Array is set to have value 0. The flag bits are recovered by assigning bits 0~7 of Flag Bit Array to bits 24~31 of First Loop Index, bits 8~15 of Flag Bit Array to bits 24~31 of Last Loop Index, bits 16~23 of Flag Bit Array to bits 24~31 of Surface Index, and bits 24~31 of Flag Bit Array to bits 24~31 of Material Index.

7.2.8.1.1.6 Loops Topology Data

A Loop (often called Trimming Loop) defines in parameter space a 1D boundary around which geometric surfaces are trimmed to form a Face. Loops Topology Data specifies the CoEdges making up each Loop along with an anti-hole flag and identifier tag for each Loop. The complete description of loop and its relation to the CoEdges can be found in 7.2.3.1.3.4 Loops Topology Data.

Figure 179: Loops Topology Data collection


U8: Loop Array Flag
Loop Array Flag & 0x01 != 0
VecI32{Int32CDP2, Combined:NULL}: CoEdge Index Difference
Recover First and Last CoEdge Indices
Loop Array Flag & 0x02 != 0
VecI32{Int32CDP2, Combined:NULL}: Flag Bit Array
Recover Flag Bits

U8: Loop Array Flag

Loop Array Flag indicates which arrays of loop topology data are not trivial and therefore encoded.

VecI32{Int32CDP2, Combined:NULL}: CoEdge Index Difference

CoEdge Index Difference is a vector of indices representing the integer value by subtracting first CoEdge index from last CoEdge index in each loop, encoded using Combined Predictor Type. CoEdge Index Difference is compressed and encoded using the Int32 version of second generation CODEC.

Recover First and Last CoEdge Indices

The first CoEdge index of the first loop is 0, and the last CoEdge index of the first loop is element 0 of CoEdge Index Difference. The first CoEdge index of loop $k, k \geq 1$ equals to the last CoEdge index of loop $k - 1$ plus 1. The last CoEdge index of loop $k, k \geq 1$ equals to the first CoEdge index of loop k plus element k of CoEdge Index Difference array.

VecI32{Int32CDP2, Combined:NULL}: Flag Bit Array

Only the lower 24 bits of the two integer indices, namely first CoEdge index and last CoEdge index are used as integer identifiers. The other bits of these integers are either used to encode additional information, or reserved for future usage.

	24	25	26	27	28	29	30	31
First CoEdge Index	Reserved							isAntiHoleLoop
Last CoEdge Index	Reserved							

Bits 0~7 of Flag Bit Array are equal to bits 24~31 of First CoEdge Index

Bits 8~15 of Flag Bit Array are equal to bits 24~31 of Last CoEdge Index

Bits 16~31 of Flag Bit Array are set to be 0

In an uncompressed/decoded form, the AntiHole Loop Flag has the following meaning:

= 0	Loop is not an anti-hole Loop
= 1	Loop is an anti-hole Loop

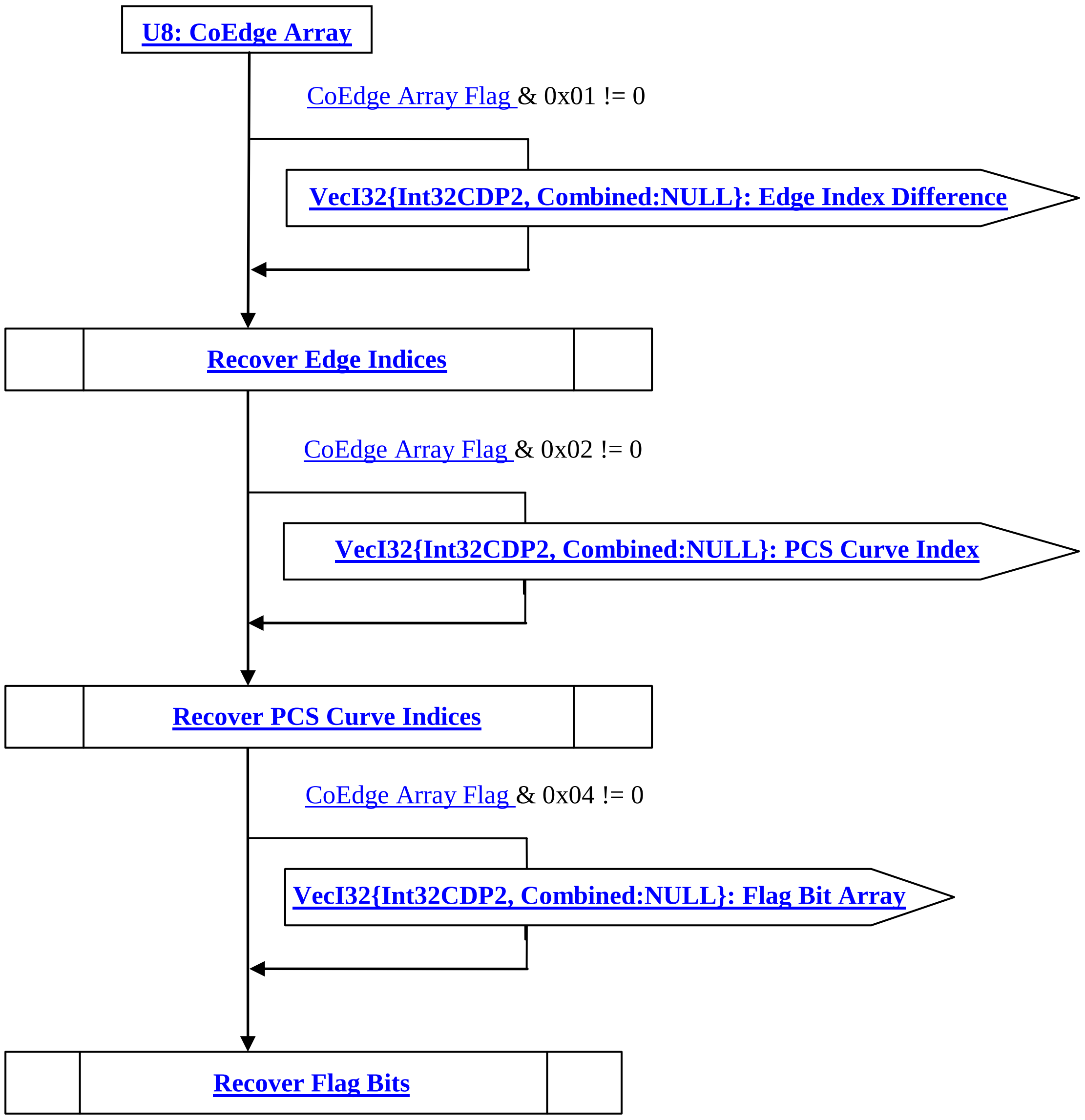
Recover Flag Bits

The flag bits are recovered by assigning bits 0~7 of Flag Bit Array to bits 24~31 of First CoEdge Index, and bits 8~15 of Flag Bit Array to bits 24~31 of Last CoEdge Index.

7.2.8.1.1.7 CoEdges Topology Data

A CoEdge defines a parameter space edge trim Loop segment (i.e. the projection of an Edge into the parameter space of the Face). CoEdges Topology Data specifies the underlying Edge and PCS Curve making up each CoEdge along with a MCS curve reversed flag and tag for each CoEdge. The complete description of CoEdge and its relation to the Edge can be found in 7.2.3.1.3.5 CoEdges Topology Data.

Figure 180: CoEdges Topology Data collection


U8: CoEdge Array
CoEdge Array Flag & 0x01 != 0
VecI32{Int32CDP2, Combined:NULL}: Edge Index Difference
Recover Edge Indices
CoEdge Array Flag & 0x02 != 0
VecI32{Int32CDP2, Combined:NULL}: PCS Curve Index
Recover PCS Curve Indices
CoEdge Array Flag & 0x04 != 0
VecI32{Int32CDP2, Combined:NULL}: Flag Bit Array
Recover Flag Bits

U8: CoEdge Array Flag

CoEdge Array Flag indicates which arrays of coedge topology data are not trivial and therefore encoded.

VecI32{Int32CDP2, Combined:NULL}: Edge Index Difference

Edge Index Difference is a vector of indices representing the integer value by subtracting the Edge index from the CoEdge index for each CoEdge, encoded using Combined Predictor Type. Edge Index Difference is compressed and encoded using the Int32 version of second generation CODEC.

Recover Edge Indices

If CoEdge Array Flag & 0x01 is equal to 0, then the Edge index of each CoEdge is equal to the CoEdge index. Otherwise, the Edge index of CoEdge with index k can be computed by substracting element k of Edge Index Difference array from k, the CoEdge index.

VecI32{Int32CDP2, Combined:NULL}: PCS Curve Index Difference

PCS Curve Index Difference is a vector of indices representing the integer value by subtracting the PCS Curve index from the CoEdge index for each CoEdge, encoded using Combined Predictor Type. PCS Curve Index Difference is compressed and encoded using the Int32 version of second generation CODEC.

Recover PCS Curve Indices

If CoEdge Array Flag & 0x02 is equal to 0, then the PCS Curve index of each CoEdge is equal to the CoEdge index. Otherwise, the PCS Curve index of CoEdge with index k can be computed by substracting element k of PCS Curve Index Difference array from k, the CoEdge index.

VecI32{Int32CDP2, Combined:NULL}: Flag Bit Array

Only the lower 24 bits of the two integer indices, namely Edge index and PCS Curve index, are used as integer identifiers. The other bits of these integers are either used to encode additional information, or reserved for future usage.

	24	25	26	27	28	29	30	31
Edge Index	Knot Type		Domain Type			PCS Curve Type		isXYZReversed
PCS Curve Index	isUvInc	Reserved						

Bits 0~7 of Flag Bit Array are equal to bits 24~31 of Edge Index

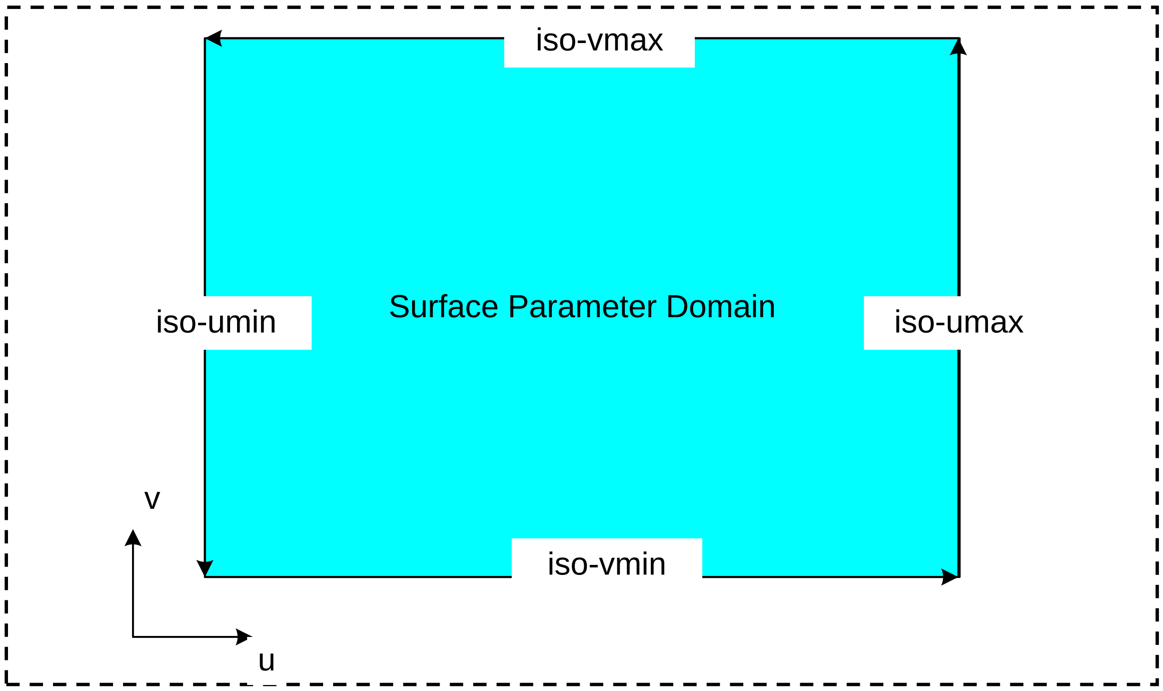
Bits 8~15 of Flag Bit Array are equal to bits 24~31 of PCS Curve Index

Bits 16~31 of Flag Bit Array are set to be 0

The Knot Type, defined in Supported Knot Type, is an integer with its value between 0 and 3.

Domain Type

Figure 181: Surface Domain Classification



In an uncompressed/decoded form, the supported PCS Curve types are listed below.

0	General
1	PCS curve is coincident with iso-umin curve in the surface parameter domain
2	PCS curve is coincident with iso-umax curve in the surface parameter domain
3	PCS curve is coincident with iso-vmin curve in the surface parameter domain
4	PCS curve is coincident with iso-vmax curve in the surface parameter domain
5	Reserved
6	Reserved
7	PCS curve is to be derived from MCS curve and surface geometry

PCS Curve Type

In an uncompressed/decoded form, the supported PCS Curve types are listed below.

0	Nurbs
1	Line
2	Circle
3	Reserved

In an uncompressed/decoded form, the XYZReversed Flag has the following meaning:

= 0	Directional sense of associated edges MCS curve should not be interpreted as opposite the direction its parameterization implies.

= 1	Directional sense of associated edges MCS curve should be interpreted as opposite the direction its parameterization implies.

In an uncompressed/decoded form, the isUVInc Flag has the following meaning:

= 0	PCS Curve is iso-parameteric in surface parameter domain in one direction and the parameter increases in the other direction
= 1	PCS Curve is iso-parameteric in surface parameter domain in one direction and the parameter decreases in the other direction

The isUVInc flag is set only if the Domain Type of this CoEdge has value between 1 and 4 inclusive.

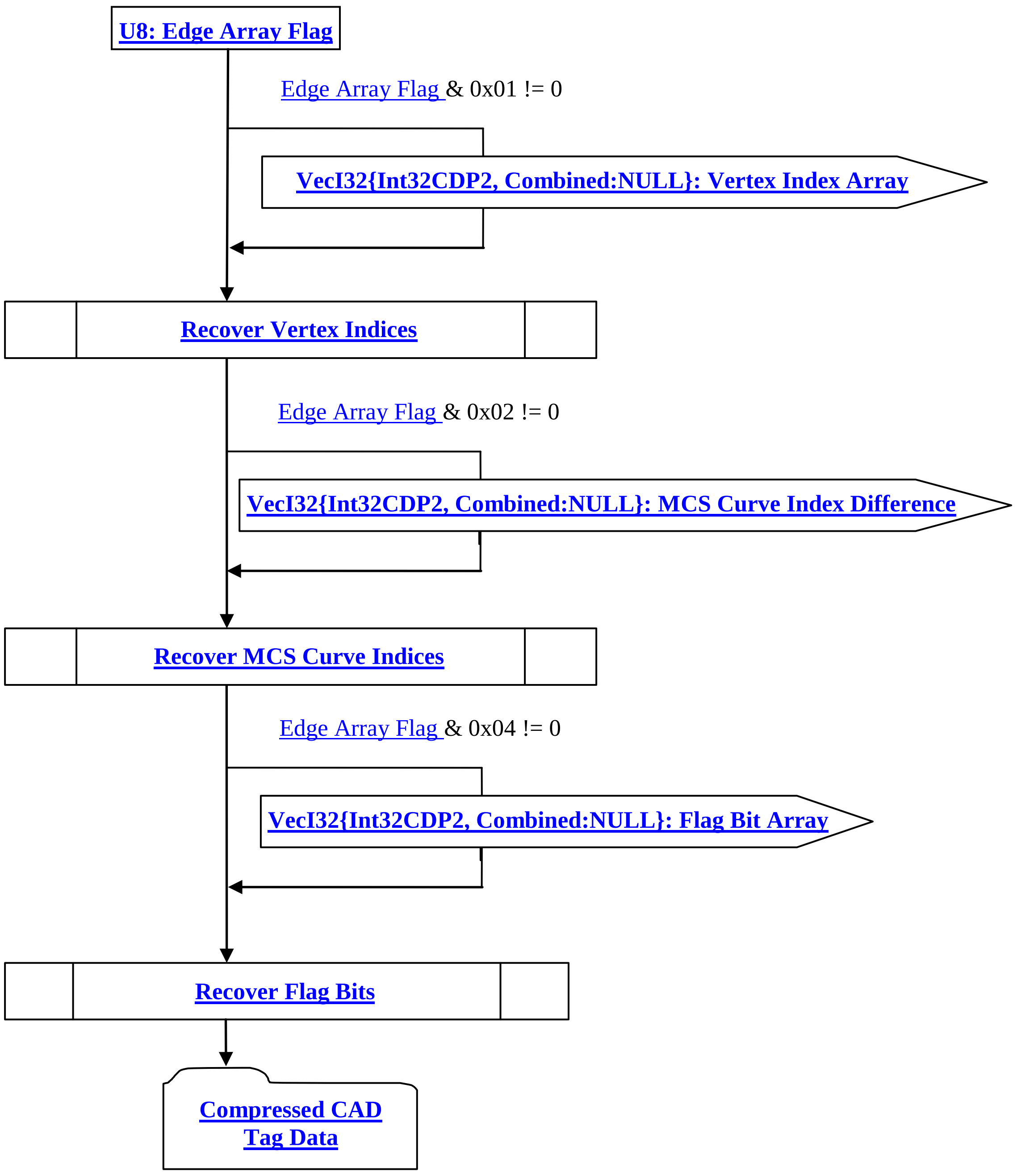
Recover Flag Bits

If CoEdge Array Flag & 0x04 is equal to 0, then each element in Flag Bit Array is set to have value 0. The flag bits are recovered by assigning bits 0~7 of Flag Bit Array to bits 24~31 of Edge Index, and bits 8~15 of Flag Bit Array to bits 24~31 of PCS Curve Index.

7.2.8.1.1.8 Edges Topology Data

An Edge defines a model space trim Loop segment. Edges Topology Data specifies the underlying MCS Curve and start and end Vertex making up each Edge along with an identification tag for each Edge. The complete description of Edge can be found in 7.2.3.1.3.6 Edges Topology Data.

Figure 182: Edges Topology Data collection


U8: Edge Array Flag
Edge Array Flag & 0x01 != 0
VecI32{Int32CDP2, Combined:NULL}: Vertex Index Array
Recover Vertex Indices
Edge Array Flag & 0x02 != 0
VecI32{Int32CDP2, Combined:NULL}: MCS Curve Index Difference
Recover MCS Curve Indices
Edge Array Flag & 0x04 != 0
VecI32{Int32CDP2, Combined:NULL}: Flag Bit Array
Recover Flag Bits
Compressed CAD Tag Data

U8: Edge Array Flag

Edge Array Flag indicates which arrays of edge topology data are not trivial and therefore encoded.

VecI32{Int32CDP2, Combined:NULL}: Vertex Index Array

Vertex Index Array is a vector of indices representing the start and end vertex indices of each Edge, encoded using Combined Predictor Type. Vertex Index Array is compressed and encoded using the Int32 version of second generation CODEC.

Recover Vertex Indices

If Edge Array Flag & 0x01 is equal to 0, then all the vertex indices of each edge are set to be 0. Otherwise, the start vertex index of Edge with index k is set to be equal to element $2 * k$ of Vertex Index Array, while the end vertex index of this Edge is set to be equal to element $2 * k + 1$ of Vertex Index Array.

VecI32{Int32CDP2, Combined:NULL}: MCS Curve Index Difference

MCS Curve Index Difference is a vector of indices representing the integer value by subtracting the MCS Curve index from the Edge index for each Edge, encoded using Combined Predictor Type. MCS Curve Index Difference is compressed and encoded using the Int32 version of second generation CODEC.

Recover MCS Curve Indices

If Edge Array Flag & 0x02 is equal to 0, then the MCS Curve index of each Edge is equal to the Edge index. Otherwise, the MCS Curve index of Edge with index k can be computed by substracting element k of MCS Curve Index Difference array from k, the Edge index.

VecI32{Int32CDP2, Combined:NULL}: Flag Bit Array

Only the lower 24 bits of the three integer indices, namely MCS Curve index, Start Vertex index, and End Vertex index, are used as integer identifiers. The other bits of these integers are either used to encode additional information, or reserved for future usage.

	24	25	26	27	28	29	30	31
MCS Curve Index	Knot Type		MCS Curve Type		Reserved			
Start Vertex Index	Reserved							
End Vertex Index	Reserved							

The Knot Type, defined in Supported Knot Type, is an integer with its value between 0 and 3.

MCS Curve Type

In an uncompressed/decoded form, the supported MCS Curve types are listed below.

0	Nurbs
1	Line
2	Circle
3	Projection: MCS curve geometry is to be computed from surface geometry and/or PCS curve geometry

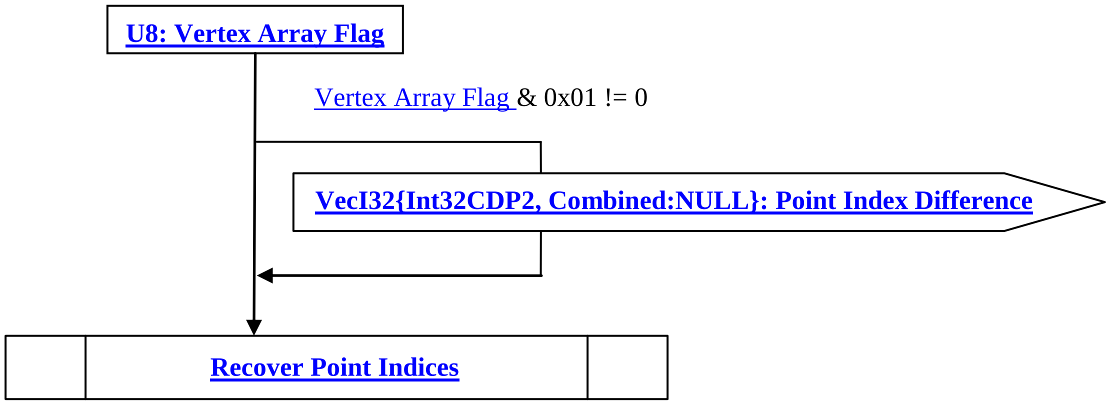
Recover Flag Bits

If Edge Array Flag & 0x04 is equal to 0, then each element in Flag Bit Array is set to have value 0. The flag bits are recovered by assigning bits 0~7 of Flag Bit Array to bits 24~31 of MCS Curve Index.

7.2.8.1.1.9 Vertices Topology Data

A Vertex is the simplest topological entity and is basically made up of a geometric Point. Vertices Topology Data specifies the underlying geometric Point making up each Vertex. A Vertex is usually shared/referenced by two or more Edges (e.g. if the corners of four rectangular Faces touches at a common point, this point is represented by a Vertex and is shared by four Edges).

Figure 183: Vertices Topology Data collection


U8: Vertex Array Flag
Vertex Array Flag & 0x01 != 0
VecI32{Int32CDP2, Combined:NULL}: Point Index Difference
Recover Point Indices

U8: Vertex Array Flag

Vertex Array Flag indicates which arrays of vertex topology data are not trivial and therefore encoded.

VecI32{Int32CDP2, Combined:NULL}: Point Index Difference

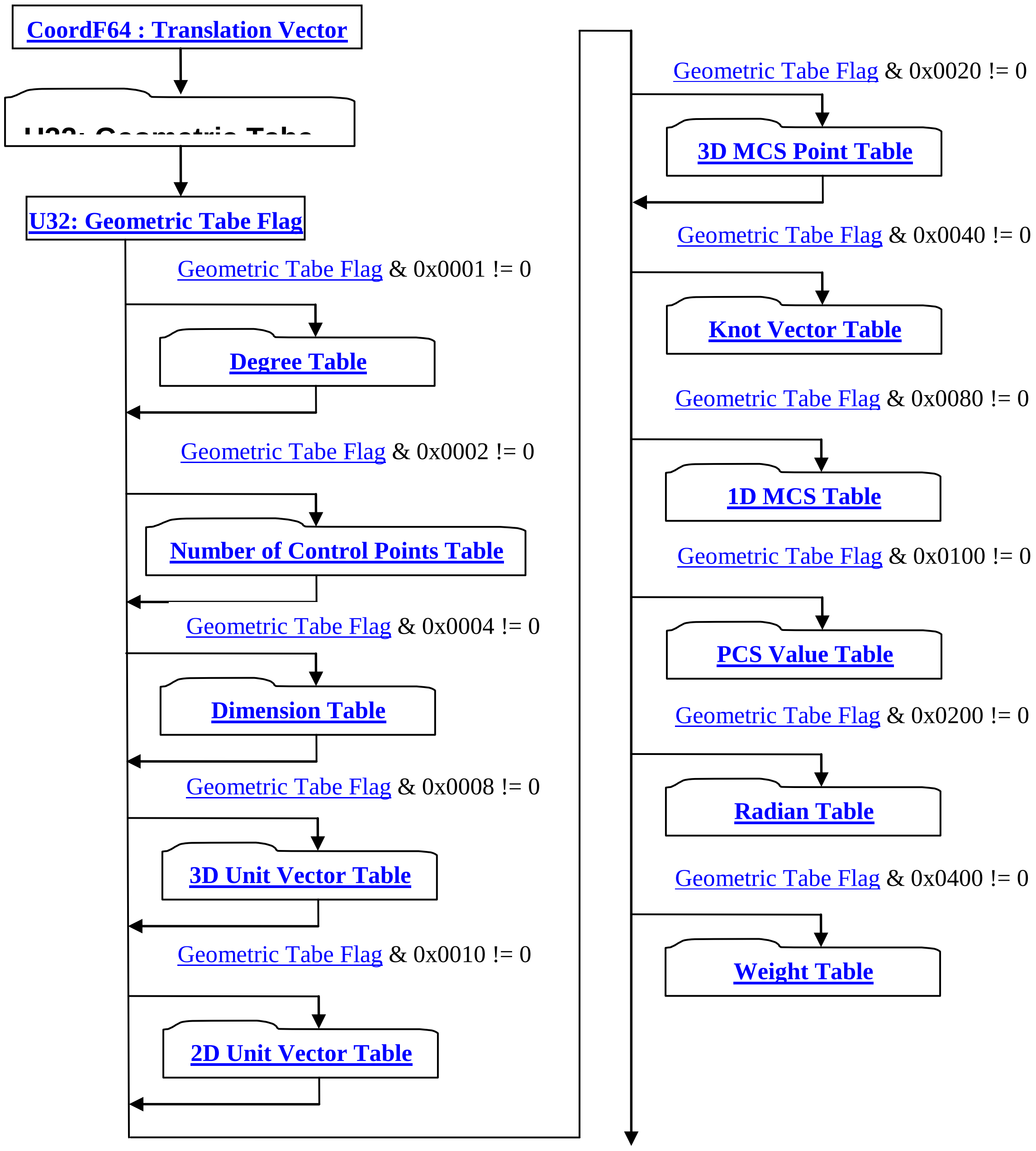
Point Index Difference is a vector of indices representing the integer value obtained by subtracting point index from vertex index, encoded using Combined Predictor Type. Point Index Difference is compressed and encoded using the Int32 version of second generation CODEC.

Recover Point Indices

If Vertex Array Flag & 0x01 is equal to 0, then the point index of each vertex is equal to the vertex index. Otherwise, the point index of vertex k is recovered by substrating element k of Point Index Difference array from k, the vertex index.

7.2.8.1.2 Geometric Data

Figure 184: Geometric Data collection



CoordF64 : Translation Vector
U32: Geometric Tabe
U32: Geometric Tabe Flag
Geometric Tabe Flag & 0x0001 != 0
Degree Table
Geometric Tabe Flag & 0x0002 != 0
Number of Control Points Table
Geometric Tabe Flag & 0x0004 != 0
Dimension Table
Geometric Tabe Flag & 0x0008 != 0
3D Unit Vector Table
Geometric Tabe Flag & 0x0010 != 0
2D Unit Vector Table
Geometric Tabe Flag & 0x0020 != 0
3D MCS Point Table
Geometric Tabe Flag & 0x0040 != 0
Knot Vector Table
Geometric Tabe Flag & 0x0080 != 0
1D MCS Table
Geometric Tabe Flag & 0x0100 != 0
PCS Value Table
Geometric Tabe Flag & 0x0200 != 0
Radian Table
Geometric Tabe Flag & 0x0400 != 0
Weight Table

CoordF64 : Translation Vector

Translation Vector is a 3-dimensional vector that represents how the ULP geometry is defined w.r.t. the original B-Rep definition from which ULP geometry is derived. If the Translation Vector is not zero vector, then the ULP geometry read from disk is translated from original B-Rep definition by the amount of Translation Vector. This is usually done by the JT writer implementation to improve numerical accuracy of floating point numbers in the ULP geometry. It is important for all the JT readers to take this Translation Vector into consideration when consuming ULP geometry. For example if a LOD is generated from ULP geometry, e.g. by tessellation, then the LOD geometry must be translated to undo the effect of

Translation Vector for it be consistent with the original B-Rep definition. In other words, if we denote the Translation Vector as v, then the LOD geometry from ULP must be translated by $-v$.

U32: Geometric Tabe Flag

Geometric Tabe Flag indicates which geometric tables are not trivial and therefore encoded.

7.2.8.1.2.1 Geometric Entity Counts

U32: Geometric Tabe Flag

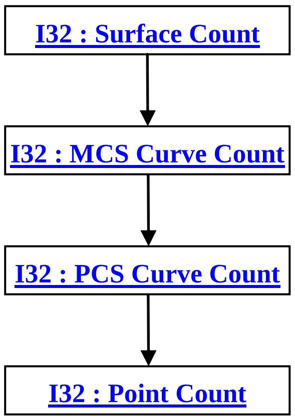
Geometric Tabe Flag indicates which geometric tables are not trivial and therefore encoded.

Geometric Entity Counts data collection defines the counts for each of the various geometric entities within a ULP.

Figure 185: U32: Geometric Tabe Flag

Geometric Tabe Flag indicates which geometric tables are not trivial and therefore encoded.

Geometric Entity Counts data collection



I32 : Surface Count

Surface Count indicates the number of distinct geometric surface entities in the ULP

I32 : MCS Curve Count

MCS Curve Count indicates the number of distinct geometric (Model Coordinate Space) curves (i.e. XYZ curve) entities in the ULP.

I32 : PCS Curve Count

PCS Curve Count indicates the number of distinct geometric Parameter Coordinate Space curves (i.e. UV curve) entities in the ULP

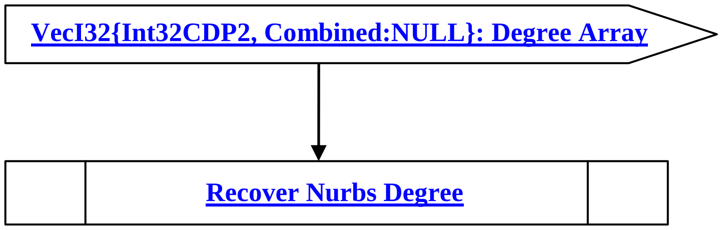
I32 : Point Count

Point Count indicates the number of distinct geometric point entities in the ULP.

7.2.8.1.2.2 Degree Table

Degree Table stores a vector of integers that represent the degree information of Nurbs surfaces and/or curves. If the ULP does not contain any Nurbs entity, then the table is empty and bit 0x0001 in Geometric Tabe Flag is set to be 0.

Figure 186: Degree Table data collection



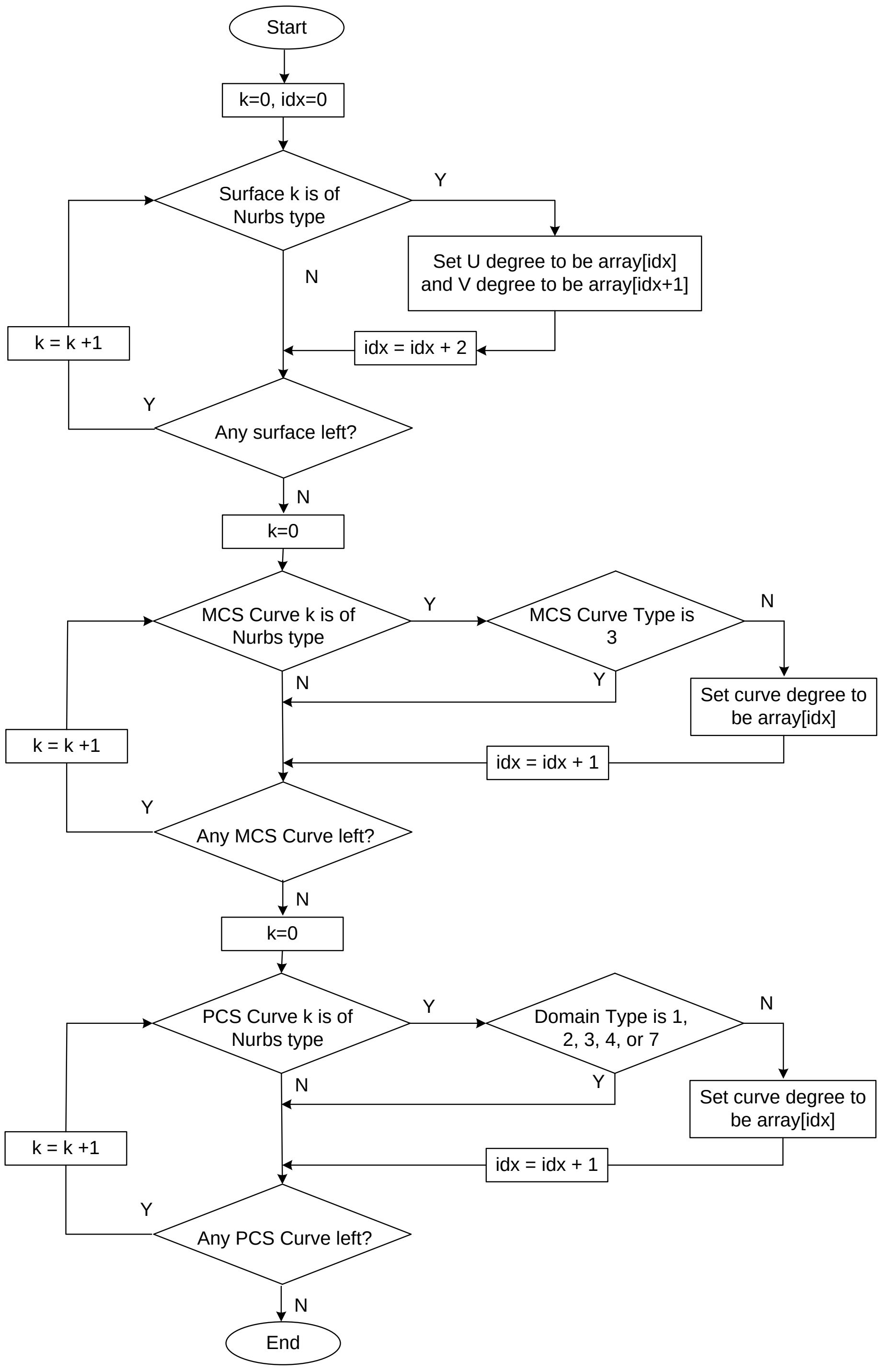
VecI32{Int32CDP2, Combined:NULL}: Degree Array

Degree Array is a vector of integers that stores the degree information for all the Nurbs entities in the ULP, encoded using Combined Predictor Type. Degree Array is compressed and encoded using the Int32 version of second generation CODEC.

Recover Nurbs Degree

The logic diagram to recover degree information for all the Nurbs entities in the ULP from the Degree Array is shown below.

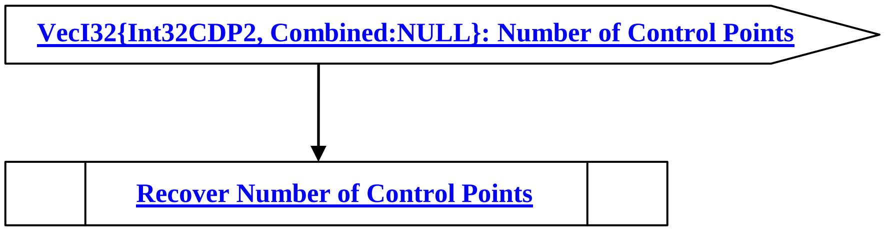
Figure 187: Recover Nurbs Degree


Start
k=0, idx=0
Surface k is of Nurbs type
Y
Set U degree to be array[idx] and V degree to be array[idx+1]
N
k = k +1
idx = idx + 2
Y
Any surface left?
N
k=0
MCS Curve k is of Nurbs type
Y
MCS Curve Type is 3
N
Y
N
Set curve degree to be array[idx]
k = k +1
idx = idx + 1
Y
Any MCS Curve left?
N
k=0
PCS Curve k is of Nurbs type
Y
Domain Type is 1, 2, 3, 4, or 7
N
Y
N
Set curve degree to be array[idx]
k = k +1
idx = idx + 1
Y
Any PCS Curve left?
N
End

7.2.8.1.2.3 Number of Control Points Table

Number of Control Points Table stores a vector of integers that represent the number of control points information of Nurbs surfaces and/or curves. If the ULP does not contain any Nurbs entity, then the table is empty and bit 0x0002 in Geometric Tabe Flag is set to be 0.

Figure 188: Number of Control Points Table data collection


VecI32{Int32CDP2, Combined:NULL}: Number of Control Points
Recover Number of Control Points

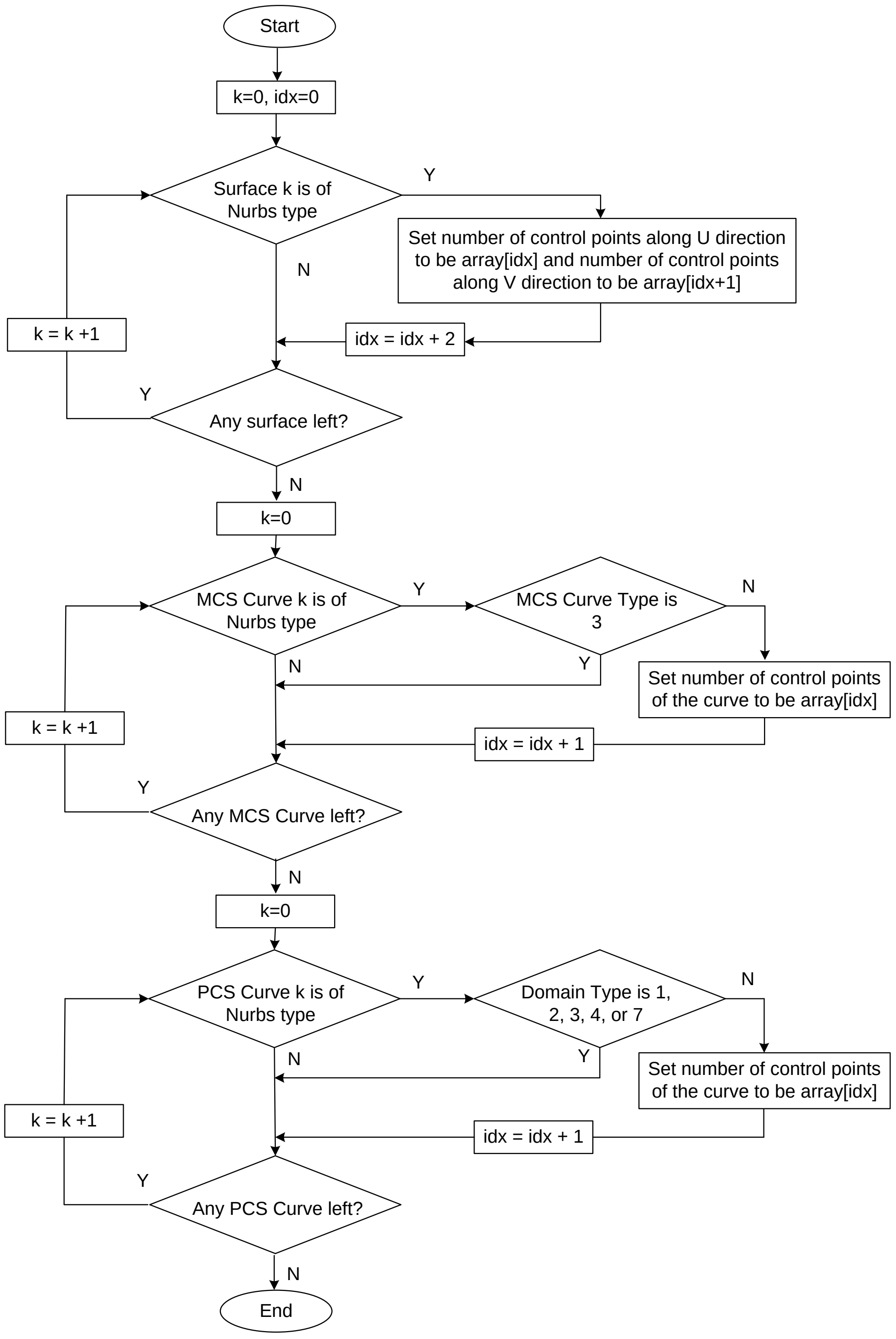
VecI32{Int32CDP2, Combined:NULL}: Number of Control Points Array

Number of Control Points Array is a vector of integers that stores the number of control points information for all the Nurbs entities in the ULP, encoded using Combined Predictor Type. Number of Control Points Array is compressed and encoded using the Int32 version of second generation CODEC.

Recover Number of Control Points

The logic diagram to recover number of control points information for all the Nurbs entities in the ULP from the Number of Control Points Array is shown below.

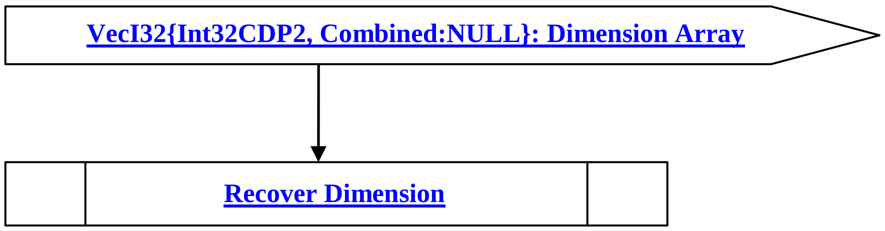
Figure 189: Recover Number of Control Points


Start
k=0, idx=0
Surface k is of Nurbs type
Y
N
Set number of control points along U direction to be array[idx] and number of control points along V direction to be array[idx+1]
k = k +1
idx = idx + 2
Y
Any surface left?
N
k=0
MCS Curve k is of Nurbs type
Y
MCS Curve Type is 3
N
N
Y
Set number of control points of the curve to be array[idx]
k = k +1
idx = idx + 1
Y
Any MCS Curve left?
N
k=0
PCS Curve k is of Nurbs type
Y
Domain Type is 1, 2, 3, 4, or 7
N
N
Y
Set number of control points of the curve to be array[idx]
k = k +1
idx = idx + 1
Y
Any PCS Curve left?
N
End

7.2.8.1.2.4Dimension Table

Dimension Table stores a vector of integers that represent the dimension information of Nurbs surfaces and/or curves. If the ULP does not contain any Nurbs entity, then the table is empty and bit 0x0004 in Geometric Tabe Flag is set to be 0.

Figure 190: Dimension Table data collection



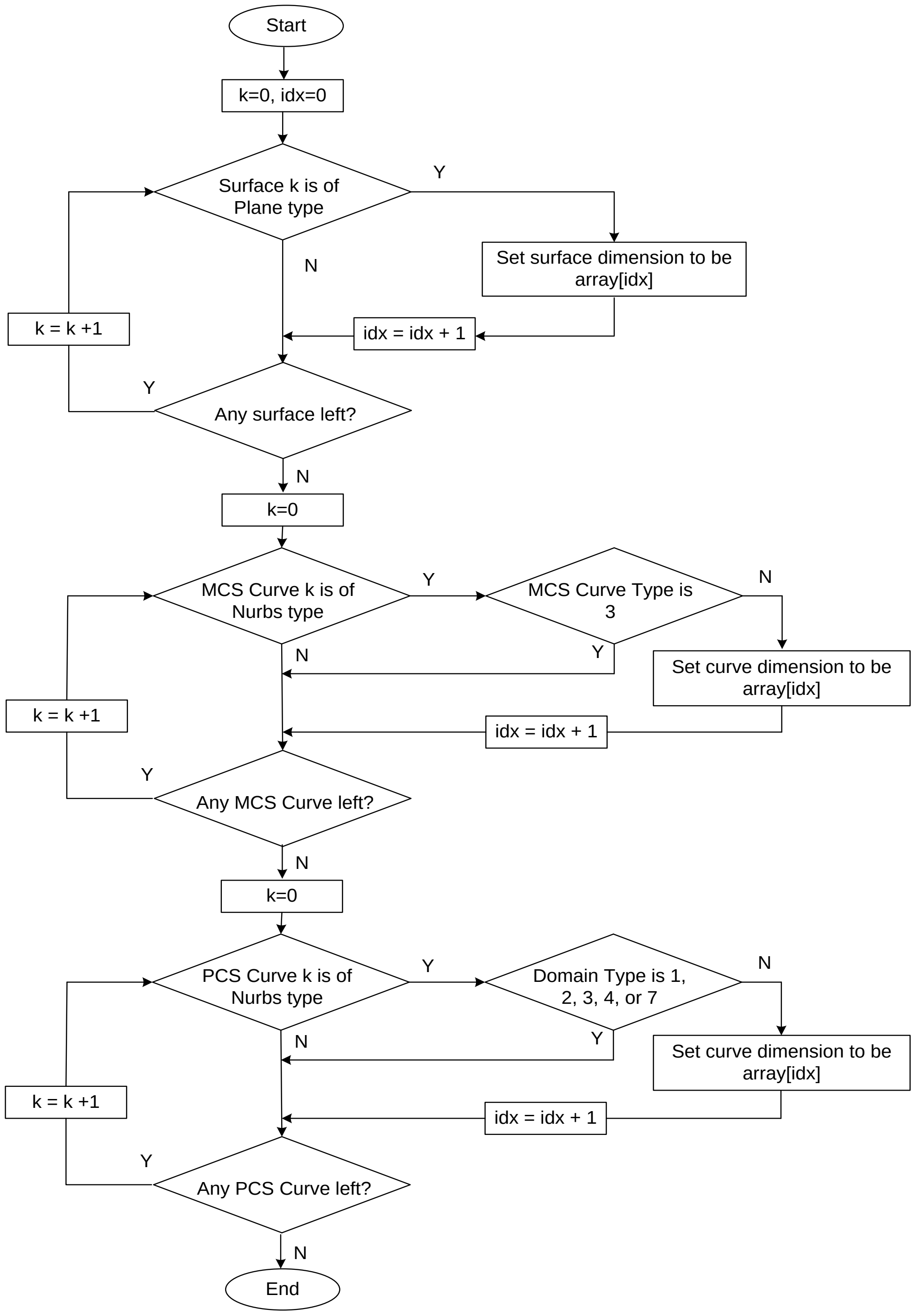
VecI32{Int32CDP2, Combined:NULL}: Dimension Array

Dimension Array is a vector of integers that stores the dimension information for all the Nurbs entities in the ULP, encoded using Combined Predictor Type. Dimension Array is compressed and encoded using the Int32 version of second generation CODEC.

Recover Dimension

The logic diagram to recover dimension information for all the Nurbs entities in the ULP from the Dimension Array is shown below.

Figure 191: Recover Dimension

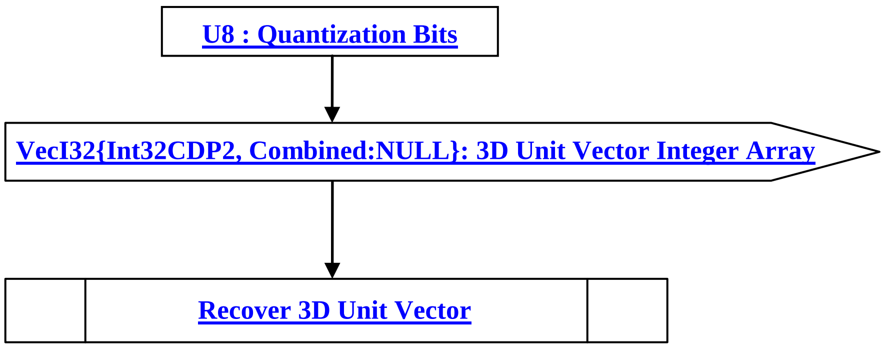

Start
k=0, idx=0
Surface k is of Plane type
Y
Set surface dimension to be array[idx]
N
k = k +1
idx = idx + 1
Y
Any surface left?
N
k=0
MCS Curve k is of Nurbs type
Y
MCS Curve Type is 3
N
Y
N
Set curve dimension to be array[idx]
k = k +1
idx = idx + 1
Y
Any MCS Curve left?
N
k=0
PCS Curve k is of Nurbs type
Y
Domain Type is 1, 2, 3, 4, or 7
N
Y
N
Set curve dimension to be array[idx]
k = k +1
idx = idx + 1
Y
Any PCS Curve left?
N
End

7.2.8.1.2.53D Unit Vector Table

3D Unit Vector Table stores an array of unit vectors in 3D that form part of the analytic surface or curve representation in ULP. If the ULP does not contain any analytic entity, then the table is empty and bit 0x0008 in Geometric Tabe Flag is set to be 0. The supported analytic surface types include plane, cylinder, cone, sphere, and torus, and the supported analytic curve types include line and circle for both parameter space and model space curves. The analytic representation of ULP follows Parasolid convention as detailed in Appendix F: Parasolid XT Format Reference.

Similar to the coding of 8.1.5 Compressed Vertex Normal Array, each 3D unit vector is encoded as a single 32 bit integer using 8.2.4 Deering Normal CODEC.

Figure 192: 3D Unit Vector Table data collection


U8 : Quantization Bits
VecI32{Int32CDP2, Combined:NULL}: 3D Unit Vector Integer Array
Recover 3D Unit Vector

U8 : Quantization Bits

The number of bits used for the Deering Normal CODEC if quantization is enabled. A value of 0 denotes that quantization is disabled.

VecI32{Int32CDP2, Combined:NULL}: 3D Unit Vector Integer Array

3D Unit Vector Integer Array is a vector of integers that stores the encoded 3D unit vector from all analytic entities in the ULP, encoded using Combined Predictor Type. 3D Unit Vector Integer Array is compressed and encoded using the Int32 version of second generation CODEC.

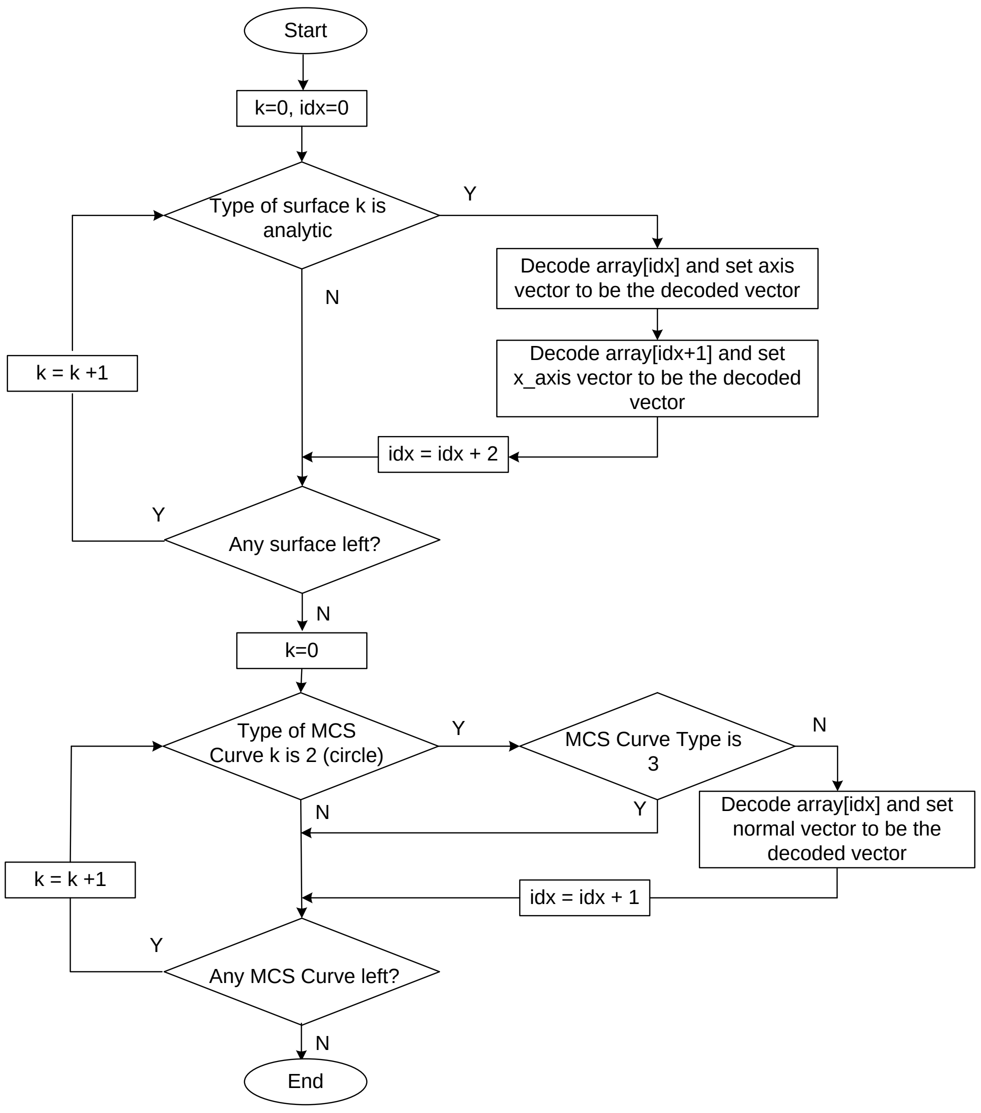
Recover 3D Unit Vector

The logic diagram to recover 3D unit vector information for all the analytic entities in the ULP from the 3D Unit Vector Integer Array is shown below.

The recovery of a unit vector from an element in the 3D Unit Vector Integer Array is done as part of Deering Normal CODEC.

As described in Appendix F: Parasolid XT Format Reference, the representation of an analytic surface of types plane, cylinder, cone, sphere, or torus, includes two 3D unit vectors. One is called “axis” and the other is called “x_axis”. These two unit vectors of each analytic surface are recovered for each analytic surface. In addition, the “normal” vector to the plane containing a 3D circle is also recovered.

Figure 193: Recover Dimension

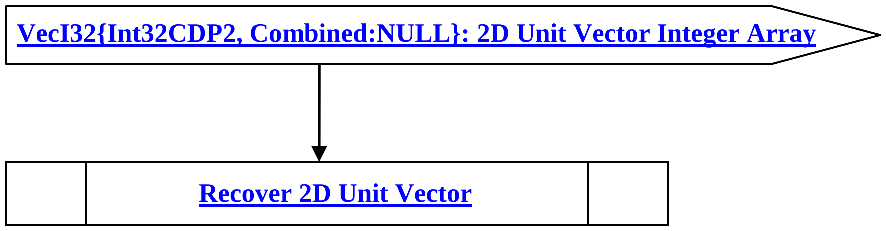

Start
k=0, idx=0
Type of surface k is analytic
Y
N
Decode array[idx] and set axis vector to be the decoded vector
Decode array[idx+1] and set x_axis vector to be the decoded vector
k = k +1
idx = idx + 2
Y
Any surface left?
N
k=0
Type of MCS Curve k is 2 (circle)
Y
MCS Curve Type is 3
N
Decode array[idx] and set normal vector to be the decoded vector
N
Y
k = k +1
idx = idx + 1
Y
Any MCS Curve left?
N
End

7.2.8.1.2.62D Unit Vector Table

2D Unit Vector Table stores an array of unit vectors in 2D that form part of PCS analytic circle representation in ULP. If the ULP does not contain any analytic circle in the PCS, then the table is empty and bit 0x0010 in Geometric Tabe Flag is set to be 0. The analytic curve representation of ULP follows Parasolid convention as detailed in Appendix F: Parasolid XT Format Reference.

Similar to the coding of 8.1.5 Compressed Vertex Normal Array, each 2D unit vector is treated as a 3D unit vector with z component set to be 0.0, and encoded as a single 32 bit integer using 8.2.4 Deering Normal CODEC. In addition, the Quantization Bits information of Deering Normal CODEC used to encode 2D Unit Vector Table is always the same as the one used for 3D Unit Vector Table.

Figure 194: 2D Unit Vector Table data collection


VecI32{Int32CDP2, Combined:NULL}: 2D Unit Vector Integer Array
Recover 2D Unit Vector

VecI32{Int32CDP2, Combined:NULL}: 2D Unit Vector Integer Array

2D Unit Vector Integer Array is a vector of integers that stores the encoded 2D unit vector from all analytic entities in the ULP.

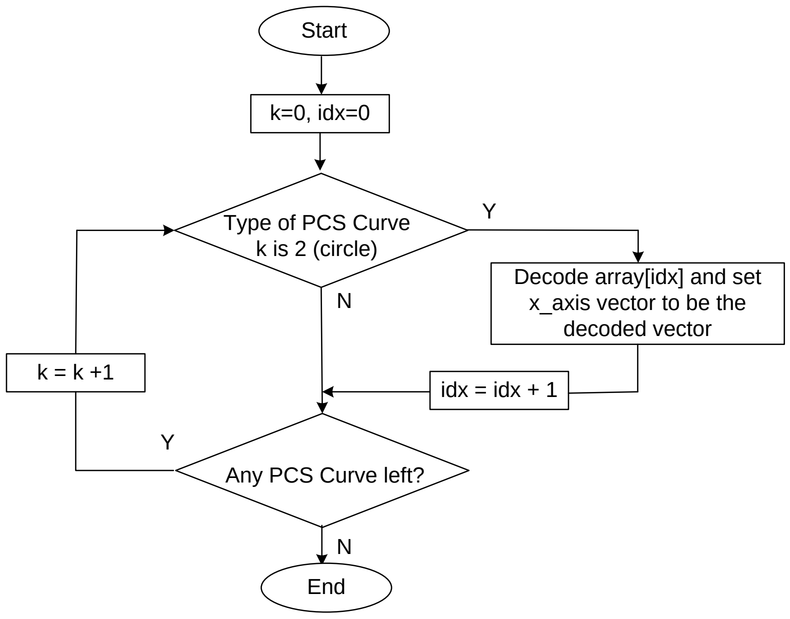
Recover 2D Unit Vector

The logic diagram to recover 2D unit vector information for all the analytic entities in the ULP from the 2D Unit Vector Integer Array is shown below.

The recovery of a unit vector from an element in the 2D Unit Vector Integer Array is done as part of Deering Normal CODEC. The Quantization Bits read from 3D Unit Vector Table should be used for Deering Normal CODEC to decode the vector information from each element in 2D Unit Vector Integer Array.

The "x_axis" vector to the circle in the PCS, as described in Appendix F: Parasolid XT Format Reference, is recovered.

Figure 195: Recover 2D Unit Vector

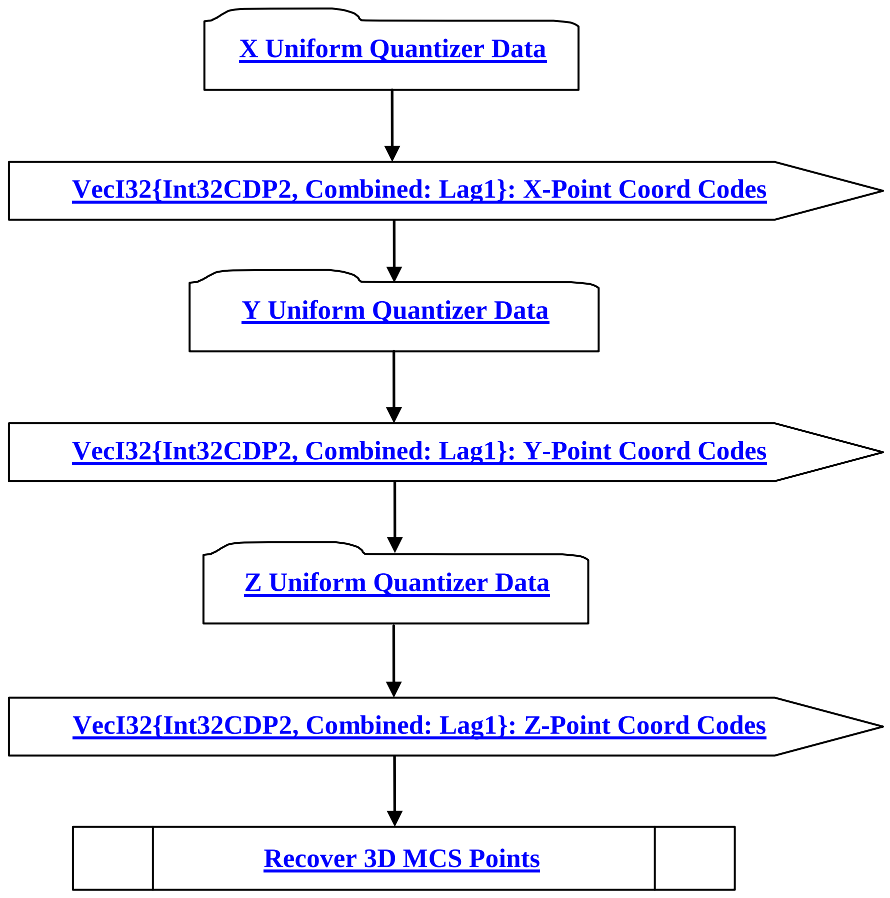

Start
k=0, idx=0
Type of PCS Curve k is 2 (circle)
Y
Decode array[idx] and set x_axis vector to be the decoded vector
N
k = k +1
idx = idx + 1
Y
Any PCS Curve left?
N
End

7.2.8.1.2.7 3D MCS Point Table

3D MCS Point Table stores the quantization representation of an array of 3D MCS points in ULP. If the ULP does not contain 3D MCS points, then the table is empty and bit 0x0020 in Geometric Tabe Flag is set to be 0.

Each point coordinate is first encoded into an integer with uniform quantizer (see 8.1.12 Uniform Quantizer Data) and then all the integers from each coordinate are grouped into an integer array, which is then encoded using the Int32 version of second generation CODEC with Combined Predictor Type.

Figure 196: 3D MCS Point Table data collection


X Uniform Quantizer Data
VecI32{Int32CDP2, Combined: Lag1}: X-Point Coord Codes
Y Uniform Quantizer Data
VecI32{Int32CDP2, Combined: Lag1}: Y-Point Coord Codes
Z Uniform Quantizer Data
VecI32{Int32CDP2, Combined: Lag1}: Z-Point Coord Codes
Recover 3D MCS Points

VecI32{Int32CDP2, Combined: Lag1}: X-Point Coord Codes

X-Point Coord Codes is a vector of quantizer "codes" for all the X-components of an array of point coordinates. X-Point Coord Codes uses the Int32 version of the second generation CODEC to compress and encode data.

VecI32{Int32CDP2, Combined: Lag1}: Y-Point Coord Codes

Y-Point Coord Codes is a vector of quantizer "codes" for all the Y-components of an array of point coordinates. Y-Point Coord Codes uses the Int32 version of the second generation CODEC to compress and encode data.

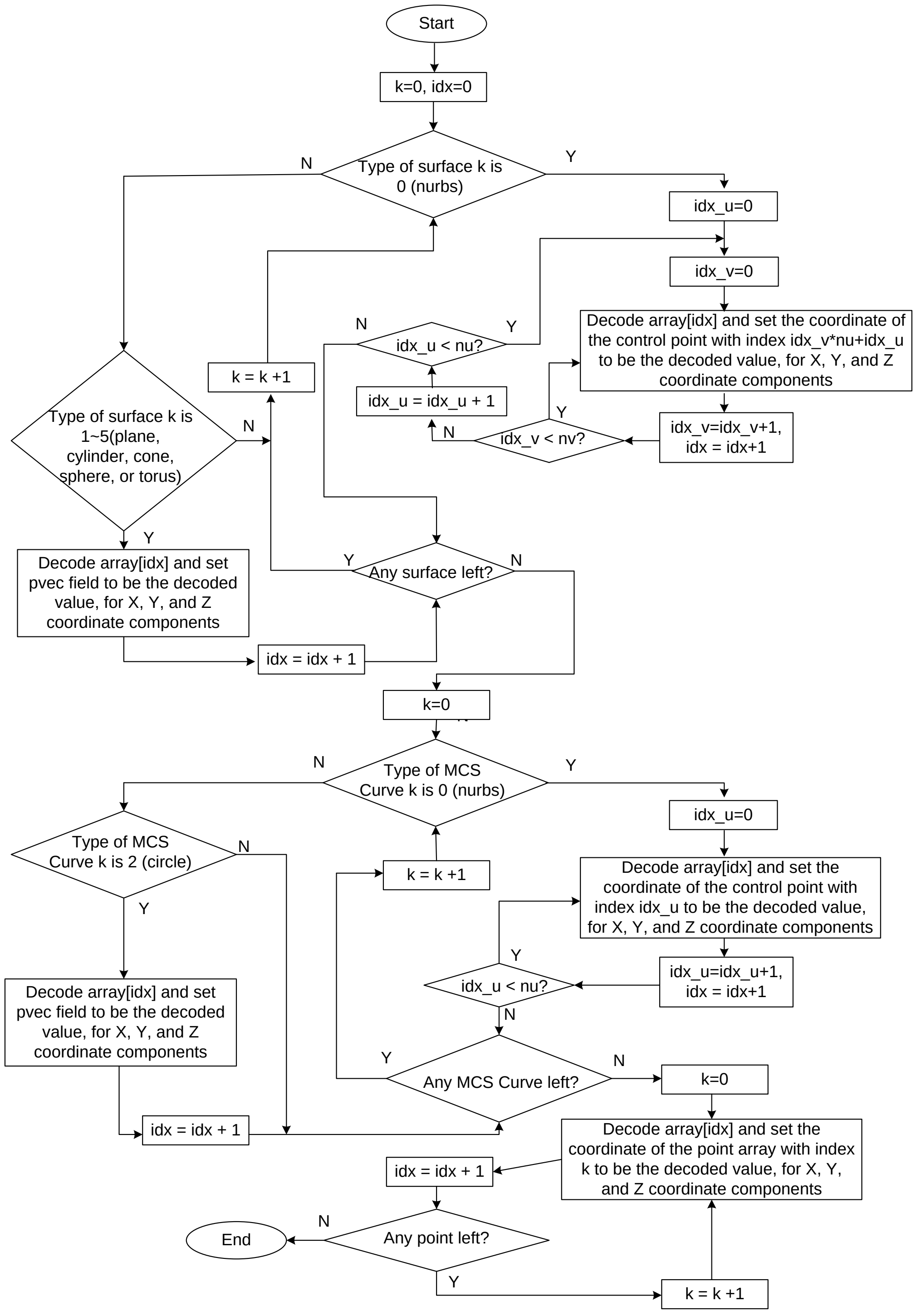
VecI32{Int32CDP2, Combined: Lag1}: Z-Point Coord Codes

Z-Point Coord Codes is a vector of quantizer "codes" for all the Z-components of an array of point coordinates. Z-Point Coord Codes uses the Int32 version of the second generation CODEC to compress and encode data.

Recover 3D MCS Points

The logic diagram to recover 3D MCS points information in the ULP from the three arrays, X-Point Coord Codes, Y-Point Coord Codes, and Z-Point Coord Codes, is shown below. Note that the point coordinates are decoded from the integer elements with Uniform Quantizer (see 8.1.12 Uniform Quantizer Data).

Figure 197: Recover 3D MCS Points

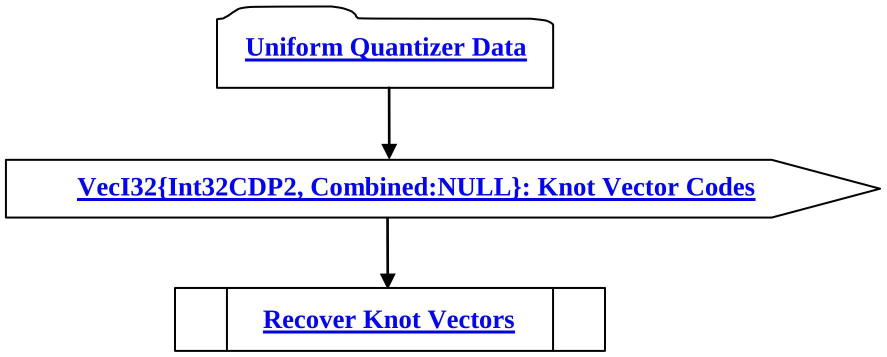

Start
k=0, idx=0
Type of surface k is 0 (nurbs)
N
Y
idx_u=0
idx_v=0
Decode array[idx] and set the coordinate of the control point with index idx_v*nu+idx_u to be the decoded value, for X, Y, and Z coordinate components
idx_u < nu?
N
Y
k = k +1
idx_u = idx_u + 1
idx_v < nv?
N
Y
idx_v=idx_v+1, idx = idx+1
Type of surface k is 1~5(plane, cylinder, cone, sphere, or torus)
N
Y
Decode array[idx] and set pvec field to be the decoded value, for X, Y, and Z coordinate components
Any surface left?
Y
N
idx = idx + 1
k=0
Type of MCS Curve k is 0 (nurbs)
N
Y
idx_u=0
Type of MCS Curve k is 2 (circle)
N
Y
k = k +1
Decode array[idx] and set the coordinate of the control point with index idx_u to be the decoded value, for X, Y, and Z coordinate components
idx_u < nu?
Y
N
idx_u=idx_u+1, idx = idx+1
Decode array[idx] and set pvec field to be the decoded value, for X, Y, and Z coordinate components
Any MCS Curve left?
Y
N
k=0
idx = idx + 1
Decode array[idx] and set the coordinate of the point array with index k to be the decoded value, for X, Y, and Z coordinate components
idx = idx + 1
End
Any point left?
N
Y
k = k +1

7.2.8.1.2.8 Knot Vector Table

Knot Vector Table stores the quantization representation of knot vectors in ULP. If the ULP does not contain any knot vector that needs be stored, then the table is empty and bit 0x0040 in Geometric Tabe Flag is set to be 0.

In ULP every knot vector starts with 0.0 and ends with 1.0 and is always clamped at both ends. The encoding of knot vector depends on its classified knot type. The knot values in the middle of a knot vector need be written only if the knot type is 0 (see Supported Knot Type). For all the knot values that need be written, each of them is encoded into an integer with uniform quantizer (see 8.1.12 Uniform Quantizer Data) and then all the integers are grouped into an integer array. The integer array is then encoded using the Int32 version of second generation CODEC with Combined Predictor Type.

Figure 198: Knot Vector Table data collection



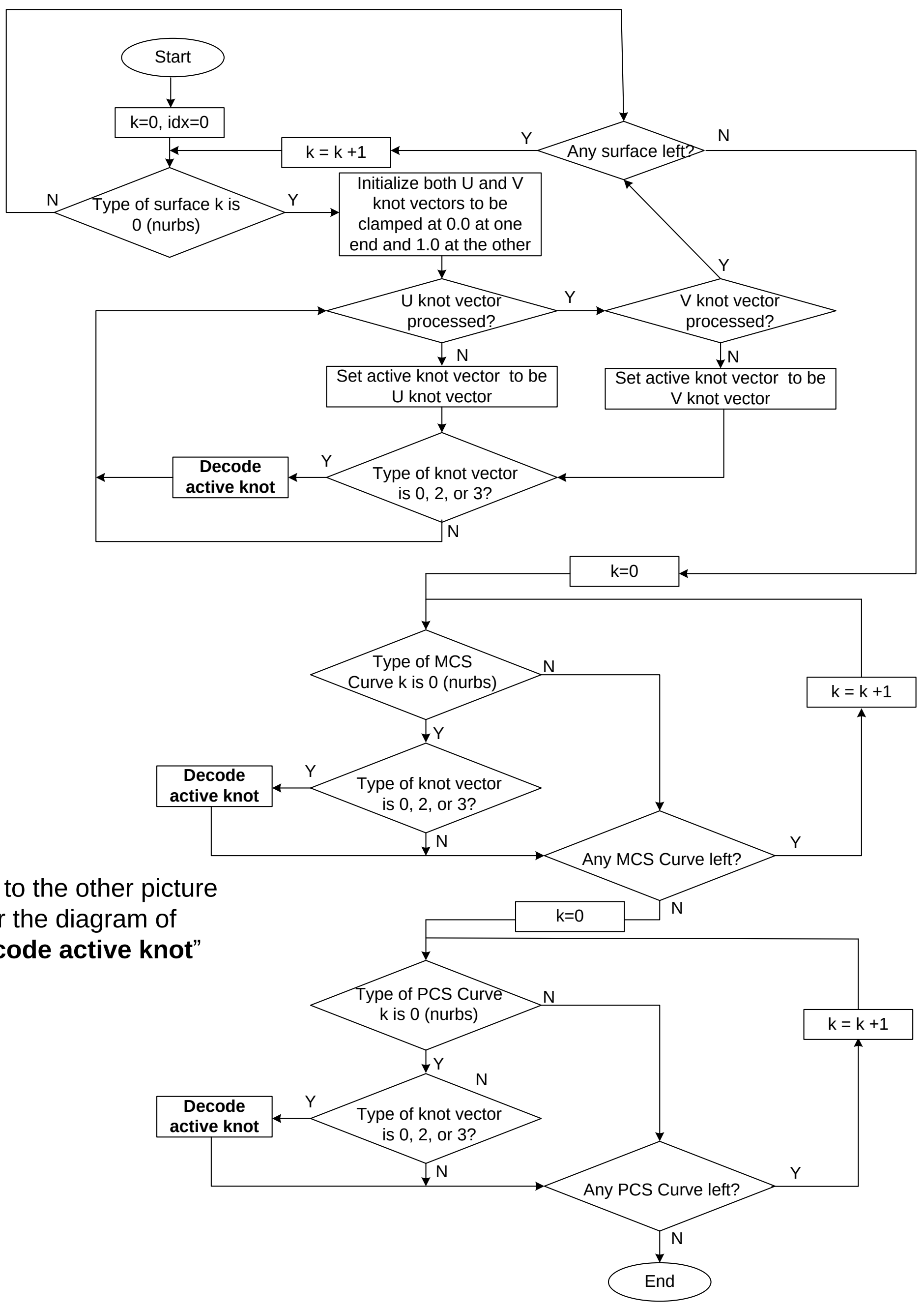
VecI32{Int32CDP2, Combined:NULL}: Knot Vector Codes

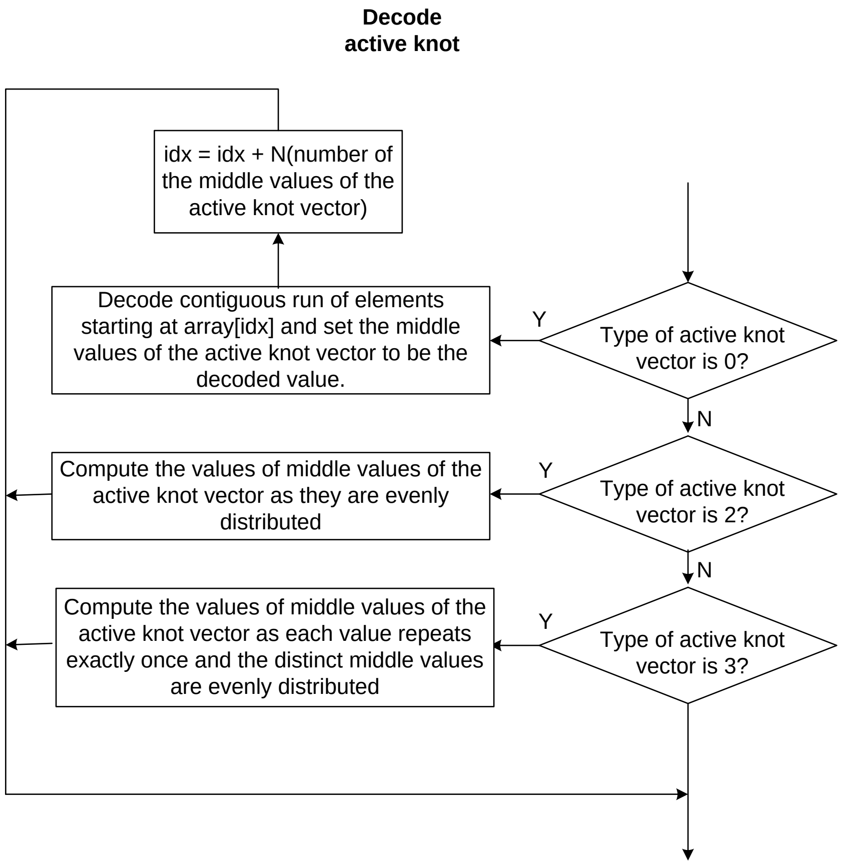
Knot Vector Codes is a vector of quantizer "codes" for all the knot vectors. Knot Vector Codes uses the Int32 version of the second generation CODEC with Combined Predictor Type to compress and encode data.

Recover Knot Vectors

The logic diagram to recover knot vector information in the ULP from the Knot Vector Codes is shown below. Note that each integer element in the Knot Vector Codes array is decoded with Uniform Quantizer.

Figure 199: Recover Knot Vectors

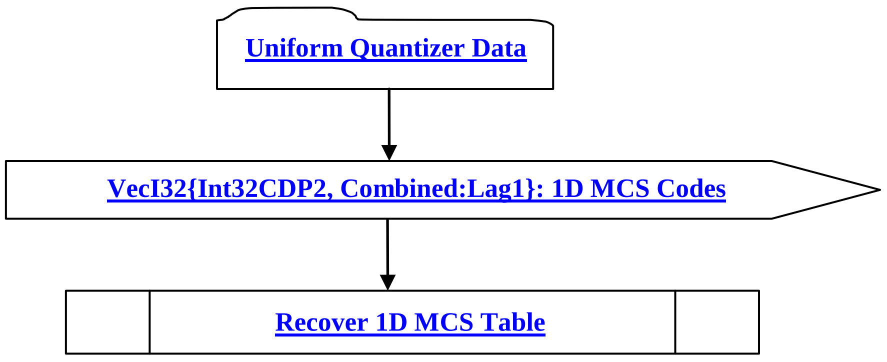

Start
k=0, idx=0
k = k +1
Any surface left?
Y
N
Type of surface k is 0 (nurbs)
N
Y
Initialize both U and V knot vectors to be clamped at 0.0 at one end and 1.0 at the other
U knot vector processed?
Y
V knot vector processed?
Y
N
N
Set active knot vector to be U knot vector
Set active knot vector to be V knot vector
Decode active knot
Y
Type of knot vector is 0, 2, or 3?
N
k=0
Type of MCS Curve k is 0 (nurbs)
N
k = k +1
Y
Decode active knot
Y
Type of knot vector is 0, 2, or 3?
N
Any MCS Curve left?
Y
N
Refer to the other picture for the diagram of "Decode active knot"
k=0
Type of PCS Curve k is 0 (nurbs)
N
k = k +1
Y
N
Decode active knot
Y
Type of knot vector is 0, 2, or 3?
N
Any PCS Curve left?
Y
N
End


Decode
active knot
idx = idx + N(number of the middle values of the active knot vector)
Decode contiguous run of elements starting at array[idx] and set the middle values of the active knot vector to be the decoded value.
Y
Type of active knot vector is 0?
N
Compute the values of middle values of the active knot vector as they are evenly distributed
Y
Type of active knot vector is 2?
N
Compute the values of middle values of the active knot vector as each value repeats exactly once and the distinct middle values are evenly distributed
Y
Type of active knot vector is 3?

7.2.8.1.2.91D MCS Table

1D MCS Table stores the quantization representation of floating point values in MCS. If the ULP does not contain any such value, then the table is empty and bit 0x0080 in Geometric Tabe Flag is set to be 0. Each floating point value is encoded into an integer with uniform quantizer (see 8.1.12 Uniform Quantizer Data) and then all the integers are grouped into an integer array. The integer array is then encoded using the Int32 version of second generation CODEC with Combined Predictor Type.

Figure 200: 1D MCS Table data collection



VecI32{Int32CDP2, Combined:Lag1}: 1D MCS Codes

1D MCS Codes is a vector of quantizer "codes" for all the 1D floating point values in MCS . 1D MCS Codes uses the Int32 version of the second generation CODEC with Combined Predictor Type to compress and encode data.

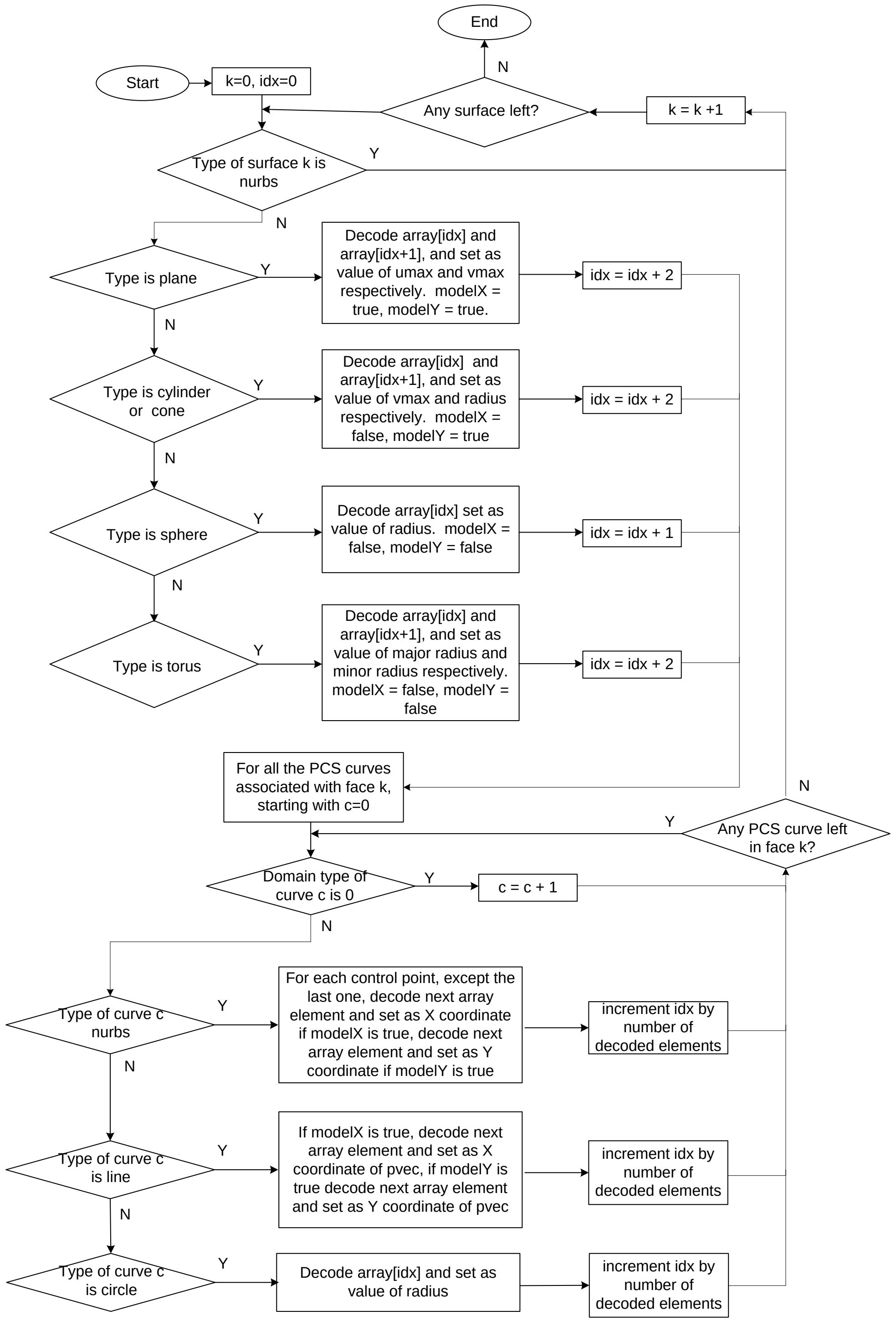
Recover 1D MCS Table

The representation of each surface or curve in ULP includes information that describes the extent of the surface or curve in the parameter domain. For curves the extent information is represented by two numbers, umin and umax, while for surfaces it is represented by two additional numbers for the other parametric direction, vmin and vmax. For surfaces or curves of NURBS type such extent information is implied by the knot vector information. For surfaces or curves of other types the extent information needs be read from 1D MCS Table if the parameter value represents value in MCS, or Radian Table if the parameter value represents angle information. The detailed information about how the parameter domain information of different entities should be read is listed in Table 8.

Table 8: Parameter Domain

Entity Type	umin	umax	vmin	vmax
NURBS Surface	n/a (from knot)	n/a (from knot))	n/a (from knot)	n/a (from knot)
Plane	n/a (always 0)	1D MCS Table	n/a (always 0)	1D MCS Table
Cylinder	n/a (always 0)	Radian Table	n/a (always 0)	1D MCS Table
Cone	n/a (always 0)	Radian Table	n/a (always 0)	1D MCS Table
Sphere	n/a (always 0)	Radian Table	Radian Table	Radian Table
Torus	n/a (always 0)	Radian Table	Radian Table	Radian Table
XYZ NURBS Curve	n/a (from knot)	n/a (from knot)	n/a	n/a
XYZ Line	n/a (always 0)	n/a (from vertex geometry)	n/a	n/a
XYZ Circle	n/a (always 0)	Radian Table	n/a	n/a
UV NURBS Curve	n/a (from knot)	n/a (from knot)	n/a	n/a
UV Line	n/a (always 0)	n/a (from next uv curve)	n/a	n/a
UV Circle	Radian Table	Radian Table	n/a	n/a

Figure 201: Recover 1D MCS Table

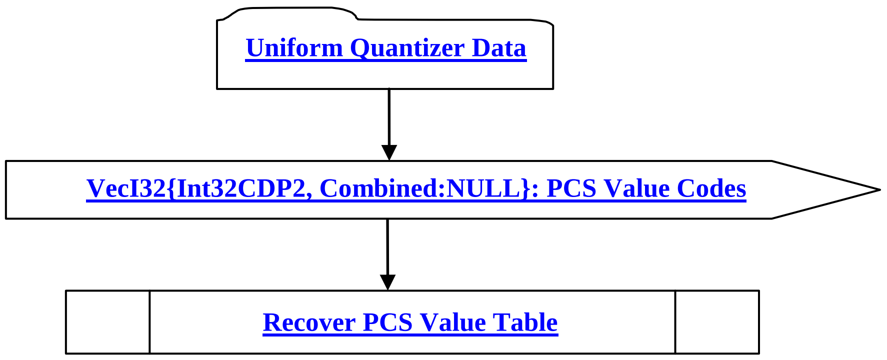

End
Start
k=0, idx=0
N
Any surface left?
k = k +1
Type of surface k is nurbs
Y
N
Type is plane
Y
Decode array[idx] and array[idx+1], and set as value of umax and vmax respectively. modelX = true, modelY = true.
idx = idx + 2
N
Type is cylinder or cone
Y
Decode array[idx] and array[idx+1], and set as value of vmax and radius respectively. modelX = false, modelY = true
idx = idx + 2
N
Type is sphere
Y
Decode array[idx] set as value of radius. modelX = false, modelY = false
idx = idx + 1
N
Type is torus
Y
Decode array[idx] and array[idx+1], and set as value of major radius and minor radius respectively. modelX = false, modelY = false
idx = idx + 2
For all the PCS curves associated with face k, starting with c=0
N
Y
Any PCS curve left in face k?
Domain type of curve c is 0
Y
c = c + 1
N
Type of curve c nurbs
Y
For each control point, except the last one, decode next array element and set as X coordinate if modelX is true, decode next array element and set as Y coordinate if modelY is true
increment idx by number of decoded elements
N
Type of curve c is line
Y
If modelX is true, decode next array element and set as X coordinate of pvec, if modelY is true decode next array element and set as Y coordinate of pvec
increment idx by number of decoded elements
N
Type of curve c is circle
Y
Decode array[idx] and set as value of radius
increment idx by number of decoded elements

The logic diagram to recover 1D MCS table information in the ULP from the 1D MCS Codes is shown in igure 200: 1D MCS Table data collectionFigure 201. Note that each integer element in the 1D MCS Codes array is decoded with Uniform Quantizer.

7.2.8.1.2.10 PCS Value Table

PCS Value Table stores the quantization representation of floating point values in PCS. If the ULP does not contain any such value, then the table is empty and bit 0x0100 in Geometric Tabe Flag is set to be 0. Each floating point value is encoded into an integer with uniform quantizer (see 8.1.12 Uniform Quantizer Data) and then all the integers are grouped into an integer array. The integer array is then encoded using the Int32 version of second generation CODEC with Combined Predictor Type.

Figure 202: PCS Value Table data collection



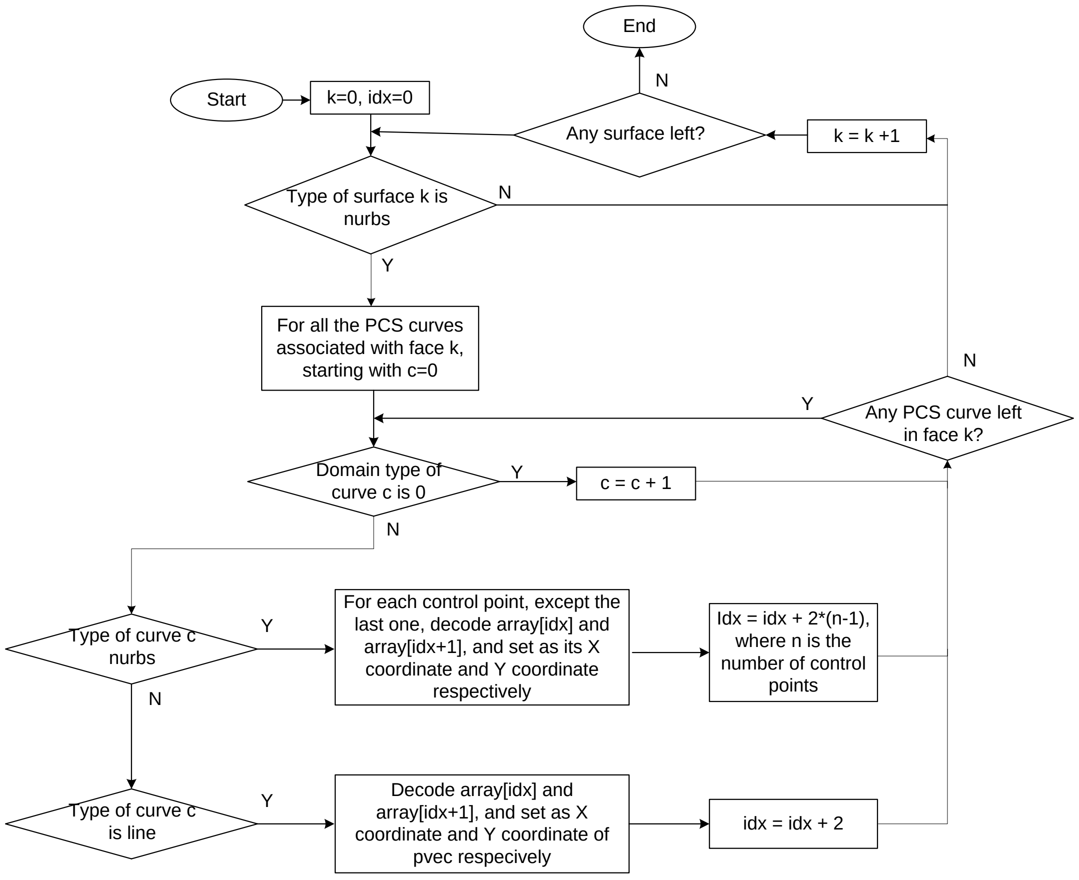
VecI32{Int32CDP2, Combined:NULL}: PCS Value Codes

PCS Value Codes is a vector of quantizer "codes" for all the floating point values in PCS . PCS Value Codes uses the Int32 version of the second generation CODEC with Combined Predictor Type to compress and encode data.

Recover PCS Value Table

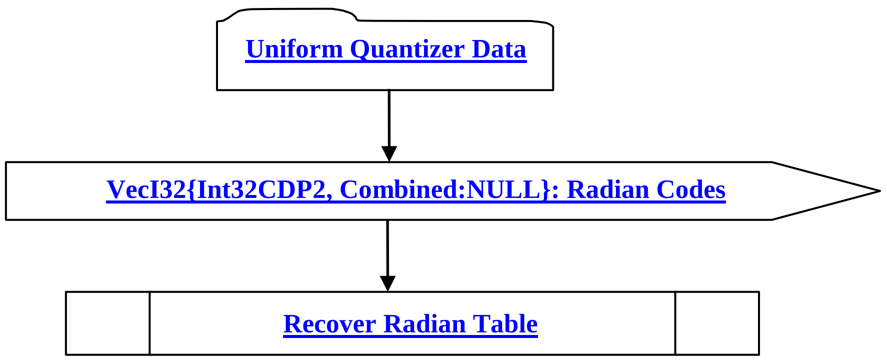
The logic diagram to recover PCS Value Table information in the ULP from the PCS Value Codes is shown in Figure 203. Note that each integer element in the PCS Value Codes array is decoded with Uniform Quantizer.

Figure 203: Recover PCS Value Table



Start
k=0, idx=0
End
N
Any surface left?
k = k +1
Type of surface k is nurbs
N
Y
For all the PCS curves associated with face k, starting with c=0
N
Y
Any PCS curve left in face k?
Domain type of curve c is 0
Y
c = c + 1
N
Type of curve c nurbs
Y
For each control point, except the last one, decode array[idx] and array[idx+1], and set as its X coordinate and Y coordinate respectively
Idx = idx + 2*(n-1), where n is the number of control points
N
Type of curve c is line
Y
Decode array[idx] and array[idx+1], and set as X coordinate and Y coordinate of pvec respecively
idx = idx + 2

Figure 204: Radian Table data collection



7.2.8.1.2.11 Radian Table

Radian Table stores the quantization representation of angular values. If the ULP does not contain any such angular value, then the table is empty and bit 0x0200 in Geometric Tabe Flag is set to be 0. Each angular value is encoded into an integer with uniform quantizer (see 8.1.12 Uniform Quantizer Data) and then all the integers are grouped into an integer array. The integer array is then encoded using the Int32 version of second generation CODEC with Combined Predictor Type.

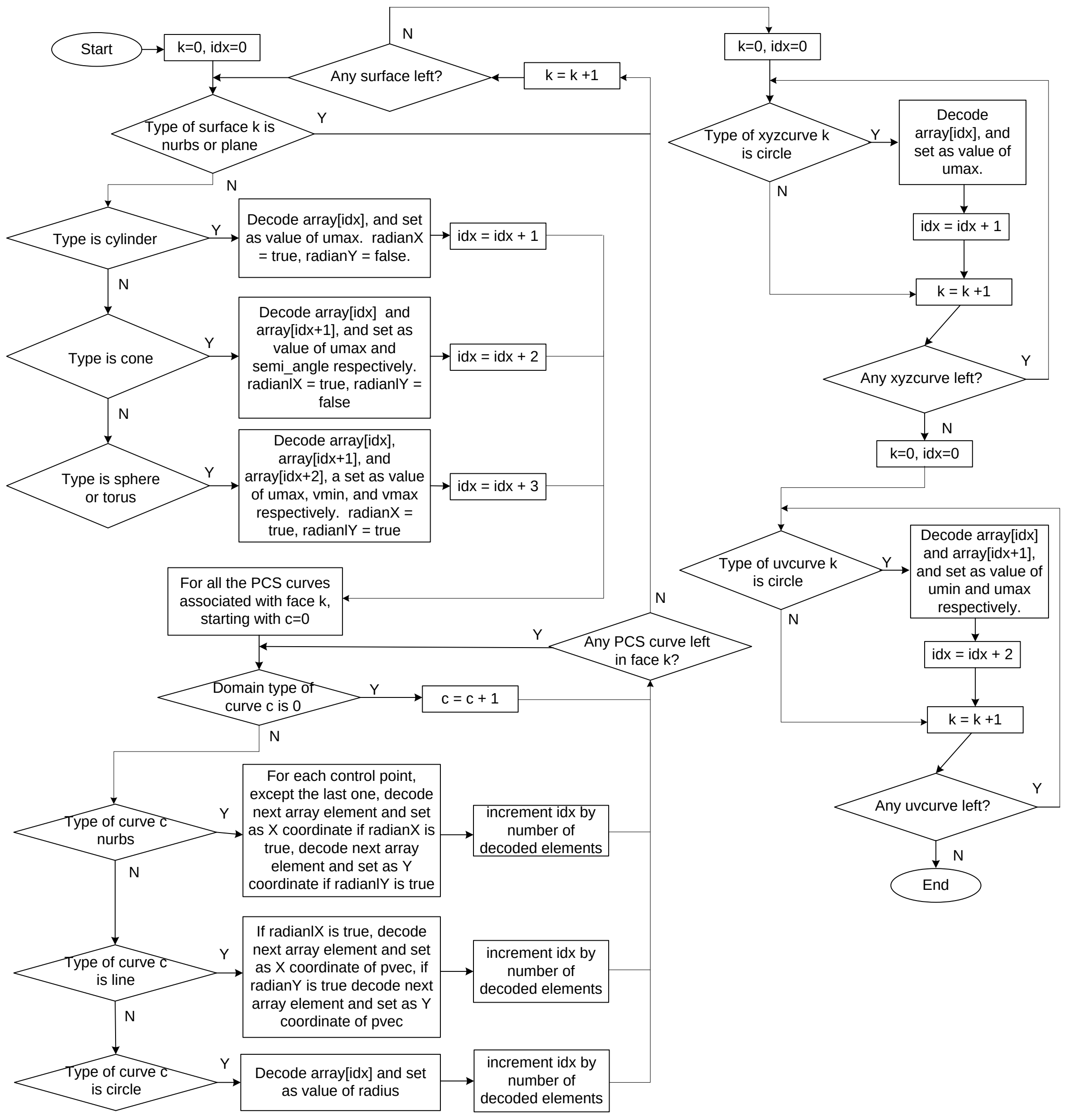
VecI32{Int32CDP2, Combined:NULL}: Radian Codes

Radian Codes is a vector of quantizer "codes" for all the angular values. Radian Codes uses the Int32 version of the second generation CODEC with Combined Predictor Type to compress and encode data.

Recover Radian Table

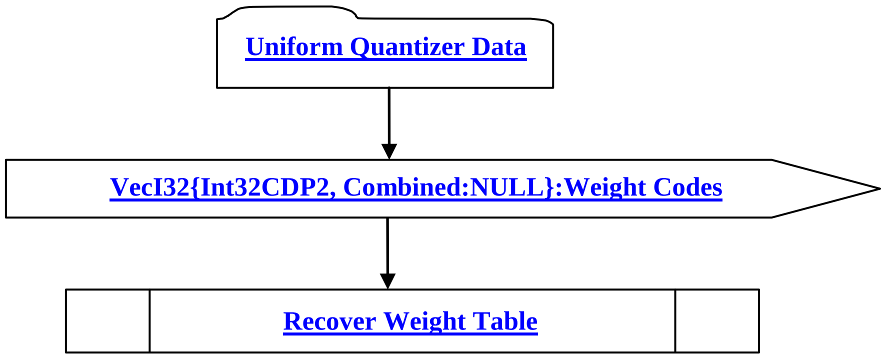
The logic diagram to recover Radian Table information in the ULP from the Radian Codes is shown in Figure 205. Note that each integer element in the Radian Codes array is decoded with Uniform Quantizer.

Figure 205: Recover Radian Table



Start
k=0, idx=0
Any surface left?
N
Y
k = k +1
Type of surface k is nurbs or plane
Type is cylinder
Decode array[idx], and set as value of umax. radianX = true, radianY = false.
idx = idx + 1
Type is cone
Decode array[idx] and array[idx+1], and set as value of umax and semi_angle respectively. radianlX = true, radianlY = false
idx = idx + 2
Type is sphere or torus
Decode array[idx], array[idx+1], and array[idx+2], a set as value of umax, vmin, and vmax respectively. radianX = true, radianlY = true
idx = idx + 3
For all the PCS curves associated with face k, starting with c=0
Any PCS curve left in face k?
Domain type of curve c is 0
c = c + 1
Type of curve c nurbs
For each control point, except the last one, decode next array element and set as X coordinate if radianX is true, decode next array element and set as Y coordinate if radianlY is true
increment idx by number of decoded elements
Type of curve c is line
If radianlX is true, decode next array element and set as X coordinate of pvec, if radianY is true decode next array element and set as Y coordinate of pvec
Type of curve c is circle
Decode array[idx] and set as value of radius
Type of xyzcurve k is circle
Decode array[idx], and set as value of umax.
idx = idx + 1
Any xyzcurve left?
Type of uvcurve k is circle
Decode array[idx] and array[idx+1], and set as value of umin and umax respectively.
idx = idx + 2
Any uvcurve left?
End

Figure 206: Weight Table data collection



7.2.8.1.2.12 Weight Table

Weight Table stores the quantization representation of weight values. If the ULP does not contain any such weight value, then the table is empty and bit 0x0400 in Geometric Tabe Flag is set to be 0. Each weight value is encoded into an integer with uniform quantizer (see 8.1.12 Uniform Quantizer Data) and then all the integers are grouped into an integer array. The integer array is then encoded using the Int32 version of second generation CODEC with Combined Predictor Type.

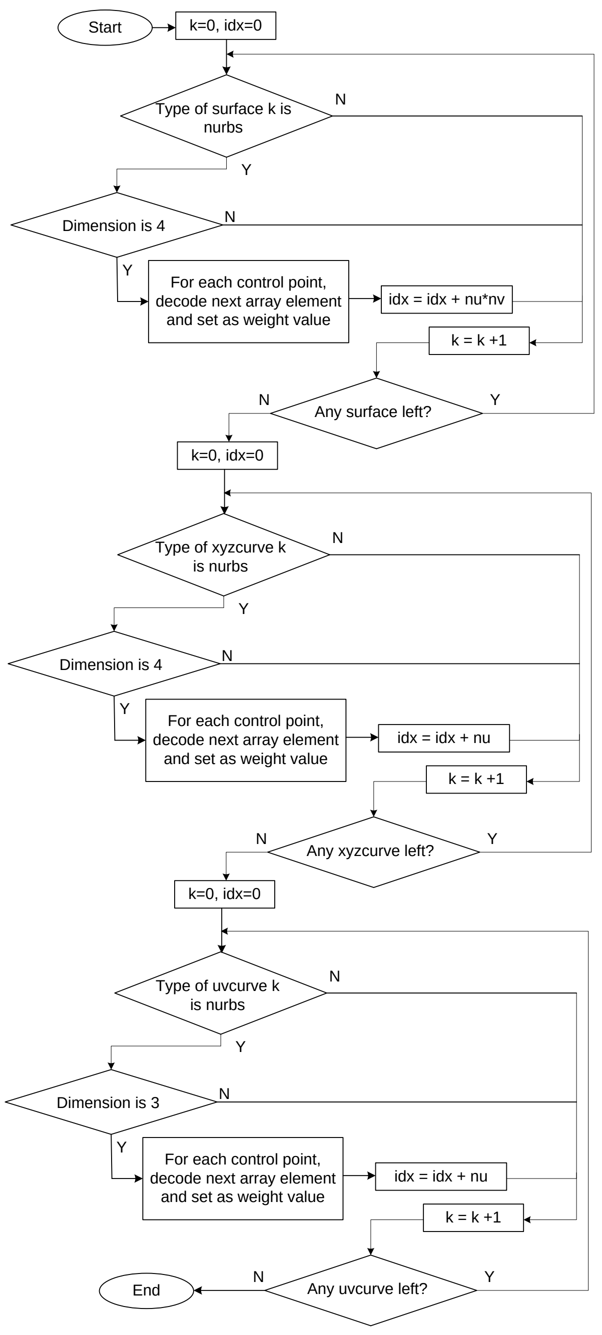
VecI32{Int32CDP2, Combined:NULL}:Weight Codes

Weight Codes is a vector of quantizer "codes" for all the weight values. Weight Codes uses the Int32 version of the second generation CODEC with Combined Predictor Type to compress and encode data.

Recover Weight Table

The logic diagram to recover Weight Table information in the ULP from the Weight Codes is shown in Figure 207. Note that each integer element in the Weight Codes array is decoded with Uniform Quantizer.

Figure 207: Recover Weight Table

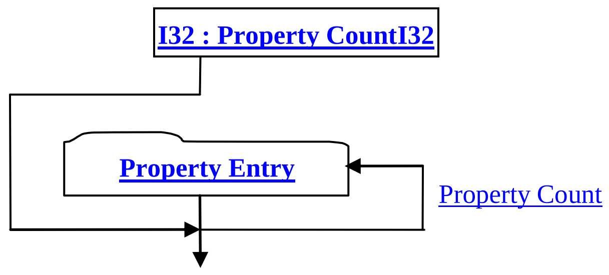


Start
k=0, idx=0
Type of surface k is nurbs
N
Y
Dimension is 4
N
Y
For each control point, decode next array element and set as weight value
idx = idx + nu*nv
k = k +1
N
Any surface left?
Y
k=0, idx=0
Type of xyzcurve k is nurbs
N
Y
Dimension is 4
N
Y
For each control point, decode next array element and set as weight value
idx = idx + nu
k = k +1
N
Any xyzcurve left?
Y
k=0, idx=0
Type of uvcurve k is nurbs
N
Y
Dimension is 3
N
Y
For each control point, decode next array element and set as weight value
idx = idx + nu
k = k +1
End
N
Any uvcurve left?
Y

7.2.8.1.3 Material Attribute Element Properties

The properties attached to material attribute are standard JT properties, and the logic diagram to read the properties attached a material attribute is shown in Figure 208.

Figure 208: Material Attribute Element Properties



I32 : Property Count

Property count is the number of properties attached.

Property Entry

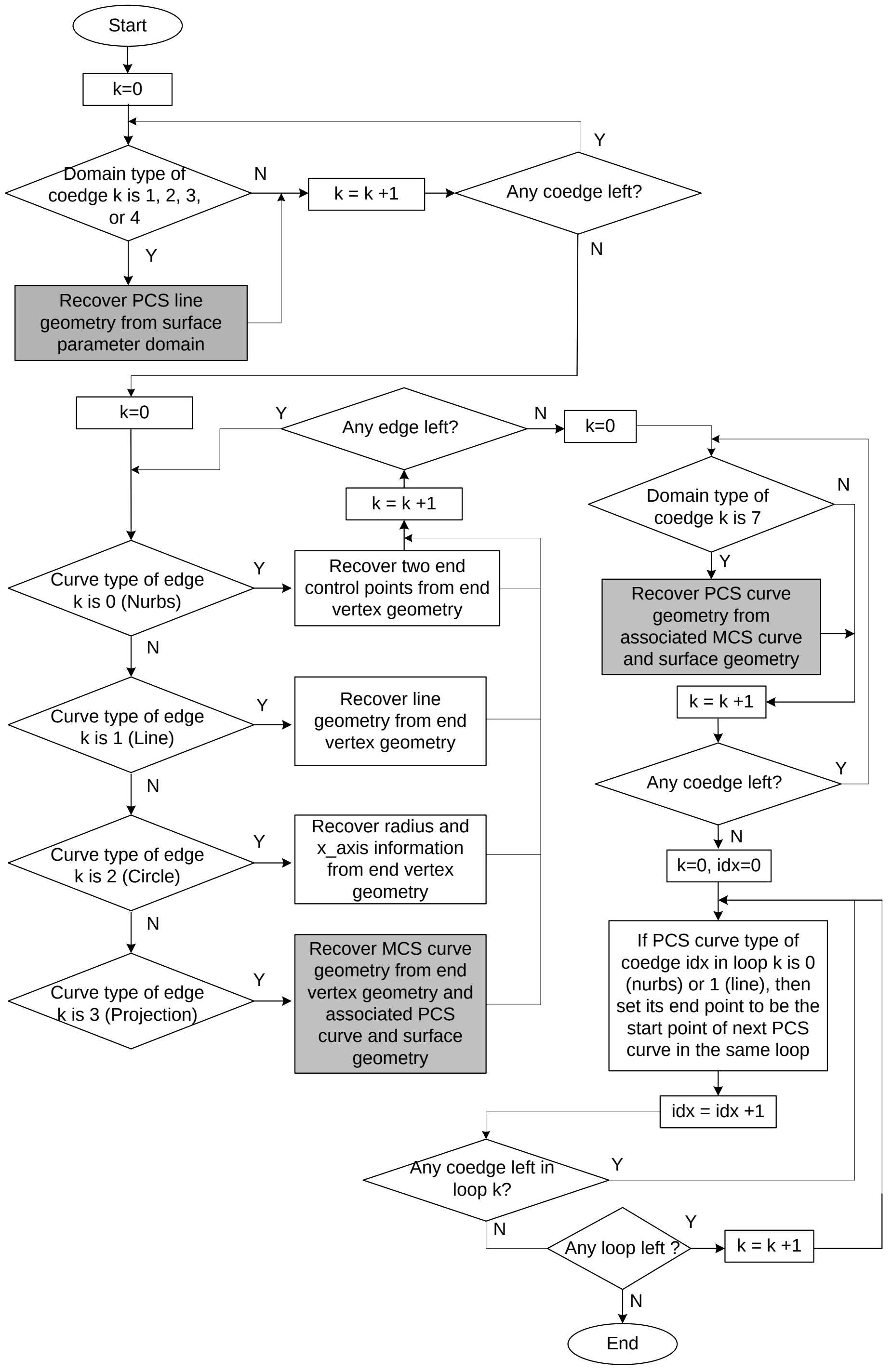
Standard JT property entry, consisting of key and value pair.

7.2.8.1.4 Information Recovery

The information in ULP is classified as "essential information" that is explicitly written on disk, and "derivative information" that can be computed from the "essential information". How "essential information" of ULP can be read from disk was covered in previous sections, and this section focuses on the logic to recover "derivative information" from "essential information".

The derivative information consists of curve information either in the parameter or model space. For example, the PCS curves associated with an untrimmed face can be inferred from the parameter domain of the surface, or an MCS curve may be computed from vertex information and/or the combination of corresponding PCS curve geometry and surface geometry, etc.. Shown in Figure 209 is the high level diagram to recover "derivative information". First, all the PCS line geometry are recovered from the associated surface domain information if the domain type of those PCS curves, stored in its associated coedge, are of value 1, 2, 3, 4 meaning that the PCS curve is identical to one of the parameter boundaries of the surface. Second, the MCS curve geometry is recovered depending on its type. If the MCS curve type is 0, 1, or 2, then the geometry of its two end vertices is used to compute the curve geometry. If the MCS curve type is 3, then its geometry is computed by projecting PCS curve onto the surface geometry. After all the MCS curve geometry is computed, all the PCS curves of type 7 is computed by projecting MCS curve onto the parameter domain. Some part of PCS curve definition may still be missing after all these steps. At the end, all the information that is still missing in some of the PCS curves is recovered by leveraging the knowledge that all PCS curves within the same loop are connected in a head to tail fashion. The logical steps that are displayed with dark color indicate steps that will be elaborated in more detail later.

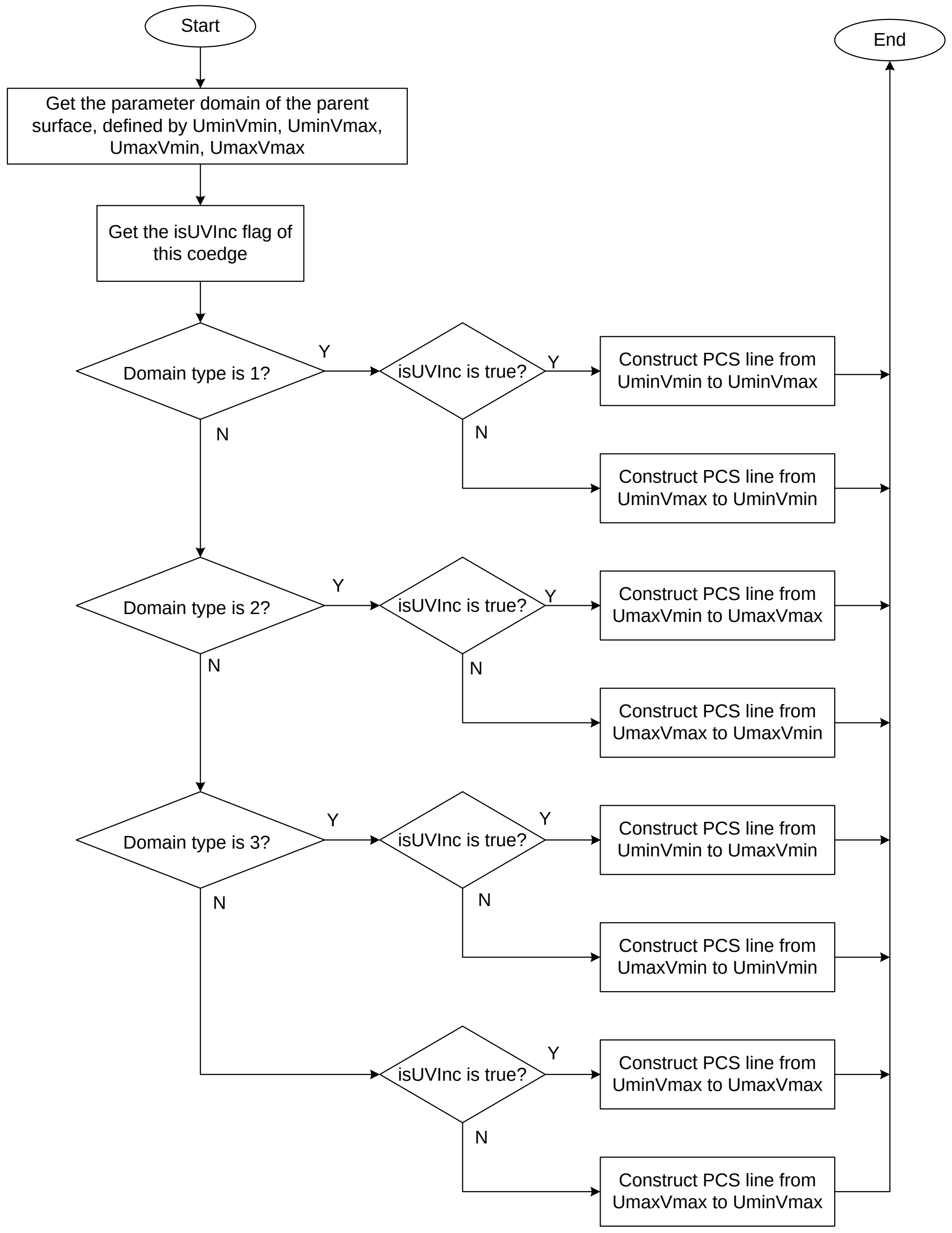
Figure 209: Information Recovery


Start
k=0
Domain type of coedge k is 1, 2, 3, or 4
N
Y
k = k +1
Any coedge left?
Y
N
Recover PCS line geometry from surface parameter domain
k=0
Any edge left?
Y
N
k=0
k = k +1
Domain type of coedge k is 7
N
Y
Curve type of edge k is 0 (Nurbs)
Y
N
Recover two end control points from end vertex geometry
Recover PCS curve geometry from associated MCS curve and surface geometry
Curve type of edge k is 1 (Line)
Y
N
Recover line geometry from end vertex geometry
k = k +1
Any coedge left?
Y
N
Curve type of edge k is 2 (Circle)
Y
N
Recover radius and x_axis information from end vertex geometry
k=0, idx=0
Curve type of edge k is 3 (Projection)
Y
Recover MCS curve geometry from end vertex geometry and associated PCS curve and surface geometry
If PCS curve type of coedge idx in loop k is 0 (nurbs) or 1 (line), then set its end point to be the start point of next PCS curve in the same loop
idx = idx +1
Any coedge left in loop k?
Y
N
Any loop left ?
Y
k = k +1
N
End

7.2.8.1.4.1PCS Curve Recovery from Surface Domain

Shown in Figure 210 is the diagram illustrating how the PCS curve geometry is recovered from surface parameter domain information.

Figure 210: PCS Curve Recovery from Surface Domain

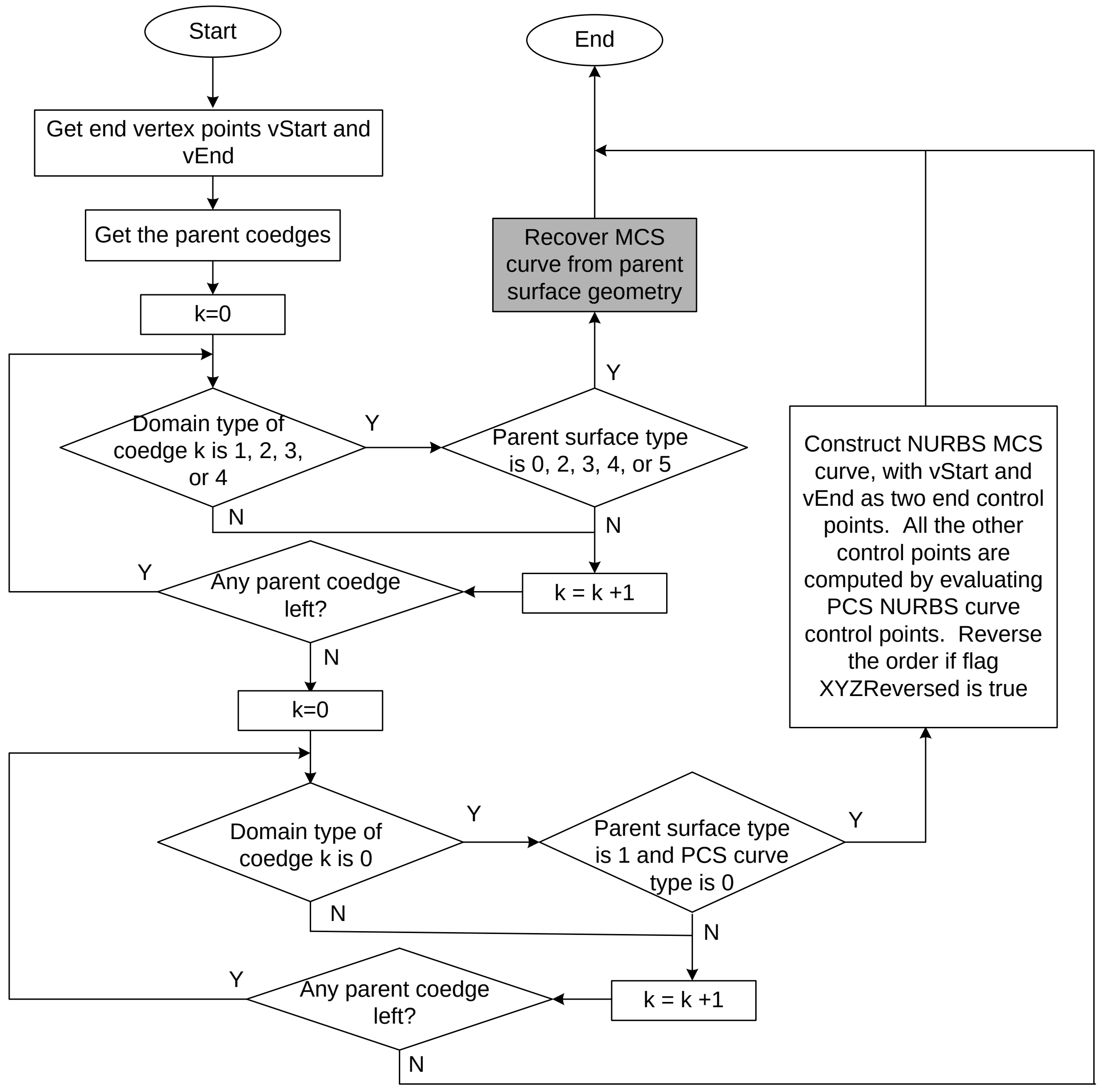


Start
End
Get the parameter domain of the parent surface, defined by UminVmin, UminVmax, UmaxVmin, UmaxVmax
Get the isUVInc flag of this coedge
Domain type is 1?
Y
N
isUVInc is true?
Y
N
Construct PCS line from UminVmin to UminVmax
Construct PCS line from UminVmax to UminVmin
Domain type is 2?
Y
N
isUVInc is true?
Y
N
Construct PCS line from UmaxVmin to UmaxVmax
Construct PCS line from UmaxVmax to UmaxVmin
Domain type is 3?
Y
N
isUVInc is true?
Y
N
Construct PCS line from UminVmin to UmaxVmin
Construct PCS line from UmaxVmin to UminVmin
isUVInc is true?
Y
N
Construct PCS line from UminVmax to UmaxVmax
Construct PCS line from UmaxVmax to UminVmax

7.2.8.1.4.2 MCS Curve Recovery

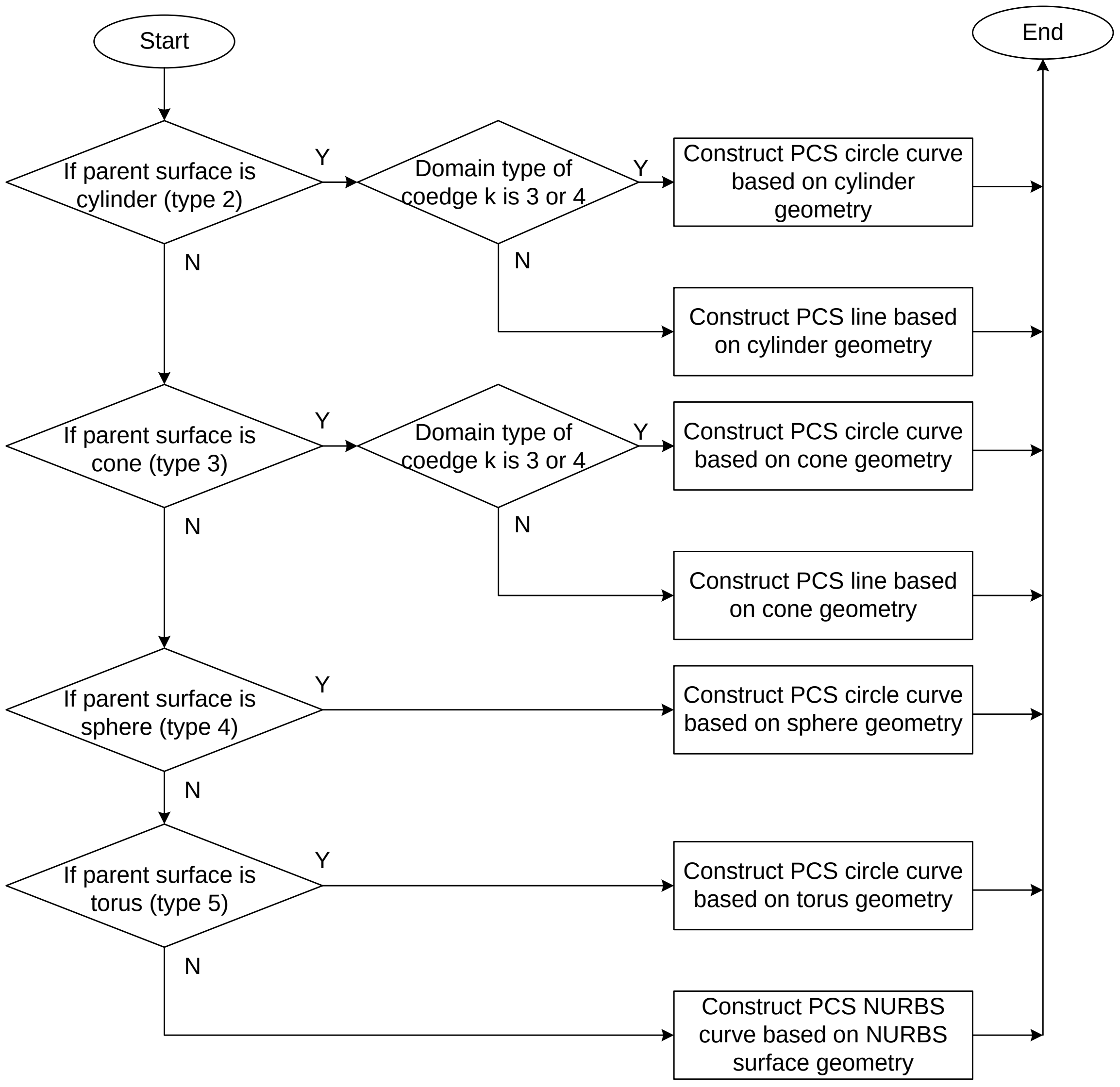
Shown in Figure 211 is the diagram illustrating how MCS curve geometry is recovered from its end vertex geometry, and/or its associated PCS curve geometry and surface geometry. If the associated PCS curve is coincident with one of the parameter boundaries of the parent surface, then the MCS curve can be recovered from parent surface geometry. Otherwise, if the surface type is planar and PCS curve is of type NURBS, then the MCS curve geometry can be recovered by projecting the PCS curve from parameter domain to model space onto the planar surface.

Figure 211: MCS Curve Recovery


Start
End
Get end vertex points vStart and vEnd
Get the parent coedges
k=0
Recover MCS curve from parent surface geometry
Y
Domain type of coedge k is 1, 2, 3, or 4
Y
Parent surface type is 0, 2, 3, 4, or 5
N
N
Construct NURBS MCS curve, with vStart and vEnd as two end control points. All the other control points are computed by evaluating PCS NURBS curve control points. Reverse the order if flag XYZReversed is true
Y
Any parent coedge left?
k = k +1
N
k=0
Y
Domain type of coedge k is 0
Parent surface type is 1 and PCS curve type is 0
Y
N
N
Y
Any parent coedge left?
k = k +1
N

Shown in Figure 212 is the detailed description of how MCS curve can be recovered from surface geometry.

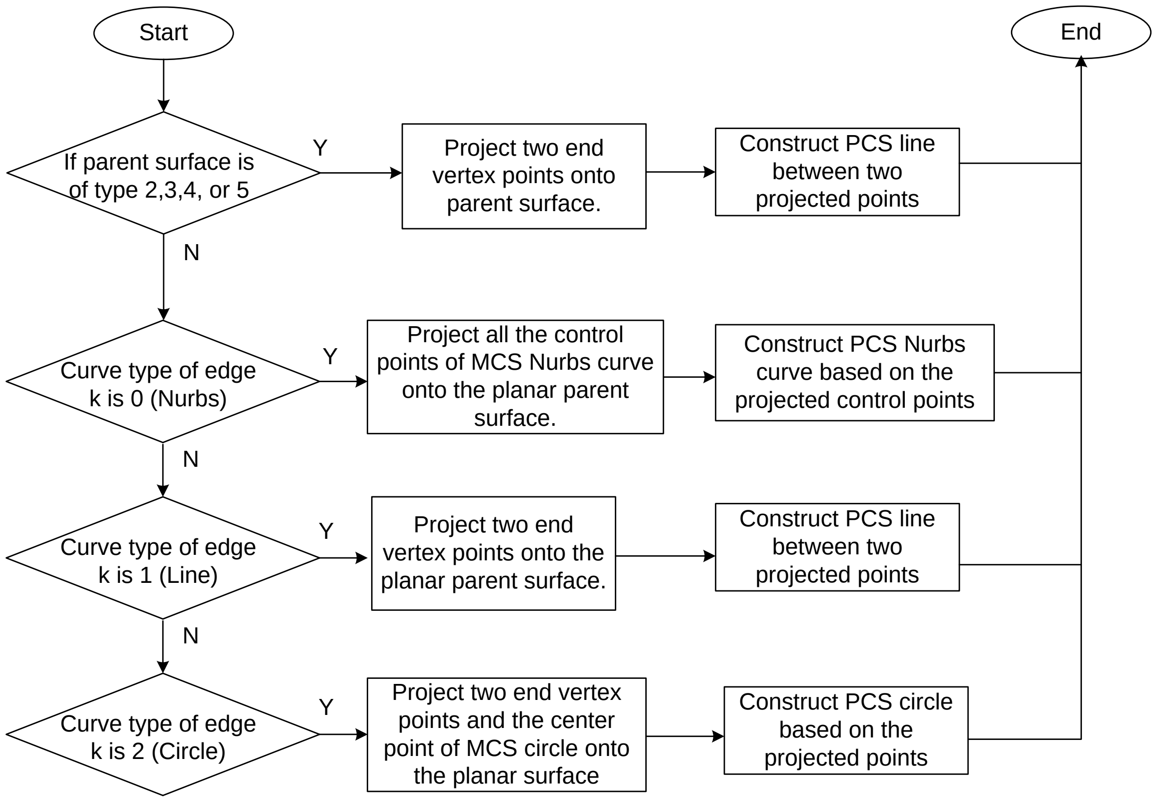
Figure 212: MCS Curve Recovery from Surface Geometry


Start
End
If parent surface is cylinder (type 2)
Y
N
Domain type of coedge k is 3 or 4
Y
N
Construct PCS circle curve based on cylinder geometry
Construct PCS line based on cylinder geometry
If parent surface is cone (type 3)
Y
N
Domain type of coedge k is 3 or 4
Y
N
Construct PCS circle curve based on cone geometry
Construct PCS line based on cone geometry
If parent surface is sphere (type 4)
Y
N
Construct PCS circle curve based on sphere geometry
If parent surface is torus (type 5)
Y
N
Construct PCS circle curve based on torus geometry
Construct PCS NURBS curve based on NURBS surface geometry

7.2.8.1.4.3 PCS Curve Recovery from MCS Curve and Surface Geometry

Shown in Figure 213 is the diagram illustrating how PCS curve geometry can be recovered from the combination of MCS curve and surface geometry.

Figure 213: PCS Curve Recovery from MCS Curve and Surface Geometry


Start
End
If parent surface is of type 2,3,4, or 5
Y
Project two end vertex points onto parent surface.
Construct PCS line between two projected points
N
Curve type of edge k is 0 (Nurbs)
Y
Project all the control points of MCS Nurbs curve onto the planar parent surface.
Construct PCS Nurbs curve based on the projected control points
N
Curve type of edge k is 1 (Line)
Y
Project two end vertex points onto the planar parent surface.
Construct PCS line between two projected points
N
Curve type of edge k is 2 (Circle)
Y
Project two end vertex points and the center point of MCS circle onto the planar surface
Construct PCS circle based on the projected points

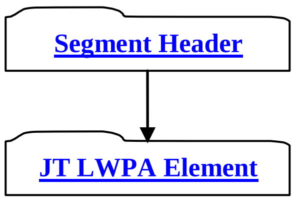
7.2.9 JT LWPA Segment

JT LWPA Segment contains an Element that defines light weight precise analytic data for a particular part. More specifically LWPA contains the collection of analytic surfaces in the B-Rep definition of the part.

JT LWPA Segments are typically referenced by Part Node Elements (see 7.2.1.1.1.5Part Node Element) using Late Loaded Property Atom Elements (see 0Second specifies the date Second value. Valid values are [0, 59] inclusive.

Late Loaded Property Atom Element Late Loaded Property Atom ElementLate Loaded Property Atom Element). The JT LWPA Segment type supports ZLIB compression on all element data, so all elements in JT LWPA Segment use the Logical Element Header ZLIB form of element header data.

Figure 214: JT LWPA Segment data collection



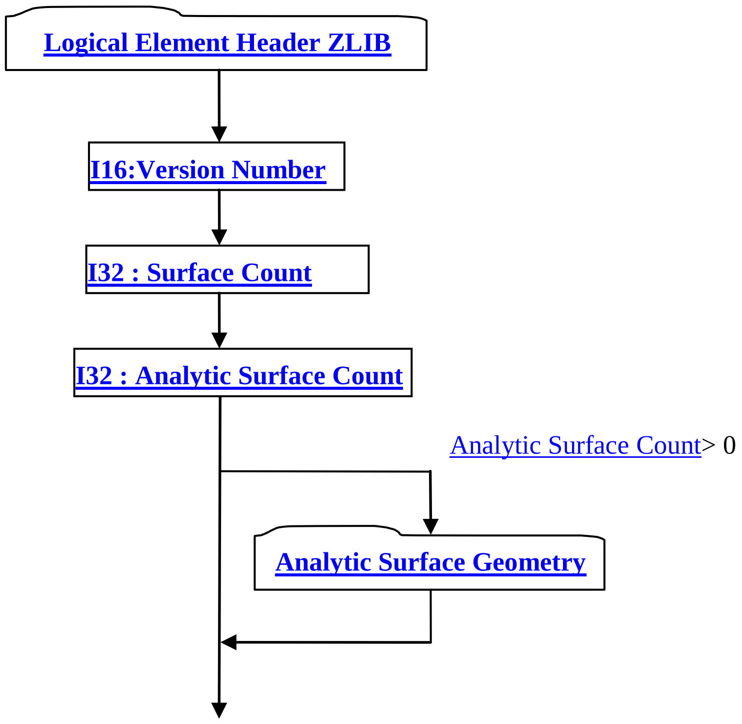
Complete description for Segment Header can be found in 7.1.3.1Segment Header.

7.2.9.1 JT LWPA Element

Object Type ID: 0xd67f8ea8, 0xf524, 0x4879, 0x92, 0x8c, 0x4c, 0x3a, 0x56, 0x1f, 0xb9, 0x3a

JT LWPA Segment represents a particular Part's precise analytic surfaces. It can be viewed as a subset of B-Rep representation where the subset refers to the complete collection of all the surfaces that are of one of the analytic types shown in the Supported Surface Type table, i.e., plane, cylinder, cone, sphere, or torus. Unlike JT B-Rep Element or XT B-Rep Element, JT LWPA Element does not contain any B-Rep topology information, nor does it contain geometric curve or point information. LWPA is designed to represent most essential part geometry information with much lighter weight on disk and much faster to load than B-Rep. Typically LWPA is less than 2 percent of B-Rep size on disk, and takes less than 5 percent time to load into memory. The analytic representation of LWPA follows Parasolid convention as detailed in Appendix F: Parasolid XT Format Reference.

Figure 215: JT LWPA Element data collection


Logical Element Header ZLIB
I16:Version Number
I32 : Surface Count
I32 : Analytic Surface Count
Analytic Surface Count> 0
Analytic Surface Geometry

I16:Version Number

Version Number is the version identifier for this JT LWPA Element. Version numbers "1" is currently supported.

I32 : Surface Count

Surface Count indicates the number of surface entries in LWPA. The number of surface entries is equal to the number of surfaces in the B-Rep representation. The surface entry does not contain any information if the corresponding B-Rep surface is not of analytic type.

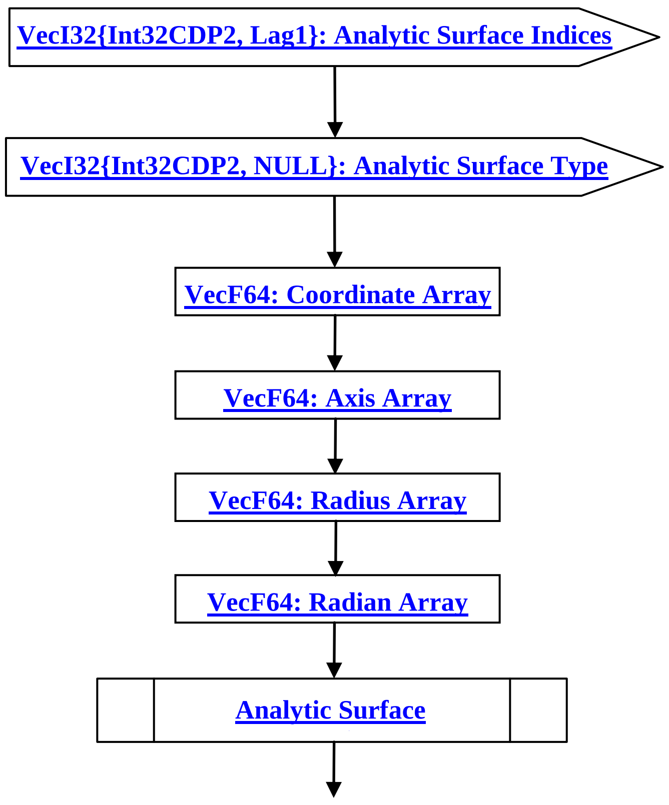
I32 : Analytic Surface Count

Analytic Surface Count indicates the number of analytic surface entries in LWPA.

7.2.9.1.1 Analytic Surface Geometry

Analytic Surface Geometry defines a collection of analytic surfaces and their mapping to the original B-Rep surfaces.

Figure 216: Analytic Surface Geometry data collection



VecI32{Int32CDP2, Lag1}: Analytic Surface Indices

Analytic Surface Indices is an integer array with its length equal to the number of analytic surfaces in the LWPA. The value of each element in this array represents the index of this analytic surface in the original B-Rep representation.

VecI32{Int32CDP2, NULL}: Analytic Surface Type

Analytic Surface Type is an integer array with its length equal to the number of analytic surfaces in the LWPA. The value of each element in this array represents the type of each analytic surface, as defined in table Supported Surface Type

VecF64: Coordinate Array

Coordinate Array contains an array of double precision floating point numbers that represent the collection of point coordinate information in the definition of the analytic surface entities. The composite type VecF64 is defined in Table 2. Each floating point number in the array is written in binary form.

VecF64: Axis Array

Axis Array contains an array of double precision floating point numbers that represent the collection of unit vector information in the definition of the analytic surface entities. The composite type VecF64 is defined in Table 2. Each floating point number in the array is written in binary form.

VecF64: Radius Array

Radius Array contains an array of double precision floating point numbers that represent the collection of radius information in the definition of the analytic surface entities. The composite type VecF64 is defined in Table 2. Each floating point number in the array is written in binary form.

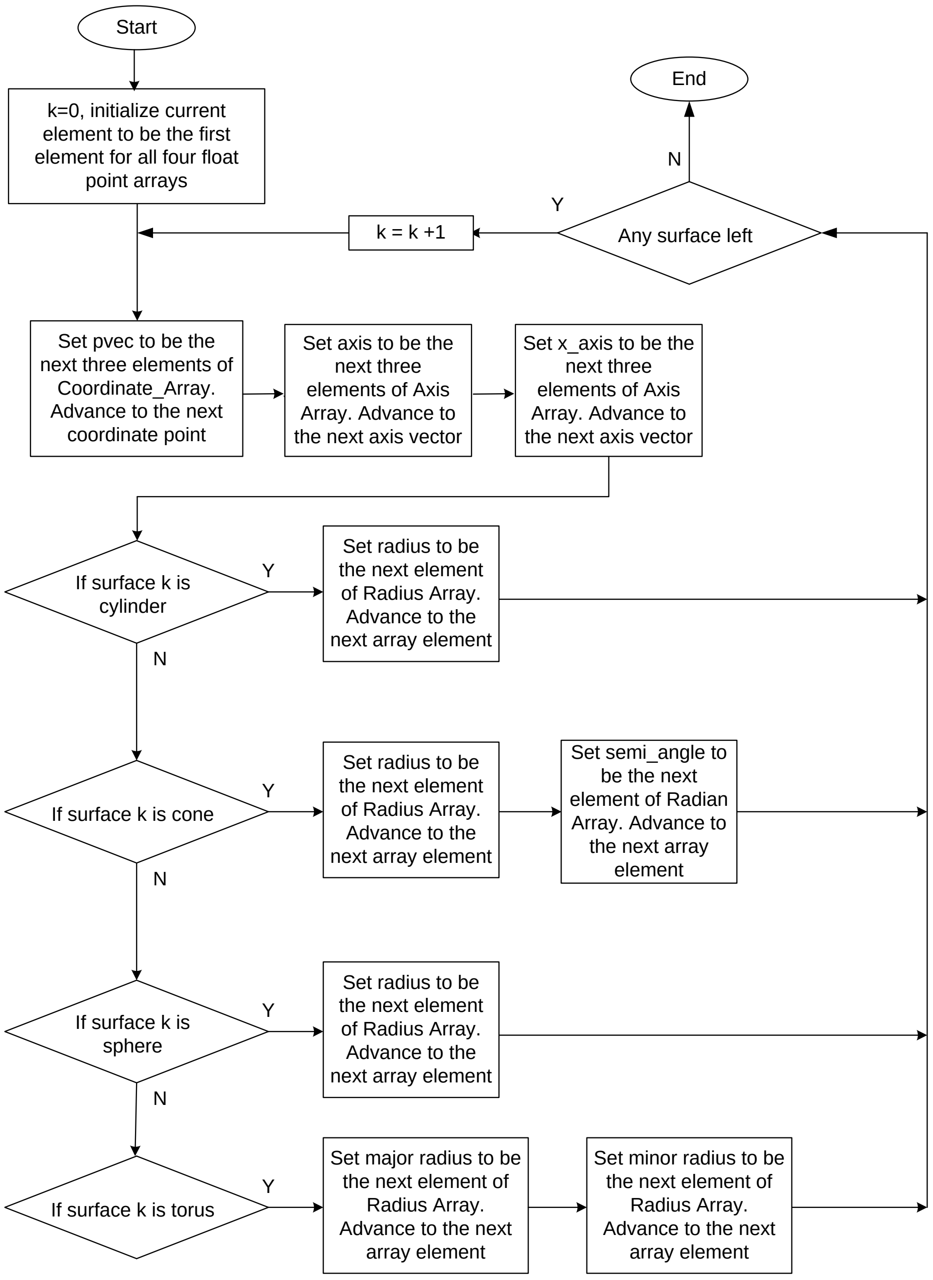
VecF64: Radian Array

Radian Array contains an array of double precision floating point numbers that represent the collection of radian information in the definition of the analytic surface entities. The composite type VecF64 is defined in Table 2. Each floating point number in the array is written in binary form.

Analytic Surface Creation

Analytic surfaces in LWPA is constructed based on the information of the above arrays, as illustrated by logical diagram in Figure 217.

Figure 217: Analytic Surface Creation


Start
k=0, initialize current element to be the first element for all four float point arrays
End
N
Y
Any surface left
k = k +1
Set pvec to be the next three elements of Coordinate_Array. Advance to the next coordinate point
Set axis to be the next three elements of Axis Array. Advance to the next axis vector
Set x_axis to be the next three elements of Axis Array. Advance to the next axis vector
If surface k is cylinder
Y
N
Set radius to be the next element of Radius Array. Advance to the next array element
If surface k is cone
Y
N
Set radius to be the next element of Radius Array. Advance to the next array element
Set semi_angle to be the next element of Radian Array. Advance to the next array element
If surface k is sphere
Y
N
Set radius to be the next element of Radius Array. Advance to the next array element
If surface k is torus
Y
Set major radius to be the next element of Radius Array. Advance to the next array element
Set minor radius to be the next element of Radius Array. Advance to the next array element

8 Data Compression and Encoding

The JT File format utilizes best-in-class compression and encoding algorithms to produce compact and efficient representations of data. The types of compression algorithms supported by the JT format vary from standard data type agnostic ZLIB deflation to advanced arithmetic algorithms that exploit knowledge of the characteristics of the data types they are compressing. Some of the JT format data collections are always stored in a compressed format, whereas other data collections support multiple compression storage formats that qualitatively vary from “Lossless” compression to more aggressive strategies that employ “lossy” compression. This support by the JT format of varying qualitative levels of compression allows producers of JT data to fine tune the tradeoff between compression ratio and fidelity of the data.

In some instances, data may be encoded/compressed using multiple techniques applied on top of one another in a serial fashion (i.e. encoding applied to the output of another encoder). One common example of this multiple encoding is when an array/vector of floating point data is first quantized into some integer codes and then these resulting integer codes are further compressed/encoded using an Arithmetic or BitLength CODEC (see 8.2 Encoding Algorithms).

Beyond the data collection specific compression/encoding, some JT format Data Segment types (see 7.1.3 Data Segment) also support having a ZLIB compression conditionally applied to all the bytes of information persisted within the segment. So individual fields or collections of data may first have data type specific encoding/compression algorithms applied to them, and then if their Data Segment type supports it, the resulting data may be additionally compressed using a ZLIB deflation algorithm.

Whether, and at what qualitative level, a particular Data Segment’s data is compressed/encoded is indicated through compression related data values stored as part of the particular Data Segment storage format. In general, aggressive application of advanced compression/encoding techniques is reserved for the heavy-weight renderable geometric data (e.g. triangles and wireframe lines) which can exist in a JT File.

The following sections document the format of the data compression/encoding within the JT file. Along with documenting the format, a technical description of the various compression/encoding algorithms is included and an example implementation of the decoding portion of the algorithms can be found within Appendix C: Decoding Algorithms – An Implementation.

8.1 Common Compression Data Collection Formats

For convenience and brevity in documenting the JT format, this section of the reference documents the format for several common “data compression/encoding” related data collections that can exist in the JT format. You will find references to these common compression data collections in the 7.2 Data Segments section of the document.

8.1.1 Int32 Compressed Data Packet

The Int32 Compressed Data Packet collection represents the format used to encode/compress a collection of data into a series of Int32 based symbols. Note that the Int32 Compressed Data Packet collection can in itself contain another Int32 Compressed Data Packet collection if there are any “Out-Of-Band data.” In the context of the JT format data compression algorithms and Int32 Compressed Data Packet, “out-of-band data” has the following meaning.

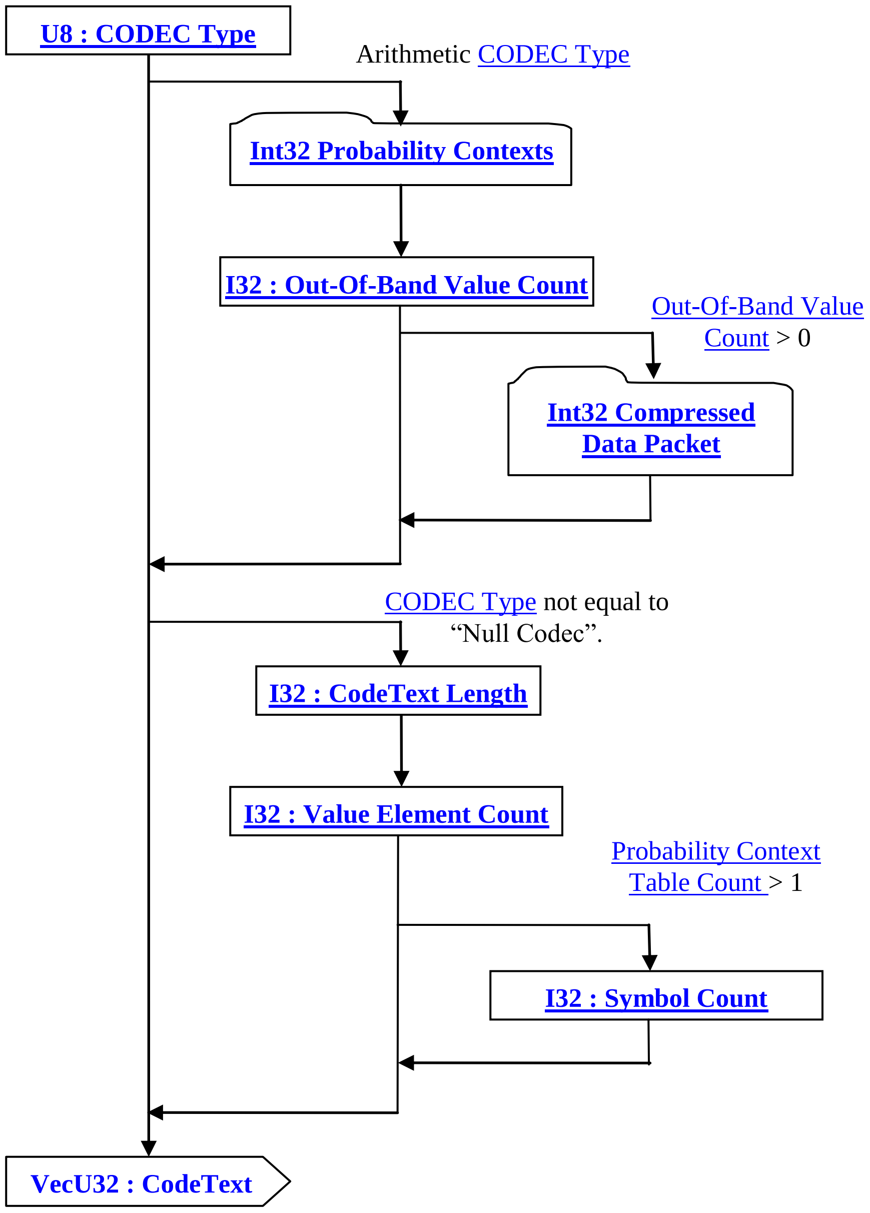
CODECs (e.g. Arithmetic, see 8.2 Encoding Algorithms for technical description) exploit the statistics present in the relative frequencies of the values being encoded. Values that occur frequently enough allow these methods to encode each of the values as a “symbol” in fewer bits that it would take to encode the value itself. Values that occur too infrequently to take advantage of this property are written *aside* into the “out-of-band data” array to be encoded separately. An “escape” symbol is encoded in their place as a placeholder in the primal CODEC (note, see “Symbol” data field definition in 8.1.1.1.1 Int32 Probability Context Table Entry for further details on the representation of “escape” symbol).

Essentially the “out-of-band data” is the high-entropy residue left over after the CODECs have squeezed all the advantage out of the original data stream that they can. However, this “out-of-band data” is sent back around for another pass because sometimes there are *different* statistics to be taken advantage of. When all other coding options have been exhausted, the Bitlength CODEC is invoked. The Bitlength CODEC directly encodes all values given to it, does not require a probability context, and hence never produces additional “out-of-band data”. The byte stops there, in other words.

In some cases, all values may be written as "out of band" when the Codec cannot perform *any* useful compression. In this case, the encoded I32 : CodeText Length field will be 0, and the I32 : Out-Of-Band Value Count will be equal to I32 : Value

Element Count. The implied action in this case is to merely copy the Out-Of-Band value data into the output Value Element array instead of invoking the Codec.

Figure 218: Int32 Compressed Data Packet data collection



U8 : CODEC Type
Arithmetic CODEC Type
Int32 Probability Contexts
I32 : Out-Of-Band Value Count
Out-Of-Band Value Count > 0
Int32 Compressed Data Packet
CODEC Type not equal to "Null Codec".
I32 : CodeText Length
I32 : Value Element Count
Probability Context Table Count > 1
I32 : Symbol Count
VecU32 : CodeText

U8 : CODEC Type

CODEC Type specifies the algorithm used to encode/decode the data. See 8.2 Encoding Algorithms for complete explanation of each of the encoding algorithms.

= 0	Null CODEC
= 1	Bitlength CODEC
= 3	Arithmetic CODEC
= 4	Chopper CODEC

I32 : Out-Of-Band Value Count

Out-Of-Band Value Count specifies the number of values that are “Out-Of-Band.” This data field is only present for the Arithmetic CODEC Type.

I32 : CodeText Length

CodeText Length specifies the total number of bits of CodeText data (CodeText data field is described below). This data field is only present if CODEC Type is not equal to “Null CODEC.”

I32 : Value Element Count

Value Element Count specifies the number of values that the CODEC is expected to decode (i.e. it’s like the “length” field written if you’re just writing out a vector of integers). This data field is only present if CODEC Type is not equal to “Null CODEC.” Upon completion of decoding the CodeText data field below, the number of decoded Values should be equal to Value Element Count. When only a single Probability Context Table is used, Value Element Count will also be equal to the number of Symbols decoded upon completion of decoding.

I32 : Symbol Count

When two Probability Context Tables are being used, Symbol Count specifies the number of Symbols to be decoded by the Arithmetic CODEC. There is a subtlety present in the method CodecDriver::addOutputSymbol() when it is passed an Escape symbol. Only if the Codec is using Probability Context Table 0 when it receives an Escape symbol does it emit a Value from the "Out-Of-Band" data array. Because of this subtlety, the number of Symbols decoded can be larger than the number of Values produced, thus the reason for writing this field distinct from Value Element Count.

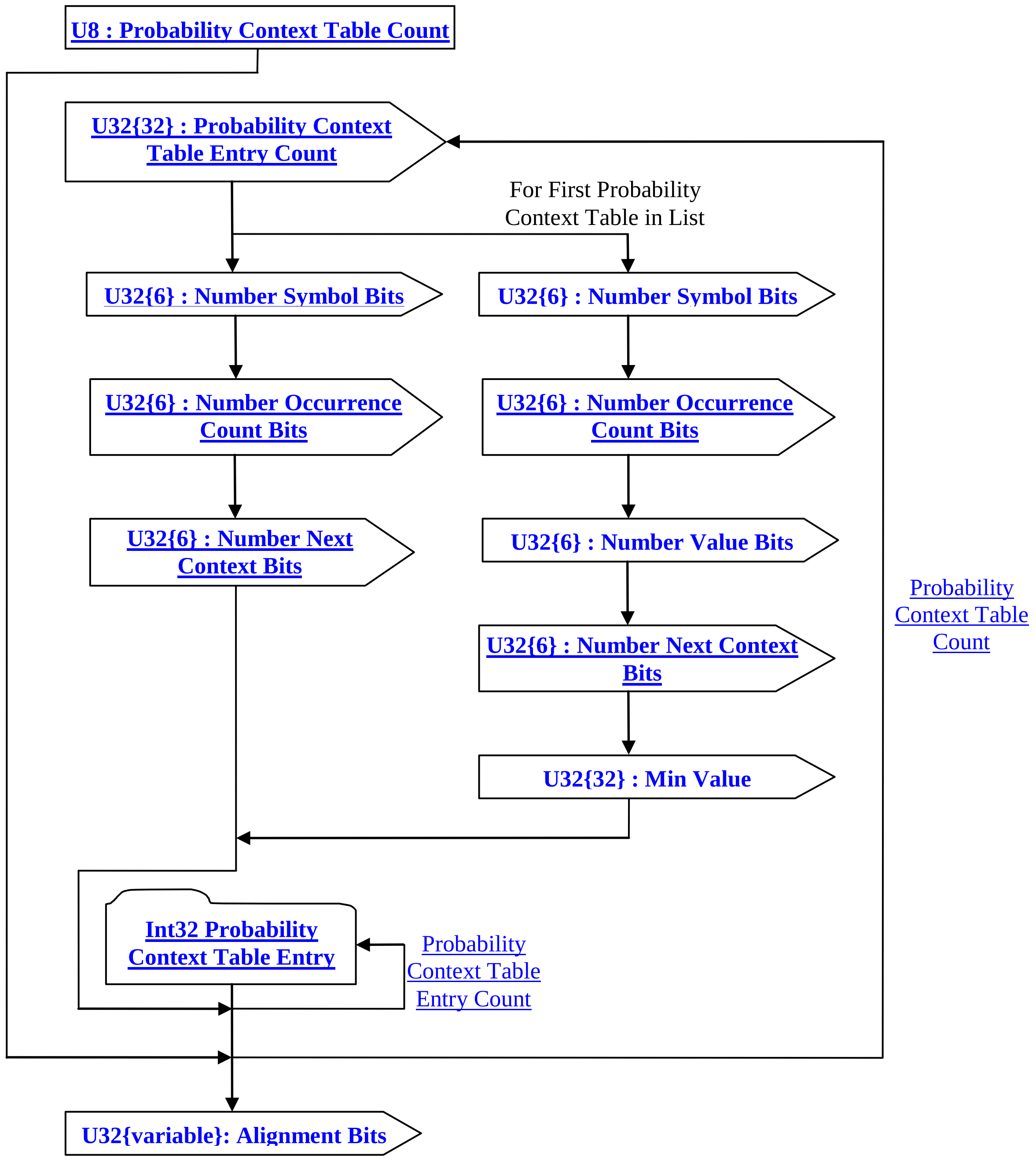
VecU32 : CodeText

CodeText is the array/vector of encoded symbols. For CODEC Type not equal to “Null CODEC”, the total number of bits of encoded data in this array is indicated by the previously described CodeText Length data field.

8.1.1.1 Int32 Probability Contexts

Int32 Probability Contexts data collection is a list of Probability Context Tables. The Int32 Probability Contexts data collection is only present for the Arithmetic CODEC Type. A Probability Context Table is a trimmed and scaled histogram of the input values. It tallies the frequencies of the several most frequently occurring values. It is central to the operation of the arithmetic CODEC.

Figure 219: Int32 Probability Contexts data collection



U8 : Probability Context Table Count
U32{32} : Probability Context Table Entry Count
For First Probability Context Table in List
U32{6} : Number Symbol Bits
U32{6} : Number Symbol Bits
U32{6} : Number Occurrence Count Bits
U32{6} : Number Occurrence Count Bits
U32{6} : Number Next Context Bits
U32{6} : Number Value Bits
Probability Context Table Count
U32{6} : Number Next Context Bits
U32{32} : Min Value
Int32 Probability Context Table Entry
Probability Context Table Entry Count
U32{variable}: Alignment Bits

U8 : Probability Context Table Count

Probability Context Table Count specifies the number of Probability Context Tables to follow and will always have a value of either “1” or “2”.

U32{32} : Probability Context Table Entry Count

Probability Context Table Entry Count specifies the number of entries in this Probability Context Table.

U32{6} : Number Symbol Bits

Number Symbol Bits specifies the number of bits used to encode the Symbol range.

U32{6} : Number Occurrence Count Bits

Number Occurrence Count Bits specifies the number of bits used to encode the Occurrence Count range.

U32{6} : Number Value Bits

Number Value Bits specifies the number of bits used to encode the Associated Value range. Note that Number Value Bits is only specified in the JT file for the *first* Probability Context Table. If a second Probability Context Table is present, the Number Value Bits from the first should be used for the second as well.

U32{6} : Number Next Context Bits

Number Next Context Field Bits specifies the number of bits used for the Next Context Field in 8.1.1.1.1 Int32 Probability Context Table Entry.

U32{32} : Min Value

Min Value specifies the minimum of all Associated Values (i.e. one per table entry) stored in this Probability Context Table. This value is used to compute the real Associated Value for a Probability Context Table Entry. See Associated Value description in 8.1.1.1.1 Int32 Probability Context Table Entry.

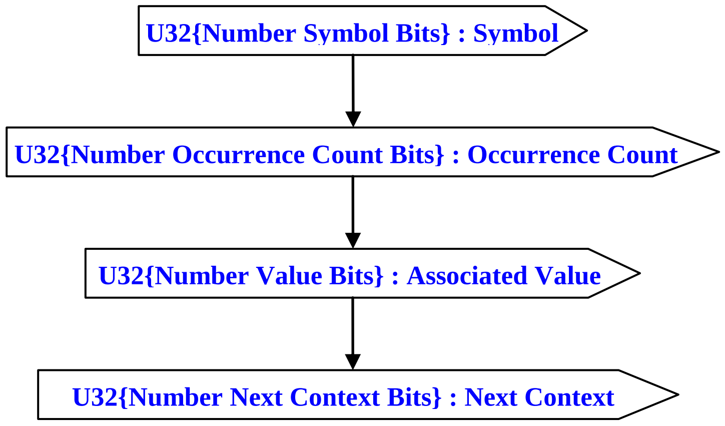
U32{variable}: Alignment Bits

Alignment Bits represents the number of additional padding bits stored to arrive at the next even multiple of 8 bits. Values of "0" are stored in the alignment bits.

Note: Data written into the JT file is always aligned on bytes. Therefore after reading in a block of bit data such as the probability context tables it is necessary to discard any remaining bits on the last byte that is read in. This is represented by the "Alignment Bits" entry.

8.1.1.1.1 Int32 Probability Context Table Entry

Figure 220: Int32 Probability Context Table Entry data collection


U32{Number Symbol Bits} : Symbol
U32{Number Occurrence Count Bits} : Occurrence Count
U32{Number Value Bits} : Associated Value
U32{Number Next Context Bits} : Next Context

U32{Number Symbol Bits} : Symbol

Symbol is a small integer number associated with a specific value in the context table. It serves only to impose an order on the entries in the Probability Context Table. The symbol is stored with a "+2" added to the value and thus a reader must subtract "2" from the read value to get the true symbol value. Complete description for Number Symbol Bits can be found in 8.1.1.1 Int32 Probability Contexts.

Note: Even though the symbol is written as a U32{Number Symbol Bits} it is possible to end up with a negative number after subtracting "2" from the read in value. One example that will occur frequently is the escape symbol used for out-of-band data which will have the value "0" in the file, however it will become "-2", its true symbol value, after subtracting "2" from the read in "0" value.

U32{Number Occurrence Count Bits} : Occurrence Count

Occurrence Count specifies the relative frequency of the value. Complete description for Number Occurrence Count Bits can be found in 8.1.1.1 Int32 Probability Contexts.

Note: Occurrence Counts for all symbols are normalized (converted to a relative frequency) during the write process in order to ensure the minimum amount of bits possible is used to write them. This has several implications the reader should be aware of:

The sum of all Occurrence Counts is not guaranteed to equal the number of symbols to be decoded (see Value Element Count in section 8.1.1 for number of symbols to be decoded). During Arithmetic decoding as described in Appendix C: 3.2.

pDriver->numSymbolsToRead() – Refers to the total number of symbols to be decoded (i.e. Value Element Count in section 8.1.1 when the number of Probability Context Tables is equal to 1, or Symbol Count when the number of Probability Context Tables is 2).

pCurrContext->totalCount() – Refers to the sum of the "Occurrence Count" values for all the symbols associated with a Probability Context.

U32{Number Value Bits} : Associated Value

Associated Value is the value (from the input data) that the symbol represents. The CODECs don't directly encode values, they encode symbols. Symbols, then, are associated with specific values, so when the CODEC decodes an array of symbols, you can reconstruct the array of values that was intended by looking up the symbols in the Probability Context Table. This value is stored with "Min Value" subtracted from the value. Complete descriptions for "Min Value" and Number Value Bits can be found in 8.1.1.1 Int32 Probability Contexts.

Note: The associated value for an escape symbol is undefined and therefore can be any valid U32 number.

U32{Number Next Context Bits} : Next Context

Next Context field specifies which Probability Context Table to use when decoding the next symbol. The value of this field will be greater than or equal to 0, and less than Probability Context Table Count.

8.1.2 Int32 Compressed Data Packet Mk. 2

The Int32 Compressed Data Packet Mk. 2 collection represents an enhanced form of the original Int32 Compressed Data Packet. Note that the Int32 Compressed Data Packet Mk. 2 collection can in itself contain another Int32 Compressed Data Packet Mk. 2 collection if there are any "Out-Of-Band data." In the context of the JT format data compression algorithms and Int32 Compressed Data Packet Mk. 2, "out-of-band data" has the meaning described below.

Entropy CODECs (e.g. Arithmetic) exploit the statistics present in the relative frequencies of the values being encoded. Values that occur frequently enough allow these methods to encode each of the values as a "symbol" in fewer bits that it would take to encode the value itself. Values that occur too infrequently to take advantage of this property are written *aside* into the "out-of-band data" array to be encoded separately. An "escape" symbol is encoded in their place as a placeholder in the primal CODEC (note, see "Symbol" data field definition in 8.1.2.1.1 Int32 Probability Context Table Entry Mk. 2 for further details on the representation of "escape" symbol).

Essentially the "out-of-band data" is the high-entropy residue left over after the CODEC has squeezed all the advantage out of the original data stream that it can. However, this "out-of-band data" is sent back around for another pass because sometimes there are *new* or *different* statistics to be exploited.

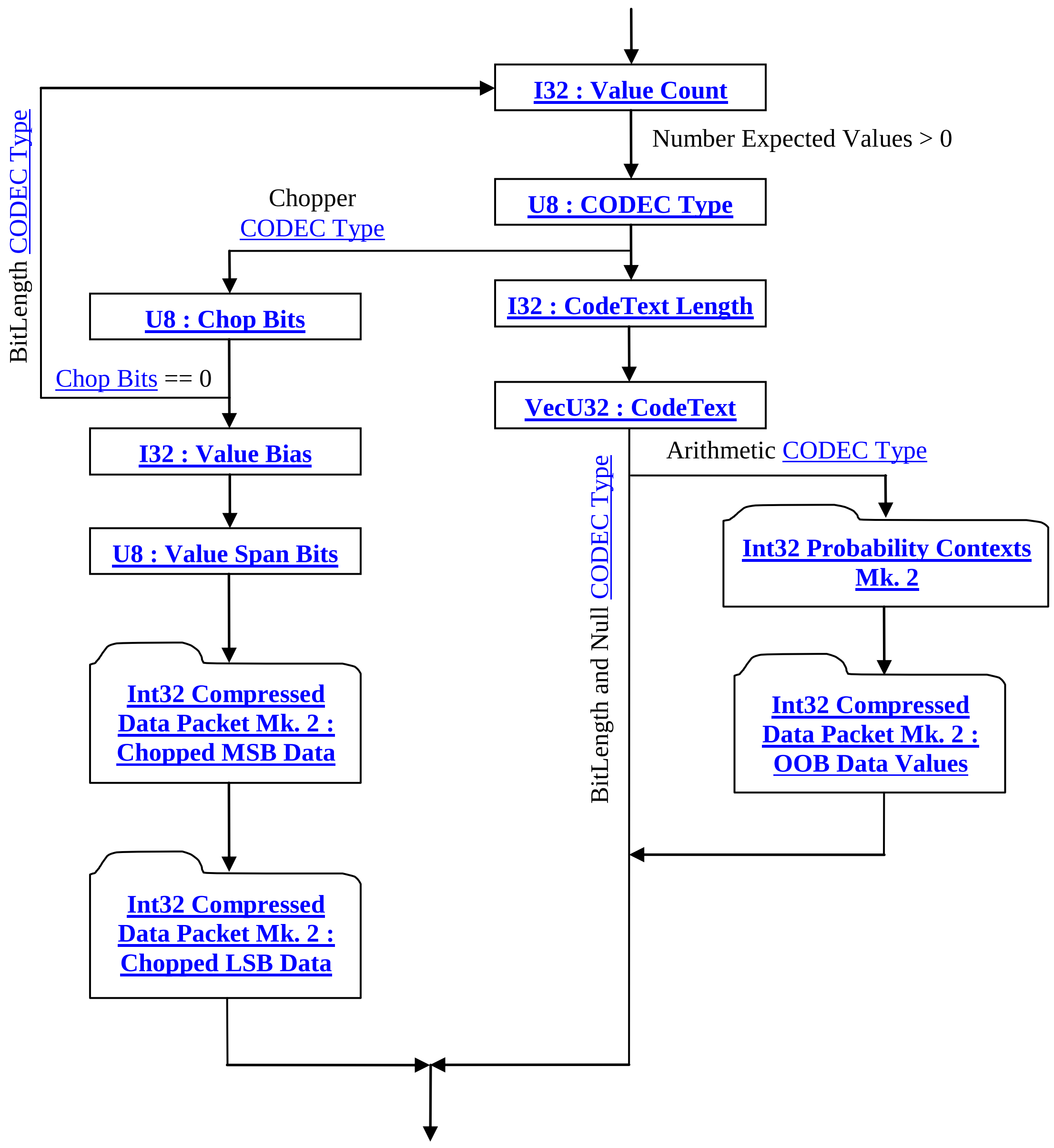
The Int32 Compressed Data Packet Mk. 2 brings the new *Chopper* pseudo-CODEC to the table. Its job is to identify fields of bits in a sequence of otherwise incompressible data that may be hiding low-entropy statistics that can be profitably exploited. In other words, it "chops" the input data up into bit fields, and then encodes them separately using the Arithmetic or BitLength CODECs, or in some cases, another round of chopping. The Chopper also removes *value bias* from the original input data array. Some input data arrays may contain values that are clustered around a certain central value. In these cases, it is profitable to first subtract out a *bias value* from the original input data. In some cases, this simple expedient may dramatically reduce the apparent field width necessary to code the variation in the original sequence.

In some cases, all values may be written as "out of band" when the Codec cannot perform *any* useful compression. In this case, the encoded I32 : CodeText Length field will be 0, and the I32 : Out-Of-Band Value Count will be equal to I32 : Value Element Count. The implied action in this case is to merely copy the Out-Of-Band value data into the output Value Element array instead of invoking the Codec.

When all other coding options have been exhausted, the Bitlength CODEC is invoked. The Bitlength CODEC directly encodes all values given to it, does not require a probability context, and hence never produces additional “out-of-band data”. The byte stops there, in other words.

Note that in the diagram below, encoding can loop back recursively for Out-Of-Band data and chopper fields. *For JT v9 files, the maximum recursion depth may not exceed three*.

Figure 221: Int32 Compressed Data Packet Mk. 2 data collection


I32 : Value Count
Number Expected Values > 0
U8 : CODEC Type
Chopper CODEC Type
BitLength CODEC Type
I32 : CodeText Length
U8 : Chop Bits
Chop Bits == 0
VecU32 : CodeText
I32 : Value Bias
Arithmetic CODEC Type
U8 : Value Span Bits
Int32 Probability Contexts Mk. 2
BitLength and Null CODEC Type
Int32 Compressed Data Packet Mk. 2 : Chopped MSB Data
Int32 Compressed Data Packet Mk. 2 : OOB Data Values
Int32 Compressed Data Packet Mk. 2 : Chopped LSB Data

I32 : Value Count

Value Count specifies the number of values that the CODEC is expected to decode (i.e. it's like the "length" field written if you're just writing out a vector of integers). Upon completion of decoding the CodeText data field below, the number of decoded Values should be equal to Value Count. When only a single Probability Context Table is used, Value Element Count will also be equal to the number of Symbols decoded upon completion of decoding.

U8 : CODEC Type

CODEC Type specifies the algorithm used to encode/decode the data. See 8.2 Encoding Algorithms for complete explanation of each of the encoding algorithms.

= 0	Null CODEC
= 1	Bitlength CODEC
= 3	Arithmetic CODEC
= 4	Chopper CODEC

I32 : CodeText Length

CodeText Length specifies the total number of bits of CodeText data (CodeText data field is described below).

VecU32 : CodeText

CodeText is the array/vector of encoded symbols. For CODEC Type not equal to "Null CODEC", the total number of bits of encoded data in this array is indicated by the previously described CodeText Length data field.

U8 : Chop Bits

Chop Bits specifies the number of high-order bits "chopped off" from the *biased* input data array and coded separately from the low-order bits. Repeated applications of the Chopper pseudo-CODEC can expose low-entropy bit fields that would be inaccessible by directly coding the data array. Chop Bits is the number of bits coded into the Chopped MSB Data field.

I32 : Value Bias

Value Bias is the (signed) number that is subtracted from the original input data array elements *before* computing Value Span Bits and Chop Bits. See Chopped LSB Data below for a full explanation of how to reconstitute the original data values using Value Bias and the two chopped fields.

U8 : Value Span Bits

Value Span Bits specifies the total bit width of the *biased* input data array. Note that Value Span Bits minus Chop Bits is the number of low-order bits present in the Chopped LSB Data field.

Int32 Compressed Data Packet Mk. 2 : Chopped MSB Data

This field contains the separately compressed most significant bits of the *biased* input data array, whose elements contain Value Span Bits bits of significance. In other words, this field contains the bit field from the *biased* data array beginning at bit number ValueSpan-ChopBits and ending at bit number ValueSpan-1 inclusive. This field may contain negative numbers.

Int32 Compressed Data Packet Mk. 2 : Chopped LSB Data

This field contains the separately compressed most significant bits of the original input data array, whose elements contain Value Span Bits bits of significance. In other words, this field contains the bit field from the original data array beginning at bit number 0 and ending at bit number ValueSpan-ChopBits-1 inclusive. This field may only contain positive numbers; all bits above this range must encode to 0. A pseudo-code representation of the re-constituting the original data values is as follows:

```
    OrigValue[i] = (LSBValue[i] | (MSBValue[i] << (ValSpanBits - ChopBits))) + ValueBias;
```

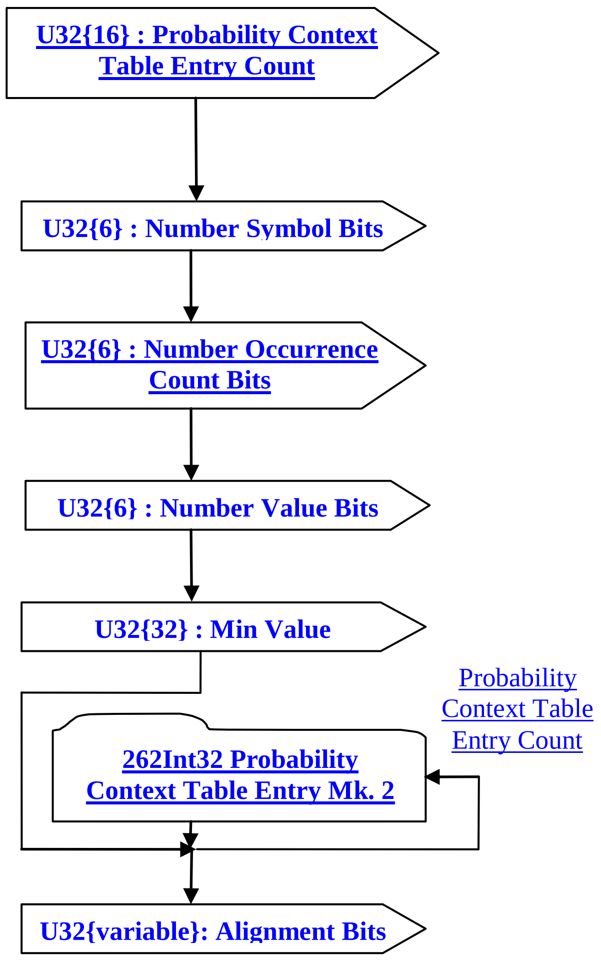
Int32 Compressed Data Packet Mk. 2 : OOB Data Values

This field encodes the out-of-band values associated with the Arithmetic CODEC.

8.1.2.1 Int32 Probability Contexts Mk. 2

Int32 Probability Contexts Mk. 2 data collection encodes a Probability Context Table, and is present only for the Arithmetic CODEC Type. A Probability Context Table is a trimmed and scaled histogram of the input values. It tallies the frequencies of the several most frequently occurring values. It is central to the operation of the Arithmetic CODEC.

Figure 222: Int32 Probability Contexts Mk. 2 data collection


U32{16} : Probability Context Table Entry Count
U32{6} : Number Symbol Bits
U32{6} : Number Occurrence Count Bits
U32{6} : Number Value Bits
U32{32} : Min Value
Probability Context Table Entry Count
262Int32 Probability Context Table Entry Mk. 2
U32{variable}: Alignment Bits

U32{16} : Probability Context Table Entry Count

Probability Context Table Entry Count specifies the number of entries in this Probability Context Table.

U32{6} : Number Symbol Bits

Number Symbol Bits specifies the number of bits used to encode the Symbol range.

U32{6} : Number Occurrence Count Bits

Number Occurrence Count Bits specifies the number of bits used to encode the Occurrence Count range.

U32{6} : Number Value Bits

Number Value Bits specifies the number of bits used to encode the Associated Value range. Note that Number Value Bits is only specified in the JT file for the *first* Probability Context Table. If a second Probability Context Table is present, the Number Value Bits from the first should be used for the second as well.

U32{32} : Min Value

Min Value specifies the minimum of all Associated Values (i.e. one per table entry) stored in this Probability Context Table. This value is used to compute the real Associated Value for a Probability Context Table Entry. See Associated Value description in 8.1.1.1.1 Int32 Probability Context Table Entry.

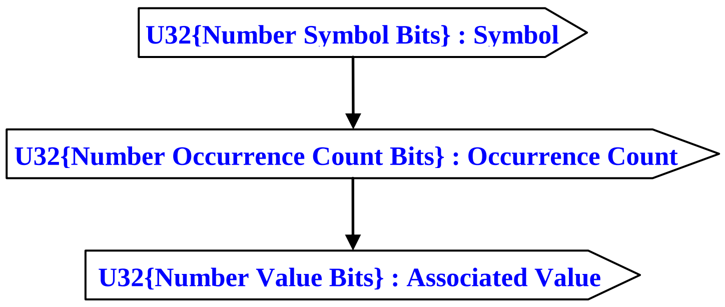
U32{variable}: Alignment Bits

Alignment Bits represents the number of additional padding bits stored to arrive at the next even multiple of 8 bits. Values of “0” are stored in the alignment bits.

Note: Data written into a JT file is always aligned on bytes. Therefore after reading in a block of bit data such as the probability context tables it is necessary to discard any remaining bits on the last byte that is read in. This is represented by the “Alignment Bits” entry.

8.1.2.1.1 Int32 Probability Context Table Entry Mk. 2

Figure 223: Int32 Probability Context Table Entry Mk. 2 data collection


U32{Number Symbol Bits} : Symbol
U32{Number Occurrence Count Bits} : Occurrence Count
U32{Number Value Bits} : Associated Value

U32{Number Symbol Bits} : Symbol

Symbol is a small integer number associated with a specific value in the context table. It serves only to impose an order on the entries in the Probability Context Table. The symbol is stored with a “+2” added to the value and thus a reader must subtract “2” from the read value to get the true symbol value. Complete description for Number Symbol Bits can be found in 8.1.2.1 Int32 Probability Contexts Mk. 2.

Note: Even though the symbol is written as a U32{Number Symbol Bits} it is possible to end up with a negative number after subtracting “2” from the read in value. One example that will occur frequently is the escape symbol used for out-of-band data which will have the value “0” in the file, however it will become “-2”, its true symbol value, after subtracting “2” from the read in “0” value.

U32{Number Occurrence Count Bits} : Occurrence Count

Occurrence Count specifies the relative frequency of the value. Complete description for Number Occurrence Count Bits can be found in 8.1.2.1 Int32 Probability Contexts Mk. 2.

Note: Occurrence Counts for all symbols are normalized (converted to a relative frequency) during the write process in order to ensure the minimum amount of bits possible is used to write them while closely approximating their actual frequency. This has several implications the reader should be aware of:

The sum of all Occurrence Counts is not guaranteed to equal the number of symbols to be decoded (see I32 : Value Count in section 8.1.2 for number of symbols to be decoded).

During Arithmetic decoding as described in Appendix C: 3.2.

pDriver->numSymbolsToRead() – Refers to the total number of symbols to be decoded (i.e. I32 : Value Count in section 8.1.2).

pCurrContext->totalCount() – Refers to the sum of the "Occurrence Count" values for all the symbols associated with a Probability Context.

U32{Number Value Bits} : Associated Value

Associated Value is the value (from the input data) that the symbol represents. The CODECs don't directly encode values, they encode symbols. Symbols, then, are associated with specific values, so when the CODEC decodes an array of symbols, you can reconstruct the array of values that was intended by looking up the symbols in the Probability Context Table. This value is stored with "Min Value" subtracted from the value. Complete descriptions for "Min Value" and Number Value Bits can be found in 8.1.2.1 Int32 Probability Contexts Mk. 2.

Note: The associated value for an escape symbol is undefined and therefore can be any valid U32 number.

8.1.3 Float64 Compressed Data Packet

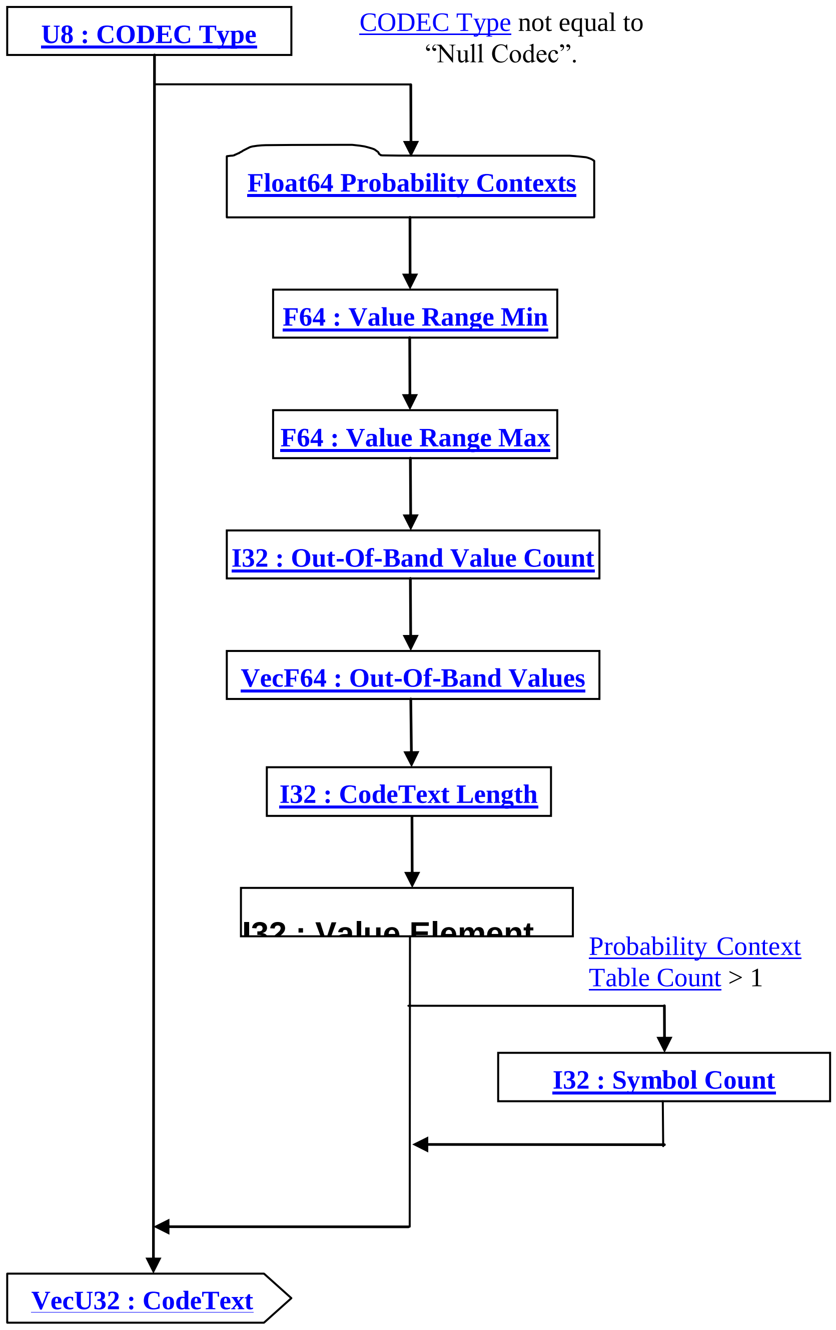
The Float64 Compressed Data Packet collection represents the format used to encode/compress a collection of data into a series of Float64 based symbols. This compression format also uses the concept of "out-of-band data" in its data contents definition. In the context of the JT format data compression algorithms and Float64 Compressed Data Packet, "out-of-band data" has the following meaning.

The Arithmetic CODEC (see 8.2 Encoding Algorithms for technical description) can exploit the statistics present in the relative frequencies of the values being encoded. Values that occur frequently enough allow the CODEC to encode each of the values as a "symbol" in fewer bits that it would take to encode the value itself. Values that occur too infrequently to take advantage of this property are written *aside* into the "out-of-band data" array. An "escape" symbol (i.e. value of "-2") is encoded in their place as a marker in the primal CODEC. Essentially the "out-of-band data" is the high-entropy junk/residue/slag left over after the CODECs have squeezed all the advantage out that it can.

Whereas the Int32 Compressed Data Packet (see 8.1.1 Int32 Compressed Data Packet) then sends this "out-of-band data" back around through a new CODEC looking for *different* statistics to be taken advantage of, the Float64 Compressed Data Packet simply writes out the "out-of-band data" array with no additional encoding attempted.

In some cases, all values may be written as "out of band" when the Codec cannot perform *any* useful compression. In this case, the encoded I32 : CodeText Length field will be 0, and the I32 : Out-Of-Band Value Count will be equal to I32 : Value Element Count. The implied action in this case is to merely copy the Out-Of-Band value data into the output Value Element array instead of invoking the Codec.

Figure 224: Float64 Compressed Data Packet data collection


U8 : CODEC Type
CODEC Type not equal to "Null Codec".
Float64 Probability Contexts
F64 : Value Range Min
F64 : Value Range Max
I32 : Out-Of-Band Value Count
VecF64 : Out-Of-Band Values
I32 : CodeText Length
I32 : Value Element
Probability Context Table Count > 1
I32 : Symbol Count
VecU32 : CodeText

U8 : CODEC Type

CODEC Type specifies the algorithm used to encode/decode the data. See 8.2 Encoding Algorithms for complete explanation of each of the encoding algorithms.

= 0	Null CODEC
= 1	Bitlength CODEC
= 3	Arithmetic CODEC
= 4	Chopper CODEC

F64 : Value Range Min

Value Range Min specifies the minimum of the value range used to encode the values. This data field is only present if CODEC Type is not equal to "Null CODEC."

F64 : Value Range Max

Value Range Max specifies the maximum of the value range used to encode the values. This data field is only present if CODEC Type is not equal to "Null CODEC."

I32 : Out-Of-Band Value Count

Out-Of-Band Value Count specifies the number of values that are "Out-Of-Band." This data field is only present if CODEC Type is not equal to "Null CODEC."

VecF64 : Out-Of-Band Values

Out-Of-Band Values specifies the vector/list of "Out-Of-Band" values. This data field is only present if CODEC Type is not equal to "Null CODEC."

I32 : CodeText Length

CodeText Length specifies the total number of bits of CodeText data (described below). This data field is only present if CODEC Type is not equal to "Null CODEC."

I32 : Value Element Count

Value Element Count specifies the number of values that the CODEC is expected to decode (i.e. it's like the "length" field written if you're just writing out a vector of integers). This data field is only present if CODEC Type is not equal to "Null CODEC." Upon completion of decoding the CodeText data field below, the number of decoded symbol values should be equal to Value Element Count.

I32 : Symbol Count

When two Probability Context Tables are being used, Symbol Count specifies the number of Symbols to be decoded by the Arithmetic CODEC. There is a subtlety present in the method CodecDriver::addOutputSymbol() when it is passed an Escape symbol. Only if the Codec is using Probability Context Table 0 when it receives an Escape symbol does it emit a Value from the "Out-Of-Band" data array. Because of this subtlety, the number of Symbols decoded can be larger than the number of Values produced, thus the reason for writing this field distinct from Value Element Count.

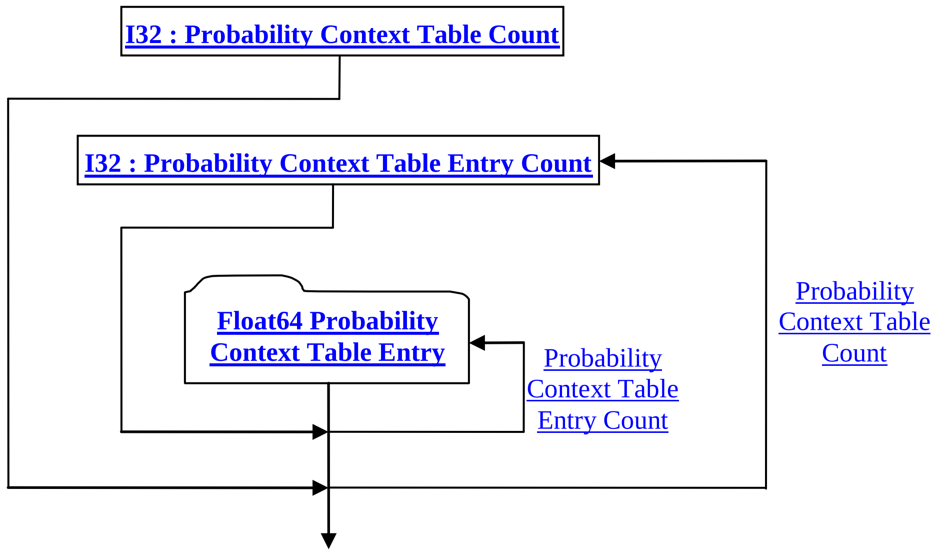
VecU32 : CodeText

CodeText is the array/vector of encoded symbols. For CODEC Type not equal to "Null CODEC", the total number of bits of encoded data in this array is indicated by the previously described CodeText Length data field.

8.1.3.1 Float64 Probability Contexts

Float64 Probability Contexts data collection is a list of Probability Context Tables. A Probability Context Table is a trimmed and scaled histogram of the input values. It tallies the frequencies of the several most frequently occurring values. It is central to the operation of the arithmetic CODEC.

Figure 225: Float64 Probability Contexts data collection


I32 : Probability Context Table Count
I32 : Probability Context Table Entry Count
Float64 Probability Context Table Entry
Probability Context Table Entry Count
Probability Context Table Count

I32 : Probability Context Table Count

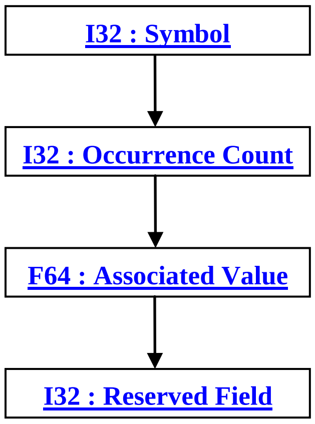
Probability Context Table Count specifies the number of Probability Context Tables to follow and will always have a value of either “1” or “2”.

I32 : Probability Context Table Entry Count

Probability Context Table Entry Count specifies the number of entries in this Probability Context Table.

8.1.3.1.1 Float64 Probability Context Table Entry

Figure 226: Float64 Probability Context Table Entry data collection



I32 : Symbol

Symbol is a small integer number associated with a specific value in the context table. It serves only to impose an order on the entries in the Probability Context Table. Note that a value of “-2” represents the “escape” symbol placeholder encoded for “out-of-band data” (see 8.1.3 Float64 Compressed Data Packet for additional details).

I32 : Occurrence Count

Occurrence Count specifies the relative frequency of the value.

F64 : Associated Value

Associated Value is the value (from the input data) that the symbol represents. The CODECs don't directly encode *values*, they encode *symbols*. Symbols, then, are associated with specific values, so when the CODEC decodes an array of symbols, you can reconstruct the array of values that was intended by looking up the symbols in the Probability Context Table.

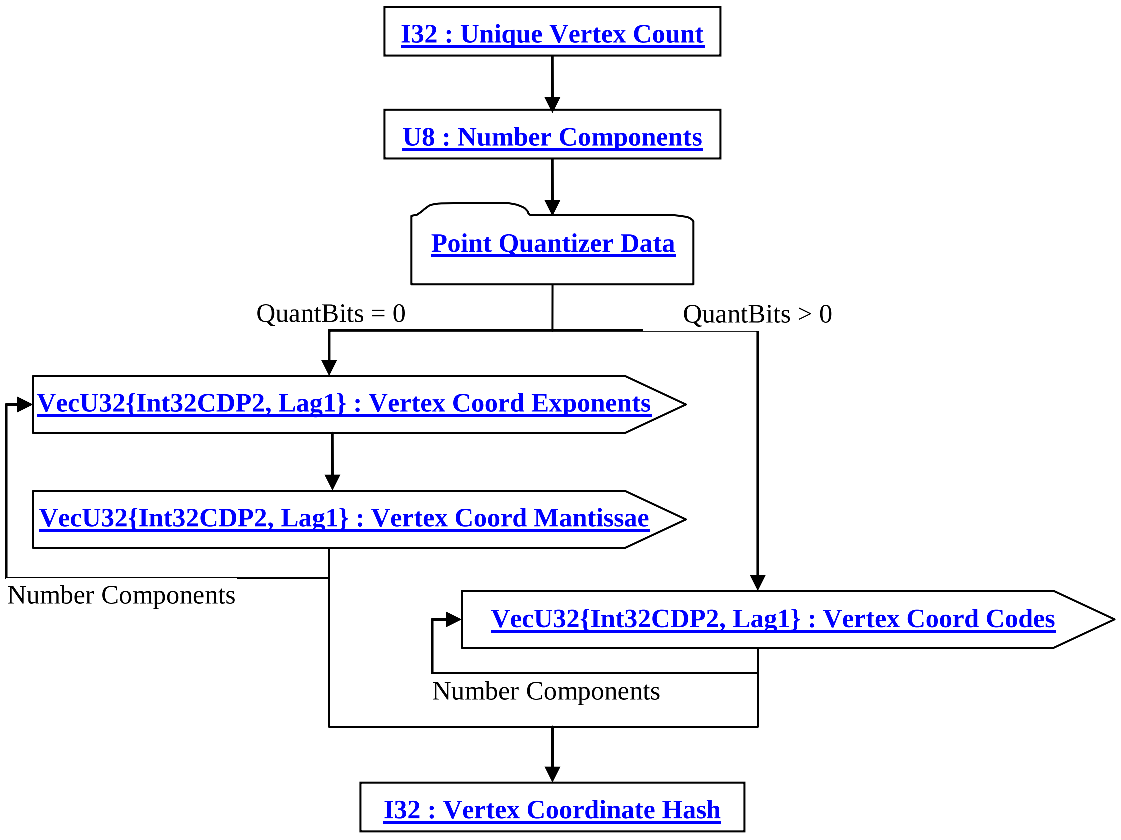
I32 : Reserved Field

Reserved Field is a data field reserved for future JT format expansion.

8.1.4 Compressed Vertex Coordinate Array

The Compressed Vertex Coordinate Array data collection contains the quantization data/representation for a set of vertex coordinates.

Figure 227: Compressed Vertex Coordinate Array data collection


I32 : Unique Vertex Count
U8 : Number Components
Point Quantizer Data
QuantBits = 0
QuantBits > 0
VecU32{Int32CDP2, Lag1} : Vertex Coord Exponents
VecU32{Int32CDP2, Lag1} : Vertex Coord Mantissae
Number Components
VecU32{Int32CDP2, Lag1} : Vertex Coord Codes
Number Components
I32 : Vertex Coordinate Hash

Complete description for Point Quantizer Data can be found in 8.1.4 Point Quantizer Data.

I32 : Unique Vertex Count

Vertex Count specifies the count (number of unique) vertices in the Vertex Codes arrays. Identical values are only stored once therefore it may be necessary to smear out the vertices as described in TopoMesh Compressed Rep Data V1 and TopoMesh Topologically Compressed LOD Data.

U8 : Number Components

Number Components specifies the number of vertex components present for each vertex record in the set of vertex records.

VecU32{Int32CDP2, Lag1} : Vertex Coord Exponents

Vertex Coord Exponents is a vector of Floating Point Exponents and Sign for all the ith component values of a set of vertex coordinates. Vertex Coord Exponents uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2, Lag1} : Vertex Coord Mantissae

Vertex Coord Mantissae is a vector of Floating Point Mantissae for all the ith component values of a set of vertex coordinates. Vertex Coord Mantissae uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2, Lag1} : Vertex Coord Codes

Vertex Coord Codes is a vector of quantizer "codes" for all the ith component values of a set of vertex coordinates. Vertex Coord Codes uses the Int32 version of the CODEC to compress and encode data.

I32 : Vertex Coordinate Hash

The Vertex Coordinate Hash is the combined hash of the unique vertex coordinate records. If the number of quantization bits is equal to zero the hash value is equal to the combined hash of the vertex coordinate values for each of the component arrays. If the number of quantization bits is greater than 0 the hash value is equal to the combined hash of the vertex coordinates codes for each of the component arrays. Refer to section 9.5 for a more detailed description on hashing.

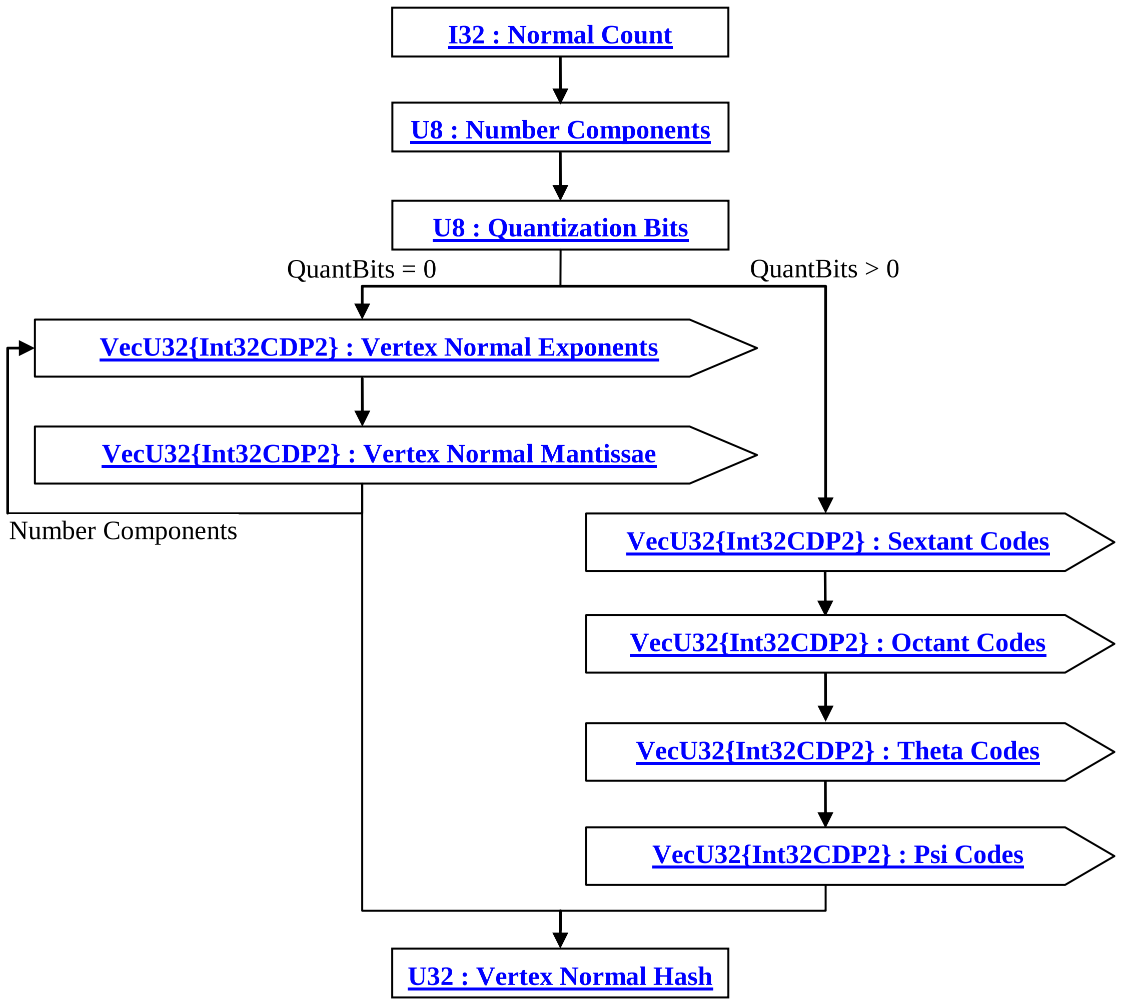
```
UInt32 uHash    = 0;
uInt32 nUniqVtx = 0;
vecF32 vCoord[nUniqVtx][3];
vecU32 vCodes[3];
...
if ( uQuantBits == 0 ) {
  for ( int i=0 ; i<nComp ; i++ ) {
    for ( int j=0 ; j<nUniqVtx ; j++) {
      uHash = hash32( (UInt32*)(&vCoord[j][i]), 1, uHash );
    }
  }
} else {
  for ( int i=0 ; i<nComp ; i++ ) {
    uHash = hash32( &vCodes[i], nUniqVtx, uHash );
  }
}
```

8.1.5 Compressed Vertex Normal Array

The Compressed Vertex Normal Array data collection contains the compressed data/representation for a set of vertex normals. Compressed Vertex Normal Array data collection is only present if previously read vertex bindings denote normals are presents (See Vertex Shape LOD Data U64 : Vertex Bindings for complete explanation of the vertex bindings).

A variation of the CODEC developed by Michael Deering at Sun Microsystems is used to encode the normals when quantization is enabled. The variation being that the "Sextants" are arranged differently than in Deering's scheme [6], for better delta encoding. See 8.2.4 Deering Normal CODEC for a complete explanation on the Deering CODEC used.

Figure 228: Compressed Vertex Normal Array data collection


I32 : Normal Count
U8 : Number Components
U8 : Quantization Bits
QuantBits = 0
QuantBits > 0
VecU32{Int32CDP2} : Vertex Normal Exponents
VecU32{Int32CDP2} : Vertex Normal Mantissae
Number Components
VecU32{Int32CDP2} : Sextant Codes
VecU32{Int32CDP2} : Octant Codes
VecU32{Int32CDP2} : Theta Codes
VecU32{Int32CDP2} : Psi Codes
U32 : Vertex Normal Hash

I32 : Normal Count

Normal count specifies the number of normals. This number should equal the total number of vertex records.

U8 : Number Components

Number Components specifies the number of normal components present for each vertex record in the set of vertex records.

U8 : Quantization Bits

The number of bits used when the Deering Normal CODEC if quantization is enabled. A value of 0 denotes that quantization is disabled.

VecU32{Int32CDP2} : Vertex Normal Exponents

Vertex Normal Components is a vector of Floating Point Exponents for all the ith component values of a set of vertex coordinates. Vertex Normal Components uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Vertex Normal Mantissae

Vertex Normal Components is a vector of Floating Point Mantissae for all the ith component values of a set of vertex coordinates. Vertex Normal Components uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Sextant Codes

Sextant Codes is a vector of "codes" (one per normal) for a set of normals identifying which Sextant of the corresponding sphere Octant each normal is located in. Sextant Codes uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Octant Codes

Octant Codes is a vector of "codes" (one per normal) for a set of normals identifying which sphere Octant each normal is located in. Octant Codes uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Theta Codes

Theta Codes is a vector of "codes" (one per normal) for a set of normals representing in Sextant coordinates the quantized theta angle for each normal's location on the unit radius sphere; where theta angle is defined as the angle in spherical coordinates about the Y-axis on a unit radius sphere. Theta Codes uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Psi Codes

Psi Codes is a vector of "codes" (one per normal) for a set of normals representing in Sextant coordinates the quantized Psi angle for each normal's location on the unit radius sphere; where Psi angle is defined as the longitudinal angle in spherical coordinates from the y = 0 plane on the unit radius sphere. Psi Codes uses the Int32 version of the CODEC to compress and encode data

U32 : Vertex Normal Hash

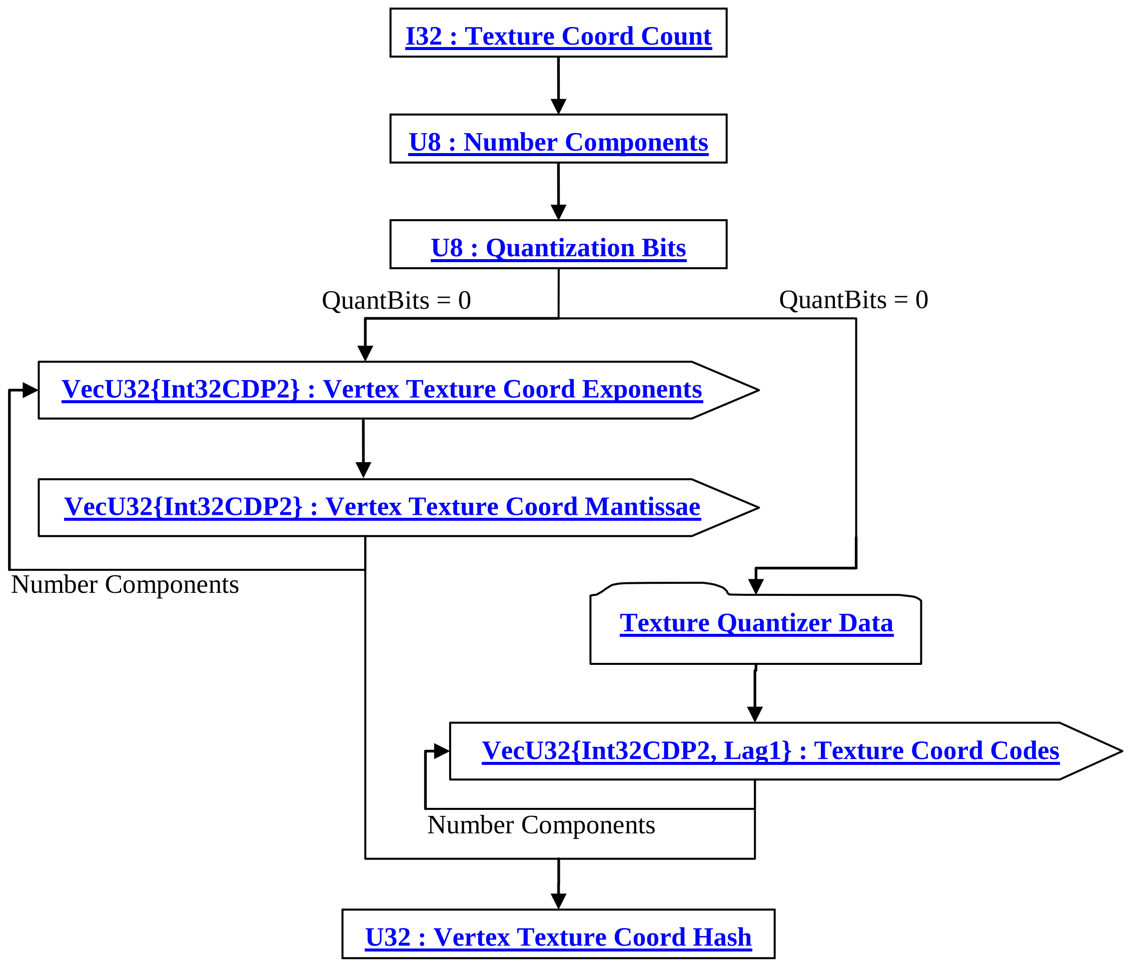
The Vertex Normal Hash is the combined hash of the vertex normals. If the number of quantization bits is equal to zero the hash value is equal to the combined hash of the vertex normal values for each of the component arrays. If the number of quantization bits is greater than 0 the hash value is equal to the combined hash of the Sextant, Octant, Theta, and Psi Codes for all vertex records. Refer to section 9.5 for a more detailed description on hashing.

```
UInt32 uHash   = 0;
uInt32 nVtxRec = 0;
vecF32 vNorm[nVtxRec][3];
vecU32 vSextant, vOctant. vTheta, vPsi;
...
if ( uQuantBits == 0 ) {
  for ( int i=0 ; i<nComp ; i++ ) {
    for ( int j=0 ; j<nVtxRec ; j++) {
      uHash = hash32( (UInt32*)(&vNorm[j][i]), 1, uHash );
    }
  }
} else {
    uHash = hash32( &vSextant, nVtxRec, uHash );
    uHash = hash32( &vOctant, nVtxRec, uHash );
    uHash = hash32( &vTheta, nVtxRec, uHash );
    uHash = hash32( &vPsi, nVtxRec, uHash );
}
```

8.1.6 Compressed Vertex Texture Coordinate Array

The Compressed Vertex Texture Coordinate Array data collection contains the quantization data/representation for a set of vertex texture coordinates. Compressed Vertex Texture Coordinate Array data collection is only present if previously read vertex bindings denote texture coordinates are presents (See Vertex Shape LOD Data U64 : Vertex Bindings for complete explanation of the vertex bindings).

Figure 229: Compressed Vertex Texture Coordinate Array data collection


I32 : Texture Coord Count
U8 : Number Components
U8 : Quantization Bits
QuantBits = 0
QuantBits = 0
VecU32{Int32CDP2} : Vertex Texture Coord Exponents
VecU32{Int32CDP2} : Vertex Texture Coord Mantissae
Number Components
Texture Quantizer Data
VecU32{Int32CDP2, Lag1} : Texture Coord Codes
Number Components
U32 : Vertex Texture Coord Hash

Complete description for Texture Quantizer Data can be found in 8.1.10 Texture Quantizer Data.

I32 : Texture Coord Count

Color count specifies the number of Texture Coordinates. This number should equal the total number of vertex records.

U8 : Number Components

Number Components specifies the number of Texture Coordinate components present for each vertex record in the set of vertex records.

U8 : Quantization Bits

Number of Bits specifies the quantized size (i.e. the number of bits of precision) for each of the components. The actual number of quantization bits used is specified within Texture Quantizer Data. Value must be within range [0:24] inclusive.

VecU32{Int32CDP2} : Vertex Texture Coord Exponents

Vertex Texture Coordinate Components is a vector of Floating Point Exponents for all the ith component values of a set of vertex coordinates. Vertex Texture Coordinate Components uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Vertex Texture Coord Mantissae

Vertex Texture Coordinate Components is a vector of Floating Point Mantissae for all the ith component values of a set of vertex coordinates. Vertex Texture Coordinate Components uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2, Lag1} : Texture Coord Codes

V-Texture Coord Codes is a vector of quantizer "codes" for all the nth-component of a set of vertex texture coordinates. V-Texture Coord Codes uses the Int32 version of the CODEC to compress and encode data.

U32 : Vertex Texture Coord Hash

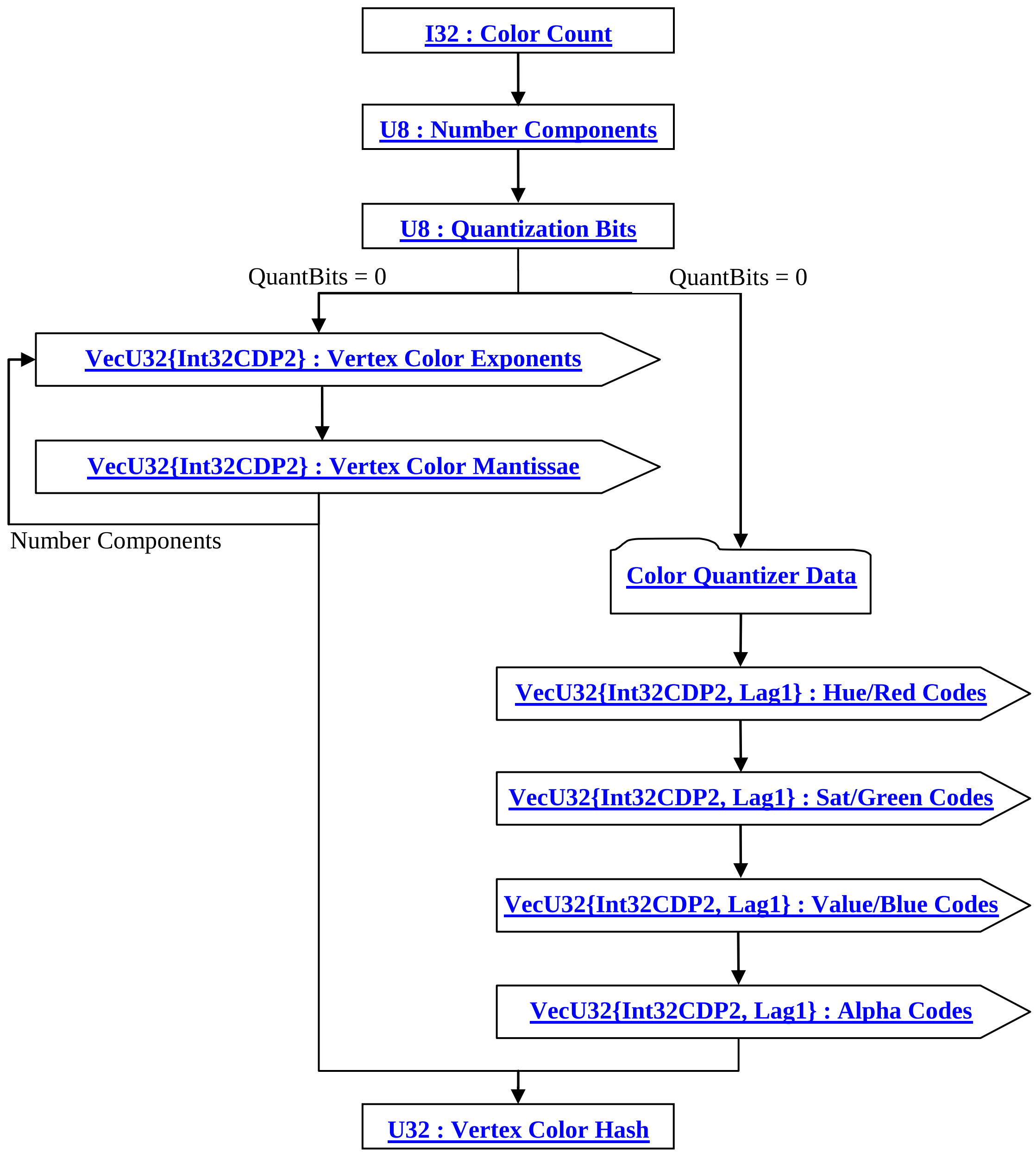
The Vertex Texture Coord Hash is the combined hash of the Vertex Texture Coordinates. If the number of quantization bits is equal to zero the hash value is equal to the combined hash of the vertex texture coordinate values for each of the component arrays. If the number of quantization bits is greater than 0 the hash value is equal to the combined hash of the vertex texture coordinates codes for each of the component arrays. Refer to section 9.5 for a more detailed description on hashing.

```
UInt32 uHash    = 0;
uInt32 nVtxRec = 0;
vecF32 vTexCoord[nVtxRec][4];
vecU32 vCodes[4];
...
if ( uQuantBits == 0 ) {
  for ( int i=0 ; i<nComp ; i++ ) {
    for ( int j=0 ; j<nVtxRec ; j++) {
      uHash = hash32( (UInt32*)(&vTexCoord[j][i]), 1, uHash );
    }
  }
} else {
  for ( int i=0 ; i<nComp ; i++ ) {
    uHash = hash32( &vCodes[i], nVtxRec, uHash );
  }
}
```

8.1.7 Compressed Vertex Color Array

The Compressed Vertex Color Array data collection contains the quantization data/representation for a set of vertex colors. Compressed Vertex Color Array data collection is only present if previously read Color Binding value is not equal to zero (See Vertex Shape LOD Data for complete explanation of Color Binding data field).

Figure 230: Compressed Vertex Color Array data collection


I32 : Color Count
U8 : Number Components
U8 : Quantization Bits
QuantBits = 0
QuantBits = 0
VecU32{Int32CDP2} : Vertex Color Exponents
VecU32{Int32CDP2} : Vertex Color Mantissae
Number Components
Color Quantizer Data
VecU32{Int32CDP2, Lag1} : Hue/Red Codes
VecU32{Int32CDP2, Lag1} : Sat/Green Codes
VecU32{Int32CDP2, Lag1} : Value/Blue Codes
VecU32{Int32CDP2, Lag1} : Alpha Codes
U32 : Vertex Color Hash

Complete description for Color Quantizer Data can be found in 8.1.11 Color Quantizer Data.

I32 : Color Count

Color count specifies the number of color records. This number should equal the total number of vertex records.

U8 : Number Components

Number Components specifies the number of Color components present for each vertex record in the set of vertex records.

U8 : Quantization Bits

Number of Bits specifies the quantized size (i.e. the number of bits of precision) for each of the 3 or 4 color components. This value must satisfy the following condition: "0 <= Number Of Bits <= 8".

VecU32{Int32CDP2} : Vertex Color Exponents

Vertex Normal Components is a vector of Floating Point Exponents for all the ith component values of a set of vertex coordinates. Vertex Normal Components uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2} : Vertex Color Mantissae

Vertex Normal Components is a vector of Floating Point Mantissae for all the ith component values of a set of vertex coordinates. Vertex Normal Components uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2, Lag1} : Hue/Red Codes

Hue/Red Codes is a vector of quantizer "codes" for all the Hue/Red color components of a set of vertex colors. Hue/Red Codes uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2, Lag1} : Sat/Green Codes

Sat/Green Codes is a vector of quantizer "codes" for all the Saturation/Green color components of a set of vertex colors. Sat/Green Codes uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2, Lag1} : Value/Blue Codes

Value/Blue Codes is a vector of quantizer "codes" for all the Value/Blue color components of a set of vertex colors. Value/Blue Codes uses the Int32 version of the CODEC to compress and encode data.

VecU32{Int32CDP2, Lag1} : Alpha Codes

Alpha Codes is a vector of quantizer "codes" for all the Alpha color components of a set of vertex colors. Alpha Codes uses the Int32 version of the CODEC to compress and encode data.

U32 : Vertex Color Hash

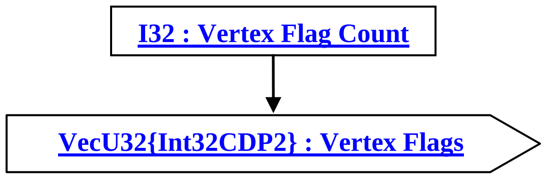
The Vertex Color Hash is the combined hash of the vertex colors. If the number of quantization bits is equal to zero the hash value is equal to the combined hash of the vertex color values for each of the component arrays. If the number of quantization bits is greater than 0 the hash value is equal to the combined hash of the Hue/Red, Sat/Green, Value/Blue, and Alpha Codes for all vertex records. Refer to section 9.5 for a more detailed description on hashing.

```
UInt32 uHash    = 0;
uInt32 nVtxRec = 0;
vecF32 vCol[nVtxRec][3];
vecU32 vHue, vSat, vVal, vAlp;
...
if ( uQuantBits == 0 ) {
  for ( int i=0 ; i<nComp ; i++ ) {
    for ( int j=0 ; j<nVtxRec ; j++) {
      uHash = hash32( (UInt32*)(&vCol[j][i]), nVtxRec, uHash );
    }
  }
} else {
    uHash = hash32( &vHue, nVtxRec, uHash );
    uHash = hash32( &vSat, nVtxRec, uHash );
    uHash = hash32( &vVal, nVtxRec, uHash );
    uHash = hash32( &vAlp, nVtxRec, uHash );
}
```

8.1.8 Compressed Vertex Flag Array

The Compressed Vertex Flag Array data collection contains the quantization data/representation for per vertex flags. Compressed Vertex Flag Array data collection is only present if previously read Vertex Flag Binding value is not equal to zero.

Figure 231: Compressed Vertex Flag Array data collection



I32 : Vertex Flag Count

Vertex flag count specifies the number of vertex flags. This number should be equal to the total number of vertex records.

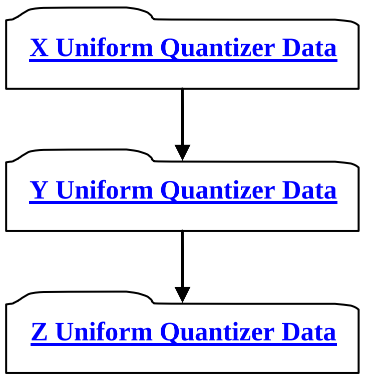
VecU32{Int32CDP2} : Vertex Flags

Vertex Flags is a vector of per vertex bit flags encoded as integers with valid values of either 0 (false) or 1 (true). Vertex Flags uses the Int32 version of the CODEC to compress and encode data.

8.1.9 Point Quantizer Data

A Point Quantizer Data collection is made up of three Uniform Quantizer Data collections; there is a separate Uniform Quantizer Data collection for the X, Y, and Z values of point coordinates.

Figure 232: Point Quantizer Data collection

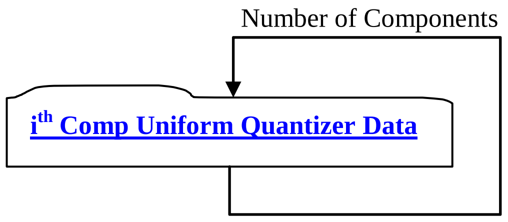


Complete description for X Uniform Quantizer Data, Y Uniform Quantizer Data and Z Uniform Quantizer Data can be found in 8.1.12 Uniform Quantizer Data.

8.1.10 Texture Quantizer Data

A Texture Quantizer Data collection is made up of n Uniform Quantizer Data collections; there is a separate Uniform Quantizer Data collection for each component of the texture coordinates. The number of components is not specified within the quantizer, but rather is determined by the number of texture components present in the underlying data (See Compressed Vertex Texture Coordinate Arrays U8 : Number Components).

Figure 233: Texture Quantizer Data collection



Complete description for U Uniform Quantizer Data, and V Uniform Quantizer Data can be found in 8.1.12 Uniform Quantizer Data.

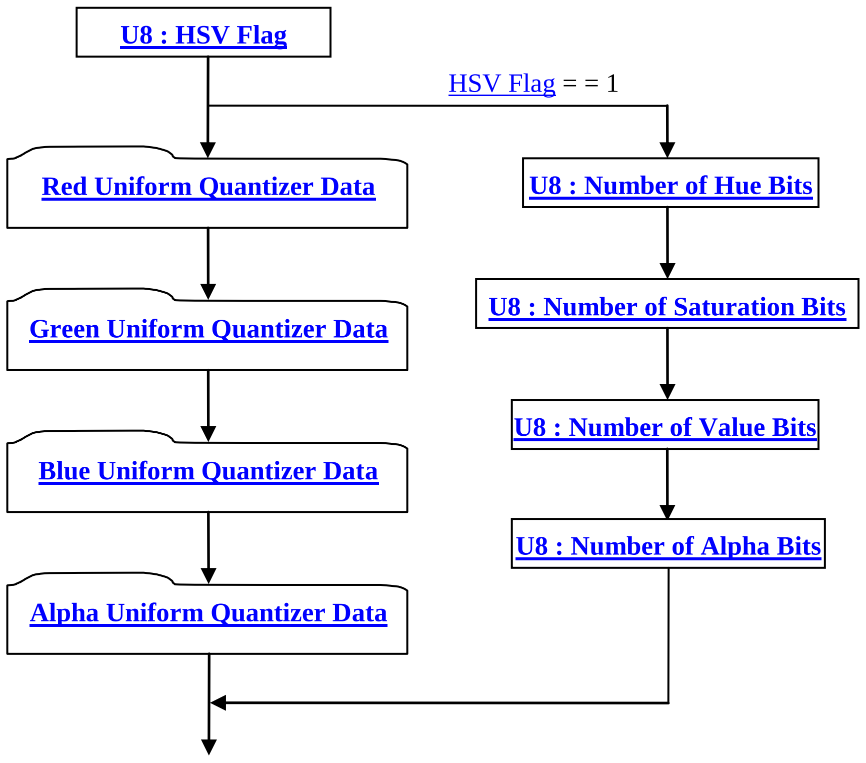
8.1.11 Color Quantizer Data

A Color Quantizer Data collection contains the quantizer information for each of the color components. The Color Quantizer utilizes a separate Uniform Quantizer Data collection for each of the 4 color components, but if the HSV color model is being used, then it is not necessary to store a complete Uniform Quantizer Data Collection.

For the HSV model, since the range values for each color component are constant, only the Number of Bits of precision for each color component's Uniform Quantizer is stored. The Uniform Quantizer range values for the HSV color components should always be assumed to be the following:

Component	Quantizer Range	
	Min	Max
Hue	0.0	6.0
Saturation	0.0	1.0
Value	0.0	1.0
Alpha	0.0	1.0

Figure 234: Color Quantizer Data collection


U8 : HSV Flag
HSV Flag = = 1
Red Uniform Quantizer Data
Green Uniform Quantizer Data
Blue Uniform Quantizer Data
Alpha Uniform Quantizer Data
U8 : Number of Hue Bits
U8 : Number of Saturation Bits
U8 : Number of Value Bits
U8 : Number of Alpha Bits

Complete descriptions for Red Uniform Quantizer Data, Green Uniform Quantizer Data, Blue Uniform Quantizer Data, and Alpha Uniform Quantizer Data can be found in 8.1.12 Uniform Quantizer Data. These four Uniform Quantizer Data collections are only present when data field HSV Flag = = 0.

U8 : HSV Flag

HSV Flag is a flag indicating whether color component data is stored in HSV color model form.

= 0	Color component data stored in RGB color model form.
= 1	Color component data stored in HSV color model form.

U8 : Number of Hue Bits

Number of Hue Bits specifies the quantized size (i.e. the number of bits of precision) for the Hue component of the color. Number of Hue Bits data is only present when data field HSV Flag = = 1.

U8 : Number of Saturation Bits

Number of Saturation Bits specifies the quantized size (i.e. the number of bits of precision) for the Saturation component of the color. Number of Saturation Bits data is only present when data field HSV Flag = = 1.

U8 : Number of Value Bits

Number of Value Bits specifies the quantized size (i.e. the number of bits of precision) for the Value component of the color. Number of Value Bits data is only present when data field HSV Flag = = 1.

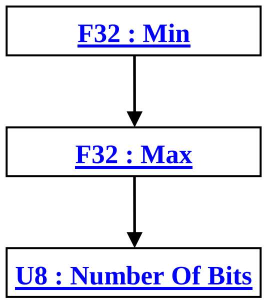
U8 : Number of Alpha Bits

Number of Alpha Bits specifies the quantized size (i.e. the number of bits of precision) for the Alpha component of the color. Number of Alpha Bits data is only present when data field HSV Flag = = 1.

8.1.12 Uniform Quantizer Data

The Uniform Quantizer Data collection contains information that defines a scalar quantizer/dequantizer (encoder/decoder) whose range is divided into levels of equal spacing.

Figure 235: Uniform Quantizer Data collection



F32 : Min

Min specifies the minimum of the quantized range.

F32 : Max

Max specifies the maximum of the quantized range.

U8 : Number Of Bits

Number of Bits specifies the quantized size (i.e. the number of bits of precision). In general, this value must satisfy the following condition: “0 <= Number Of Bits <= 32”.

8.1.13 Compressed Entity List for Non-Trivial Knot Vector

Compressed Entity List for Non-Trivial Knot Vector data collection specifies index identifiers (i.e. indices to particular entities within a list of entities) for a set of entities that contain Non-Trivial Knot Vectors. The entity types which can contain non-trivial knot vectors include:

JT B-Rep NURBS Surfaces

JT B-Rep PCS NURBS Curves

JT B-Rep MCS NURBS Curves

Wireframe MCS NURBS Curves

Note that any one occurrence of Compressed Entity List for Non-Trivial Knot Vector data collection will only contain index identifiers for one particular type of the above listed entities. The entity type is inferred based on the data collection which includes/references the Compressed Entity List for Non-Trivial Knot Vector.

A trivial knot vector is one which completely satisfies all conditions of at least one of the following cases:

Case-1 for trivial knot vector

Number of knots is an even number

Knot vector has a [0:1] knot range

There are no interior knots (i.e. NumberKnots = = 2 * (NurbsEntityDegree + 1)

Case-2 for trivial knot vector

Number of knots is an even number.

Knot vector has a [0:1] knot range

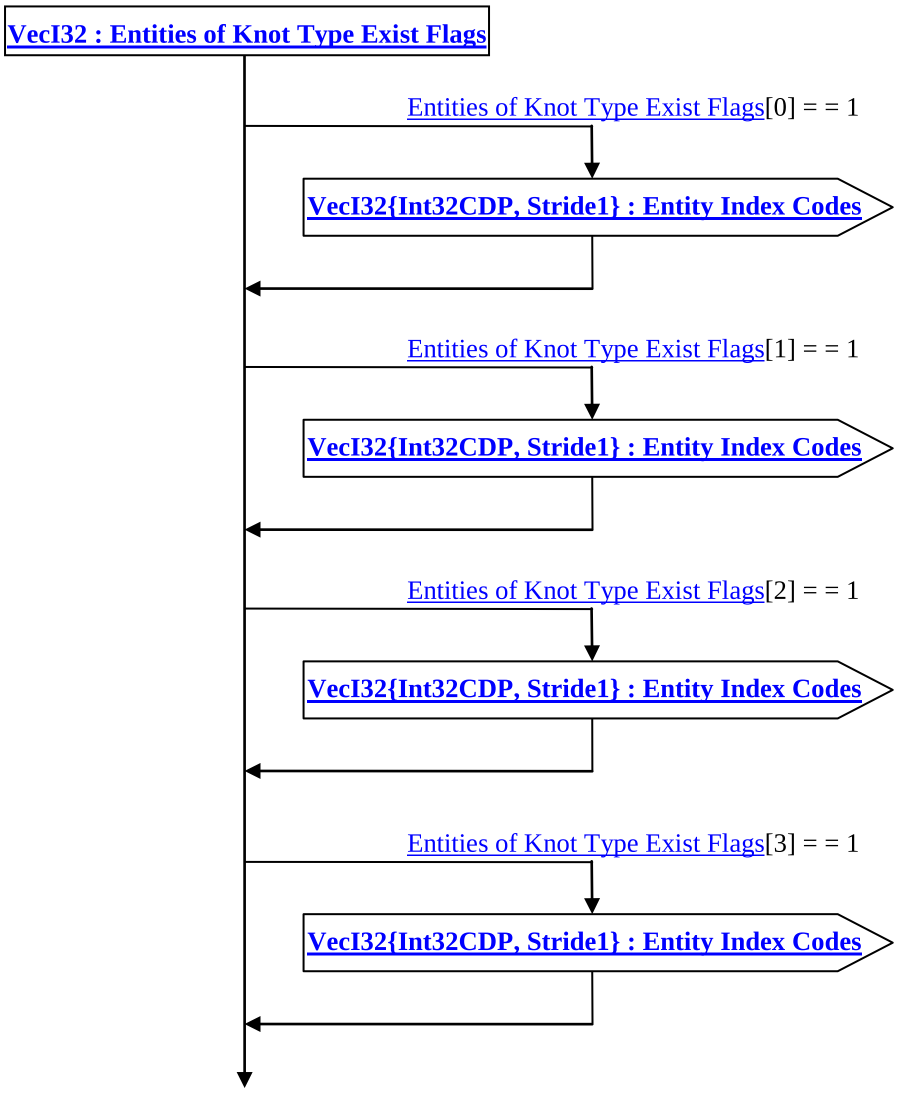
NurbsEntityDegree < 3

Difference between successive non-repeating knots (i.e. KnotDelta) is:

KnotDelta = 2.0 / (NumberKnots – (2.0 * NurbsEntityDegree))

Any knot vector which does not satisfy one of the above cases for “trivial knot vector” is classified as a “non-trivial knot vector.”

Figure 236: Compressed Entity List for Non-Trivial Knot Vector data collection


VecI32 : Entities of Knot Type Exist Flags
Entities of Knot Type Exist Flags[0] = = 1
VecI32{Int32CDP, Stride1} : Entity Index Codes
Entities of Knot Type Exist Flags[1] = = 1
VecI32{Int32CDP, Stride1} : Entity Index Codes
Entities of Knot Type Exist Flags[2] = = 1
VecI32{Int32CDP, Stride1} : Entity Index Codes
Entities of Knot Type Exist Flags[3] = = 1
VecI32{Int32CDP, Stride1} : Entity Index Codes

VecI32 : Entities of Knot Type Exist Flags

Entities of Knot Type Exist Flags, is a vector of flags indicating for each knot vector type whether Entity Index ID data collections exist/follow for that knot vector type. Knot Vectors are categorized into types based on the following characteristics: whether internal knots occur in *adjacent pairs* and whether the knot range is [0:1] or some other [x_1:x_2] range.

Currently there are four knot vector types, so this Entities of Knot Type Exist Flags vector should be of length four. The four flags have the following meaning:

[0]	Flag indicating whether Entity IDs data collection exists for "Even Count [0:1] Range" knot type. Knots in this category have their knot range on [0:1], internal knots occur in *adjacent pairs*, *except* when there are no internal knots, in which case Type = 1 instead. = 0 – No Entity IDs data collection exists. = 1 – Entity IDs data collection exists.
[1]	Flag indicating whether Entity IDs data collection exists for "Even Count [x_1:x_2] Range" knot type. Knots in this category have their knot range on [x_1:x_2], and internal knots occur in *adjacent pairs*. = 0 – No Entity IDs data collection exists. = 1 – Entity IDs data collection exists.
[2]	Flag indicating whether Entity IDs data collection exists for "Odd Count [0:1] Range" knot type. Knots of this type have their knot range on [0:1], and are not Type 0. = 0 – No Entity IDs data collection exists. = 1 – Entity IDs data collection exists.
[3]	Flag indicating whether Entity IDs data collection exists for "Odd Count [x_1:x_2] Range" knot type. Knots of this type have their knot range on [x_1:x_2], and are not Type 1. = 0 – No Entity IDs data collection exists. = 1 – Entity IDs data collection exists.

Examples of knot vectors of Type 0:

```
0 0 X X 1 1
0 0 X X Y Y 1 1
0 0 X X Y Y Z Z 1 1
```

Examples of knot vectors of Type 1:

```
0 0 1 1         (Note: This is the exception to Type 0)
X X Y Y
X X Y Y Z Z
X X Y Y Z Z W W
```

Examples of knot vectors of Type 2:

```
0 0 X 1 1
0 0 X Y 1 1
0 0 X Y Z 1 1
0 0 X X X 1 1
0 0 X X Y Z Z 1 1
```

Examples of knot vectors of Type 3:

```
X X Y Z Z
X X Y Z W W
```

With this information in hand, the reader is able to reconstruct complete knot vectors in the following manner. When reconstructing the knot vector, you only take just enough values from the decoded knot value array. This may be as few as one. All the other values are inferred. Here's a sketch of the reconstruction algorithm:

```
// Number of knots in the knot vector
cNumKnots = numCtlPts + degree + 1;
// Necessary knot multiplicity at both ends of the knot vector
cClamping = degree + 1;
switch (knotType) {
    // Clamping is 0..1, internal knots occur in ADJACENT PAIRS
    // *EXCEPT* when there are no internal knots, in which case
    // Type = 1 instead.
    case 0: numVals = (cNumKnots - 2 * cClamping)/2;
    // Clamping is X1..X2, internal knots occur in ADJACENT PAIRS
    case 1: numVals = (cNumKnots - 2 * cClamping)/2 + 2;
    // Clamping is 0..1, and not Type 0
    case 2: numVals = (cNumKnots - 2 * cClamping);
    // Clamping is X1..X2, and not Type 1
    case 3: numVals = (cNumKnots - 2 * cClamping) + 2;
}
// numVals is the number of non-inferrable knot values needed
// Let vVals be the knot vector value array
// vKnot will be the final output knot vector
if (knotType is either 0 or 2)
    Set vKnot[0 .. cClamping-1] to 0
    Set vKnot[cNumKnots-cClamping .. cNumKnots-1] to 1
else
    Set vKnot[0 .. cClamping-1] to vVals[0]
    Set vKnot[cNumKnots-cClamping .. cNumKnots-1] to vVals[numVals-1]
Set vKnot[cClamping .. cNumKnots-cClamping-1] from vVals[1 .. numVals-2]
```

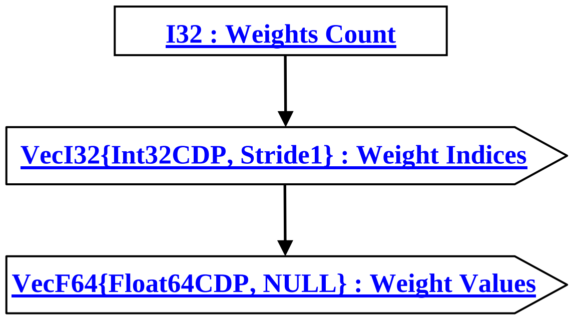
VecI32{Int32CDP, Stride1} : Entity Index Codes

Entity Index Codes is a vector of quantizer "codes" representing entity index identifiers for a set of entities (i.e. indices to particular entities within a list of entities). Entity Index Codes uses the Int32 version of the CODEC to compress and encode data.

8.1.14 Compressed Control Point Weights Data

Compressed Control Point Weights Data collection is the compressed and/or encoded representation of weight data for some set of Control Points. All NURBS based geometry use this data collection to compress/encode Control Point Weight data.

Figure 237: Compressed Control Point Weights Data collection


I32 : Weights Count
VecI32{Int32CDP, Stride1} : Weight Indices
VecF64{Float64CDP, NULL} : Weight Values

I32 : Weights Count

Weights Count specifies the total number of Weights. This count can differ from the Control Point count (see 7.2.3.1.4.1.3 NURBS Surface Control Point Counts) because if the Control Point Dimensionality is non-rational (see data field NURBS Surface Control Point Dimensionality in 7.2.3.1.4.1 Surfaces Geometric Data), then no Weight values are stored for the particular Control Point. Weights Count value also does not necessarily equate to the actual number of Weights stored, since if a particular Control Point's Weight values is "1", then no actual Weight value is stored (i.e. JT file loaders/readers can infer that the Weight Value is "1" for Control Points that don't have a Weight value stored).

VecI32{Int32CDP, Stride1} : Weight Indices

Weight Indices is a vector of indices representing the index identifiers for the conditional set of weights for which an actual Weight Values is stored in Weight Values. Weight Indices uses the Int32 version of the CODEC to compress and encode data.

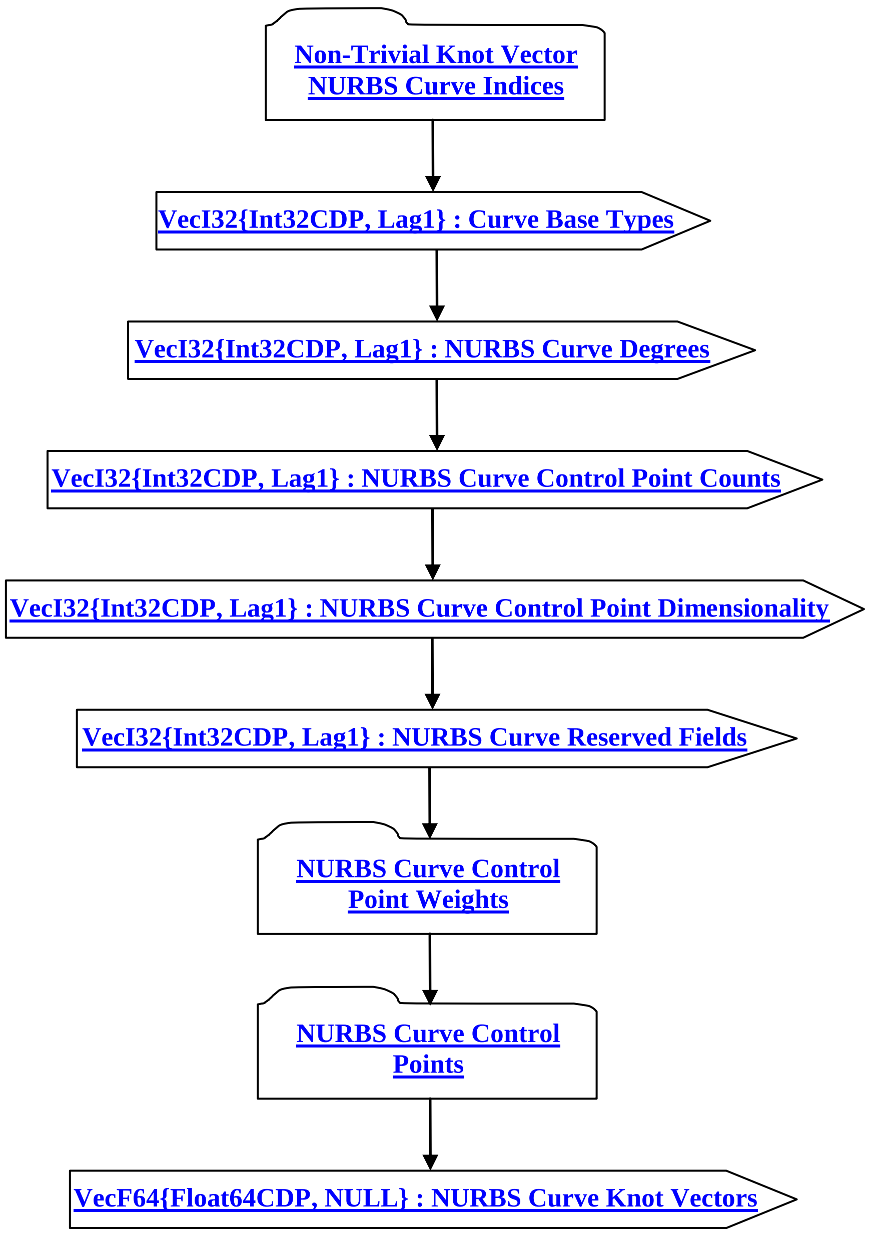
VecF64{Float64CDP, NULL} : Weight Values

Weight Values is a vector of weight values for the conditional set of weights. Weight Values uses the Float64 version of the CODEC to compress and encode data.

8.1.15 Compressed Curve Data

Compressed Curve Data collection contains JT B-Rep or Wireframe Rep compressed/encoded geometric Curve data. Currently only NURBS Curve types are supported as part of this data collection. Complete documentation for JT B-Rep and Wireframe Rep can be found in sections 7.2.3.1 JT B-Rep Element and 7.2.5.1 Wireframe Rep Element respectively.

Figure 238: Compressed Curve Data collection


Non-Trivial Knot Vector NURBS Curve Indices
VecI32{Int32CDP, Lag1} : Curve Base Types
VecI32{Int32CDP, Lag1} : NURBS Curve Degrees
VecI32{Int32CDP, Lag1} : NURBS Curve Control Point Counts
VecI32{Int32CDP, Lag1} : NURBS Curve Control Point Dimensionality
VecI32{Int32CDP, Lag1} : NURBS Curve Reserved Fields
NURBS Curve Control Point Weights
NURBS Curve Control Points
VecF64{Float64CDP, NULL} : NURBS Curve Knot Vectors

VecI32{Int32CDP, Lag1} : Curve Base Types

Each Curve is assigned a base type identifier. Curve Base Types is a vector of base type identifiers for each Curve in a list of Curves. Currently only NURBS Curve Base Type is supported, but a type identifier is still included in the specification to allow for future expansion of the JT Format to support other curve types.

In an uncompressed/decoded form the Curves base type identifier values have the following meaning:

= 1	Curve is a NURBS curve

Curve Base Types uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : NURBS Curve Degrees

NURBS Curve Degrees is a vector of Curve degree values for each NURBS Curve in a list of Curves (there is a stored value for each NURBS Curve in the list). NURBS Curve Degrees uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : NURBS Curve Control Point Counts

NURBS Curve Control Point Counts is a vector of control point counts for each NURBS Curve in a list of curves (there is a stored value for each NURBS Curve in the list). NURBS Curve Control Point Counts uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : NURBS Curve Control Point Dimensionality

NURBS Curve Control Point Dimensionality is a vector of control point dimensionality values for each NURBS Curve in a list of Curve s(i.e. there is a stored values for each NURBS Curve in the list).

In an uncompressed/decoded form the control point dimensionality values meaning is dependent upon the NURBS Entity type.

For NURBS UV Curve entities the dimensionality value has the following definition:

= 2	Non-Rational (each control point has 2 coordinates)
= 3	Rational (each control point has 3 coordinates)

For NURBS XYZ Curve entities the dimensionality value has the following definition:

= 3	Non-Rational (each control point has 3 coordinates)
= 4	Rational (each control point has 4 coordinates)

NURBS Curve Control Point Dimensionality uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP, Lag1} : NURBS Curve Reserved Fields

NURBS Curve Reserved Fields is a vector of data reserved for future expansion of the JT format. Each NURBS Curve in a list of Curves has one reserved data field entry in this NURBS Curve Reserved Fields vector. NURBS Curve Reserved Fields uses the Int32 version of the CODEC to compress and encode data

VecF64{Float64CDP, NULL} : NURBS Curve Knot Vectors

NURBS Curve Knot Vectors is a list of knot vector values for each NURBS Curve having non-trivial knot vectors in a list of Curves (i.e. there are stored values for each non-trivial knot vector NURBS Curve in the list). All these NURBS Curve non-trivial knot vectors are accumulated into this single list in the same order as the Curve appears in the Curve list (i.e. Curve-N Non-Trivial Knot Vector, Curve-M Non-Trivial Knot Vector, etc.). The NURBS Curves for which knot vectors are stored (i.e. those containing non-trivial knot vectors) are identified in data collection Non-Trivial Knot Vector NURBS Curve

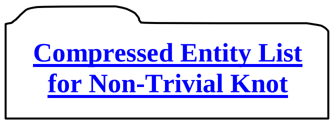
Indices documented in 8.1.15.1 Non-Trivial Knot Vector NURBS Curve Indices. NURBS Curve Knot Vectors uses the Float64 version of the CODEC to compress and encode data.

8.1.15.1 Non-Trivial Knot Vector NURBS Curve Indices

Non-Trivial Knot Vector NURBS Curve Indices data collection specifies the Curve index identifiers (i.e. indices to particular NURBS Curves within a list of Curves) for all NURBS Curves containing non-trivial knot vectors. A description/definition for "non-trivial knot vector" can be found in 8.1.13 Compressed Entity List for Non-Trivial Knot Vector.

This Curve index data is stored in a compressed format.

Figure 239: Non-Trivial Knot Vector NURBS Curve Indices data collection



Complete description for Compressed Entity List for Non-Trivial Knot Vector can be found in 8.1.13 Compressed Entity List for Non-Trivial Knot Vector.

8.1.15.2 NURBS Curve Control Point Weights

NURBS Curve Control Point Weights data collection defines the Weight values for a conditional set of Control Points for a list of NURBS Curves. The storing of the Weight value for a particular Control Point is conditional, because if NURBS Curve Control Point Dimension is "non-rational" or the actual Control Point's Weight value is "1", then no Weight value is stored for the Control Point (i.e. Weight value can be inferred to be "1").

The NURBS Curve Control Point Weights data is stored in a compressed format.

Figure 240: NURBS Curve Control Point Weights data collection

Complete description for Compressed Control Point Weights Data can be found in 8.1.14 Compressed Control Point Weights Data.

8.1.15.3 NURBS Curve Control Points

NURBS Curve Control Points is the compressed and/or encoded representation of the Control Point coordinates for each NURBS Curve in a list of Curves (i.e. there are stored values for each NURBS Curve in the list). Note that these are non-homogeneous coordinates (i.e. Control Point coordinates have been divided by the corresponding Control Point Weight values).

Figure 241: NURBS Curve Control Points data collection

VecF64{Float64CDP, NULL} : Control Points

VecF64{Float64CDP, NULL} : Control Points

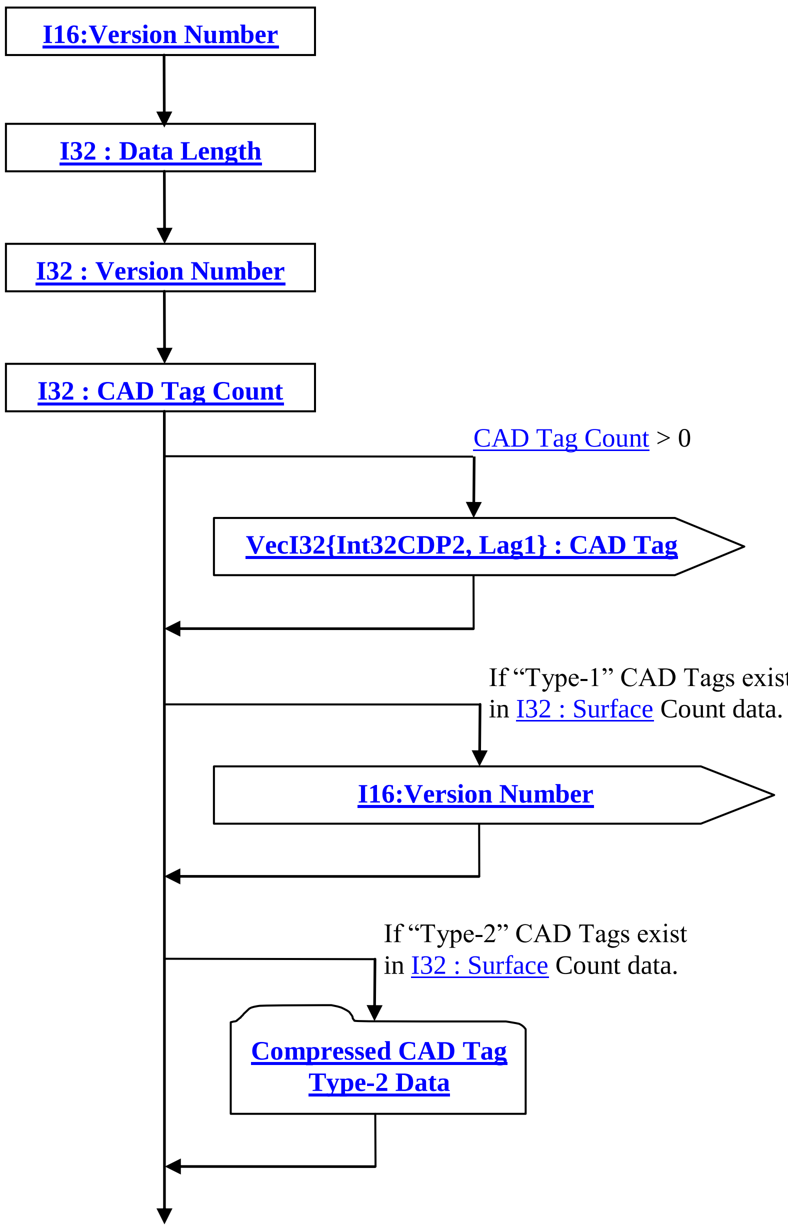
Control Points is a vector of Control Point coordinates for all the NURBS Curves in a list of Curves. All the NURBS Curve Control Point coordinates are accumulated into this single vector in the same order as the Curve appears in the Curve list (i.e. Curve-1 Control Points, Curve-2 Control Points, etc.). Control Points uses the Float64 version of the CODEC to compress and encode data in a "lossless" manner.

8.1.16 Compressed CAD Tag Data

The Compressed CAD Tag Data collection contains the persistent IDs, as defined in the CAD System, to uniquely identify individual CAD entities (e.g. Faces and Edges of a JT B-Rep, PMI, etc.). Exactly what CAD entity types have CAD Tags and what order they are stored in Compressed CAD Tag Data is defined by users of this data collection (e.g. 7.2.3.1.6 B-Rep CAD Tag Data, 7.2.6.2.7 PMI CAD Tag Data)

What constitutes a CAD Tag is outside the scope of the JT File format and is indeed part of the CAD system. The JT File format simply provides a way to store any kind of CAD Tag as provided by the CAD system which produced the CAD entity.

Figure 242: Compressed CAD Tag Data collection


I16:Version Number
I32 : Data Length
I32 : Version Number
I32 : CAD Tag Count
CAD Tag Count > 0
VecI32{Int32CDP2, Lag1} : CAD Tag
If "Type-1" CAD Tags exist in I32 : Surface Count data.
I16:Version Number
If "Type-2" CAD Tags exist in I32 : Surface Count data.
Compressed CAD Tag Type-2 Data

I16:Version Number

Version Number is the version identifier for the CADTag element. Only version number 0x001 is currently supported.

I32 : Data Length

Data Length specifies the length in bytes of the Compressed CAD Tag Data collection. A JT file loader/reader may use this information to compute the end position of the Compressed CAD Tag Data within the JT file and thus skip reading the remaining Compressed CAD Tag Data.

I32 : Version Number

Version Number is the version identifier for the Compressed CAD Tag Data. Version number "1" is currently the only valid value.

I32 : CAD Tag Count

CAD Tag Count specifies the number of CAD Tags

VecI32{Int32CDP2, Lag1} : CAD Tag Types

CAD Tag Types is a vector of type identifiers for a list of CAD Tags (where each CAD Tag in the list has a type identifier value).

In an uncompressed/decoded form the CAD Tag type identifier values have the following meaning:

= 1	32 Bit Integer CAD Tag Type
= 2	64 Bit Integer CAD Tag Type

CAD Tag Types uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP2, Lag1} : CAD Tags Type-1

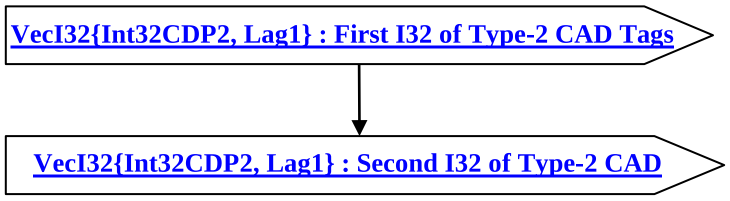
CAD Tags Type-1 is a vector of the Type-1 (i.e. 32 Bit Integer Type) CAD Tags for a list of CAD Tags. CAD Tags Type-1 uses the Int32 version of the CODEC to compress and encode data. CAD Tags Type-1 is only present if there are Type-1 CAD Tags in the CAD Tag Types vector. Thus a loader/reader of JT file must first uncompress/decode and evaluate the previously read CAD Tag Types to determine if there are any Type-1 CAD Tags and if so, then the CAD Tags Type-1 data vector is present.

8.1.16.1 Compressed CAD Tag Type-2 Data

Compressed CAD Tag Type-2 Data collection contains the Type-2 (i.e. 64 Bit integer Type) CAD Tag data for a list of CAD Tags.

The Compressed CAD Tag Type-2 Data collection is only present if there are Type-2 CAD Tags in the CAD Tag Types vector. Thus a loader/reader of JT file must first uncompress/decode and evaluate the previously read CAD Tag Types vector to determine if there are any Type-2 CAD Tags and if so, then the Compressed CAD Tag Type-2 Data collection is present.

Figure 243: Compressed CAD Tag Type-2 Data collection


VecI32{Int32CDP2, Lag1} : First I32 of Type-2 CAD Tags
VecI32{Int32CDP2, Lag1} : Second I32 of Type-2 CAD

VecI32{Int32CDP2, Lag1} : First I32 of Type-2 CAD Tags

First I32 of Type-2 CAD Tags is a vector of the first 32 bits of each Type-2 CAD Tag in the list of CAD Tags. First I32 Of Type-2 CAD Tags uses the Int32 version of the CODEC to compress and encode data.

VecI32{Int32CDP2, Lag1} : Second I32 of Type-2 CAD Tags

Second I32 of Type-2 CAD Tags is a vector of the second 32 bits of each Type-2 CAD Tag in the list of CAD Tags. Second I32 Of Type-2 CAD Tags uses the Int32 version of the CODEC to compress and encode data.

8.2 Encoding Algorithms

The following sections give a brief technical overview/descriptions of the various encoding algorithms used in the JT format. Additional information on each of the algorithms can be found within references listed in 3 References and Additional Information section of this document. Also, a sample implementation of the decoding portion of each algorithm can be found in Appendix C: Decoding Algorithms – An Implementation.

8.2.1 Uniform Data Quantization

Uniform Data Quantization is a lossy encoding algorithm in which a continuous set of input values (floating point data) is approximated with integral multiples (i.e. integers) of a common factor. How close the quantization output approximates the original input data is dependent upon the quantization data range and the number of bits specified to hold the resulting integer value.

The quantization is considered "uniform" because the algorithm divides the data input range into levels of equal spacing (i.e. a uniform scale). The form of Uniform Data Quantization used by the JT format is also considered scalar in nature, in that each input value is treated separately in producing the output integer value.

Given the following definitions:

```
inputVal:      Input floating point data to quantize
outputval:     Resulting quantized output integer value
minInputRange: Specified minimum value of input data range
maxInputRange: Specified maximum value of input data  range
nBits:         Specified number of bits of precision (quantized size)
```

The basic algorithm (using C++ style syntax) for Uniform Data Quantization is as follows:

```
UInt32 iMaxCode = (nBits < 32) ? (0x1 << nBits) - 1 : 0xffffffff;
Float64 encodeMultiplier = Float64(iMaxCode) / (maxInputRange - minInputRange);
UInt32 outputVal = UInt32( (inputVal - minInputRange) * encodeMultiplier + 0.5 );
```

Note: For reasons of robustness, "outputVal" must also be explicitly clamped to the range [0,iMaxCode]. This is because floating-point roundoff error in the calculation of "encodeMultiplier" can otherwise cause "outputVal" to sometimes come out equal to "iMaxCode + 1".

Note that all compression algorithms in the following sections operate on quantized integer data.

8.2.2 Bitlength CODEC

This is a very simple compression algorithm that runs an adaptive-width bit field encoding for each value. As each input value is encountered, the number of bits needed to represent it is calculated and compared to the current "field width". The current field width is then adjusted upwards or downwards by a constant "step_size" number of bits (i.e. 2 bits for the JT format) to accommodate the input value storage. This increment or decrement of the current field width is indicated for each encoded value by a prefix code stored with each value.

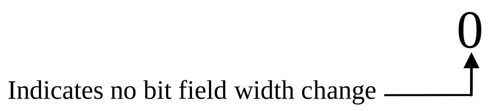
The prefix code will be one of the following two forms:

A single '0' bit to denote the same (i.e. current) field width is to be used for the next value.

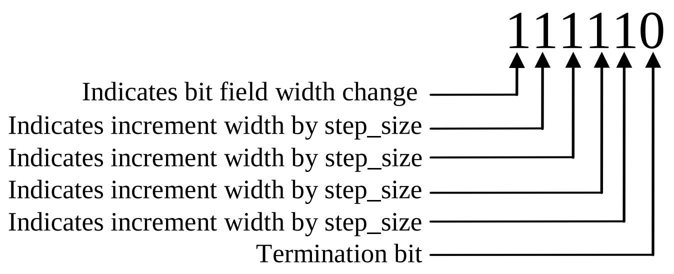
A '1' bit followed by a series of one or more bits where each bit indicates whether the field width is to be incremented (a '1' bit) or decremented (a '0' bit) by the field step_size, followed by a single terminator bit (which is complement of the previous increment/decrement bit). Note that there can only be increments or decrements in a given prefix code, never both, and that is why the prefix code terminator bit can be recognized as bits are read by simply looking for the complement of the previous increment/decrement bit.

Some examples of prefix codes and their interpretation are as follows:

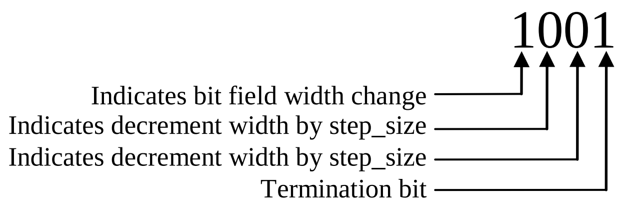
Example 1: Prefix code to maintain same (current) field width.



Example 2: Prefix code to increment field width four times (8 bits).


111110
Indicates bit field width change
Indicates increment width by step_size
Indicates increment width by step_size
Indicates increment width by step_size
Indicates increment width by step_size
Termination bit

Example 3: Prefix code to decrement field width two times.


1001
Indicates bit field width change
Indicates decrement width by step_size
Indicates decrement width by step_size
Termination bit

A pseudo-code sample implementation of bit length decoding is available in Appendix C: Decoding Algorithms – An Implementation.

8.2.3 Arithmetic CODEC

In 1948, Claude Shannon of Bell Laboratories published his seminal paper “A mathematical theory of communication” that launched the new field of Information Theory. In that same year, two Doctoral students at the Massachusetts Institute of Technology (MIT) made breakthroughs in the coding of information. The first to press was David Huffman, whose coding scheme we now know as Huffman Coding. In that same class with Huffman was Peter Elias who reportedly developed the first articulation of arithmetic coding, but it lay unpublished until 1976, when Jorma Rissanen and Richard Pasco, of IBM, refined it into a practically useful algorithm.

Arithmetic encoding is a lossless compression algorithm that replaces an input stream of symbols or bytes with a single fixed point output number (i.e. only the mantissa bits to the right of the binary point are output from MSB to LSB). The total number of bits needed in the output number is dependent upon the length/complexity of the input message (i.e. the longer the input message the more bits needed in the output number). This single fixed point number output from an arithmetic encoding process must be uniquely decodable to create the exact stream of input symbols that were used to create it.

Initially all symbols being encoded have a probability value assigned to them based on the likelihood that the symbol will occur next in the input stream (i.e. the frequency of the symbol in the input stream). Given probability value assignments, each individual symbol is then assigned an interval range along a nominal 0 to 1 “probability line”, where the size of each range corresponds to the symbol’s probability value. Note that a particular symbol owns all values within its assigned range up to, but not including, the range high value, and that it does not matter which symbols are assigned which segment of the range as long it is done in the same manner by both the encoder and the decoder.

Given the above described input stream probability and interval range assignments, a high level description of the arithmetic encoding process is as follows:

Begin with a “current interval” initialized to [0,1). Note, that in interval range notation (i.e. “[0,1)”), the “[“ symbol indicates inclusive of the interval low limit and “)” symbol indicates exclusive of the interval high limit.

Sequentially for each symbol of the input stream, perform two steps

Subdivide the current interval into subintervals based on the input stream symbol probability values as described above.

Select the subinterval corresponding to the current input stream symbol being sequentially processed and make it the new “current interval”.

After all input stream symbols have been sequentially processed; output enough bits to distinguish the final “current interval” from all other possible final intervals.

In pseudo code form, the algorithm to accomplish the above described arithmetic encoding for an input stream message of any length could look as follows:

```
Set low to 0.0
Set high to 1.0
While there are still input symbols do
    cur_symbol = get next input symbol
    range = high – low
    high = low + range * high_range(cur_symbol)
    low = low + range * low_range(cur_symbol)
End of While
Output low
```

So the arithmetic encoding process is simply one in which we narrow the range of possible numbers with every new sequentially processed input symbol; where the new narrowed range is proportional to the predefined probability values assigned to each symbol in the input stream.

The arithmetic decoding process is the inverse procedure; where the range is expanded in proportion to the probability of each symbol as it is extracted. For the arithmetic decoding process we find the first symbol in the message by seeing which symbol owns the interval range that our encoded message falls in. Then, since we know the low and high range limit values of the first symbol we can remove their effects by reversing the process that put them in.

In pseudo code form, the algorithm for decoding the incoming number could look as follows:

```
Get encoded_number
Do
    find symbol whose range straddles the encoded_number
    output the symbol
    range = symbol_high_value – symbol_low_value
    encoded_number = encoded_number – symbol_low_value
    encoded_number = encoded_number / range
until no more symbols
```

8.2.3.1 Example

Following is an example to demonstrate in practice the basic principles of arithmetic coding.

Suppose you want to compress, using arithmetic coding, the following sequence/array of integer data:

{2, 9, 12, 12, 0, 7, 1, 20, 5, 19}

For this input stream of data, the assigned probability values will be as follows:

Number	Probability
0	1/10
1	1/10
2	1/10
5	1/10

Number	Probability
7	1/10
9	1/10
12	2/10
19	1/10
20	1/10

Then based on each input numbers probability value, an interval range along a 0 to 1 "probability line" can be assigned to each input number as follows:

Number	Probability	Range
0	1/10	[0.00, 0.10)
1	1/10	[0.10, 0.20)
2	1/10	[0.20, 0.30)
5	1/10	[0.30, 0.40)
7	1/10	[0.40, 0.50)
9	1/10	[0.50, 0.60)
12	2/10	[0.60, 0.80)
19	1/10	[0.80, 0.90)
20	1/10	[0.90, 1.00)

Now proceeding with encoding the example input integer sequence {2, 9, 12, 12, 0, 7, 1, 20, 5, 19}, the first number to be encoded is "2"; so the final encoded value will be a number that is greater than or equal to 0.20 and less than 0.30. Now as each subsequent number in the input stream is sequentially processed for encoding, the possible range of the output number is further restricted. In our example the next number to be encoded is "9" which owns the range [0.50, 0.60) within the new sub-range of [0.20, 0.30); which now further restricts our output number to the range [0.25, 0.26). If we continue this logic for the complete input integer sequence we end up with the following:

New integer number	Low value	High value
	0.0	1.0
2	0.2	0.3
9	0.25	0.26
12	0.256	0.258
12	0.2572	0.2576
0	0.25720	0.25724
7	0.257216	0.257220
1	0.2572164	0.2572168
20	0.25721676	0.2572168
5	0.257216772	0.257216776
19	**0.2572167752**	0.2572167756

From the above table, are final low values is "0.2572167752" which is the output number that uniquely encodes the integer number sequence {2, 9, 12, 12, 0, 7, 1, 20, 5, 19}.

Given this encoding scheme, the decoding would simply follow the process previously described. We find the first number in the sequence by looking up in the probability range for the value, whose range, our encoded number "0.2572167752" falls within. In our example this equates to the value “2” and so our first decoded value must be “2”. Then we apply the previously described decoding subtraction and division steps to arrive at a new encoded value of “0.572167752”. Using this new “0.572167752” encoded value and the same logic of the first step, the second decoded value will be “9”. We continue this process until there are no more numbers to decode.

In practice, due to floating point size (i.e. number of bits) restrictions and possible differences in floating point formats on machines, arithmetic encoding is best implemented using 16 bit or 32 bit integer math. Using 16 bit or 32 bit integer math, an incremental transmission scheme can be implemented, where fixed size integer state variables receive new bits in at the low end and shift them out the high end, forming a single number that can be as many bits long as are available on the computer’s storage medium.

Using our example as a guide, define the starting range [0.0, 1.0) to instead be 0 to 0.999 (which is .111 in binary). Then in order to use integer registers to store these numbers, justify the values so that the implied decimal point is at the left hand side of the word. Now load the initial range values based on the word size we are using. In the case of a 16 bit implementation the initial range values will be low equals 0x0000 and high equals 0xFFFF. Since we know these values will go on forever (e.g. 0.999… will continue with FFs) we can shift those extra bits in as needed with no detrimental effects.

Going back to our example and using a 5 digit register, we start with the range:

High: 99999

Low: 00000

Applying the previously described encoding algorithm we first calculate the range between the low and high values; which in this case is 100000 (not 9999 since we assume the high value has an infinite number of 9’s). Next, we calculate the new high value which in this example will be 30000. But before we store the new high value we must decrement it to account for the implied digits appended to it; so new high value will be 29999. Applying similar logic to computing the new low value results in a new range of:

High: 29999 (999…)

Low: 20000 (000…)

In looking at the newly computed high and low range values, it can be seen that the most significant digits of high and low match. A property of arithmetic coding is that as this encoding process continues, the high and low values will continue to get closer, but will never match exactly. Given this property, once the most significant digit of high and low match, it will never change, and thus we can output this most significant digit as the first number in the coded word and continue working with just 16 bit high and low values. This output process is accomplished by shifting both the high and low values left by one digit and shifting in a “9” in the least significant digit of the high value.

Applying the previously described encoding algorithm and continuing the above described process of shifting out most significant digit into the coded word as high and low continually grow closer together looks as follows for encoding our example integer number sequence {2, 9, 12, 12, 0, 7, 1, 20, 5, 19}:

	High	**Low**	**Range**	**Cumulative output**
Initial State	99999	00000	100000	
Encode “2” [0.2, 0.3)	29999	20000		
Shift out 2	99999	00000	100000	.2
Encode “9” [0.5, 0.6)	59999	50000		.2
Shift out 5	99999	00000	100000	.25
Encode “12” [0.6, 0.8)	79999	60000	20000	.25
Encode “12” [0.6, 0.8)	75999	72000		.25
Shift out 7	59999	20000	40000	.257
Encode “0” [0.0, 0.1)	23999	20000		.257

	High	Low	Range	Cumulative output
Shift out 2	39999	00000	40000	.2572
Encode “7” [0.4, 0.5)	19999	16000		.2572
Shift out 1	99999	60000	40000	.25721
Encode “1” [0.1, 0.2)	67999	64000		.25721
Shift out 6	79999	40000	40000	.257216
Encode “20” [0.9, 1.0)	79999	76000		.257216
Shift out 7	99999	60000	40000	.2572167
Encode “5” [0.3, 0.4)	75999	72000		.2572167
Shift out 7	59999	20000	40000	.25721677
Encode “19” [0.8, 0.9)	55999	52000		.25721677
Shift out 5	59999	20000	40000	.257216775
Shift out 2				.2572167752
Shift out 0				.25721677520

As can be seen in the above table, after all values in the input stream have been encoded and any final matching most significant digit has been output, the arithmetic coding algorithm requires that two extra digits be shifted out of either the high or low value to finish up the cumulative output word.

Although the above example incrementally encodes very nicely with the arithmetic coding algorithm, there are certain cases where the computed high and low values get closer, but never actually converge to one value in the most significant digit (e.g. High = 0.300001, Low = 0.29992). Thus after a few iterations the difference between high and low becomes so small that 16 bits is not sufficient to represent any difference between the values (i.e. all calculations return the same values). This conditions is known as “underflow” and special logic must added to the arithmetic coding algorithm to recognize that “underflow” is occurring and thus head it off before the computations reach an impasse.

The additional logic for recognizing that “underflow” is occurring would be executed after each recalculation of High and Low value set, and in pseudo code form this logic would look as follows:

```
underflow = FALSE
if( (High and Low value’s significant digits don’t match but are on adjacent numbers) &&
 (2nd most significant digit of High is “0” and the 2nd most significant digit of low is “9”) )
{
underflow = TRUE
}
```

When/If it is identified that “underflow” is occurring, the encoding algorithm must perform the following steps to stop the current “underflow”:

Delete the 2nd most significant digit from both the High and Low value.

Shift the other digits (those to the right of the deleted 2nd digit) to the left to fill up the space (note that the most significant digit stays in place).

Increment a counter to remember that we threw away a digit and don’t know whether it was going to converge to “0” or “9”.

A before and after example of performing the above steps to the High and Low values when ‘underflow” occurs is as follows:

	Before	After
High	40344	43449
Low	39810	38100
Underflow_counter	0	1

Now as the encoding algorithm continues and the most significant digit of High and Low values once again converge to a common value, then that value must be output to the coded word along with "Underflow_counter" number of "underflow" digits that were previously deleted. The underflow digits output to the coded word will either be all 9s or 0s, depending on whether the High and Low value converged to the higher or lower value.

A pseudo-code sample implementation of arithmetic decoding is available in Appendix C: Decoding Algorithms – An Implementation.

8.2.4 Deering Normal CODEC

Michael Deering first published his work on geometry compression in 1995 [5] and later helped present a course on the subject at SIGGRAPH'99 [6]. Although Deering's approach to geometric compression involves compression of vertices, colors and normals, the description detailed here will focus solely on compression of normals since this is the only component of Deering's approach used in the JT format.

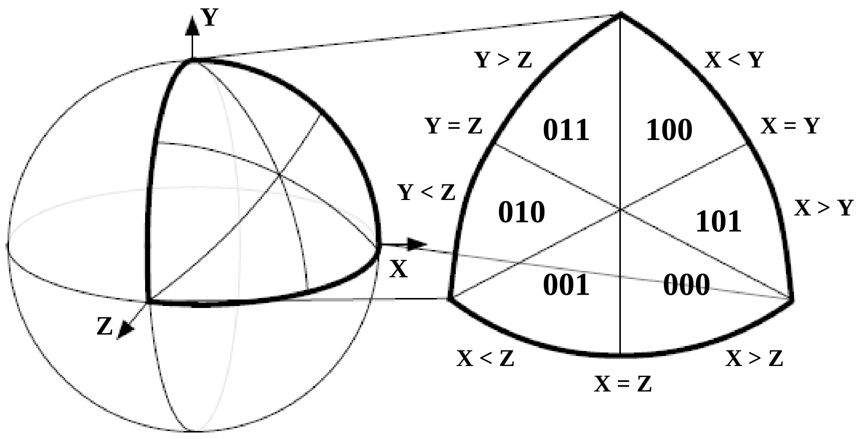
Through both theoretical examination and empirical testing, Deering found that an angular density of 0.01 radians between normals (about 100,000 normalized normals distributed over unit sphere) gave results that were not visually distinguishable from results obtained from finer normal representations. This observation reduced the problem of having to "exactly" represent any general surface normal, to only having to represent about 100,000 specific normals (i.e. general surface normal replaced by the appropriate one of the 100,000 specific normals).

If there were no run-time memory concerns and no concerns for on disk footprint size, these specific 100,000 normals could be simply represented in a table that is indexed into, to reference a particular normal. Instead, Deering's approach leverages symmetrical properties of the unit sphere to reduce the size of the table and allow any normal to be represented by, at max, an 18 bit index as summarized below:

- All normals are normalized (i.e. can be represented as points on the surface of the unit sphere).
- Unit sphere is divided into eight symmetrical octants based on sign bits of normal's X,Y,Z rectilinear representation (see Figure 244). Using three bits to represent the three sign bits of the normals XYZ components reduces the problem space to one eighth of the unit sphere
- Each octant of the unit sphere is divided into six identical sextants by folding about the planes of symmetry; x=y, x=z, and y=z (see Figure 244). The particular sextant can be encoded using another three bits. So now unit sphere is divided into 48 identically shaped triangle patches reducing the normal look-up table to about 2000 entries (i.e. 100000/48).
- Then, a local rectangular orthogonal two dimensional grid is created on the sextant and all normals within the sextant are represented as two n-bit angular addresses (i.e. a quantization of two angular values along the unit sphere) where "n" is in the range from 0 to 6 bits.
- Resulting in a max grand total of 18 bits (3 + 3 + 6 + 6) to represent any normal on the unit sphere.

In the figure below, the sphere is divided into eight octants and each octant is divided into six sextants. Each sextant is assigned an identifying three bit code.

Figure 244: Sextant Coding on the Sphere



Note that the sextant three bit code assignments used by the JT format (as seen in Figure 244) are slightly modified from the original assignments as specified by Deering.

The representation of all normals within a sextant by two n-bit angular addresses, as summarized above, is based on the following:

- In spherical coordinates, points on a unit sphere can be parameterized by two angles, θ and φ; where θ is the angle about the y axis and φ is the longitudinal angle from the y=0 plane.
- Mapping between rectangular and spherical coordinates is:
  $x = \cos\theta * \cos\varphi$ $y = \sin\varphi$ $z = \sin\theta * \cos\varphi$
- All encoding takes place in the positive octant.
- Angles θ and φ can be quantized into two n-bit integers θ'_n and φ'_n (where "n" is in the range of 0 to 6) and the relationship between these n-bit integers and angles θ and φ for a given "n" is:
  $\theta(\theta'_n) = \text{asin}\ \tan(\varphi_{max} * (n - \theta'_n) / 2n)$
  $\varphi(\varphi'_n) = \varphi_{max} * \varphi'_n / 2n$

Thus to encode (i.e. quantize) a given normal **N** into θ'_n and φ'_n:

- N must be first represented (see Figure 244) in the positive octant and appropriate sextant within that octant, resulting in N'.
- Then N' must be dotted with all quantized normals in the sextant.
- For a fixed "n", the corresponding θ'n and φ'n values of the quantized sextant normal that result in the largest (nearest unity) dot product defines the proper θ'n and φ'n encoding of N.

With this encoding of normal **N** into θ'_n and φ'_n n-bit integers the complete bit representation of normal **N** can now be defined as follows:

- Uppermost three bits specify the octant.
- Next three bits specify the sextant code as defined in Figure 244.
- Next two n-bit fields specify θ'n and φ'n values respectively.

8.3 ZLIB Compression

ZLIB compression is a lossless data compression algorithm and is essentially the same as that in gzip and Zip. Zlib's compression method, called deflation, creates compressed data as a sequence of blocks. The JT format uses *Version 1.1.2* of the ZLIB compression library.

9 Best Practices

The proceeding sections of this document specify the mandatory clauses for creating a reference compliant Version 9.5 JT file. This "Best Practices" section focusing on documenting format conventions that although not required to have a reference compliant JT file, have become commonplace within JT format translators to the point where these conventions are considered *best practices* for constructing JT files.

9.1 Late-Loading Data

The JT format was designed and structured to load entities from a JT file on a deferred or as-needed basis.. This concept is referred to within this JT Format Reference document as "late-loading data". The JT format has many structures in support of this and it is recommended as a best practice that writers/loaders of JT data leverage these capabilities.

Initial loading only requires the Table of Contents and the LSG. All Meta Data Node Elements, JT B-Rep Elements, XT B-Rep Elements, Wireframe Rep Elements, PMI Manager Meta Data Elements, JT ULP Elements, JT LWPA Elements, and Shape LOD Elements may be ignored until they are actually needed. These Late-Loaded data containers are accessed via a Late Loaded Property Atom Element which appears in a LSG Node's Property list. Contained in this Property is the GUID associated with the segment to be loaded. This GUID can be looked up in the TOC Segment, which will give the location in the JT from which to load the actual Element via the Data Segment convention.

9.2 Bit Fields

In the 7 File Format section of this reference many bit field data descriptions (e.g. 7.2.1.1.1.1.1 Base Node Data "Node Flags" field) contain the words "*All undocumented bits are reserved*." These words should be interpreted to mean that these undocumented bits should be set to "0" when writing the bit field data to a JT file.

9.3 Reserved Field

In the 7 File Format section of this reference some data fields may be named/documented "Reserved Field" (e.g. 7.2.1.1.1.7.1LOD Node Data "Reserved Field" field). A "Reserved Field" exists for potential future expansion of the Format and best practices suggests that these fields should be treated as follows:

If you are writing a JT file whose data did not originate from reading a previous JT file, then Reserved Fields should be set to a value a "0" when writing the field to a JT file.

If you are writing a JT file whose data originated from reading a previous JT file (i.e. rewriting a JT File), then "Reserved Fields" should be written with the same value that was read from the originating JT file.

9.4 Local Version

The local version values seen throughout the data collections provides a simple means by which those data collections can be extended within current and future minor versions of the 9.x file format. The standard convention followed by each data collection, unless explicitly specified otherwise, is to write the data from each local version in order. This allows readers to read up to the maximum local version they support and then use the segment length that was read in the Segment Header to skip over any data they may not understand.

9.5 Hash Value

Hashing is a means by which a large chunk of values can be represented by single value through the use of a mathematical function that provides a distinctive value for each unique set of ordered values. The hash function used within the v9.x format was published by Bob Jenkins in Dr Dobbs back in 1997 and its implementation is provided in Appendix D: .

The hash function takes a pointer to a set of values, the number of values, and a seed hash value. It returns the resulting hash value. Initially the seed value is set to 0, however when hashing multiple data fields together the hash of previous data field is used as the seed hash value of the next data field:

```
UInt32 uHash = 0;
uHash = hash32( pVal0, nVal0, uHash );
uHash = hash32( pVal1, nVal1, uHash );
```

The order that individual fields are hashed is extremely important since v9.x readers are strongly encouraged to assert that the stored hash value matches the calculated hash value of the corresponding fields after reading in all the corresponding data. To this end each hash value stored within the v9.x format carefully documents which fields it encompasses and the order in which they should be hashed.

9.6 Metadata Conventions

Although there are really no restrictions/limits/requirements on what metadata (i.e. properties) can/must be attached to nodes in the LSG in order to have a reference compliant JT file, there are some conventions that have been generally followed in the industry when translating CAD data to the JT file format. See 7.2.1.2 Property Atom Elements section of this document for complete description of the file Elements used to attach this property information to nodes.

9.6.1 CAD Properties

The following table lists the conventions that CAD data translators typically (although not always) follow in placing CAD information in a JT file as properties on various LSG nodes. Some of these properties are considered required in order for the data in the file to be interpreted correctly while other properties are optional. See flowing sub-sections for additional information on required versus optional properties.

The convention is to place these Units properties on every Part and Assembly grouping node in the LSG. By following this convention, JT file format readers/writers are provided maximum flexibility in understanding/indicating the appropriate JT data unit processing for both, monolithic and shattered JT file Assembly structures.

JT Property Key	Meaning	JT File Data Type	Encoded Data Type	Valid Values	Required / Optional
JT_PROP_MEASUREMENT_UNITS	Model Units	MbString	MbString	millimeters centimeters meters inches feet yards micrometers decimeters kilometers mils miles	Required
CAD_MASS_UNITS	Units of mass	MbString	MbString	micrograms milligrams grams kilograms ounces pounds	Required
CAD_SURFACE_AREA	Surface area of solids within part.	MbString	F64	numeric	Optional
CAD_VOLUME	Volume of solids within part	MbString	F64	numeric	Optional
CAD_DENSITY	Density of solids within part (6)	MbString	F64	numeric	Optional
CAD_MASS	Mass or weight of solids within part	MbString	F64	numeric	Optional
CAD_CENTER_OF_GRAVITY	Center of gravity of solids within part	MbString	3 space separated F64	3 numeric values	Optional
CAD_PROP_MATERIAL_THICKNESS	Sheet thickness within part	MbString	F64	numeric	Optional
CAD_PART_NAME	Component name from translator	MbString	MbString	<string>	Optional
CAD_SOURCE	CAD program the Part originated from	MbString	MbString	<string>	Optional

Table 9: CAD Property Conventions

9.6.1.1 Required Properties

The required unit properties are really necessary for viewers of JT file data to properly interpret numeric data for analysis operations (e.g. measure) and support the building of assemblies through the reading of multiple JT files in disparate units. There are two units of measure that are relevant, units of distance and units of weight.

The JT_PROP_MEASURMENT_UNITS property is used to specify units of distance. The CAD_MASS_UNITS property is used to specify units for weight. JT_PROP_MEASURMENT_UNITS property is strictly required, while CAD_MASS_UNITS property is "optionally required". By "optionally required", we mean, it is required if other optional metadata intends to specify properties that would depend on these units of measure (e.g. CAD_DENSITY and CAD_MASS). Notice that the Mass units are specified, instead of the Density units, since Density is a derived unit of Mass/Volume.

9.6.1.2 Optional Properties

Optional properties can be provided, but if the property is a units based value, then the value must be in units that are consistent with the JT_PROP_MEASURMENT_UNITS and CAD_MASS_UNITS properties. Thus the units for the optional units based properties must be as follows:

Optional Property	Units
CAD_SURFACE_AREA	$(\text{JT\_PROP\_MEASUREMENT\_UNITS})^2$
CAD_VOLUME	$(\text{JT\_PROP\_MEASUREMENT\_UNITS})^3$
CAD_DENSITY	$\text{CAD\_MASS\_UNITS}/(\text{JT\_PROP\_MEASUREMENT\_UNITS})^3$
CAD_MASS	CAD_MASS_UNITS
CAD_CENTER_OF_GRAVITY	JT_PROP_MEASUREMENT_UNITS
CAD_PROP_MATERIAL_THICKNESS	JT_PROP_MEASUREMENT_UNITS

Table 10: CAD Optional Property Units

Note of caution regarding the node placement for the CAD_DENSITY property. Following the recommended convention for the placing of CAD properties (see description in 9.6.1CAD Properties) implies that all solids within a single JT part are of a uniform density, which may not be true in all cases.

9.6.2 Tessellation Properties

When dealing with facetted graphical representations (i.e. LODs) of precise models (e.g. JT B-Rep), depending on the desired use it is often useful/necessary to know what tessellation tolerances were used to generate the facetted representation. To that end, two properties are typically stored on Part Node Elements (if part also has precise model) to indicate the tessellation tolerances used to generate each LOD. These two tessellation properties are as follows

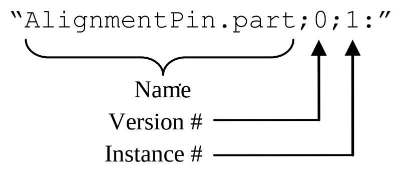
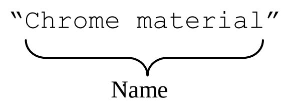
JT Property Key	Meaning	JT File Data Type	Encoded Data Type	Valid Values
Chordal::	Chordal deviation tessellation tolerance in MCS units for each LOD. Measure of maximum allowable distance a linear approximation for a curve/surface may deviate from the true curve/surface. Encoded value string would look as follows for the case of two LODs:	MbString	space separated F32 values	Numeric

JT Property Key	Meaning	JT File Data Type	Encoded Data Type	Valid Values
	"0.045603 0.069245"			
Angular::	Angular tessellation tolerance for each LOD in degrees. Two consecutive segments in a linear approximation of a curve/surface form an angle; this value specifies the maximum angle allowed. Encoded value string would look as follows for the case of two LODs: "30.000000 40.000000"	MbString	space separated F32 values	Numeric

9.6.3 Miscellaneous Properties

The below table documents some miscellaneous properties often placed on various nodes in the LSG to communicate specific information about the node or its contents.

JT Property Key	Meaning	JT File Data Type	Encoded Data Type	Valid Values
PMI_TYPE_TABLE	May be attached to Part Node Element to indicate the list of PMI type values and associated names for all PMI types (basically equivalent to the Entity Type field documented in Generic PMI Entities). The string is a "." and "," delimited string of the following form: "10.Groove Weld,11.Fillet Weld,12.Plug/Slot Weld,14.Edge Weld"	MbString	<string>	
JT_PROP_SHAPE_DATA_TYPE	May be attached to Shape Node Elements to indicate what geometry type the shape data represents.	MbString	<string>	"Surface" "Wire"
~~JT_PROP_TRISTRIP_DATA_LAYOUT~~	This property is deprecated, and is no longer used.			
JT_PROP_ORIGINATING_BREPTYPE	May be attached to Part Node Element to indicate the type of B-Rep associated with the Part.	MbString	<string>	"None" "JtBrep" "XTBrep"
JT_PROP_NAME	May be attached to any form of node or attribute with which one wants to associate a textual name (e.g. Part/Assembly/Instance name, Material name, Light Set name, etc.). For Part/Assembly/Instance names this string has the following encoded form where ";" is a delimiter and ":' is a terminator:	MbString	<string>	

JT Property Key	Meaning	JT File Data Type	Encoded Data Type	Valid Values
	 For attribute names this string has the following encoded form: 			

9.7 LSG Attribute Accumulation Semantics

For applications producing or consuming JT format data, it is important that the JT format semantics of how attributes are meant to be applied and accumulated down the LSG are followed. If not followed, then consistency between the applications in terms of 3D positioning and rendering of LSG model data will not be achieved.

Although each attribute type defines its own application and accumulation LSG semantics (the details of which can be found in each attribute type sub-section under 7.2.1.1.2 Attribute Elements), there are some general rules which apply:

Attributes at lower level in the LSG take precedence and replace or accumulate with attributes set at higher levels. When multiple Attributes of the same type are present on a Node, they accumulate in the order they are specified (i.e. from the front of the Attribute list toward the back).

Nodes with no associated attributes inherit those of their parents.

Attributes are inherited only from a node's parents. Thus a given node's attributes do not affect those on the node's siblings.

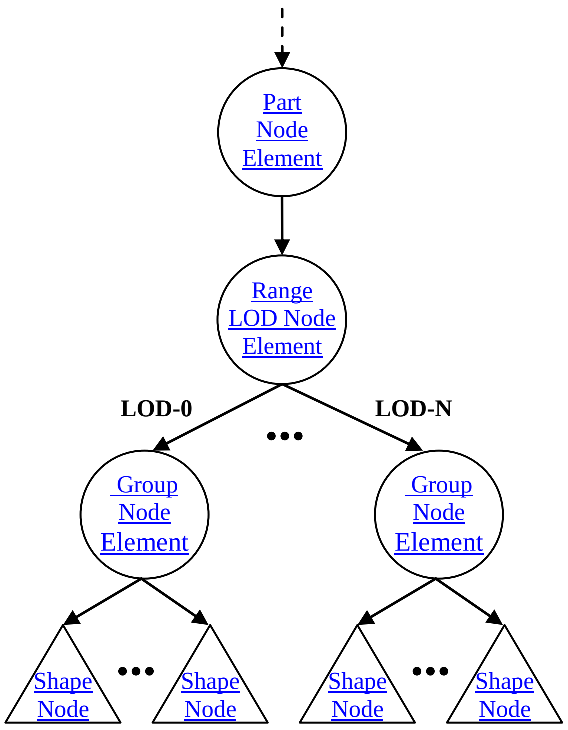
The root of a partition inherits the attributes in effect at the referring partition node.

Attributes can be marked "final", which terminates accumulation of that attribute type at that marked attribute and propagates the accumulated value at that point to all descendants of the associated node. Descendants can override a "final" attribute using the "force" flag. Note that "force" does not turn OFF "final" – it is simply a one-shot override of "final" for the specific attribute marked as "forcing." Multiple attributes of the same type may be marked as "forcing" and in this case, the last one wins. Both of these flags are OFF by default. An analogy for this "force" and "final" interaction is that "final" is a back-door in the attribute accumulation semantics, and that "force" is the doggy-door in the back-door!

9.8 LSG Part Structure

The JT Format Reference does not mandate that a particular node hierarchy be used for modeling physical Parts within a LSG structure. In fact there are many node hierarchies for representing Parts in LSG that will function correctly in most JT enabled applications. Still, there is a convention that most JT translators follow (and some JT enabled applications may assume exists) for modeling Parts within a LSG. The convention is to model each Part within a LSG structure with the following node hierarchy:

Figure 245: JT Format Convention for Modeling each Part in LSG



9.9 Range LOD Node Alternative Rep Selection

Best practices suggest that LSG traversers apply the following strategy, at Range LOD Nodes (see 7.2.1.1.1.8 Range LOD Node Element), when making alternative representation selection decisions based on Range Limits: The first alternate representation is valid when the world coordinate distance between the center and the eye point is less than or equal to the first range limit (and when no range limits are specified). The second alternate representation is valid when the distance is greater than the first limit and less than or equal to the second limit, and so on. The last alternate representation is valid for all distances greater than the last specified limit.

9.10 Brep Face Group Associations

The original purpose of the face group concept was to provide associativity between Brep faces and geometry. Exactly how a Brep face associates to a face group number is the topic of this section. An implicit scheme has been chosen for face group associativity, rather than storing some kind of explicit data on either the Vertex Shape LOD Data or the Brep. The primary motivation for this implicit scheme is to keep the JT files simple and small; additional association information would not only be redundant, but also wasteful. Tessellators must exercise this policy when producing Vertex Shape LOD Data from Breps, grouping the triangles into face groups according to its rules. Tristrips may not cross face groups. Applications must be able to count on this policy so that, for example, they can map a picking action back to its corresponding Brep face reliably.

JTBrep/ULP: In the case of JtBrep and ULP reps, the mapping is simple. These Reps have a consistent, sequential, index origin-0 numbering scheme for their regions, shells, and faces. So the Brep faces are simply assigned sequentially to face group by increasing region and shell. For example, suppose we have a JTBrep with 2 regions, each with 2 shells, each with 2 faces. The Face Group ⇔ Region/Shell/Face mapping will be as follows:

```
FG0 ⇔ R0 S0 F0
FG1 ⇔ R0 S0 F1
FG2 ⇔ R0 S1 F0
FG3 ⇔ R0 S1 F1
FG4 ⇔ R1 S0 F0
FG5 ⇔ R1 S0 F1
FG6 ⇔ R1 S1 F0
FG7 ⇔ R1 S1 F1
```

JtXTBrep: In the case of JtXTBrep, the mapping is based on Parasolid identifier of each XT face that is persisted on disk. The identifier is unique within each Parasolid body, but it is not an index. XTBrep maintains a zero-based contiguous index of XT face based on increasing identifier value within the same XT body. If XTBrep contains multiple XT bodies, then the sequence of those XT bodies are fixed across different Parasolid releases and therefore the index of each XT body is implied. In the case when multiple bodies are present in JtXTBrep, face index is assigned sequentially by increasing XT body index. For example, suppose we have a JtXTBrep with 2 bodies, each with 2 faces, then the Face Group to Body/Face mapping will be as follows:

```
FG0 ⇔ B0 F0
FG1 ⇔ B0 F1
FG2 ⇔ B1 F0
FG3 ⇔ B1 F1
```

Appendix A: Object Type Identifiers

All objects stored in a JT file are classified by type and thus include an object type identifier as part of their persisted data. The data format for these Object Type identifiers is a GUID. These Object Type identifiers are consistent for all objects, of a particular type, in all Version 8.1 JT files.

Table 11: Object Type Identifiers lists the assigned identifier for each Object Type that can exist in a Version 9.5 JT file.

GUID	Object Type
0xffffffff, 0xffff, 0xffff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff	Identifier to signal End-Of-Elements.
Types Stored Within LSG Segment (Segment Type = 1)	
0x10dd1035, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Base Node Element
0x10dd101b, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Group Node Element
0x10dd102a, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Instance Node Element
0x10dd102c, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	LOD Node Element
0xce357245, 0x38fb, 0x11d1, 0xa5, 0x6, 0x0, 0x60, 0x97, 0xbd, 0xc6, 0xe1	Meta Data Node Element
0xd239e7b6, 0xdd77, 0x4289, 0xa0, 0x7d, 0xb0, 0xee, 0x79, 0xf7, 0x94, 0x94	NULL Shape Node Element
0xce357244, 0x38fb, 0x11d1, 0xa5, 0x6, 0x0, 0x60, 0x97, 0xbd, 0xc6, 0xe1	Part Node Element
0x10dd103e, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Partition Node Element
0x10dd104c, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Range LOD Node Element
0x10dd10f3, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Switch Node Element
0x10dd1059, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Base Shape Node Element
0x98134716, 0x0010, 0x0818, 0x19, 0x98, 0x08, 0x00, 0x09, 0x83, 0x5d, 0x5a	Point Set Shape Node Element
0x10dd1048, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Polygon Set Shape Node Element
0x10dd1046, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Polyline Set Shape Node Element
0xe40373c1, 0x1ad9, 0x11d3, 0x9d, 0xaf, 0x0, 0xa0, 0xc9, 0xc7, 0xdd, 0xc2	Primitive Set Shape Node Element

GUID	Object Type
0x10dd1077, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Tri-Strip Set Shape Node Element
0x10dd107f, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Vertex Shape Node Element
0x10dd1001, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Base Attribute Data
0x10dd1014, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Draw Style Attribute Element
0xad8dccc2, 0x7a80, 0x456d, 0xb0, 0xd5, 0xdd, 0x3a, 0xb, 0x8d, 0x21, 0xe7	Fragment Shader Attribute Element
0x10dd1083, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Geometric Transform Attribute Element
0x10dd1028, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Infinite Light Attribute Element
0x10dd1096, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Light Set Attribute Element
0x10dd10c4, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Linestyle Attribute Element
0x10dd1030, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Material Attribute Element
0x10dd1045, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Point Light Attribute Element
0x8d57c010, 0xe5cb, 0x11d4, 0x84, 0xe, 0x00, 0xa0, 0xd2, 0x18, 0x2f, 0x9d	Pointstyle Attribute Element
0xaa1b831d, 0x6e47, 0x4fee, 0xa8, 0x65, 0xcd, 0x7e, 0x1f, 0x2f, 0x39, 0xdb	Shader Effects Attribute Element
0x10dd1073, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Texture Image Attribute Element
0x2798bcad, 0xe409, 0x47ad, 0xbd, 0x46, 0xb, 0x37, 0x1f, 0xd7, 0x5d, 0x61	Vertex Shader Attribute Element
0xad8dccc2, 0x7a80, 0x456d, 0xb0, 0xd5, 0xdd, 0x3a, 0xb, 0x8d, 0x21, 0xe7	Fragment Shader Attribute Element
0xaa1b831d, 0x6e47, 0x4fee, 0xa8, 0x65, 0xcd, 0x7e, 0x1f, 0x2f, 0x39, 0xdc	Texture Coordinate Generator Attribute Element
0xa3cfb921, 0xbdeb, 0x48d7, 0xb3, 0x96, 0x8b, 0x8d, 0xe, 0xf4, 0x85, 0xa0	Mapping Plane Element
0x3e70739d, 0x8cb0, 0x41ef, 0x84, 0x5c, 0xa1, 0x98, 0xd4, 0x0, 0x3b, 0x3f	Mapping Cylinder Element
0x72475fd1, 0x2823, 0x4219, 0xa0, 0x6c, 0xd9, 0xe6, 0xe3, 0x9a, 0x45, 0xc1	Mapping Sphere Element

GUID	Object Type
0x92f5b094, 0x6499, 0x4d2d, 0x92, 0xaa, 0x60, 0xd0, 0x5a, 0x44, 0x32, 0xcf	Mapping TriPlanar Element
0x10dd104b, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Base Property Atom Element
0xce357246, 0x38fb, 0x11d1, 0xa5, 0x6, 0x0, 0x60, 0x97, 0xbd, 0xc6, 0xe1	Date Property Atom Element
0x10dd102b, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Integer Property Atom Element
0x10dd1019, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Floating Point Property Atom Element
0xe0b05be5, 0xfbbd, 0x11d1, 0xa3, 0xa7, 0x00, 0xaa, 0x00, 0xd1, 0x09, 0x54	Late Loaded Property Atom ElementSecond specifies the date Second value. Valid values are [0, 59] inclusive. Late Loaded Property Atom Element
0x10dd1004, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	JT Object Reference Property Atom Element
0x10dd106e, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	String Property Atom Element
Types Stored Within JT B-Rep Segment (Segment Type = 2)	
0x873a70c0, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	JT B-Rep Element
Types Stored Within Meta Data Segment (Segment Type = 4)	
0xce357249, 0x38fb, 0x11d1, 0xa5, 0x6, 0x0, 0x60, 0x97, 0xbd, 0xc6, 0xe1	PMI Manager Meta Data Element
0xce357247, 0x38fb, 0x11d1, 0xa5, 0x6, 0x0, 0x60, 0x97, 0xbd, 0xc6, 0xe1	Property Proxy Meta Data Element
Types Stored Within Shape LOD Segment (Segment Type = 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16)	
0x3e637aed, 0x2a89, 0x41f8, 0xa9, 0xfd, 0x55, 0x37, 0x37, 0x3, 0x96, 0x82	Null Shape LOD Element
0x98134716, 0x0011, 0x0818, 0x19, 0x98, 0x08, 0x00, 0x09, 0x83, 0x5d, 0x5a	Point Set Shape LOD Element
0x10dd10a1, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Polyline Set Shape LOD Element
0xe40373c2, 0x1ad9, 0x11d3, 0x9d, 0xaf, 0x0, 0xa0, 0xc9, 0xc7, 0xdd, 0xc2	Primitive Set Shape Element
0x10dd10ab, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Tri-Strip Set Shape LOD Element

GUID	Object Type
0x10dd10b0, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Vertex Shape LOD Element
Types Stored Within XT B-Rep Segment (Segment Type = 17)	
0x873a70e0, 0x2ac9, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	XT B-Rep Element
Types Stored Within Wireframe Segment (Segment Type = 18)	
0x873a70d0, 0x2ac8, 0x11d1, 0x9b, 0x6b, 0x00, 0x80, 0xc7, 0xbb, 0x59, 0x97	Wireframe Rep Element
Types Stored Within JT ULP Segment (Segment Type = 20)	
0xf338a4af, 0xd7d2, 0x41c5, 0xbc, 0xf2, 0xc5, 0x5a, 0x88, 0xb2, 0x1e, 0x73	JT ULP Element
Types Stored Within JT LWPA Segment (Segment Type = 24)	
0xd67f8ea8, 0xf524, 0x4879, 0x92, 0x8c, 0x4c, 0x3a, 0x56, 0x1f, 0xb9, 0x3a	JT LWPA Element

Table 11: Object Type Identifiers

Appendix B: Semantic Value Class Shader Parameter Values

7.2.1.1.2.12 Vertex Shader Attribute Element and 7.2.1.1.2.13 Fragment Shader Attribute Element contain shader parameters. These shader parameters can be of a "Semantic" Value Class which indicates that the shader parameter is implicitly tied/bound to a piece of either OpenGL or JT graphics system state. Table 12 below documents all the possible "Semantic" Value Class shader parameter Values (i.e. the graphics system state the parameter is bound to).

Table 12: Semantic Value Class Shader Parameter Values

Value	Description of Semantically Bound Graphics State	Notes
= 0	– Unknown	
	Related to Current OpenGL State	
= 30	– View Transform Matrix	Cg only
= 31	– Combined Model-View Transform Matrix	Cg only
= 32	– Projection Transform Matrix	Cg only
= 33	– Texture Transform Matrix	Cg only
= 34	– Combined Model-View-Projection Transform Matrix	Cg only
= 35	– View Matrix Transposed	Cg only
= 36	– Combined Model-View Transform Matrix Transposed	Cg only
= 37	– Projection Transform Matrix Transposed	Cg only
= 38	– Texture Transform Matrix Transposed	Cg only
= 39	– Combined Model-View-Projection Transform Matrix Transposed	Cg only
= 40	– View Transform Matrix Inverse	Cg only
= 41	– Combined Model-View Transform Matrix Inverse	Cg only
= 42	– Projection Transform Matrix Inverse	Cg only
= 43	– Texture Transform Matrix Inverse	Cg only
= 44	– Combined Model-View-Projection Transform Matrix Inverse	Cg only
= 45	– View Transform Matrix Inverse Transposed	Cg only
= 46	– Combined Model-View Transform Matrix Inverse Transposed	Cg only
= 47	– Projection Transform Matrix Inverse Transposed	Cg only
= 48	– Texture Transform Matrix Inverse Transposed	Cg only
= 49	– Combined Model-View-Projection Transform Matrix Inverse Transposed	Cg only
	Related to Current JT State	
= 70	– Current Model Transform	
= 71	– Current Model Transform Transposed	
= 72	– Current Model Transform Inverse	
= 73	– Current Model Transform Inverse Transposed	
= 75	– Current Material Emissive Color	
= 76	– Current Material Diffuse Color	
= 77	– Current Material Specular Color	
= 78	– Current Material Ambient Color	
= 79	– Current Material Shininess	
= 80	– Current Fog Color	
= 81	– Separate Specular Color Flag	
= 82	– Global Ambient Light Color	
= 83	– Exposure	
= 84	– Bumpiness	
= 85	– Environment Reflectivity	
= 86	– Depth Peeling Texture 0	

= 87	– Depth Peeling Texture 1	
= 99	– Number of VPCS Lights	
= 101	– VPCS Light-0 Specular Color	
= 102	– VPCS Light-0 Ambient Color	
= 103	– VPCS Light-0 Attenuation	
= 104	– VPCS Light-0 Position	
= 105	– VPCS Light-0 Direction	
= 106	– VPCS Light-0 Spot Direction	
= 107	– VPCS Light-0 Spot Cone Angle	
= 108	– VPCS Light-0 Cosine of Spot Cone Angle	
= 109	– VPCS Light-0 Spot Exponent	
= 110	– VPCS Light-0 Shadow Opacity	
= 120 → 130	– Same as values 100 → 110 except for VPCS Light-1	
= 140 → 150	– Same as values 100 → 110 except for VPCS Light-2	
= 160 → 170	– Same as values 100 → 110 except for VPCS Light-3	
= 180 → 190	– Same as values 100 → 110 except for VPCS Light-4	
= 200 → 210	– Same as values 100 → 110 except for VPCS Light-5	
= 220 → 230	– Same as values 100 → 110 except for VPCS Light-6	
= 240 → 250	– Same as values 100 → 110 except for VPCS Light-7	
= 499	– Number of MCS Lights	
= 500 → 510	– Same as values 100 → 110 except for MCS Light-0	
= 520 → 530	– Same as values 100 → 110 except for MCS Light-1	
= 540 → 550	– Same as values 100 → 110 except for MCS Light-2	
= 560 → 570	– Same as values 100 → 110 except for MCS Light-3	
= 580 → 590	– Same as values 100 → 110 except for MCS Light-4	
= 600 → 610	– Same as values 100 → 110 except for MCS Light-5	
= 620 → 630	– Same as values 100 → 110 except for MCS Light-6	
= 640 → 650	– Same as values 100 → 110 except for MCS Light-7	
= 899	– Number of WCS Lights	
= 900 → 910	– Same as values 100 → 110 except for WCS Light-0	
= 920 → 930	– Same as values 100 → 110 except for WCS Light-1	
= 940 → 950	– Same as values 100 → 110 except for WCS Light-2	
= 960 → 970	– Same as values 100 → 110 except for WCS Light-3	
= 980 → 990	– Same as values 100 → 110 except for WCS Light-4	
= 1000 → 1010	– Same as values 100 → 110 except for WCS Light-5	
= 1020 → 1030	– Same as values 100 → 110 except for WCS Light-6	
= 1040 → 1050	– Same as values 100 → 110 except for WCS Light-7	
= 1500	– Current Texture Object-0	Cg only
= 1501	– Current Texture Object-1	Cg only
= 1502	– Current Texture Object-2	Cg only
= 1503	– Current Texture Object-3	Cg only
= 1504	– Current Texture Object-4	Cg only
= 1505	– Current Texture Object-5	Cg only
= 1506	– Current Texture Object-6	Cg only
= 1507	– Current Texture Object-7	Cg only

= 1600	– Current Texture Unit-0	GLSL only
= 1601	– Current Texture Unit-1	GLSL only
= 1602	– Current Texture Unit-2	GLSL only
= 1603	– Current Texture Unit-3	GLSL only
= 1604	– Current Texture Unit-4	GLSL only
= 1605	– Current Texture Unit-5	GLSL only
= 1606	– Current Texture Unit-6	GLSL only
= 1607	– Current Texture Unit-7	GLSL only
= 1700	– Texture Channel-0 VCS Texture Coordinate Generation S-Plane	
= 1701	– Texture Channel-0 VCS Texture Coordinate Generation T-Plane	
= 1702	– Texture Channel-0 VCS Texture Coordinate Generation R-Plane	
= 1703	– Texture Channel-0 VCS Texture Coordinate Generation Q-Plane	
= 1710 → 1713	– Same as 1700 → 1703 except for Chanel-1 VCS	
= 1720 → 1723	– Same as 1700 → 1703 except for Chanel-2 VCS	
= 1730 → 1733	– Same as 1700 → 1703 except for Chanel-3 VCS	
= 1740 → 1743	– Same as 1700 → 1703 except for Chanel-4 VCS	
= 1750 → 1753	– Same as 1700 → 1703 except for Chanel-5 VCS	
= 1760 → 1763	– Same as 1700 → 1703 except for Chanel-6 VCS	
= 1770 → 1773	– Same as 1700 → 1703 except for Chanel-7 VCS	
= 2000 → 2003	– Same as 1700 → 1703 except for Chanel-0 MCS	
= 2010 → 2013	– Same as 1700 → 1703 except for Chanel-1 MCS	
= 2020 → 2023	– Same as 1700 → 1703 except for Chanel-2 MCS	
= 2030 → 2033	– Same as 1700 → 1703 except for Chanel-3 MCS	
= 2040 → 2043	– Same as 1700 → 1703 except for Chanel-4 MCS	
= 2050 → 2053	– Same as 1700 → 1703 except for Chanel-5 MCS	
= 2060 → 2063	– Same as 1700 → 1703 except for Chanel-6 MCS	
= 2070 → 2073	– Same as 1700 → 1703 except for Chanel-7 MCS	
= 3000	– Texture Channel-0 Matrix	
= 3001	– Texture Channel-1 Matrix	
= 3002	– Texture Channel-2 Matrix	
= 3003	– Texture Channel-3 Matrix	
= 3004	– Texture Channel-4 Matrix	
= 3005	– Texture Channel-5 Matrix	
= 3006	– Texture Channel-6 Matrix	
= 3007	– Texture Channel-7 Matrix	
= 3100	– Texture Channel-0 Map Resolution	
= 3101	– Texture Channel-1 Map Resolution	
= 3102	– Texture Channel-2 Map Resolution	
= 3103	– Texture Channel-3 Map Resolution	
= 3104	– Texture Channel-4 Map Resolution	
= 3105	– Texture Channel-5 Map Resolution	
= 3106	– Texture Channel-6 Map Resolution	
= 3107	– Texture Channel-7 Map Resolution	
= 3200	– Texture Channel-0 Map Resolution Inverses (i.e. 1.0 /"Map Resolution")	
= 3201	– Texture Channel-1 Map Resolution Inverses	

= 3202	– Texture Channel-2 Map Resolution Inverses	
= 3203	– Texture Channel-3 Map Resolution Inverses	
= 3204	– Texture Channel-4 Map Resolution Inverses	
= 3205	– Texture Channel-5 Map Resolution Inverses	
= 3206	– Texture Channel-6 Map Resolution Inverses	
= 3207	– Texture Channel-7 Map Resolution Inverses	
= 3300	– Texture Channel-0 Blend Color	
= 3301	– Texture Channel-1 Blend Color	
= 3302	– Texture Channel-2 Blend Color	
= 3303	– Texture Channel-3 Blend Color	
= 3304	– Texture Channel-4 Blend Color	
= 3305	– Texture Channel-5 Blend Color	
= 3306	– Texture Channel-6 Blend Color	
= 3307	– Texture Channel-7 Blend Color	

Appendix C: Decoding Algorithms – An Implementation

This Appendix provides a sample C++ implementation for the decoding portion of the various compression CODECs (as detailed in 8.2 Encoding Algorithms) used in the JT format. This sample code is not intended to be fully functional decoder class implementations, but is instead intended to demonstrate the fundamentals of implementing the decoding portion of the CODEC algorithms used in the JT format.

1 Common classes

The following sub-sections define some general classes used by all the decoding algorithms.

1.1 CntxEntry class

```
//
// Type used to build probability context tables.
// Used by ProbabilityContext class.
//
class CntxEntry
{
public:

    Int32 iSym;          // Symbol
    Int32 cCount;        // Number of occurrences
    Int32 cCumCount;     // Cumulative number of occurrences
    Int32 iNextCntx = 0; // Next context if this symbol seen
};
```

1.2 ProbabilityContext class

```
//
// Type used to build probability context tables.
// Used by CodecDriver class.
//
class ProbabilityContext
{
public:

    // Returns total cumulative count for all context entries
    Int32 totalCount();

    // Returns number of context entries
    Int32 numEntries();

    // Returns context entry of index iEntry
    Bool getEntry(Int32 iEntry, CntxEntry& rpEntry);

    // Looks up the next context field given by the context entry
    // with input symbol 'iSymbol'
    Bool lookupNextContext(Int32 iSymbol, Int32& iNextContext);

    // Looks up the index of the context entry for the given
    // input symbol 'iSymbol'
    Bool lookupSymbol(Int32 iSymbol, Int32& iOutEntry);

    // Looks up the index of the context entry that falls just above
    // the accumulated count.
    Bool lookupEntryByCumCount(Int32 iCount, Int32& iOutEntry);
};
```

1.3 CodecDriver class

```
//
// A class that deals with the conversions from SYMBOL to VALUE and
// provides end-consumer APIs for using the codecs.
//
class CodecDriver
```

```
{
public:
    // ---------- Codec Decoding Interface ----------
    // Returns the number of symbols to be read
    Int32 numSymbolsToRead();

    // Returns index of the first context entry and total number of bits
    Bool getDecodeData(Int32& iFirstContext, Int32& nTotalBits);

    // Returns the next 32 bits of CodeText
    Bool getNextCodeText(UInt32& uCodeText, Int32& nBits);

    // Adds the decoded symbol back to the driver
    Bool addOutputSymbol(Int32 iSymbol, Int32& iNextContext) ;

    // ---------- Symbol Probability Context Interface ----------
    Bool clearAllContexts();

    // Retrieves a new probability context
    Bool getNewContext(ProbabilityContext& rpCntx);

    // Returns the total number of contexts
    Int32 numContexts();

    // Returns the probability context for a given index
    Bool getContext(Int32 iSymContext, ProbabilityContext& rpCntx);

    // ---------- Predictor Type Residual Unpacking ----------

    typedef enum
    {
        PredLag1       = 0,
        PredLag2       = 1,
        PredStride1    = 2,
        PredStride2    = 3,
        PredStripIndex = 4,
        PredRamp       = 5,
        PredXor1       = 6,
        PredXor2       = 7,
        PredNULL       = 8
    } PredictorType;

    // Returns the original values from the predicted residual values.
    static Bool unpackResiduals(Vector<Int32>& rvResidual,
                                   Vector<Int32>& rvVals,
                                   PredictorType  ePredType);

    static Bool unpackResiduals(Vector<Float64>& rvResidual,
                                   Vector<Float64>& rvVals,
                                   PredictorType  ePredType);

    // Predict values
    static Int32 predictValue(Vector<Int32>& vVal,
                                Int32 iIndex,
                                PredictorType ePredType);

    static Float64 predictValue(Vector<Float64>& vVal,
                                   Int32 iIndex,
                                   PredictorType ePredType);
}

Bool CodecDriver::unpackResiduals(Vector<Int32>& rvResidual,
                                      Vector<Int32>& rvVals,
                                      PredictorType  ePredType)
{
    Int32 iPredicted;

    Int32 len = rvResidual.length();
    rvVals.setLength(len);
    Int32* aVals = (Int32 *) rvVals;
    Int32* aResidual = (Int32 *) rvResidual;
    for( Int32 i = 0; i < len; i++ )
    {
        if( i < 4 )
        {
            // The first four values are just primers
            aVals[i] = aResidual[i];
        }
        else
        {
            // Get a predicted value
            iPredicted = predictValue(rvVals, i, ePredType);

            if( ePredType == PredXor1 || ePredType == PredXor2 )
            {
                // Decode the residual as the current value XOR predicted
                aVals[i] = aResidual[i] ^ iPredicted;
            }
            else
            {
                // Decode the residual as the current value plus predicted
                aVals[i] = aResidual[i] + iPredicted;
            }
        }
    }

    return True;
}

Bool CodecDriver::unpackResiduals(Vector<Float64>& rvResidual,
                                          Vector<Float64>& rvVals,
                                          PredictorType  ePredType)
{
    if( ePredType == PredXor1 || ePredType == PredXor2 )
        return False;

    if( ePredType == PredNULL )
    {
        rvVals = rvResidual;
        return True;
    }

    Float64 iPredicted;
    Int32 len = rvResidual.length();
    rvVals.setLength(len);

    for( Int32 i = 0; i < len; i++ )
    {
        if( i < 4 )
        {
            // The first four values are just primers
            rvVals[i] = rvResidual[i];
        }
        else
        {
            // Get a predicted value
            iPredicted = predictValue(rvVals, i, ePredType);

            // Decode the value as the residual plus predicted
            rvVals[i]   = rvResidual[i] + iPredicted;
        }
    }

    return True;
}

Int32 CodecDriver::predictValue(Vector<Int32>& vVal,
                                        Int32 iIndex,
                                        PredictorType ePredType)
{
    Int32* aVals = (Int32 *) rvVals;
    JtInt32 iPredicted,
             v1 = aVals[iIndex-1],
             v2 = aVals[iIndex-2],
             v3 = aVals[iIndex-3],
             v4 = aVals[iIndex-4];

    switch( ePredType )
    {
        default:
        case PredLag1:
        case PredXor1:
            iPredicted = v1;
            break;

        case PredLag2:
        case PredXor2:
            iPredicted = v2;
            break;

        case PredStride1:
            iPredicted = v1 + (v1 - v2);
            break;

        case PredStride2:
            iPredicted = v2 + (v2 - v4);
            break;

        case PredStripIndex:
            if( v2 - v4 < 8 && v2 - v4 > -8 )
                iPredicted = v2 + (v2 - v4);
            else
                iPredicted = v2 + 2;
            break;

        case PredRamp:
            iPredicted = iIndex;
            break;
    }

    return iPredicted;
}


Float64 CodecDriverBase::predictValue(Vector<Float64>& vVal,
                                              Int32 iIndex,
                                              PredictorType ePredType)
{
    Float64* aVals = (Float64 *) rvVals;
    Float64 iPredicted,
             v1 = aVals[iIndex-1],
             v2 = aVals[iIndex-2],
             v3 = aVals[iIndex-3],
             v4 = aVals[iIndex-4];

    switch( ePredType )
    {
        default:
        case PredLag1:
            iPredicted = v1;
            break;

        case PredLag2:
            iPredicted = v2;
            break;

        case PredStride1:
            iPredicted = v1 + (v1 - v2);
            break;

        case PredStride2:
            iPredicted = v2 + (v2 - v4);
            break;

        case PredStripIndex:
            if( v2 - v4 < 8 && v2 - v4 > -8 )
                iPredicted = v2 + (v2 - v4);
            else
                iPredicted = v2 + 2;
            break;

        case PredRamp:
            iPredicted = iIndex;
            break;
    }

    return iPredicted;
}
```

1.4 CodecDriver2 class

2 Bitlength decoding classes

The following sub-sections contain a sample implementation of the decoding portion of the Bitlength CODEC algorithm. A summary technical explanation of the Bitlength CODEC can be found in 8.2.2 Bitlength CODEC.

2.1 BitLengthCodec class

```
class BitLengthCodec
{
public:
    // This method decodes a given stream of symbols into their values.
    // The stream is described by the codec driver
    Bool decode(CodecDriver* pDriver);

    Int32 cStepBits = 2;
};

Bool BitLengthcodec::decode(CodecDriver* pDriver)
{
    Int32 iBit;                 // Codetext bit number
    Int32 nBits = 0;            // Number of codetext bits decoded so far
    Int32 nTotalBits = 0;  // Total number of codetext bits expected
    Int32 nValBits = 0;         // Number of accumulated value bits
    Int32 iContext = 0;         // Probability context number
    Int32 iSymbol;              // Decoded symbol value
    UInt32 uVal = 0;            // Current chunk of codetext bits
    UInt32 uAccVal = 0;         // Number of valid bits returned from
                                    // getNextCodeText
    UInt32 uLastIncBit = 0;     // Used to calculate whether terminator bit
                                    // is 0 or 1
    Int32 cNumCurBits = 0; // Current field width in bits
    Int32 nAccBits = 0;         // Number of bits accum'ed in uAccVal
    Int32 iDecodeState = 0;     // State of decoder; see below

    // Get codetext from the driver and loop over it until it's gone!
    pDriver->getDecodeData(iContext, nTotalBits);

    while( nBits < nTotalBits )
    {
        // Get the next 32 bits from the input stream
        pDriver->getNextCodeText(uVal, nValBits);

        // Scan through each bit either walking the Huffman code
        // tree or accumulating escaped bit values.
        Int32 n = min(32, min(nValBits, nTotalBits - nBits));
        for( iBit = 0; iBit < n ; iBit++ )
        {
            // Code-accumulation mode is handled is this block
            // as many bits at a time as possible.
```

```
if( iDecodeState == 2 )
{

    // Slice off as many bits as we can all at once.
    Int32 m = min(n - iBit, cNumCurBits - nAccBits);
    if( m < 32 )
    {
        uAccVal <<= m;
        uAccVal |= ((uVal >> (32 - m)) & ((1 << m) - 1));
        nAccBits += m;
        iBit += m - 1;

        // Advance the bit-marching counters
        uVal <<= m;
        nBits += m;
        nValBits -= m;
    }
    else
    {
        uAccVal = uVal;
        nAccBits += m;
        iBit += m - 1;

        // Advance the bit-marching counters
        uVal = 0;
        nBits += m;
        nValBits -= m;
    }

    if( nAccBits >= cNumCurBits )
    {
        // Convert and sign-extend the symbol
        iSymbol = Int32(uAccVal);
        iSymbol <<= (32 - cNumCurBits);
        iSymbol >>= (32 - cNumCurBits);

        // Output the symbol and restart
        pDriver->addOutputSymbol(iSymbol, iContext);
        iDecodeState = 0;
        uAccVal  = 0;
        nAccBits = 0;
    }
}
else
{
    // All other decode states are handled one bit at a time
    // inside this block.
    // Get the next bit
    uAccVal = (uVal >> 31);

    switch( iDecodeState )
    {

        // DecodeState = 0: Recognize prefix bit (0=Same size
        // code, 1=Different size code).
        case 0:
            // Recognize "same length" prefix code
            if( uAccVal == 0 )
                iDecodeState = 2;
            else
            {
                // Recognize "different length" prefix code
                iDecodeState = 1;
                uLastIncBit = 2;
            }

            uAccVal  = 0;
            break;

        case 1:  // Length adjustment mode
            // Recognize the terminator bit
```

```
                        if( uLastIncBit != 2 && (uAccVal ^ uLastIncBit) )
                        {
                            iDecodeState = 2;
                            uLastIncBit = 2;
                        }
                        else
                        {
                            // Recognize the "increment" prefix code
                            if( uAccVal == 1 )
                            {
                                cNumCurBits += cStepBits;
                            }
                            else
                            {
                                // Recognize the "decrement" prefix code
                                cNumCurBits -= cStepBits;
                            }

                            uLastIncBit = uAccVal;
                        }

                        uAccVal  = 0;
                        break;
                }

                // Advance the bit-marching counters that keep track of the
                // "current codetext bit", and how many bits are left.
                uVal <<= 1;
                nBits++;
                nValBits--;
            }
        }
    }

    // If the last symbol was zero and the current bit length
    // is also zero, then the above loop terminated before
    // actually decoding the last zero-valued symbol.  Test
    // for that condition here and decode it if necessary.
    if( iDecodeState == 2 && cNumCurBits == 0 )
    {
        // Output the symbol and restart
        iSymbol = Int32(0);
        pDriver->addOutputSymbol(iSymbol, iContext);
    }

    return True;
}
```

3 Arithmetic decoding classes

The following sub-sections contain a sample implementation of the decoding portion of the Arithmetic CODEC algorithm. A summary technical explanation of the Arithmetic CODEC can be found in 8.2.3 Arithmetic CODEC.

3.1 ArithmeticProbabilityRange class

```
class ArithmeticProbabilityRange
{
public:
    UInt16 low_count;
    UInt16 high_count;
    UInt16 scale;
}
```

3.2 ArithmeticCodec class

ArithmeticCodec class is the class that decodes arithmetic encoded data.

```
class ArithmeticCodec
{
```

```
public:
    ArithmeticCodec() :
        code = 0x0000,
        low = 0x0000,
        high = 0xffff,
        nUnderflowBits = 0,
        bitBuffer =0x00000000,
        nBits = 0
    {
    }

    // Decodes a list of symbols. The codecDriver provides the range
    // info for the symbols to decode.  It also stores the symbols as
    // they are decoded.
    Bool decode(CodecDriver* pDriver);

private:
    // Remove the most recently decoded symbol from the front of the
    // list of encoded symbols.
    Bool removeSymbolFromStream(ArithmeticProbabilityRange& sym,
                                CodecDriver* pDriver);

    //State variables used in decoding.
    UInt16 code;      // Present input code value, for decoding only
    UInt16 low;       // Start of the current code range
    UInt16 high;      // End of the current code range

    UInt32 bitBuffer; // Temporary i/o buffer
    Int32  nBits;     // Number of bits in _bitBuffer
};

Bool ArithmeticCodec::decode(CodecDriver* pDriver )
{
    ArithmeticProbabilityRange newSymbolRange;
    Int32 iCurrContext, nDummyTotalBits, cSymbolsCurrCtx, iCurrEntry;

    Int32 nSymbols = pDriver->numSymbolsToRead();

    ProbabilityContext* pCurrContext = NULL;
    CntxEntry* pCntxEntry = NULL;

    // Initialize decoding process
    Int32 nBitsRead = -1;
    pDriver->getNextCodeText(bitBuffer, nBitsRead);

    low  = 0;
    high = 0xffff;
    code = (bitBuffer >> 16);

    bitBuffer <<= 16;
    nBits = 16;

    // Begin decoding
    pDriver->getDecodeData(iCurrContext, nDummyTotalBits);
    for( Int32 ii = 0; ii < nSymbols; ii++ )
    {
        pDriver->getContext(iCurrContext, pCurrContext);

        cSymbolsCurrCtx = pCurrContext->totalCount();
        UInt16 rescaledCode =
            ((((UInt32)(code - low) + 1) * (UInt32) cSymbolsCurrCtx - 1) /
                ((UInt32)(high - low) + 1));

        pCurrContext->lookupEntryByCumCount((Int32)rescaledCode,
                                                     iCurrEntry);

        pCurrContext->getEntry(iCurrEntry, pCntxEntry);

        newSymbolRange.high_count = pCntxEntry->cCumCount +
                                           pCntxEntry.cCount;
        newSymbolRange.low_count  = pCntxEntry->cCumCount;
        newSymbolRange.scale      = cSymbolsCurrCtx;

        removeSymbolFromStream(newSymbolRange, pDriver);

        pDriver->addOutputSymbol(pCntxEntry);

        iCurrContext = pCntxEntry->iNextCntx;
    }

    return True;
}

Bool ArithmeticCodec::removeSymbolFromStream(
                                  ArithmeticProbabilityRange& sym,
                                  CodecDriver* pDriver)
{
    // First, the range is expanded to account for the symbol removal.
    UInt32 range = UInt32(high - low)  + 1;
    high = low + (UInt32)((range * sym.high_count) / sym.scale - 1);
    low  = low + (UInt32)((range * sym.low_count ) / sym.scale);

    //Next, any possible bits are shipped out.
    for (;;)
    {
        // If the most signif digits match, the bits will be shifted out.
        if( (~(high^low)) & 0x8000 )
        {
        }
        else if( (low & 0x4000) && !(high & 0x4000) )
        {
            // Underflow is threatening, shift out 2nd most signif digit.
            code ^= 0x4000;
            low  &= 0x3fff;
            high |= 0x4000;
        }
        else
        {
            // Nothing can be shifted out, so return.
            return True;
        }

        low  <<= 1;
        high <<= 1;
        high |=  1;
        code <<= 1;

        if( nBits == 0 )
        {
          // The returned nBits here will always be 32
            pDriver->getNextCodeText(bitBuffer, nBits);
        }

        code |= (UInt16)(bitBuffer >> 31);
        bitBuffer <<= 1;
        nBits--;
    }
}
```

4 Deering Normal decoding classes

The following sub-sections contain a sample implementation of the decoding portion of the Deering Normal CODEC algorithm. A summary technical explanation of the Deering Normal CODEC can be found in 8.2.4 Deering Normal CODEC.

4.1 DeeringNormalLookupTable class

The DeeringNormalLookupTable class represents a lookup table used by the DeeringNormalCodec class for faster conversion from the compressed normal representation to the standard 3-float representation. The tables hold precomputed results of the trig functions called during conversion.

```
class DeeringNormalLookupTable
{
public:
    DeeringNormalLookupTable();

    // Lookup and return the result of converting iTheta and iPsi to
    // real angles and taking the sine and cosine of both.  This gives
    // a slight speedup for normal decoding.
    Bool lookupThetaPsi(Int32 iTheta,
                            Int32 iPsi,
                            UInt32 numberBits,
                            Float32 outCosTheta,
                            Float32 outSinTheta,
                            Float32 outCosPsi,
                            Float32 outSinPsi );

    UInt32 numBitsPerAngle() {return nBits;}

private:
    UInt32 nBits;
    Vector vCosTheta;
    Vector vSinTheta;
    Vector vCosPsi;
    Vector vSinPsi;
};

DeeringNormalLookupTable::DeeringNormalLookupTable()
{
    UInt32 numberbits = 8;
    nBits = min(numberbits, (UInt32)31);

    Int32 tableSize = (1 << nBits);

    vCosTheta.setLength(tableSize+1);
    vSinTheta.setLength(tableSize+1);
    vCosPsi.setLength(tableSize+1);
    vSinPsi.setLength(tableSize+1);

    Float32 fPsiMax = 0.615479709;
    Float32 fTableSize = (Float32)tableSize;

    for( Int32 ii = 0; ii <= tableSize; ii++ )
    {
    Float32 fTheta =
        asin(tan(fPsiMax * Float32(tableSize - ii) / fTableSize));

        Float32 fPsi  = fPsiMax * (((Float32)ii) / fTableSize);
        vCosTheta[ii] = cos(fTheta);
        vSinTheta[ii] = sin(fTheta);
        vCosPsi[ii]   = cos(fPsi);
        vSinPsi[ii]   = sin(fPsi);
    }
}

Bool DeeringNormalLookupTable::lookupThetaPsi(Int32 iTheta,
                                                         Int32 iPsi,
                                                         UInt32 numberBits,
    Float32 outCosTheta,
    Float32 outSinTheta,
    Float32 outCosPsi,
    Float32 outSinPsi)
{
    Int32 offset = nBits - numberBits;
    outCosTheta = vCosTheta[iTheta << offset];
    outSinTheta = vSinTheta[iTheta << offset];
    outCosPsi   = vCosPsi[iPsi << offset];
    outSinPsi   = vSinPsi[iPsi << offset];

    return True;
}
```

4.2 DeeringNormalCodec class

The DeeringNormalCodec class converts a normal vector to and from the standard 3-float representation and a lower-precision representation. The precision can be adjusted using the nbits parameter.

```
class DeeringNormalCodec
{
public:
    DeeringNormalCodec(Int32 numberbits = 6)
    {
        numBits = numberbits;
    }

    // Converts a compressed normal into a vector.
    Bool convertCodeToVec(UInt32 code, Vector& outVec);

    // Converts a compressed normal into a vector.
    Bool convertCodeToVec(UInt32 iSextant,
 UInt32 iOctant,
 UInt32 iTheta,
 UInt32 iPsi,
 Vector& outVec);

    // Separates an encoded normal into its 4 pieces
    Bool unpackCode(UInt32  code,
 UInt32& outSextant,
 UInt32& outOctant,
 UInt32& outTheta,
 UInt32& outPsi );

    private:
        Int32 numBits;
}

Bool DeeringNormalCodec::convertCodeToVec(UInt32 code, Vector& outVec)
{
    UInt32 s=0, o=0, t=0, p=0;
    unpackCode(code, s, o, t, p);

    convertCodeToVec(s, o, t, p, outVec);

    return True;
}

Bool DeeringNormalCode::convertCodeToVec(UInt32 iSextant,
                                                  UInt32 iOctant,
                                                  UInt32 iTheta,
                                                  UInt32 iPsi,
                                                  Vector& outVec)
{
    // Size of code = 6+2*numBits, and max code size is 32 bits,
    // so numBits must be <= 13.

    // Code layout: [sextant:3][octant:3][theta:numBits][psi:numBits]

    outVec.setValues(0,0,0);
    Float32 fPsiMax = 0.615479709;

    UInt32  iBitRange = 1<<numBits;
    Float32 fBitRange = Float32(iBitRange);

    // For sextants 1, 3, and 5, iTheta needs to be incremented
```

```
iTheta += (iSextant & 1);

Float32 fCosTheta, fSinTheta, fCosPsi, fSinPsi;

DeeringNormalLookupTable LookupTable;

if( (LookupTable.numBitsPerAngle() < (UInt32)numBits) ||
     !LookupTable.lookupThetaPsi(iTheta, iPsi, numBits,
                                        fCosTheta, fSinTheta,
                                        fCosPsi, fSinPsi) )
{
    Float32 fTheta = asin(tan(fPsiMax * Float32(iBitRange - iTheta) /
                                    fBitRange));

    Float32 fPsi = fPsiMax * (iPsi / fBitRange);
    fCosTheta = cos(fTheta);
    fSinTheta = sin(fTheta);
    fCosPsi   = cos(fPsi);
    fSinPsi   = sin(fPsi);
}

Float32 x,y,z;
Float32 xx = x = fCosTheta * fCosPsi;
Float32 yy = y = fSinPsi;
Float32 zz = z = fSinTheta * fCosPsi;

//Change coordinates based on the sextant
switch( iSextant )
{
    case 0:     // No op
        break;

    case 1:     // Mirror about x=z plane
        z = xx;
        x = zz;
        break;

    case 2:     // Rotate CW
        z = xx;
        x = yy;
        y = zz;
        break;

    case 3:     // Mirror about x=y plane
        y = xx;
        x = yy;
        break;

    case 4:     // Rotate CCW
        y = xx;
        z = yy;
        x = zz;
        break;

    case 5:     // Mirror about y=z plane
        z = yy;
        y = zz;
        break;
};

//Change some more based on the octant

//if first bit is 0, negate x component
if( !(iOctant & 0x4) )
    x = -x;

//if second bit is 0, negate y component
if( !(iOctant & 0x2) )
    y = -y;

//if third bit is 0, negate z component
```

```
    if( !(iOctant & 0x1) )
        z = -z;

    outVec.setValues(x,y,z);

    return True;
}

Bool DeeringNormalCodec::unpackCode(UInt32 code,
                                             UInt32& outSextant,
                                             UInt32& outOctant,
                                             UInt32& outTheta,
                                             UInt32& outPsi)
{
    UInt32 mask = (1<<numBits)-1;

    outSextant = (code >> (numBits+numBits+3)) & 0x7;
    outOctant  = (code >> (numBits+numBits))   & 0x7;
    outTheta   = (code >> (numBits))           & mask;
    outPsi     = (code)                        & mask;

    return True;
}
```

Appendix D: Hashing – An Implementation

This Appendix provides a sample C++ implementation for the creation of hash values (as detailed in 8.2 Encoding Algorithms) used in the JT format.

```
unsigned int hash32( const unsigned int *pWords,
                     int nWords,
                     unsigned int uSeedHashValue )
{ return hash2(pWords, nWords, uSeedHashValue); }

unsigned int jthash16(const unsigned short *pBytes,
                      int nShort,
                      unsigned int uSeedHashValue)
{ return hash3(pBytes, nShort, uSeedHashValue); }

//--------------------------------------------------------------------
//  mix -- mix 3 32-bit values reversibly.
// For every delta with one or two bit set, and the deltas of all three
//   high bits or all three low bits, whether the original value of a,b,c
//   is almost all zero or is uniformly distributed,
// * If mix() is run forward or backward, at least 32 bits in a,b,c
//   have at least 1/4 probability of changing.
// * If mix() is run forward, every bit of c will change between 1/3 and
//   2/3 of the time.  (Well, 22/100 and 78/100 for some 2-bit deltas.)
// mix() was built out of 36 single-cycle latency instructions in a
//   structure that could supported 2x parallelism, like so:
//       a -= b;
//       a -= c; x = (c>>13);
//       b -= c; a ^= x;
//       b -= a; x = (a<<8);
//       c -= a; b ^= x;
//       c -= b; x = (b>>13);
//       ...
//   Unfortunately, superscalar Pentiums and Sparcs can't take advantage
//   of that parallelism.  They've also turned some of those single-cycle
//   latency instructions into multi-cycle latency instructions.  Still,
//   this is the fastest good hash I could find.  There were about 2^^68
//   to choose from.  I only looked at a billion or so.
--------------------------------------------------------------------

#define mix(a,b,c) \
{ \
  a -= b; a -= c; a ^= (c>>13); \
  b -= c; b -= a; b ^= (a<<8); \
  c -= a; c -= b; c ^= (b>>13); \
  a -= b; a -= c; a ^= (c>>12);  \
  b -= c; b -= a; b ^= (a<<16); \
  c -= a; c -= b; c ^= (b>>5); \
  a -= b; a -= c; a ^= (c>>3);  \
  b -= c; b -= a; b ^= (a<<10); \
  c -= a; c -= b; c ^= (b>>15); \
}

--------------------------------------------------------------------
// hash() -- hash a variable-length key into a 32-bit value
//   k     : the key (the unaligned variable-length array of bytes)
//   len   : the length of the key, counting by bytes
//   level : can be any 4-byte value
// Returns a 32-bit value.  Every bit of the key affects every bit of
// the return value.  Every 1-bit and 2-bit delta achieves avalanche.
// About 36+6len instructions.

// The best hash table sizes are powers of 2.  There is no need to do
// mod a prime (mod is sooo slow!).  If you need less than 32 bits,
// use a bitmask.  For example, if you need only 10 bits, do
//   h = (h & hashmask(10));
// In which case, the hash table should have hashsize(10) elements.
//
```

```
// If you are hashing n strings (JtUInt8 **)k, do it like this:
//   for (i=0, h=0; i<n; ++i) h = hash( k[i], len[i], h);
//
// By Bob Jenkins, 1996.  bob_jenkins@burtleburtle.net.  You may use this
// code any way you wish, private, educational, or commercial.  It's free.
//
// See http://burtleburtle.net/bob/                  // 2010/02/12
// See http://burtleburtle.net/bob/hash/doobs.html   // 2010/02/12
//
// Use for hash table lookup, or anything where one collision in 2^32 is
// acceptable.  Do NOT use for cryptographic purposes.
//----------------------------------------------------------------------

//----------------------------------------------------------------------
// This works on all machines.  hash2() is identical to hash() on
// little-endian machines, except that the length has to be measured
// in ub4s instead of bytes.  It is much faster than hash().  It
// requires
// -- that the key be an array of UInt32's, and
// -- that all your machines have the same endianness, and
// -- that the length be the number of UInt32's in the key
// ----------------------------------------------------------------------
unsigned int hash(const usigned char *k,        // key
                  unsigned int        length,   // length of the key
                  unsigned int        initval)  // prev hash, or an arbitrary value
{
   register unsigned int a,b,c,len;

   /* Set up the internal state */
   len = length;
   a = b = 0x9e3779b9;  /* the golden ratio; an arbitrary value */
   c = initval;           /* the previous hash value */
   /*---------------------------------------- handle most of the key */
   while (len >= 12) {
      a += (k[0] +((UInt32)k[1]<<8) +((UInt32)k[2]<<16) +((UInt32)k[3]<<24));
      b += (k[4] +((UInt32)k[5]<<8) +((UInt32)k[6]<<16) +((UInt32)k[7]<<24));
      c += (k[8] +((UInt32)k[9]<<8) +((UInt32)k[10]<<16)+((UInt32)k[11]<<24));
      mix(a,b,c);
      k += 12; len -= 12;
   }
   /*------------------------------------- handle the last 11 bytes */
   c += length;
   switch(len) {            /* all the case statements fall through */
     case 11: c+=((UInt32)k[10]<<24);
     case 10: c+=((UInt32)k[9]<<16);
     case 9 : c+=((UInt32)k[8]<<8);
      /* the first byte of c is reserved for the length */
     case 8 : b+=((UInt32)k[7]<<24);
     case 7 : b+=((UInt32)k[6]<<16);
     case 6 : b+=((UInt32)k[5]<<8);
     case 5 : b+=k[4];
     case 4 : a+=((UInt32)k[3]<<24);
     case 3 : a+=((UInt32)k[2]<<16);
     case 2 : a+=((UInt32)k[1]<<8);
     case 1 : a+=k[0];
     /* case 0: nothing left to add */
   }
   mix(a,b,c);
   /*-------------------------------------------- report the result */
   return c;
}

unsigned int hash3(const unsigned short *k,       /* the key */
                   unsigned int          length,  /* the length of the key */
                   unsigned int          initval) /* the previous hash, or an arbitrary value */
{
   unsigned int a,b,c,len;

   /* Set up the internal state */
   len = length;
   a = b = 0x9e3779b9;    /* the golden ratio; an arbitrary value */
   c = initval;           /* the previous hash value */

   /*---------------------------------------- handle most of the key */
   while (len >= 6)
   {
      a += (k[0] + (UInt32(k[1]) << 16));
      b += (k[2] + (UInt32(k[3]) << 16));
      c += (k[4] + (UInt32(k[5]) << 16));
      mix(a,b,c);
      k += 6; len -= 6;
   }

   /*-------------------------------------- handle the last 2 uint32s */
   c += length;
   switch(len)              /* all the case statements fall through */
   {
       case 5 : c+=(UInt32(k[4]) << 16);
       /* c is reserved for the length */
       case 4 : b+=(UInt32(k[3]) << 16);
       case 3 : b+=k[2];
       case 2 : a+=(UInt32(k[1]) << 16);
       case 1 : a+=k[0];
       /* case 0: nothing left to add */
   }
   mix(a,b,c);
   /*-------------------------------------------- report the result */
   return c;
}
```

Appendix E: Polygon Mesh Topology Coder

The topology coding algorithm described here is used to code the *dual* of the desired mesh. Thus, for example, the reader will need to take the dual of the decoded mesh in order to obtain the original primal mesh. Presented below are classes suitable for representing the dual of a polygon mesh and the dual topology decoding algorithm.

At a high level, the topology coder works by traversing the dual mesh to be encoded one vertex and one face at a time. The coder maintains a queue of faces to be processed; the initial queue is created using the valence of an arbitrary vertex of the mesh followed by the degrees of the faces adjacent to that vertex, and adds the adjacent faces to the face queue. Each time it visits a face, it encodes the *degree* of that face and emits any incident vertices that have not yet been visited. Each time the coder visits a vertex, it encodes the *valence* of the vertex (usually 3 in the current case), and emits any incident faces that have not yet been visited. It works its way through the mesh in this fashion until all vertices and faces have been encoded. Thus, the primary output from the topology coder is a list of vertex valences and face degrees. These two fields plus two more encoding so-called *split faces*, coupled with the exact coder implementation completely encode the mesh topology in a very compact manner[1].

In addition to these two basic fields are added a number of other fields that organize the dual vertices into *vertex groups*, and also encode the *vertex attributes* (e.g. normals, colors, and texture coordinates) around each dual face's *degree ring*.

The topological coder can only encode *closed, manifold* meshes. It cannot encode *boundaries*; it can only encode edges with exactly two incident faces. But, as we know, real-world data is chock full of meshes with boundaries. In order to encode these types of meshes, it is necessary to add *cover faces* incident to all boundary loops whose sole job is to turn the mesh into a *closed* mesh. It is the dual of this closed, manifold mesh that is actually encoded. Thus, most meshes encoded in JT files contain a few cover faces. These faces may be of arbitrarily high degree, and they represent the only exceptions to the general rule that the numbers in the dual vertex valence array are usually three. It is necessary to flag all such artificially introduced cover faces so that they can be removed by the loader. These flags are encoded below in the Face Flags array. Primal faces are flagged with zero, while cover faces are flagged with one.

Now, let us make the connection between topological vertices and how vertex attributes relate to them. Several faces may be incident on the same topological mesh vertex. While this topological vertex has only a single 3D coordinate, it may have a different set of *vertex attributes* for each incident face. Vertex attributes include color, normal, and texture coordinates. An important observation in real-world data is that adjacent faces tend to share the same vertex attributes. Thus, a natural way to encode which vertex attributes map to which faces within a given valence ring (the counter-clockwise ordered set of faces incident on a given vertex) is by way of a bit vector. The bit vector begins at the first face the coder encounters that is incident to the vertex, and proceeds counter clockwise around the vertex, allocating one bit per incident face. A value of 0 is assigned to the bit if all vertex attributes for the face are the same as the face immediately clockwise. A value of 1 is assigned if the vertex attributes for the face are different. Recall that these bits from the original primal mesh are encoded as face attributes in the dual mesh.

Thus, at the end of the coding process, there will be one such bit vector per topological vertex in the mesh. These bit vectors will be of disparate lengths because all vertex valences are not the same. Though there is no theoretical limit to the valence of any given vertex, in practice, the vertex valences seldom rise above six, and only rarely rise into the dozens. As a matter of practicality, then, we break this list of bit vectors into those of length 64 and smaller into one group, and all others into a list of so-called “high-valence” bit vectors. The low-valence bit vectors are encoded into three fields of 30, 30, and 4 bits respectively. The high-valence bit vectors are adjoined end-to-end into a single long bit vector, and encoded as a single array of integers. As an additional optimization, the low-valence bit vectors are grouped into 8 “context groups” depending on the valence of the vertex being coded. This is done in order to improve compression performance because the valence bit vectors in each of the most common groups typically share similar statistics. Context group number 8 is the only one that encodes valence rings up to valence 64. Again, recall that these attribute bits from the original primal mesh are encoded as face attribute bits in the dual mesh.

[1] Similar methods of topology coding are described in [18] and US patent # 7,098,916. The topology coding algorithm described herein differs from such methods in that while they utilize a queue of active *vertices*, the instant algorithm utilizes a queue of active *faces*. Other differences include the tracking of face group numbers and per-vertex attributes such as normals, colors, and texture coordinates.

1 DualVFMesh

The DualVFMesh (Dual Vertex-Facet Mesh) is a support class paired with the topology decoder itself, and represents a closed two-manifold polygon mesh. The topology decoder reconstructs the encoded dual mesh into a DualVFMesh, building it one vertex and one facet at a time. When the decoder is finished, it will have visited each vertex and each face of the dual mesh exactly once. DualVFMesh is not intended as a work horse in-memory storage container because its way of encoding the topological connections between faces and vertices is memory-intensive.

```
class DualVFMesh
{
  public:
    // ========== Housekeeping Interface ==========
    DualVFMesh();
    DualVFMesh (const DualVFMesh &rhs);
    DualVFMesh &operator=(const DualVFMesh &rhs);

    // ========== Topology Interface ==========

    // Vtx creation
    bool          isValidVtx (Int32  iVtx) const;
    bool          newVtx     (Int32  iVtx,
                              Int32  iValence,
                              UInt16 uFlags = 0);
    bool          setVtxFlags(Int32  iVtx,
                              UInt16 uFlags);
    bool          setVtxGrp  (Int32  iVtx,
                              Int32  iVGrp);
    UInt16        vtxFlags   (Int32  iVtx) const;
    Int32         vtxGrp     (Int32  iVtx) const;

    // Face creation
    bool          isValidFace  (Int32  iFace) const;
    bool          newFace      (Int32  iFace,
                                Int32  cDegree,
                                Int32  cFaceAttrs = 0,
                                UInt64 uFaceAttrMask = 0,
                                UInt16 uFlags = 0);
    bool          newFace      (Int32  iFace,
                                Int32  cDegree,
                                Int32  cFaceAttrs,
                                const BitVec *pvbFaceAttrMask,
                                UInt16 uFlags);
    bool          setFaceFlags (Int32  iFace,
                                UInt16 uFlags);
    UInt16        faceFlags    (Int32  iVtx) const;
    bool          setFaceAttr  (Int32  iFace,
                                Int32  iAttrSlot,
                                Int32  iFaceAttr);
    Int32         faceAttr     (Int32  iFace,
                                Int32  iAttrSlot) const;

    // Topology connection
    bool          setVtxFace(Int32  iVtx,
                             Int32  iFaceSlot,
                             Int32  iFace);
    bool          setFaceVtx(Int32  iFace,
                             Int32  iVtxSlot,
                             Int32  iVtx);

    // Queries
    Int32         valence    (Int32  iVtx) const
        { return _vVtxEnts[iVtx].cVal; }
    Int32         degree   (Int32  iFace ) const
        { return _vFaceEnts[iFace].cDeg; }
    Int32         face    (Int32  iVtx,
                           Int32  iFaceSlot) const
          { return _viVtxFaceIndices[(_vVtxEnts[iVtx]).iVFI + iFaceSlot]; }
    Int32         vtx      (Int32  iFace,
                            Int32  iVtxSlot) const
          { return _viFaceVtxIndices[_vFaceEnts[iFace].iFVI + iVtxSlot]; }
    Int32         numVts       () const
        { return _vVtxEnts.length(); }
    Int32         numFaces     () const
        { return _vFaceEnts.length(); }
    Int32         numAttrs     () const
        { return _viFaceAttrIndices.length(); }
    Int32         numAttrs       (Int32 iFace) const
        { return _vFaceEnts[iFace].cFaceAttrs; }
    UInt64        attrMask       (Int32 iFace) const
        { return _vFaceEnts[iFace].u.uAttrMask; }
    const BitVec *attrMaskV      (Int32 iFace) const
        { return _vFaceEnts[iFace].u.pvbAttrMask; }
    Int32         findVtxSlot   (Int32 iFace,
                                 Int32 iTargVtx) const;
    Int32         findFaceSlot    (Int32 iVtx,
                                   Int32 iTargFace) const;
    Int32         emptyFaceSlots  (Int32 iFace) const
        { return _vFaceEnts[iFace].cEmptyDeg; }

    // ========== VFMesh Data Members ==========
  public:
    class VtxEnt {
      public:
        VtxEnt() : cVal(0), uFlags(0), iVGrp(-1), iVFI(-1) {}
        UInt16    cVal;   // Vtx valence
        UInt16    uFlags; // User flags
        Int32     iVGrp;  // Vtx group
        Int32     iVFI;   // Idx into _viVtxFaceIndices of cVal incident faces
    };

    // Number of optimized mask bits.
    static const Int32 cMBits = 64;

    class FaceEnt {
      public:
        FaceEnt() : cDeg(0), uFlags(0), cEmptyDeg(0),
                   cFaceAttrs(0), iFVI(-1), iFAI(-1) { u.uAttrMask = 0; }
        FaceEnt(const FaceEnt &rhs) : cDeg(rhs.cDeg), cEmptyDeg(rhs.cEmptyDeg),
                                    cFaceAttrs(rhs.cFaceAttrs), iFVI(rhs.iFVI),
                                    iFAI(rhs.iFAI)
        {
            if (cDeg <= cMBits)
                u.uAttrMask = rhs.u.uAttrMask;
            else
                JtWrapNew(u.pvbAttrMask, new BitVec(*rhs.u.pvbAttrMask));
        }
        ~FaceEnt() { if (cDeg > cMBits && u.pvbAttrMask) delete u.pvbAttrMask; }
        UInt16    cDeg;       // Face degree
        UInt16    cEmptyDeg;  // Empty degrees (opt for emptyFaceSlots())
        UInt16    cFaceAttrs;  // Number of face attributes
        UInt16    uFlags;     // User flags
        union {
            UInt64  uAttrMask;    // Degree-ring attr mask as a UInt64
            BitVec *pvbAttrMask;  // Degree-ring attr mask as a BitVec
        } u;
        Int32     iFVI; // Idx into _viFaceVtxIndices of cDeg incident vts
        Int32     iFAI; // Idx into _viFaceAttrIndices of cAttr attributes
    };

  protected:
    // Subscripted by atom number, the entry contains the vtx valence and
    // points to the location in _viVtxFaceIndices of valence consecutive
    // integers that in turn contain the indices of the incident faces
    // in _vFaceRecs to the vtx.
    JtVec<VtxEnt>  _vVtxEnts;

    // Subscripted by unique vertex record number, the entry contains the
    // face degree and points to the location in _viFaceVtxIndices of
    // cDeg consecutive integers that in turn contain the indices of the
    // vertices indicent upon the face, in CCW order, in _vVtxRecs.
```

```
    JtVec<FaceEnt>   _vFaceEnts;

    // Combined storage for all vtxs.
    JtVeci          _viVtxFaceIndices;

    // Combined storage for all faces.
    JtVeci          _viFaceVtxIndices;

    // Combined storage for all face attribute record identifiers
    JtVeci          _viFaceAttrIndices;
};

bool
DualVFMesh::isValidVtx(Int32 iVtx) const
{
    bool bRet = JtFalse;
    if (iVtx >= 0 && iVtx < _vVtxEnts.length()) {
        const VtxEnt &rFE = _vVtxEnts[iVtx];
        bRet = (rFE.cVal != 0);
    }
    return bRet;
}

bool
DualVFMesh::newVtx(Int32 iVtx,
                   Int32 iValence,
                   UInt16 uFlags)
{
    VtxEnt &rFE = _vVtxEnts[iVtx];
    if (rFE.cVal != iValence) {
        rFE.cVal   = iValence;
        rFE.uFlags = uFlags;
        rFE.iVFI   = _viVtxFaceIndices.length();
        _viVtxFaceIndices.verify(rFE.iVFI + iValence - 1);
        for (Int32 i = rFE.iVFI ; i < rFE.iVFI + iValence ; i++)
            _viVtxFaceIndices[i] = -1;
    }
    return true;
}

bool
DualVFMesh::setVtxGrp(Int32  iVtx,
                     Int32  iVGrp)
{
    VtxEnt &rFE = _vVtxEnts[iVtx];
    rFE.iVGrp = iVGrp;
    return true;
}

bool
DualVFMesh::setVtxFlags(Int32  iVtx,
                       UInt16 uFlags)
{
    VtxEnt &rFE = _vVtxEnts[iVtx];
    rFE.uFlags = uFlags;
    return true;
}

Int32
DualVFMesh::vtxGrp   (Int32  iVtx) const
{
    Int32 u = -1;
    if (iVtx >= 0 && iVtx < _vVtxEnts.length()) {
        const VtxEnt &rFE = _vVtxEnts[iVtx];
        u = rFE.iVGrp;
    }
    return u;
}

UInt16
DualVFMesh::vtxFlags   (Int32  iVtx) const
```

```
{
    UInt16 u = 0;
    if (iVtx >= 0 && iVtx < _vVtxEnts.length()) {
        const VtxEnt &rFE = _vVtxEnts[iVtx];
        u = rFE.uFlags;
    }
    return u;
}


bool
DualVFMesh::isValidFace(Int32 iFace) const
{
    bool bRet = JtFalse;
    if (iFace >= 0 && iFace < _vFaceEnts.length()) {
        const FaceEnt &rVE = _vFaceEnts[iFace];
        bRet = (rVE.cDeg != 0);
    }
    return bRet;
}

bool
DualVFMesh::newFace(Int32  iFace,
                    Int32  cDegree,
                    Int32  cFaceAttrs,
                    UInt64 uFaceAttrMask,
                    UInt16 uFlags)
{
    FaceEnt &rVE = _vFaceEnts[iFace];
    if (rVE.cDeg != cDegree) {
        rVE.cDeg        = cDegree;
        rVE.cEmptyDeg   = cDegree;
        rVE.cFaceAttrs   = cFaceAttrs;
        rVE.uFlags      = uFlags;
        rVE.u.uAttrMask = uFaceAttrMask;
        rVE.iFVI        = _viFaceVtxIndices.length();
        rVE.iFAI        = _viFaceAttrIndices.length();
        _viFaceVtxIndices.verify(rVE.iFVI + cDegree  - 1);
        if (cFaceAttrs > 0)
            _viFaceAttrIndices.verify(rVE.iFAI + cFaceAttrs - 1);
        for (Int32 i = rVE.iFVI ; i < rVE.iFVI + cDegree ; i++)
            _viFaceVtxIndices[i] = -1;
        for (Int32 i = rVE.iFAI ; i < rVE.iFAI + cFaceAttrs ; i++)
            _viFaceAttrIndices[i] = -1;
    }
    return true;
}

bool
DualVFMesh::newFace(Int32  iFace,
                    Int32  cDegree,
                    Int32  cFaceAttrs,
                    const BitVec *pvbFaceAttrMask,
                    UInt16 uFlags)
{
    FaceEnt &rVE = _vFaceEnts[iFace];
    if (rVE.cDeg != cDegree) {
        rVE.cDeg        = cDegree;
        rVE.cEmptyDeg   = cDegree;
        rVE.cFaceAttrs   = cFaceAttrs;
        rVE.uFlags      = uFlags;
        rVE.u.pvbAttrMask = new BitVec(*pvbFaceAttrMask);
        rVE.iFVI        = _viFaceVtxIndices.length();
        rVE.iFAI        = _viFaceAttrIndices.length();
        _viFaceVtxIndices.verify(rVE.iFVI + cDegree  - 1);
        if (cFaceAttrs > 0)
            _viFaceAttrIndices.verify(rVE.iFAI + cFaceAttrs - 1);
        for (Int32 i = rVE.iFVI ; i < rVE.iFVI + cDegree ; i++)
            _viFaceVtxIndices[i] = -1;
        for (Int32 i = rVE.iFAI ; i < rVE.iFAI + cFaceAttrs ; i++)
            _viFaceAttrIndices[i] = -1;
    }
    return true;
}

bool
DualVFMesh::setFaceFlags(Int32  iFace,
                         UInt16 uFlags)
{
    FaceEnt &rVE = _vFaceEnts[iFace];
    rVE.uFlags = uFlags;
    return true;
}

UInt16
DualVFMesh::faceFlags   (Int32  iFace) const
{
    UInt16 u = 0;
    if (iFace >= 0 && iFace < _vFaceEnts.length()) {
        const FaceEnt &rVE = _vFaceEnts[iFace];
        u = rVE.uFlags;
    }
    return u;
}

bool
DualVFMesh::setFaceAttr(Int32  iFace,
                        Int32  iAttrSlot,
                        Int32  iFaceAttr)
{
    FaceEnt &rVE = _vFaceEnts[iFace];
    Int32 *paiFAI = _viFaceAttrIndices.ptr();
    paiFAI[rVE.iFAI + iAttrSlot] = iFaceAttr;
    return true;
}

Int32
DualVFMesh::faceAttr(Int32  iFace,
                     Int32  iAttrSlot) const
{
    Int32 u = 0;
    if (iFace >= 0 && iFace < _vFaceEnts.length()) {
        const FaceEnt &rVE = _vFaceEnts[iFace];
        if (iAttrSlot >= 0 && iAttrSlot < rVE.cDeg) {
            const Int32 *paiFAI = _viFaceAttrIndices.ptr();
            u = paiFAI[rVE.iFAI + iAttrSlot];
        }
    }
    return u;
}

// Attaches VF face iFace to VF vertex iVtx in the vertex's
// face slot iFaceSlot
bool
DualVFMesh::setVtxFace(Int32 iVtx,
                       Int32 iFaceSlot,
                       Int32 iFace)
{
    VtxEnt &rFE = _vVtxEnts[iVtx];
    _viVtxFaceIndices[rFE.iVFI + iFaceSlot] = iFace;
    return true;
}

// Attaches VF vertex iVtx to VF face iFace in the face's
// vertex slot iVtxSlot
bool
DualVFMesh::setFaceVtx(Int32 iFace,
                       Int32 iVtxSlot,
                       Int32 iVtx)
{
    FaceEnt &rVE = _vFaceEnts[iFace];
    Int32 *paiFVI = _viFaceVtxIndices.ptr();
    rVE.cEmptyDeg -= (paiFVI[rVE.iFVI + iVtxSlot] != iVtx);
    paiFVI[rVE.iFVI + iVtxSlot] = iVtx;
    return true;
}

// Searches the list of incident vts to face iFace for
// iTargVtx and returns the vtx slot at which it is found
// or -1 if iTargVtx is not found.
Int32
DualVFMesh::findVtxSlot(Int32 iFace,
                        Int32 iTargVtx) const
{
    const FaceEnt &rVE = _vFaceEnts[iFace];
    const Int32 *const pFaceVtxIndices = _viFaceVtxIndices.ptr() + rVE.iFVI;
    Int32 cDeg = rVE.cDeg;
    Int32 iSlot = -1;
    for (Int32 iVtxSlot = 0 ; iVtxSlot < cDeg ; iVtxSlot++) {
        if (pFaceVtxIndices[iVtxSlot] == iTargVtx) {
            iSlot = iVtxSlot;
            break;
        }
    }
    return iSlot;
}

// Searches the list of incident faces to vertex iVtx for
// iTargFace and returns the face slot at which it is found
// or -1 if iTargFace is not found.
Int32
DualVFMesh::findFaceSlot (Int32 iVtx,
                          Int32 iTargFace) const
{
    const VtxEnt &rFE = _vVtxEnts[iVtx];
    const Int32 *const pVtxFaceIndices = _viVtxFaceIndices.ptr() + rFE.iVFI;
    for (Int32 iFaceSlot = 0 ; iFaceSlot < rFE.cVal ; iFaceSlot++) {
        if (pVtxFaceIndices[iFaceSlot] == iTargFace) {
            return iFaceSlot;
        }
    }
    return -1;
}
```

2 Topology Decoder

Partial implementations of three classes are given here for MeshCoderDriver, MeshCodec, and MeshDecoder. MeshCodec contains the abstract implementation of the topology coder. MeshDecoder implements the functionality needed to *decode* a mesh from the input data read from a JT file (see 7.2.2.1.2.5 Topologically Compressed Rep Data). MeshCoderDriver manages the input data, the output VFMesh, and the MeshDecoder itself, providing a simple three-step API.

2.1 MeshCoderDriver class

```
// This class serves as a coordinating driver for mesh coding and decoding.
class MeshCoderDriver
{
  public:
    MeshCoderDriver ();

    // ========== Operations Interface ==========
    void      setInputData(const Veci   vviOutValSyms[/*8*/],
                           const Veci  &viOutDegSyms,
                           const Veci  &viOutFGrpSyms,
                           const Vecus &vuOutFaceFlags,
                           const Veclu  vvuOutAttrMasks[/*8*/],
                           const Vecu  &vuOutAttrMasksLrg,
                           const Veci  &viOutSplitVtxSyms,
                           const Veci  &viOutSplitPosSyms)
                           { /* Copy into 22 fields below */ }
    void      decode();
    VFMesh   *vfm() const { return _pOutVFM; }
    // ========== Utility Methods ==========
    Int32          _nextDegSymbol    (Int32 iCCntx);
    Int32          _nextValSymbol    ();
    Int32          _nextFGrpSymbol   ();
    UInt16         _nextVtxFlagSymbol();
    UInt64         _nextAttrMaskSymbol(Int32 iCCntx);     // <= 64-bit attrmask
    void           _nextAttrMaskSymbol(BitVec *iopvbAttrMask,
                                      Int32   cDegree);  // > 64 bit attrmask
    Int32          _nextSplitFaceSymbol();
    Int32          _nextSplitPosSymbol();
    Int32          _faceCntxt(Int32 iVtx, JtDualVFMesh *pVFM);

    // ========== Member Data ==========
  protected:
    SharedPtr<MeshCodec>      _pMC;      // The mesh coder or decoder being used
    SharedPtr<JtDualVFMesh>   _pOutVFM;  // Back-end VFMesh built by decoder
    SharedPtr<MeshDecoder>    _pMeshDecoder;

    // Coding symbols generated by encoding operation, auxiliary data such as
    // offsets, etc.
    Veci           _vviOutDegSyms[8];  // Face degree + SPLIT symbols for multiple contexts
    Veci           _viOutValSyms;      // Vtx valence symbols
    Veci           _viOutVGrpSyms;     // Vtx group of each encoded vtx
    Vecus          _vuOutVtxFlags;     // Vtx flags; parallel to _viOutValSyms.
    Veclu          _vvuOutAttrMasks[8];// Attribute bitmasks per face for multiple contexts.
                                       //  One per non-split entry in _viOutValSyms.
    Vecu           _vuOutAttrMasksLrg; // > 64-bit attrmasks
    Veci           _viOutSplitFaceSyms;// Split face offsets
    Veci           _viOutSplitPosSyms; // Split face vtx slots

    // The next symbol to be consumed by _next*Symbol()
    Int32          _iValReadPos[8];
    Int32          _iDegReadPos;
    Int32          _iVGrpReadPos;
    Int32          _iFFlagReadPos;
    Int32          _iAttrMaskReadPos[8];
    Int32          _iAttrMaskLrgReadPos;
    Int32          _iSplitFaceReadPos;
    Int32          _iSplitPosReadPos;
};

void MeshCoderDriver::decode()
{
    // Allocate a coder
    if (!_pMeshDecoder) {
        _pMeshDecoder = new MeshDecoder(this);
    }
    _pMC = _pMeshDecoder;
    _pMC->setTopoDualMeshCoder(this);

    // Reset the symbol counters
    for (Int32 i = 0 ; i < 8 ; i++) {
        _iValReadPos[i] = 0;
        _iAttrMaskReadPos[i] = 0;
    }
    _iDegReadPos = 0;
    _iVGrpReadPos = 0;
    _iFFlagReadPos = 0;
    _iAttrMaskLrgReadPos = 0;
    _iSplitFaceReadPos = 0;
    _iSplitPosReadPos = 0;

    // Run the decoder
    _pMC->run();

    // Assert that ALL symbols have been consumed
    for (Int32 i = 0 ; i < 8 ; i++) {
        Assert(_iValReadPos[i]         == _vviOutDegSyms[i].length());
        Assert(_iAttrMaskReadPos[i]    == _vvuOutAttrMasks[i].length());
    }
    Assert(_iDegReadPos         == _viOutValSyms.length());
    Assert(_iVGrpReadPos        == _viOutVGrpSyms.length());
    Assert(_iFFlagReadPos       == _vuOutVtxFlags.length());
    Assert(_iAttrMaskLrgReadPos == _vuOutAttrMasksLrg.length());
    Assert(_iSplitFaceReadPos    == _viOutSplitFaceSyms.length());
    Assert(_iSplitPosReadPos    == _viOutSplitPosSyms.length());

    // Set output VFMesh
    _pOutVFM = _pMC->vfm();
}

Int32 MeshCoderDriver::_nextDegSymbol  (Int32 iCCntx)
{
    Int32 eSym = -1;
    if (_iValReadPos[iCCntx] < _vviOutDegSyms[iCCntx].length())
        eSym = _vviOutDegSyms[iCCntx].value(_iValReadPos[iCCntx]++);
    return eSym;
}

Int32
MeshCoderDriver::_nextValSymbol  ()
{
    Int32 eSym = -1;
    if (_iDegReadPos < _viOutValSyms.length())
        eSym = _viOutValSyms.value(_iDegReadPos++);
    return eSym;
}

Int32 MeshCoderDriver::_nextFGrpSymbol()
{
    Int32 eSym = -1;
    if (_iVGrpReadPos < _viOutVGrpSyms.length())
        eSym = _viOutVGrpSyms.value(_iVGrpReadPos++);
    return eSym;
}

UInt16 MeshCoderDriver::_nextVtxFlagSymbol  ()
{
    UInt16 eSym = 0;
    if (_iFFlagReadPos < _vuOutVtxFlags.length())
        eSym = _vuOutVtxFlags.value(_iFFlagReadPos++);
    return eSym;
}

UInt64 MeshCoderDriver::_nextAttrMaskSymbol  (Int32 iCCntx)
{
    UInt64 eSym = 0;
    if (_iAttrMaskReadPos[iCCntx] < _vvuOutAttrMasks[iCCntx].length())
        eSym = _vvuOutAttrMasks[iCCntx].value(_iAttrMaskReadPos[iCCntx]++);
    return eSym;
}

void MeshCoderDriver::_nextAttrMaskSymbol(BitVec *iopvbAttrMask, Int32 cDegree)
{
    if (_iAttrMaskLrgReadPos < _vuOutAttrMasksLrg.length()) {
        iopvbAttrMask->setLength(cDegree);
        UInt32 *pu = iopvbAttrMask->ptr();
        Int32 nWords = (cDegree + BitVec::cWordBits - 1) >> BitVec::cBitsLog2;
        memcpy(pu, &_vuOutAttrMasksLrg.value(_iAttrMaskLrgReadPos), nWords * sizeof(UInt32));
        _iAttrMaskLrgReadPos += nWords;
    }
    else {
        iopvbAttrMask->setLength(0);
    }
}

Int32 MeshCoderDriver::_nextSplitFaceSymbol  ()
{
    Int32 eSym = -1;
    if (_iSplitFaceReadPos < _viOutSplitFaceSyms.length())
        eSym = _viOutSplitFaceSyms.value(_iSplitFaceReadPos++);
    return eSym;
}

Int32 MeshCoderDriver::_nextSplitPosSymbol  ()
{
    Int32 eSym = -1;
    if (_iSplitPosReadPos < _viOutSplitPosSyms.length())
        eSym = _viOutSplitPosSyms.value(_iSplitPosReadPos++);
    return eSym;
}

// Computes a "compression context" from 0 to 7 inclusive for
// faces on vertex iVtx.  The context is based on the vertex's
// valence, and the total _known_ degree of already-coded
// faces on the vertex at the time of the call.
Int32 MeshCoderDriver::_faceCntxt(JtInt32 iVtx, JtDualVFMesh *pVFM)
{
    // Here, we are going to gather data to be used to determine a
    // compression contest for the face degree.
    JtInt32 cVal = pVFM->valence(iVtx);
    JtInt32 nKnownFaces = 0;
    JtInt32 cKnownTotDeg = 0;
    for (JtInt32 i = 0 ; i < cVal ; i++) {
        JtInt32 iTmpFace = pVFM->face(iVtx, i);
        if (!pVFM->isValidFace(iTmpFace))
            continue;
        nKnownFaces++;
        cKnownTotDeg += pVFM->degree(iTmpFace);
    }
    JtInt32 iCCntxt = 0;
    if (cVal == 3) {
        // Regular tristrip-like meshes tend to have degree 6 faces
        iCCntxt = (cKnownTotDeg <  nKnownFaces * 6) ? 0 :
                  (cKnownTotDeg == nKnownFaces * 6) ? 1 : 2;
    }
    else if (cVal == 4) {
        // Regular quadstrip-like meshes tend to have degree 4 faces
        iCCntxt = (cKnownTotDeg <  nKnownFaces * 4) ? 3 :
                  (cKnownTotDeg == nKnownFaces * 4) ? 4 : 5;
    }
    else if (cVal == 5)
        // Pentagons are all lumped into context 6
        iCCntxt = 6;
    else
        // All other polygons are lumped into context 7
        iCCntxt = 7;

    return iCCntxt;
}
```

2.2 MeshCodec class

```
// This class serves as the abstract base class from which two concrete classes
// are derived to implement the core operations for a polygonal
// mesh coder or decoder.  An instance of this object is used by the
// MeshCoderDriver to encode and decode polygonal meshes.
//
// This class makes extensive use of DualVFMesh objects as the primary source and
// destination mesh topology storage data structures. This mediating data
// structure is necessary because the mesh coding scheme is deeply cooperative
// with and dependent upon such a vertex-facet data structure.  Please refer to
// DualVFMesh for more information.
class MeshCodec {
  public:
    // ========== Housekeeping Interface ==========
    MeshCodec (MeshCoderDriver *pTMC = NULL);
  protected:
    virtual ~MeshCodec() {}
  public:
    // ========== Setup and Apply Interface ==========
    void setMeshCoderDriver(MeshCoderDriver *pTMC) { _pTMC = pTMC; }
    JtDualVFMesh *vfm() const                      { return _pDstVFM; }
    void  run();

    // ========== Generic encode/decode Driver Chain ==========
    void  clear();
    void  runComponent(bool &obFoundComponent);
    void  initNewComponent(bool &obFoundComponent);
    void  completeV(Int32 iFace);
    Int32 activateV(Int32 iVtx,  Int32 iVSlot);
    Int32 activateF(Int32 iFace, Int32 iFSlot);
    void  completeF(Int32 iVtx,  Int32 jFSlot);
    void  addVtxToFace (Int32 iVtx, Int32 iVSlot,
                        Int32 iFace,  Int32 iFSlot);

    // Active face list management
    void  addActiveFace(Int32 iFace);
    Int32 nextActiveFace();
    void  removeActiveFace(Int32 iFace);
    Int32 activeFaceOffset(Int32 iFace) const;

  private:
    // ========== Polymorphic I/O Interface ==========
    virtual Int32 ioVtxInit   ()                         = 0;
    virtual Int32 ioVtx       (Int32 iFace, Int32 jFSlot) = 0;
    virtual Int32 ioFace      (Int32 iVtx,  Int32 iVSlot) = 0;
    virtual Int32 ioSplitFace (Int32 iVtx,  Int32 iVSlot) = 0;
    virtual Int32 ioSplitPos  (Int32 iVtx,  Int32 iVSlot) = 0;

    // ========== Member Data ==========
  protected:
    MeshCoderDriver         *_pTMC;          // TopoDualMeshCoder this codec is attached to
    SharedPtr<JtDualVFMesh>  _pSrcVFM;       // Input VFMesh
    SharedPtr<JtDualVFMesh>  _pDstVFM;       // Output VFMesh
    Veci                     _viActiveFaces; // Stack of incomplete "active faces"
    BitVec                   _vbRemovedActiveFaces;   // Helper bitvec parallel to above
    // Used by decoder to assign running attr indices
    Int32              _iFaceAttrCtr;
};


// Runs the mesh encoder/decoder machine.
// If decoding is being performed, it consumes the mesh
// coding symbols from pre-filled member variables to produce
// the output VFMesh _pDstVFM.
void MeshCodec::run()
{
    // Assert state is consistent and ready to co/dec
    if (!_pDstVFM)
        _pDstVFM = new JtDualVFMesh();
    Assert(_pDstVFM);
    _pDstVFM->clear();
    clear();

    // Co/dec connected mesh components one at a time
    bool bFoundComponent = JtTrue;
    while (bFoundComponent) {
        runComponent(bFoundComponent);
    }
}

void MeshCodec::clear()
{
    // Setup
    _viActiveFaces.setLength(0);
    _vbRemovedActiveFaces.setLength(0);
    _iFaceAttrCtr = 0;
}

// Decodes one "connected component" (contiguous group of polygons) into
// _pDstVFM. Because the polygonal model may be formed of multiple
//  disconnected mesh components, it may be necessary for run() to call this
// method multiple times.  This method returns obFoundComponent = True
// if it actually encoded a new mesh component, and obFoundComponent = False
// if it did not.
void MeshCodec::runComponent(bool &obFoundComponent)
{
    Int32 iFace;
    initNewComponent(obFoundComponent);
    if (!obFoundComponent)
        return;
    while ((iFace = nextActiveFace()) != -1) {
        completeF(iFace);
        removeActiveFace(iFace);
    }
}

// Locates an unencoded vertex and begins the encoding
// process for the newly-found mesh component.
void MeshCodec::initNewComponent(bool &obFoundComponent)
{
    obFoundComponent = JtTrue;

    // Call ioVtxInit() to start us off with the seed face
    // from a new "connected component" of polygons.
    Int32 iVtx, i;
    if ((iVtx = ioVtxInit()) == -1) {
        obFoundComponent = JtFalse;  // All vtxs are processed
        return;
    }
    Int32 cVal = _pDstVFM->valence(iVtx);
    for (i = 0 ; i < cVal ; i++)
        activateF(iVtx, i);    // Process all faces
}

// Completes the VFMesh face iFace on _pDstVFM by calling activateV() and
// completeV() for each as-yet inactive incident vertexes in the face's
// degree ring.
void MeshCodec::completeF(Int32 iFace)
{
    // While there is an empty vtx slot on the face
    Int32 jVtxSlot, iVtx;
    Int32 iVSlot = 0;
    while ((jVtxSlot = _pDstVFM->findVtxSlot(iFace, -1)) != -1) {
        // Create and return a vtx iVtx, attaching it to iFace at vtx
        // slot jVtxSlot.
        iVtx = activateV(iFace, jVtxSlot);

        // Assert FV consistency
        Assert(_pDstVFM->vtx (iFace,  jVtxSlot) == iVtx &&
               _pDstVFM->face(iVtx,   iVSlot)   == iFace   );

        // Process the faces of iVtx starting from face slot
        // jVtxSlot where iVtx is incident on iFace.
        completeV(iVtx, jVtxSlot);

        // Invariant "VF": vtx(iVtx).face(iVSlot) == iFace &&
        //                 face(iFace).vtx(jVtxSlot) == iVtx
    }
}

// "Activates" the VFMesh face, on _pDstVFM, at face iFace vertex slot iVSlot
// by calling ioFace() to obtain a new vertex number and hooking it up to the
// topological structure.  If the face is a SPLIT face, then call
// ioSplitFace() and ioSplitPos() to get the information necessary to connect
// to an already-active face.  Note that we use the term "activate" here to
// mean "read" for mesh decoding.
Int32 MeshCodec::activateF(Int32 iVtx, Int32 iVSlot)
{
    Int32 jFSlot;
    // ioFace might return -2 as an error condition
    Int32 iFace = ioFace(iVtx, iVSlot);
    if (iFace >= 0) {   // If a new active face
        if (!_pDstVFM->setVtxFace(iVtx, iVSlot, iFace) ||
            !_pDstVFM->setFaceVtx(iFace, 0, iVtx)      ||
            !addActiveFace(iFace)                          )
        {
            return -2;
        }
    }
    else if (iFace == -1) {                   // Face already exists, so Split
        iFace = ioSplitFace(iVtx, iVSlot);    // v's index in ActiveSet, returns v
        jFSlot = ioSplitPos(iVtx, iVSlot);    // Position of iVtx in v
        _pDstVFM->setVtxFace(iVtx, iVSlot, iFace);
        addVtxToFace(iVtx, iVSlot, iFace, jFSlot);
    }
    return iFace;
}

// "Activates" the VFMesh vertex, on _pDstVFM, at face iFace vertex slot iVSlot
// by calling ioFace() to obtain a new face number and hooking it up to the
// topological structure.  Note that we use the term "activate" here to
// mean "read" for mesh decoding.
Int32 MeshCodec::activateV(Int32 iFace, Int32 iVSlot)
{
    Int32 iVtx = ioVtx(iFace, iVSlot);   // I/O valence; create a vtx
    _pDstVFM->setVtxFace(iVtx, 0, iFace);
    addVtxToFace (iVtx, 0, iFace, iVSlot);
    return iVtx;
}

// Completes the vertex iVtx on _pDstVFM by activating all inactive faces
// incident upon it.  As an optimization, the user must also pass in iVSlot
// which is the vertex slot on face 0 of iVtx where iVtx is located.  This
// method begins its examination of iVtx's faces at face 0 by working its
// way around the vertex in both CCW and CW directions, checking to see if there
// are any faces that can be hooked into iVtx without calling activateF().
// This can happen when a face is completed by a nearby vertex before coming
// here.  The situation can be detected by traversing the topology of the
// _pDstVFM over to the neighboring vertex and checking if it already has a
// face number for the corresponding face entry on iVtx.  If so, then
// iVtx and the already completed face are connected together, and the
// next face around iVtx is examined. When the process can go no further,
// this method calls _activateF() on the remaining unresolved span of faces
// around the vertex.
void MeshCodec::completeF(Int32 iVtx, Int32 iVSlot)
{
    JtDualVFMesh *pDstVFM = _pDstVFM;
    Int32 i, vp, vn, jp, jn,
            iVtx2,
            cVal = pDstVFM->valence(iVtx);

    // Walk CCW from face slot 0, attempting to link in as many
    // already-reachable faces as possible until we reach one
    // that is inactive.
    vp = pDstVFM->face(iVtx, 0);
    jp = iVSlot;
    i = 1;
    JtDebugOnly(_assertParallelValRings(vp);)
    while ((vn = pDstVFM->face(iVtx, i)) != -1) {  // Forces "FV" in the "next" direction
        DecModN(jp, pDstVFM->degree(vp));
        iVtx2 = pDstVFM->vtx(vp, jp);
        if (iVtx2 == -1)
            break;
        jn = pDstVFM->findVtxSlot(vn, iVtx2);
        Assert(jn > -1);
        DecModN(jn, pDstVFM->degree(vn));
        addVtxToFace(iVtx, i, vn, jn);
        vp = vn;
        jp = jn;
        i++;
        if (i >= cVal)
```

```
            return;
    }

    // Walk CW from face slot 0, attempting to link in as many
    // already-reachable faces as possible until we reach one
    // that is inactive.
    Int32 ilast = i;
    vp = pDstVFM->face(iVtx, 0);
    jp = iVSlot;
    i = pDstVFM->valence(iVtx) - 1;
    while ((vn = pDstVFM->face(iVtx, i)) != -1) { // Forces "VF" in "prev" direction
        IncModN(jp, pDstVFM->degree(vp));
        iVtx2 = pDstVFM->vtx(vp, jp);
        if (iVtx2 == -1)
            break;
        jn = pDstVFM->findVtxSlot(vn, iVtx2);
        Assert(jn > -1);
        IncModN(jn, pDstVFM->degree(vn));
        addVtxToFace(iVtx, i, vn, jn);
        vp = vn;
        jp = jn;
        i--;
        if (i < ilast)
            return;
    }

    // Activate the remaining faces on iVtx that cannot be decuced from
    // the already-assembled topology in the destination VFMesh.
    for (; ilast <= i ; ilast++) {
        Int32 iFace = activateV(iVtx, ilast);
        JtDemandState(iFace >= -1);
    }
}

// This method connects vertex iVtx into the topology of
// _pDstVFM at and around iFace.  First, it connects iVtx
// to iFace's degree ring at position iVSlot.  Next, it
// will connect iVtx into the faces at the other ends of
// the shared edges between iVtx and the next vertices CS and
// CCW about iFace if necessary.
void MeshCodec::addVtxToFace (Int32 iVtx,  Int32 jFSlot,
                              Int32 iFace, Int32 iVSlot)
{
    Int32   iVSlotCW  = iVSlot,
            iVSlotCCW = iVSlot,
            fp, ip,
            fn, in;
    JtDualVFMesh *pDstVFM = _pDstVFM;
    IncModN(iVSlotCCW, pDstVFM->degree(iFace));
    DecModN(iVSlotCW,  pDstVFM->degree(iFace));

    // Connect iVtx to iFace/iVSlot
    JtRethrow(pDstVFM->setFaceVtx(iFace, iVSlot, iVtx));

    // Connect iVtx across the shared edge between iVtx and the vtx CW
    // from iVtx at iFace.  Connect iVtx into the face at the other
    // end of this edge if it is not already connected there.
    if ((fp = pDstVFM->vtx(iFace, iVSlotCW)) != -1) {
        ip = pDstVFM->findFaceSlot(fp, iFace);
        Int32 iVSlotCCW = jFSlot;
        IncModN(iVSlotCCW, pDstVFM->valence (iVtx));
        if (pDstVFM->face(iVtx, iVSlotCCW) == -1) {
            DecModN(ip, pDstVFM->valence(fp));
            pDstVFM->setVtxFace(iVtx, iVSlotCCW, pDstVFM->face(fp, ip));
        }
    }

    // Connect iVtx across the shared edge between iVtx and the vtx CCW
    // from iVtx at iFace.  Connect iVtx into the face at the other
    // end of this edge if it is not already connected there.
    if ((fn = pDstVFM->vtx(iFace, iVSlotCCW)) != -1) {
        in = pDstVFM->findFaceSlot(fn, iFace);
        Int32 iVSlotCW  = jFSlot;
        DecModN(iVSlotCW,  pDstVFM->valence (iVtx));
        if (pDstVFM->face(iVtx, iVSlotCW) == -1) {
            IncModN(in, pDstVFM->valence(fn));
            pDstVFM->setVtxFace(iVtx, iVSlotCW, pDstVFM->face(fn, in));
        }
    }
}

void MeshCodec::addActiveFace(Int32 iFace)
{
    JtRethrow(_viActiveFaces.pushBack(iFace));
}

// Returns a face from the active queue to be completed. This needn't be the
// one at the end of the queue, because the choice of the next active face
// can affect how many SPLIT symbols are produced.  This method employs a
// fairly simple scheme of searching the most recent 16 active faces for the
// fist one with the smallest number of incomplete slots in its degree ring.
Int32 MeshCodec::nextActiveFace()
{
    Int32 iFace = -1;
    // Search the 16 face record at the end of the
    // queue for the one with lowest remaining degree.
    while (_viActiveFaces.length() > 0 && _vbRemovedActiveFaces.test(_viActiveFaces.back()))
        _viActiveFaces.popBack();
    Int32 cLowestEmptyDegree = 9999999;
    Int32 i, iFace0, cEmptyDeg;
    const Int32 cWidth = 16;
    JtDualVFMesh *pDstVFM = _pDstVFM;
    for (i = _viActiveFaces.length() - 1 ;
         i >= ::jtmax(0, _viActiveFaces.length() - cWidth) ;
         i--)
    {
        iFace0 = _viActiveFaces[i];
        if (_vbRemovedActiveFaces.test(iFace0)) {
            _viActiveFaces.remove(i); // TOXIC: O(N^2)
            continue;
        }
        cEmptyDeg = pDstVFM->emptyFaceSlots(iFace0);
        if (cEmptyDeg < cLowestEmptyDegree) {
            cLowestEmptyDegree = cEmptyDeg;
            iFace = iFace0;
        }
    }

    // Return the selected active face
    return iFace;
}

// Removes iFace from the active face queue.
void MeshCodec::removeActiveFace(Int32 iFace)
{
    _vbRemovedActiveFaces.set(iFace);
}

// Searches the active face queue for iFace and returns
// its index position from the _end_ of the queue.  This is
// needed by the ioFace() method when encoding a SPLIT
// symbol.
Int32 MeshCodec::activeFaceOffset(Int32 iFace) const
{
    Int32 iOffset = -1;
    Int32 i, cLen = _viActiveFaces.length();
    const Int32 *paiActiveFaces = _viActiveFaces.ptr();
    for (i = cLen - 1 ; i >= 0 ; i--) {
        if (paiActiveFaces[i] == iFace) {
            // The offset is how far FROM THE END of the active
            // face list we found iFace.  This serves the make
            // the iOffset a much smaller number, which is better
            // for compression!
            iOffset = cLen - i;
            break;
        }
    }
    return iOffset;
}
```

2.3 MeshDecoder class

```
// This class implements the five abstract methods from
// MeshCodec to realize a mesh decoder.
class MeshDecoder : public MeshCodec {
  public:
    // ========== Housekeeping Interface ==========
    MeshDecoder (MeshCoderDriver *pTMC = NULL);
  protected:
    virtual ~MeshDecoder() {}

  private:
    // ========== Polymorphic I/O Interface ==========
    virtual Int32 ioVtxInit  ()                         ;
    virtual Int32 ioVtx      (Int32 iFace, Int32 iVSlot);
    virtual Int32 ioFace     (Int32 iVtx , Int32 jFSlot);
    virtual Int32 ioSplitFace(Int32 iVtx , Int32 jFSlot);
    virtual Int32 ioSplitPos (Int32 iVtx , Int32 jFSlot);
};

// Begins decoding a new connected mesh component by calling
// ioVtx() to read the next vertex from the symbol stream.
Int32 MeshDecoder::ioVtxInit()
{
    return ioVtx(-1, -1);
}

// Read a vertex valence symbol, vertex group number, and vertex
// flags from the input symbols stream.  Create a new vertex
// on _pDstVFM with this data, and return the new vertex number.
// It is this method's responsibility to detect the end of
// the input symbol stream by returning -1 when that happens.
Int32 MeshDecoder::ioVtx (Int32 /*iFace*/ , Int32 /*iVSlot*/)
{
    // Obtain a VERTEX VALENCE symbol
    Int32 eSym = _pTMC->_nextValSymbol();
    Int32 iVtxVal, iVtx = -1;
    if (eSym > -1) {
        // Create a new vtxt on the VFMesh
        iVtx = _pDstVFM->numVts();
        iVtxVal = eSym;
        _pDstVFM->newVtx     (iVtx, iVtxVal);
        _pDstVFM->setVtxGrp  (iVtx, _pTMC->_nextFGrpSymbol());
        _pDstVFM->setVtxFlags(iVtx, _pTMC->_nextVtxFlagSymbol());
    }

    return iVtx;
}

// Read a face degree symbol, and attribute mask bit
// vector, create a new DualVFMesh face, initialize the
// face attribute record numbers from a running counter,
// and return the new face number.  If the degree symbol
// read from the input symbol stream is 0, signify this by
// returning -1.
Int32
MeshDecoder::ioFace     (Int32 iVtx, Int32 /*jFSlot*/)
{
    // Obtain a FACE DEGREE symbol
    Int32 iCntxt = _pTMC->_faceCntxt(iVtx, _pDstVFM);
    Int32 eSym = _pTMC->_nextDegSymbol(iCntxt);
    Int32 cDeg, iFace = -1;
    if (eSym != 0) {
        // Create a new face on the VFMesh
        iFace = _pDstVFM->numFaces();
        cDeg = eSym;
        Int32 nFaceAttrs = 0;
        if (cDeg <= JtDualVFMesh::cMBits) {
            UInt64 uAttrMask = _pTMC->_nextAttrMaskSymbol(/*iCntxt*/::jtmin(7,::jtmax(0,cDeg-2)));
            for (UInt64 uMask = uAttrMask ; uMask ; nFaceAttrs += (uMask & 1), uMask >>= 1);
            _pDstVFM->newFace(iFace, cDeg, nFaceAttrs, uAttrMask);
        }
        else {
            BitVec vbAttrMask;
            _pTMC->_nextAttrMaskSymbol(&vbAttrMask, cDeg);
            for (Int32 i = 0 ; i < cDeg ; i++) {
                if (vbAttrMask.test(i))
                    nFaceAttrs++;
            }
            _pDstVFM->newFace(iFace, cDeg, nFaceAttrs, &vbAttrMask, 0);
        }

        // Error check for a corrupt degree or attrmask
        if (nFaceAttrs > cDeg) {
            Assert (nFaceAttrs <= cDeg);
            return -2;
        }

        // Set up the face attributes
        for (Int32 iAttrSlot = 0 ; iAttrSlot < nFaceAttrs ; iAttrSlot++) {
            _pDstVFM->setFaceAttr(iFace, iAttrSlot, _iFaceAttrCtr++);
        }
    }

}

// Consumes a split offset symbol from the SPLIT offset
// symbol stream, and determines the face number referenced
// by the offset.  Returns the referenced face number.
Int32 MeshDecoder::ioSplitFace(Int32 /*iVtx*/, Int32 /*jFSlot*/)
{
    // Obtain a SPLITFACE symbol
    Int32 eSym = _pTMC->_nextSplitFaceSymbol();
    Assert(eSym >= -1);
    Int32 iOffset = -1, iFace = -1;
    if (eSym > -1) {
        // Use the offset to index into the active face queue
        // to determine the actual face number.
        iOffset = eSym;
        Int32 cLen = _viActiveFaces.length();
        Assert(iOffset > 0 && iOffset <= cLen);
        iFace = _viActiveFaces[cLen - iOffset];
    }

    return iFace;
}

// Consumes a split position symbol from the associated symbol
// stream, and returns the vertex slot number on the current
// split face at which the topological split/merge occurred.
Int32 MeshDecoder::ioSplitPos   (Int32 /*iVtx*/, Int32 /*jFSlot*/)
{
    // Obtain a SPLITVTX symbol
    Int32 eSym = _pTMC->_nextSplitPosSymbol();
    Assert(eSym >= -1);
    Int32 iVSlot = -1;
    if (eSym > -1) {
        // Return the vtx slot number
        iVSlot = eSym;
    }

    return iVSlot;
}
```

Appendix F: Parasolid XT Format Reference

November 2008

Table of Contents

Introduction to the Parasolid XT Format

This Parasolid® Transmit File Format manual describes the formats in which Parasolid represents model information in external files. Parasolid is a geometric modeling kernel that can represent wireframe, surface, solid, cellular and general non-manifold models.

Parasolid stores topological and geometric information defining the shape of models in transmit files. These files have a published format so that applications can have access to Parasolid models without necessarily using the Parasolid kernel.

This manual documents the Parasolid transmit file format. This format will change in subsequent Parasolid releases at which time this manual will be updated. As new versions of Parasolid can read and write older transmit file formats these changes will not invalidate applications written based on the information herein.

Types of File Documented

There are a number of different interface routines in Parasolid for writing transmit files. Each of these routines can write slightly different combinations of Parasolid data, the ones that are documented herein are:

- Individual components (or assemblies) written using SAVMOD
- Individual components written using PK_PART_transmit
- Lists of components written using PK_PART_transmit
- Partitions written using PK_PARTITION_transmit

The basic format used to write data in all the above cases is identical; there are a small number of node types that are specific to each of the above file types.

Text and Binary Formats

Parasolid can encode the data it writes out in four different formats:

1. Text (usually ASCII)
2. Neutral binary
3. Bare binary (this is not recommended)
4. Typed binary

In text format all the data is written out as human readable text, they have the advantage that they are readable but they also have a number of disadvantages. They are relatively slow to read and write, converting to and from text forms of real numbers introduces rounding errors that can (in extreme cases) cause problems and finally there are limitations when dealing with multi-byte character sets. Carriage return or line feed characters can appear anywhere in a text transmit file but other unexpected non-printing characters will cause Parasolid to reject the file as corrupt.

Neutral binary is a machine independent binary format.

Bare binary is a machine dependent binary format. It is not a recommended format since the machine type which wrote it must be known before it can be interpreted.

Typed binary is a machine dependent binary format, but it has a machine independent prefix describing the machine type that wrote it and so can be read on all machine types.

Standard File Names and Extensions

Due to changing operation system restrictions on file names over the years Parasolid has used several different file extensions to denote file contents. The recommended set of file extensions is:

- .X_T and .X_B for part files, .P_T and .P_B for partition files.

Extensions that have been used in the past are:

- xmt_txt, xmp_txt - text format files on VMS or Unix platforms
- xmt_bin, xmp_bin - binary format files on VMS or Unix platforms

Logical Layout

The logical layout of a Parasolid transmit file is:

- A human-oriented text header.
    - The initial text header is read and written by applications' Frustrums and is not accessible to Parasolid. Its detailed format is described in the section `Physical layout'.
- A short flag sequence describing the file format, followed by modeller identification information and user field size.
    - The various flag sequences (mixtures of text and numbers) are documented under `Physical layout'; the content of the modeller identification information is:

  the modeller version used to write the file, as a text string of the form:

  : TRANSMIT FILE created by modeller version 1200123

  This information is used by routines such as PK_PART_ask_kernel_version.

  the schema version describing the field sequences of the part nodes as a text string of the form:

  SCH_1200123_12006

  This example denotes a file written by Parasolid V12.0.123 using schema number 12006: there will be a corresponding file sch_12006 in the Parasolid schema distribution.

  Note that applications writing XT files should use version 1200000 and schema number 12006.

    - The user field size is a simple integer.
- The objects (known as ‘nodes’) in the file in an unordered sequence, followed by a terminator.
    - Every node in the file is assigned an integer index from 1 upwards (some indices may not be used). Pointer fields are output as these indices, or as zero for a null pointer.
    - Each node entry begins with the node type. If the node is of variable length (see below), this is followed by the length of the variable field. The index of the node is then output, followed by the fields of the node. If the file contains user fields, and the node is visible at the PK interface, then the fields are followed by the user field, in integers.
    - The terminator which follows the sequence of nodes is a two-byte integer with value 1, followed by an index with value 0. The index is output as ‘0’ in a text file, and as a 2-byte integer with value 1 in a binary file.
    - The node with index 1 is the root node of the transmit file as follows:
    -

Contents of file	**Type of root node**
Body	BODY
Assembly	ASSEMBLY
Array of parts	POINTER_LIS_BLOCK
Partition	WORLD

Schema

Parasolid permanent structures are defined in a special language akin to C which generates the appropriate files for a C compiler, the runtime information used by Parasolid, along with a schema file used during transmit and receive. The schema file for version 12.0 is named sch_12006 and is distributed with Parasolid. It is not necessary to have a copy of this file to understand the XT format.

For each node type, the schema file has a node specifier of the form

<nodetype> <nodename>; <description>; <transmit 1/0> <no. of fields> <variable 1/0>

e.g.

29 POINT; Point; 1 6 0

This is followed by a list of field specifiers which say what fields, and in what order, occur in the transmit file.

Field specifiers have the format:

<fieldname>; <type>; <transmit 1/0> <node class> <n_elements>

e.g.

owner; p; 1 1011 1

Nodes and fields with a transmit flag of zero are ephemeral information not written to a transmit file. Only pointer fields have non-zero node class, in which case it specifies the set of node types to which this field is allowed to point. The element count is interpreted as follows:

0	a scalar, a single value
1	a variable length field (see below)
n > 1	an array of n values

Note that in the schema file, fins are referred to as ‘halfedges’, and groups are referred to as ‘features’. These are internal names not used elsewhere in this document.

Embedded schemas

When reading a part, partition, or delta, Parasolid converts any data that it encounters from older versions of Parasolid to the current format using a mixture of automatic table conversion (driven by the appropriate schemas), and explicit code for more complex algorithms.

However, backwards compatibility of file information – that is, reading data created by a newer version of Parasolid into an application (such as data created by a subcontractor) – can never be guaranteed to work using this method, because the older version does not contain any special-case conversion code.

From Parasolid V14 onwards, parts, partitions and deltas can be transmitted with extra information that is intended to replace the schema normally loaded to describe the data layout. This information contains the **differences** between its schema and a defined base schema (currently V13's SCH_13006).

This enables parts, partitions, and deltas to be successfully read into older versions of Parasolid without loss of information.

The only fields that are included in this information are those which can be referenced in a cut-down version of the schema pertaining only to the XT part data that is transmitted. Specifically, a full schema definition can contain fields that are not relevant in the context of the transmitted data (fields relating to snapshots, for example), and these fields are excluded.

Fields that are included are referred to as **effective fields**, and are either transmittable (`xmt_code` == 1) or have variable-length (`n_elts` == 1)

Physical layout

Most of the data are composed of integers, logical flags, and strings, but are of restricted ranges and so transmitted specially in binary format. The binary representation is given in **bold** type, such as “integer (**byte**)”. This is relevant to applications that attempt to read or write Parasolid data directly. Two important elements are

- **short string**s

  These are transmitted as an integer length (**byte**) followed by the characters (without trailing zero).

- **positive integer**s

  These are transmitted similarly to the pointer indices which link individual objects together, i.e., small values 0..32766 are transmitted as a single **short** integer, larger ones encoded into two.

XT format

Presence of the new format is indicated by a change to the standard header: the archive name is extended by the number of the base schema, e.g., `SCH_1400068_14000_13006`, and then the maximum number of node types is inserted (**short**).

Transmission then continues as normal, except that when transmitting the first node of any particular type, extra information is inserted between the nodetype and the variable-length, index data as follows:

- The arrays of effective fields in the base schema node and the current schema node are assembled.
- If the nodetype does not exist in the base schema then it is output as follows:
  - number of fields (**byte**)
  - name and description (**short string**s)
  - fields one by one as

`name`	short string	
`ptr_class`	Short	
`n_elts`	Positive integer	
`type`	short string	The field type. Allowed values are described in “Field types”, below. Omitted if `ptr_class` non-zero
`xmt_code`	logical (byte)	Omitted for fixed-length (`n_elts` != 1)

- If the two arrays match (equal length and all fields match in `name`, `xmt_code`, `ptr_class`, `n_elts` and `type`) then output the flag value 255 (**byte** 0xff).
- If the two arrays do not match, output the number of effective fields in the current schema (**byte**), and an edit sequence as follows.
  - Initialize pointers to the first base field and first current field, then while there are still unprocessed base and current fields, output a sequence of Copy, Delete and Insert instructions
    - If the base field matches the current field, output 'C' (**char**) to indicate an unchanged (Copied) field and advance to the next base and current fields;
    - If the base field does not match any unprocessed current field, output 'D' (**char**) to indicate a Deleted field and advance to the next base field;
    - Otherwise, output 'I' (**char**) to indicate an Inserted field, followed by the current field in the above format, and advance to the next current field.
  - If there are any unprocessed current fields, then output an Append sequence, each instruction being 'A' (**char**) followed by the field.
- Finally, output 'Z' (**char**) to signal the end.

Space compression

For text data in transmit formats PK_transmit_format_text_c and PK_transmit_format_xml_c, a new escape sequence is defined: the 2-character sequence **\9** denotes a sequence of nine spaces. At V14, this applies to attribute definition names, field names, and attribute strings.

Field types

The XT format is not itself a binary protocol, and so does not define data sizes; the only requirement is that a runtime implementation has sufficient room for the information. The available implementations run with 8bit ASCII characters, 8bit unsigned bytes (0..255), 16bit short integers (0..65535 or -32768..32767), 32bit integers (0..4G-1, -2G..2G-1) and IEEE reals. The implementation used in a given binary file is specified by the "PS<code>" at the start of the file. See the chapter on “Physical Layout” for more information.

The full list of field types used in transmit files is as follows:

u	unsigned byte 0-255
c	char
l	unsigned byte 0-1 (i.e. logical) `typedef char logical;`
n	short int
w	unicode character, output as a short int
d	int
p	pointer-index Small indices (less than 32767) are treated specially in binary files to save space. See the section below on binary format.
f	double

i These correspond to a region of the real line:

```
typedef struct { double low, high; }interval;
```

v array [3] of doubles

These correspond to a 3-space position or direction:

```
typedef struct { double x,y,z; } vector;
```

b array [6] of doubles

These correspond to a 3-spce region:

```
typedef struct { interval x,y,z; } box;
```

Note that the ordering is not the same as presented at Parasolid's external PK or KI interfaces.

h array [3] of doubles

These represent points of intersection between two surfaces; only the position vector is written to a transmit file, as Parasolid will recalculate other data as required. The structure is documented further in the section on intersection curves.

Point

As an example, consider a POINT; its formal description is

```
struct POINT_s         // Point
    {
    int                     node_id;              // $d
    union  ATTRIB_GROUP_u   attributes_groups;    // $p
    union  POINT_OWNER_u    owner;                // $p
    struct POINT_s         *next;                 // $p
    struct POINT_s         *previous;             // $p
    vector                  pvec;                 // $v
    };
typedef struct POINT_s         *POINT;
```

Its corresponding schema file entry is

```
29 POINT; Point; 1 6 0
node_id; d; 1 0 0
attributes_groups; p; 1 1019 0
owner; p; 1 1011 0
next; p; 1 29 0
previous; p; 1 29 0
```

pvec; v; 1 0 0

Pointer classes

In the above example, the attributes_groups field must be of class ATTRIB_GROUP_cl, the owner must be of class POINT_OWNER_cl, and the next and previous fields must refer to POINTs. A full list of node types and node classes is given at the end of the document.

Each node class corresponds to a union of pointers given in the Schema Definition section.

Variable-length nodes

Variable-length nodes differ from fixed-length nodes in that their last field is of variable length, i.e. different nodes of the same type may have different lengths. In the schema the length is notionally given as 1, e.g.

```
struct REAL_VALUES_s          // Real values
        {
        Double                    values[1];                // $f[]
        };
```

Its schema file entry would be

83 REAL_VALUES;   Real values; 1 1 1

values; f; 1 0 1

The number of entries in each such node is indicated by an integer in the transmit file between its nodetype and index, so an example might be

    83 3 15 1 2 3

Unresolved indices

In some cases a node will contain an index field which does not correspond to a node in the transmit file, in this case the index is to be interpreted as zero.

Simple example

Here is a reformatted text example of a sheet circle with a color attribute on its single edge:

```
**ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz************

**PARASOLID !"#$%&'()*+,-./:;<=>?@[\]^_`{|}~0123456789************

**PART1;MC=osf65;MC_MODEL=alpha;MC_ID=sdlosf6;OS=OSF1;OS_RELEASE=V4.0;FRU=sdl_parasolid
_test_osf64;APPL=unknown;SITE=sdl-cambridge-
u.k.;USER=davidj;FORMAT=text;GUISE=transmit;DATE=29-mar-2000;

**PART2;SCH=SCH_1200000_12006;USFLD_SIZE=0;

**PART3;
```

```
**END_OF_HEADER************************************************
T51 : TRANSMIT FILE created by modeller version 120000017 SCH_1200000_120060
12 1 12 0 2 0 0 0 0 1e3 1e-8 0 0 0 1 0 3 1 3 4 5 0 6 7 0      body
 70 2 0 1 0 0 4 1 20 8 8 8 1 T                                 list
13 3 3 0 1 0 9 0 0 6 9                                         shell
 50 4 11 0 9 0 0 0 +0 0 0 0 0 1 1 0 0                          plane
 31 5 10 0 7 0 0 0 +0 0 0 0 0 1 1 0 0 1                        circle
 19 6 5 0 1 0 0 3 V                                            region
16 7 6 0 ?10 0 0 5 0 0 1                                       edge
 17 10 0 11 10 10 0 12 7 0 0 +                                 fin
15 11 7 0 10 9 0                                               loop
 17 12 0 0 0 0 0 10 7 0 0 -                                    fin (dummy)
14 9 2 13 ?0 0 11 3 4 +0 0 0 0 3                               face
 81 1 13 12 14 9 0 0 0 0 15                                    attribute (variable 1)
 80 1 14 0 16 8001 0 0 0 0 3 5 0 0 FFFFTFTFFFFFF2              attrib_def (variable 1)
83 3 15 1 2 3                                                  real_values (variable 3)
 79 15 16 SDL/TYSA_COLOUR                                      att_def_id (variable 15)
74 20 8 1 0 13 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0          pointer_lis_block
 1 0                                                           terminator
```

Note that the tolerance fields of the face and edge are unset, and represented as ‘?’ in the text transmit file and that the annotations in the column ‘body’ to ‘terminator’ give the node type of each line and are not part of the actual file. If the above file had no trailing spaces, it would be a valid XT file (the leading spaces on some of the lines are necessary).

Physical Layout

Parasolid transmit files have two headers:

- a textual introduction containing human-directed information about the part, written by the Frustrum and not accessible to Parasolid, and
- an internal prefix to the part data, describing to Parasolid the format of the part data and thus not seen explicitly by an application's Frustrum.

Common header

The Parasolid common header recommended to Frustrum writers consists of:

- A preamble containing all characters in the ASCII printing set. This is used by the KID Frustrum to detect obvious network corruption, but could be used to attempt to translate a text file from one character set to another.
- Part 1 data: a sequence of keyword-value pairs, separated by semicolons, of possibly interesting information. All are optional.

MC	=	vax, hppa, sparc, ...
		// make of computer
MC_MODEL	=	4090, 9000/780, sun4m, ...
		// model of computer
MC_ID	=	...
		// unique machine identifier
OS	=	vms, HP-UX, SunOS, ...
		// name of operating system
OS_RELEASE	=	V6.2, B.10.20, 5.5.1, ...
		// version of operating system
FRU	=	sdl_parasolid_test_vax, mdc_ugii_v7.0_djl_can_vrh, ...
// frustrum supplier and implementation name		
APPL	=	kid, unigraphics, ...
// application which is using Parasolid		
SITE	=	...
// site at which application is running		
USER	=	...
		// login name of user
FORMAT	=	binary, text, applio
		// format of file
GUISE	=	transmit, transmit_partition

// guise of file

KEY = ...

// name of key

FILE = ...

// name of file

DATE = dd-mmm-yyyy

// e.g. 5-apr-1998

The ‘part 1’ data is ‘standard’ information which should be accessible to the Frustrum (e.g. by operating system calls). It is the responsibility of the Frustrum to gather the relevant information and to format it as described in this specification.

- part 2 data: a sequence of keyword-value pairs, separated by semicolons.

SCH = SCH_m_n

// name of schema key e.g.SCH_1200000_12006

USFLD_SIZE = m

// length of user field (0 - 16 integer words)

Applications writing XT files must use a schema name of `SCH_1200000_12006`

- part 3 data: non-standard information, which is only comprehensible to the Frustrum which wrote it.

The ‘part 3’ data is non-standard information, which is only comprehensible to the Frustrum which wrote it. However, other Frustrum implementations must be able to parse it (in order to reach the end of the header), and it should therefore conform to the same keyword/value syntax as for ‘part 1’ and ‘part 2’ data. However, the choice and interpretation of keywords for the ‘part 3’ data is entirely at the discretion of the Frustrum which is writing the header.

- a trailer record.

An example is:

```
**ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz************
**PARASOLID !"#$%&'()*+,-./:;<=>?@[\]^_`{|}~0123456789******************
**PART1;MC=vax;MC_MODEL=4090;MC_ID=VAX14;OS=vms;OS_RELEASE=V6.2;FRU=sdl_parasolid_te
st_vax;APPL=unknown;SITE=sdl-cambridge
u.k.;USER=ALANS;FORMAT=text;GUISE=transmit;KEY=temp;FILE=TEMP.XMT_TXT;DATE=8-sep-1997;
**PART2;SCH=SCH_701169_7007;USFLD_SIZE=0;
**PART3;
**END_OF_HEADER*****************************************************
```

Keyword Syntax

All keyword definitions which appear in the three parts of data are written in the form

```
<name>=<value> e.g. MC=hppa;MC_MODEL=9000/710;
```

where

`<name>` consists of 1 to 80 uppercase, digit, or underscore characters

`<value>` consists of 1 or more ASCII printing characters (except space)

Escape sequences provide a way of being able to use the full (7 bit) set of ASCII printing characters and the new line character within keyword values. Certain characters must be escaped if they are to appear in a keyword value:

• Character	Escape sequence
newline	^n
space	^_
semicolon	^;
uparrow	^^

The two character escape sequences may be split by a new line character as they are written to file. They must not cause any output lines to be longer than 80 characters.

Only those characters which belong to the ASCII (7 bit) printing sequence, plus the new line character, can be included as part of a keyword value.

Text

Parasolid has no knowledge of how files are stored. On writing, Parasolid produces an internal bytestream which is then split into roughly 80-character records separated by newline characters ('\n'). The newlines are not significant.

As operating systems vary in their treatment of text data, on reading all newline and carriage return characters ('\r') are ignored, along with any trailing spaces added to the records. However, leading spaces are not ignored, and the file must not contain adjacent space characters not at the end of a record.

Text XT files written by version 12.1 and later versions use escape sequences to output the following characters, except for '\n' at the end of each line:

null "\0"

carriage return "\n"

line feed "\r"

backslash "\\"

These characters are not escaped by versions 12.0 and earlier.

The flag sequence is the character ‘T’. This is followed by the length of the modeler version, separated by a space from the characters of the modeler version, similarly the schema version, finally the userfield size. For example:

T

51 : TRANSMIT FILE created by modeller version 1200000

17 SCH_1200000_12006

0

NB: because of ignored layout, what Parasolid would read is

T51 : TRANSMIT FILE created by modeller version 120000017 SCH_1200000_120060

For partition files, the modeller version string would be given as

63 : TRANSMIT FILE (partition) created by modeller version 1200000

All numbers are followed by a single space to separate them from the next entry. Fields of type c and l are not followed by a space.

Logical values (0,1) are represented as characters F,T.

There are two special numeric values (-32764 for integral values, -3.14158e13 for floating point) which are used inside Parasolid to mark an ‘unset’ or ‘null’ value, and they are represented in a text transmit file as the question mark ‘?’. If a vector has one component null, then all three components must be null, and it will be output in a text file as a single ‘?’.

Binary

There are three types of binary file: `bare' binary, typed binary, and neutral binary. They are distinguished by a short flag sequence at the beginning of the file. In all cases, the flag sequence is followed by the length of the modeller version as a 2-byte integer, the characters of the modeller version, the length of the schema version as a 4-byte integer, the characters of the schema version, and finally the userfield size as a 4-byte integer.

As with text files, there are two special numeric values (-32764 for integral values, -3.14158e13 for floating point) which are used inside Parasolid to mark an ‘unset’ or ‘null’ value, and they are represented in a text transmit file as the question mark ‘?’.

bare binary

In bare binary, data is represented in the natural format of the machine which wrote the data. The flag sequence is the single character 'B' (for ASCII machines, '\102'). The data must be read on a machine with the same natural format with respect to character set, endianness and floating point format.

typed binary

In typed binary, data is represented in the natural format of the machine that wrote the data. The flag sequence is the 4-byte sequence “PS” followed by a zero byte and a one byte, i.e., ‘P’ ‘S’ ‘\0’ ‘\1’, followed by a 3-byte sequence of machine description.

	Byte order	**Double representation**	**Character representation**
0	Big-endian	IEEE	ASCII
1	Little-endian	VAX D-float	EBCDIC

neutral binary

In neutral binary, data is represented in big-endian format, with IEEE floating point numbers and ASCII characters. The flag sequence is the 4-byte sequence "PS" followed by two zero bytes, i.e., 'P' 'S' '\0' '\0'. At Parasolid V9, the initial letters are ASCII, thus '\120' '\123'.

The nodetype at the start of a node is a 2-byte integer, the variable length which may follow it is a 4-byte integer.

Logical values (0,1) are represented as themselves in 1 byte.

Small pointer indices (in the range 0-32766) are implemented as a 2-byte integer, larger indices are represented as a pair, thus:

```
if (index < 32767)
        {                                   // case: small index
        op_short( index + 1 );              // offset so is > 0
        }
else
        {                                   // case: big index
        op_short( -(index % 32767 + 1) );   // remainder: add 1 so > 0
        op_short( index / 32767 );          // nonzero quotient
        }
```

where op_short outputs a 2-byte integer.

The inverse is performed on reading:

```
short q = 0, r;
ip_short( &r );
if (r < 0)
        {
        ip_short( &q );
        r = -r;
        }
index = q * 32767 + r - 1;
```

where ip_short reads a 2-byte integer.

Model Structure

Topology

This section describes the Parasolid Topology model, it gives an overview of how the nodes in an XT file are joined together. In this section the word ‘entity’ means a node which is visible to a PK application – a table of which nodes are visible at the PK interface appears in the section `Node Types'.

The topological representation allows for:

- Non-manifold solids
- Solids with internal partitions
- Bodies of mixed dimension (i.e. with wire, sheet, and solid `bits')
- Pure wire-frame bodies
- Disconnected bodies

Each entity is described, and its properties and links to other entities given.

General points

In this section a set is called **finite** if it can be enclosed in a ball of finite radius - not that it has a finite number of members.

A set of points in 3-dimensional space is called **open** if it does not contain its boundary.

Back-pointers, next and previous pointers in a chain, and derived pointers are not described explicitly here. For information on this see the following description of the schema-level model.

Entity definitions

Assembly

An assembly is a collection of instances of bodies or assemblies. It may also contain construction geometry. An assembly has the following fields:

- A set of instances.
- A set of geometry (surfaces, curves and points).

Instance

An instance is a reference to a body or an assembly, with an optional transform:

- Body or assembly.
- Transform. If null, the identity transform is assumed.

Body

A body is a collection of faces, edges and vertices, together with the 3-dimensional connected regions into which space is divided by these entities. Each region is either **solid** or **void** (indicating whether it represents material or not).

The point-set represented by the body is the disjoint union of the point-sets represented by its solid regions, faces, edges, and vertices. This point-set need not be connected, but it must be finite.

A body has the following fields:

- A set of regions.

  A body has one or more regions. These, together with their boundaries, make up the whole of 3-space, and do not overlap, except at their boundaries. One region in the body is distinguished as the exterior region, which must be infinite; all other regions in the body must be finite.
- A set of geometry (surfaces, curve and/or points).
- A body-type. This may be wire, sheet, solid or general.

Region

A region is an open connected subset of 3-dimensional space whose boundary is a collection of vertices, edges, and oriented faces.

Regions are either solid or void, and they may be non-manifold. A solid region contributes to the point-set of its owning body; a void region does not (although its boundary will).

Two regions may share a face, one on each side.

A region may be infinite, but a body must have exactly one infinite region. The infinite region of a body must be void.

A region has the following fields:

- A logical indicating whether the region is solid.
- A set of shells. The positive shell of a region, if it has one, is not distinguished.

The shells of a region do not overlap or share faces, edges or vertices.

A region may have no shells, in which case it represents all space (and will be the only region in its body, which will have no faces, edges or vertices).

Shell

A shell is a connected component of the boundary of a region. As such it will be defined by a collection of faces, each used by the shell on one `side', or on both sides; and some edges and vertices.

A shell has the following fields:

- A set of (face, logical) pairs.

  Each pair represents one side of a face (where true indicates the front of the face, i.e. the side towards which the face normal points), and means that the region to which the shell belongs lies on that side of the face. The same face may appear twice in the shell (once with each orientation), in which case the face is a 2-dimensional cut subtracted from the region which owns the shell.
- A set of wireframe edges.

  Edges are called **wireframe** if they do not bound any faces, and so represent 1-dimensional cuts in the shell's region. These edges are not shared by other shells.
- A vertex.

  This is only non-null if the shell is an **acorn** shell, i.e. it represents a 0-dimensional hole in its region, and has one vertex, no edges and no faces.

A shell must contain at least one vertex, edge, or face.

Face

A face is an open finite connected subset of a surface, whose boundary is a collection of edges and vertices. It is the 2-dimensional analogy of a region.

A face has the following fields:

- A set of loops. A face may have zero loops (e.g. a full spherical face), or any number.
- Surface. This may be null, and may be used by other faces.
- Sense. This logical indicates whether the normal to the face is aligned with or opposed to that of the surface.

Loop

A loop is a connected component of the boundary of a face. It is the 2-dimensional analogy of a shell. As such it will be defined by a collection of fins and a collection of vertices.

A loop has the following fields:

- An ordered ring of fins.

  Each fin represents the oriented use of an edge by a loop. The sense of the fin indicates whether the loop direction and the edge direction agree or disagree. A loop may not contain the same edge more than once in each direction.

  The ordering of the fins represents the way in which their owning edges are connected to each other via common vertices in the loop (i.e. nose to tail, taking the sense of each fin into account).

  The loop direction is such that the face is locally on the left of the loop, as seen from above the face and looking in the direction of the loop.

- A vertex.

  This is only non-null if the loop is an **isolated** loop, i.e. has no fins and represents a 0-dimensional hole in the face.

Consequently, a loop must consist either of:

- A single fin whose owning **ring** edge has no vertices, or
- At least one fin and at least one vertex, or
- A single vertex.

Fin

A fin represents the oriented use of an edge by a loop.

A fin has the following fields:

- A logical **sense** indicating whether the fin's orientation (and thus the orientation of its owning loop) is the same as that of its owning edge, or different.
- A curve. This is only non-null if the fin’s edge is tolerant, in which case every fin of that edge will reference a trimmed SP-curve. The underlying surface of the SP-curve must be the same as that of the corresponding face. The curve must not deviate by more than the edge tolerance from curves on other fins of the edge, and its ends must be within vertex tolerance of the corresponding vertices.

Note that fins are referred to as ‘halfedges’ in the Schema file.

Edge

An edge is an open finite connected subset of a curve; its boundary is a collection of zero, one or two vertices. It is the 1-dimensional analogy of a region.

An edge has the following fields:

- Start vertex.
- End vertex. If one vertex is null, then so is the other; the edge will then be called a **ring** edge.
- An ordered ring of distinct fins.

  The ordering of the fins represents the spatial ordering of their owning faces about the edge (with a right-hand screw rule, i.e. looking in the direction of the edge the fin ordering is clockwise). The edge may have zero or any number of fins; if it has none, it is called a **wireframe** edge.
- A curve. This will be null if the edge has a tolerance. Otherwise, the vertices must lie within vertex tolerance of this curve, and if it is a Trimmed Curve, they must lie within vertex tolerance of the corresponding ends of the curve. The curve must also lie in the surfaces of the faces of the edge, to within modeller resolution.
- Sense. This logical indicates whether the direction of the edge (start to end) is the same as that of the curve.
- A tolerance. If this is null-double, the edge is **accurate** and is regarded as having a tolerance of half the modeller linear resolution, otherwise the edge is called **tolerant**.

Vertex

A vertex represents a point in space. It is the 0-dimensional analogy of a region.

A vertex has the following fields:

- A geometric point.
- A tolerance. If this is null-double, the vertex is **accurate** and is regarded as having a tolerance of half the modeller linear resolution.

Attributes

An attribute is an entity which contains data, and which can be attached to any other entity except attributes, fins, lists, transforms or attribute definitions. An attribute has the following fields:

- Definition. An attribute definition is an entity which defines the number and type of the data fields in a specific type of attribute, which entities may have such an attribute attached, and what happens to the attribute when its owning entity is changed. An XT document must not contain duplicate attribute definitions. Each attribute of a given type should reference the same instance of the attribute definition for that type. It is incorrect, for example, to create a copy of an attribute definition for each instance of the attribute of that type. Only those attribute definitions referenced by attributes in the part occur in the transmit file.
- Owner.
- Fields. These are data fields consisting of one or more integers, doubles, vectors etc.

There are a number of system attribute definitions which Parasolid creates on startup. These are documented in the section `System Attribute Definitions'. Parasolid applications can create user attribute definitions during a Parasolid session. These are transmitted along with any attributes that use them.

Groups

A group is a collection of entities in the same part. Groups in assemblies may contain instances, surfaces, curves and points. Groups in bodies may contain regions, faces, edges, vertices, surfaces, curves and points. Groups have

- Owning part.
- A set of member entities.
- Type. The type of the group specifies the allowed type of its members, e.g. a 'face' group in a body may only contain faces, whereas a 'mixed' group may have any valid members.

Node-ids

All entities in a part, other than fins, have a non-zero integer node-id which is unique within a part. This is intended to enable the entity to be identified within a transmit file.

Entity matrix

Thus the relations between entities can be represented in matrix form as follows. The numbers represent the number of distinct entities connected (either directly or indirectly) to the given one.

	Body	**Region**	**Shell**	**Face**	**Loop**	**Fin**	**Edge**	**Vertex**
Body	-	>0	any	any	any	any	any	any
Region	1	-	any	any	any	any	any	any
Shell	1	1	-	any	any	any	any	any
Face	1	1-2	1-2	-	any	any	any	any
Loop	1	1-2	1-2	1	-	any	any	any
Fin	1	1-2	1-2	1	1	-	1	0-2
Edge	1	any	any	any	any	any	-	0-2
Vertex	1	any	any	any	any	any	any	-

Representation of manifold bodies

Body types

Parasolid bodies have a field body_type which takes values from an enumeration indicating whether the body is

- **solid**, representing a manifold 3-dimensional volume, possibly with internal voids. It need not be connected.
- **sheet**, representing a 2-dimensional subset of 3-space which is either manifold or manifold with boundary (certain cases are not strictly manifold – see below for details). It need not be connected.
- **wire**, representing a 1-dimensional subset of 3-space which is either manifold or manifold with boundary, and which need not be connected. An **acorn** body, which represents a single 0-dimensional point in space, also has body-type wire.
- **general -** none of the above.

A general body is not necessarily non-manifold, but at the same time it is not constrained to be manifold, connected, or of a particular dimensionality (indeed, it may be of mixed dimensionality).

Restrictions on entity relationships for manifold body types

Solid, sheet, and wire bodies are best regarded as special cases of the topological model; for convenience we call them the manifold body types (although as stated above, a general body may also be manifold).

In particular, bodies of these manifold types must obey the following constraints:

- An acorn body must consist of a single void region with a single shell consisting of a single vertex.
- A wire body must consist of a single void region, with one or more shells, consisting of one or more wireframe edges and zero or more vertices (and no faces). Every vertex in the body must be used by exactly one or two of the edges (so, in particular, there are no acorn vertices).

  So each connected component will be either: closed, where every vertex has exactly two edges; or open, where all but two vertices have exactly two edges each, and the

  A wire is called open if all its components are open, and closed if all its components are closed.
- Solid and sheet bodies must each contain at least one face; they may not contain any wireframe edges or acorn vertices.
- A solid body must consist of at least two regions; at least one of its regions must be solid. Every face in a solid body must have a solid region on its negative side and a void region on its positive side (in other words, every face forms part of the boundary of the solid, and the face normals always point away from the solid).
- Every edge in a solid body must have exactly two fins, which will have opposite senses. Every vertex in a solid body must either belong to a single isolated loop, or belong to one or more edges; in the latter case, the faces which use those edges must form a single edgewise-connected set (when considering only connections via the edges which meet at the vertex).

  These constraints ensure that the solid is manifold.
- All the regions of a sheet body must be void. It is known as an open sheet if it has one region, and a closed sheet if it has no boundary.
- Every edge in a sheet body must have exactly one or two fins; if it has two, these must have opposite senses. In a closed sheet body, all the edges will have exactly two fins. Every vertex in a sheet body must either belong to a single isolated loop, or belong to one or more edges; in the latter case, the faces which use those edges must either form a single edgewise-connected set where all the edges involved have exactly two fins, or any number of edgewise-connected sets, each of which must involve exactly two edges with one fin each (again, considering only connections via the edges which meet at the vertex).

  Note that, although the constraints on edges and vertices in a sheet body are very similar to those which apply to a solid, in this case they do not guarantee that the body will be manifold; indeed, the rather complicated rules about vertices in an open sheet body specifically allow bodies which are non-manifold (such as a body consisting of two square faces which share a single corner vertex, say).

Schema Definition

Underlying types

```
union CURVE_OWNER_u
        {
        struct EDGE_s                    *edge;
        struct FIN_s                     *fin;
        struct BODY_s                    *body;
        struct ASSEMBLY_s                *assembly;
        struct WORLD_s                   *world;
        };

union SURFACE_OWNER_u
        {
        struct FACE_s                    *face;
        struct BODY_s                    *body;
        struct ASSEMBLY_s                *assembly;
        struct WORLD_s                   *world;
        };

union ATTRIB_GROUP_u
        {
        struct ATTRIBUTE_s               *attribute;
        struct GROUP_s                   *group;
        struct                           *member_of_group;
        MEMBER_OF_GROUP_s
        };
typedef union ATTRIB_GROUP_u  ATTRIB_GROUP;
```

Geometry

```
union CURVE_u
        {
        struct LINE_s                    *line;
        struct CIRCLE_s                  *circle;
        struct ELLIPSE_s                 *ellipse;
        struct INTERSECTION_s            *intersection;
        struct TRIMMED_CURVE_s           *trimmed_curve;
        struct PE_CURVE_s                *pe_curve;
        struct B_CURVE_s                 *b_curve;
        struct SP_CURVE_s                *sp_curve;
        };
typedef union CURVE_u      CURVE;

union SURFACE_u
        {
        struct PLANE_s                   *plane;
        struct CYLINDER_s                *cylinder;
        struct CONE_s                    *cone;
        struct SPHERE_s                  *sphere;
        struct TORUS_s                   *torus;
        struct BLENDED_EDGE_s            *blended_edge;
        struct BLEND_BOUND_s             *blend_bound;
        struct OFFSET_SURF_s             *offset_surf;
        struct SWEPT_SURF_s              *swept_surf;
        struct SPUN_SURF_s               *spun_surf;
        struct PE_SURF_s                 *pe_surf;
        struct B_SURFACE_s               *b_surface;
        };
typedef union SURFACE_u    SURFACE;

union GEOMETRY_u
        {
        union  SURFACE_u                  surface;
        union  CURVE_u                    curve;
        struct POINT_s                   *point;
        struct TRANSFORM_s               *transform;
        };
typedef union GEOMETRY_u GEOMETRY;
```

Curves

In the following field tables, 'pointer0' means a reference to another node which may be null. 'pointer' means a non-null reference.

All curve nodes share the following common fields:

Field name	Data type	Description
node_id	int	Integer value unique to curve in part
attributes_groups	pointer0	Attributes and groups associated with curve
owner	pointer0	topological owner
next	pointer0	next curve in geometry chain
previous	pointer0	previous curve in geometry chain
geometric_owner	pointer0	geometric owner node
sense	char	sense of curve: '+' or '-' (see end of Geometry section)

```
struct ANY_CURVE_s          // Any Curve
    {
    int                         node_id;                // $d
    union  ATTRIB_GROUP_u       attributes_groups;      // $p
    union  CURVE_OWNER_u        owner;                  // $p
    union  CURVE_u              next;                   // $p
    union  CURVE_u              previous;               // $p
    struct                     *geometric_owner;        // $p
    GEOMETRIC_OWNER_s
    char                        sense;                  // $c
    };
typedef struct ANY_CURVE_s *ANY_CURVE;
```

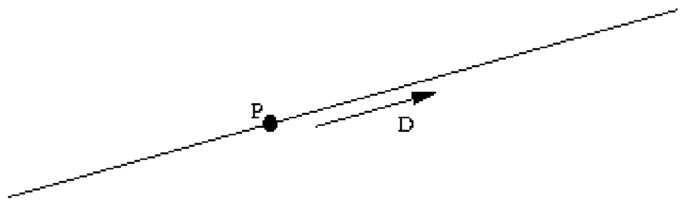
- **LINE**

A straight line has a parametric representation of the form:

R(t) = P + t D

where

- P is a point on the line



- D is its direction

Field name	Data type	Description
pvec	vector	point on the line
direction	vector	direction of the line (a unit vector)

```
struct LINE_s == ANY_CURVE_s     // Straight line
        {
        int                           node_id;                  // $d
        union  ATTRIB_GROUP_u         attributes_groups;        // $p
        union  CURVE_OWNER_u          owner;                    // $p
        union  CURVE_u                next;                     // $p
        union  CURVE_u                previous;                 // $p
        struct                       *geometric_ owner;         // $p
        GEOMETRIC_OWNER_s
        char                          sense;                    // $c
        vector                        pvec;                     // $v
        vector                        direction;                // $v
        };
typedef struct LINE_s      *LINE;
```

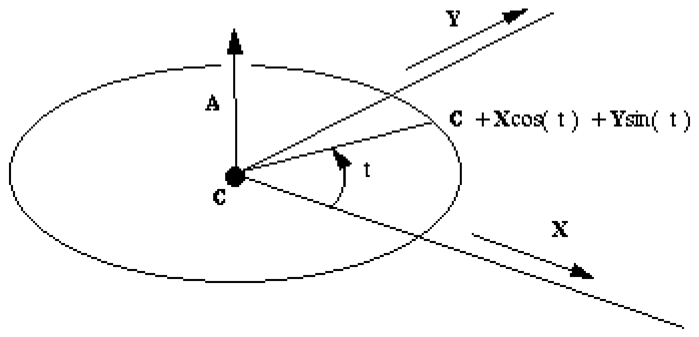
CIRCLE

A circle has a parametric representation of the form

R(t) = C+ r X cos(t) + r Y sin(t)

Where

- C is the centre of the circle
- r is the radius of the circle
- X and Y are the axes in the plane of the circle.



Field name	Data type	Description
centre	vector	Centre of circle
normal	vector	Normal to the plane containing the circle (a unit vector)
x_axis	vector	X axis in the plane of the circle (a unit vector)
radius	double	Radius of circle

The Y axis in the definition above is the vector cross product of the normal and x_axis.

```
struct CIRCLE_s == ANY_CURVE_s                    // Circle
    {
    int                             node_id;                // $d
    union  ATTRIB_GROUP_u           attributes_groups;      // $p
    union  CURVE_OWNER_u            owner;                  // $p
    union  CURVE_u                  next;                   // $p
    union  CURVE_u                  previous;               // $p
    struct GEOMETRIC_OWNER_s       *geometric_owner;        // $p
    char                            sense;                  // $c
    vector                          centre;                 // $v
    vector                          normal;                 // $v
    vector                          x_axis;                 // $v
    double                          radius;                 // $f
    };
typedef struct CIRCLE_s    *CIRCLE;
```

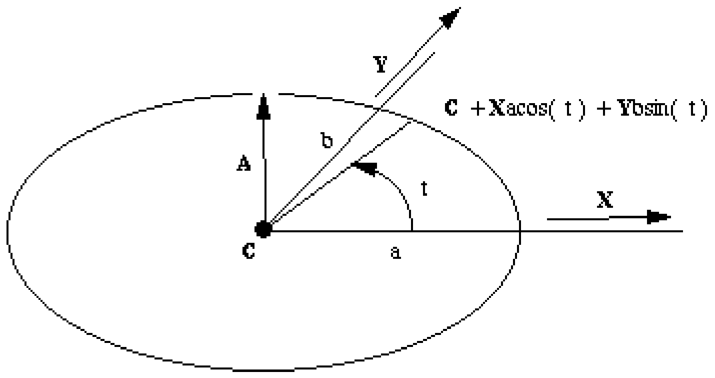
- **ELLIPSE**

An ellipse has a parametric representation of the form

R(t) = C+ a X cos(t) + b Y sin(t)

where

- C is the centre of the circle
- X is the major axis
- r is the major radius



- Y and b are the minor axis and minor radius respectively.

Field name	**Data type**	**Description**
centre	Vector	Centre of ellipse
normal	Vector	Normal to the plane containing the ellipse (a unit vector)
x_axis	Vector	major axis in the plane of the ellipse (a unit vector)
major_radius	Double	major radius
minor_radius	Double	minor radius

The minor axis (Y) in the definition above is the vector cross product of the normal and x_axis.

```
struct ELLIPSE_s == ANY_CURVE_s      // Ellipse
        {
        int                             node_id;                        // $d
        union  ATTRIB_GROUP_u           attributes_groups;              // $p
        union  CURVE_OWNER_u            owner;                          // $p
        union  CURVE_u                  next;                           // $p
        union  CURVE_u                  previous;                       // $p
        struct GEOMETRIC_OWNER_s       *geometric_owner;                // $p
        vector                          centre;                         // $v
        char                            sense;                          // $c
```

```
    vector                   normal;                // $v
    vector                   x_axis;                // $v
    double                   major_radius;          // $f
    double                   minor_radius;          // $f
  };
typedef struct ELLIPSE_s   *ELLIPSE;
```

B_CURVE (B-spline curve)

Parasolid supports B spline curves in full NURBS format. The mathematical description of these curves is:

- Non Uniform Rational B-splines as (NURBS)

$$P(t) = \frac{\sum_{i=0}^{n-1} b_i(t) w_i V_i}{\sum_{i=0}^{n-1} b_i(t) w_i}$$

- and the more simple Non Uniform B-spline

$$P(t) = \sum_{i=0}^{n-1} b_i(t) V_i$$

  •
  - Where:

    n = number of vertices (n_vertices in the PK standard form)

    $V_0 \ldots V_{n-1}$ are the B-spline vertices

    $w_0 \ldots w_{n-1}$ are the weights

    $b_i\ (t), I = 0 \ldots n-1$ are the B-spline basis functions

KNOT VECTORS

The parameter t above is global. The user supplies an ordered set of values of t at specific points. The points are called knots and the set of values of t is called the knot vector. Each successive value in the set must be greater than or equal to its predecessor. Where two or more such values are the same we say that the knots are coincident, or that the knot has multiplicity greater than 1. In this case it is best to think of the knot set as containing a null or zero length span. The principal use of coincident knots is to allow the curve to have less continuity at that point than is formally required for a spline. A curve with a knot of multiplicity equal to its *degree* can have a discontinuity of first derivative and hence of tangent direction. This is the highest permitted multiplicity except at the first or last knot where it can go as high as *(degree+1)* .

In order to avoid problems associated, for example with rounding errors in the knot set, Parasolid stores an array of distinct values and an array of integer multiplicities. This is reflected in the standard form used by the PK for input and output of B-curve data.

Most algorithms in the literature, and the following discussion refer to the expanded knot set in which a knot of multiplicity n appears explicitly n times.

- **THE NUMBER OF KNOTS AND VERTICES**

The knot set determines a set of basis functions which are bell shaped, and non zero over a span of *(degree+1)* intervals. One basis function starts at each knot, and each one finishes *(degree +1)* knots higher. The control vectors are the coefficients applied to these basis functions in a linear sum to obtain positions on the curve. Thus it can be seen that we require the number of knots n_knots = n_vertices + degree + 1

THE VALID RANGE OF THE B-CURVE

So if the knot set is numbered {t_0 to $t_{n\_knots-1}$ } it can be seen then that it is only after t_{degree} that sufficient (*degree + 1*) basis functions are present for the curve to be fully defined, and that the B-curve ceases to be fully defined after $t_{n\_knots - 1 - degree}$.

The first *degree* knots and the last *degree* knots are known as the imaginary knots because their parameter values are outside the defined range of the B-curve.

PERIODIC B-CURVES

When the end of a B-curve meets its start sufficiently smoothly Parasolid allows it to be defined to have periodic parametrisation. That is to say that if the valid range were from t_{degree} to $t_{n\_knots - 1 - degree}$ then the difference between these values is called the period and the curve can continue to be evaluated with the same point reoccurring every period.

The minimal smoothness requirement for periodic curves in Parasolid is tangent continuity, but we strongly recommend $C_{degree-1}$, or continuity in the (*degree-1*)th derivative. This in turn is best achieved by repeating the first *degree* vertices at the end, and by matching knot intervals so that counting from the start of the defined range, t_{degree}, the first *degree* intervals between knots match the last *degree* intervals, and similarly matching the last *degree* knot intervals before the end of the defined range to the first *degree* intervals.

CLOSED B-CURVES

A periodic B-curve must also be closed, but is permitted to have a closed Bcurve that is not periodic.

In this case the rules for continuity are relaxed so that only C_0 or positional continuity is required between the start and end. Such closed non-periodic curves are not able to be attached to topology.

RATIONAL B-CURVE

In the rational form of the curve, each vertex is associated with a weight, which increases or decreases the effect of the vertex without changing the curve hull. To ensure that the convex hull property is retained, the curve equation is divided by a denominator which makes the coefficients of the vertices sum to one.

$$P(t) = \frac{\sum_{i=0}^{n-1} b_i(t) w_i V_i}{\sum_{i=0}^{n-1} b_i(t) w_i}$$

Where $w_0 \ldots w_{n-1}$ are weights.

Each weight may take any positive value, and the larger the value, the greater the effect of the associated vertex. However, it is the relative sizes of the weights which is important, as may be seen from the fact that in the equation given above, all the weights may be multiplied by a constant without changing the equation.

In Parasolid the weights are stored with the vertices by treating these as having an extra dimension. In the usual case of a curve in 3-d cartesian space this means that vertex_dim is 4, the x, y, z values are multiplied through by the corresponding weight and the 4th value is the weight itself.

B-SURFACE DEFINITION

$$P(u,v) = \frac{\sum_{i=0}^{n-1}\sum_{j=0}^{m-1} b_i(u) \quad b_j(v) \quad w_{ij}V_{ij}}{\sum_{i=0}^{n-1}\sum_{j=0}^{m-1} b_i(u) \quad b_j(v) \quad w_{ij}}$$

The B-surface definition is best thought of as an extension of the B-curve definition into two parameters, usually called u and v. Two knot sets are required and the number of control vertices is the product of the number that would be required for a curve using each knot vector. The rules for periodicity and closure given above for curves are extended to surfaces in an obvious way.

For attachment to topology a B-surface is required to have G_1 continuity. That is to say that the surface normal direction must be continuous.

Parasolid does not support modelling with surfaces that are self-intersecting or contain cusps. Although they can be created they are not permitted to be attached to topology.

Field name	Data type	Description
nurbs	Pointer	Geometric definition
data	Pointer0	Auxiliary information

```
struct B_CURVE_s == ANY_CURVE_s                    // B curve
        {
        int                              node_id;                  // $d
        union  ATTRIB_GROUP_u            attributes_groups;        // $p
        union  CURVE_OWNER_u             owner;                    // $p
        union  CURVE_u                   next;                     // $p
        union  CURVE_u                   previous;                 // $p
        struct GEOMETRIC_OWNER_s        *geometric_owner;          // $p
        char                             sense;                    // $c
        struct NURBS_CURVE_s            *nurbs;                    // $p
        struct CURVE_DATA_s             *data;                     // $p
        };
typedef struct B_CURVE_s        *B_CURVE;
```

The data stored in an XT file for a NURBS_CURVE is

Field name	Data type	Description
degree	Short	degree of the curve
n_vertices	Int	number of control vertices (‘poles’)
vertex_dim	Short	dimension of control vertices
n_knots	Int	number of distinct knots
knot_type	Byte	form of knot vector
periodic	Logical	true if curve is periodic
closed	Logical	true if curve is closed
rational	Logical	true if curve is rational
curve_form	Byte	shape of curve, if special
bspline_vertices	Pointer	control vertices node
knot_mult	Pointer	knot multiplicities node
knots	Pointer	knots node

The knot_type enum is used to describe whether or not the knot vector has a certain regular spacing or other common property:

```
typedef enum
    {
    SCH_unset = 1,                  // Unknown
    SCH_non_uniform = 2,            // Known to be not special
    SCH_uniform = 3,                // Uniform knot set
    SCH_quasi_uniform = 4,          // Uniform apart from bezier ends
    SCH_piecewise_bezier = 5,       // Internal multiplicity of order-1
    SCH_bezier_ends = 6             // Bezier ends, no other property
    }
  SCH_knot_type_t;
```

A uniform knot set is one where all the knots are of multiplicity one and are equally spaced. A curve has bezier ends if the first and last knots both have multiplicity ‘order’.

The curve_form enum describes the geometric shape of the curve. The parameterisation of the curve is not relevant.

```
typedef enum
    {
    SCH_unset       = 1,          // Form is not known
    SCH_arbitrary    = 2,          // Known to be of no particular shape
```

```
        SCH_polyline       = 3,
        SCH_circular_arc   = 4,
        SCH_elliptic_arc   = 5,
        SCH_parabolic_arc  = 6,
        SCH_hyperbolic_arc = 7
        }
    SCH_curve_form_t;

struct NURBS_CURVE_s                    // NURBS curve
        {
        short                       degree;                  // $n
        int                         n_vertices;              // $d
        short                       vertex_dim;              // $n
        int                         n_knots;                 // $d
        SCH_knot_type_t             knot_type;               // $u
        logical                     periodic;                // $l
        logical                     closed;                  // $l
        logical                     rational;                // $l
        SCH_curve_form_t            curve_form;              // $u
        struct BSPLINE_VERTICES_s  *bspline_vertices;        // $p
        struct KNOT_MULT_s         *knot_mult;               // $p
        struct KNOT_SET_s          *knots;                   // $p
        };
typedef struct NURBS_CURVE_s *NURBS_CURVE;
```

The bspline vertices node is simply an array of doubles; ‘vertex_dim’ doubles together define one control vertex. Thus the length of the array is n_vertices * vertex_dim.

```
struct BSPLINE_VERTICES_s           // B-spline vertices
        {
        double                     vertices[ 1 ];            // $f[]
        };
typedef struct BSPLINE_VERTICES_s *BSPLINE_VERTICES;
```

The knot vector of the NURBS _CURVE is stored as an array of distinct knots and an array describing the multiplicity of each distinct knot. Hence the two nodes

```
struct KNOT_SET_s                         // Knot set
```

```
    {
    double                  knots[ 1 ];                 // $f[]
    };
typedef struct KNOT_SET_s *KNOT_SET;
```

and

```
struct KNOT_MULT_s                  // Knot multiplicities
    {
    short                   mult[ 1 ];                  // $n[]
    };
typedef struct KNOT_MULT_s *KNOT_MULT;
```

The data stored in an XT file for a CURVE_DATA node is:

```
typedef enum
    {
    SCH_unset = 1,                          // check has not been performed
    SCH_no_self_intersections = 2,          // passed checks
    SCH_self_intersects = 3,                // fails checks
    SCH_checked_ok_in_old_version = 4       // see below
    }
  SCH_self_int_t;


struct CURVE_DATA_s             // curve_data
     {
     SCH_self_int_t          self_int;                  // $u
     Struct HELIX_CU_FORM_s  *analytic_form             // $p
     };
typedef struct CURVE_DATA_s *CURVE_DATA;
```

The self-intersection enum describes whether or not the geometry has been checked for self-intersections, and whether such self-intersections were found to exist:

The SCH_checked_ok_in_old_version enum indicates that the self-intersection check has been performed by a Parasolid version 5 or earlier but not since.

If the analytic_form field is not null, it will point to a HELIX_CU_FORM node, which indicates that the curve has a helical shape, as follows:

```
struct HELIX_CU_FORM_s
     {
     vector                  axis_pt                    // $v
```

```
    vector              axis_dir            // $v
    vector              point               // $v
    char                hand                // $c
    interval            turns               // $i
    double              pitch               // $f
    double              tol                 // $f
    };
typedef struct HELIX_CU_FORM_s *HELIX_CU_FORM;
```

The axis_pt and axis_dir fields define the axis of the helix. The hand field is '+' for a right-handed and '-' for a left-handed helix. A representative point on the helix is at turn position zero. The turns field gives the extent of the helix relative to the point. For instance, an interval [0 10] indicates a start position at the point and an end 10 turns along the axis. Pitch is the distance travelled along the axis in one turn. Tol is the accuracy to which the owning bcurve fits this specification.

INTERSECTION

An intersection curve is one of the branches of a surface / surface intersection. Parasolid represents these curves exactly; the information held in an intersection curve node is sufficient to identify the particular intersection branch involved, to identify the behavior of the curve at its ends, and to evaluate precisely at any point in the curve. Specifically, the data is:

- The two surfaces involved in the intersection.
- The two ends of the intersection curve. These are referred to as the 'limits' of the curve. They identify the particular branch involved.
- An ordered array of points along the curve. This array is referred to as the 'chart' of the curve. It defines the parameterization of the curve, which increases as the array index increases.

The natural tangent to the curve at any point (i.e. in the increasing parameter direction) is given by the vector cross-product of the surface normals at that point, taking into account the senses of the surfaces.

Singular points where the cross-product of the surface normals is zero, or where one of the surfaces is degenerate, are called terminators. Intersection curves do not contain terminators in their interior. At terminators, the tangent to the curve is defined by the limit of the curve tangent as the curve parameter approaches the terminating value.

Field name	Data type	Description
Surface	pointer array [2]	Surfaces of intersection curve
chart	Pointer	array of hvecs on the curve – see below
start	Pointer	start limit of the curve
end	Pointer	end limit of the curve

```
struct INTERSECTION_s == ANY_CURVE_s                // Intersection
    {
    int                     node_id;                // $d
    union  ATTRIB_GROUP_u         attributes_groups;           // $p
    union  CURVE_OWNER_u          owner;                       // $p
    union  CURVE_u                next;                        // $p
    union  CURVE_u                previous;                    // $p
    struct GEOMETRIC_OWNER_s     *geometric_owner;             // $p
    char                          sense;                       // $c
    union  SURFACE_u              surface[ 2 ];                // $p[2]
    struct CHART_s               *chart;                       // $p
    struct LIMIT_s               *start;                       // $p
    struct LIMIT_s               *end;                         // $p
    };
typedef struct INTERSECTION_s  *INTERSECTION;
```

A point on an intersection curve is stored in a data structure called an ‘hvec’ (hepta-vec, or 7-vector):

```
typedef struct hvec_s              // hepta_vec
    {
    vector              Pvec;                    // position
    double              u[2];                    // surface parameters
    double              v[2];
    vector              Tangent;                 // curve tangent
    double              t;                       // curve parameter
    } hvec;
```

where

- pvec is a point common to both surfaces
- u[] and v[] are the u and v parameters of the pvec on each of the surfaces.
- tangent is the tangent to the curve at pvec. This will be equal to the (normalised) vector cross product of the surface normals at pvec, when this cross product is non-zero. These surface normals take account of the surface sense fields.
- t is the parameter of the pvec on the curve

Note that only the pvec part of an hvec is actually transmitted.

The chart data structure essentially describes a piecewise-linear (chordal) approximation to the true curve. As well as containing the ordered array of hvecs defining this approximation, it contains extra information pertaining to the accuracy of the approximation:

```
struct CHART_s                              // Chart
    {
    double              Base_parameter;          // $f
    double              Base_scale;             // $f
    int                 Chart_count;            // $d
    double              Chordal_error;          // $f
    double              Angular_error;          // $f
    double              Parameter_error[2];     // $f[2]
    hvec                Hvec[ 1 ];              // $h[]
    };
```

where

- base_parameter is the parameter of the first hvec in the chart
- base_scale determines the scale of the parameterisation (see below)
- chart_count is the length of the hvec array
- chordal_error is an estimate of the maximum deviation of the curve from the piecewise-linear approximation given by the hvec array. It may be null.
- angular_error is the maximum angle between the tangents of two sequential hvecs. It may be null.
- parameter_error[] is always [null, null].
- hvec[] is the ordered array of hvecs.

The limits of the intersection curve are stored in the following data structure:

```
struct LIMIT_s                  // Limit
     {
     char                    type;                   // $c
     hvec                    hvec[ 1 ];              // $h[]
     };
```

The ‘type’ field may take one of the following values

```
     const char SCH_help          = 'H';            // help hvec
     const char SCH_terminator    = 'T';            // terminator
     const char SCH_limit         = 'L';            // arbitrary limit
     const char SCH_boundary      = 'B';            // spine boundary
```

The length of the hvec array depends on the type of the limit.

- a SCH_help limit is an arbitrary point on a closed intersection curve. There will be one hvec in the hvec array, locating the curve.
- a SCH_terminator limit is a point where one of the surface normals is degenerate, or where their cross-product is zero. Typically, there will be more than one branch of intersection between the two surfaces at these singularities. Ther will be two values in the hvec array. The first will be the exact position of the singularity, and the second will be a point on the curve a small distance away from the terminator. This ‘branch point’ identifies which branch relates to the curve in question. The branch point is the one which appears in the chart, at the corresponding end – so the singularity lies just outside the parameter range of the chart.

- a SCH_limit limit is an artificial boundary of an intersection curve on an otherwise potentially infinite branch. The single hvec describes the end of the curve.
- a SCH_boundary limit is used to describe the end of a degenerate rolling-ball blend. It is not relevant to intersection curves.

The parameterization of the curve is given as follows. If the chart points are P_i, i = 0 to n, with parameters t_i, and natural tangent vectors T_i, then define

$C_i = | P_{i+1} – P_i |$

$\cos(a_i) = T_i . (P_{i+1} – P_i)$

$\cos(b_i) = T_i . (P_i – P_{i-1})$

Then at any chart point P_i the angles a_i and b_i are the deviations between the tangent at the chart point and the next and previous chords respectively.

Let f_0 = base_scale

$f_i = (\cos(b_i) / \cos(a_i)) f_{i-1}$

Then t_0 = base_parameter

$t_i = t_{i-1} + C_{i-1} f_{i-1}$

The parameter of a point between two chart points is given by projecting the point onto the tangent line at the previous chart point. The factors f_i are chosen so that the parameterization is C_1.

TRIMMED_CURVE

A trimmed curve is a bounded region of another curve, referred to as its basis curve. It is defined by the basis curve and two points and their corresponding parameters. Trimmed curves are most commonly attached to fins (fins) of tolerant edges in order to specify which portion of the underlying basis curve corresponds to the tolerant edge. They are necessary since the tolerant vertices of the edge do not necessarily lie exactly on the basis curve; the ‘point’ fields of the trimmed curve lie exactly on the basis curve, and within tolerance of the relevant vertex.

The rules governing the parameter fields and points are:

- point_1 and point_2 correspond to parm_1 and parm_2 respectively.
- If the basis curve has positive sense, parm_2 > parm_1.
- If the basis curve has negative sense, parm_2 < parm_1.

In addition,

For open basis curves.

- Both parm_1 and parm_2 must be in the parameter range of the basis curve.
- point_1 and point_2 must not be equal.

For periodic basis curves

- parm_1 must lie in the base range of the basis curve.
- If the whole basis curve is required then parm_1 and parm_2 should be a period apart and point_1 = point_2. Equality of parm_1 and parm_2 is not permitted.
- parm_1 and parm_2 must not be more than a period apart.

For closed but non-periodic basis curves

- Both parm_1 and parm_2 must be in the parameter range of the basis curve.
- If the whole of the basis curve is required, parm_1 and parm_2 must lie close enough to each end of the valid parameter range in order that point_1 and point_2 are coincident to Parasolid tolerance (1.0e-8 by default).

The sense of a trimmed curve is positive.

Field name	Data type	Description
basis_curve	pointer	Basis curve
point_1	vector	start of trimmed portion
point_2	vector	end of trimmed portion
parm_1	double	parameter on basis curve corresponding to point_1
parm_2	double	parameter on basis curve corresponding to point_2

```
struct TRIMMED_CURVE_s == ANY_CURVE_s          // Trimmed Curve
    {
    int                          node_id;                    // $d
    union  ATTRIB_GROUP_u        attributes_groups;          // $p
    union  CURVE_OWNER_u         owner;                      // $p
    union  CURVE_u               next;                       // $p
    union  CURVE_u               previous;                   // $p
    struct GEOMETRIC_OWNER_s    *geometric_owner;            // $p
    char                         sense;                      // $c
    union  CURVE_u               basis_curve;                // $p
    vector                       point_1;                    // $v
    vector                       point_2;                    // $v
    double                       parm_1;                     // $f
    double                       parm_2;                     // $f
    };
typedef struct TRIMMED_CURVE_s     *TRIMMED_CURVE;
```

PE_CURVE (Foreign Geometry curve)

Foreign geometry in Parasolid is a type used for representing customers' in-house proprietary data. It is also known as PE (parametrically evaluated) geometry. It can also be used internally for representing geometry connected with this data (for example, offsets of foreign surfaces). These two types of foreign geometry usage are referred to as 'external' and 'internal' PE data respectively. Internal PE curves are not used at present.

Applications not using foreign geometry will never encounter either external or internal PE data structures at Parasolid V9 or beyond.

Field name	Data type	Description
type	char	whether internal or external
data	pointer	internal or external data
tf	pointer0	transform applied to geometry
internal geom	pointer array	reference to other related geometry

```
union PE_DATA_u                                    // PE_data_u
        {
        struct EXT_PE_DATA_s          *external;                    // $p
        struct INT_PE_DATA_s          *internal;                    // $p
        };
typedef union PE_DATA_u PE_DATA;
```

The PE internal geometry union defined below is used by internal foreign geometry only.

```
union PE_INT_GEOM_u
        {
        union SURFACE_u               surface;                      // $p
        union CURVE_u                 curve;                        // $p
        };
typedef union PE_INT_GEOM_u PE_INT_GEOM;


struct PE_CURVE_s == ANY_CURVE_s                  // PE_curve
        {
        int                           node_id;                      // $d
        union  ATTRIB_GROUP_u         attributes_groups;            // $p
        union  CURVE_OWNER_u          owner;                        // $p
        union  CURVE_u                next;                         // $p
        union  CURVE_u                previous;                     // $p
        struct                       *geometric_owner;              // $p
        GEOMETRIC_OWNER_s
        char                          sense;                        // $c
        char                          type;                         // $c
        union  PE_DATA_u              data;                         // $p
        struct TRANSFORM_s           *tf;                           // $p
        union  PE_INT_GEOM_u          internal_geom[ 1 ];           // $p[]
```

```
    };
typedef struct PE_CURVE_s       *PE_CURVE;
```

The type of the foreign geometry (whether internal or external) is identified in the PE curve node by means of the char ‘type’ field, taking one of the values

```
    const char SCH_external  = 'E';          // external PE geometry
    const char SCH_interna   = 'I';          // internal PE geometry
```

The PE_data union is used in a PE curve or surface node to identify the internal or external evaluator corresponding to the geometry, and also holds an array of real and/or integer parameters to be passed to the evaluator. The data stored corresponds exactly to that passed to the PK routine PK_FSURF_create when the geometry is created.

```
struct EXT_PE_DATA_s                // ext_PE_data
    {
    struct KEY_s                *key;                       // $p
    struct REAL_VALUES_s        *real_array;                // $p
    struct INT_VALUES_s         *int_array;                 // $p
    };
typedef struct EXT_PE_DATA_s *EXT_PE_DATA;


struct INT_PE_DATA_s                // int_PE_data
    {
    int                         geom_type;                  // $d
    struct REAL_VALUES_s        *real_array;                // $p
    struct INT_VALUES_s         *int_array;                 // $p
    };
typedef struct INT_PE_DATA_s *INT_PE_DATA;
```

The only internal pe type in use at the moment is the offset PE surface, for which the geom_type is 2.

SP_CURVE

An SP curve is the 3D curve resulting from embedding a 2D curve in the parameter space of a surface.

The 2D curve must be a 2D BCURVE; that is it must either be a rational B curve with a vertex dimensionality of 3, or a non-rational B curve with a vertex dimensionality of 2.

Field name	Data type	Description
surface	pointer	surface
b_curve	pointer	2D Bcurve

original	pointer0	not used
tolerance_to_original	double	not used

```
struct   SP_CURVE_s == ANY_CURVE_s                  // SP curve
        {
        int                             node_id;                        // $d
        union  ATTRIB_GROUP_u           attributes_groups;              // $p
        union  CURVE_OWNER_u            owner;                          // $p
        union  CURVE_u                  next;                           // $p
        union  CURVE_u                  previous;                       // $p
        struct
        GEOMETRIC_OWNER_s              *geometric_owner;                // $p
        char                            sense;                          // $c
        union  SURFACE_u                surface;                        // $p
        struct B_CURVE_s               *b_curve;                        // $p
        union  CURVE_u                  original;                       // $p
        double                          tolerance_to_original;          // $f
        };
typedef struct SP_CURVE_s   *SP_CURVE;
```

Surfaces

All surface nodes share the following common fields:

Field name	Data type	Description
node_id	int	Integer value unique to surface in part
attributes_groups	pointer0	Attributes and groups associated with surface
owner	pointer	topological owner
next	pointer0	next surface in geometry chain
previous	pointer0	previous surface in geometry chain
geometric_owner	pointer0	geometric owner node
sense	char	sense of surface: '+' or '-'(see end of Geometry section)

```
struct ANY_SURF_s                           // Any Surface
        {
        int                             node_id;                        // $d
        union  ATTRIB_GROUP_u          attributes_groups;          // $p
        union  SURFACE_OWNER_u         owner;                      // $p
        union  SURFACE_u               next;                       // $p
        union  SURFACE_u               previous;                   // $p
        struct                        *geometric_owner;            // $p
        GEOMETRIC_OWNER_s
        char                           sense;                      // $c
        };
typedef struct ANY_SURF_s  *ANY_SURF;
```

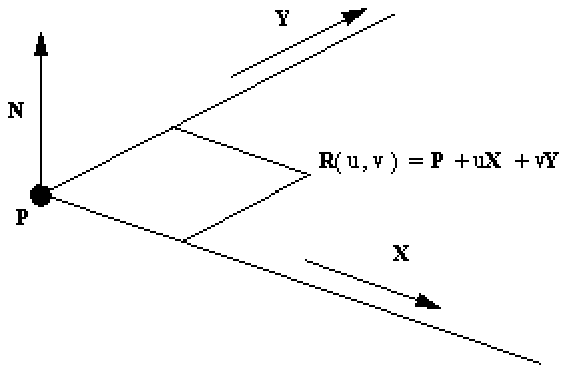
PLANE

A plane has a parametric representation of the form

R(u, v) = P + uX + vY

where

- P is a point on the plan



- X and Y are axes in the plane.

Field name	Data type	Description
pvec	vector	point on the plane
normal	vector	normal to the plane (a unit vector)
x_axis	vector	X axis of the plane (a unit vector)

The Y axis in the definition above is the vector cross product of the normal and x_axis.

```
struct PLANE_s == ANY_SURF_s                    // Plane
        {
```

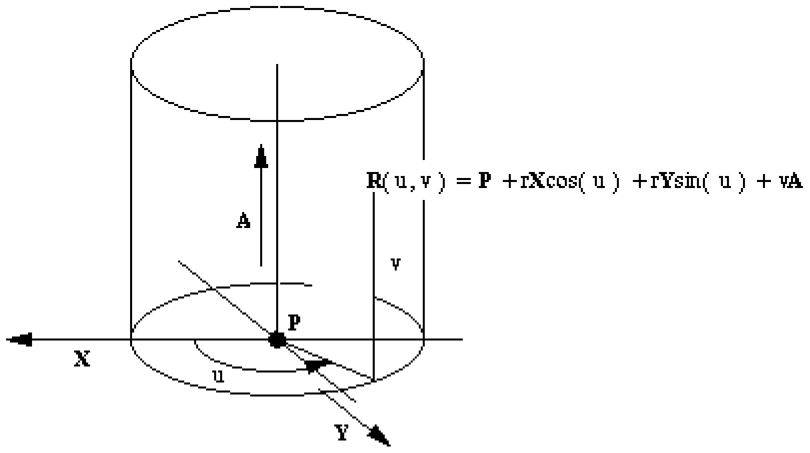
```
    int                         node_id;                  // $d
    union  ATTRIB_GROUP_u       attributes_groups;        // $p
    union  SURFACE_OWNER_u      owner;                    // $p
    union  SURFACE_u            next;                     // $p
    union  SURFACE_u            previous;                 // $p
    struct                     *geometric_owner;          // $p
    GEOMETRIC_OWNER_s
    char                        sense;                    // $c
    vector                      pvec;                     // $v
    vector                      normal;                   // $v
    vector                      x_axis;                   // $v
    };
typedef struct PLANE_s    *PLANE;
```

CYLINDER

A cylinder has a parametric representation of the form:

R(u,v) = P + rXcos(u) + rYsin(u) + vA

where



- P is a point on the cylinder axis
- r is the cylinder radius
- A is the cylinder axis
- X and Y are unit vectors such that A, X and Y form an orthonormal set

Field name	Data type	Description

pvec	vector	point on the cylinder axis
axis	vector	direction of the cylinder axis (a unit vector)
radius	double	radius of cylinder
x_axis	vector	X axis of the cylinder (a unit vector)

The Y axis in the definition above is the vector cross product of the axis and x_axis.

```
struct CYLINDER_s == ANY_SURF_s                 // Cylinder
        {
        int                             node_id;                // $d
        union  ATTRIB_GROUP_u           attributes_groups;      // $p
        union  SURFACE_OWNER_u          owner;                  // $p
        union  SURFACE_u                next;                   // $p
        union  SURFACE_u                previous;               // $p
        struct GEOMETRIC_OWNER_s       *geometric_owner;        // $p
        char                            sense;                  // $c
        vector                          pvec;                   // $v
        vector                          axis;                   // $v
        double                          radius;                 // $f
        vector                          x_axis;                 // $v
        };
typedef struct CYLINDER_s  *CYLINDER;
```

CONE

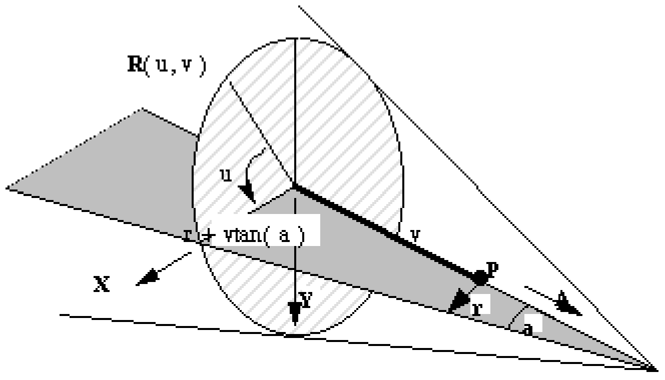
A cone in Parasolid is only half of a mathematical cone. By convention, the cone axis points away from the half of the cone in use. A cone has a parametric representation of the form:

$R(u, v) = P - vA + (X\cos(u) + Y\sin(u))(r + v\tan(a))$

where

- P is a point on the cone axis
- r is the cone radius at the point P
- A is the cone axis
- X and Y are unit vectors such that A, X and Y form an orthonormal set, i.e. Y = A x X.

- a is the cone half angle.



Field name	Data type	Description
pvec	vector	point on the cone axis
axis	vector	direction of the cone axis (a unit vector)
radius	double	radius of the cone at its pvec
sin_half_angle	double	sine of the cone's half angle
cos_half_angle	double	cosine of the cone's half angle
x_axis	vector	X axis of the cone (a unit vector)

The Y axis in the definition above is the vector cross product of the axis and x_axis.

```
struct CONE_s == ANY_SURF_s                  // Cone
    {
    int                          node_id;                // $d
    union  ATTRIB_GROUP_u        attributes_groups;      // $p
    union  SURFACE_OWNER_u       owner;                  // $p
    union  SURFACE_u             next;                   // $p
    union  SURFACE_u             previous;               // $p
    struct                      *geometric_owner;        // $p
    GEOMETRIC_OWNER_s
    char                         sense;                  // $c
    vector                       pvec;                   // $v
    vector                       axis;                   // $v
    double                       radius;                 // $f
    double                       sin_half_angle;         // $f
```

```
        double                          cos_half_angle;                 // $f
        vector                          x_axis;                         // $v
        };
typedef struct CONE_s      *CONE;
```

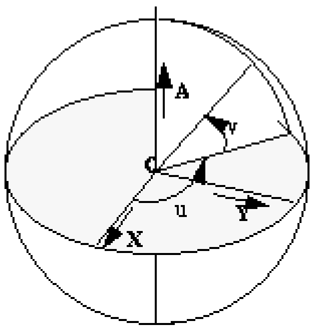
SPHERE

A sphere has a parametric representation of the form:

R(u, v) = C + (Xcos(u) + Ysin(u)) rcos(v) + rAsin(v)

where

- C is centre of the sphere
- r is the sphere radius



- A, X and Y form an orthonormal axis set.

Field name	Data type	Description
centre	vector	centre of the sphere
radius	double	radius of the sphere
axis	vector	A axis of the sphere (a unit vector)
x_axis	vector	X axis of the sphere (a unit vector)

The Y axis of the sphere is the vector cross product of its A and X axes.

```
struct SPHERE_s == ANY_SURF_s                   // Sphere
        {
        int                             node_id;                        // $d
        union  ATTRIB_GROUP_u           attributes_groups;              // $p
        union  SURFACE_OWNER_u          owner;                          // $p
        union  SURFACE_u                next;                           // $p
        union  SURFACE_u                previous;                       // $p
```

```
    struct GEOMETRIC_OWNER_s    *geometric_owner;    // $p
    char                        sense;               // $c
    vector                      centre;              // $v
    double                      radius;              // $f
    vector                      axis;                // $v
    vector                      x_axis;              // $v
    };
typedef struct SPHERE_s    *SPHERE;
```

TORUS

A torus has a parametric representation of the form

$R(u, v) = C + (X \cos(u) + Y \sin(u))(a + b \cos(v)) + b A \sin(v)$

where

- C is center of the torus
- A is the torus axis
- a is the major radius
- b is the minor radius
- X and Y are unit vectors such that A, X and Y form an orthonormal set.

In Parasolid, there are three types of torus:

Doughnut - the torus is not self-intersecting ($a > b$)

Apple - the outer part of a self-intersecting torus ($a <= b, a > 0$)

Lemon - the inner part of a self-intersecting torus ($a < 0, |a| < b$)

The limiting case a = b is allowed; it is called an ‘osculating apple’, but there is no ‘lemon’ surface corresponding to this case.

The limiting case a = 0 cannot be represented as a torus; this is a sphere.

Field name	Data type	Description
centre	vector	centre of the torus
axis	vector	axis of the torus (a unit vector)
major_radius	double	major radius
minor_radius	double	minor radius
x_axis	vector	X axis of the torus (a unit vector)

The Y axis in the definition above is the vector cross product of the axis of the torus and the x_axis.

```
struct TORUS_s == ANY_SURF_s                  // Torus
        {
           int                               node_id;                    // $d
        union  ATTRIB_GROUP_u                attributes_groups;          // $p
        union  SURFACE_OWNER_u               owner;                      // $p
        union  SURFACE_u                     next;                       // $p
        union  SURFACE_u                     previous;                   // $p
        struct GEOMETRIC_OWNER_s            *geometric_owner;            // $p
        char                                 sense;                      // $c
        vector                               centre;                     // $v
        vector                               axis;                       // $v
        double                               major_radius;               // $f
        double                               minor_radius;               // $f
        vector                               x_axis;                     // $v
        };

typedef struct TORUS_s     *TORUS;
```

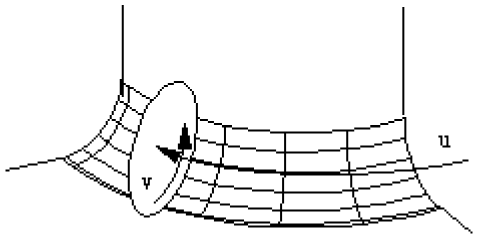
BLENDED_EDGE (Rolling Ball Blend)

Parasolid supports exact rolling ball blends. They have a parametric representation of the form

$R(u, v) = C(u) + rX(u)\cos(v\, a(u)) + rY(u)\sin(v a(u))$

where

- $C(u)$ is the spine curve
- r is the blend radius
- $X(u)$ and $Y(u)$ are unit vectors such that $C'(u) . X(u) = C'(u) . Y(u) = 0$
- $a(u)$ is the angle subtended by points on the boundary curves at the spine



X, Y and a are expressed as functions of u, as their values change with u.

The spine of the rolling ball blend is the center line of the blend; i.e. the path along which the center of the ball moves.

Field name	Data type	Description
type	char	type of blend: ‘R’ or ‘E’
surface	pointer[2]	supporting surfaces (adjacent to original edge)
spine	pointer	spine of blend
range	double[2]	offsets to be applied to surfaces
thumb_weight	double[2]	always [1,1]
boundary	pointer0[2]	always [0, 0]
start	pointer0	Start LIMIT in certain degenerate cases
end	pointer0	End LIMIT in certain degenerate cases

```
struct BLENDED_EDGE_s == ANY_SURF_s                    // Blended edge
    {
    int                          node_id;              // $d
    union  ATTRIB_GROUP_u        attributes_groups;    // $p
    union  SURFACE_OWNER_u       owner;                // $p
    union  SURFACE_u             next;                 // $p
    union  SURFACE_u             previous;             // $p
    struct                      *geometric_owner;      // $p
    GEOMETRIC_OWNER_s
    char                         sense;                // $c
    char                         blend_type;           // $c
    union  SURFACE_u             surface[2];           // $p[2]
    union  CURVE_u               spine;                // $p
    double                       range[2];             // $f[2]
    double                       thumb_weight[2];      // $f[2]
    union  SURFACE_u             boundary[2];          // $p[2]
    struct LIMIT_s              *start;                // $p
    struct LIMIT_s              *end;                  // $p
    };
typedef struct BLENDED_EDGE_s *BLENDED_EDGE;
```

.

The parameterisation of the blend is as follows. The u parameter is inherited from the spine, the constant u lines being circles perpendicular to the spine curve. The v parameter is zero at the blend boundary on the first surface, and one on the blend boundary on the second surface; unless the sense of the spine curve is negative, in which case it is the other way round. The v parameter is proportional to the angle around the circle.

Transmit files can contain blends of the following types:

```
const char SCH_rolling_ball = 'R';          //  rolling ball blend
const char SCH_cliff_edge   = 'E';          //  cliff edge blend
```

For rolling ball blends, the spine curve will be the intersection of the two surfaces obtained by offsetting the supporting surfaces by an amount given by the respective entry in range[]. Note that the offsets to be applied may be positive or negative, and that the sense of the surface is significant; i.e. the offset vector is the natural unit surface normal, times the range, times –1 if the sense is negative.

For cliff edge blends, one of the surfaces will be a blended_edge with a range of [0,0]; its spine will be the cliff edge curve, and its supporting surfaces will be the surfaces of the faces adjacent to the cliff edge. Its type will be R.

The limit fields will only be non-null if the spine curve is periodic but the edge curve being blended has terminators – for example if the spine is elliptical but the blend degenerates. In this case the two LIMIT nodes, of type ‘L’, determine the extent of the spine.

BLEND_BOUND (Blend boundary surface)

A blend_bound surface is a construction surface, used to define the boundary curve where a blend becomes tangential to its supporting surface. It is an implicit surface defined internally so that it intersects one of the supporting surfaces along the boundary curve. It is orthogonal to the blend and the supporting surface along this boundary curve. Since the actual shape of the surface is not significant for the blend geometry, it is not described here.

Blend boundary surfaces are most commonly referenced by the intersection curve representing the boundary curve of the blend.

The data stored in an XT file for a blend_bound is only that necessary to identify the relevant blend and supporting surface:

Field name	Data type	Description
boundary	short	index into supporting surface array
blend	pointer	corresponding blend surface

```
struct BLEND_BOUND_s == ANY_SURF_s        // Blend boundary
      {
      int                          node_id;              // $d
      union  ATTRIB_GROUP_u        attributes_groups;    // $p
      union  SURFACE_OWNER_u       owner;                // $p
      union  SURFACE_u             next;                 // $p
      union  SURFACE_u             previous;             // $p
      struct                      *geometric_owner;      // $p
      GEOMETRIC_OWNER_s
      char                         sense;                // $c
      short                        boundary;             // $n
      union  SURFACE_u             blend;                // $p
      };
typedef struct BLEND_BOUND_s  *BLEND_BOUND;
```

The supporting surface corresponding to the blend_bound is

blend_bound->blend.blended_edge->surface[1 - blend_bound->boundary].

OFFSET_SURF

An offset surface is the result of offsetting a surface a certain distance along its normal, taking into account the surface sense. It inherits the parameterization of this underlying surface.

Field name	Data type	Description
check	char	check status
true_offset	logical	not used
surface	pointer	underlying surface
offset	double	signed offset distance
scale	double	for internal use only – may be set to null

```
struct OFFSET_SURF_s == ANY_SURF_s      // Offset surface
      {
      int                          node_id;              // $d
```

```
        union  ATTRIB_GROUP_u           attributes_groups;             // $p
        union  SURFACE_OWNER_u          owner;                         // $p
        union  SURFACE_u                next;                          // $p
        union  SURFACE_u                previous;                      // $p
        struct GEOMETRIC_OWNER_s       *geometric_owner;               // $p
        char                            sense;                         // $c
        char                            check;                         // $c
        logical                         true_offset;                   // $l
        union  SURFACE_u                surface;                       // $p
        double                          offset;                        // $f
        double                          scale;                         // $f
        };
typedef struct OFFSET_SURF_s    *OFFSET_SURF;
```

The offset surface is subject to the following restrictions:

- The offset distance must not be within modeller linear resolution of zero
- The sense of the offset surface must be the same as that of the underlying surface
- Offset surfaces may not share a common underlying surface

The ‘check’ field may take one of the following values:

```
        const char SCH_valid       = 'V';              // valid
        const char SCH_invalid     = 'I';              // invalid
        const char SCH_unchecked   = 'U';              // has not been checked
```

B_SURFACE

Parasolid supports B spline curves in full NURBS format.

Field name	Data type	Description
nurbs	pointer	Geometric definition
data	pointer0	Auxiliary information

```
struct B_SURFACE_s == ANY_SURF_s                          // B surface
        {
        int                             node_id;                       // $d
        union ATTRIB_GROUP_u            attributes_groups;             // $p
        union  SURFACE_OWNER_u          owner;                         // $p
        union  SURFACE_u                 next;                         // $p
        union  SURFACE_u                 previous;                     // $p
        struct GEOMETRIC_OWNER_s        *geometric_owner;              // $p
        char                             sense;                        // $c
        struct NURBS_SURF_s             *nurbs;                        // $p
        struct SURFACE_DATA_s           *data;                         // $p
        };
typedef struct B_SURFACE_s       *B_SURFACE;
```

The data stored in an XT file for a NURBS surface is

Field name	**Data type**	**Description**
u_periodic	logical	true if surface is periodic in u parameter
v_periodic	logical	true if surface is periodic in v parameter
u_degree	short	u degree of the surface
v_degree	short	v degree of the surface
n_u_vertices	int	number of control vertices (‘poles’) in u direction
n_v_vertices	int	number of control vertices (‘poles’) in v direction
u_knot_type	byte	form of u knot vector – see “B curve”
v_knot_type	byte	form of v knot vector
n_u_knots	int	number of distinct u knots
n_v_knots	int	number of distinct v knots
rational	logical	true if surface is rational
u_closed	logical	true if surface is closed in u
v_closed	logical	true if surface is closed in v
surface_form	byte	shape of surface, if special
vertex_dim	short	dimension of control vertices
bspline_vertices	pointer	control vertices (poles) node
u_knot_mult	pointer	multiplicities of u knot vector
v_knot_mult	pointer	multiplicities of v knot vector
u_knots	pointer	u knot vector
v_knots	pointer	v knot vector

The surface form enum is defined below.

typedef enum

```
    {
    SCH_unset = 1,                      // Unknown
    SCH_arbitrary = 2,                  // No particular shape
    SCH_planar = 3,
    SCH_cylindrical = 4,
    SCH_conical = 5,
    SCH_spherical = 6,
    SCH_toroidal = 7,
    SCH_surf_of_revolution = 8,
    SCH_ruled = 9,
    SCH_quadric = 10,
    SCH_swept = 11
    }
  SCH_surface_form_t;

struct NURBS_SURF_s                     // NURBS surface
    {
    logical                      u_periodic;          // $l
    logical                      v_periodic;          // $l
    short                        u_degree;            // $n
    short                        v_degree;            // $n
    int                          n_u_vertices;        // $d
    int                          n_v_vertices;        // $d
    SCH_knot_type_t              u_knot_type;         // $u
    SCH_knot_type_t              v_knot_type;         // $u
    int                          n_u_knots;           // $d
    int                          n_v_knots;           // $d
    logical                      rational;            // $l
    logical                      u_closed;            // $l
    logical                      v_closed;            // $l
    SCH_surface_form_t           surface_form;        // $u
    short                        vertex_dim;          // $n
    struct BSPLINE_VERTICES_s   *bspline_vertices;    // $p
    struct KNOT_MULT_s          *u_knot_mult;         // $p
    struct KNOT_MULT_s              *v_knot_mult;                  // $p
    struct KNOT_SET_s               *u_knots;                      // $p
    struct KNOT_SET_s               *v_knots;                      // $p
    };
typedef struct NURBS_SURF_s *NURBS_SURF;
```

The ‘bspline_vertices’, ‘knot_set’ and ‘knot_mult’ nodes and the ‘knot_type’ enum are described in the documentation for BCURVE.

The ‘surface data’ field in a B surface node is a structure designed to hold auxiliary or ‘derived’ data about the surface: it is not a necessary part of the definition of the B surface. It may be null, or the majority of its individual fields may be null. It is recommended that it only be set by Parasolid.

```
struct  SURFACE_DATA_s               // auxiliary surface data
     {
     interval                      original_uint;                 // $i
     interval                      original_vint;                 // $i
     interval                      extended_uint;                 // $i
     interval                      extended_vint;                 // $i
     SCH_self_int_t                self_int;                      // $u
     char                          original_u_start;              // $c
     char                          original_u_end;                // $c
     char                          original_v_start;              // $c
     char                          original_v_end;                // $c
     char                          extended_u_start;              // $c
     char                          extended_u_end;                // $c
     char                          extended_v_start;              // $c
     char                          extended_v_end;                // $c
     char                          analytic_form_type;            // $c
     char                          swept_form_type;               // $c
     char                          spun_form_type;                // $c
     char                          blend_form_type;               // $c
     void                         *analytic_form;                 // $p
     void                         *swept_form;                    // $p
     void                         *spun_form;                     // $p
     void                         *blend_form;                    // $p
     };
typedef struct SURFACE_DATA_s *SURFACE_DATA;
```

The ‘original_’ and ‘extended_’ parameter intervals and corresponding character fields original_u_start etc. are all connected with Parasolid’s ability to extend B surfaces when necessary – functionality which is commonly exploited in “local operation” algorithms for example. This is done automatically without the need for user intervention.

In cases where the required extension can be performed by adding rows or columns of control points, then the nurbs data will be modified accordingly – this is referred to as an ‘explicit’ extension. In some rational B surface cases, explicit extension is not possible - in these cases, the surface will be ‘implicitly’ extended. When a B surface is implicitly extended, the nurbs data is not changed, but it will be treated as being larger by allowing out-of-range evaluations on the surface. Whenever an explicit or implicit extension takes place, it is reflected in the following fields:

- “original_u_int” and “original_v_int” are the original valid parameter ranges for a B surface before it was extended
- “extended_u_int” and “extended_v_int” are the valid parameter ranges for a B surface once it has been extended.

The character fields ‘original_u_start’ etc. all refer to the status of the corresponding parameter boundary of the surface before or after an extension has taken place. For B surfaces, the character can have one of the following values:

```
const char SCH_degenerate = 'D';        // Degenerate edge
const char SCH_periodic   = 'P';        // Periodic parameterisation
const char SCH_bounded    = 'B';        // Parameterisation bounded
const char SCH_closed     = 'C';        // Closed, but not periodic
```

The separate fields original_u_start and extended_u_start etc. are necessary because an extension may cause the corresponding parameter boundary to become degenerate.

If the surface_data node is present, then the original_u_int, original_v_int, original_u_start, original_u_end, original_v_start and original_v_end fields should be set to their appropriate values. If the surface has not been extended, the extended_u_int and extended_v_int fields should contain null, and the extended_u_start etc. fields should contain

```
const char SCH_unset_char = '?'; // generic uninvestigated value
```

As soon as any parameter boundary of the surface is extended, all the fields should be set, regardless of whether the corresponding boundary has been affected by the extension.

The SCH_self_int_t enum is documented in the corresponding curve_data structure under B curve.

The ‘swept_form_type’, ‘spun_form_type’ and ‘blend_form_type’ characters and the corresponding pointers swept_form, spun_form and blend_form, are for future use and are not implemented in Parasolid V12.0. The character fields should be set to SCH_unset_char (‘?’) and the pointers should be set to null pointer.

If the analytic_form field is not null, it will point to a HELIX_SU_FORM node, which indicates that the surface has a helical shape. In this case the analytic_form_type field will be set to ‘H’.

```
struct HELIX_SU_FORM_s
    {
    vector                  axis_pt                     // $v
```

vector	axis_dir	// $v
char	hand	// $c
interval	turns	// $i
double	pitch	// $f
double	gap	// $f
double	tol	// $f

};

typedef struct HELIX_SU_FORM_s *HELIX_SU_FORM;

The axis_pt and axis_dir fields define the axis of the helix. The hand field is '+' for a right-handed and '-' for a left-handed helix. The turns field gives the extent of the helix relative to the profile curve which was used to generate the surface. For instance, an interval [0 10] indicates a start position at the profile curve and an end 10 turns along the axis. Pitch is the distance travelled along the axis in one turn. Tol is the accuracy to which the owning bsurface fits this specification. Gap is for future expansion and will currently be zero. The v parameter increases in the direction of the axis.

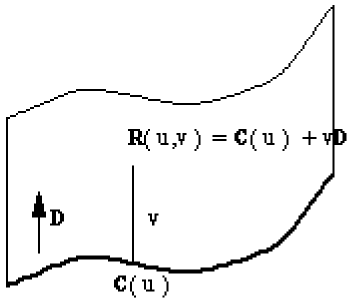
SWEPT_SURF

A swept surface has a parametric representation of the form:

R(u, v) = C(u) + vD

where

- C(u) is the section curve.
- D is the sweep direction (unit vector).



- C must not be an intersection curve or a trimmed curve.

Field name	Data type	Description
section	pointer	section curve
sweep	vector	sweep direction (a unit vector)
scale	double	for internal use only – may be set to null

struct SWEPT_SURF_s == ANY_SURF_s // Swept surface

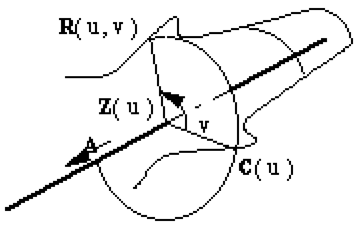
```
    {
    int                             node_id;                 // $d
    union  ATTRIB_GROUP_u           attributes_groups;       // $p
    union  SURFACE_OWNER_u          owner;                   // $p
    union  SURFACE_u                next;                    // $p
    union  SURFACE_u                previous;                // $p
    struct                         *geometric_owner;         // $p
    GEOMETRIC_OWNER_s
    char                            sense;                   // $c
    union  CURVE_u                  section;                 // $p
    vector                          sweep;                   // $v
    double                          scale;                   // $f
    };
typedef struct SWEPT_SURF_s *SWEPT_SURF;
```

SPUN_SURF

A spun surface has a parametric representation of the form:

R(u, v) = Z(u) + (C(u) - Z(u))cos(v) + A X (C(u) - Z(u)) sin(v)

where



- C(u) is the profile curve
- Z(u) is the projection of C(u) onto the spin axis
- A is the spin axis direction (unit vector)
- C must not be an intersection curve or a trimmed curve

NOTE: Z(u) = P + ((C(u) - P) . A)A where P is a reference point on the axis.

Field name	**Data type**	**Description**
profile	pointer	profile curve
base	vector	point on spin axis
axis	vector	spin axis direction (a unit vector)
start	vector	position of degeneracy at low u (may be null)
end	vector	position of degeneracy at low v (may be null)
start_param	double	curve parameter at low u degeneracy (may be null)
end_param	double	curve parameter at high u degeneracy (may be null)
x_axis	vector	unit vector in profile plane if common with spin axis
scale	double	for internal use only – may be set to null

```
struct SPUN_SURF_s == ANY_SURF_s                  // Spun surface
        {
        int                              node_id;                    // $d
        union  ATTRIB_GROUP_u            attributes_groups;          // $p
        union  SURFACE_OWNER_u           owner;                      // $p
        union  SURFACE_u                 next;                       // $p
        union  SURFACE_u                 previous;                   // $p
        struct                          *geometric_owner;            // $p
        GEOMETRIC_OWNER_s
        char                             sense;                      // $c
        union  CURVE_u                   profile;                    // $p
        vector                           base;                       // $v
        vector                           axis;                       // $v
        vector                           start;                      // $v
        vector                           end;                        // $v
        double                           start_param;                // $f
        double                           end_param;                  // $f
        vector                           x_axis;                     // $v
        double                           scale;                      // $f
        };
typedef struct SPUN_SURF_s *SPUN_SURF;
```

The ‘start’ and ‘end’ vectors correspond to physical degeneracies on the spun surface caused by the profile curve crossing the spin axis at that point. The values start_param and end_param are the corresponding parameters on the curve. These parameter values define the valid range for the u parameter of the surface. If either value is null, then the valid range for u is infinite in that direction. For example, for a straight line profile curve intersecting the spin axis at the parameter t=1, values of null for start_param and 1 for end_param would define a cone with u parameterisation (-infinity, 1].

If the profile curve lies in a plane containing the spin axis, then x_axis must be set to a vector perpendicular to the spin axis and in the plane of the profile, pointing from the spin axis to a point on the profile curve in the valid range. If the profile curve is not planar, or its plane does not contain the spin axis, then x_axis should be set to null.

PE_SURF (Foreign Geometry surface)

Foreign (or 'PE') geometry in Parasolid is a type used for representing customers' in-house proprietary data. It can also be used internally for representing geometry connected with this data (for example, offset foreign surfaces). These two types of foreign geometry usage are referred to as 'external' and 'internal' respectively. The only internal PE surface is the offset PE surface.

Applications not using foreign geometry will never encounter either external or internal PE data structures at Parasolid V9 or beyond.

Field name	Data type	Description
type	char	whether internal or external
data	pointer	internal or external data
tf	pointer0	transform applied to geometry
internal geom	pointer array	reference to other related geometry

```
struct PE_SURF_s == ANY_SURF_s              // PE_surface
     {
     int                          node_id;                  // $d
     union  ATTRIB_GROUP_u        attributes_groups;        // $p
     union  SURFACE_OWNER_u       owner;                    // $p
     union  SURFACE_u             next;                     // $p
     union  SURFACE_u             previous;                 // $p
     struct GEOMETRIC_OWNER_s    *geometric_owner;          // $p
     char                         sense;                    // $c
     char                         type;                     // $c
     union  PE_DATA_u             data;                     // $p
     struct TRANSFORM_s          *tf;                       // $p
     union  PE_INT_GEOM_u         internal_geom[ 1 ];       // $p[]
     };
typedef struct PE_SURF_s  *PE_SURF;
```

The PE_DATA and PE_INT_GEOM unions are defined under 'PE curve'.

Point

Field name	Data type	Description
node_id	int	integer unique within part
attributes_groups	pointer0	attributes and groups associated with point
owner	pointer	Owner
next	pointer0	next point in chain
previous	pointer0	previous point in chain
pvec	vector	position of point

```
union POINT_OWNER_u
     {
     struct VERTEX_s                   *vertex;
     struct BODY_s                     *body;
     struct ASSEMBLY_s                 *assembly;
     struct WORLD_s                    *world;
     };

struct POINT_s                      // Point
     {
     int                             node_id;                         // $d
     union  ATTRIB_GROUP_u           attributes_groups;               // $p
     union  POINT_OWNER_u            owner;                           // $p
     struct POINT_s                 *next;                            // $p
     struct POINT_s                 *previous;                        // $p
     vector                          pvec;                            // $v
     };
typedef struct POINT_s    *POINT;
```

Transform

Field name	Data type	Description
node_id	int	integer unique within part
owner	pointer	owning instance or world
next	pointer0	next transform in chain

previous	pointer0	previous pointer in chain
rotation_matrix	double[3][3]	rotation component
translation_vector	vector	translation component
scale	double	scaling factor
flag	byte	binary flags indicating non-trivial components
perspective_vector	vector	perspective vector (always null vector)

The transform acts as

x’ = (rotation_matrix . x + translation_vector) * scale

The ‘flag’ field contains various bit flags which identify the components of the transformation:

Flag Name	Binary Value	Description
translation	00001	set if translation vector non-zero
rotation	00010	set if rotation matrix is not the identity
scaling	00100	set if scaling component is not 1.0
reflection	01000	set if determinant of rotation matrix is negative
general affine	10000	set if the rotation_matrix is not a rigid rotation

```
union TRANSFORM_OWNER_u
    {
    struct INSTANCE_s           *instance;
    struct WORLD_s              *world;
    };

struct TRANSFORM_s              // Transformation
    {
    int                         node_id;                    // $d
    union                       owner;                      // $p
    TRANSFORM_OWNER_u
    struct TRANSFORM_s          *next;                      // $p
    struct TRANSFORM_s          *previous;                  // $p
    double                      rotation_matrix[3][3];      // $f[9]
    vector                      translation_vector;         // $v
    double                      scale;                      // $f
    unsigned                    flag;                       // $d
    vector                      perspective_vector;         // $v
    };
typedef struct TRANSFORM_s *TRANSFORM;
```

Curve and Surface Senses

The 'natural' tangent to a curve is that in the increasing parameter direction, and the 'natural' normal to a surface is in the direction of the cross-product of dP/du and dP/dv. For some purposes these are modified by the curve and surfaces senses, respectively – for example in the definition of blend surfaces, offset surfaces and intersection curves.

At the PK interface, the edge/curve and face/surface sense orientations are regarded as properties of the topology/geometry combination. In the XT format, this orientation information resides in the curves, surfaces and faces as follows:

The edge/curve orientation is stored in the curve->sense field. The face/surface orientation is a combination of sense flags stored in the face->sense and surface->sense fields, so the face/surface orientation is true (i.e. the face normal is parallel to the natural surface normal) if neither, or both, of the face and surface senses are positive.

Geometric_owner

Where geometry has dependants, the dependants point back to the referencing geometry by means of Geometric Owner nodes. Each geometric node points to a doubly-linked ring of Geometric Owner nodes which identify its referencing geometry. Referenced geometry is as follows:

Intersection:	2 surfaces
SP-curve:	Surface
Trimmed curve:	basis curve
Blended edge:	2 supporting surfaces, 2 blend_bound surfaces, 1 spine curve
Blend bound:	blend surface
Offset surface:	underlying surface
Swept surface:	section curve
Spun surface:	profile curve

Note that the 2D B-curve referenced by an SP-curve is not a dependent in this sense, and does not need a geometric owner node.

●

• **Field name**	• **Dat a type**	• **Description**
• owner	• poin ter	• referencing geometry
• next	• poin ter	• next in ring of geometric owners referring to the same geometry
• previous	• poin ter	• previous in above ring
• shared_geome try	• poin ter	• referenced (dependent) geometry

•

```
struct GEOMETRIC_OWNER_s         //  geometric owner of geometry
        {
        union  GEOMETRY_u                   owner;                              //  $p
        struct GEOMETRIC_OWNER_s      *next;                              //  $p
        struct GEOMETRIC_OWNER_s      *previous;                          // $p
        union  GEOMETRY_u                   shared_geometry;                    //  $p
        };
typedef struct GEOMETRIC_OWNER_s *GEOMETRIC_OWNER;
```

Topology

In the following tables, 'ignore' means this may be set to null (zero) if an XT file is created outside Parasolid. For an XT file created by Parasolid, this may take any value, but should be ignored.

Unless otherwise stated, all chains of nodes are doubly-linked and null-terminated.

- **WORLD**

• **Field name**	• **Type**	• **Description**
• assembly	• pointer0	• Head of chain of assemblies
• attribute	• pointer0	• Ignore
• body	• pointer0	• Head of chain of bodies
• transform	• pointer0	• Head of chain of transforms
• surface	• pointer0	• Head of chain of surfaces
• curve	• pointer0	• Head of chain of curves
• point	• pointer0	• Head of chain of points
• alive	• logical	• True unless partition is at initial pmark
• attrib_def	• pointer0	• Head of chain of attribute definitions
• highest_id	• int	• Highest pmark id in partition
• current_id	• int	• Id of current pmark
• index_map_offset	• int	• Must be set to 0
• index_map	• pointer0	• Must be set to null
• schema_embedding_map	• pointer0	• Must be set to null

•

The World node is only used when a partition is transmitted. Because some of the attribute definitions may be referenced by nodes which have been deleted, but which may reappear on rollback, the attribute definitions are chained off the World node rather than simply being referenced by attributes.

The fields index_map_offset, index_map, and schema_embedding_map are used for Indexed Transmit; applications writing XT data must set them to 0 and null.

```
struct WORLD_s                         // World
     {
     struct ASSEMBLY_s        *assembly;                    // $p
     struct ATTRIBUTE_s       *attribute;                   // $p
```

```
        struct BODY_s                 *body;                        // $p
        struct TRANSFORM_s            *transform;                   // $p
        union  SURFACE_u               surface;                     // $p
        union  CURVE_u                 curve;                       // $p
        struct POINT_s                *point;                       // $p
        logical                        alive;                       // $l
        struct ATTRIB_DEF_s           *attrib_def;                  // $p
        int                            highest_id;                  // $d
        int                            current_id;                  // $d
        };
typedef struct WORLD_s  *WORLD;
```

ASSEMBLY

highest_node_id	int	Highest node-id in assembly
attributes_groups	pointer0	Head of chain of attributes of, and groups in, assembly
attribute_chains	pointer0	List of attributes, one for each attribute definition used in the assembly
list	pointer0	Null
surface	pointer0	Head of construction surface chain
curve	pointer0	Head of construction curve chain
point	pointer0	Head of construction point chain
key	pointer0	Ignore
res_size	double	Value of ‘size box’ when transmitted (normally 1000)
res_linear	double	Value of modeller linear precision when transmitted (normally 1.0e-8).
ref_instance	pointer0	Head of chain of instances referencing this assembly
next	pointer0	Ignore
previous	pointer0	Ignore
state	byte	Set to 1.
owner	pointer0	Ignore
type	byte	Always 1.
sub_instance	pointer0	Head of chain of instances in assembly

The value of the ‘state’ field should be ignored, as should any nodes of type ‘KEY’ referenced by the assembly. If an XT file is constructed outside Parasolid, the state field should be set to 1, and the key to null.

The highest_node_id gives the highest node-id of any node in the assembly. Certain nodes within the assembly (namely instances, transforms, geometry, attributes and groups) have unique node-ids which are non-zero integers.

```
typedef enum
        {
        SCH_collective_assembly  = 1,
        SCH_conjunctive_assembly = 2,
        SCH_disjunctive_assembly = 3
        }
        SCH_assembly_type;

typedef enum
        {
        SCH_new_part       = 1,
        SCH_stored_part    = 2,
        SCH_modified_part  = 3,
        SCH_anonymous_part = 4,
        SCH_unloaded_part  = 5
        }
        SCH_part_state;

struct ASSEMBLY_s                        //  Assembly
        {
        int                         highest_node_id;              //  $d
        union ATTRIB_GROUP_u        attributes_groups;            //  $p
        struct LIST_s              *attribute_chains;             //  $p
        struct LIST_s              *list;                         //  $p
        union SURFACE_u             surface;                      //  $p
        union CURVE_u               curve;                        //  $p
        struct POINT_s             *point;                        //  $p
        struct KEY_s               *key;                          //  $p
        double                      res_size;                     //  $f
        double                      res_linear;                   //  $f
        struct INSTANCE_s          *ref_instance;                 //  $p
        struct ASSEMBLY_s            *next;                             //  $p
        struct ASSEMBLY_s            *previous;                         //  $p
        SCH_part_state                state;                            //  $u
        struct WORLD_s               *owner;                            //  $p
        SCH_assembly_type             type;                             //  $u
        struct INSTANCE_s            *sub_instance;                     //  $p
        };
typedef struct ASSEMBLY_s *ASSEMBLY;
struct KEY_s                                          // Key
        {
        string[1];                   char                               // $c[]
        };
typedef struct KEY_s *KEY;
```

INSTANCE

Field name	Type	Description
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of instance and member_of_groups of instance
type	byte	Always 1
part	pointer	Part referenced by instance
transform	pointer0	Transform of instance
assembly	pointer	Assembly in which instance lies
next_in_part	pointer0	Next instance in assembly
prev_in_part	pointer0	Previous instance in assembly
next_of_part	pointer0	Next instance of instance->part
prev_of_part	pointer0	Previous instance of instance->part

```
typedef enum
        {
        SCH_positive_instance = 1,
        SCH_negative_instance = 2
        }
        SCH_instance_type;
```

```
union  PART_u
        {
        struct BODY_s                *body;
        struct ASSEMBLY_s            *assembly;
        };
typedef union PART_u      PART;

struct INSTANCE_s                        //  Instance
        {
        int                              node_id;                    //  $d
        union  ATTRIB_GROUP_u            attributes_groups;          //  $p
        SCH_instance_type                type;                       //  $u
        union  PART_u                    part;                       //  $p
        struct TRANSFORM_s               *transform;                 //  $p
        struct ASSEMBLY_s                *assembly;                  //  $p
        struct INSTANCE_s                *next_in_part;              //  $p
        struct INSTANCE_s                *prev_in_part;              //  $p
        struct INSTANCE_s                *next_of_part;              //  $p
        struct INSTANCE_s                *prev_of_part;              //  $p
        };
typedef struct INSTANCE_s *INSTANCE;
```

BODY

Field name	Type	Description
highest_node_id	int	Highest node-id in body
attributes_groups	pointer0	Head of chain of attributes of, and groups in, body
attribute_chains	pointer0	List of attributes, one for each attribute definition used in the body
surface	pointer0	Head of construction surface chain
curve	pointer0	Head of construction curve chain
point	pointer0	Head of construction point chain
key	pointer0	Ignore

res_size	double	Value of ‘size box’ when transmitted (normally 1000)
res_linear	double	Value of modeller linear precision when transmitted (normally 1.0e-8)
ref_instance	pointer0	Head of chain of instances referencing this part
next	pointer0	Ignore
previous	pointer0	Ignore
state	byte	Set to 1 (see below)
owner	pointer0	Ignore
body_type	byte	Body type
nom_geom_state	byte	Set to 1 (for future use)
shell	pointer0	For general bodies: null For solid bodies: the first shell in one of the solid regions For other bodies: the first shell in one of the regions This field is **obsolete**, and should be ignored by applications reading XT files. When writing XT files, it must be set as above.
boundary_surface	pointer0	Head of chain of surfaces attached directly or indirectly to faces or edges or fins
boundary_curve	pointer0	Head of chain of curves attached directly or indirectly to edges or faces or fins
boundary_point	pointer0	Head of chain of points attached to vertices
region	pointer	Head of chain of regions in body; this is the infinite region
edge	pointer0	Head of chain of all non-wireframe edges in body
vertex	pointer0	Head of chain of all vertices in body
index_map_offset	int	Must be set to 0
index_map	pointer0	Must be set to null
node_id_index_map	pointer0	Must be set to null
schema_embedding_map	pointer0	Must be set to null

The value of the ‘state’ field should be ignored, as should any nodes of type ‘KEY’ referenced by the body. If an XT file is constructed outside Parasolid, the state field should be set to 1, and the key to null.

The highest_node_id gives the highest node of any node in this body. Most nodes in a body which are visible at the PK interface have node-ids, which are non-zero integers unique to that node within the body. Applications writing XT files must ensure that node-ids are present and distinct. The details of which nodes have node ids are given in an appendix.

The fields index_map_offset, index_map, node_id_index_map, and schema_embedding_map are used for Indexed Transmit; applications writing XT files must ensure that these fields are set to 0 and null.

```
typedef enum
        {
        SCH_solid_body      = 1,
        SCH_wire_body       = 2,
        SCH_sheet_body      = 3,
        SCH_general_body    = 6
        }
        SCH_body_type;

typedef short short enum
          {
          SCH_nom_geom_off = 1,            --- Entirely off
          SCH_nom_geom_on  = 2             --- Entirely on
          }
          SCH_nom_geom_state_t;

struct BODY_s                          //  Body
        {
        int                         highest_node_id;              //  $d
        union ATTRIB_GROUP_u        attributes_groups;            //  $p
        struct LIST_s              *attribute_chains;             //  $p
        union SURFACE_u             surface;                      //  $p
        union CURVE_u               curve;                        //  $p
        struct POINT_s             *point;                        //  $p
        struct KEY_s               *key;                          //  $p
        double                      res_size;                     //  $f
        double                      res_linear;                   //  $f
        struct INSTANCE_s          *ref_instance;                 //  $p
        struct BODY_s              *next;                         //  $p
        struct BODY_s              *previous;                     //  $p
        SCH_part_state                  state;                          //  $u
        struct WORLD_s                 *owner;                          //  $p
        SCH_body_type                   body_type;                      //  $u
        SCH_nom_geom_state_t           nom_geom_state;                  //  $u
        struct SHELL_s                 *shell;                          //  $p
        union SURFACE_u                 boundary_surface;               //  $p
        union CURVE_u                   boundary_curve;                 //  $p
        struct POINT_s                 *boundary_point;                 //  $p
        struct REGION_s                *region;                         //  $p
        struct EDGE_s                  *edge;                           //  $p
        struct VERTEX_s                *vertex;                         //  $p
        int                            index_map_offset;                //  $d
        struct INT_VALUES_s            *index_map;                      //  $p
        struct INT_VALUES_s            *node_id_index_map;              //  $p
        struct INT_VALUES_s            *schema_embedding_map;           //  $p
        };
typedef struct BODY_s     *BODY;
```

Attaching Geometry to Topology

The faces which reference a surface are chained together, surface->owner is the head of this chain. Similarly the edges which reference the same curve are chained together. Fins do not share curves.

Geometry in parts may be chained into one of the three boundary geometry chains, or one of the three construction geometry chains. A geometric node will fall into one of the following cases:

Geometry	**Owner**	**Whether chained**
Attached to face	face	In boundary_surface chain
Attached to edge or fin	edge or fin	In boundary_curve chain
Attached to vertex	vertex	In boundary_point chain
Indirectly attached to face or edge or fin	body	In boundary_surface chain or boundary_curve chain
Construction geometry	body or assembly	In surface, curve or point chain
2D B-curve in SP-curve	null	Not chained

Here ‘indirectly attached’ means geometry which is a dependent of a dependent of (... etc) of geometry attached to an edge, face or fin.

Geometry in a construction chain may reference geometry in a boundary chain, but not vice-versa.

REGION

Field name	**Type**	**Description**
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of region and member_of_groups of region
body	pointer	Body of region
next	pointer0	Next region in body
prev	pointer0	Previous region in body
shell	pointer0	Head of singly-linked chain of shells in region
type	char	Region type – solid (‘S’) or void (‘V’)

```
struct REGION_s                    //  Region
     {
     int                           node_id;                      //  $d
```

```
        union  ATTRIB_GROUP_u          attributes_groups;              //  $p
        struct BODY_s                 *body;                           //  $p
        struct REGION_s               *next;                           //  $p
        struct REGION_s               *previous;                       //  $p
        struct SHELL_s                *shell;                          //  $p
        char                           type;                           //  $c
        };
typedef struct REGION_s   *REGION;
```

SHELL

Field name	**Type**	**Description**
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of shell
body	pointer0	For shells in wire and sheet bodies, and for shells bounding a solid region of a solid body, this is set to the body of the shell. For shells in general bodies, or void shells in solid bodies, it is null. This field is **obsolete**, and should be ignored by applications reading XT files. When writing XT files, it must be set as above.
next	pointer0	Next shell in region
face	pointer0	Head of chain of back-faces of shell (i.e. faces with face normal pointing out of region of shell).
edge	pointer0	Head of chain of wire-frame edges of shell
vertex	pointer0	If shell consists of a single vertex, this is it; else null
region	pointer	Region of shell
front_face	pointer0	Head of chain of front-faces of shell (i.e. faces with face normal pointing into region of shell)

```
struct SHELL_s                         //  Shell
        {
        int                            node_id;                        //  $d
        union  ATTRIB_GROUP_u          attributes_groups;              //  $p
        struct BODY_s                 *body;                           //  $p
        struct SHELL_s                *next;                           //  $p
        struct FACE_s              *face;                  //  $p
        struct EDGE_s              *edge;                  //  $p
        struct VERTEX_s            *vertex;                //  $p
        struct REGION_s            *region;                //  $p
        struct FACE_s              *front_face;            //  $p
        };
typedef struct SHELL_s    *SHELL;
```

FACE

Field name	Type	Description
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of face and member_of_groups of face
tolerance	double	Not used (null double)
next	pointer0	Next back-face in shell
previous	pointer0	Previous back-face in shell
loop	pointer0	Head of singly-linked chain of loops
shell	pointer	Shell of which this is a back-face
surface	pointer0	Surface of face
sense	char	Face sense – positive ('+') or negative ('-')
next_on_surface	pointer0	Next in chain of faces sharing the surface of this face
previous_on_surface	pointer0	Previous in chain of faces sharing the surface of this face
next_front	pointer0	Next front-face in shell
previous_front	pointer0	Previous front-face in shell
front_shell	pointer	Shell of which this is a front-face

```
struct FACE_s                      //  Face
        {
        int                         node_id;               //  $d
        union  ATTRIB_GROUP_u       attributes_groups;     //  $p
        double                      tolerance;             //  $f
        struct FACE_s              *next;                  //  $p
        struct FACE_s              *previous;              //  $p
        struct LOOP_s                *loop;                  //  $p
        struct SHELL_s               *shell;                 //  $p
        union  SURFACE_u              surface;               //  $p
        char                          sense;                 //  $c
        struct FACE_s                *next_on_surface;       //  $p
        struct FACE_s                *previous_on_surface;   //  $p
        struct FACE_s                *next_front;            //  $p
        struct FACE_s                *previous_front;        //  $p
        struct SHELL_s               *front_shell;           //  $p
        };
typedef struct FACE_s     *FACE;
```

LOOP

Field name	Type	Description
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of loop
fin	pointer	One of ring of fins of loop
face	pointer	Face of loop
next	pointer0	Next loop in face

- **Isolated Loops**

An isolated loop (one consisting of a single vertex) does not refer directly to a vertex, but points to a fin which refers to that vertex. This isolated fin has fin->forward = fin->backward = fin, and fin->other = fin->curve = fin->edge = null. Its sense is not significant. The fin is chained into the chain of fins referencing the isolated vertex.

```
struct LOOP_s                        //  Loop
        {
        int                           node_id;               //  $d
        union  ATTRIB_GROUP_u         attributes_groups;     //  $p
        struct FIN_s                 *fin;                   //  $p
        struct FACE_s                *face;                  //  $p
        struct LOOP_s                *next;                  //  $p
        };
typedef struct LOOP_s     *LOOP;
```

FIN

Field name	**Type**	**Description**
attributes_groups	pointer0	Head of chain of attributes of fin
loop	pointer0	Loop of fin
forward	pointer0	Next fin around loop
backward	pointer0	Previous fin around loop
vertex	pointer0	Forward vertex of fin
other	pointer0	Next fin around edge, clockwise looking along edge
edge	pointer0	Edge of fin
curve	pointer0	For a non-dummy fin of a tolerant edge, this will be a trimmed SP-curve, otherwise null.
next_at_vx	pointer0	Next fin referencing the vertex of this fin
sense	char	Positive ('+') if the fin direction is parallel to that of its edge, else negative ('-')

Dummy Fins

An application will see edges as having any number of fins, including zero. However internally, they have at least two. This is so that the forward and backward vertices of an edge can always be found as edge->fin->vertex and edge->fin->other->vertex respectively - the first one being a positive fin, the second a negative fin. If an edge does not have both a positive and a negative externally-visible fin, **dummy** fins will exist for this purpose. Dummy fins have fin->loop = fin->forward = fin->backward = fin->curve = fin->next_at_vx = null. For example the boundaries of a sheet always have one dummy fin.

```
struct FIN_s                          //  Fin
      {
      union  ATTRIB_GROUP_u          attributes_groups;              //  $p
      struct LOOP_s                  *loop;                          //  $p
      struct FIN_s                   *forward;                       //  $p
      struct FIN_s                   *backward;                      //  $p
      struct VERTEX_s                *vertex;                        //  $p
      struct FIN_s                   *other;                         //  $p
      struct EDGE_s                  *edge;                          //  $p
      union  CURVE_u                  curve;                         //  $p
      struct FIN_s                   *next_at_vx;                    //  $p
      char                            sense;                         //  $c
```

```
        };
typedef struct FIN_s *FIN;
```

VERTEX

Field name	Type	Description
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of vertex and member_of_groups of vertex
fin	pointer0	Head of singly-linked chain of fins referencing this vertex
previous	pointer0	Previous vertex in body
next	pointer0	Next vertex in body
point	pointer	Point of vertex
tolerance	double	Tolerance of vertex (null-double for accurate vertex)
owner	pointer	Owning body (for non-acorn vertices) or shell (for acorn vertices)

```
union SHELL_OR_BODY_u
        (
        struct BODY_s                 *body;
        struct SHELL_s                *shell;
        };
typedef union SHELL_OR_BODY_u SHELL_OR_BODY;

struct VERTEX_s                        //  Vertex
        {
        int                            node_id;                  //  $d
        union  ATTRIB_GROUP_u          attributes_groups;        //  $p
        struct FIN_s                  *fin;                      //  $p
        struct VERTEX_s               *previous;                 //  $p
        struct VERTEX_s               *next;                     //  $p
        struct POINT_s                *point;                    //  $p
        double                         tolerance;                //  $f
        union  SHELL_OR_BODY_u         owner;                    //  $p
        };
```

typedef struct VERTEX_s   *VERTEX;

EDGE

Field name	**Type**	**Description**
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of edge and member_of_groups of edge
tolerance	double	Tolerance of edge (null-double for accurate edges)
fin	pointer	One of singly-linked ring of fins around edge
previous	pointer0	Previous edge in body or shell
next	pointer0	Next edge in body or shell
curve	pointer0	Curve of edge, zero for tolerant edge. If edge is accurate, but any of its vertices are tolerant, this will be a trimmed curve
next_on_curve	pointer0	Next in chain of edges sharing the curve of this edge
previous_on_curve	pointer0	Previous in chain of edges sharing the curve of this edge
owner	pointer	Owning body (for non-wireframe edges) or shell (for wireframe edges)

```
struct EDGE_s                       //  Edge
     {
     int                             node_id;                       //  $d
     union  ATTRIB_GROUP_u           attributes_groups;             //  $p
     double                          tolerance;                     //  $f
     struct FIN_s                   *fin;                           //  $p
     struct EDGE_s                  *previous;                      //  $p
     struct EDGE_s                  *next;                          //  $p
     union  CURVE_u                  curve;                         //  $p
     struct EDGE_s;                 *next_on_curve                  //  $p
     struct EDGE_s                  *previous_on_curve;             //  $p
     union                           owner;                         //  $p
     SHELL_OR_BODY_u
     };
typedef struct EDGE_s     *EDGE;
```

Associated Data

LIST

Field name	**Type**	**Description**
node_id	int	Zero
list_type	byte	Always 4
notransmit	logical	Ignore
owner	pointer	Owning part
next	pointer0	Ignore
previous	pointer0	Ignore
list_length	int	Length of list (>= 0)
block_length	int	Length of each block of list. Always 20
size_of_entry	int	Ignore
finger_index	int	Any integer between 1 and list->list_length (set to 1 if length is zero). Ignore
finger_block	pointer	Any block e.g. the first one. Ignore
list_block	pointer	Head of singly-linked chain of pointer list blocks

Lists only occur in part files as the list of attributes referenced by a part.

```
typedef enum
    {
    LIS_pointer    = 4
    }
LIS_type_t;

union LIS_BLOCK_u
    {
    struct POINTER_LIS_BLOCK_s        *pointer_block;
    };
typedef union LIS_BLOCK_u       LIS_BLOCK;

union LIST_OWNER_u
    {
    struct BODY_s                     *body;
```

```
        struct ASSEMBLY_s                  *assembly;
        struct WORLD_s                     *world;
        };
typedef union LIST_OWNER_u LIST_OWNER;

struct LIST_s                          //  List Header
        {
        int                                 node_id;                   //  $d
        LIS_type_t                          list_type;                 //  $u
        logical                             notransmit;                //  $l
        union LIST_OWNER_u                  owner;                     //  $p
        struct LIST_s                      *next;                      //  $p
        struct LIST_s                      *previous;                  //  $p
        int                                 list_length;               //  $d
        int                                 block_length;              //  $d
        int                                 size_of_entry;             //  $d
        int                                 finger_index;              //  $d
        union LIS_BLOCK_u                   finger_block;              //  $p
        union LIS_BLOCK_u                   list_block;                //  $p
        };
typedef struct LIST_s *LIST;
```

POINTER_LIS_BLOCK:

Field name	Type	Description
n_entries	int	Number of entries in this block (0 <= n_entries <= 20). Only the first block may have n_entries = 0.
index_map_offset	int	Must be set to 0
next_block	pointer0	Next pointer list block in chain
Entries[20]	pointer0	Pointers in block, those beyond n_entries must be zero

When the pointer_lis_block is used as the root node in a transmit file containing more than one part, the restriction n_entries <= 20 does not apply.

The index_map_offset field is used for Indexed Transmit; applications writing XT files must ensure this field is set to 0.

```
struct POINTER_LIS_BLOCK_s                    //  Pointer List
        {
        int                                    n_entries;              //  $d
        int                                   index_map_offset         // $d
        struct POINTER_LIS_BLOCK_s            *next_block;             //  $p
        void                                  *entries[ 1 ];           //  $p[]
        };
typedef struct POINTER_LIS_BLOCK_s *POINTER_LIS_BLOCK;
```

ATT_DEF_ID

Field name	Type	Description
string[]	char	String name e.g. "SDL/TYSA_COLOUR"

```
struct ATT_DEF_ID_s          //  name field type for attrib def.
        {
        char                                  String[1];               //  $c[]
        };
typedef struct ATT_DEF_ID_s *ATT_DEF_ID;
```

FIELD_NAMES

Field name	Type	Description
names[]	pointer	Array of field names – unicode or char

```
typedef union FIELD_NAME_u
        {
        struct CHAR_VALUES_s          *name
        struct UNICODE_VALUES_s       *uname
        };
      FIELD_NAME_t;


struct FIELD_NAME_s          //  attribute field name
```

```
    {
    union FIELD_NAME_u            names[1];                  //  $p[]
    };
typedef struct FIELD_NAME_s *FIELD_NAME;
```

ATTRIB_DEF

Field name	Type	Description
next	pointer0	Next attribute definition. This can be ignored, except in a partition transmit file.
identifier	pointer	Pointer to string name
type_id	int	Numeric id, e.g. 8001 for color. 9000 for user-defined attribute definitions
actions[8]	byte	Required actions on various events
field_names	pointer0	Names of fields (unicode or char)
legal_owners[14]	logical	Allowed owner types
fields[]	byte	Array of field types. Note that the number of fields is given by the length of the variable length part of this node, i.e. the integer following the node type in the transmit file.

The legal_owners array is an array of logicals determining which node types may own this type of attribute.

e.g. if faces are allowed attrib_def -> legal_owners [SCH_fa_owner] = true.

Note that if the file contains user fields, the ‘fields’ field of an attribute definition may contain extra values, set to zero. These are to be ignored.

The ‘actions’ field in an attribute definition defines the behaviour of the attribute when an event (rotate, scale, translate, reflect, split, merge, transfer, change) occurs. The actions are:

do_nothing	Leave attribute as it is
delete	Delete the attribute
transform	Transform the transformable fields (point, vector, direction, axis) by appropriate part of transformation
propagate	Copy attribute onto split-off node
keep_sub_dominant	Move attribute(s) from deleted node onto surviving node in a merge, but any such attributes already on the surviving node are deleted.
keep_if_equal	Keep attribute if present on both nodes being merged, with the same field values.
combine	Move attribute(s) from deleted node onto surviving node, in a merge

The PK attribute classes 1-7 correspond as follows:

	split	merge	transfer	change	Rotate	scale	translate	reflect
class 1	propagate	keep_equal	do_nothing	do_nothing	do_nothing	do_nothing	do_nothing	do_nothing
class 2	delete	delete	delete	delete	do_nothing	delete	do_nothing	do_nothing
class 3	delete	delete	delete	delete	Delete	delete	delete	delete
class 4	propagate	keep_equal	do_nothing	do_nothing	Transform	transform	transform	transform
class 5	delete	delete	delete	delete	Transform	transform	transform	transform
class 6	propagate	combine	do_nothing	do_nothing	do_nothing	do_nothing	do_nothing	do_nothing
class 7	propagate	combine	do_nothing	do_nothing	Transform	transform	transform	transform

Certain attribute definitions are created by Parasolid on startup, these are documented in an appendix.

```
typedef enum
    {
    SCH_rotate     = 0,
    SCH_scale      = 1,
    SCH_translate  = 2,
    SCH_reflect    = 3,
    SCH_split      = 4,
    SCH_merge      = 5,
    SCH_transfer   = 6,
    SCH_change     = 7,
    SCH_max_logged_event       //  last entry; value in $d[] code for
                               actions
```

```
        }
        SCH_logged_event_t;

typedef enum
        {
        SCH_do_nothing          = 0,
        SCH_delete              = 1,
        SCH_transform           = 2,
        SCH_propagate           = 3,
        SCH_keep_sub_dominant = 4,
        SCH_keep_if_equal       = 5,
        SCH_combine             = 6
        }
        SCH_action_on_fields_t;

typedef enum
        {
        SCH_as_owner  = 0,
        SCH_in_owner  = 1,
        SCH_by_owner  = 2,
        SCH_sh_owner  = 3,
        SCH_fa_owner  = 4,
        SCH_lo_owner  = 5,
        SCH_ed_owner  = 6,
        SCH_vx_owner  = 7,
        SCH_fe_owner  = 8,
        SCH_sf_owner  = 9,
        SCH_cu_owner  = 10,
        SCH_pt_owner  = 11,
        SCH_rg_owner  = 12,
        SCH_fn_owner  = 13,
        SCH_max_owner                 //  last entry; value in $l[] for
                                      .legal_owners
        } SCH_attrib_owners_t;
```

```
typedef enum
        {
        SCH_int_field          = 1,
        SCH_real_field         = 2,
        SCH_char_field         = 3,
        SCH_point_field        = 4,
        SCH_vector_field       = 5,
        SCH_direction_field    = 6,
        SCH_axis_field         = 7,
        SCH_tag_field          = 8,
        SCH_pointer_field      = 9,
        SCH_unicode_field      = 10
        } SCH_field_type_t;

struct ATTRIB_DEF_s              //  attribute definition
        {
        struct ATTRIB_DEF_s        *next;                          //  $p
        struct ATT_DEF_ID_s        *identifier;                    //  $p
        int                         type_id;                       //  $d
        SCH_action_on_fields_t      actions                        //  $u[8]
                                   [(int)SCH_max_logged_event];
        struct FIELD_NAMES_s       *field_names                    //  $p
        logical                     legal_owners                   //  $l[14]
                                    [(int)SCH_max_owner];
        SCH_field_type_t            fields[1];                     //  $u[]
        };
typedef struct ATTRIB_DEF_s    *ATTRIB_DEF;
```

ATTRIBUTE

Field name	**Type**	**Description**
node_id	int	Node-id
definition	pointer	Attribute definition
owner	pointer	Attribute owner
next	pointer0	Next attribute, group, or member_of_group
previous	pointer0	Previous ditto

next_of_type	pointer0	Next attribute of this type in this part
previous_of_type	pointer0	Previous attribute of this type in this part
fields[]	pointer	Fields, of type int_values etc. The number of fields is given by the length of the variable part of the node. There may be no fields.

The attributes of a node are chained using the next and previous pointers in the attribute. The attribute_groups pointer in the node points to the head of this chain. This chain also contains the member_of_groups of the node.

Attributes within the same part, with the same attribute definition, are chained together by the next_of_type and previous_of_type pointers. The part points to the head of this chain as follows. The attribute_chains pointer in the part points to a list which contains the heads of these attribute chains, one for each attribute definition which has attributes in the part. The list may be null.

Note that the attributes_groups chains in parts, groups and nodes contain the following types of node:

Part:	attributes and groups
Group:	attributes
Node:	attributes and member_of_groups

Fields of type ‘pointer’ can be used in Parasolid V12.0, but they are always transmitted as empty.

```
union ATTRIBUTE_OWNER_u
     {
    struct ASSEMBLY_s          *assembly;
    struct INSTANCE_s          *instance;
    struct BODY_s              *body;
    struct SHELL_s             *shell;
    struct REGION_s            *region;
    struct FACE_s              *face;
    struct LOOP_s              *loop;
    struct EDGE_s              *edge;
    struct FIN_s               *fin;
    struct VERTEX_s            *vertex;
    union  SURFACE_u            Surface;
    union  CURVE_u              Curve;
    struct POINT_s             *point;
    struct GROUP_s             *group;
    };
```

```
typedef union ATTRIBUTE_OWNER_u ATTRIBUTE_OWNER;

union FIELD_VALUES_u
        {
        struct INT_VALUES_s             *int_values;
        struct REAL_VALUES_s            *real_values;
        struct CHAR_VALUES_s            *char_values;
        struct POINT_VALUES_s           *point_values;
        struct VECTOR_VALUES_s          *vector_values;
        struct DIRECTION_VALUES_s       *direction_values;
        struct AXIS_VALUES_s            *axis_values;
        struct TAG_VALUES_s             *tag_values;
        struct UNICODE_VALUES_s         *unicode_values;
        };
typedef union FIELD_VALUES_u FIELD_VALUES;

struct ATTRIBUTE_s                      //  Attribute
        {
        int                                     node_id;                //  $d
        struct ATTRIB_DEF_s                    *definition;             //  $p
        union  ATTRIBUTE_OWNER_u                owner;                  //  $p
        union  ATTRIB_GROUP_u                   next;                   //  $p
        union  ATTRIB_GROUP_u                   previous;               //  $p
        struct ATTRIBUTE_s                     *next_of_type;           //  $p
        struct ATTRIBUTE_s                     *previous_of_type;       //  $p
        union  FIELD_VALUES_u                   fields[1];              //  $p[]
        };
typedef struct ATTRIBUTE_s *ATTRIBUTE;
```

INT_VALUES

values[]	int	Integer values

```
struct INT_VALUES_s                     //  Int values
        {
```

```
        int                     values[1];              //  $d[]
        };
typedef struct INT_VALUES_s *INT_VALUES;
```

REAL_VALUES

values[]	double	Real values

```
struct REAL_VALUES_s            //  Real values
        {
        double                  values[1];              //  $f[]
        };
typedef struct REAL_VALUES_s *REAL_VALUES;
```

CHAR_VALUES

values[]	char	Character values

```
struct CHAR_VALUES_s            //  Character values
        {
        char                    values[1];              //  $c[]
        };
typedef struct CHAR_VALUES_s *CHAR_VALUES;
```

UNICODE_VALUES

values[]	short	Unicode character values

```
struct UNICODE_VALUES_s                 //  Unicode character values
        {
        short                   values[1];              //  $w[]
        };
typedef struct UNICODE_VALUES_s *UNICODE_VALUES;
```

POINT_VALUES

values[]	vector	Point values

```
struct POINT_VALUES_s                  //  Point values
         {
        vector                          values[1];                                     // $v[]
        };
typedef struct POINT_VALUES_s *POINT_VALUES;
```

VECTOR_VALUES

values[]	vector	Vector values

```
struct VECTOR_VALUES_s                 //  Vector values
        {
        vector                          values[1];                                     //  $v[]
        };
typedef struct VECTOR_VALUES_s *VECTOR_VALUES;
```

DIRECTION_VALUES

values[]	vector	Direction values

```
struct DIRECTION_VALUES_s              //  Direction values
        {
        vector                          values[1];                                     //  $v[]
        };
typedef struct DIRECTION_VALUES_s *DIRECTION_VALUES;
```

AXIS_VALUES

values[]	vector	Axis values

Note that an axis takes up two vectors.

```
struct AXIS_VALUES_s                   //  Axis values
        {
        vector                          values[1];                                     //  $v[]
```

```
    };
typedef struct AXIS_VALUES_s *AXIS_VALUES;
```

TAG_VALUES

values[]	int	Integer tag values

The tag field type and the tag_values node are not available for use in user-defined attributes, they occur only in certain system attributes.

```
struct TAG_VALUES_s                 //  Tag values
    {
    int                 values[1];                  //  $t[]
    };
typedef struct TAG_VALUES_s *TAG_VALUES;
```

GROUP

Field name	**Type**	**Description**
node_id	int	Node-id
attributes_groups	pointer0	Head of chain of attributes of this group
owner	pointer	Owning part
next	pointer0	Next group or attribute
previous	pointer0	Previous group or attribute
type	byte	Type of node allowed in group
first_member	pointer0	Head of chain of member_of_group nodes in group

The groups in a part are chained by the next and previous pointers in a group. The attributes_groups pointer in the part points to the head of the chain. This chain also contains the attributes attached directly to the part - groups and attributes are intermingled in this chain, the order is not significant.

Each group has a chain of member_of_groups. These are chained together using the next_member and previous_member pointers. The first_member pointer in the group points to the head of the chain. Each member_of_group has an owning_group pointer which points back to the group.

Each member_of_group has an owner pointer which points to a node. Thus the group references its member nodes via the member_of_groups.

The member_of_groups which refer to a particular node are chained using the next and previous pointers in the member_of_group. The attributes_groups pointer in the node points to the head of this chain. This chain also contains the attributes attached to the node.

```
typedef enum
        {
        SCH_instance_fe   = 1,
        SCH_face_fe       = 2,
        SCH_loop_fe       = 3,
        SCH_edge_fe       = 4,
        SCH_vertex_fe     = 5,
        SCH_surface_fe    = 6,
        SCH_curve_fe      = 7,
        SCH_point_fe      = 8,
        SCH_mixed_fe      = 9,
        SCH_region_fe     = 10
        }  SCH_group_type_t;

struct GROUP_s                        //  Group
        {
        int                                   node_id;                       //  $d
        union   ATTRIB_GROUP_u                attributes_groups;             //  $p
        union   PART_u                        owner;                         //  $p
        union   ATTRIB_GROUP_u                next;                          //  $p
        union   ATTRIB_GROUP_u                previous;                      //  $p
        SCH_group_type_t                      type;                          //  $u
        struct  MEMBER_OF_GROUP_s            *first_member;                  //  $p
        };
typedef struct GROUP_s *GROUP;
```

MEMBER_OF_GROUP

Field name	Type	Description
dummy_node_id	int	Entity label
owning_group	pointer	Owning group
owner	pointer	Referenced member of group
next	pointer0	Next attribute, group or member_of_group
previous	pointer0	Previous ditto

next_member	pointer0	Next member_of_group in this group
previous_member	pointer0	Previous ditto

```
union GROUP_MEMBER_u
     {
     struct INSTANCE_s              *instance;
     struct FACE_s                  *face;
     struct REGION_s                *region;
     struct LOOP_s                  *loop;
     struct EDGE_s                  *edge;
     struct VERTEX_s                *vertex;
     union  SURFACE_u                surface;
     union  CURVE_u                  curve;
     struct POINT_s                 *point;
     };
typedef union GROUP_MEMBER_u GROUP_MEMBER;

struct MEMBER_OF_GROUP_s          //  Member of group
     {
     int                                dummy_node_id;          //  $d
     struct GROUP_s                    *owning_group;           //  $p
     union  GROUP_MEMBER_u              owner;                  //  $p
     union  ATTRIB_GROUP_u              next;                   //  $p
     union  ATTRIB_GROUP_u              previous;               //  $p
     struct MEMBER_OF_GROUP_s          *next_member;            //  $p
     struct MEMBER_OF_GROUP_s          *previous_member;        //  $p
     };
typedef struct MEMBER_OF_GROUP_s *MEMBER_OF_GROUP;
```

Node Types

Node name	**Node type**	**Visible at PK**	**Has node-id**
ASSEMBLY	10	Yes	No
INSTANCE	11	Yes	Yes
BODY	12	Yes	No
SHELL	13	Yes	Yes
FACE	14	Yes	Yes
LOOP	15	Yes	Yes
EDGE	16	Yes	Yes
FIN	17	Yes	No
VERTEX	18	Yes	Yes
REGION	19	Yes	Yes
POINT	29	Yes	Yes
LINE	30	Yes	Yes
CIRCLE	31	Yes	Yes
ELLIPSE	32	Yes	Yes
INTERSECTION	38	Yes	Yes
CHART	40	No	
LIMIT	41	No	
BSPLINE_VERTICES	45	No	
PLANE	50	Yes	Yes
CYLINDER	51	Yes	Yes
CONE	52	Yes	Yes
SPHERE	53	Yes	Yes
TORUS	54	Yes	Yes
BLENDED_EDGE	56	Yes	Yes
BLEND_BOUND	59	No	
OFFSET_SURF	60	Yes	Yes

SWEPT_SURF	67	Yes	Yes
SPUN_SURF	68	Yes	Yes
LIST	70	Yes	Yes
POINTER_LIS_BLOCK	74	No	
ATT_DEF_ID	79	No	
ATTRIB_DEF	80	Yes	No
ATTRIBUTE	81	Yes	Yes
INT_VALUES	82	No	
REAL_VALUES	83	No	
CHAR_VALUES	84	No	
POINT_VALUES	85	No	
VECTOR_VALUES	86	No	
AXIS_VALUES	87	No	
TAG_VALUES	88	No	
DIRECTION_VALUES	89	No	
GROUP	90	Yes	Yes
MEMBER_OF_GROUP	91	No	
UNICODE_VALUES	98	No	
FIELD_NAMES	99	No	
TRANSFORM	100	Yes	Yes
WORLD	101	No	
KEY	102	No	
PE_SURF	120	Yes	Yes
INT_PE_DATA	121	No	
EXT_PE_DATA	122	No	
B_SURFACE	124	Yes	Yes
SURFACE_DATA	125	No	
NURBS_SURF	126	No	

KNOT_MULT	127	No	
KNOT_SET	128	No	
PE_CURVE	130	Yes	Yes
TRIMMED_CURVE	133	Yes	Yes
B_CURVE	134	Yes	Yes
CURVE_DATA	135	No	
NURBS_CURVE	136	No	
SP_CURVE	137	Yes	Yes
GEOMETRIC_OWNER	141	No	
HELIX_CU_FORM	163	No	
HELIX_SU_FORM	184	No	

Node Classes

Node class name	**Node class**
GEOMETRY	1003
PART	1005
SURFACE	1006
SURFACE_OWNER	1007
CURVE	1008
CURVE_OWNER	1010
POINT_OWNER	1011
LIS_BLOCK	1012
LIST_OWNER	1013
ATTRIBUTE_OWNER	1015
GROUP_OWNER	1016
GROUP_MEMBER	1017
FIELD_VALUES	1018
ATTRIB_GROUP	1019
TRANSFORM_OWNER	1023
PE_DATA	1027
PE_INT_GEOM	1028
SHELL_OR_BODY	1029
FIELD_NAME	1037

System Attribute Definitions

All system attribute definitions are of class 1.

Hatching

Identifier	SDL/TYSA_HATCHING	
Type_id	8003	
Entity types	face	
Fields	real	real 1
		real 2
		real 3
		real 4
	integer	Hatching type
Set by	Application	
Used by	Parasolid hidden line and wireframe images	

For **planar hatching -** the four real values define the hatch orientation as a vector and a spacing between consecutive planes.

For **radial hatching -** the first three real values define the spacing of the hatch lines. The fourth value is not used.

For **parametric hatching -** the first two real values define the spacing in *u* and *v* respectively. The last two values are not used.

Planar Hatch

Identifier	SDL/TYSA_PLANAR_HATCH		
Type_id	8021		
Entity types	face		
Fields	real	x component	‘direction’ or plane normal
		y component	
		z component	
		‘pitch’ or separation	
		x component	position vector
		y component	
		z component	
Set by	Application		
Used by	Parasolid hidden line and wireframe images		

For planar hatching, an attribute with this definition takes precedence over an attribute with the SDL/TYSA_HATCHING definition, if a face has both types of attribute attached.

Radial Hatch

Identifier	SDL/TYSA_RADIAL_HATCH	
Type_id	8027	
Entity types	face	
Fields	real	radial around
		radial along
		radial about
		radial around start
		radial along start
		radial about start
Set by	Application	
Used by	Parasolid hidden line and wireframe images	

For radial hatching, an attribute with this definition takes precedence over an attribute with the SDL/TYSA_HATCHING definition, if a face has both types of attribute attached.

Parametric Hatch

Identifier	SDL/TYSA_PARAM_HATCH	
Type_id	8028	
Entity types	face	
Fields	real	u spacing
		v spacing
		u start
		v start
Set by	Application	
Used by	Parasolid hidden line and wireframe images	

For parametric hatching, an attribute with this definition takes precedence over an attribute with the SDL/TYSA_HATCHING definition, if a face has both types of attribute attached.

Density Attributes

There are density attributes for each of regions, faces, edges and vertices in addition to the system attribute for density of a body.

The region/face/edge/vertex attributes will be taken into account when finding the mass, centre of gravity and moment of inertia of a body or of the entity to which the attribute is attached:

- The mass of a region will not include that of any of its faces or edges, and the same applies to faces and edges and their boundaries.
- A void region will always have zero mass whatever its density and a solid region will inherit its density from the body if it does not have a density of its own.
- The default density for faces, edges and vertices is always zero.

Density (of a body)

Identifier	SDL/TYSA_DENSITY	
Type_id	8004	
Entity types	body	
Fields	real	Density
	string	Units
Set by	Application	
Used by	Parasolid Mass Properties - calculation of mass	

A body without a density attribute is taken to have, by default, a density of 1.0.

The character field units is not used by Parasolid but it can be set and read by the application.

- ### *Region Density*

Identifier	SDL/TYSA_REGION_DENSITY

Type_id	8023	
Entity types	region	
Fields	real	Density of region
	string	Units
Set by	Application	
Used by	Parasolid Mass Properties - calculation of mass	

This attribute only makes sense for solid regions; void regions always have a mass of zero.

A solid region without a density attribute is taken to have, by default, the same density as its owning body.

The character field units is not used by Parasolid but it can be set and read by the user.

Face Density

Identifier	SDL/TYSA_FACE_DENSITY	
Type_id	8024	
Entity types	face	
Fields	real	Density of face
	string	Units
Set by	Application	
Used by	Parasolid Mass Properties - calculation of mass	

The value of this attribute is treated as a mass per unit area.

A mass will be calculated for a face only when a face possesses this attribute. In all other cases the mass of a face is not defined.

The character field units is not used by Parasolid but it can be set and read by the user.

- ### *Edge Density*

Identifier	SDL/TYSA_EDGE_DENSITY	
Type_id	8025	
Entity types	edge	
Fields	real	Density of edge
	string	Units
Set by	Application	
Used by	Parasolid Mass Properties - calculation of mass	

The value of this attribute is treated as a mass per unit length.

A mass will be calculated for an edge only when an edge possesses this attribute. In all other cases the mass of an edge is not defined.

The character field units is not used by Parasolid but it can be set and read by the user.

Vertex Density

Identifier	SDL/TYSA_VERTEX_DENSITY

Type_id	8026	
Entity types	vertex	
Fields	real	Mass of vertex
	string	Units
Set by	Application	
Used by	Parasolid Mass Properties - calculation of mass	

The value of this attribute is treated as a point mass.

A mass will be calculated for a vertex only when a vertex possesses this attribute. In all other cases the mass of a vertex is not defined.

The character field units is not used by Parasolid but it can be set and read by the user.

Region

Identifier	SDL/TYSA_REGION	
Type_id	8013	
Entity types	face	
Fields	string	Unused
Set by	Application	
Used by	Parasolid hidden line images	

Regional data will allow the application to analyze a hidden-line picture for distinct regions in the 2D view.

Colour

Identifier	SDL/TYSA_COLOUR		
Token	8001		
Entity types	face edge		
Fields	real	Red value	These three values should be in the range 0.0 to 1.0
		Green value	
		Blue value	
Set by	Application		
Used by	Application		

Reflectivity

Identifier	SDL/TYSA_REFLECTIVITY	
Token	8014	
Entity types	face	
Fields	real	Coefficient of specular reflection
		Proportion of colored light in highlights
		Coefficient of diffuse reflection
		Coefficient of ambient reflection
	integer	Reflection power
Set by	Application	
Used by	Application	

The attribute types for Reflectivity and Translucency are also used by the Parasolid routine RRPIXL, but the use of this routine is not recommended.

• Translucency

Identifier	SDL/TYSA_TRANSLUCENCY		
Token	8015		
Entity types	face		
Fields	real	Transparency coefficient	range 0.0 to 1.0, where 0 is opaque and 1 is transparent
Set by	Application		
Used by	Application		

Name

Identifier	SDL/TYSA_NAME	
Token	8017	
Entity types	assembly, body, instance, shell, face, loop, edge, vertex, group, surface, curve, point	
Fields	string	Name of entity
Set by	Application	
Used by	Application	

Entities read into Parasolid from a Romulus 6.0 transmit file have their names held in name attributes. Only entities to which the user has given names will be treated in this way.

Incremental faceting

Identifier	SDL/TYSA_INCREMENTAL_FACETTING	
Token	TYSAIF	
Entity types	face	
Fields	string	Unused
Set by	Parasolid incremental faceting/Application	
Used by	Parasolid incremental faceting/Application	

Transparency

Identifier	SDL/TYSA_TRANSPARENCY	
Token	TYSATY	
Entity types	Body, face	
Fields	integer	Non-zero transparency coefficient value is transparent
Set by	Application	
Used by	Parasolid hidden-line drawings	

A body may be rendered transparent if it has an attached transparency attribute with a non-zero transparency coefficient

Non-mergeable edges

Identifier	SDL/TYSA_NO_MERGE
Token	TYSAEN
Entity types	edge

Fields	string	Unused
Set by	Application	
Used by	Parasolid modeling operations	

If an edge has an attribute of this definition attached, it indicates that the edge should not be merged in any modelling operations.

Group merge behavior

Identifier	SDL/TYSA_GROUP_MERGE	
Token	TYSAGM	
Entity types	group	
Fields	string	Unused
Set by	Application	
Used by	Parasolid modeling operations	

If a group has an attribute of this definition attached, it indicates that alternative behavior should be used if an entity in the group is merged with an entity not in that group.