Digital Imaging and Communications in Medicine (DICOM)

Supplement 132: Surface Segmentation Storage SOP Class

Prepared by:

DICOM Standards Committee, Working Group 17 (3D) and 24 (Surgery)

1300 N. 17th Street, Suite 1752

Rosslyn, Virginia 22209 USA

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Table of Contents

Scope and Field

The domain of this Supplement is surface segmentation instances created during acquisition, post-processing, interpretation and treatment. The existing Segmentation SOP Class is limited to voxel segmentation. A growing number of applications perform surface segmentations and work with the resulting surfaces for which there is no widely used representation within DICOM. The Supplement introduces a new Surface Mesh Module that is used to encode the surface segmentation data and will be used for other surface representations. The Surface Segmentation Storage SOP Class can specify a surface derived from any DICOM modality or non-DICOM measurement technique. It can also be used to specify designed surfaces.

This IOD can be used to encode tissue segmentation, functional segmentation, and artifact identification for quantification or visualization.

The supplement supports the following features:

1. The segmentation shapes are encoded in a polygonal representation of the surface.
2. More than one segmentation object is supported per SOP instance.
3. Position and orientation are defined within the coordinate system specified by the Frame of Reference UID.
4. A Spatial Registration Instance is used to map surfaces onto other Instances, e.g. images, for display.
5. Surface segmentation is not slice based, unlike voxel segmentations.

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Changes to NEMA Standards Publication PS 3.2-2006

Digital Imaging and Communications in Medicine (DICOM)

Part 2: Conformance

105 **Item: Add SOP Class to Table A.1-2**

Table A.1-2
UID VALUES

UID Value	UID NAME	Category
…		
1.2.840.10008.5.1.4.1.1.66.5	Surface Segmentation Storage	Transfer
…		

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Changes to NEMA Standards Publication PS 3.3-2006

115 # Digital Imaging and Communications in Medicine (DICOM)

Part 3: Information Object Definitions

Item: Add in Section 7, Figure 7-1 a

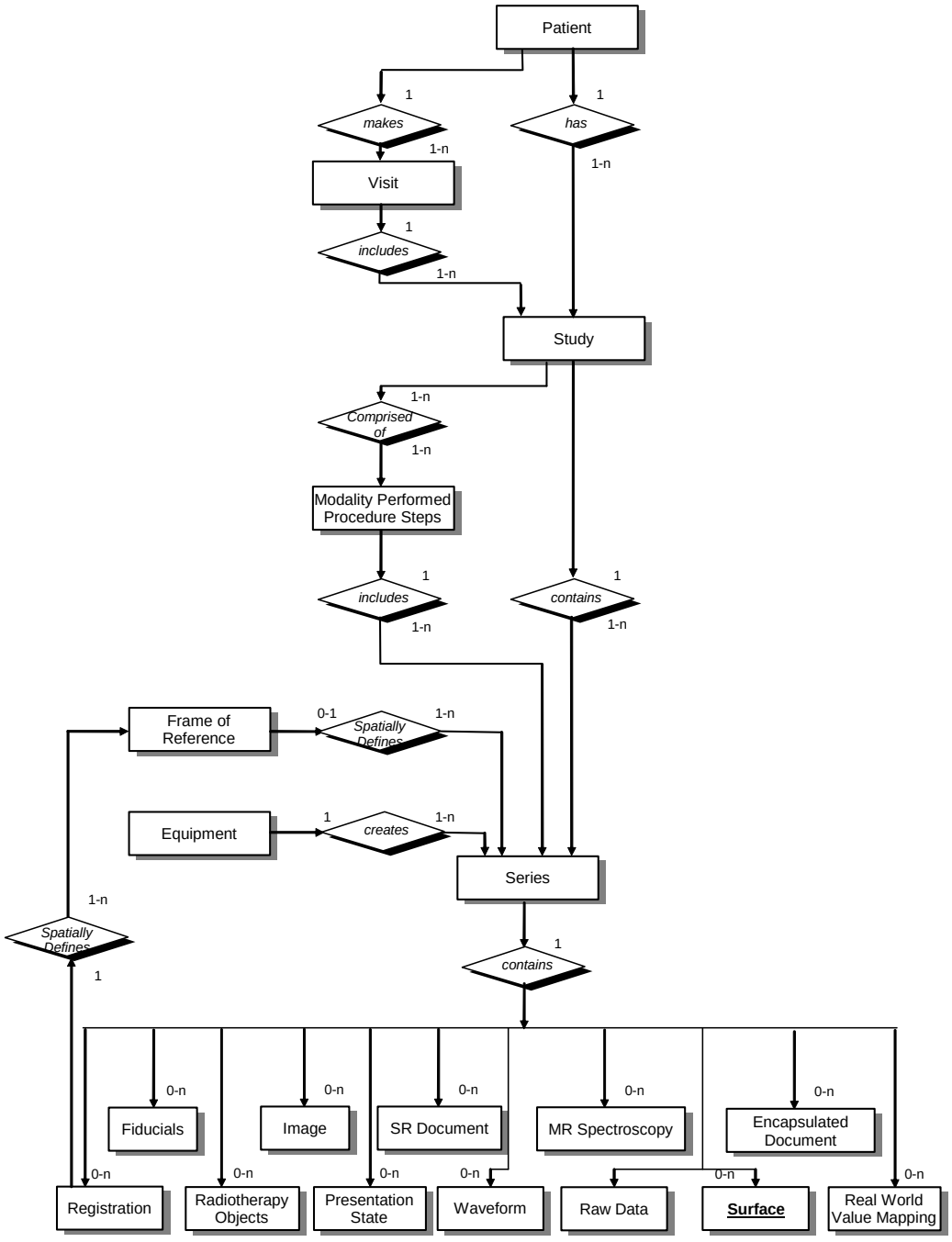

Figure 7-1a
DICOM MODEL OF THE REAL-WORLD

Item: Add in Section 7, Figure 7-2 a

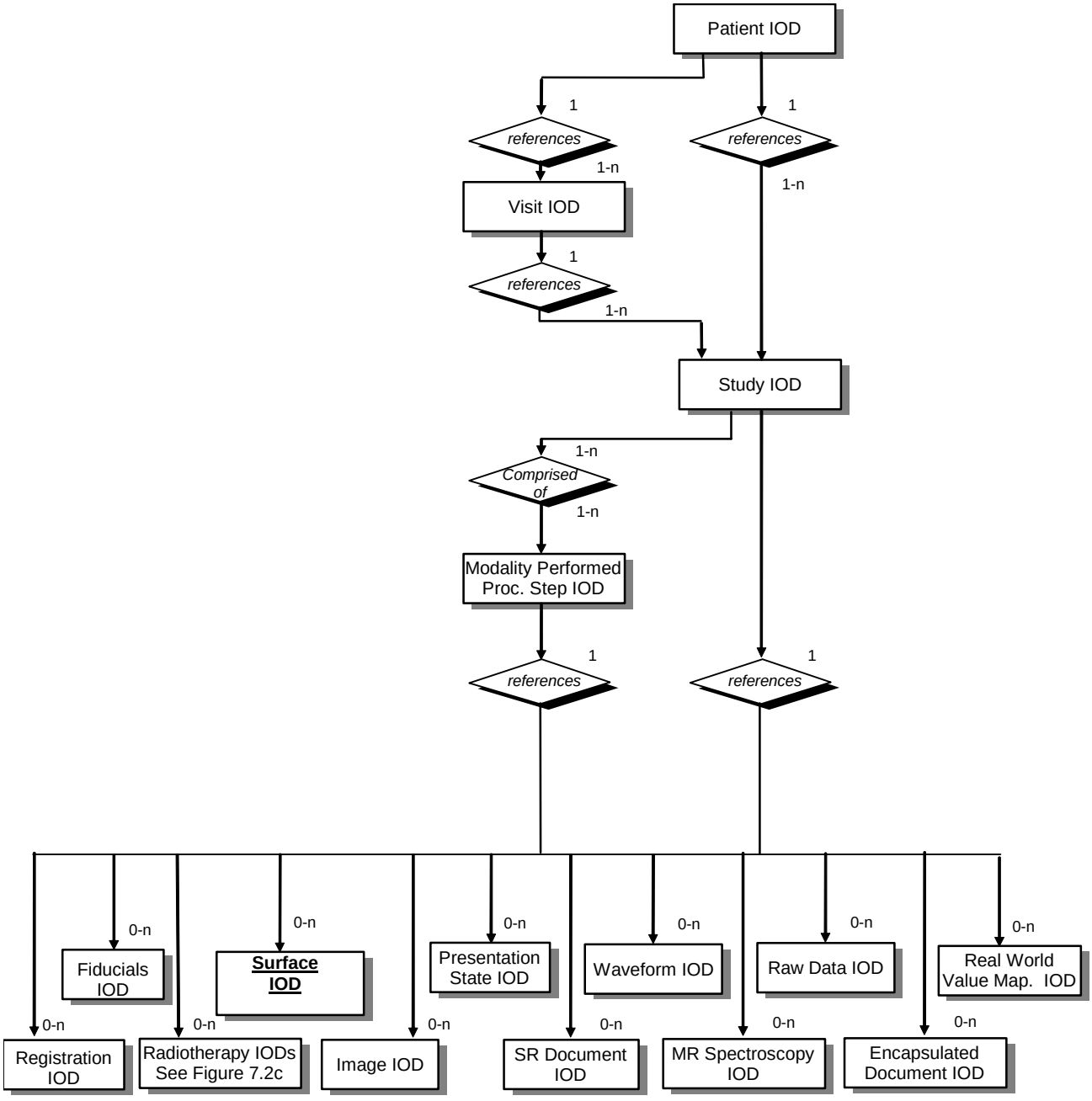

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Figure 7-2a
DICOM INFORMATION MODEL

Item: Modify Table 10-3 as shown

10.3 IMAGE SOP INSTANCE REFERENCE MACRO

130 **Table 10-3**
IMAGE SOP INSTANCE REFERENCE MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Referenced SOP Class UID	(0008,1150)	1	Uniquely identifies the referenced SOP Class.
Referenced SOP Instance UID	(0008,1155)	1	Uniquely identifies the referenced SOP Instance.
Referenced Frame Number	(0008,1160)	1C	Identifies the frame numbers within the Referenced SOP Instance to which the reference applies. The first frame shall be denoted as frame number 1. Note: This Attribute may be multi-valued. Required if the Referenced SOP Instance is a multi-frame image and the reference does not apply to all frames, and Referenced Segment Number (0062,000B) is not present.
Referenced Segment Number	(0062,000B)	1C	Identifies the Segment Number to which the reference applies. Required if the Referenced SOP Instance is a Segmentation **or Surface Segmentation** and the reference does not apply to all segments and Referenced Frame Number (0008,1160) is not present.

Item: Add the following Section.

10.X ALGORITHM IDENTIFICATION MACRO

Table 10-X describes the Attributes for encoding the algorithm used to create or derive a SOP Instance. An algorithm is described by the Algorithm Family, a specific Algorithm Name, and an Algorithm Version. A character string containing parameters that were used in the algorithm can be included.

Table 10-X
ALGORITHM IDENTIFICATION MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Algorithm Family Code Sequence	(0066,002F)	1	The family of algorithm(s) that best describes the software algorithm used. Only one item shall be permitted in the sequence.
>Include 'Code Sequence Macro Table 8.8-1'			*Context ID may be defined in the macro invocation.*
Algorithm Name Code Sequence	(0066,0030)	3	The code assigned by a manufacturer to a specific software algorithm. Only one item shall be permitted in the sequence.
>Include 'Code Sequence Macro Table 8.8-1'			*No Baseline Context ID is defined.*
Algorithm Name	(0066,0036)	1	The name assigned by a manufacturer to a specific software algorithm.
Algorithm Version	(0066,0031)	1	The software version identifier assigned by a manufacturer to a specific software algorithm.
Algorithm Parameters	(0066,0032)	3	The input parameters used by a manufacturer to configure the behavior of a specific software algorithm.

Item: Add in Section A.1.2, Figure A.1-1

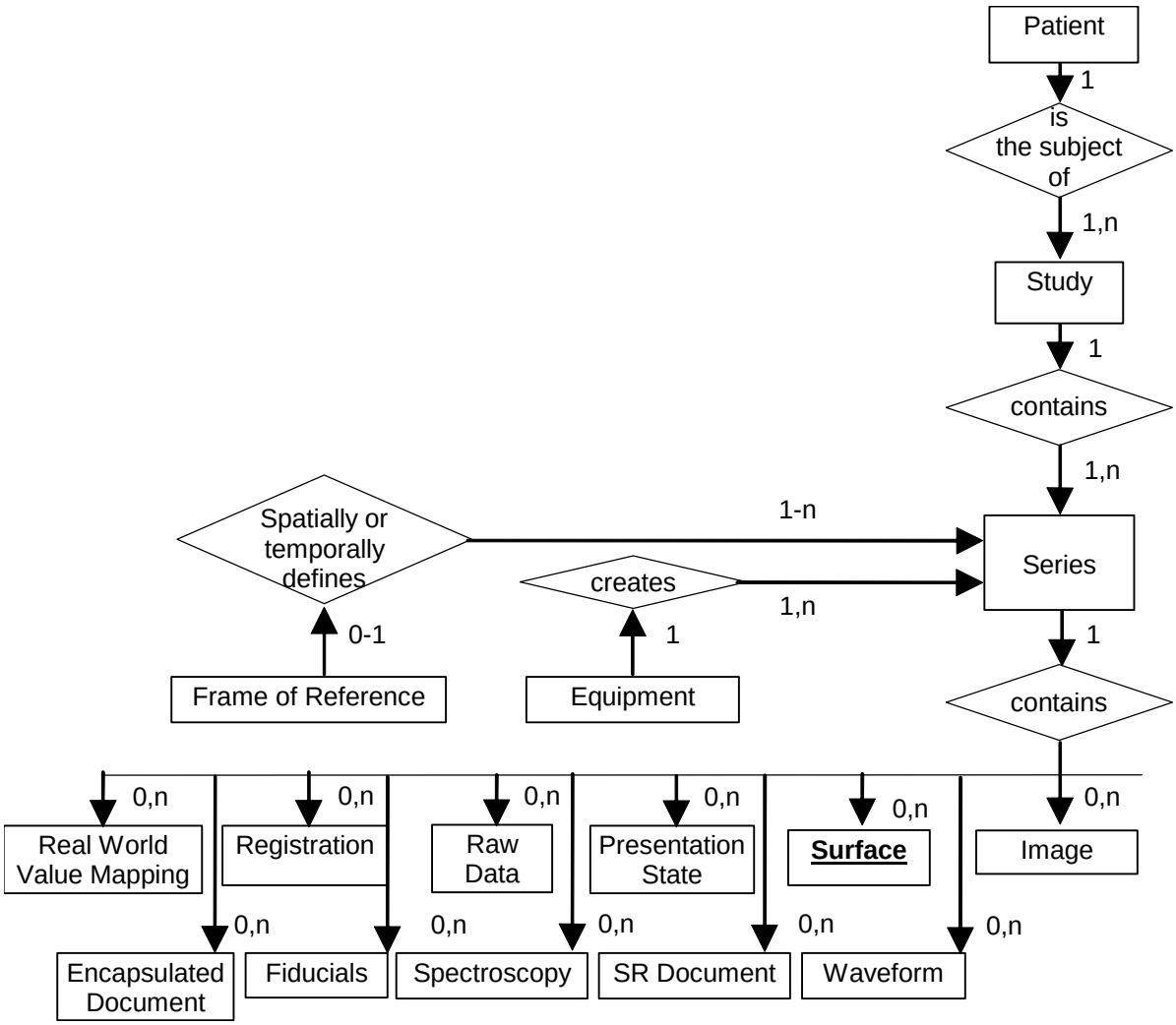


Figure A.1-1
DICOM COMPOSITE INSTANCE IOD INFORMATION MODEL

A.1.2.X SURFACE IE

The Surface IE defines the Attributes that describe a surface in a spatial coordinate system. A surface is defined by its shape and can be further defined by normals on that shape. The surface may be reconstructed from either spatial scans (e.g. laser scanners) or based on images. A surface is described by its finite volume and manifold property, gray scale and color mapping characteristics, presentation type, opacity, and modality specific characteristics.

A surface is related to a single Series.

Item: Add in Section A.1.4, rows and column to Table A.1-2

A.1.4 Overview of the Composite IOD Module Content

IODs Modules	Surf. Seg.
Patient	M
Specimen	U
Clinical Trial Subject	U
General Study	M
Patient Study	U
Clinical Trial Study	U
General Series	M
Segmentation Series	M
Clinical Trial Series	U
Frame Of Reference	M
General Equipment	M
Enhanced General Equipment	M
Surface Segmentation	M
Surface Mesh	M
Common Instance Reference	C
SOP Common	M

Item: Add in the following new section in Annex A

A.X SURFACE SEGMENTATION INFORMATION OBJECT DEFINITION

A.X.1 Surface Segmentation IOD Description

The Surface Segmentation Information Object Definition (IOD) specifies a polygonal representation of a three dimensional surface. A Surface Segmentation SOP Instance may reference an externally defined coordinate system via the Frame of Reference UID or establish its own coordinate system.

The Surface Segmentation IOD does not include the full set of acquisition parameters of the referenced images, e.g. cardiac phase. An application rendering or processing the segmentation may need to access the referenced images for such information.

One Segmented Surface Instance can contain one or more surfaces. Each surface within a Segmented Surface IE is represented as a single object.

A.X.2 Surface Segmentation IOD Entity-Relationship Model

The E-R Model in Section A.1.2 depicts those components of the DICOM Information Model that directly reference the Surface Segmentation IOD. The Surface Segmentation uses a polygonal surface mesh representation to define the contained surfaces.

A.X.3 Surface Segmentation IOD Module Table

Table A.X-1
SURFACE SEGMENTATION IOD MODULES

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Specimen	C.7.1.2	U
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Segmentation Series	C.8.20.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Surface	Surface Segmentation	C.8.X.1	M
	Surface Mesh	C.X.1	M
	Common Instance Reference	C.12.2	C – Required if the surface has been derived from another SOP Instance
	SOP Common	C.12.1	M

Item: Add in the following new sections in C.8

C.8.X Surface Segmentation

This section describes the specific modules for the Surface Segmentation IOD.

185 ### C.8.X.1 Surface Segmentation Module

Table C.8.X-1 defines the general Attributes of the Surface Segmentation Module.

Table C.8.X-1
SURFACE SEGMENTATION MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Include 'Content Identification Macro' Table 10-12			
Segment Sequence	(0062,0002)	1	Describes the segments that are contained within the data. One or more Items shall be present.
>Segment Number	(0062,0004)	1	Identification number of the segment. Uniquely identifies a segment within the SOP Instance.
>Segment Label	(0062,0005)	1	User-defined label identifying this segment. This may be the same as the Code Meaning (0008,0104) of the Segmented Property Type Code Sequence (0062,000F).
>Segment Description	(0062,0006)	3	User-defined description for this segment.
>Segment Algorithm Type	(0062,0008)	1	Type of algorithm used to generate the segment. Enumerated Values are: AUTOMATIC = calculated segment SEMIAUTOMATIC = calculated segment with user assistance MANUAL = user-entered segment
>*Include 'General Anatomy Mandatory Macro' Table 10-5*			
>Segmented Property Category Code Sequence	(0062,0003)	1	Sequence defining the general category of this segment. This sequence shall contain one item.
>>*Include 'Code Sequence Macro' Table 8.8-1*		*Baseline Context ID is 7150.*	
>Segmented Property Type Code Sequence	(0062,000F)	1	Sequence defining the specific property type of this segment. This sequence shall contain one item.
>>*Include 'Code Sequence Macro' Table 8.8-1*			
>Surface Count	(0066,002A)	1	The number of surfaces which comprise this segment. Shall be greater than zero.
>Referenced Surface Sequence	(0066,002B)	1	Sequence referencing the surfaces composed to construct this segment. The number of Items shall equal the value of Surface Count (0066,002A).
>>Referenced Surface Number	(0066,002C)	1	Identifies the Surface Number (0066,0003) within the Surface Sequence (0066,0002) to which this reference applies.

>>Segment Surface Generation Algorithm Identification Sequence	(0066,002D)	1	A description of how this segment surface was derived.
>>>Include 'Algorithm Identification Macro' Table 10-X			*Baseline Context ID for Algorithm Family Code Sequence (0066,002F) is 7162.*
>>Segment Surface Source Instance Sequence	(0066,002E)	2	A Sequence that identifies the set of Instances by their SOP Class/Instance pair that were used to derive this segment surface. Zero or more items shall be included in this Sequence.
>>>Include 'Image SOP Instance Reference Macro' Table C.10-3			

Item: Add in the following new sections in C

C.X Common Surface IE Modules

This section describes the specific modules for the Surface IE.

C.X.1 Surface Mesh Module

Table C.X-1 specifies the Attributes of the Surface Mesh Module.

Table C.X-1
SURFACE MESH MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Number of Surfaces	(0066,0001)	1	Number of surfaces contained in the Instance. Shall be 1 or more. Shall be the same as the number of Items in Surface Sequence (0066,0002).
Surface Sequence	(0066,0002)	1	The surfaces that are described within the data. There shall be Number of Surfaces (0066,0001) Items in the sequence. See C.X.1.1.1.
>Surface Number	(0066,0003)	1	Identification number of the surface. Uniquely identifies a surface within this SOP instance. Shall start at a value of 1, and increase monotonically by 1.
>Surface Comments	(0066,0004)	3	User-defined comments describing the surface.
>Surface Processing	(0066,0009)	2	Specifies whether the surface has been modified subsequent to the original generation of the surface. Enumerated Values: YES NO See C.X.1.1.2.
>Surface Processing Ratio	(0066,000a)	2C	The Ratio of Remaining points to Original points after processing. Required if Surface Processing (0066,0009) is YES.
>Surface Processing Description	(0066,000b)	3	A textual description of the surface processing performed.
>Surface Processing Algorithm Identification Sequence	(0066,0035)	2C	Describes the processing method. Required if Surface Processing (0066,0009) is YES.
>>Include 'Algorithm Identification Macro' Table 10-X			*Baseline Context ID for Algorithm Family Code Sequence (0066,002F) is 7162.*

>Recommended Display Grayscale Value	(0062,000C)	1	A default single gray unsigned value in which it is recommended that the maximum pixel value in this surface be rendered on a monochrome display. The units are specified in P-Values from a minimum of 0000H (black) up to a maximum of FFFFH (white). Note: The maximum P-Value for this Attribute may be different from the maximum P-Value from the output of the Presentation LUT, which may be less than 16 bits in depth.
>Recommended Display CIELab Value	(0062,000D)	1	A default triplet value in which it is recommended that the surface be rendered on a color display. The units are specified in PCS-Values, and the value is encoded as CIELab. See C.10.7.1.1
>Recommended Presentation Opacity	(0066,000c)	1	Specifies the opacity in which it is recommended that the surface be rendered. See C.X.1.1.3.
>Recommended Presentation Type	(0066,000d)	1	Specifies the presentation type in which it is recommended that the surface be rendered. See C.X.1.1.3.
>Finite Volume	(0066,000e)	1	Indicates, whether the surface represents a solid (“waterproof”) object with an outside and an inside. Enumerated Values: YES = Contains a finite volume NO = Does not contain a finite volume UNKNOWN = Might or might not contain a finite volume See C.X.1.1.4.
>Manifold	(0066,0010)	1	Indicates whether the surface is describing an n-1 dimensional manifold in the underlying n-dimensional vector space. Enumerated Values: YES = Manifold in every point NO = Does contain non-manifold points UNKNOWN = Might or might not contain non-manifold points See C.X.1.1.5.
>Surface Points Sequence	(0066,0011)	1	The point positions representing vertices of the surface. Only one item shall be permitted in the sequence.

>> Include 'Points Macro' Table C.X-2			
>Surface Points Normals Sequence	(0066,0012)	2	The normals on the surface for each point. Only one item shall be permitted in the sequence. See C.X.1.1.6.
>>Include 'Vectors Macro' Table C.X-3			*The Number of Vectors (0066,001E) shall equal Number of Points (0066,0015) in this Surface Sequence Item..* *The Vector Dimensionality (0066,001F) shall be 3.* *If Finite Volume (0066,000e) is YES, the normals of the vertices shall point toward the outside of the object. If Finite Volume (0066,000e) is not YES, the direction of the normals shall be consistent where possible.*
>Surface Mesh Primitives Sequence	(0066,0013)	1	Only one item shall be permitted in the sequence.
>>Include 'Surface Mesh Primitives Macro Table' C.X-4			*The primitives' indices shall not exceed Number of Points (0066,0015) in this Surface Sequence Item..*

C.X.1.1 Surface Mesh Module Attribute Descriptions

C.X.1.1.1 Surface Sequence

Surface Sequence (0066,0002) describes individual surfaces. There is no requirement that a surface be contiguous. For example, both kidneys could be described as a single surface consisting of 2 non-contiguous areas.

C.X.1.1.2 Surface Processing

Surface Processing refers to methods of surface modification such as smoothing operations, which remove redundant vertices, or decimation which will modify the resolution of the surface. If a surface has been subject to processing, a description of the process may be provided in Surface Processing Description (0066,000b).

C.X.1.1.3 Recommended Presentation

Recommended Presentation Opacity (0066,000c) is a fraction between 0.0 and 1.0 encoded as a float value representing the percentage of transmission through the surface.

The Recommended Presentation Type (0066,000d) attribute provides guidance as to the default presentation of the Surface. Defined terms are:

SURFACE — Render the surface as a solid, applying the opacity as specified in the Recommended Presentation Opacity (0066,000c) attribute.

WIREFRAME — Represent the surface as a series of lines connecting the vertices to form the defined primitive faces.

POINTS — Represent the surface as a cloud of points.

C.X.1.1.4 Finite Volume

The Finite Volume attribute (0066,000e) shall be YES when the surface mesh generated by the primitives is topologically closed and has an inside and an outside. A surface mesh is closed if it has no rim (every facet has a neighboring facet along each edge). Figure C.X.1.1-1 shows a surface that is not closed on the left, and a closed and waterproof version of the same shape on the right:

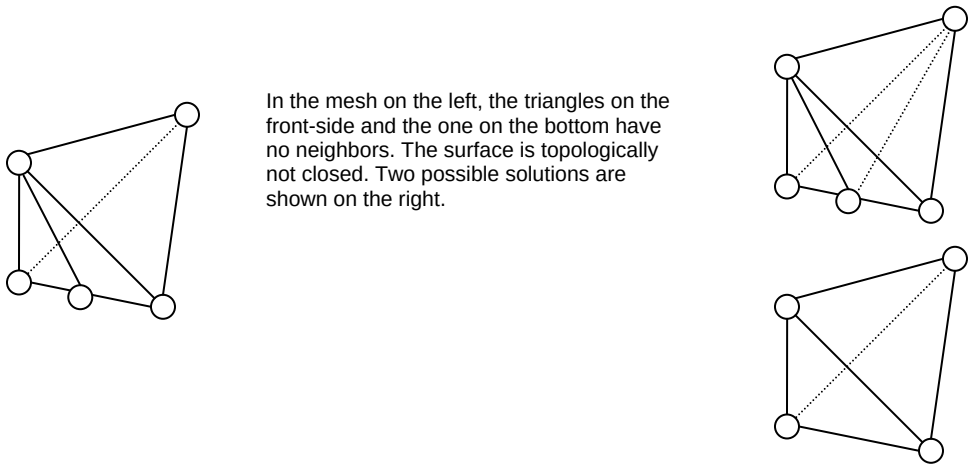


Figure C.X.1.1-1 - Finite Volume Illustration

Not all closed surfaces contain a finite volume, for example if the surface self-intersects. Such surfaces do not contain a finite volume. A surface is not required to be contiguous.

A value of NO indicates that the surface is not closed.

A value of UNKNOWN indicates that the transmitting application did not determine if the surface is closed.

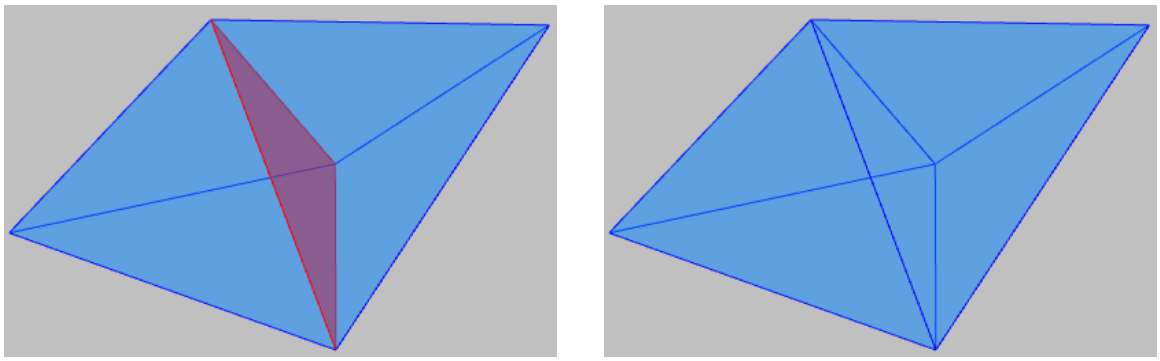
C.X.1.1.5 Manifold

The Manifold attribute (0066,0010) shall be YES when the surface mesh is a manifold.

A surface embedded into an n-dimensional vector space is called an n-1 manifold if it resembles an n-1 dimensional Euclidian space in a neighborhood of every point lying on the surface. This means that every point has a neighborhood for which there exists a homeomorphism mapping that neighborhood to the n-1 dimensional Euclidian space.

A sphere in 3-space is a 2-dimensional manifold: Every point has a neighborhood that looks like a plane.

Figure C.X.1.1-2 shows examples of a surface that is not a manifold is given below:



The two tetrahedrons in the left image share one face and three edges (marked red). The points along the shared edges are non-manifold, since the edges belong to three triangles: The neighbors of each point on these edges are lying in three different planes.

The same shape can be modeled with a manifold surface by leaving out the triangle separating the tetrahedrons Doubled vertices spanning two topologically unconnected tetrahedrons would also result in manifold surfaces.

Figure C.X.1.1-2 - Manifold Illustration

A value of NO indicates that the surface is not a manifold.

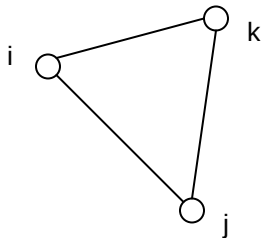
A value of UNKNOWN indicates that the transmitting application did not determine if the surface is a manifold.

C.X.1.1.6 Surface Points Normals Sequence

The Surface Points Normals Sequence (0066,0012) attribute provides an explicit normal vector for each point in the Surface Points Sequence (0066,0011) in the Point Coordinates Data (0066,0016) attribute.

If an Item of the Surface Points Normals Sequence (0066,0012) is present the normal for a primitive may be computed by combining the normals for each vertex making up the primitive.

If an Item of the Surface Points Normals Sequence (0066,0012) is not present the normal for a primitive shall be computed by computing the cross product of two segments of the primitive. The segments shall be formed using the primitive definitions as specified within the Surface Mesh Primitives Sequence (0066,0013). The primitive vertices are taken in the order specified within the Primitive Point Index List (0066,0029) attribute. Figure C.X.1.1-3 shows the method to compute the normal:



$$n = \vec{ij} \times \vec{jk}$$

Figure C.X.1.1-3 – Triangle Normal Computation

The computed normal shall point in the direction of the outside of the surface.

For Triangle Strip or Triangle Fan primitives (see Section C.X.4), the normal direction is determined by the order of the points referenced by the first triangle in the strip or fan. When constructing a list of triangles from a triangle strip, the order of the points must be flipped for every second triangle to maintain consistency in the normal directions for the triangle.

C.X.2 Points Macro

Table C.X-2 specifies the Attributes of the Points Macro.

Table C.X-2
POINTS MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Number Of Points	(0066,0015)	1	Specifies the number of points in the point set.
Point Coordinates Data	(0066,0016)	1	See C.X.2.1.1
Point Position Accuracy	(0066,0017)	3	A single standard deviation of the error for all the points' spatial positions. The units shall be the same as the units of the coordinate system in which the point coordinates are specified.
Average Point Distance	(0066,0018)	3	The average point distance of the point set. It is given by the average of the distances to the nearest neighbor over all points. The units shall be the same as the units of the coordinate system in which the point coordinates are specified.
Maximum Point Distance	(0066,0019)	3	The maximum distance of one point to its nearest neighbor. The units shall be the same as the units of the coordinate system in which the point coordinates are specified.
Points Bounding Box Coordinates	(0066,001A)	3	Two 3D locations defining the cuboid bounding box, parallel to the coordinate system axes, encompassing the point set.
Axis of Rotation	(0066,001B)	3	A 3D location that combined with Center of Rotation (0066,001C) specifies the preferred axis of rotation of this object.
Center of Rotation	(0066,001C)	1C	A 3D location defining the preferred center of rotation for this point set. Required if Axis of Rotation (0066,001B) is present. May be present otherwise.

C.X.2.1 Points Macro Attribute Descriptions

All Attributes within this module containing points or vectors are in x-y-z order. If multiple elements are encoded, the ordering is $x_1,y_1,z_1,\ldots,x_n,y_n,z_n$.

The points are in the coordinate system identified by the Frame of Reference UID (0020,0052). To map these points into the coordinate system of another SOP Instance a Spatial Registration Instance can be used.

C.X.2.1.1 Point Coordinates Data

When referencing individual points the index of the first point shall be 1.

C.X.3 Vectors Macro

Table C.X-3 specifies the attributes of the Vectors Macro.

Table C.X-3
VECTORS MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Number of Vectors	(0066,001E)	1	The number of vectors in the Vector Coordinate Data (0066,0021). See C.X.3.1.
Vector Dimensionality	(0066,001F)	1	The dimensionality of the underlying vector field. See C.X.3.1.
Vector Accuracy	(0066,0020)	3	A single standard deviation for all the vectors' coordinates. The units shall be the same as the units of the coordinate system in which the vector coordinates are specified. See C.X.3.1.
Vector Coordinate Data	(0066,0021)	1	A data stream of coordinates encoded as floats. See C.X.3.1.

C.X.3.1 Vectors Macro Attribute Descriptions

All Attributes within this module containing points or vectors are encoded as multi-valued floats in an x-y-z ordering. If multiple elements are encoded, the ordering is $x_1,y_1,z_1,\ldots,x_n,y_n,z_n$.

The vectors encoded in this macro can be anything from 1D to nD objects. The vectors are encoded as a stream of values in the Vector Coordinate Data (0066,0021) Attribute. Vector Dimensionality (0066,001F) defines how many subsequent entries in Vector Coordinate Data (0066,0021) describe one element. Vector Coordinate Data (0066,0021) shall have (Number of Vectors) x (Vector Dimensionality) values.

For measured vectors, the Vector Accuracy Attribute (0066,0020) describes the error per dimension in a multi-valued float attribute.

Note: The vectors are located at the points specified by the table including this macro.

C.X.4 Surface Mesh Primitives Macro

300 Table C.X-4 specifies the attributes of the Surface Mesh Primitives Macro.

Table C.X-4
SURFACE MESH PRIMITIVES MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Vertex Point Index List	(0066,0025)	2	Contains n point indices describing Vertices. See C.X.4.1.
Edge Point Index List	(0066,0024)	2	Contains 2n point indices describing unconnected Edges. See C.X.4.1.
Triangle Point Index List	(0066,0023)	2	Contains 3n point indices describing unconnected Triangles. See C.X.4.1.
Triangle Strip Sequence	(0066,0026)	2	All Triangle Strips in this Surface. Zero or more Items shall be present.
>Primitive Point Index List	(0066,0029)	1	See C.X.4.1.
Triangle Fan Sequence	(0066,0027)	2	All Triangle Fans in this Surface. Zero or more Items shall be present.
>Primitive Point Index List	(0066,0029)	1	See C.X.4.1.
Line Sequence	(0066,0028)	2	All Lines in this Surface. Zero or more Items shall be present.
>Primitive Point Index List	(0066,0029)	1	See C.X.4.1.
Facet Sequence	(0066,0034)	2	All Facets in this Surface. Each sequence Item describes one facet. Zero or more Items shall be present.
>Primitive Point Index List	(0066,0029)	1	See C.X.4.1.

C.X.4.1 Surface Mesh Primitives Macro Attribute Descriptions

305 The Surface Mesh Primitives Macro uses point indices to reference the point rather than repeating point coordinates. All of the point coordinates used are specified within the Surface Points Sequence (0066,0011) of the same Surface Sequence (0066,0002) item. Point indices are described in C.X.2.1.1.

A Surface Mesh shall contain one or more of the following primitive types:

310 Vertex a single Vertex, referencing a single point

Edge an Edge, referencing two points

Line a series of connected points describing a path

Triangle a Triangle, referencing three points:

Triangle Strip	a Triangle Strip with n triangles, referencing n+2 points. The first three referenced points describe the first triangle, the second, third and fourth referenced points describe the second triangle.
Triangle Fan	a Triangle Fan with n triangles, referencing n+2 points. The first referenced point is in the center of the fan. Together with two subsequent referenced points, it describes a complete triangle.
Facet	a closed planar polygon, referencing n points. The final point in the point index list shall be connected to the first point in the point index list to close the facet.

If the Surface Points Normals Sequence (0066,0012) is not present, the default normals can be derived from the Surface Mesh Primitives.

For the Triangle Strip, Triangle Fan, Line, and Facet the Primitive Point Index List (0066,0029) the ordering of the point references implies the direction of the primitive's normal: The normal points in the direction from which the referenced points are specified in a counterclockwise order. For finite volumes this shall be the outward direction.

For Primitives of type Triangle Strip or Triangle Fan, the orientation of the normals is given by the order of the points in the first triangle.

Note: These points may be used to compute normals to the primitive. (See section C.X.1.1.6.) The order these point references are presented in the Primitive Point Index List (0066,0029) will affect the direction the computed normal points. If the order of the point references is reversed, the direction of the normals will be reversed as well.

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Changes to NEMA Standards Publication PS 3.4-2006

Digital Imaging and Communications in Medicine (DICOM)

Part 4: Service Class Specifications

Item: Add the following to Table B.5-1

B.5 STANDARD SOP CLASSES

Table B.5-1
STANDARD SOP CLASSES

SOP Class Name	SOP Class UID	IOD Specification (defined in PS 3.3)
Surface Segmentation Storage	1.2.840.10008.5.1.4.1.1.66.5	Surface Segmentation

Item: Add the following to Table I.4-1

I.4 MEDIA STORAGE STANDARD SOP CLASSES

Table I.4-1
Media Storage Standard SOP Classes

SOP Class Name	SOP Class UID	IOD Specification
Surface Segmentation Storage	1.2.840.10008.5.1.4.1.1.66.5	Surface Segmentation

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Changes to NEMA Standards Publication PS 3.6-2006

365 # Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

Item: Add or the following Data Elements to Part 6 Section 6:

6 Registry of DICOM data elements

Tag	Name	VR	VM
(0066,0001)	Number of Surfaces	UL	1
(0066,0002)	Surface Sequence	SQ	1
(0066,0003)	Surface Number	UL	1
(0066,0004)	Surface Comments	LT	1
(0066,0009)	Surface Processing	CS	1
(0066,000a)	Surface Processing Ratio	FL	1
(0066,000b)	Surface Processing Description	LO	1
(0066,000c)	Recommended Presentation Opacity	FL	1
(0066,000d)	Recommended Presentation Type	CS	1
(0066,000e)	Finite Volume	CS	1
(0066,0010)	Manifold	CS	1
(0066,0011)	Surface Points Sequence	SQ	1
(0066,0012)	Surface Points Normals Sequence	SQ	1
(0066,0013)	Surface Mesh Primitives Sequence	SQ	1
(0066,0015)	Number of Points	UL	1
(0066,0016)	Point Coordinates Data	OF	1
(0066,0017)	Point Position Accuracy	FL	3
(0066,0018)	Mean Point Distance	FL	1
(0066,0019)	Maximum Point Distance	FL	1
(0066,001A)	Points Bounding Box Coordinates	FL	6
(0066,001B)	Axis of Rotation	FL	3
(0066,001C)	Center of Rotation	FL	3
(0066,001E)	Number of Vectors	UL	1
(0066,001F)	Vector Dimensionality	US	1
(0066,0020)	Vector Accuracy	FL	1-n
(0066,0021)	Vector Coordinate Data	OF	1
(0066,0023)	Triangle Point Index List	OW	1
(0066,0024)	Edge Point Index List	OW	1
(0066,0025)	Vertex Point Index List	OW	1
(0066,0026)	Triangle Strip Sequence	SQ	1
(0066,0027)	Triangle Fan Sequence	SQ	1
(0066,0028)	Line Sequence	SQ	1
(0066,0029)	Primitive Point Index List	OW	1
(0066,002A)	Surface Count	UL	1

(0066,002B)	Referenced Surface Sequence	SQ	1
(0066,002C)	Referenced Surface Number	UL	1
(0066,002D)	Segment Surface Generation Algorithm Identification Sequence	SQ	1
(0066,002E)	Segment Surface Source Instance Sequence	SQ	1
(0066,002F)	Algorithm Family Code Sequence	SQ	1
(0066,0030)	Algorithm Name Code Sequence	SQ	1
(0066,0031)	Algorithm Version	LO	1
(0066,0032)	Algorithm Parameters	LT	1
(0066,0034)	Facet Sequence	SQ	1
(0066,0035)	Surface Processing Algorithm Identification Sequence	SQ	1
(0066,0036)	Algorithm Name	LO	1

370 **Item: Add the following UIDs to Part 6 Annex A:**

Annex A Registry of DICOM unique identifiers (UID) (Normative)

Table A-1
UID VALUES

UID Value	UID NAME	UID TYPE	Part
1.2.840.10008.5.1.4.1.1.66.5	Surface Segmentation Storage	SOP Class	PS 3.4

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Table A-3
CONTEXT GROUP UID VALUES

Context UID	Context Identifier	Context Group Name
1.2.840.10008.6.1.636	7162	Surface Processing Algorithm Families

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Changes to NEMA Standards Publication PS 3.15-2006

385 ## Digital Imaging and Communications in Medicine (DICOM)

Part 15: Security and Systems Management Profiles

Item: Add to Section C2 and C3

C.2 CREATOR RSA DIGITAL SIGNATURE PROFILE

…

a. the SOP Class and Instance UIDs
b. the SOP Creation Date and Time, if present
c. the Study and Series Instance UIDs
d. any attributes of the General Equipment module that are present
e. any attributes of the Overlay Plane, Curve or Graphic Annotation modules that are present
f. any attributes of the General Image and Image Pixel modules that are present
g. any attributes of the SR Document General and SR Document Content modules that are present
h. any attributes of the Waveform and Waveform Annotation modules that are present
i. any attributes of the Multi-frame Functional Groups module that are present
j. any attributes of the Enhanced MR Image module that are present
k. any attributes of the MR Spectroscopy modules that are present
l. any attributes of the Raw Data module that are present
m. any attributes of the Enhanced CT Image module that are present
n. any attributes of the Enhanced XA/XRF Image module that are present
o. <u>any attributes of the Surface Segmentation module that are present</u>
p. <u>any attributes of the Surface Mesh Module that are present</u>

C.3 AUTHORIZATION RSA DIGITAL SIGNATURE PROFILE

…

a. the SOP Class and Instance UIDs
b. the Study and Series Instance UIDs
c. any attributes whose Values are verifiable by the technician or physician (e.g., their Values are displayed to the technician or physician)
d. any attributes of the Overlay Plane, Curve or Graphic Annotation modules that are present
e. any attributes of the General Image and Image Pixel modules that are present
f. any attributes of the SR Document General and SR Document Content modules that are present
g. any attributes of the Waveform and Waveform Annotation modules that are present
h. any attributes of the Multi-frame Functional Groups module that are present
i. any attributes of the Enhanced MR Image module that are present
j. any attributes of the MR Spectroscopy modules that are present
k. any attributes of the Raw Data module that are present
l. any attributes of the Enhanced CT Image module that are present
m. any attributes of the Enhanced XA/XRF Image module that are present

n. **any attributes of the Surface Segmentation module that are present**

o. **any attributes of the Surface Mesh Module that are present**

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Changes to NEMA Standards Publication PS 3.16-2006

Digital Imaging and Communications in Medicine (DICOM)

Part 16: Content Mapping Resource

Item: Add following to Annex B

CONTEXT GROUP 7162 – SURFACE PROCESSING ALGORITHM FAMILIES

CID 7162
Surface Processing Algorithm Families
Type: Extensible Version: 20080829

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	1231001	Neighborhood Analysis
DCM	1231002	Adaptive Filtering
DCM	1231003	Edge Detection
DCM	1231004	Morphological Operations
DCM	1231005	Histogram Analysis
DCM	1231006	Multi-Scale/Resolution Filtering
DCM	1231007	Cluster Analysis
DCM	1231008	Multispectral Processing
DCM	1231009	Manual Processing
DCM	1231010	Artificial Intelligence
DCM	1231011	Deformable Models

Item: Add the following entries to the table in Annex D.

DICOM Code Definitions

Code Value	Code Meaning	Definition	Notes
…	…	…	…
1231001	Neighborhood Analysis	Surface processing utilizing predefined weighting factors (i.e. kernels) applied to different data values depending on their location relative to other data values within the data domain. Includes Low Pass, High Pass, Gaussian, Laplacian, etc.	
1231002	Adaptive Filtering	Surface processing applied non-uniformly utilizing a priori knowledge of the system and/or relative locations of the data values within the data domain. Example: Neighborhood analysis where weighting factors are modified continuously based on predefined criteria.	
1231003	Edge Detection	Surface processing through the exploitation of discontinuities in the data values within their domain.	

		Includes Gradient filters.	
1231004	Morphological Operations	Surface processing based on the connectivity of values based on the shape or structure of the data values within their domain. Includes erode, dilate, etc.	
1231005	Histogram Analysis	Surface processing applied to the distribution of the data values. Includes thresholding, Bayesian Classification, etc.	
1231006	Multi-Scale/Resolution Filtering	Surface processing accomplished through varying the data domain size. Include deformable models.	
1231007	Cluster Analysis	Surface processing accomplished by combining data values based on their relative location within their domain or value distribution. Includes K- and C-means, Fuzzy Analysis, Watershed, Seed Growing, etc.	
1231008	Multispectral Processing	Surface processing accomplished through the weighted combination of multiple data sets. Includes Principle Component Analysis, linear and non-linear weighed combinations, etc.	
1231009	Manual Processing	Surface processing accomplished through human interaction. Region drawing	
1231010	Artificial Intelligence	Surface processing using Artificial Intelligence techniques, such as Machine Learning, Neural Networks, etc.	
1231011	Deformable Models	Surface processing using Deformable Model techniques, such as Point Distribution Models, Level Sets, Simplex Meshes, etc.	
…	…	…	…

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Changes to NEMA Standards Publication PS 3.17-2006

Digital Imaging and Communications in Medicine (DICOM)

Part 17: Explanatory Information

Item: Add following Section to PS 3.17

X Surface Mesh Representation

For a general introduction into the underlying principles used in the Surface Mesh Module see:

Foley & van Dam [et al], Computer Graphics: Principles and Practice, Second Edition, Addison-Wesley, 1990.

X.1 MULTIDIMENSIONAL VECTORS

The dimensionality of the Vectors Macro (PS 3.3, C.X.7.3) is not restricted to accommodate broader use of this macro in the future. Usage beyond 3-dimensional Euclidian geometry is possible The Vectors Macro may be used to represent any multi-dimensional numerical entity, like a set of parameters that are assigned to a voxel in an image or a primitive in a surface mesh.

Examples:

In electro anatomical mapping, one or more tracked catheters are used to sample the electrophysiological parameters of the inner surface of the heart. Using magnetic tracking information, a set of vertices is generated according to the positions the catheter was moved to during the examination. In addition to its 3D spatial position each vertex is loaded with a 7D-Vector containing the time it was measured at, the direction the catheter pointed to, the maximal potential measured in that point, the duration of that potential and the point in time (relative to the heart cycle) the potential was measured.

For biomechanical simulation the mechanical properties of a vertex or voxel can be represented with a n-dimensional vector.

X.2 ENCODING EXAMPLES

The following example demonstrates the usage of the Surface Mesh Module for a tetrahedron.

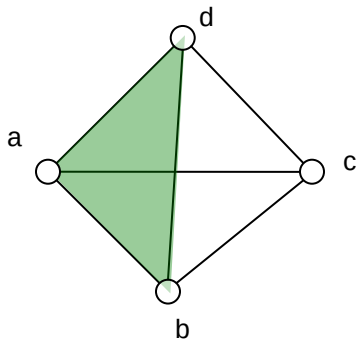

Figure X.2-1 – Surface Mesh Tetrahedron

Tag	Name	Value **(Note: When the actual values are binary a text string is shown.)**	Comment
(0066,0001)	Number of Surfaces	1	
(0066,0002)	Surface Sequence		
(0066,0003)	Surface Number	1	
(0066,0004)	Surface Comments	Test Surface	
(0066,0009)	Surface Processing	YES	
(0066,000a)	Surface Processing Ratio	1.0	
(0066,000b)	Surface Processing Description	Moved Object	
(0066,0035)	Surface Processing Algorithm Identification Sequence		
(0066,002F)	Algorithm Family Code Sequence		
(0008,0100)	Code Value	1231009	
(0008,0102)	Coding Scheme Designator	DCM	
(0008,0104)	Code Meaning	Manual Processing	
(0066,0030)	Algorithm Name Code Sequence		
(0008,0100)	Code Value	AA01	
(0008,0102)	Coding Scheme Designator	ICCAS	
(0008,0104)	Code Meaning	Interactive Shift	
(0066,0036)	Algorithm Name	Interactive Shift	
(0066,0031)	Algorithm Version	“V1.0”	
(0066,0032)	Algorithm Parameters	“x = 5 y = 1 z = 0”	
(0062,000C)	Recommended Display Grayscale Value	FFFFH	
(0062,000D)	Recommended Display CIELab Value	FFFF\8080\8080	
(0066,000c)	Recommended Presentation Opacity	1.0	
(0066,000d)	Recommended Presentation Type	SURFACE	
(0066,000e)	Finite Volume	YES	
(0066,0010)	Manifold	YES	

	(0066,0011)	Surface Points Sequence		
	(0066,0015)	Number Of Points	4	
	(0066,0016)	Point Coordinates Data	-5.\-3.727\-4.757\ 5.\-3.707\-4.757\ 0.\7.454\-4.757\ 0.\0.\8.315	4 triplets. The points are marked a,b,c,d in the sketch.
	(0066,0017)	Point Position Accuracy	0.001\0.001\0.001	
	(0066,0018)	Mean Point Distance	10.0	
	(0066,0019)	Maximum Point Distance	10.0	
	(0066,001A)	Points Bounding Box Coordinates	-5.\-3.727\-4.757\ 5.\7.454\8.315	2 triplets
	(0066,001B)	Axis of Rotation	0.0\0.0\1.0	
	(0066,001C)	Center of Rotation	0.0\0.0\0.0	
	(0066,0012)	Surface Points Normals Sequence	<empty>	
	(0066,0013)	Surface Mesh Primitives Sequence		
	(0066,0025)	Vertex Point Index List	<empty>	
	(0066,0024)	Edge Point Index List	<empty>	
	(0066,0023)	Triangle Point Index List	1\3\2\1\2\4\2\3\4\ 3\1\4	The second triangle is the one marked green in the sketch.
	(0066,0026)	Triangle Strip Sequence	<empty>	
	(0066,0027)	Triangle Fan Sequence	<empty>	
	(0066,0028)	Line Sequence	<empty>	
	(0066,0034)	Facet Sequence	<empty>	