Digital Imaging and Communications in Medicine (DICOM)

Supplement 240: Heightmap Segmentation and Revised Ophthalmic OCT En Face Image

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Document History

Document Version	Date	Content
00	20-Apr-2023	Initial Draft for discussion at ARVO
01	17-May-2023	Approach with one row per frame – editorial group review
02	22-May-2023	Approach with one frame per layer – editorial group review
03	30-May-2023	Add quality measures per frame and per pixel, changes to OCT En Face segmentation reference, separate derivation image and referenced anatomic image – editorial group review
04	6-June-2023	For WG-06 first reading
05	5-Aug-2023	Sup240: After WG-06 first reading - WG-09 review
06	21-Aug-2023	WG-09 review – change En Face boundary spec; extract Confidence Map to separate CP
07	23-Aug-2023	For WG-06 meeting
08	19-Oct-2023	Retire/replace OCT En Face Image; use Derivation Image; revised figures; intro to Part 17. For WG-09 review
09	31-Oct-2023	Updated Part 17
10	6-Nov-2023	Add 2D Heightmap position and orientation, remove frame quality measure, update En Face segmentation references, add vocabulary
11	10-Nov-2023	Corrections from 11/7 WG-06 meeting; revert to revise OCT En Face Image
12	02-Jan-2024	Add Image Orientation and localization to En Face Image
13	26-Jan-2024	Corrections from 01/08 WG-06 meeting
PC	26-Jan-2024	For Public Comment

Scope and Field of Application

HEIGHTMAP SEGMENTATION

This Supplement introduces a new Heightmap Segmentation IOD and SOP Class.

heightmap (computer graphics) A two-dimensional raster image used to store surface elevations that can later be applied to a three-dimensional object. *https://en.wiktionary.org/wiki/heightmap*

In its DICOM use, heightmap is a type of segmentation using a 2D set of pixels to identify a surface in the 3D volume of a referenced multi-frame image. In the degenerate case, it can identify the intersection of a surface with a single image plane, i.e., a 1D raster for a 2D object.

The Heightmap Segmentation IOD follows the current enhanced multi-frame image data architecture. For data management purposes, e.g., with Media Exchange, Heightmap Segmentation SOP Instances may be treated similarly to other segmentation images. While intended to be broadly applicable for a variety of medical imaging domains, the initial use case is in ophthalmic tomography (OPT) for representing segmentation of retinal layers.

Further description of Heightmap Segmentation is found in the proposed informative annex to PS3.17.

OPHTHALMIC OCT EN FACE IMAGE

This Supplement also revises the current Ophthalmic Optical Coherence Tomography En Face Image IOD, which had required use of Surface Segmentation SOP Instances to specify a retinal layer, to allow use of any type of segmentation SOP Instances, including Heightmap Segmentation or other (including future) SOP Classes.

The reference to the segmentation object in the En Face Image object enables traceability of the processing steps that produced the image. It is not necessarily the case that a receiving application could reproduce the En Face Image from the original source Ophthalmic Tomography Image(s) and the referenced segmentation object(s).

Open Issues for Public Comment

Issue #	Section	Question
1	A.XX	Are there features of the Heightmap Segmentation IOD that would make it ineffective for use in non-ophthalmic domains? In particular, consider the geometry requirements in Section A.XX.5.1.
2	C.8.17.14	Are the non-backward-compatible changes to the Ophthalmic OCT En Face Image IOD acceptable? Specifically: • a new specification with a change of Type 1 attributes is defined for referencing segmentations identifying the en face slab surfaces • the required reference to Surface Segmentation SOP Instances is revised to allow reference to any type of segmentation (Surface Segmentation has proven to be problematic in implementation) • a Type 1 required reference to a localizer image (en face image location on fundus image) is added WG-9 has not identified any product implementations of the En Face Image SOP class since its publication in Sup197 in 2017. The preference of WG-9 and WG-6 is to introduce this revision without changing the currently specified SOP Class UID.
3	CID 7162	Are the Context Groups, concepts, and definitions for segmentation algorithms adequate for heightmap segmentation?
4	CID 427x	Are the Context Groups, concepts, and definitions for anterior eye imaging adequate? Although the primary use case in the development of this Supplement has been retinal imaging, WG-09 recognizes that ophthalmic OCT is also used for the cornea and associated anatomy. Clinical and technical guidance on anterior eye imaging is requested to ensure adequacy of the IOD for that use. In particular in CID 427x, are SNOMED-CT codes 15775008 “Corneal epithelium surface” and 65431007 ”Corneal endothelium surface” used appropriately in this context?
5	C.8.17.14	Surface Offset (0022,eee2) specifies an offset from the referenced segmentation surface to the surface of the en face image slab in pixels - should this offset be specified in mm or µm? While processing with Heightmap Segmentation is in pixels, other segmentations (e.g., Surface Segmentation) define the surface in real-world distances in the Frame of Reference.
6	C.8.17.14.1.2	Is there a simpler or more efficient way to specify the en face slab surfaces?
7	C.8.17.14.1.2	Is the specification of “implementation dependent” appropriate for EnFace pixels outside the extent of the segmentation(s)?

Issues for Change Proposals for other IODs

Out of scope for Sup240, but may have dependencies

IOD	Assigned CP	Issue
Ophthalmic Tomography	CP2346	Ocular Region Imaged Module - Ophthalmic Anatomic Reference Point Coordinates inappropriate for longitudinal (non-transverse) images
Ophthalmic Tomography	CP2347	Clarify deformed Patient-based Coordinate System used in OPT Frame of Reference
Ophthalmic Thickness Map		Identify slab boundaries similar to En Face images (create a shared macro?)
Various	CP2352	IEEE754 NaN and infinities
Pixel-Aligned Parametric Map	Supplement pursuant to Work Item 2013-12-A	Confidence map and flags – new SOP Class

DICOM PS 3.3: Information Object Definitions

Add Heightmap Segmentation IOD to Section A.1.4 summary table

A.1.4 Overview of the Composite IOD Module Content

…

Table A.1-1c. Composite Information Object Modules Overview - More Images

IODs / Module	…	Htmp Seg
Patient		M
Clinical Trial Subject		U
General Study		M
Patient Study		U
Clinical Trial Study		U
General Series		M
Clinical Trial Series		U
Segmentation Series		M
Whole Slide Microscopy Series		
Intravascular OCT Series		
Frame of Reference		M
Synchronization		
Cardiac Synchronization		
General Equipment		M
Enhanced General Equipment		M
General Acquisition		
General Image		M
Image Pixel		
Floating Point Image Pixel		M
Supplemental Palette Color Lookup Table		
Enhanced Contrast/Bolus		
Cine		
Multi-frame		

Multi-frame Functional Groups		**M**
Multi-frame Dimension		**M**
Device		
Specimen		
VL Image		
Slide Coordinates		
Whole Slide Microscopy Image		
Optical Path		
Multi-Resolution Navigation		
Slide Label		
Intravascular OCT Image		
Intravascular OCT Acquisition Parameters		
Intravascular OCT Processing Parameters		
Intravascular Image Acquisition Parameters		
Segmentation Image		
Heightmap Segmentation Image		**M**
Overlay Plane		
Common Instance Reference		**M**
Acquisition Context		
ICC Profile		**U**
SOP Common		**M**
Frame Extraction		**C**

Revise Ophthalmic OCT En Face Image IOD description

A.83 OPHTHALMIC OPTICAL COHERENCE TOMOGRAPHY EN FACE IMAGE IOD

This Section defines an Information Object to be used with several types of en face images that are derived from volumetric images obtained using **optical coherence tomography (**OCT**)** technology. En face images may be based upon structural OCT volumes and ~~**surface mesh**~~ **segmentation** information only, or structural OCT volumes, ~~**surface mesh**~~ **segmentation** information and angiographic flow volume information.

> **Note** **This IOD has been modified with non-backward compatible changes relative to the definition in PS3.3-2024c and prior editions, which was determined to have significant deficiencies for implementation.**

Add new section for Heightmap Segmentation IOD

A.XX HEIGHTMAP SEGMENTATION IOD

A.XX.1 Heightmap Segmentation IOD Description

The Heightmap Segmentation Information Object Definition (IOD) specifies the location of one or more layer surfaces within a 3D volume, e.g., for retinal or epithelial layers. For each coordinate of the reference plane, each layer has at most one surface point at a distance perpendicular to the reference plane. However, not all coordinates of the reference plane might have a corresponding distance specified for any particular layer.

Each frame of a Heightmap Segmentation SOP Instance corresponds to a segmented layer within a referenced derivation image. Each row in a Heightmap Segmentation frame corresponds to a single frame in a derivation image, and the pixel values in a row represent the heightmap data for a segmented layer as it intersects the derivation image frame. The Heightmap Segmentation SOP Instance does not include the full set of acquisition parameters of the derivation image and frames, e.g., Plane Orientation, or Plane Position. An application rendering or processing the segmentation may need to access the referenced derivation image for such information.

> Note The frames of the derivation image may not form a regularly spaced voxel set (see concepts in CID 4272 OPT Scan Pattern Type). The image rows in the segmentation frame pixel set follow the orientations of the derivation image frames, and thus rendering a frame of the heightmap segmentation in Cartesian 3D space may require obtaining the orientation and position of each derivation image frame.

A.XX.2 Heightmap Segmentation IOD Entity-Relationship Model

The Heightmap Segmentation IOD uses the E-R Model specified in Section A.1.2, with only the Image IE below the Series IE.

A.XX.3 Heightmap Segmentation IOD Module Table

Table A.XX-1 lists the Modules that make up the Heightmap Segmentation IOD.

Table A.XX-1. Heightmap Segmentation IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	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
Image	General Image	C.7.6.1	M
	Multi-frame Functional Groups	C.7.6.16	M
	Multi-frame Dimension	C.7.6.17	M
	Floating Point Image Pixel	C.7.6.24	M
	Heightmap Segmentation Image	C.8.20.x	M
	ICC Profile	C.11.15	U
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	M
	Frame Extraction	C.12.3	C - Required if the SOP Instance was created in response to a Frame-Level retrieve request
	General Reference	C.12.4	U

A.XX.4 Heightmap Segmentation IOD Constraints

A.XX.4.1 Frame of Reference UID

Frame of Reference UID (0020,0052) in this SOP Instance shall have the same value as the Frame of Reference UID (0020,0052) of the SOP Instance(s) referenced in the Derivation Image Functional Group.

Note: The coordinate system associated with the Frame of Reference may be deformed (e.g., see Section A.52.4.3). The heightmap data is defined with respect to image frames within the identified Frame of Reference.

A.XX.5 Heightmap Segmentation Functional Groups

Table A.XX-2 specifies the use of the Functional Group Macros used in the Multi-frame Functional Groups Module for the Heightmap Segmentation IOD.

Table A.XX-2. Heightmap Segmentation Functional Group Macros

Functional Group Macro	Section	Usage
Pixel Measures	C.7.6.16.2.1	M
Frame Content	C.7.6.16.2.2	M - May not be used as a Shared Functional Group.
Plane Position (Patient)	C.7.6.16.2.3	C – Required if value of Rows is greater than 1, may be present otherwise
Plane Orientation (Patient)	C.7.6.16.2.4	C – Required if value of Rows is greater than 1, may be present otherwise
Referenced Image	C.7.6.16.2.5	U
Derivation Image	C.7.6.16.2.6	M
Real World Value Mapping	C.7.6.16.2.11	M
Segmentation	C.8.20.3.1	M

A.XX.5.1 Heightmap Segmentation Functional Groups Description

A.XX.5.1.1 Derivation Image

The Derivation Image Functional Group shall identify one or more Image SOP Instances that are the source for the volumetric space to which the Heightmap Segmentation frame applies. Referenced Derivation Images shall have the same Frame of Reference UID (0020,0052).

Each Item of the Derivation Image Functional Group shall specify a number of frames equal to the value of Rows (0028,0010) in the Heightmap Segmentation SOP Instance. The Derivation Image Functional Group for a Heightmap Segmentation frame with multiple rows shall enumerate the referenced frame for each row in Referenced Frame Number (0008,1160). Alternatively, if the Functional Group references a single Derivation Image with a number of frames equal to the number of Heightmap Segmentation rows, the Referenced Frame Number (0008,1160) Attribute may be omitted, and the Heightmap Segmentation rows shall correspond to the Derivation Image frames in their storage order in the pixel data.

The value of Purpose of Reference Sequence (0040,A170) in the Derivation Image Functional Group shall be (121322, DCM, "Source Image for Image Processing Operation"). The value of Derivation Code Sequence (0008,9215) shall be (113076, DCM, "Segmentation").

Note: The referenced Derivation Image is the source of the pixel/voxel matrix extent in which the Heightmap Segmentation is defined. It might technically not be a source image from which the segmentation is derived, e.g., if both the referenced image and the segmentation are derived from a raw acquisition data set. Use of (121322, DCM, "Source Image for Image Processing Operation") is specified to maintain consistency with the Segmentation IOD (see Section A.51.5.1). Other source data SOP Instances can be identified in the Referenced Image Functional Group.

A.XX.5.1.2 Pixel Measures

Pixel Spacing (0028,0030) in the Pixel Measures Functional Group specifies the real-world physical distance in the imaging target (patient) as row spacing and column spacing in mm (see Section C.7.6.16.2.1 and Section 10.7.1.3). The Pixel Spacing of the Heightmap Segmentation Image is determined by the pixel measures of the referenced Derivation Image (see Figure A.XX.5-1). As each heightmap row corresponds to a Derivation Image frame with the same number of columns, value 2 (column spacing) of Pixel Spacing (0028,0030) in the Heightmap Segmentation Image will equal value 2 of Pixel Spacing (0028,0030) in the referenced Derivation Image.

Heightmap Segmentation frames with more than one row correspond to a set of parallel Derivation Image frames, i.e., whose Image Orientation (Patient) (0020,0037) values are identical. As the heightmap frame is orthogonal to those Derivation Image frames, value 1 (row spacing) of Pixel Spacing (0028,0030) in the Heightmap Segmentation Image will equal the spacing between Derivation Image frames, computed from differences in Image Position (Patient) (0020,0032) of the referenced Derivation Image frames.

Notes

1. As specified in Section 10.7.1.3, if there is only a single row in the Heightmap Segmentation frames, the row spacing value may be zero.

2. Heightmap Segmentation is defined only for cases where the rows of heightmap data correspond to the top rows of Derivation Image frames, and the columns of the Heightmap Segmentation correspond to the frames of the Derivation Image. It is not defined for cases where the Derivation Image frames are parallel to the Heightmap Segmentation frame, or for the 90 degree rotation with the Heightmap Segmentation columns corresponding to the Derivation Image rows, or for the Heightmap Segmentation to be aligned to the bottom of the Derivation Image frames.

3. The value of Spacing Between Slices (0018,0088) in the Derivation Image may be used to determine the row spacing of the Heightmap Segmentation, but that Attribute is Type 3 optional in the Ophthalmic Tomography

IOD, and might not be present. Even if present, it would not be valid if decimated frames of the Derivation Image are referenced.

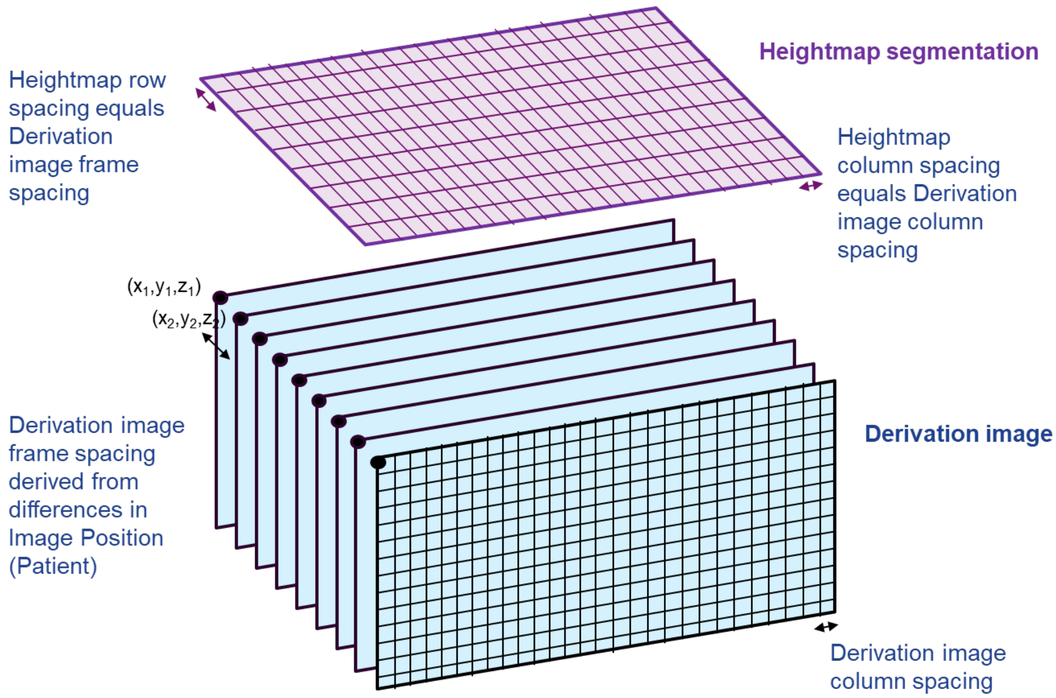

Figure A.XX.5-1 – Heightmap pixel spacing from Derivation Image Attributes

A.XX.5.1.3 Plane Position and Plane Orientation

The Plane Position (Patient) and Plane Orientation (Patient) Functional Groups shall be present in a Heightmap Segmentation with multiple rows. The values of Image Position (Patient) (0020,0032) and Image Orientation (Patient) (0020,0037) are derived from the values in the Derivation Image.

Note: The value of Image Position (Patient) (0020,0032) will be equal to the value of Image Position (Patient) (0020,0032) in the first referenced frame of the Derivation Image. The value of Image Orientation (Patient) (0020,0037) will have row direction cosines equal to the row direction cosines of the referenced Derivation Image, and column direction cosines equal to the cross product of the column direction cosines and row direction cosines of the referenced Derivation Image. If the coordinate system associated with the Frame of Reference is deformed (e.g., see Section A.52.4.3), then the orientation will be the nominal real world orientation.

Image Position (Patient) (0020,0032) and Image Orientation (Patient) (0020,0037) might not be present in the Derivation Image, in particular for non-volumetric (e.g., circular) scans, where the Derivation Image is located in space by reference to points on a localizer image rather than by Plane Position and Plane Orientation.

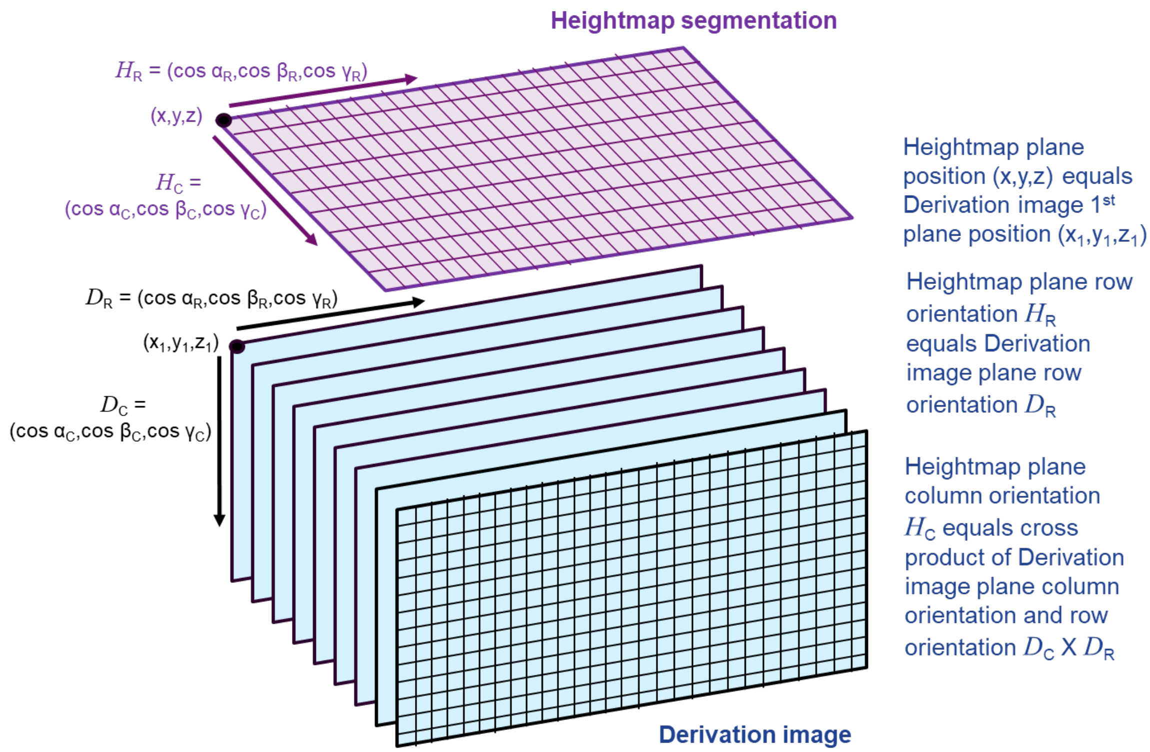

Figure A.XX.5-2 – 2D Heightmap Plane Position and Orientation from Derivation Image Attributes

A.XX.5.1.4 Real World Value Mapping

The Real World Value Mapping Functional Group shall provide the mapping of Heightmap Segmentation pixel values to real world distance in the volume defined by the Derivation Image. Heightmap values are floating point numbers representing vertical pixel distances with sub-pixel resolution in the pixel matrix of the Derivation Image. The value of Measurement Units Code Sequence (0040,08EA) shall be (mm, UCUM, “mm”). Values in the pixel padding range, i.e., between the values of Float Pixel Padding Value (0028,0122) and Float Pixel Padding Range Limit (0028,0124), shall not be mapped.

Note: The value of Real World Value Slope (0040,9225) will typically be equal to first value (row spacing) of the Pixel Spacing (0028,0030) Attribute in the Pixel Measures Functional Group of the referenced Derivation Image. If the coordinate system associated with the Frame of Reference is deformed (e.g., see Section A.52.4.3), then the value mapping will be the nominal real world distance.

The value of Real World Value First Value Mapped (0040,9216) or Double Float Real World Value First Value Mapped (0040,9214) will typically be 0. The value of Real World Value Last Value Mapped (0040,9211) or Double Float Real World Value Last Value Mapped (0040,9213) will typically be equal to the number of rows in the Derivation Image.

For information only – Functional Group Macros invoked in Heightmap Segmentation IOD

C.7.6.16.2.1 Pixel Measures Macro

Table C.7.6.16-2 specifies the Attributes of the Pixel Measures Macro, which is used as a Functional Group Macro.

Table C.7.6.16-2. Pixel Measures Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Pixel Measures Sequence	(0028,9110)	1	Identifies the physical characteristics of the pixels of this frame. Only a single Item shall be included in this Sequence.
>Pixel Spacing	(0028,0030)	1C	Physical distance in the imaging target (patient, specimen, or phantom) between the centers of each pixel, specified by a numeric pair - adjacent row spacing (delimiter) adjacent column spacing in mm. See Section 10.7.1.3 for further explanation of the value order. Required if: • Volumetric Properties (0008,9206) is other than DISTORTED or SAMPLED, and Image Type (0008,0008) Value 3 is not LABEL or OVERVIEW, or • SOP Class UID is Segmentation Storage ("1.2.840.10008.5.1.4.1.1.66.4") and Frame of Reference UID (0020,0052) is present, or • SOP Class UID is Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4") and Ophthalmic Volumetric Properties Flag (0022,1622) is YES, or • SOP Class UID is Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.8"), or • … May be present otherwise.
>Slice Thickness	(0018,0050)	1C	Nominal reconstructed slice thickness (for tomographic imaging) or depth of field (for optical non-tomographic imaging), in mm. See Section C.7.6.16.2.3.1 for further explanation.… Required if: • Volumetric Properties (0008,9206) is VOLUME or SAMPLED, and Image Type (0008,0008) Value 3 is not LABEL or OVERVIEW, or • SOP Class UID is Segmentation Storage ("1.2.840.10008.5.1.4.1.1.66.4") and Frame of Reference UID (0020,0052) is present, or • SOP Class UID is Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4") and Ophthalmic Volumetric Properties Flag (0022,1622) is YES, or • SOP Class UID is Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.8"). May be present otherwise, if • SOP Class UID is not Enhanced RT Image ("1.2.840.10008.5.1.4.1.1.481.23"), and • SOP Class UID is not Enhanced Continuous RT Image ("1.2.840.10008.5.1.4.1.1.481.24").

Attribute Name	Tag	Type	Attribute Description
>Spacing Between Slices	(0018,0088)	1C	Spacing between adjacent slices, in mm. The spacing is measured from the center-to-center of each slice, and if present shall not be negative. Required if Dimension Organization Type (0020,9311) is TILED_FULL and Total Pixel Matrix Focal Planes (0048,0303) is greater than 1. May be present otherwise. Note In the case of Whole Slide Images, Spacing Between Slices (0018,0088) describes the spacing of focal planes separately encoded, and is distinct from Distance Between Focal Planes (0048,0014), which describes in what manner different focal planes were combined into a single encoded plane (focus stacking).

275 ## C.7.6.16.2.2 Frame Content Macro

Table C.7.6.16-3 specifies the Attributes of the Frame Content Macro, which is used as a Functional Group Macro.

This Functional Group Macro may only be part of the Per-frame Functional Groups Sequence (5200,9230) Attribute.

Table C.7.6.16-3. Frame Content Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Frame Content Sequence	(0020,9111)	1	Identifies general characteristics of this frame. Only a single Item shall be included in this Sequence.
>Frame Acquisition Number	(0020,9156)	3	A number identifying the single continuous gathering of data over a period of time that resulted in this frame.
>Frame Reference DateTime	(0018,9151)	1C	The point in time that is most representative of when data was acquired for this frame. See Section C.7.6.16.2.2.1 and Section C.7.6.16.2.2.2 for further explanation. Note The synchronization of this time with an external clock is specified in the Synchronization Module in Acquisition Time Synchronized (0018,1800). Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and the SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" or "1.2.840.10008.5.1.4.1.1.4.4" or "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted) or 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image Storage). May be present otherwise.
>Frame Acquisition DateTime	(0018,9074)	1C	The date and time that the acquisition of data that resulted in this frame started. See Section C.7.6.16.2.2.1 for further explanation. Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and the SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" or "1.2.840.10008.5.1.4.1.1.4.4" or "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted) or 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image Storage). May be present otherwise.

Attribute Name	Tag	Type	Attribute Description
>Frame Acquisition Duration	(0018,9220)	1C	The actual amount of time [in milliseconds] that was used to acquire data for this frame. See Section C.7.6.16.2.2.1 and Section C.7.6.16.2.2.3 for further explanation. Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and the SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" or "1.2.840.10008.5.1.4.1.1.4.4" or "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted) or 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image Storage). May be present otherwise.
>Cardiac Cycle Position	(0018,9236)	3	Description of the position in the cardiac cycle that is most representative of this frame. Defined Terms: **END_SYSTOLE** **END_DIASTOLE** **UNDETERMINED**
>Respiratory Cycle Position	(0018,9214)	3	Description of the position in the respiratory cycle that is most representative of this frame. Defined Terms: **START _RESPIR** **END_RESPIR** **UNDETERMINED**
>Dimension Index Values	(0020,9157)	1C	Contains the values of the indices defined in the Dimension Index Sequence (0020,9222) for this multi-frame header frame. The number of values is equal to the number of Items of the Dimension Index Sequence and shall be applied in the same order. See Section C.7.6.17.1 for a description. … Required if the value of Dimension Index Sequence (0020,9222) exists. Note For some IODs, such as the VL Whole Slide Microscopy Image IOD, the entire Frame Content Sequence (0020,9111) may be omitted, but if it is present and Dimensions are explicitly defined, then the index values need to be supplied here.
>Temporal Position Index	(0020,9128)	1C	Ordinal number (starting from 1) of the frame in the set of frames with different temporal positions. Required if the value of SOP Class UID (0008,0016) equals "1.2.840.10008.5.1.4.1.1.130" or Functional MR Sequence (0018,9621) is present. May be present otherwise. See Section C.7.6.16.2.2.6 and Section C.7.6.16.2.2.8.
>Stack ID	(0020,9056)	1C	Identification of a group of frames, with different positions and/or orientations that belong together, within a dimension organization. See Section C.7.6.16.2.2.4 for further explanation. Required if the value of SOP Class UID (0008,0016) equals "1.2.840.10008.5.1.4.1.1.130" or Functional MR Sequence (0018,9621) is present. May be present otherwise. See Section C.7.6.16.2.2.7 and Section C.7.6.16.2.2.8.

Attribute Name	Tag	Type	Attribute Description
>In-Stack Position Number	(0020,9057)	1C	The ordinal number of a frame in a group of frames, with the same Stack ID (0020,9056). Required if Stack ID (0020,9056) or Functional MR Sequence (0018,9621) is present. See Section C.7.6.16.2.2.4 and Section C.7.6.16.2.2.8 for further explanation.
>Frame Comments	(0020,9158)	3	User-defined comments about the frame.
>Frame Label	(0020,9453)	3	Label corresponding to a specific dimension index value. Selected from a set of dimension values defined by the application. This Attribute may be referenced by the Dimension Index Pointer (0020,9165) Attribute in the Multi-frame Dimension Module. See Section C.7.6.16.2.2.5 for further explanation.

C.7.6.16.2.3 Plane Position (Patient) Macro

Table C.7.6.16-4 specifies the Attributes of the Plane Position (Patient) Macro, which is used as a Functional Group Macro.

Table C.7.6.16-4. Plane Position (Patient) Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Plane Position Sequence	(0020,9113)	1	Identifies the position of the plane of this frame. Only a single Item shall be included in this Sequence.
>Image Position (Patient)	(0020,0032)	1C	The x, y, and z coordinates of the upper left hand corner (center of the first voxel transmitted) of the frame, in mm. See Section C.7.6.2.1.1 and Section C.7.6.16.2.3.1 for further explanation. Note In the case of CT images with an Acquisition Type (0018,9302) of CONSTANT_ANGLE the image plane is defined to pass through the data collection center and be normal to the central ray of the diverging X-Ray beam. Required if: • Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and Volumetric Properties (0008,9206) of this frame is other than DISTORTED, or • SOP Class UID is Segmentation Storage ("1.2.840.10008.5.1.4.1.1.66.4") and Frame of Reference UID (0020,0052) is present, or • SOP Class UID is Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4") and Ophthalmic Volumetric Properties Flag (0022,1622) is YES, or • SOP Class UID is Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.8"). May be present otherwise.

C.7.6.16.2.4 Plane Orientation (Patient) Macro

Table C.7.6.16-5 specifies the Attributes of the Plane Orientation (Patient) Macro, which is used as a Functional Group Macro.

Table C.7.6.16-5. Plane Orientation (Patient) Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Plane Orientation Sequence	(0020,9116)	1	Identifies orientation of the plane of this frame. Only a single Item shall be included in this Sequence.
>Image Orientation (Patient)	(0020,0037)	1C	The direction cosines of the first row and the first column with respect to the patient. See Section C.7.6.2.1.1 and Section C.7.6.16.2.3.1 for further explanation. Required if: • Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and Volumetric Properties (0008,9206) of this frame is other than DISTORTED, or • SOP Class UID is Segmentation Storage ("1.2.840.10008.5.1.4.1.1.66.4") and Frame of Reference UID (0020,0052) is present, or • SOP Class UID is Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4") and Ophthalmic Volumetric Properties Flag (0022,1622) is YES, or • SOP Class UID is Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.8"), or • SOP Class UID is Enhanced RT Image ("1.2.840.10008.5.1.4.1.1.481.23"), or • SOP Class UID is Enhanced Continuous RT Image ("1.2.840.10008.5.1.4.1.1.481.24"). May be present otherwise.

C.7.6.16.2.5 Referenced Image Macro

Table C.7.6.16-6 specifies the Attributes of the Referenced Image Macro, which is used as a Functional Group Macro.

Table C.7.6.16-6. Referenced Image Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Referenced Image Sequence	(0008,1140)	2	The set of images or other composite SOP Instances used to plan the acquisition, if any, and other significant related images. See Section C.7.6.16.2.5.1 for further explanation. Zero or more Items shall be included in this Sequence.
>Include Table 10-3 “Image SOP Instance Reference Macro Attributes”			
>Purpose of Reference Code Sequence	(0040,A170)	1C	Describes the purpose for which the reference is made. Only a single Item shall be included in this Sequence. Required if SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" (Legacy Converted Enhanced CT Image Storage) and not "1.2.840.10008.5.1.4.1.1.4.4" (Legacy Converted Enhanced MR Image Storage) and not "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted Enhanced PET Image Storage), may be present otherwise. See Section C.7.6.16.2.5.1 for further explanation.
>>Include Table 8.8-1 “Code Sequence Macro Attributes”			*DCID 7201 “Referenced Image Purpose of Reference”, or as specified in the IOD invocation of this Functional Group.*

C.7.6.16.2.6 Derivation Image Macro

Table C.7.6.16-7 specifies the Attributes of the Derivation Image Macro, which is used as a Functional Group Macro.

Table C.7.6.16-7. Derivation Image Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Derivation Image Sequence	(0008,9124)	2	The set of Images or other composite SOP Instances that were used to derive this frame. Zero or more Items shall be included in this Sequence.
>Derivation Description	(0008,2111)	3	A text description of how this frame data was derived. See Section C.12.4.1.1 for further explanation.
>Derivation Code Sequence	(0008,9215)	1C	A coded description of how this frame was derived. See Section C.12.4.1.1 for further explanation. One or more Items shall be included in this Sequence. More than one Item indicates that successive derivation steps have been applied. Required if SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" (Legacy Converted Enhanced CT Image Storage) and not "1.2.840.10008.5.1.4.1.1.4.4" (Legacy Converted Enhanced MR Image Storage) and not "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted Enhanced PET Image Storage), may be present otherwise.
>>Include Table 8.8-1 "Code Sequence Macro Attributes"			*DCID 7203 "Image Derivation".*
>Source Image Sequence	(0008,2112)	2	The set of Images or other Composite SOP Instances that were used to derive this frame. Zero or more Items shall be included in this Sequence. See Section C.12.4.1.2 for further explanation.
>>Include Table 10-3 "Image SOP Instance Reference Macro Attributes"			
>>Purpose of Reference Code Sequence	(0040,A170)	1C	Describes the purpose for which the reference is made, that is what role the source image or frame played in the derivation of this image or frame. Only a single Item shall be included in this Sequence. Required if SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" (Legacy Converted Enhanced CT Image Storage) and not "1.2.840.10008.5.1.4.1.1.4.4" (Legacy Converted Enhanced MR Image Storage) and not "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted Enhanced PET Image Storage), may be present otherwise.
>>>Include Table 8.8-1 "Code Sequence Macro Attributes"			*DCID 7202 "Source Image Purpose of Reference".*

Attribute Name	Tag	Type	Attribute Description
>>Spatial Locations Preserved	(0028,135A)	3	The extent to which the spatial locations of all pixels are preserved during the processing of the source image that resulted in the current image or frame. Enumerated Values: **YES** **NO** **REORIENTED_ONLY** A projection radiograph that has been flipped, and/or rotated by a multiple of 90 degrees Note 1. This applies not only to images with a known relationship to a 3D space, but also to projection images. For example, a projection radiograph such as a mammogram that is processed by a point image processing operation such as contrast enhancement, or a smoothing or edge enhancing convolution, would have a value of YES for this Attribute. A projection radiograph that had been magnified or warped geometrically would have a value of NO for this Attribute. A projection radiograph that has been flipped, and/or rotated by a multiple of 90 degrees, such that transformation of pixel locations is possible by comparison of the values of Patient Orientation (0020,0020) would have a value of REORIENTED_ONLY. This Attribute is typically of importance in relating images with Presentation Intent Type (0008,0068) values of FOR PROCESSING and FOR PRESENTATION. 2. When the value of this Attribute is NO, it is not possible to locate on the current image any pixel coordinates that are referenced relative to the source image, such as for example, might be required for rendering CAD findings derived from a referenced FOR PROCESSING image on the current FOR PRESENTATION image.
>>Patient Orientation	(0020,0020)	1C	The Patient Orientation values of the source image. Required if the value of Spatial Locations Preserved (0028,135A) is REORIENTED_ONLY.

C.7.6.16.2.11 Real World Value Mapping Macro

Table C.7.6.16-12 specifies the Attributes of the Real World Value Mapping Macro, which is used as a Functional Group Macro.

Table C.7.6.16-12. Real World Value Mapping Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Real World Value Mapping Sequence	(0040,9096)	1	The mapping of stored values to associated Real World values. One or more Items shall be included in this Sequence.
>Include Table C.7.6.16-12b “Real World Value Mapping Item Macro Attributes”			*Measurement Units Code Sequence DCID 82 “Measurement Unit”, or as specified in the Macro invocation.*

Table C.7.6.16-12b. Real World Value Mapping Item Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Real World Value First Value Mapped	(0040,9216)	1C	Specifies the first stored value mapped for the Real Word Value Intercept (0040,9224) and Real World Value Slope (0040,9225) or Real World Value LUT Data (0040,9212) of this Item. Required if Pixel Data (7FE0,0010) or Real World Value LUT Data (0040,9212) is present or Double Float Real World Value First Value Mapped (0040,9214) is absent. Note This Attribute may be used even when Float Pixel Data (7FE0,0008) or Double Float Pixel Data (7FE0,0009) are used instead of Pixel Data (7FE0,0010) if an integer of the size of this Attribute is sufficient to define the range. See Section C.7.6.16.2.11.1 for further explanation.
Real World Value Last Value Mapped	(0040,9211)	1C	Specifies the last stored value mapped for the Real Word Value Intercept (0040,9224) and Real World Value Slope (0040,9225) or Real World Value LUT Data (0040,9212) of this Item. Required if Pixel Data (7FE0,0010) or Real World Value LUT Data (0040,9212) is present or Double Float Real World Value Last Value Mapped (0040,9213) is absent. Note This Attribute may be used even when Float Pixel Data (7FE0,0008) or Double Float Pixel Data (7FE0,0009) are used instead of Pixel Data (7FE0,0010) if an integer of the size of this Attribute is sufficient to define the range. See Section C.7.6.16.2.11.1 for further explanation.
Double Float Real World Value First Value Mapped	(0040,9214)	1C	Specifies the first stored value mapped for the Real Word Value Intercept (0040,9224) and Real World Value Slope (0040,9225) of this Item. Required if Real World Value First Value Mapped (0040,9216) is absent. Note The same Attribute with a double float precision value is used whether or not Float Pixel Data (7FE0,0008) or Double Float Pixel Data (7FE0,0009) are present, an integer value is not sufficient.
Double Float Real World Value Last Value Mapped	(0040,9213)	1C	Specifies the last stored value mapped for the Real Word Value Intercept (0040,9224) and Real World Value Slope (0040,9225) of this Item. Required if Real World Value Last Value Mapped (0040,9211) is absent. Note The same Attribute with a double float precision value is used whether or not Float Pixel Data (7FE0,0008) or Double Float Pixel Data (7FE0,0009) are present, an integer value is not sufficient.

Attribute Name	Tag	Type	Attribute Description
Real World Value Intercept	(0040,9224)	1C	The Intercept value in relationship between stored values (SV) and the Real World values. See Section C.7.6.16.2.11.1.2 for further explanation. Required if Float Pixel Data (7FE0,0008) or Double Float Pixel Data (7FE0,0009) are present or Real World Value LUT Data (0040,9212) is not present.
Real World Value Slope	(0040,9225)	1C	The Slope value in relationship between stored values (SV) and the Real World Values. See Section C.7.6.16.2.11.1.2 for further explanation. Required if Float Pixel Data (7FE0,0008) or Double Float Pixel Data (7FE0,0009) are present or Real World Value LUT Data (0040,9212) is not present.
Real World Value LUT Data	(0040,9212)	1C	LUT Data in this Sequence. Required if Real World Value Intercept (0040,9224) is not present.
LUT Explanation	(0028,3003)	1	Free form text explanation of the meaning of the transformation in this Item.
LUT Label	(0040,9210)	1	Label that is used to identify the transformation of this Item.
Measurement Units Code Sequence	(0040,08EA)	1	Units of measurement. Only a single Item shall be included in this Sequence. See Section C.7.6.16.2.11.1 for further explanation.
>Include Table 8.8-1 “Code Sequence Macro Attributes”			*DCID 7181 “Abstract Multi-dimensional Image Model Component Unit”, or as specified in the Macro invocation.*
Quantity Definition Sequence	(0040,9220)	3	A list of name-value pairs that describe the characteristics of the quantity represented by the Real World Value. One or more Items are permitted in this Sequence.
>Include Table 10.2.1-1 “Content Item with Modifiers Macro Attributes”			*BTID 15400 “Real-World Quantity Definition”.* Other TIDs may be defined by the IOD or application that uses this Macro.

For information only – Segmentation Macros invoked in Heightmap Segmentation IOD

C.8.20.3.1 Segmentation Macro

Table C.8.20-3 specifies the Attributes of the Segmentation Macro.

Table C.8.20-3. Segmentation Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Segment Identification Sequence	(0062,000A)	1	Identifies the characteristics of this frame. Only a single Item shall be included in this Sequence.
>Referenced Segment Number	(0062,000B)	1	Uniquely identifies the segment described in Segment Sequence (0062,0002) by reference to Segment Number (0062,0004). Referenced Segment Number (0062,000B) shall not be multi-valued.

C.8.20.4.1 Segment Description Macro

Table C.8.20-4 specifies the Attributes of the Segment Description Macro.

Table C.8.20-4. Segment Description Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Segment Number	(0062,0004)	1	Identification number of the segment. The value of Segment Number (0062,0004) shall be unique within the Segmentation instance in which it is created. See Section C.8.20.2.4.
Segment Label	(0062,0005)	1	User-defined label identifying this segment. This may be the same as Code Meaning (0008,0104) of 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: **AUTOMATIC** calculated segment **SEMIAUTOMATIC** calculated segment with user assistance **MANUAL** user-entered segment
Include Table 10-7b “Multiple Site General Anatomy Optional Macro Attributes”			*May not be necessary if the anatomy is implicit in the Segmented Property Type Code Sequence.* *More than one Item in Anatomic Region Sequence (0008,2218) may be used when a region of interest spans multiple anatomical locations and there is not a single pre-coordinated code describing the combination of locations. There is no requirement that the multiple locations be contiguous.*
Segmented Property Category Code Sequence	(0062,0003)	1	Sequence defining the general category of the property the segment represents. Only a single Item shall be included in this Sequence.
>Include Table 8.8-1 “Code Sequence Macro Attributes”			*BCID 7150 “Segmentation Property Categories”.*

Attribute Name	Tag	Type	Attribute Description
Segmented Property Type Code Sequence	(0062,000F)	1	Sequence defining the specific property the segment represents. Note "Property" is used in the sense of meaning "what the segmented voxels represent", whether it be a physical or biological object, be real or conceptual, having spatial, temporal or functional extent or not. I.e., it is what the segment "is" (as opposed to some feature, attribute, quality, or characteristic of it, like color or shape or size). Only a single Item shall be included in this Sequence.
>Include Table 8.8-1 “Code Sequence Macro Attributes”			*BCID 7151 “Segmentation Property Types”.*
>Segmented Property Type Modifier Code Sequence	(0062,0011)	3	Sequence defining the modifier of the property type of this segment. One or more Items are permitted in this Sequence.
>>Include Table 8.8-1 “Code Sequence Macro Attributes”			*DCID 244 “Laterality”.* Note For Retinal Segmentation Surfaces, laterality is not typically specified.
Tracking ID	(0062,0020)	1C	A text label used for tracking a finding or feature, potentially across multiple reporting objects, over time. This label shall be unique within the domain in which it is used. Required if Tracking UID (0062,0021) is present. Note 1. May or may not have the same value as Segment Label (0062,0005). 2. Related SR instances may exist, for example, to record measurements related to this segment, but need not exist for this Attribute to be used. 3. This Attribute will have the same value as the value of the (112039, DCM, "Tracking Identifier") Content Item in SR instances that reference this Segment in this Segmentation Instance.

Attribute Name	Tag	Type	Attribute Description
Tracking UID	(0062,0021)	1C	A unique identifier used for tracking a finding or feature, potentially across multiple reporting objects, over time. Required if Tracking ID (0062,0020) is present. Note 1. Related SR instances may exist, for example, to record measurements related to this segment, but need not exist for this Attribute to be used. 2. This Attribute will have the same value as the value of the (112040, DCM, "Tracking Unique Identifier") Content Item in SR instances that reference this Segment in this Segmentation Instance.
Definition Source Sequence	(0008,1156)	3	Instances containing the source of the Segment information. Only a single Item is permitted in this Sequence.
>Include Table 10-11 “SOP Instance Reference Macro Attributes”.			
>Referenced ROI Number	(3006,0084)	1C	The value of ROI Number (3006,0022) in the referenced SOP Instance that identifies the ROI that is the origin of the Segment information. Required if Referenced SOP Class UID (0008,1150) is RT Structure Set Storage ("1.2.840.10008.5.1.4.1.1.481.3").

Add new section for Heightmap Segmentation Image Module to Annex C

C.8.20.x Heightmap Segmentation Image Module

Table C.8.20-x defines the Attributes of the Heightmap Segmentation Image Module.

Table C.8.20-x. Heightmap Segmentation Image Module Attributes

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Image identification characteristics. Value 1 shall be DERIVED. Value 2 shall be PRIMARY. No other values shall be present.
Include Table 10-12 “Content Identification Macro Attributes”			
Samples Per Pixel	(0028,0002)	1	Number of samples (planes) in this image. Enumerated Values: **1**
Photometric Interpretation	(0028,0004)	1	The intended interpretation of the pixel data. Enumerated Values: **MONOCHROME2**
Rows	(0028,0010)	1	Number of rows in the image. Value shall be identical to the number of frames referenced in the Derivation Image. See Section C.8.20.x.2.
Columns	(0028,0011)	1	Number of columns in the image. Value shall be identical to value of Columns (0028,0011) in the Derivation Image. See Section C.8.20.x.1
Segmentation Type	(0062,0001)	1	The type of encoding used to indicate the presence of the segmented property at a location in the derivation image. See Section C.8.20.x.1 Enumerated Value: **HEIGHTMAP**
Segment Sequence	(0062,0002)	1	Describes the segments that are contained within the data. One or more Items shall be included in this Sequence.
>Include Table C.8.20-4 “Segment Description Macro Attributes”			
>Segment Algorithm Name	(0062,0009)	1C	Name of algorithm used to generate the segment. Required if Segment Algorithm Type (0062,0008) is not MANUAL.
>Segmentation Algorithm Identification Sequence	(0062,0007)	3	A description of how this segment was derived. Algorithm Name (0066,0036) within this Sequence may be identical to Segment Algorithm Name (0062,0009). Only a single Item is permitted in this Sequence.
>>Include Table 10-19 “Algorithm Identification Macro Attributes”			*BCID 7162 “Surface Processing Algorithm Families”.*
>Recommended Display Grayscale Value	(0062,000C)	3	A default single gray unsigned value in which it is recommended that this segment 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).

Attribute Name	Tag	Type	Attribute Description
>Recommended Display CIELab Value	(0062,000D)	3	A default triplet value in which it is recommended that this segment be rendered on a color display. The units are specified in PCS-Values, and the value is encoded as CIELab. See Section C.10.7.1.1.

C.8.20.x.1 HEIGHTMAP Segmentation and Columns (0028,0011)

Segmentation Type (0062,0001) of HEIGHTMAP specifies a segmented surface within a referenced Derivation Image pixel/voxel matrix volume. Each row of a Heightmap Segmentation frame corresponds to a single full frame of a Derivation Image (see Section A.XX.5.1.1.) and shall have the same value for Columns (0028,0011).

The Heightmap Segmentation Float Pixel Data (7FE0,0008) value specifies the location of the segmented surface in the corresponding pixel column in the referenced Derivation Image (see Figure C.8.20.x-1). The location is specified in units of vertical pixels from the top center of the column in the Derivation Image, with the floating point value providing fractional pixel resolution (see Figure C.8.20.x-2).

Note The DICOM convention is to specify fractional pixel offsets from the top left hand corner of an image. Since the horizontal offset is specified by column correspondence between the Derivation Image and the Heightmap Segmentation, the horizontal position is nominally the midline of the column.

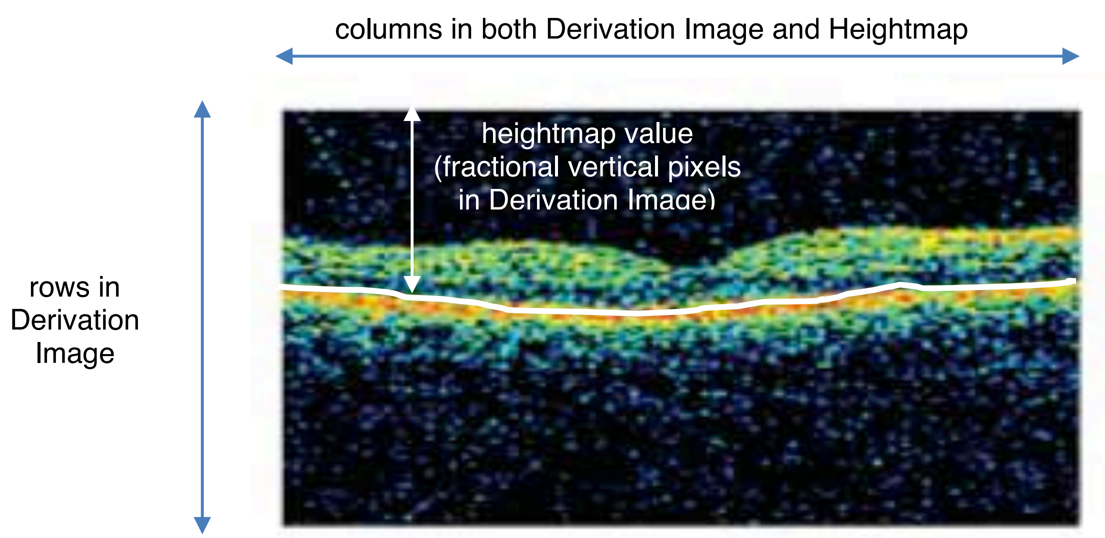

Figure C.8.20.x-1 - Heightmap Segmentation mapped onto Derivation Image frame

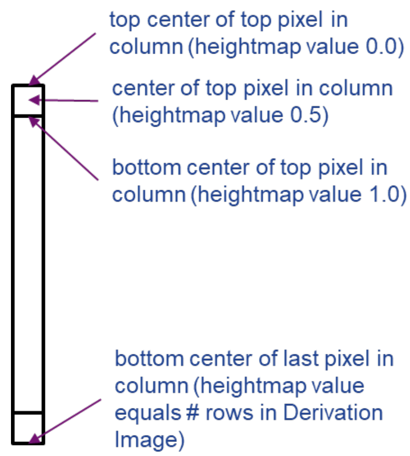

Figure C.8.20.x-2 - Heightmap fractional pixel resolution in Derivation Image column

A segmented surface might not span the entire frame of a Derivation Image, and therefore there would be columns for which there is no valid heightmap value. The absence of a segmented surface in a Derivation Image pixel column is specified by a “padding value” in the heightmap, i.e., a heightmap value in the range specified by Float Pixel Padding Value (0028,0122) and Float Pixel Padding Range Limit (0028,0124) in the Floating Point Image Pixel Module (see Section C.7.6.24). The padding value range shall not overlap the range of zero to the number of rows of the Derivation Image.

C.8.20.x.2 Rows (0028,0010)

One heightmap frame with multiple rows may specify the heightmap across all the referenced frames only if the Heightmap Segmentation is specified for multiple, equally spaced parallel frames of the referenced Derivation Image. The multiple frames of the Derivation Image may be encoded in a single multi-frame SOP Instance, or in a Series of single frame or multi-frame SOP Instances, as long as the frames are parallel, equally sized, and equally spaced.

The segmentation might not extend across all of the frames of the SOP Instances referenced in the Derivation Image Functional Group. All the frames that are segmented shall be enumerated.

Notes

1. A heightmap with multiple rows might be used for segmentation of a cube-scan OPT image. Referenced OPT images with equal slice spacing might have the Ophthalmic Volumetric Properties Flag (0022,1622) value YES.

2. The heightmap may be specified for a subset of frames of the Derivation Image. The frames in the subset are not necessarily adjacent, e.g., if only even numbered frames are segmented. As long as the referenced frames are equally spaced, a single heightmap frame with multiple rows may specify the heightmap across all the referenced frames

The value of Rows (0028,0010) of the Heightmap Segmentation Image shall equal the number of frames referenced in the Derivation Image. The orientation of a Heightmap Segmentation frame with more than one row is thus orthogonal to the orientation of the Derivation Image frames. See example in Figure C.8.20.x-3.

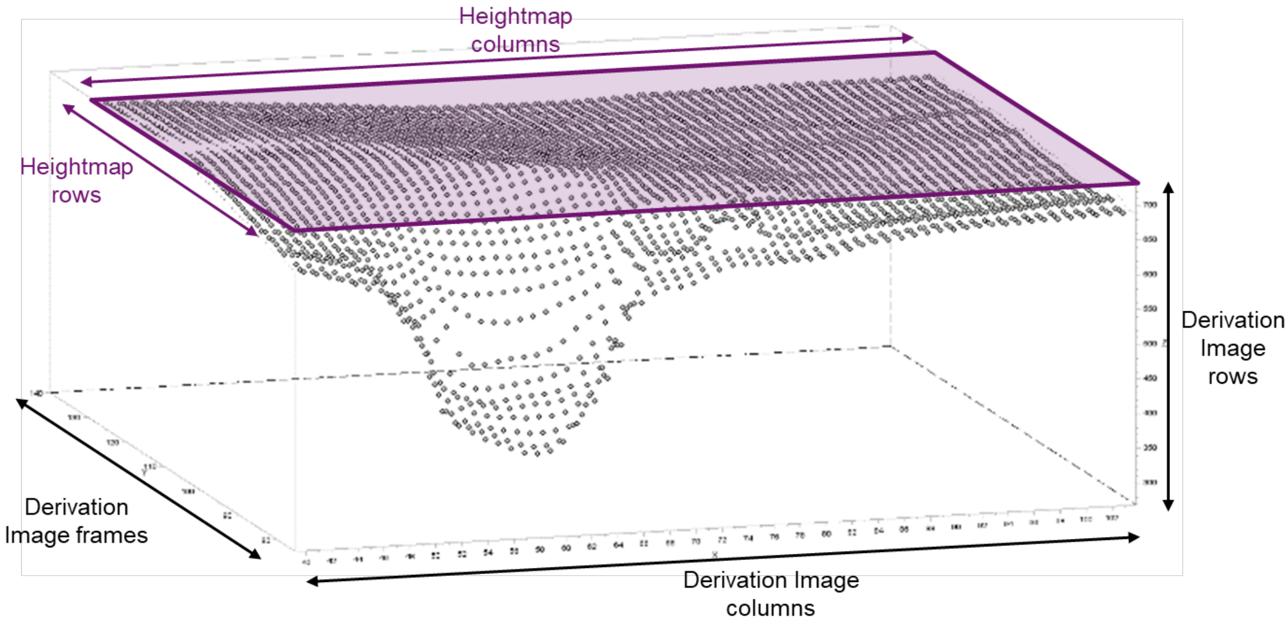

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Figure C.8.20.x-3 – 2D Heightmap pixel values rendered into 3D volume of Derivation Image

Revise Ophthalmic OCT En Face Image Module to allow any Segmentation type rather than requiring Surface Segmentation, and add reference to a localizer image

C.8.17.14 Ophthalmic OCT En Face Image Module

Table C.8.17.14-1 specifies the Attributes that describe the Ophthalmic OCT En Face Image Module.

Table C.8.17.14-1. Ophthalmic OCT En Face Image Module Attributes

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Image identification characteristics. See Section C.8.17.14.1.5 for specialization.
…			
Pixel Representation	(0028,0103)	1	Data representation of pixel samples. Enumerated Values: **0** **unsigned integer**
Pixel Spacing	(0028,0030)	1	Nominal physical distance at the focal plane (in the retina) between the center of each pixel, specified by a numeric pair - adjacent row spacing (delimiter) adjacent column spacing in mm. See Section 10.7.1.3 for further explanation of the value order. *Note* *Since a patient's retina is curved and the image representation is planar, there can be an error in using Pixel Spacing (0028,0030) for measurements in the periphery of the image. En face imaging does not support wide field measurements.*
Image Orientation (Patient)	**(0020,0037)**	**1**	**The direction cosines of the first row and the first column with respect to the patient. See Section C.7.6.2.1.1 for further explanation.** ***Note*** ***Since the coordinate system associated with the Frame of Reference is deformed and the selected en face data volume might be non-planar, the orientation will be a nominal real world orientation.***
Ophthalmic Frame Location Sequence	**(0022,0031)**	**1**	**Specifies the location of this image in terms of location on a referenced localizer image.** **Only a single Item shall be included in this Sequence.**
>Include Table 10-3 "Image SOP Instance Reference Macro Attributes"			
>Reference Coordinates	**(0022,0032)**	**1**	**Image coordinates for the points on the referenced image that correspond to the Top Left Hand Corner (TLHC) and the Bottom Right Hand Corner (BRHC) of the En Face Image.** **Exactly two pairs of values where the first value of each pair is the row (vertical) offset and the second value of each pair is the column (horizontal) offset.** **Specified with sub-pixel resolution such that the origin at the Top Left Hand Corner (TLHC) of the TLHC pixel is 0.0\0.0, the Bottom Right Hand Corner (BRHC) of the TLHC pixel is 1.0\1.0, and the BRHC of the BRHC pixel is Rows\Columns (see Figure C.10.5-1, except that row and column order is**

			reversed). The values must be within the range 0\0 to Rows\Columns of the referenced image. **See Section C.8.17.10.1.1. Alignment of an En Face Image is equivalent to that of a transverse OPT Image.**
Content Time	(0008,0033)	1	The time the image pixel data creation started.
…			
Derivation Algorithm Sequence	(0022,1612)	1	Software algorithm that performed the derivation. Only a single Item shall be included in this Sequence.
>Include Table 10-19 “Algorithm Identification Macro Attributes”			~~***DCID 4270 “OCT-A Processing Algorithm Family”***~~ ***DCID 427v “En Face Processing Algorithm Family”*** *shall be used for Algorithm Family Code Sequence (0066,002F)* **Note Additional processing, such as artifact removal, that are used in the derivation but not strictly part of the algorithm, can be described in Algorithm Parameters (0066,0032).**
…			
Ophthalmic FOV	(0022,1517)	3	The horizontal field of view used to capture the ophthalmic image, in degrees. The field of view is the maximum image size displayed on the image plane, expressed as the angle subtended at the exit pupil of the eye by the maximum dimension 2r (where r equals the radius).
En Face Volume Descriptor Sequence	**(0022,eee0)**	**1**	**Description of the volume or boundary surfaces used to select the en face image data from the source image(s).** **One or two Items shall be included in this Sequence.** **See Section C.8.17.14.1.2 for further explanation.**
>En Face Volume Descriptor Scope	**(0022,eee1)**	**1**	**Part of the En Face Volume described by this Item.** **Enumerated Values** **ANTERIOR Anterior surface of volume** **POSTERIOR Posterior surface of volume** **ENTIRE Entire volume** **If value is ENTIRE, this Item shall be the only Item in the En Face Volume Descriptor Sequence (0022,eee0). Otherwise, two Items shall be included in the En Face Volume Descriptor Sequence (0022,eee0), one with value ANTERIOR and the other with value POSTERIOR.**
>Referenced ~~**Surface Mesh Identification**~~ **Segmentation** Sequence	(0022,~~**1620**~~**eee2**)	1**C**	Reference to the ~~**surface mesh(s)**~~ **segmentations** used in the ~~**creation of this SOP Instance**~~ **selection of the en face data**. One or more Items shall be included in this Sequence. **Required if segmentation is used to select the en face data volume or surface.** See Section C.8.17.14.1.2 for further explanation.
~~**>Referenced SOP Instance UID**~~	~~**(0008,1155)**~~	~~**1**~~	~~**Referenced SOP Instance that contains the surface segmentation used in the creation of this SOP Instance.**~~
~~**>Referenced Surface Number**~~	~~**(0066,002C)**~~	~~**1**~~	~~**Reference to a Surface Number (0066,0003) present in Surface Sequence (0066,0002).**~~

>>Include Table 10-3 "Image SOP Instance Reference Macro"			**Reference to a segmentation SOP Instance and one or more segments thereof in Referenced Segment Number (0062,000B). Referenced Segment Number (0062,000B) shall be present, even if the referenced segmentation SOP Instance contains only a single segment.** **Note The SOP Class of the segmentation is not constrained.**
>>Segmented Property Type Code Sequence	(0062,000F)	1	Sequence defining the specific property the ~~**surface**~~ **segmentation** represents. **The Items in this Sequence shall be copied from the Segmented Property Type Code Sequence of the referenced segmentation.** ~~**Only a single Item is permitted in this Sequence.**~~ **The number of Items in this Sequence shall equal the number of values in Referenced Segment Number (0062,000B).** ~~**Note**~~ ~~**"Property" is used in the sense of meaning "what the surface represents", whether it be a physical or biological object, be real or conceptual, having spatial, temporal or functional extent or not. I.e., it is what the segment "is" (as opposed to some feature, Attribute, quality, or characteristic of it, like color or shape or size).**~~
>>>*Include Table 8.8-1 "Code Sequence Macro Attributes"*			~~***BCID 4273 "Retinal Segmentation Surfaces".***~~
>Surface Interpolation	**(0022,eee3)**	**1C**	**Percent of distance between two ref**
~~**>Surface Mesh Z-Pixel Offset**~~	~~**(0022,1658)**~~	~~**1**~~	~~**Offset in number of pixels along the z axis by which the mesh data has been shifted when generating this SOP Instance**~~ ~~**The mesh data is the Attribute Point Coordinates Data (0066,0016) of the surface mesh referenced by Attribute Referenced SOP Instance UID (0008,1155).**~~ ~~**Note**~~ ~~**If no offset is used the value is set to 0.**~~
>Surface Offset	**(0022,eee3)**	**1**	**Offset in pixels from the referenced segmentation surface, in the direction from the top towards the bottom of the source image frames. If no referenced segmentation surface is specified in this Item of En Face Volume Descriptor Sequence (0022,eee0), the offset is from the top of the source image frames.** **If no offset is used the value is set to 0.** **See Section C.8.17.14.1.2.**
>Surface Processing Description	**(0066,000B)**	**3**	**A description of processing performed to construct the surface, such as interpolation between referenced segmented surfaces.**
Ophthalmic Axial Length	(0022,1019)	3	The axial length measurement, in mm.

C.8.17.14.1 Ophthalmic Optical Coherence Tomography En Face Image Module Attribute Descriptions

In this section, the term "surface segmentation" (uncapitalized) is a generic reference to any type of segmentation that describes a surface. It includes both the Surface Segmentation IOD or SOP Class (capitalized) and the Heightmap Segmentation IOD or SOP Class.

C.8.17.14.1.1 Source Image Sequence

An OCT en face image is derived from images obtained using OCT technology. The Source Image Sequence (0008,2112) shall convey the SOP Instances used to derive this en face SOP Instance.

If Attribute Purpose of Reference Code Sequence (0040,A170) is set to (128250, DCM, "Structural image for image processing"), the Source Image Sequence will reference an Ophthalmic Tomography SOP Instance.

If Attribute Purpose of Reference Code Sequence (0040,A170) is set to (128251, DCM, "Flow image for image processing"), the Source Image Sequence will reference an Ophthalmic Optical Coherence Tomography B-scan Volume Analysis SOP Instance.

A typical example of the image processing stages performed to generate en face images is shown in Figure C.8.17.14-1.

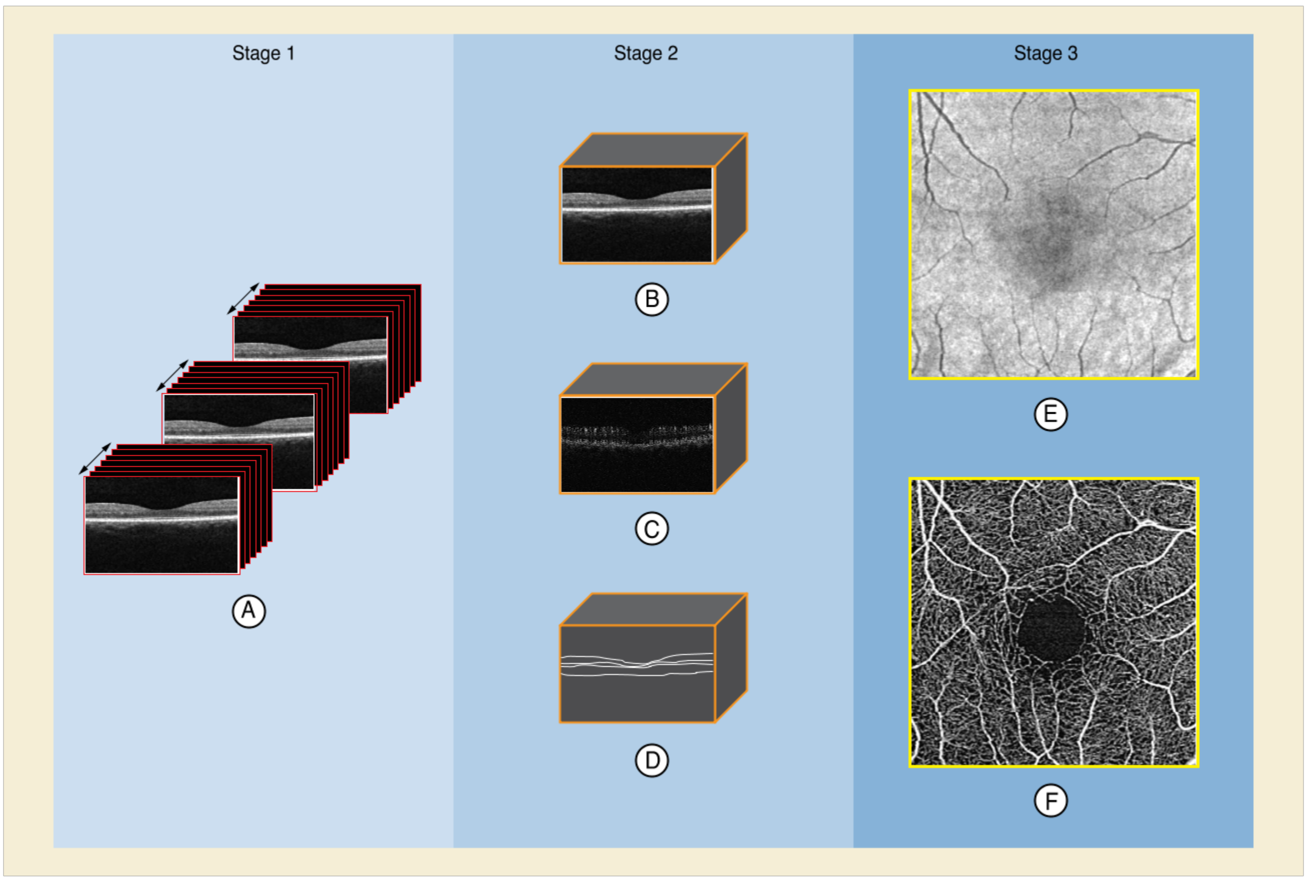


Figure C.8.17.14-1. Example of the Image Process Performed to Generate En Face Images

Figure Legend:

A. OCT proprietary B-scan data (possibly a DICOM Raw Data Instance)

B. Volumetric structural ophthalmic tomography image (Ophthalmic Tomography Image Instance)

C. OCT angiographic flow volume information (Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Instance)

D. OCT surface ~~mesh~~**segmentation** (**e.g., Heightmap Segmentation or** Surface Segmentation Instance)

E. Structural en face image (Ophthalmic Optical Coherence Tomography En Face Image Instance)

F. En Face angiographic flow image (Ophthalmic Optical Coherence Tomography En Face Image Instance)

Stage 1:OCT technology is used to acquire a volumetric dataset from a retinal region of interest. This volumetric dataset (A) consists of multiple B-scans in a raster pattern, and multiple frames are acquired at each B-scan location. The B-scans are acquired in the manufacturer's proprietary format for analysis and storage. If this information is stored in DICOM, it can use the Raw Data Storage SOP Class.

Stage 2: The OCT proprietary B-scan data (A) (or DICOM Raw Data SOP Instance) is then analyzed to derive the volumetric structural ophthalmic tomography image (B). From (B) one or more OCT surface ~~meshes~~**segmentations** (D) are generated to delineate the anatomical boundaries. The difference in signal between the frames of each individual B-scan is analyzed to produce the OCT angiographic flow volume information (C).

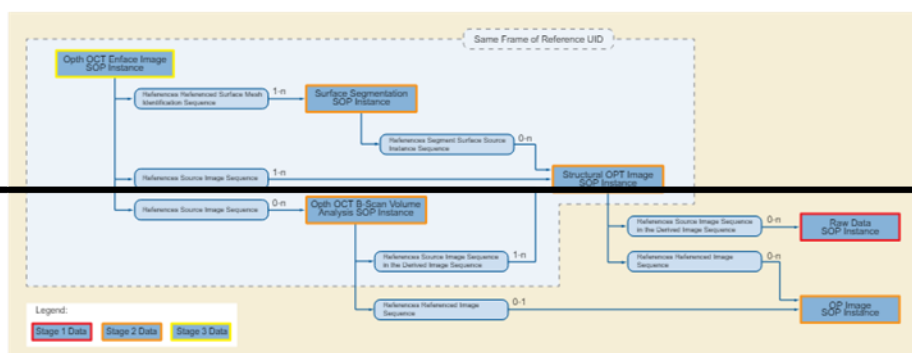
Stage 3: Clinicians typically make their assessment based upon two types of OCT en face images. The structural OCT en face image (E) is derived by using pixel information in (B) and two surface ~~meshes~~**segmentations** (C). The vascular OCT en face image (F) may be derived using the volumetric structural ophthalmic tomography image (B) , the OCT surface ~~mesh~~**segmentation** (D) and the OCT angiographic flow volume information (C).

En face images are typically derived by the acquisition modality that generated the Ophthalmic Tomography Image, ~~S~~**s**urface ~~S~~**s**egmentation, and Ophthalmic Optical Coherence Tomography B-scan Volume Analysis SOP Instances**,** or by image workstations that received the respective Ophthalmic Image, ~~S~~**s**urface ~~S~~**s**egmentation, and Ophthalmic Optical Tomography B-scan Volume Analysis SOP Instances via DICOM Storage.

Note

Image workstations receiving ophthalmic tomography images may choose to evaluate the structural ophthalmic tomography image and generate a different set of segmented surfaces than defined by an acquisition device. The surface segmentation information can be stored in a separate ~~Surface S~~**s**egmentation SOP Instance.

The Ophthalmic Tomography Image, ~~S~~**s**urface ~~S~~**s**egmentation, Ophthalmic Optical Coherence Tomography B-scan Volume Analysis and the Ophthalmic Optical Coherence Tomography En Face Image SOP Instances all reside in different DICOM Series. They share the same spatial Frame of Reference which is identified in Attribute Frame of Reference UID (0020,0052) (i.e., the value of Frame of Reference UID (0020,0052) is the same in each SOP Instance). Figure C.8.17.14-2 illustrates the relationships between the OCT angiography based SOP Instances.



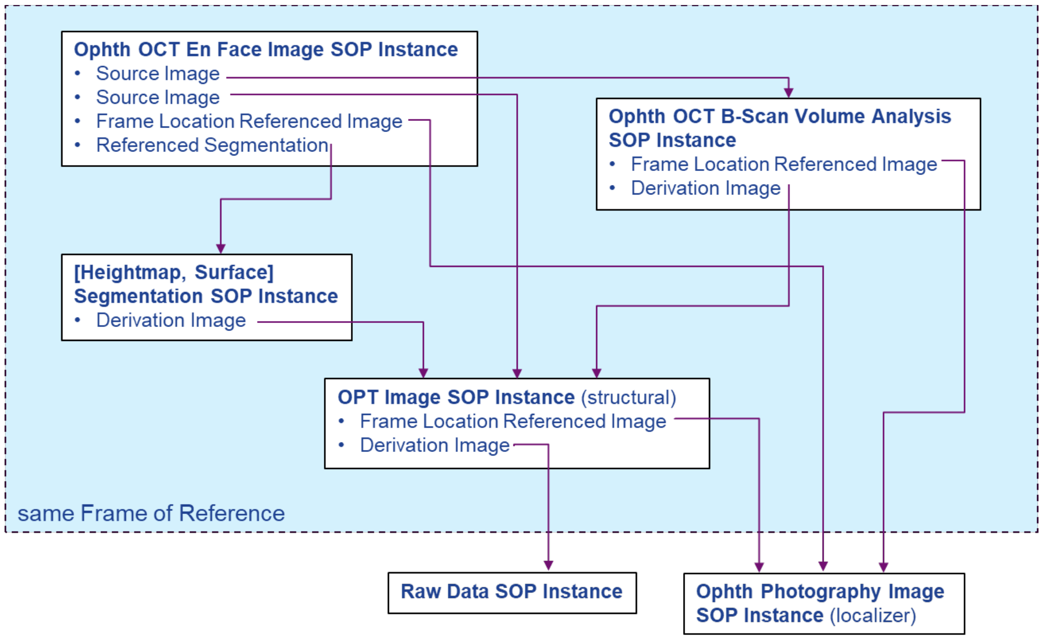


Figure C.8.17.14-2. Relationships Between OCT-A Based SOP Instances

C.8.17.14.1.2 ~~Referenced Surface Mesh Identification~~ En Face Volume Descriptor Sequence

~~Referenced Surface Mesh Identification Sequence (0022,1620) identifies one or more segmentation surfaces used to generate the derived en face image. The segmented surfaces are described in the SOP Instance identified by Referenced SOP Instance UID (0008,1155) (e.g., Surface Segmentation Storage SOP Instance).~~

The Items of the En Face Volume Descriptor Sequence (0022,eee0) identify the parameters used to select the data volume (slab) from the source image(s) for the derived en face image. The en face image data may be selected by a volumetric segmentation specified in a single Item of the En Face Volume Descriptor Sequence (0022,eee0), or by specifying an anterior and a posterior surface respectively in two Items.

Anterior and posterior surfaces may each be specified by

- a referenced surface segmentation,
- a combination (e.g., interpolation) of two referenced surface segments,
- a fixed offset from a referenced surface segmentation, or
- a fixed offset from the top of the source image frames.

If a referenced segmentation does not extend to the full pixel matrix of the en face image, the en face pixel values outside the extent of the segment are implementation specific.

Note Such pixels may be represented with values in the Pixel Padding range.

Surface Offset (0022,eee2) specifies an offset from the referenced segmentation surface to the surface of the en face image slab. If no segmentation is referenced in the same Item of the En Face Volume Descriptor Sequence (0022,eee0), the offset is from the top of the source image frames (i.e., the boundary surface is flat relative to the source image volume). The offset is a fractional number of pixels relative to the top of the frames of the source image, i.e., a positive number indicates offset toward the bottom of the frame.

Notes

1. The two en face data boundary surfaces may be specified relative to the same referenced segmentation surface, potentially with different offsets. The reference is duplicated in the two Items of the En Face Volume Descriptor Sequence (0022,eee0).

2. An ENTIRE en face data volume may be specified by two referenced surface segments in a single Item of the En Face Volume Descriptor Sequence (0022,eee0). The two referenced segments may be specified in two Items of the Referenced Segmentation Sequence (0022,eee0), or by a single Item that identifies two surfaces in Referenced Segment Number (0062,000B).

3. An en face data boundary surface may be specified by a combination (e.g., interpolation) of multiple referenced segments. The multiple referenced segments may be specified in multiple Items of the Referenced Segmentation Sequence (0022,eee0), or by a single Item that identifies multiple surfaces in Referenced Segment Number (0062,000B). The nature of the combination may be described in Surface Processing Description (0066,000B).

4. An application that wishes to specify an offset that has been determined in real world units, e.g., 0.015 mm above the segmented surface, must calculate the offset in pixels by using the pixel measures (row spacing) of the segmentation derivation image to convert from real world distances to fractional number of pixels, and use that value in the Surface Offset (0022,eee2) Attribute.

5. This Module allows the creating application to record its processing for purposes of provenance and traceability. It does not necessarily provide sufficient information for a receiving application to reproduce an identical en face image.

DICOM PS3.4: Service Class Specifications

Add Heightmap Segmentation to Annex B Storage Service Class

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Table B.5-1. Standard SOP Classes

SOP Class Name	SOP Class UID	IOD Specification (defined in PS3.3)	Specialization
…			
Heightmap Segmentation Storage	**1.2.840.10008.5.1.4.xxuid.1**	**Heightmap Segmentation IOD**	

DICOM PS 3.6: Data Dictionary

Add new data elements to Section 6 Registry of DICOM Data Elements

Table 6-1. Registry of DICOM Data Elements

Tag	Name	Keyword	VR	VM	
…					
(0022,eee0)	En Face Volume Descriptor Sequence	EnFaceVolumeDescriptorSequence	SQ	1	
(0022,eee1)	Descriptor Scope	DescriptorScope	CS	1	
(0022,eee2)	Referenced Segmentation Sequence	ReferencedSegmentationSequence	SQ	1	
(0022,eee3)	Surface Offset	SurfaceOffset	FL	1	

Add new UIDs to Annex A Registry of DICOM Unique Identifiers (UIDs)

Table A-1. UID Values

UID Value	UID Name	UID Keyword	UID Type	Part
…				
1.2.840.10008.5.1.4.xxuid.1	Heightmap Segmentation Storage	HeightmapSegmentationStorage	SOP Class	PS3.4
…				

Table A-3. Context Group UID Values

Context UID	Context Identifier	Context Group Name	Comment
…			
1.2.840.10008.6.1.cidx	CID 427x	Anterior Eye Segmentation Surface	

DICOM PS 3.16: Data Dictionary

Add new concept for OCT-A Algorithm

CID 4270 OCT-A Processing Algorithm Family

Keyword: OCTAProcessingAlgorithmFamily

FHIR Keyword: dicom-cid-4270-OCTAProcessingAlgorithmFamily

Type: Extensible

Version: ~~**20181110**~~ **2024mmdd**

UID: 1.2.840.10008.6.1.1150

Table CID 4270. OCT-A Processing Algorithm Family

Coding Scheme Designator	Code Value	Code Meaning
DCM	128252	OCT-A amplitude decorrelation
DCM	128253	OCT-A complex variance
DCM	128254	OCT-A speckle variance
DCM	128255	OCT-A correlation mapping
DCM	128256	Doppler OCT-A
DCM	128304	OCT-A one-sided ratio (lesser)
DCM	128305	OCT-A one-sided ratio (greater)
DCM	**X240-12**	**OCT-A probabilistic**

Add new concepts for En Face Image Type

CID 4271 En Face Image Type

Keyword: EnFaceImageType

FHIR Keyword: dicom-cid-4271-EnFaceImageType

Type: Extensible

Version: ~~**20170405**~~ **2024mmdd**

UID: 1.2.840.10008.6.1.1151

Table CID 4271. En Face Image Type

Coding Scheme Designator	Code Value	Code Meaning
DCM	128257	Retina depth encoded vasculature flow
DCM	128258	Retina depth encoded structural reflectance map
DCM	128259	Retina vasculature flow

DCM	128260	Retina structural reflectance map
DCM	128261	Vitreous vasculature flow
DCM	128262	Vitreous structural reflectance map
DCM	128263	Radial peripapillary vasculature flow
DCM	128264	Radial peripapillary structural reflectance map
DCM	128265	Superficial retina vasculature flow
DCM	128266	Superficial retina structural reflectance map
DCM	128267	Middle inner retina vasculature flow
DCM	128268	Middle inner structural reflectance map
DCM	128269	Deep retina vasculature flow
DCM	128270	Deep retina structural reflectance map
DCM	128271	Outer retina vasculature flow
DCM	128272	Outer retina structural reflectance map
DCM	128273	Choriocapillaris vasculature flow
DCM	128274	Choriocapillaris structural reflectance map
DCM	128275	Choroid vasculature flow
DCM	128276	Choroid structural reflectance map
DCM	128277	Whole eye vasculature flow
DCM	128278	Whole eye structural reflectance map
DCM	**X240-20**	**Avascular complex flow**
DCM	**X240-21**	**Avascular complex map**
DCM	**X240-22**	**Superficial vascular plexus flow**
DCM	**X240-23**	**Superficial vascular plexus map**
DCM	**X240-24**	**Deep capillary plexus flow**
DCM	**X240-25**	**Deep capillary plexus map**
DCM	**X240-26**	**RNFL vascular plexus flow**
DCM	**X240-27**	**RNFL vascular plexus map**
DCM	**X240-28**	**User selected volume flow**
DCM	**X240-29**	**User selected volume structure map**

Add new Context Group for En Face Algorithms

CID 427v En Face Processing Algorithm Family

Keyword: EnFaceProcessingAlgorithmFamily

FHIR Keyword: dicom-cid-427v-EnFaceProcessingAlgorithmFamily

Type: Extensible

Version:2024mmdd

UID: 1.2.840.10008.6.1.cidv

Table CID 427v. En Face Processing Algorithm Family

Coding Scheme Designator	Code Value	Code Meaning
Include CID 4270 OCT-A Processing Algorithm Family		
DCM	113078	Maximum intensity projection
DCM	113079	Minimum intensity projection
DCM	X240-01	Mean intensity projection
DCM	X240-02	Median intensity projection

DCM	X240-03	Summation projection

Add new Context Group for anterior eye segmented surfaces

CID 427x Anterior Eye Segmentation Surface

Keyword: AnteriorEyeSegmentationSurface

FHIR Keyword: dicom-cid-427x-AnteriorEyeSegmentationSurface

Type: Extensible

Version:2024mmdd

UID: 1.2.840.10008.6.1.cidx

Table CID 427x. Anterior Eye Segmentation Surface

Coding Scheme Designator	Code Value	Code Meaning
SCT	15775008	Corneal epithelium surface
SCT	65431007	Corneal endothelium surface
SCT	22040008	Anterior iris surface
SCT	53695005	Posterior iris surface
SCT	85013008	Anterior lenticular surface
SCT	47813007	Posterior lenticular surface

Add new concept for OCT-A Algorithm

CID 7162 Surface Processing Algorithm Family

Keyword: SurfaceProcessingAlgorithmFamily

FHIR Keyword: dicom-cid-7162-SurfaceProcessingAlgorithmFamily

Type: Extensible

Version: **~~20080829~~ 2024mmdd**

UID: 1.2.840.10008.6.1.636

Table CID 7162. Surface Processing Algorithm Family

Coding Scheme Designator	Code Value	Code Meaning
DCM	123101	Neighborhood Analysis
DCM	123102	Adaptive Filtering
DCM	123103	Edge Detection
DCM	123104	Morphological Operations
DCM	123105	Histogram Analysis
DCM	123106	Multi-Scale/Resolution Filtering
DCM	123107	Cluster Analysis
DCM	123108	Multispectral Processing
DCM	123109	Manual Processing
DCM	123110	Artificial Intelligence
DCM	123111	Deformable Models
DCM	**X240-11**	**Probabilistic statement**

Update Context Group listing segmentation properties with anterior eye segments

CID 7192 Anatomical Structure Segmentation Property Type

…

Version: **~~20220402~~ 2024mmdd**

UID: 1.2.840.10008.6.1.1191

Table CID 7192. Anatomical Structure Segmentation Property Type

Coding Scheme Designator	Code Value	Code Meaning	
…			
Include CID 427x Anterior Eye Segmentation Surface			

For information only – Context Groups invoked in Heightmap Segmentation Image Module

Table CID 4273. Retinal Segmentation Surface

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-RT ID	UMLS Concept Unique ID
SCT	280677004	ILM – Internal limiting membrane	T-AA62D	C0459664
DCM	128289	Outer surface of RNFL		
DCM	128290	Outer surface of GCL		
DCM	128291	Outer surface of IPL		
DCM	128292	Outer surface of INL		
DCM	128293	Outer surface of OPL		
DCM	128294	Outer surface of HFL		
SCT	76710003	ELM – External limiting membrane	T-AA650	C0229209
DCM	128295	Surface between Inner and Outer Segments of the photoreceptors		
DCM	128296	Surface of the interdigitating zone between retina and RPE		
DCM	128297	Anterior surface of the RPE		
DCM	128298	Surface of the center of the RPE		
DCM	128299	Posterior surface of the RPE		
DCM	128300	Outer surface of the BM		
DCM	128301	Surface of the choroid-sclera interface		
DCM	128302	Outer surface of the CC		

Table CID 7150. Segmentation Property Category

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-RT ID	UMLS Concept Unique ID	Segmentation Property Type Context Group
SCT	85756007	Tissue	T-D0050	C0040300	CID 7191 "Tissue Segmentation Property Type"
SCT	91723000	Anatomical Structure	T-D0005	C1268086	CID 7192 "Anatomical Structure Segmentation Property Type"
SCT	260787004	Physical object	A-00004	C0085089	CID 7193 "Physical Object Segmentation Property Type"

SCT	49755003	Morphologically Abnormal Structure	M-01000	C0221198	CID 7194 "Morphologically Abnormal Structure Segmentation Property Type"
SCT	246464006	Function	R-42019	C0542341	CID 7195 "Function Segmentation Property Type"
SCT	309825002	Spatial and Relational Concept	R-42018	C0587374	CID 7196 "Spatial and Relational Concept Segmentation Property Type"
SCT	91720002	Body Substance	T-D0080	C0504082	CID 7197 "Body Substance Segmentation Property Type"
SCT	105590001	Substance	F-61002	C0439861	CID 7198 "Substance Segmentation Property Type"

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Table CID 7151. Segmentation Property Type

Coding Scheme Designator	Code Value	Code Meaning
Include CID 7191 "Tissue Segmentation Property Type"		
Include CID 7192 "Anatomical Structure Segmentation Property Type"		
Include CID 7193 "Physical Object Segmentation Property Type"		
Include CID 7194 "Morphologically Abnormal Structure Segmentation Property Type"		
Include CID 7195 "Function Segmentation Property Type"		
Include CID 7196 "Spatial and Relational Concept Segmentation Property Type"		
Include CID 7197 "Body Substance Segmentation Property Type"		
Include CID 4273 "Retinal Segmentation Surface"		

Table CID 7162. Surface Processing Algorithm Family

Coding Scheme Designator	Code Value	Code Meaning
DCM	123101	Neighborhood Analysis
DCM	123102	Adaptive Filtering
DCM	123103	Edge Detection
DCM	123104	Morphological Operations
DCM	123105	Histogram Analysis
DCM	123106	Multi-Scale/Resolution Filtering
DCM	123107	Cluster Analysis
DCM	123108	Multispectral Processing
DCM	123109	Manual Processing
DCM	123110	Artificial Intelligence
DCM	123111	Deformable Models

Add new definitions to Annex D

560 **Table D-1. DICOM Controlled Terminology Definitions (Coding Scheme Designator "DCM" Coding Scheme Version "01")**

Code Value	Code Meaning	Definition	Notes
113078	Maximum intensity projection	Values are derived by maximum intensity projection of acquired data.	
113079	Minimum intensity projection	Values are derived by minimum intensity projection of acquired data.	
X240-01	Mean intensity projection	Values are derived by mean intensity projection of acquired data.	
X240-02	Median intensity projection	Values are derived by median intensity projection of acquired data	
X240-03	Summation projection	Values are derived by summation of values in the projection of acquired data	
X240-11	Probabilistic statement		
X240-12	OCT-A probabilistic		
X240-20	Avascular complex flow	Image that illustrates the vascular flow within the posterior layers of the retina, approximately from the posterior border of the outer plexiform layer (OPL) to the level of Bruch's Membrane (BM). For normal eyes, this image would not show detectable vascular flow.	
X240-21	Avascular complex map	Image that illustrates the structural reflectance within the posterior layers of the retina, approximately from the outer plexiform layer (OPL) to the level of Bruch's Membrane (BM).	
X240-22	Superficial vascular plexus flow	Image that illustrates the vascular flow within the anterior layers of retina, approximately from the posterior border of the retinal nerve fiber layer (RNFL) to the inner plexiform layer (IPL).	
X240-23	Superficial vascular plexus map	Image that illustrates the structural reflectance within the anterior layers of retina, approximately from the posterior border of the retinal nerve fiber layer (RNFL) to inner plexiform layer (IPL).	

X240-24	Deep capillary plexus flow	Image that illustrates the vascular flow within the plexiform layers of the retina, approximately from within the inner Nuclear layer (INL) to posterior border of the outer plexiform layer (OPL)	
X240-25	Deep capillary plexus map	Image that illustrates the structural reflectance within the plexiform layers of the retina, approximately from within the Inner Nuclear Layer (INL) to posterior border of the outer plexiform layer (OPL).	
X240-26	RNFL vascular plexus flow	Image that illustrates the vascular flow within the retinal nerve fiber layer (RNFL), approximately from inner limiting membrane (ILM) to the outer boundary of the RNFL.	
X240-27	RNFL vascular plexus map	Image that illustrates the structural reflectance within the retinal nerve fiber layer (RNFL), approximately from inner limiting membrane (ILM) to the outer boundary of the RNFL.	
X240-28	User selected volume flow	Image that illustrates the vascular flow within a volume selected by the user	
X240-29	User selected volume structure map	Image that illustrates the structural reflectance within a volume selected by the user	

DICOM PS 3.17: Explanatory Information

Add explanatory Annex

Annex XXXX Heightmap Segmentation (Informative)

INTRODUCTION

In general computer graphics usage, a heightmap describes the distance (“height”) of a surface perpendicular to a baseline plane within a volume, where a surface has at most one height position for each point on the baseline plane. The heightmap data is thus a 2D plane with a value at each coordinate position of the baseline plane. In the degenerate case of a volume consisting of a single vertical plane, the heightmap is a 1D series of data values.

DICOM Heightmap Segmentation represents the heightmap of a surface within a volume as a 2D “image”, with the pixel values representing the offset location of the surface. The volume is defined by the voxel matrix extent of a referenced multi-frame image, where the referenced image frames are perpendicular to the baseline plane of the Heightmap Segmentation image frame. In the degenerate case of a referenced image being a single frame, the heightmap data for that frame can be represented by a single row of values.

Since DICOM heightmap data represents distance from the top of the referenced image pixel matrix, the height map might more accurately be described as a “depth map”. However, that term has a different meaning in computer graphics processing, so DICOM uses the conventional term “heightmap”.

TECHNICAL APPROACH

The Heightmap Segmentation IOD uses an approach similar to the Segmentation IOD for planar segmentation without a Frame of Reference, which specifies segmentation in the imaging plane of a referenced image (the “Derivation Image”) using that image’s pixel spacing. The Heightmap Segmentation specifies a single row of “pixels” (height data) aligned to each referenced image plane and pixel matrix. The segmented surface position is represented by the number of (fractional) rows from the top of the pixel matrix of the referenced image frame (in accordance with the DICOM convention of locating a position in an image by rows and columns offset from the top left corner). Since each referenced image frame has a single row of Heightmap Segmentation data, a referenced multi-frame volume therefore has a set of Heightmap Segmentation rows. If the referenced muti-frame image frames are regularly spaced, the Heightmap Segmentation rows may be represented as a 2D plane orthogonal to the referenced image planes. See the description in PS3.3 Section C.8.20.x and especially the following figures therein:

- Figure C.8.20.x-1 - Heightmap Segmentation mapped onto Derivation Image frame
- Figure C.8.20.x-2 - Heightmap fractional pixel resolution in Derivation Image column
- Figure C.8.20.x-3 - 2D Heightmap pixel values rendered into 3D volume of Derivation Image

As with the Segmentation IOD, the Heightmap Segmentation IOD allows a SOP Instance to describe multiple segments, i.e., layer surfaces. Each segment may be associated with one or more frames in the Heightmap Segmentation SOP Instance.

Since a segmented surface might not extend across the entire referenced Derivation Image volume, typical DICOM pixel padding mechanisms are used. A Heightmap Segmentation pixel value in the pixel padding range indicates the absence of the surface at the corresponding Derivation Image location.

Note that Heightmap Segmentation does not use the second method defined in the Segmentation IOD for volumetric segmentation within a Frame of Reference, which allows segmentation in the real-world space defined by a Frame of Reference, with segmentation frame position, orientation, and matrix pixel spacing independent of the referenced image characteristics. Such an approach requires support for 3D volumetric reorientation and reconstruction, and is unnecessary for the primary heightmap use case.

COMPARISON TO SURFACE SEGMENTATION IOD

DICOM defines another method of specifying surfaces, the Surface Segmentation IOD and SOP Class. Surface Segmentation and Heightmap Segmentation are designed for different use cases. Surface Segmentation provides a capability for representing a broad variety of surfaces within a volume, Heightmap Segmentation supports a more limited capability with a simpler data structure and a significantly smaller data set. The more limited capabilities of Heightmap Segmentation allow a simpler implementation, especially for receiving applications.

Surface Segmentation allows arbitrarily folded surfaces, while Heightmap Segmentation allows one height position for each point on the baseline plane. Surface Segmentation specifies surfaces within a volumetric Frame of Reference, while Heightmap Segmentation is aligned to the voxel matrix of a reference image. Surface Segmentation requires three 32-bit values for the (X,Y,Z) coordinates for each surface point, while Heightmap Segmentation requires only one 32-bit value, as the (X,Y) positions are defined by the reference image voxel matrix.

OPHTHALMIC TOMOGRAPHY USE CASE

DICOM Heightmap Segmentation is intended to be applicable to a broad variety of imaging domains, but its initial use case is for segmentation of retinal layer surfaces in ophthalmic tomography (OPT).

OPT generally creates multi-frame images with frames that are nominally perpendicular to the retinal surface, which is treated as if it were a flat baseline coronal plane for image rendering (see PS3.3 Section A.52.4.3.1 *per CP2347 “Clarify OPT Frame of Reference Coordinate System”, in process*).

When OPT scans are acquired in a regular set of closely spaced rasters, they represent a complete volume and are characterized with the Ophthalmic Volumetric Properties Flag (0022,1622) value YES. This use may also typically have Scan Pattern Type Code Sequence (0022,1618) value (128279, DCM, “Cube B-scan pattern”). In this case, the heightmap segmentation for each surface may be a 2-D frame orthogonal to the OPT scan frames, and is analogous to an Ophthalmic Thickness Map image or a Corneal Topography Map image (which is also a type of heightmap). There will thus be one 2-D Heightmap Segmentation frame for each segmented surface layer.

However, OPT scans may not be volumetric (see CID 4272 OPT Scan Pattern Type for non-cube patterns). In that case, the segmented surface layer in each OPT frame will have a corresponding Heightmap Segmentation frame consisting of a single row. Each layer, i.e., segment, within a Heightmap Segmentation SOP Instance may therefore be specified by a set of 1-D frames.

Heightmap segmentations of OPT (or other) images may be used in a number of follow-on applications. The surfaces may be overlaid on renderings of the source images, or they may be used to select data to be further processed, e.g., to create en face images of individual retinal layers.