Digital Imaging and Communications in Medicine (DICOM)

Curved and Straightened Volumetric Presentation States

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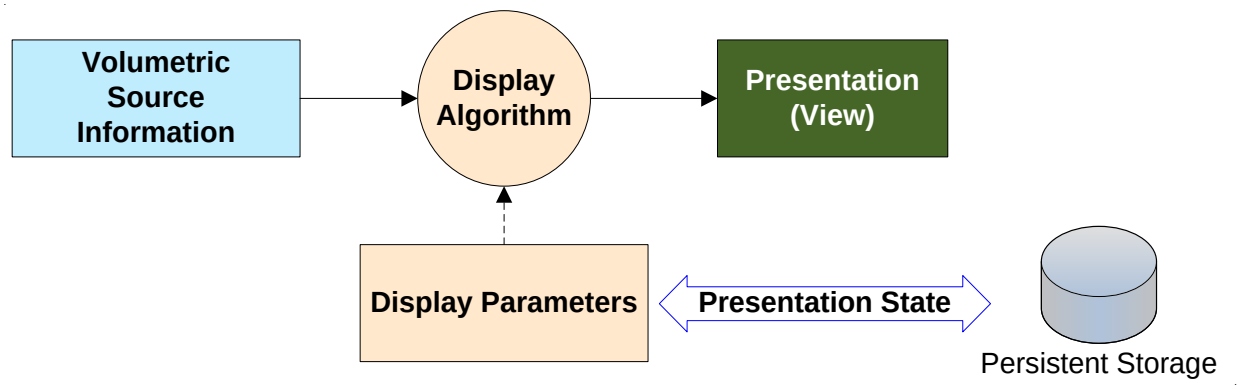
Scope and Field of Application

This supplement adds a SOP Class for Curved and Straightened MPR Volumetric Presentation State to the DICOM Standard.

The new SOP Class will allow rendering of 3D volumes which may be represented as any of the following structures:

SOP Classes in which a single instance may represent 3D volume datasets, such as XA-3D or many of the Enhanced SOP ClassesSOP Classes which by convention allow a collection of instances within a common Frame of Reference to contain spatially related frames that together comprise a 3D volume dataset. This is commonly done within the CT and MR modalities.

3D data may be used in a variety of ways, including quantification through a variety of volume-based algorithms and presentation through a variety of display algorithms, such as frame-by-frame viewing, multi-planar reformatting slicing, surface and volume rendering, and the like. When a volume presentation is created through the use of a Display Algorithm, it typically requires a set of Display Parameters that determine the specific presentation to be obtained from the volume data. Persistent storage of these Display Parameters used by a Display Algorithm to obtain a presentation from a set of volume-related data is called a Volumetric Presentation State.



The Volumetric Source Information consists of one volume (3D) input used to form the presentation.

Volumetric Presentation States can only be applied by systems capable of performing the processing described in the presentation. Volumetric Presentation State creators may still wish to create Secondary Captures or other derived images to convey basic presentation information to systems without these capabilities (see PS 3.17 Annex Y.2).

Each Volumetric Presentation State describes either a single view or an initial view and optional animation parameters. A Volumetric Presentation State may also indicate that a particular view is intended to be displayed alongside the views from other Volumetric Presentation States. However, descriptions of how multiple views should be presented are not part of a Volumetric Presentation State and must be specified by a Structured Display, a Hanging Protocol or by another means.

Whenever such complex algorithms are being described in an inter-operable way, it is very difficult or impossible to describe the display algorithms to such detail that a presentation produced at a later time is indistinguishable from that of the original presentation. While this supplement continues to use established DICOM concepts of grayscale and color matching (GSDF and ICC color profiles) and provides a generic description of the different types of display algorithms possible, variations in algorithm implementations within display devices are inevitable and an exact match of volume presentation on multiple devices cannot be guaranteed. Nevertheless, significant matching is provided, including specification of inputs,

geometric descriptions of spatial views, type of processing to be used, color mapping and blending, input fusion, and many generic rendering parameters, producing what we believe to be a clinically acceptable result.

The process used in the creation of this standard started with the collection of clinical use cases representing a large number of modalities and interested clinical specialties. From these clinical use cases, technical requirements were identified and clearly defined. These technical requirements go on to drive the definition of the actual standard.

This supplement also contains examples of how the VPS can be used to represent these clinical scenarios. See PS 3.17 Section Y.3.

Questions and Open Issues

1. Are the algorithms and parameters specified for Curved and Straightened MPRs correct and unambiguous?

Assumptions Used and Closed Issues

1. There are two philosophies that could be followed in defining the scope of presentation states: Either try to preserve the stylistic appearance of a view from the source device on the display or allow the display application to display all source objects using a consistent style.

   Assumption: This supplement takes the latter approach, giving the display device the latitude to choose style of characters, annotations, etc.as this approach makes for a simpler presentation state object and a more consistent user experience on the display device.

2. Assumption: The SOP instances defined in this Supplement contain no information regarding the layout of this View relative to other Views on a display. However, separate presentation states may be associated together using the Presentation State Spatial Collection UID (0070,x101).

3. Should there be a separate SOP Class for MPR or make it part of a general MD-PS SOP Class? If the latter, would need an attribute that indicates what type of View is being described.

   Separate SOP Classes for each view type: Planar MPR, Curved MPR, Volume Rendering. It allows an application to support one type of view without necessarily support more advanced types and communicate that via association negotiation.

4. Should only one view is defined by an Volumetric presentation state SOP instance, since to define a collection of views would appear to violate the following condition in PS3.4 N.1.1?

   > "The Softcopy Presentation State Storage SOP Classes may be used to store a single state per image, or a common state to be shared by multiple selected images."

   Web3D is concerned that this may be less efficient than designating a number of geometrics.

   Current assumption is that a single Presentation State instance may describe a collection of views if they originate from the same geometric description. A change to the wording of PS3.4 N.1.1 is made to reflect this.

5. There exists an opinion that there should be a mechanism for including annotation (text and/or graphics) without any clinical context associated with it. The rationale is that existing use models include unstructured mark-up, with clinical significance or justification to be added later during report dictation, and it would be a workflow impediment to require the user to enter machine-readable clinical context at the time of capturing the view. The proponents also state that requiring linked clinical objects would be a barrier to the adoption of Volumetric presentation state in their products. Other members disagree and feel that linked clinical objects (SR, segmentation

objects, fiducials) be the only mechanism provided for including annotation in the presentation views.

Current design explicitly defines annotations associated with each input set, annotations in the volume space, and annotations in the 2D presentation space. Segmentation objects referenced from an input set include a clinical context for the input set, and a provision for linking annotations in the volume space with external instances provides clinical context (e.g., fiducials, segments, SR measurements) for volume annotations. No provision is made to link 2D presentation annotations with external clinical instance.

6. Will we always know the real-world calibration of volume data such that the Multi Planar Reconstruction Slab Thickness (0070,xx3A) can be in millimeters?

   Yes – all such values have units of millimeters.

7. Is the allowed length of a curve sufficient for the required precision of placement for curved MPRs?

   Parametric curves are no longer used and instead a set of discrete points describe the curve. The length of the curve is limited only by the VR of Number of Contour Points (3006,0046).

8. Which direction should the MPR surface normal point – away from the viewer or toward the viewer? Assume away until additional information is available.

   Addressed this issue by specifying the upper left/lower right corners of the MPR display area relative to the volume dataset

9. Do we need a specific trapeziodal cropping method for X-ray collimation, or is Oblique plane cropping sufficient?

   No. The oblique plane cropping method may be used for this purpose.

10. Does Curved MPR need to allow blending of multiple volumes

    Yes. Both involving different data types and segmentation.

11. Does Curved MPR need to allow Input Presentation Sequences?

    Yes. Example is flow information over time.

Changes to NEMA Standards Publication PS 3.2-2011

Digital Imaging and Communications in Medicine (DICOM)

Part 2: Conformance

Item #1: Add SOP Classes to PS3.2 Table A.1-2

Table A.1-2
UID VALUES

UID Value	UID NAME	Category
…		
1.2.840.10008.5.1.4.1.1.11.x2	**Curved MPR Volumetric Presentation State Storage SOP Class**	**Transfer**
…		

Changes to NEMA Standards Publication PS 3.3-2011
Digital Imaging and Communications in Medicine (DICOM)
Part 3: Information Object Definitions

Item #2: Add definitions to PS3.3 Section 3.17

Curved MPR: An MPR where the samples are centered on a curve and parallel to the view direction.

Straightened MPR: An MPR where the samples are centered on a curve and perpendicular to the curve.

Item #3: Add IODs to PS3.3 Table A.1-1

IODs Modules	Curved MPR Volumetric Presentation State
Patient	M
Clinical Trial Subject	U
General Study	M
Patient Study	U
Clinical Trial Study	U
General Series	M
Clinical Trial Series	U
Presentation Series	M
Frame Of Reference	M
General Equipment	M
Enhanced General Equipment	M
Volumetric Presentation State Identification	M
Volumetric Presentation State Relationship	M
Volume Cropping	M
Presentation Clinical Description	M
Multi Planar Reconstruction Geometry	M
Volumetric Presentation State Display	M
Volume Graphic Annotation	U
Graphic Annotation	U
Graphic Layer	C
Presentation Animation	U
Common Instance Reference	M
SOP Common	M

Item #4: Append to PS3.3 Annex A.X VOLUMETRIC PRESENTATION STATE INFORMATION OBJECT DEFINITIONS

A.X.x2 Curved MPR Volumetric Presentation State Information Object Definition

A.X.x2.1 Curved MPR Volumetric Presentation State Description

The Curved MPR Volumetric Presentation State Information Object Definition (IOD) specifies information that may be used to present (display) 3D volume datasets that are referenced from within the IOD.

It includes capabilities for specifiying:

a. cropping of the volume datasets by a bounding box, oblique planes and segmentation objects
b. the generation geometry of thin and slab Multi Planar Reconstructions
c. the algorithm for rendering slab Multi Planar Reconstructions
d. the algorithm for generating curved and straightened Multi Planar Reconstructions
e. scalar to P-Value or RGB Value conversions
f. clinical description for the specified view
g. volume and display relative annotations, including graphics, text and overlays
h. membership to a collection of related Volumetric Presentation States intended to be processed or displayed together
i. the temporal position within a set of temporally related Volumetric Presentation States
j. hints for animating the view
k. reference to an image depicting the view described by the Presentation State

A.X.x2.2 Curved MPR Volumetric Presentation State IOD Module Table

Table A.X.x2-1
CURVED MPR VOLUMETRIC PRESENTATION STATE 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
	Clinical Trial Series	C.7.3.2	U
	Presentation Series	C.11.9	M
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
Presentation State	Volumetric Presentation State Identification	C.11.x1	M

	Volumetric Presentation State Relationship	C.11.x2	M
	Volume Cropping	C.11.x3	M
	Presentation Clinical Description	C.11.x4	M
	Multi Planar Reconstruction Geometry	C.11.x5	M
	Volumetric Presentation State Display	C.11.x8	M
	Volume Graphic Annotatation	C.11.x9	U
	Graphic Annotation	C.10.5	U
	Graphic Layer	C.10.7	C Required if Graphic Layer (0070,0002) is present in Volumetric Presentation State Relationship module, Volume Graphic Annotation, or Graphic Annotation module
	Presentation Animation	C.11.xA	U
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	M

A.X.x2.3.1 Curved MPR Volumetric Presentation State IOD Content Constraints

A.X.x2.3.1.1 Multi Planar Reconstruction Style

All Presentation Input Type(0070,x202) elements shall have a value of VOLUME.

A.X.x2.3.1.2 Multi Planar Reconstruction Style

Multi Planar Reconstruction Style (0070,x501) shall be one of CURVED or STRAIGHTENED.

A.X.x2.3.1.3 Graphic Annotation Module

The values of the following attributes, if present, shall be DISPLAY:

- Bounding Box Annotation Units (0070,0003)
- Anchor Point Annotation Units (0070,0004)
- Graphic Annotation Units (0070,0005)

The specified annotation is associated with the specified View and not with the input data, and may have clinical relevance only to the specified View. Therefore, if an application alters the View from that defined by the Presentation State, annotation may no longer be clinically correct.

Note: See PS 3.17 Annex Y “Usage of Annotations in Volumetric Presentation States (Informative)” for guidance on usage of the graphic annotation styles available in this IOD.

A.X.x1.3.1.4 Volume Cropping Module

The values of Volume Cropping Method (0070,x302) shall be selected from the following list:

- BOUNDING_BOX
- OBLIQUE_PLANES
- SEGMENTATION
- EXCLUSION

A.X.x2.3.1.5 Volumetric Presentation State Reference Coordinate System

See A.X.x1.3.1.4 “Volumetric Presentation State Reference Coordinate System”.

Item #5: Modifications to PS3.3 Annex C

C.11.x5 Multi Planar Reconstruction Geometry Module

Table C.11.x5-1 contains Attributes that describe the geometry of this Multi Planar Reconstruction view.

Table C.11.x5-1
MULTI PLANAR RECONSTRUCTION GEOMETRY MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Multi Planar Reconstruction Style	(0070,x501)	1	Style of the MPR view. Enumerated Value**s**: PLANAR **CURVED** **STRAIGHTENED**
…			
MPR View Width Vector	(0070,x511)	1C	Vector indicating the direction in the Volumetric Presentation State – Reference Coordinate System of the topmost row of the rectangular MPR view, and whose length indicates the width of the MPR view, in mm. See C.11.x5.1 **for use in Planar MPR**. **See C.11.x5.2 for use in Curved MPR.** Required if Multi Planar Reconstruction Style (0070,x501) is PLANAR **or CURVED**.
MPR View Height Vector	(0070,x512)	1C	Vector indicating the direction in the Volumetric Presentation State – Reference Coordinate System of the leftmost column of the rectangular MPR view, and whose length indicates the width of the MPR view, in mm. See C.11.x5.1 **for use in Planar MPR**. **See C.11.x5.2 for use in Curved MPR.** Required if Multi Planar Reconstruction Style (0070,x501) is PLANAR **or CURVED**.
MPR Top Left Hand Corner	(0070,x505)	1C	The 3D location in the Volumetric Presentation State – Reference Coordinate System of the upper left hand corner of the MPR View rectangle, in mm. See C.11.x5.1 **for use in Planar MPR**. **See C.11.x5.2 for use in Curved MPR.** Required if Multi Planar Reconstruction Style (0070,x501) is PLANAR **or CURVED**.
MPR Curve Sequence	**(0070,x506)**	**1C**	**Set of points comprising a stepwise-continuous curve used to generate the MPR view.** **Only one Item shall be included in this sequence.** **Required if Multi Planar Reconstruction Style (0070,x501) is CURVED or STRAIGHTENED.**
>Number of Volumetric Curve Points	**(0070,x50C)**	**1**	**Number of (x,y,z) points in Volumetric Curve Points (0070,x50D).**

Attribute Name	Tag	Type	Attribute Description
>Volumetric Curve Points	(0070,x50D)	1C	Specifies the coordinates of the curve's control points in the Volumetric Presentation State Reference Coordinate System, in mm. One triplet (x,y,z) shall be present for each point in the curve. The number of points shall not exceed ((2^16)-1)/3 so as to be encodeable in explicit VR transfer syntaxes with a 16 bit VL. Note: The curve length is considered to be sum of the lengths of the line segments between consecutive points of the curve.
MPR View Width Direction	(0070,x507)	1C	Direction cosine (x,y,z) within the VPS RCS of the first row of the MPR view. Shall be perpendicular to the curve at the start point. See C.11.x5.3 Required if Multi Planar Reconstruction Style (0070,x501) is STRAIGHTENED.
MPR View Width	(0070,x508)	1C	Width of the Straightened MPR view, in mm. See C.11.x5.3 Required if Multi Planar Reconstruction Style (0070,x501) is STRAIGHTENED.
MPR Start Point Index	(0070,x509)	1C	Index of the triplet in MPR Curve Sequence (0070,x506) of the point intersecting the first row of the Straightened MPR view, where the first triplet has an index of 1. See C.11.x5.3 Required if Multi Planar Reconstruction Style (0070,x501) is STRAIGHTENED.
MPR End Point Index	(0070,x50A)	1C	Index of the triplet in MPR Curve Sequence (0070,x506) of the point intersecting the last row of the Straightened MPR view, where the first triplet has an index of 1. See C.11.x5.3 Required if Multi Planar Reconstruction Style (0070,x501) is STRAIGHTENED.

Attribute Name	Tag	Type	Attribute Description
MPR View Orientation	**(0070,x50B)**	**1C**	**Displayed position of the first line of the MPR view.** **Enumerated Values:** **BOTTOM: The first line or slab is at the bottom of the view.** **LEFT: The first line or slab is at the the left side of the view.** **See C.11.x5.3** **Required if Multi Planar Reconstruction Style (0070,x501) is STRAIGHTENED.**

C.11.x5.1.2 CURVED Style

A CURVED MPR is a thin or thick slice of the input volume resembling a length of ribbon traversing a specified curve through the input volume. The ribbon is flattened to create the displayed Curved MPR view. The view geometry is defined by a set of parameters in the Multi Planar Reconstruction Geometry Module.

The curve is specified in MPR Curve Sequence (0070,x506) by a set of points that form a stepwise-continuous curve.

The term “anchor line” is defined as a line normal to both the MPR View Width Vector (0070,x511) and MPR View Height Vector (0070,x512). A set of anchor lines exists, intersecting the MPR View Height Vector (0070,x512) and equally spaced along the vector with the first anchor line of the set intersecting the point MPR Top Left Corner (0070,x505).

If MPR Thickness Type (0070,x502) is THIN, the MPR view consists of the set of line segments parallel to and the same length as the MPR View Width Vector (0070,x511), with each line segment on the line intersecting the curve and with the left-most point of each line segment on the corresponding anchor line.

Note: The curve intersects the line but does not need to intersect the line segment comprising the ribbon. This means that it may lie to the left or the right of the ribbon, outside the field of view at that point.

If MPR Thickness Type (0070,x502) is SLAB, instead of the Curved MPR view being comprised of line segments it shall be comprised of rectangular regions centered around the line segment and parallel to the anchor line. The volume defined by the set of rectangular regions is rendered according to the Compositing Algorithm (0070,x206).

If the specified curve is not long enough to complete the view, behavior is an implementation decision and is outside the scope of this standard.

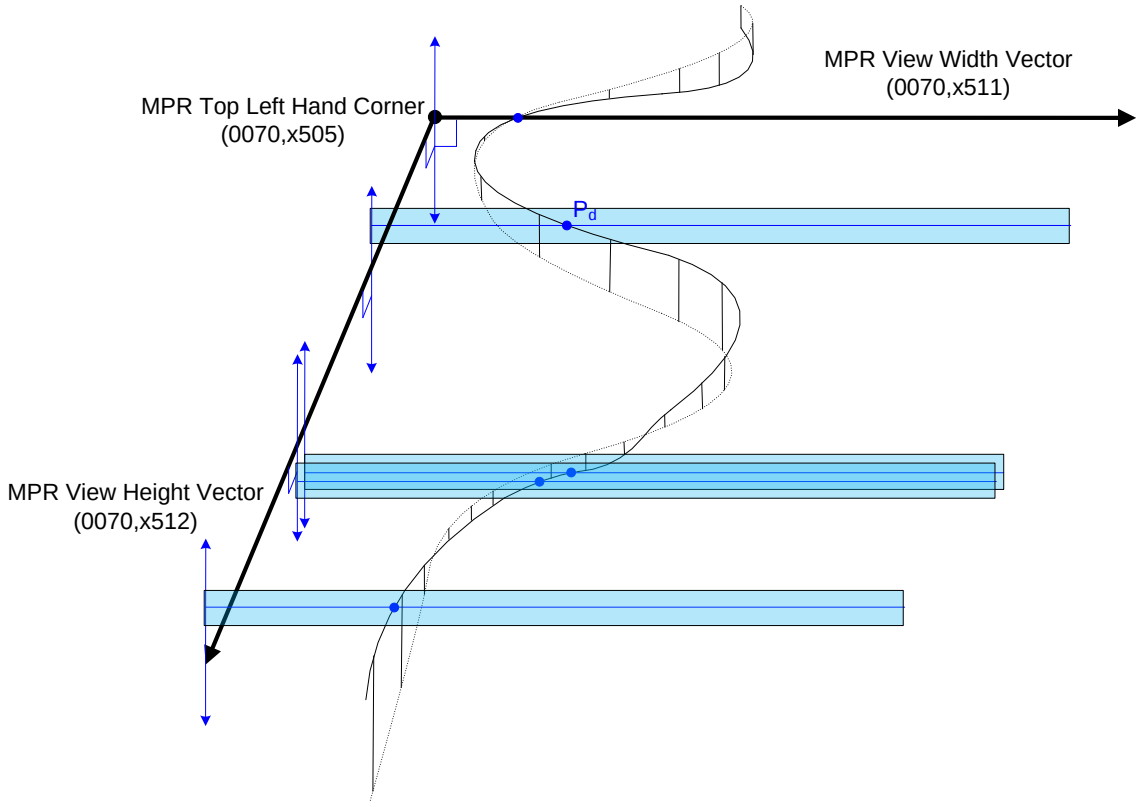


Figure C.11.x5-2: Curved MPR View Construction

C.11.x5.1.3 STRAIGHTENED Style

A STRAIGHTENED MPR is a thin or thick slice of the input volume traversing a specified curve through the input volume. The resulting view depicts the anatomy near the curve on a straight veritical line in the center of the view. See Figure C.11.x5-3.

The curve is specified in MPR Curve Sequence (0070,x506) by a set of points that form a stepwise-continuous curve. If MPR Thickness Type (0070,x502) is THIN, the Straightened MPR view is made up of line segments of length MPR View Width (0070,x508) intersecting the curve at equally-spaced points along the curve from a start point on the curve defined by MPR Start Point Index (0070,x509) to an end point on the curve defined by MPR End Point Index (0070,x50A).

Note: The points at which the line segments intersect the curve are not necessarily the points in MPR Curve Sequence (0070,x506) defining the piecewise-continuous curve. Rather, the spacing of line segments is determined by the vertical resolution of the view chosen by the implementation and is outside the scope of this standard.

Each line segment comprising the view is centered and perpendicular to the curve at the intersection point and parallel to a reference plane defined by the vector tangent to the curve at the start point and MPR View Width Direction (0070,x507). The presentation is viewed in the direction of the cross-product of the vector tangent to the curve at the start point and MPR View Width Direction (0070,x507) (the “look direction”).

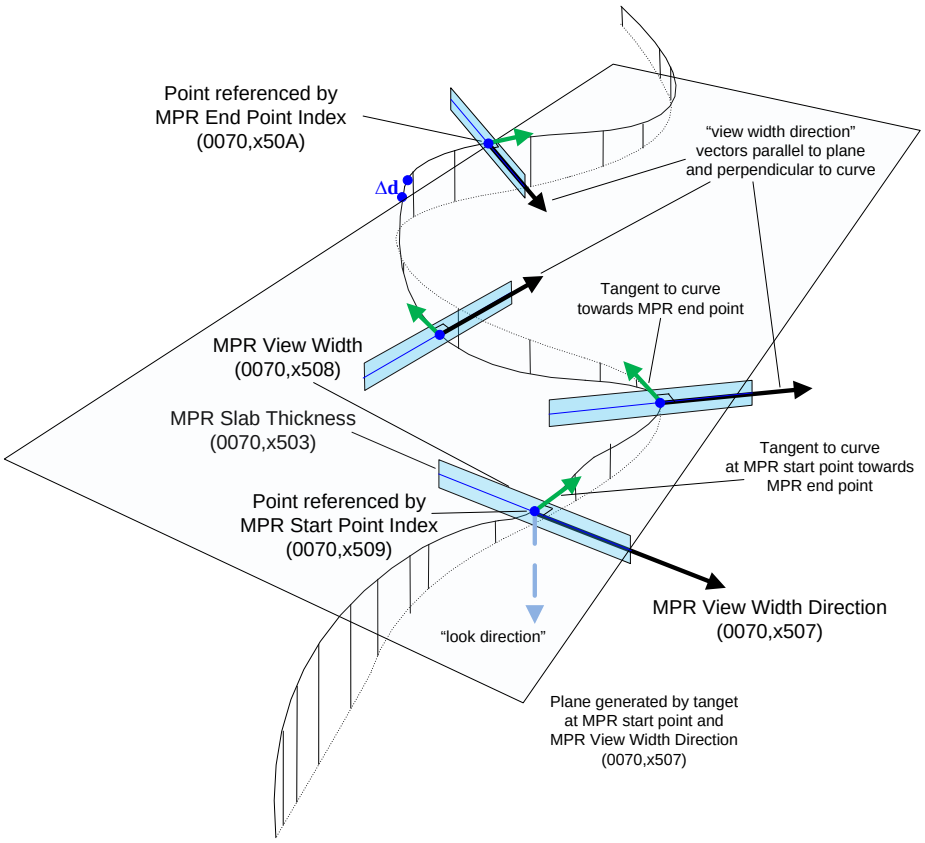


Figure C.11.x5-3: Straightened MPR View Construction

At each line intersection, there are generally two possible "view width directions" that are perpendicular to the curve and parallel to the reference plane. The view width direction for each line segment shall be that direction which has the minimum angle with the view width direction of the previous line segment.

In the special case where the curve tangent vector is normal to the reference plane at a sample point, all perpendicular intersecting lines are parallel to the reference plane. In this case, there is a view width direction at the sample just prior to the vertical curve segment and a view width direction at the sample just after the vertical curve segment. The directions of the view width directions within and subsequent to the vertical curve segment shall be determined as follows:

- The direction of the view width direction vector at the sample just after the vertical curve section is that direction which has the minimum angle to the view width direction vector at the sample just prior to the vertical curve segment.

  Note: If the change of direction is exactly 180 degrees, it is an implementation decision how to interpolate the angles of segments in the vertical curve section.

- The directions of the view width direction vectors within the vertical curve section are obtained by interpolating evenly between the view width directions at the sample just before and the sample just after the vertical section.

Once the view width direction vector is determined at each sample, the look direction is again the cross-product between the vector tangent to the curve and the view width direction at that sample.

If MPR Thickness Type (0070,x502) is SLAB, instead of the Straightened MPR view being comprised of line segments it shall be comprised of rectangular regions centered around the line segment and parallelto the plane defined by the view width direction vector and the look direction vector. The volume defined by the set of rectangular regions is rendered according to the Compositing Algorithm (0070,x206).

The final orientation of the view is determined by MPR View Orientation (0070,x50B) which specifies whether the first line (or slab) of the view is positioned at the bottom or the left side of the display.

Changes to NEMA Standards Publication PS 3.4-2011
Digital Imaging and Communications in Medicine (DICOM)

Part 4: Service Class Specifications

Item #6: Add SOP Classes to PS3.4 Annex B

B.5 Standard SOP Classes

Table B.5-1
Standard SOP Classes

SOP Class	SOP Class UID	IOD Specification (defined in PS 3.3)
Curved MPR Volumetric Presentation State Storage SOP Class	**1.2.840.10008.5.1.4.1.1.11.x2**	**Curved MPR Volumetric Presentation State**

B.5.1.y Curved MPR Volumetric Presentation State Storage SOP Classes

See Annex N.

Item #7: Modifications to PS3.4 Annex I

I.4 Media Storage Standard SOP Classes

Table I.4-1
Media Storage Standard SOP Classes

SOP Class	SOP Class UID	IOD Specification (defined in PS 3.3)
Curved MPR Volumetric Presentation State Storage SOP Class	**1.2.840.10008.5.1.4.1.1.11.x2**	**Curved MPR Volumetric Presentation State**

Item #8: Update PS3.4 Annex X VOLUMETRIC PRESENTATION STATE STORAGE SOP CLASSES (Normative)

…

Changes to NEMA Standards Publication PS 3.6-2011

Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

Item #9: Add the following rows to PS3.6 Section 6

6 Registry of DICOM data elements

Note: For attributes that were present in ACR-NEMA 1.0 and 2.0 and that have been retired, the specifications of Value Representation and Value Multiplicity provided are recommendations for the purpose of interpreting their values in objects created in accordance with earlier versions of this standard. These recommendations are suggested as most appropriate for a particular attribute; however, there is no guarantee that historical objects will not violate some requirements or specified VR and/or VM.

Tag	Name	Keyword	VR	VM
(0070,x506)	**MPR Curve Sequence**	**MPRCurveSequence**	**SQ**	**1**
(0070,x507)	**MPR View Width Direction**	**MPRViewWidthDirection**	**FD**	**3**

Item #10: Add the following rows to PS3.6 Annex A Table A-1

UID Value	UID Name	UID Type	Part
1.2.840.10008.5.1.4.1.1.11.x2	**Curved MPR Volumetric Presentation State Storage SOP Class**	**SOP Class**	**PS 3.4**

Changes to NEMA Standards Publication PS 3.17-2011
Digital Imaging and Communications in Medicine (DICOM)

Part 17: Explanatory Information

Item #11: Add Annexes to Part 17

Annex X xxx (Informative)