 Advances in X-Ray Angiography and 3D Presentation

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Introduction
  - Overview of X-Ray Angiography in DICOM

N-Dimensional Presentation
  - Introduction
  - X-Ray Use Cases

Dose Structured Report for CR-DR
  - CP1077: new Dose SR templates

Conclusion
X-Ray Angiography in DICOM

**X-Ray Acquisition**

- **2D Projection Images**
- **3D Reconstruction**

**Approved in the Standard**
- Supp 94: Radiation Dose Reporting
- Supp 83: Enhanced XA/XRF
- Supp 140: Presentation State
- Supp 139-FT: Enhanced XA P3.17

**Work in Progress**
- Follow-up of IHE REM Profile
- CR-DR Dose Reporting
- X-Ray 3D Informative Annex
- N-Dimensional Presentation State

Supp 116: X-Ray 3D Storage
N-Dimensional Presentation

Introduction
DICOM N-D Presentation State

What is Presentation State?

A “recipe” describing a particular presentation (display) of a data object. According to DICOM, 2D Presentation State includes capabilities for specifying:

- the **output grayscale** space in P-Values
- the **color output** space as PCS-Values
- grayscale **contrast transformations** including modality, VOI and presentation LUT
- **mask subtraction** for multi-frame grayscale images
- selection of the **area of the image to display** and whether to rotate or flip it
- image and display **relative annotations**, including graphics, text and overlays
- the **blending** of two image sets into a single presentation
Data objects may contain certain attributes as a “default Presentation State” for the object itself – not for relationships with other objects.

A separate Presentation State object referencing the data object overrides the default presentation state attributes within the referenced data object.
Enhanced DICOM Objects change the game

- Many modalities have created “Enhanced” data objects which allow the specification of 3D and 4D data sets (MR, CT, XA, PET, US, …)
- These 3D/4D datasets may be presented (viewed) as:

  A collection of spatially-related frames
  
  Displayed one at a time, as in a light box display
  
  Sequentially, in “fly-through” display

  A Multi-Planar Reformatting (MPR) view, which is a derived slice obliquely through the volume dataset

  Volume Rendering, which is a view of the volume dataset from a specified viewport and orientation
3D Workflow

- These derived views may be exchanged as objects linked to the source volume data objects.
- Need a way to represent the “recipe” for creating these views of volume data objects so the viewing operation may be replicated on a different system and/or at a different time.
Example 3D Image Review Workflow

- **Clinician:**
  - Reviews a 2D derived view on a PACS
  - Decides to reposition the slice or viewport or change processing

- **Presentation object:**
  - provides the recipe and a link to the source volume data

- **Workstation:**
  - uses the recipe to regenerate the same 2D view

- **Clinician:**
  - uses workstation controls to modify presentation parameters starting from the same point as the original 2D view
What’s happening within DICOM working groups

- **Working Group 11** (Presentation State) has a work item to create a general (not modality specific) n-Dimensional Presentation State object
- **WG-02** (X-Ray Angiography), **WG-12** (Ultrasound), **WG-24** (Surgery) are currently collaborating
  - Need to understand use cases and requirements for all DICOM imaging modalities
  - Other imaging modalities need to participate in the creation of nD PS objects
Standardization Challenges

- Distinguishing open-system capabilities from proprietary
  - **Open**: e.g. MPR plane position/orientation, Render viewport
  - **Proprietary**: e.g. Certain rendering or edge enhancement algorithms

- Maximizing:
  - similarity of source and review presentations without disclosing trade secrets
  - commonality while recognizing unique modality features
Standardization Challenges

Most Objective
Most Interoperable

openclass

Most Proprietary
Least Interoperable

Display Layout
- Single view
- Multiple MPR set
  - Parallel planes
  - Curvilinear
- Combination view, such as A, B, C MPR views plus Volume render view

Cropping
- Crop planes
- Sculpting Mask
- Segmentation

MPR geometry
- Plane location/orientation
- MPR view size
- Slice thickness
- Curvilinear MPRs

Render geometry
- Viewport
- Volume of interest

Annotations
- Graphics
- Text
- Anatomic View designation

Blending
- Grayscale/color maps
- Grayscale/color threshold
- General classification of algorithms
- Intensity Projection
- MIP
- MinIP
- AveIP
- Volume Rendering
- Surface Rendering

Opacity maps
- Order of application of
  - Calculation of Normals
  - Blending to RGB
  - Rendering
  - Lighting model/parameters

Slicing algorithms
- Rendering algorithms
- Edge Detection algorithms
- Smoothing algorithms
- Filtering algorithms
- Cropping and Sculpting algorithm parameters
Call for Participation

- In the best interest of vendors and clinicians for all modalities to participate
  - Desired minimum level of participation
    - Use Cases
    - Requirements
    - Test Cases
  - Better
    - Participate in Derivation of the Standard (technical IOD definition)
N-Dimensional Presentation

- X-Ray Use Cases
X-Ray 3D Angiography

Frame i:
X-ray settings
Geometry settings

Optimized 3D Reconstruction
Workflow in X-Ray N-D Presentation

- X-Ray Acquisition System
- X-Ray Calibration Procedure
- Enhanced XA Storage SOP Class
- Calibration Data Proprietary
- X-Ray 3D Reconstruction System
- X-Ray 3D Storage SOP Class
- Visualization
- In progress: N-D Presentation State SOP Class
- 3D Visualization Systems

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Clinical Specialties Considered

- Cardiology
- Oncology
- Radiology
- Electrophysiology
Specific Clinical Use Cases

1- Collimated Rotational Acquisition
2- Volume Subtraction
3- Stent Stabilization
4- Catheter Tracking
5- Stenting Planning
6- Trajectory Planning
7- Ablation Planning
8- 2D/3D Blending

Use case convention:
The angiographic equipment performs both X-Ray acquisition and 3D reconstruction
1- Collimated Rotational Acquisition

- **Specialty:** Cardiology, Radiology
- **Modality:** X-Ray Angiography
- **Description:** Acquisition with collimation
- **Procedure key steps:**

  **At the angiographic equipment**
  - Acquisition of projections with collimation to reduce radiation dose
  - Reconstruction of cubic volume, the peripheral voxels within the collimated area are not clinically relevant and are not displayed (hidden by a digital 3D shutter)
  - The operator changes the boundary of the 3D shutter to visualize a smallest region of interest, thus hiding more voxels

  **At the workstations, reviewing physician**
  - Opens the volume for review
  - The 3D shutter is applied, the collimated voxels and other hidden voxels are not displayed
  - The operator changes the boundary of the shutter to show some of the collimated area, control of the collimation edges, and to see peripheral vessels
2- Volume Subtraction

- **Specialty:** Radiology
- **Modality:** X-Ray Angiography
- **Description:** Acquisition of mask and contrast volumes
- **Procedure key steps:**

  **At the angiographic equipment**
  - Acquisition of two sets of projections by rotational angiography: one set of masks, another set of contrasted vessels
  - Reconstruction of two volumes, one with the background structures (bones, soft tissues…), another with contrasted vessels
  - The operator visualizes the volume subtracted and applies a shift between the mask and contrast to correct for patient movement between both acquisitions

  **At the workstations, reviewing physician**
  - Opens the volumes for review
  - The volume is displayed subtracted, with the previous shift applied
  - The operator changes the shift between the mask and contrast to improve the visualization
  - The operator displays and hides sequentially the background structures to better assess the relationship between the artery and the calcified plaque, stent…
3- Stent Stabilization

- **Specialty:** Cardiology
- **Modality:** X-Ray Angiography
- **Description:** Cardiac Stent Stabilization
- **Procedure key steps:**

  At the **angiographic equipment**
  - Rotational acquisition of different phases of the heart with a coronary stent
  - Reconstruction of several 3D volumes, corresponding to the phases of the heart
  - The operator defines the region of the stent in the different phases
  - The operator visualizes the dynamic view of the heart (4D) with the position and orientation of the stent stabilized on the screen

  At the **workstations, reviewing physician**
  - Opens the volumes for review
  - The volume is displayed in dynamic view, with the stent stabilized
  - The operator changes the orientation of the volume to see other view of the stent, the dynamic view continues with the stent stabilized
  - The operator may change the region to stabilize to a second coronary stent
4- Catheter Tracking

- **Specialty:** Cardiology, Radiology
- **Modality:** X-Ray Angiography
- **Description:** Catheter & Vessel Tracking
- **Procedure key steps:**

  At the **angiographic equipment**
  - Rotational acquisition and reconstruction of one volume with contrasted vessels
  - The operator defines a 3D curve from point A to point B inside an artery (simulating a catheter trajectory). This is performed during the planning phase of a catheterization intervention
  - The operator defines an animated sequence to view the progress of the 3D curve:
    - from the outside of the volume, changing the orientation of the volume to be perpendicular to the tip of the curve
    - from inside the artery (fly-thru) as virtual endoscopy
  - The operator defines a deployed view of a cross-section of the vessel along the 3D curve, and can rotate it around the 3D curve

  At the **workstations, reviewing physician**
  - Opens the volumes for review
  - The operator reviews the animated sequences, changes the position of the points A and B to see other 3D curves
5- Stenting Planning

- **Specialty:** Cardiology, Radiology
- **Modality:** X-Ray Angiography
- **Description:** Stent Placement Planning
- **Procedure key steps:**
  
  At the **angiographic equipment**
  - Rotational acquisition and reconstruction of one volume with contrasted vessels
  - The operator defines the proximal and distal points of one or more stenosis, these points represent the “start” and the “end” extremities of the stent
  - The operator defines the volume orientation that optimizes the view of the stenosis (optimal view angle)
  - This is performed during the planning phase of a stenting intervention

  At the **workstations, reviewing physician**
  - Opens the volumes for review
  - The volume is displayed at the defined orientation, centered in the stenosis
  - The operator reviews and validates the points and orientation, or change them to a better choice for the further stenting
  - The modified points and orientation will be used as reference for the stenting intervention
6- Trajectory Planning

- **Specialty:** Radiology, Oncology
- **Modality:** X-Ray Angiography
- **Description:** Needle Trajectory Planning
- **Procedure key steps:**

  At the **angiographic equipment**
  - Rotational acquisition and reconstruction of one volume
  - The operator defines one or more straight lines representing the trajectories of a device (e.g. needle) to be introduced during further treatment (e.g. cementoplasty, tumor ablation…)
  - This is performed during the planning phase of the intervention

At the **workstations, reviewing physician**
- Opens the volumes for review
- The volume is displayed at pre-defined orientations for the first trajectory (e.g. perpendicular or parallel views)
- The operator reviews and validates the different trajectories, or change them to a better choice for the further intervention
- The modified trajectories will be used as reference for the intervention
7- Ablation Planning

- **Specialty:** Electrophysiology
- **Modality:** X-Ray Angiography
- **Description:** Left Ventricle/Left Atrium Ablation Planning
- **Procedure key steps:**

  At the **angiographic equipment**
  - Rotational acquisition of the heart and reconstruction of one phase of a cardiac cycle
  - Segmentation of the heart chambers (without electrical map)
  - The operator defines one or more points on the surface, representing the ablation points to be applied during further treatment (e.g. in case of atrial flutter, to block conduction within the left atrium, especially around the pulmonary veins)
  - This is performed during the planning phase of the ablation

  At the **workstations, reviewing physician**
  - Opens the volumes for review
  - The volume is displayed with the planned ablation points
  - The operator reviews and validates the points, or change them to a better choice for the further ablation
  - The modified points will be used as reference for the ablation
8- 2D/3D Blending

- **Specialty:** Cardiology, Radiology, Oncology, Electrophysiology
- **Modality:** X-Ray Angiography
- **Description:** Blending of 2D and 3D images
- **Procedure key steps:**
  
  At the **angiographic equipment**
  - Rotational acquisition and reconstruction of one volume (3D)
  - (Or retrieve CT/MR volume)
  - 3D segmentation, adjust rendering settings, plan intervention (add landmarks)
  - Acquisition of fluoroscopy projection (2D) with catheter and/or interventional device (stent, needle…), blend with the segmented volume (3D) with its landmarks
  - Adjust 2D and 3D rendering: filters, windowing, shutter, 3D transparency

  At the **workstations, reviewing physician**
  - Opens the projection and volume for review
  - Both projection and volume are displayed blended, with the rendering settings and landmarks previously applied
  - The operator changes the rendering settings, displays and hides sequentially the 3D structures to better assess the relationship between the interventional device and the volume (for post-intervention control)
Workflow: XA 2D-3D Blending

X-Ray Rotational Acquisition → X-Ray 2D Projection SOP Class → X-Ray 3D Reconstruction

X-Ray 3D Storage SOP Class → 3D Render → 3D Segmentation → Segmentation SOP Class

3D Render State SOP Class

Segmentation Conic Projection 2D Presentation 3D Presentation

2D-3D Blending

Same Frame Of Reference

2D View → X-Ray 2D Projection SOP Class → New
Dose Structured Report for CR-DR

- CP1077: new Dose SR templates
Dose Structured Report for CR-DR

Background

- Dose Reporting becomes more important - the tracking of dose within organizations and related to the patient is being recommended (required?) by Authorities.

- Broad and complete implementation DICOM Dose Report is the enabler feature needed!
Current work – CP1077

• Add new set of Templates for “Projection Radiography” based on existing Dose Report object

• Introduce mechanism to scale contents based on the level on integration with:
  • Detector System
  • X-Ray Source
  • Mechanical System

• Group Information in Containers

• Narrow the contents on the specific acquisition context of Projection Radiography systems
  • CR Readers
  • Mobile Detector Systems
  • semi-integrated Radiographic Workplaces
Dose Structured Report for CR-DR

Concepts

- Develop dose reference points
  - Distances for table (70 cm) or upright stand (150 cm) orientations
- Include detector dose indexes
  - Exposure Index
  - Target Exposure Index
  - Deviation Index
- Counter of total number of irradiation events
  - May not be equal to number of images stored (retake/repeat analysis)
Conclusion

Enhanced XA (2D)

- Supplement 139 in Final Text (Informative - DICOM Part 17)
- Will facilitate the adoption of the Enhanced XA SOP Class (Sup 83)

Dose SR for CR-DR

- CP1077 in progress

N-D Presentation State

- N-D Presentation State - Work In Progress – Call for participation

X-Ray 3D Angiography

- New IOD approved in Standard 2007 (Supplement 116)
- Application cases (Informative) - Work In Progress

To get involved in WG-02 developments:
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