DICOM Enhancements
Current and Future

Donald Peck, PhD
Michael Flynn, PhD

Part I
An overview of the DICOM standard
- Parts of the standard
- The concept of objects
- Implementation of changes

Part II
Example enhancements and work items
- Recent enhancements
- Current work items

Dicom Standard
- Developed with an emphasis on diagnostic medical imaging as practiced in radiology, cardiology and related disciplines
- Also applicable to a range of image and non-image information exchanged in other medical environments
- Specification of strict requirements for the contents of the image "header"

Dicom Standard
- Utilizes an open standards development process that encourages the involvement and consensus of both vendors and users
- Specification of a conformance mechanism so that a user can decide whether or not devices are likely to interoperate
DICOM Functionality

- Transmission and persistence of objects
  - images, waveforms and documents
- Query and retrieval of objects
- Performance of specific actions
  - Example: printing images onto film

DICOM Functionality

- Workflow management
  - support of worklists and status information
- Quality and consistency of data
  - Example: display and printing of images

DICOM Standards Committee (DSC)

- DICOM’s executive body whose members are imaging equipment manufacturers, physician organizations, and others
  - 26 manufacturer members
  - 20 other members
- DICOM’s activities are coordinated through a general secretariat at NEMA

DICOM Standards Committee (DSC)

- Development of DICOM Standard is done through committees termed “Working Groups” (WG)
- WG propose work items based on suggestions from members or at the direction of the DSC
<table>
<thead>
<tr>
<th>WG#</th>
<th>Working Group Name</th>
<th>Relevance to Radiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cardiac and Vascular Information</td>
<td>Corovascular imaging, stress nuclear cardiology, structured reporting</td>
</tr>
<tr>
<td>2</td>
<td>Projection Radiography and Angiography</td>
<td>Development of enhanced x-ray and angiography information objects</td>
</tr>
<tr>
<td>3</td>
<td>Nuclear Medicine</td>
<td>Nuclear medicine and PET</td>
</tr>
<tr>
<td>4</td>
<td>Compression</td>
<td>Application of data compression standards, such as JPEG 2000 and JP2K</td>
</tr>
<tr>
<td>5**</td>
<td>Exchange Media</td>
<td>Distribution of images on CD-ROMs, DVDs, and USB “flash” drives</td>
</tr>
<tr>
<td>6</td>
<td>Base Standard</td>
<td>Detailed technical evaluation of proposed additions or changes to the DICOM standard</td>
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</tbody>
</table>

** Not currently active

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>7</td>
<td>Radiotherapy</td>
<td>Radiation therapy, including ion therapy</td>
</tr>
<tr>
<td>8</td>
<td>Structured Reporting</td>
<td>Standardized vocabularies, encoding of structured reports, and integration with other information systems</td>
</tr>
<tr>
<td>9</td>
<td>Strategic Advisory</td>
<td>Long-range planning and coordination of DICOM with other international standards organizations</td>
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<tr>
<td>10</td>
<td>Display Function Standard</td>
<td>Presentation and display of images on workstations, i.e., “hanging protocols”</td>
</tr>
<tr>
<td>11</td>
<td>Ultrasound</td>
<td>Ultrasound imaging, including echocardiography, 3D/4D images</td>
</tr>
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<tr>
<td>13</td>
<td>Magnetic Resonance</td>
<td>MRI</td>
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<tr>
<td>14</td>
<td>3D</td>
<td>Volumetric (multiframe) imaging modalities, including CT, MR, and ultrasound</td>
</tr>
<tr>
<td>15</td>
<td>Clinical Trials and Education</td>
<td>Application of imaging to clinical trials and medical education</td>
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</table>

* starting activity

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<tr>
<td>16</td>
<td>Security</td>
<td>Secure information exchange</td>
</tr>
<tr>
<td>17</td>
<td>Digital Mammography and CAD</td>
<td>Breast imaging; structured reporting of computed-aided detection and diagnosis (CAD) results for mammography and CT colonography</td>
</tr>
<tr>
<td>18</td>
<td>Magnetic Resonance</td>
<td>MRI</td>
</tr>
<tr>
<td>19**</td>
<td>Dermatology Standards</td>
<td>Dermatology</td>
</tr>
<tr>
<td>20</td>
<td>Integration of Imaging and Information Systems</td>
<td>Coordination of DICOM with Health Level Seven (HL7) standard for messaging between health information systems</td>
</tr>
<tr>
<td>21**</td>
<td>Computed Tomography</td>
<td>CT imaging and dosimetry reporting</td>
</tr>
<tr>
<td>22</td>
<td>Dentistry</td>
<td>Dentistry</td>
</tr>
<tr>
<td>23</td>
<td>Application Hosting</td>
<td>Develop specifications for interfaces between hosted application software</td>
</tr>
<tr>
<td>24</td>
<td>DICOM in Surgery</td>
<td>Image-guided surgery and other surgical data</td>
</tr>
<tr>
<td>25**</td>
<td>Veterinary Applications</td>
<td>Veterinary</td>
</tr>
<tr>
<td>26</td>
<td>Pathology</td>
<td>Pathology Applications</td>
</tr>
</tbody>
</table>

** Not currently active
DICOM "workflow"

- Work items are divided into Supplements and Change Orders
  - Supplements define new objects, content or structure
  - Change Orders modify the existing Standard

Output of a work item is submitted to the Base Standards Working Group (WG6) for review
  - WG6 may request changes or clarification to work item to ensure it complies with Standard
  - Once all issues are satisfied WG6 petitions the DSC to approve work item and send out for public comment

After public comment the DSC authorizes the work item for letter ballot by DICOM members
  - Change proposals are often "batched" for public comment and letter ballot, but can be instituted without comment or ballot if the change is required to reduce potential patient care issues or it is typographical or trivial in nature

Changes to Standard

- Currently 100 approved Supplements incorporated into Standard
  - Another 25 in progress or in comment stage
  - Currently ~600 Change Proposals incorporated into Standard
  - ~100 additional in progress
Currently 16 parts

- PS 3.1 Introduction and Overview
- PS 3.2 Conformance
- PS 3.3 Information Object Definitions
- PS 3.4 Service Class Specifications
- PS 3.5 Data Structures and Encoding
- PS 3.6 Data Dictionary
- PS 3.7 Message Exchange
- PS 3.8 Network Communication Support for Message Exchange
- PS 3.9 Media Storage and File Format for Data Interchange
- PS 3.10 Media Storage Application Profiles
- PS 3.11 Media Formats and Physical Media for Data Interchange
- PS 3.12 Grayscale Standard Display Function
- PS 3.13 Security Profiles
- PS 3.14 Content Mapping Resource
- PS 3.15 Explanatory Information
- PS 3.16 Web Access to DICOM Persistent Objects (WADO)

Describes how the Standard is organized

DICOM Standard

- PS 3.3 Information Object Definitions (IOD)
  - Description of an object's purpose and the Attributes which define it
- PS 3.4 Service Class Specifications
  - Associates one or more Information Object with one or more Commands to be performed upon these objects
  - Examples:
    - Storage
    - Query/Retrieve
    - Worklist Management
    - Print Management

- PS 3.5 Data Structures and Encoding
  - Specifies how applications construct and encode the Data Set
- PS 3.6 Data Dictionary
  - Centralized registry which defines the collection of all DICOM Data Elements

- PS 3.7 Message Exchange
  - Specifies the service and protocol used by an application in a medical imaging environment to exchange Messages over the communications support services defined in PS 3.8
- PS 3.8 Network Communication Support for Message Exchange
  - Specifies the communication services and the upper layer protocols necessary to support communication between DICOM applications
• PS 3.10 Media Storage and File Format for Data Interchange

• PS 3.11 Media Storage Application Profiles

• PS 3.12 Media Formats and Physical Media for Data Interchange

• PS 3.14 Grayscale Standard Display Function
  - Specifies a standardized display function for grayscale images

• PS 3.15 Security Profiles
  - Specifies security and system management profiles

• PS 3.16 Content Mapping Resource
  - templates for structuring documents and a lexicon of terms defined

• PS 3.17 Explanatory Information
  - Informative and normative annexes containing explanatory information about most IOD

• PS 3.18 Web Access to DICOM Persistent Objects (WADO)
  - Specifies the means whereby a request for access to a DICOM persistent object can be expressed as an HTTP URL/URI request that includes a pointer to a specific Instance UID
How to "read" DICOM Objects

- Attributes describe the properties of an Information Object
  - Related attributes are grouped into Modules
  - Sets of attributes can be referenced by Macros within Modules

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Tag</th>
<th>Type</th>
<th>Attribute Description</th>
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<tbody>
<tr>
<td>Attribute A</td>
<td>0000.0001</td>
<td>T</td>
<td>This is an example</td>
</tr>
<tr>
<td>Attribute B</td>
<td>0000.0002</td>
<td>T</td>
<td>This is an example</td>
</tr>
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</table>

Example Module Tasks

- Data Element Tag is a unique identifier for the attribute
  - First 4 digits = Group Number
  - Second 4 digits = Element Number
- Data elements defined by the Standard have an even group number
- Private data elements have an odd group number
- Standard does not define any Private Tag attributes
- Tag is a hexadecimal number

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- Data Element Type defines whether an attribute is required
  - Type 1 = mandatory attribute that must always be included
  - Type 2 = mandatory attribute that must be included if known
  - Type 3 = optional attribute
- In some instances, an attribute may be conditional based on specified criteria; in these cases, type # is followed by a "C"
  - i.e. Type 1C, 2C or 3C
- Value Representation (VR) for each attribute is given in PS 3.6 Data Dictionary – Registry of Data DICOM elements

DICOM Attribute Example
Pixel Spacing attributes

Pixel spacing attributes are encoded as the physical distance between centers of 2D pixel

This description applies to:

- Pixel Spacing (0028,0030)
- Imager Pixel Spacing (0018,1164)
- Nominal Scanned Pixel Spacing (0018,2010)
- Image Plane Pixel Spacing (3002,0011)
- Compensator Pixel Spacing (300A,00E9)
- Detector Element Spacing (0018,7022)
- Presentation Pixel Spacing (0070,0101)
- Printer Pixel Spacing (2010,0376)
- Object Pixel Spacing in Center of Beam (0018,9404)

DICOM Attribute Example

Information for each module includes:

- IE = Information entity
- Module name
- Reference to Section in Annex C that contains the Module
- Usage Code
  - M = module support is mandatory
  - C = module support is conditional based on specified criteria
  - U = module support is optional based on the user
Changes to the Standard

On a yearly basis all changes to the Standard are published at: http://medical.nema.org/dicom/

Parts I & II

Part I
An overview of the DICOM standard
- Parts of the standard
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- Implementation of changes

Part II
Example enhancements and work items
- Recent enhancements
- Current work item

Recent DICOM Enhancements

- WG04 (Compression)
  - JPEG 2000 Interactive Protocol
- WG16 (MR)
  - Multiframe MR Object
- WG21 (CT)
  - Enhanced CT
  - Image Storage SOP Class
  - CT Radiation Dose Reporting
- WG17 (3D)
  - Segmentation Storage SOP Class
  - Deformable Spatial Registration Storage SOP Class

New DICOM work items

- WG3 (NM)
  - Enhanced PET Image Storage SOP Class
- WG7 (RT)
  - Enhanced RT Object
- WG15 (Digital Mammography)
  - Breast Tomosynthesis
  - Image Storage SOP Class
- WG17 (3D)
  - Surface Segmentation Storage SOP Class
This Supplement extends the Pixel Data Module to allow reference to a JPIP URL to access pixel data, rather than encoding it in the image instance. The use cases for this extension to the standard relate to an application’s desire to gain access to a portion of DICOM pixel data without the need to wait for reception of all the pixel data. Examples are:

1) Stack Navigation of a large CT Study.
2) Large Single Image Navigation
3) Thumbnails
4) Display by Dimension

JPIP is a client/server communication protocol defined in Part 9 of the JPEG 2000 suite of standards.

www.2kan.org
2KAN is an EC IST project

www.kakadusoftware.com
Kakadu is a complete implementation of the JPEG2000 standard (p1)

The Kakadu software is written by:
- David Taubman, Prof. Univ. S. Wales, who was also the principle author of the JPEG2000 Verification Model (VM) software.
- Minimal license fee for the development of JPEG2000 "freeware".

Supplement 106 establishes a JPIP transfer syntax and adds a tag that provides a URL to the image data that is used instead of the traditional pixel data tag (7FE0,0010).
**1 - JPPIP: Informative Annex**

Annex X

JPPIP Referenced Pixel Data

Transfer Syntax Negotiation

Case 1: AE1 and AE2 both support both a JPPIP Referenced Pixel Data Transfer Syntax and a non-JPPIP Transfer Syntax

- AE1 makes a C-MOVE request to AE2
- AE2 proposes two presentation contexts to AE1, one for with a JPPIP Referenced Pixel Data Transfer Syntax, and the other with a non-JPPIP Transfer Syntax
- AE1 accepts both presentation contexts
- AE2 may choose either presentation context to send the object
- AE1 must be able to either receive the pixel data in the C-STORE message, or obtain it from the provider URL

**1 - JPPIP: Proprietary Implementations**

- Many PACS systems provide services for client access to images using proprietary progressive streaming technology.
- DICOM JPPIP provides a standardized method that might have particular use in an open-source application.
- Possible intellectual property issues still exist.

**2 - eMR: WG 16, Supplement 49**

Enhanced MR Image Storage SOP Class

- Working Group 16: Supplement 49
- Final Text, 26 March, 2002

The supplement describes 3 new IODs:
1. Enhanced MR Image
2. MR Spectroscopy
3. Raw Data

A Multi-Frame concept is introduced which allows attributes grouped together to vary on a frame by frame base. This method is modality independent.

**2 - eMR: Multiframe**

Pixel Measures
- Frame Content
- Plane Position
- Plane Orientation

Reference Image
- Derivation Image
- Cardiac Trigger
- Frame Anatomy
- Pixel value Transformation
- Frame VOI LUT
- Real World Value Mapping

MR Image Frame
- MR Timing & Related Parameters
- MR FOV/Geometry
- MR Echo
- MR Modifier
- MR Image Modifier
- MR Receive Coil
- MR Transmit Coil
- MR Diffusion
- MR Averages
- MR Spatial Saturation
- MR Metabolite Map
- MR Velocity Encoding
2 - eMR: Multiframe

24 Dynamic Functional Groups
For a Specific MR Image Instance:
• some Functional Groups are shared across all frames,
• some vary per frame

Pixel Measures
Frame Content
Plane Orientation
Cardiac Trigger
Frame Anatomy
Pixel value Transformation
Real World Value Mapping

MR Image Frame Type
MR Timing & Related Parameters
MR FOV/Geometry
MR Echo
MR Modifier
MR Receive Coil
MR Transmit Coil
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MR Averages
MR Spatial Saturation
MR Modulated Map
MR Velocity Encoding

MR Image Frame Type
MR Timing & Related Parameters
MR FOV/Geometry
MR Echo
MR Modifier
MR Receive Coil
MR Transmit Coil
MR Diffusion
MR Averages
MR Spatial Saturation
MR Modulated Map
MR Velocity Encoding

For a Specific MR Image Instance:
• some Functional Groups are shared across all frames,
• some vary per frame

Per Frame Functional Group Sequence
Frame 1 attributes
Frame 2 attributes

Shared Functional Groups
Attributes For all frames

MR has a large, rich set of image types
Applications need a way to determine if an image set is compatible with its processing
Supplement 49 proposes a reasonably orthogonal set of attributes for image type useful to reading applications:

1: Original/Derived – redefined
2: Primary/Secondary – Only Primary valid for MR
3: Image Flavor – the overall most important characteristic of this Image – e.g. flow encoded, max-IP, Perfusion, Stress, T1, T2, etc.
4: Derived Contrast – Diffusion aniso, Subtraction, Velocity, None – generally an indication of post processing performed

Other Image Types are separate attributes:
• Pixel Presentation
  (Palette) Color/Monochrome (color supported or not)
• Volumetric Properties
  Volume, Sampled, Distorted (used by Grx, 3D to determine image compatibility with the application)
• Volume Based Calculation Technique
  MAX_IP, MPR, Curved-MPR… (used by Grx, 3D to determine image compatibility)
• Complex Image Component
  Magnitude, Phase, Real, Imaginary (standard MR transformations of the raw data)
• Acquisition Contrast
  T1, T2, Perfusion, Combination… (MR acquisition contrast types)

From Charles Parisot, May 5, 2002, Korean PACS Conference
A large percent of the new tags in the enhanced MR object are mandatory and are those in the enhanced CT object.

<table>
<thead>
<tr>
<th>CT</th>
<th>MR</th>
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</thead>
<tbody>
<tr>
<td>BCP Class</td>
<td>Original</td>
</tr>
<tr>
<td>Attributes (Mandatory)</td>
<td>16 (0)</td>
</tr>
<tr>
<td>Terms (Enumerated)</td>
<td>4 (2)</td>
</tr>
</tbody>
</table>

Furthermore, new applications such as cardiac CT, gated studies, perfusion CT, CT fluoroscopy, contrast tracking and post-processing are not supported by the current standard.

The Acquisition Type (0008,9303) contains a description of the method used during acquisition of the frame from a list of defined terms.

C.8.15.3.1 Spiral Pitch Factor
The formula for Spiral Pitch Factor (0018,9311) in terms of Table Feed per Rotation (0018,9310) and Total Collimation Width (0018,9307) is:

Spiral Pitch Factor = (Table Feed per Rotation (mm)) / (Total Collimation Width (mm))

An example calculation of Spiral Pitch Factor (0018,9311) for a single slice spiral acquisition having a Total Collimation Width of 2.5mm and a Table Feed per Rotation of 10mm is:

Spiral Pitch Factor = (10 mm) / (2.5 mm) = 4.0

An example calculation of Spiral Pitch Factor (0018,9311) for a multiple slice spiral acquisition having a Total Collimation Width of 20mm and a Table Feed per Rotation of 10mm is:

Spiral Pitch Factor = (10 mm) / (20 mm) = 0.5

The Acquisition Type (0018,9302) has the following defined terms:

- SEQUENCED identifies that the acquisition was performed by acquiring single or dual plane data while rotating the source about the gantry while the table is not moving. Additional slices are acquired by incrementing the table position and again rotating the source about the gantry while the table is not moving.
- SPIRAL identifies that the acquisition was performed by acquiring data while rotating the source about the gantry while continuously moving the table.
- CONSTANT ANGLE identifies that the acquisition was performed by holding the source at a constant angle and moving the table to obtain a projection image (e.g., localization image).
- STATIONARY identifies that the acquisition was performed by holding the table at a constant position and acquiring multiple slices over time at the same location.
- FREE identifies that the acquisition was performed while rotating the source about the gantry while the table movement is under direct control of a human operator or under the control of an analysis application (e.g., fluoroscopic image).
Conventional hanging protocols are rarely sophisticated enough to recognize multiple phases of contrast enhancement, e.g., during CT of liver.

Old DICOM objects have no standard information about contrast phase.

New objects name phases of contrast administration for each frame:
- PRE-CONTRAST
- POST-CONTRAST
- IMMEDIATE
- DYNAMIC
- STEADY-STATE
- DELAYED, ARTERIAL
- CAPILLARY
- VENOUS
- PORTAL-VENOUS

Reduced communication latency (delay)
Opportunity for inter-slice (3D) compression

SOP Class UIDs
- Enhanced CT 1.2.840.10008.5.1.4.1.1.2.1
- Enhanced MT 1.2.840.10008.5.1.4.1.1.4.1

Enhanced PET Image Storage SOP Class
- Working Group 3: Supplement 117
- Letter Ballot, June 7, 2007

"This Supplement describes the Enhanced Positron Emission Tomography Storage SOP Class, which allows the PET Image generating system to store information on systems, which perform as a PET Storage SCP.

The old concept of the Standalone PET Curve is not retained as a part of this new IOD. A new work item could be to investigate a more general method for encoding time/intensity information, but this is outside the scope of this document."
"This supplement to the DICOM standard introduces the new X-Ray 3D Storage SOP Classes. It is based on the new multi-frame concepts, introduced with the enhanced MR SOP Classes."

X-Ray 3D Angiographic Image SOP Class
X-Ray 3D Craniofacial Image SOP Class

Scope:
The scope of this Supplement is defining a baseline for a family of dedicated X-Ray multi-dimensional storage SOP Classes that would define the 3D volume or volumes created from X-Ray cone beam projection.

Cartesian:
The slices of the volumes are in the Cartesian format, i.e., non-curved slices defined by position and orientation properties.

The X-Ray 3D Angiographic Image SOP Class allows storage of the results of a 3D reconstruction from either the current XA SOP Class images or the new Enhanced XA SOP Class. The X-Ray 3D Angiographic Image SOP Class definition will include the relationship to the isocenter reference system and the relevant acquisition attributes from 2D projection images.

The X-Ray 3D Craniofacial Image SOP Class allows storage of the results of a 3D reconstruction from the current SOP Class images used in dentistry. The X-Ray 3D Craniofacial Image SOP Class definition will include the relationship to the isocenter reference system and the relevant acquisition attributes from 2D projection images.

"The scope of this Supplement is to customize the X-Ray multi-dimensional storage SOP Class...to define the 3D volume or volumes created from digital breast tomosynthesis x-ray projections."
5 - 3D: brTS open issues

7 How should we describe the "cumulative" organ dose for all source projections of a view?

10 Are the per projection attributes in the Breast Tomosynthesis Acquisition Sequence sufficient for source image quality evaluation by physicists? Are all of the listed attributes necessary to include?

11 Can the Focal Spot of the source projections change per projection, or is it the same for all source projections?

6 - 3D: WG 17, Supplement 111

Segmentation Storage SOP Class

- Working Group 21
- Supplement 111
- Final Text - August 22, 2006

“The domain of this Supplement is segmentation instances created during acquisition, postprocessing, interpretation and treatment. A growing number of applications perform segmentations and work with the resulting segments for which there is no widely used representation within DICOM. The Supplement provides a way to encode segmentation data. It is intended for composite data objects of any modality or clinical specialty.”

6 - 3D: Segmented regions

Polygonal Segmentation Storage SOP Class

- Working Group 21
- Supplement 132
- Draft .8 - June 5, 2007

* The domain of this Supplement is ... [from sup111]
Surface renderings are commonly derived from polygonal surface descriptions.

Comment
- In the coming year, it is anticipated that the AAPM will apply to become a member organization of the DICOM Standards Committee.
- Members are being solicited for participation in specific working groups that are closely aligned with Medical Physics.

Questions?