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DICOM: What the Physicist Needs to Know

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Acknowledgments

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Educational Objectives

- History/Motivation/Evolution of DICOM
- Nature of the Standards
- DICOM Vocabulary applied to Modalities
- Image Quality and DICOM
- IHE Concepts applied to Modalities

“What the Physicist Should Know”

- Where does DICOM come from?
- What does DICOM do?
- What do the terms mean?
- What parts of DICOM does a modality need to support or use?
- How does DICOM affect image quality?
- What is this IHE thing?
- Can you get free stuff to play/learn with?

“Where does it come from?”



The Tower of Babel, by Pieter Bruegel (c. 1525-69)

Prior to establishing standards for data communication, every vendor spoke a different “language.”

“Where does it come from?”



American College of Radiology (ACR)

National Electrical Manufacturer's Association (NEMA)

ACR - NEMA

“Where does it come from?”

- ACR-NEMA establishes committee in 1983
- First ACR-NEMA standards published in 1985
- Follow up standards in 1988 (ACR-NEMA 2.0)
- In 1993, the committee published version 3.0
- Version 3.0 is “DICOM 3.0” and is updated every year (there is no DICOM 3.1, etc)

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“What does it do?”

- DICOM Standards address 5 areas of functionality....

From DICOM “Strategic Document” on <http://medical.nema.org>

“What does it do?”

- “Transmission and persistence of complete objects (such as images, waveforms and documents),
- Query and retrieval of such objects,
- Performance of specific actions (such as printing images on film),
- Workflow management (support of worklists and status information) and
- Quality and consistency of image appearance (both for display and print).”

From DICOM “Strategic Document” on <http://medical.nema.org>

“What does it do?”

- **Objects**
 - “Transmission and persistence of complete objects (such as images, waveforms and documents),
- **Services**
 - Query and retrieval of such objects,
 - Performance of specific actions (such as printing images on film),
 - Workflow management (support of worklists and status information) and
 - Quality and consistency of image appearance (both for display and print).”

From DICOM “Strategic Document” on <http://medical.nema.org>

“What does it do?”

- **“DICOM Storage”**
 - CT Image Storage SOP Class, CR Image Storage SOP Class (useful to have as SCU and SCP on modality)
- **“DICOM Print”**
 - Basic Grayscale Print Management (Meta) SOP Class (SCU only)
- **Query/Retrieve**
 - Poll a DICOM device for a list of studies or patients, then retrieve one or more (SCU and SCP useful)
 - requires C-FIND and C-MOVE and/or C-GET

“What does it do?”

- Archive Commitment
 - Enhancement to standard storage SOP classes, dropped images or series will be detected (SCU only)
- Worklist Management
 - Download a list of “scheduled procedures” to the modality from the RIS through a Worklist Management provider (modality only to be an SCU)
- Modality Performed Procedure Step
 - Modality tells RIS that the scheduled procedure has been performed (automatically) (SCU only)

“What does it do?”

- DICOM Print – an aside
 - Basic Grayscale/Color Print (Meta) SOP Class
 - Called a “meta” SOP class because it really requires and uses
 - Printer SOP Class
 - Basic Film Session SOP Class
 - Basic Film Box SOP Class
 - Basic Grayscale/Color Image Box SOP Class

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“What do the terms mean?”

- “Objects”
 - Information Object Definitions or “IOD”
 - Defined in DICOM Part 3: Information Object Definitions
 - “Recipes” for what items are required to define an “instance” of a
 - CT/MR/CR/US/Digital X-ray (DX) Image, etc
 - Basic Film Session (part of DICOM print)
 - Scheduled Procedure (for a worklist)

“What do the terms mean?”

- Information Object Definitions
 - Attributes (characteristics) of the object are defined in “Modules”
 - Patient Module
 - Patient Name, Patient ID
 - Study Module
 - Study UID, Study Date, Accession Number
 - Image Plane Module
 - Pixel Spacing, Slice Thickness, Slice Location
 - And more...

Found in DICOM Part 3: Information Object Definitions

“What do the terms mean?”

Table C.7-1
IMAGE PLANE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Pixel Spacing	(0028,0030)	1	Physical distance in the patient between the center of each pixel, specified by a numeric pair - adjacent row spacing (delimiter) adjacent column spacing in mm.
Image Orientation (Patient)	(0020,0037)	1	The direction cosines of the first row and the first column with respect to the patient. See C.7.6.2.1.1 for further explanation.
Image Position (Patient)	(0020,0032)	1	The x, y, and z coordinates of the upper left hand corner (center of the first voxel transmitted) of the image, in mm. See C.7.6.2.1.1 for further explanation.
Slice Thickness	(0018,0050)	2	Nominal slice thickness, in mm.
Slice Location	(0020,1041)	3	Relative position of exposure expressed in mm. C.7.6.2.1.2 for further explanation.

Found in DICOM Part 3: Information Object Definitions

“What do the terms mean?”

- Type 1 = Mandatory and non-NULL
- Type 2 = Mandatory but can be NULL or EMPTY
- Type 3 = Optional

Found in DICOM Part 3: Information Object Definitions

“What do the terms mean?”

- Modules
 - Consist Image Object Definitions
 - IODs contain
 - Attributes that specify characteristics
 - “Tags” that
 - Uniquely identify the attribute
 - Tags are composed of a group number and element number
 - Value Representation (VR)

Found in DICOM Part 3: Information Object Definitions

“What do the terms mean?”

Attributes also have a defined “value representation”

Value Representation (DICOM Part 5)

Person Name (PN)	Last^First^Middle (Langer^Steve^G)
Date (DA)	yyyymmdd (20030812)
Time (TM)	hhmmss.frac (091312.99999)

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What DICOM do I need for a modality?

- Store
- Print
- Modality Worklist
- Performed Procedure Step
- Presentation of Grouped Procedures
- Archive Commit
- Gray Scale Display Function
- Gray Scale Presentation State

What DICOM do I need for a modality?

- DICOM Storage (SCU and SCP)
 - Identify what objects it creates (CT, MR, etc) – does it also create secondary capture (SC)?
 - If it is an SCP, does it only accept certain kinds of images? For processing, for presentation?.
 - Can it do multiple destinations?

What DICOM do I need for a modality?

- DICOM Storage (SCU and SCP)
 - Is it autosend? Manual? Can you send if the study is not finished (stat brain exams or pulmonary embolism evals)
 - Does it send both processed and unprocessed images (CR, DX, and MG objects)
 - Can you resend easily?
 - Is there a queue? Can you stop, start, clear it?

What DICOM do I need for a modality?

- DICOM Print (SCU)
 - Can you have multiple printers?
 - Is it easy to switch printers on the fly?
 - Can you print to two printers simultaneously?
 - Can you configure min/max O.D., layouts, and requested lookup tables (in Configuration Information)?

What DICOM do I need for a modality?

- DICOM Print (SCU)
 - Does it have a queue? Can you stop, start or delete from it?
 - Is there visual indication of successful print?
 - Is it automatic print? Can you reprint easily?
 - Is there an error log?

What DICOM do I need for a modality?

- Worklist Management (SCU)
 - Can I query by Date? Pat_ID? Accession? Modality? Any combination of these? Is it configurable?
 - Is the query ad hoc or does it run every so many minutes automatically? Is it configurable?
 - Can you drive it with a barcode reader easily (not if you go through 6 dialog boxes first)
 - Will it automatically start the correct exam procedure (CT brain, two view chest, etc)
 - Is there an error log?

What DICOM do I need for a modality?

- Modality Performed Procedure Step (SCU)
 - May be useful for CT, MR
 - More challenging for mixed RF/CR studies like BE or UGI
 - Is the time savings worth it?
- Archive Commitment (SCU)
 - This is very useful and helps to guarantee that all images/series are properly transferred

What DICOM do I need for a modality?

- Grayscale Standard Display Function
 - Monitors must be capable of calibration to GSDF
- Softcopy Grayscale Presentation State
 - Useful at modality to preserve layout and presentation but many currently “burn” these things into images or send as overlay.
 - Absolute must for a PACS

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DICOM Image Quality

- New PACS user says
“When I make measurements on DX images with my PACS workstation, they come out in pixels instead of millimeters”

Why?

DICOM Image Quality

The Digital X-ray (DX) IOD requires the *DX Detector Module* which calls for “Imager Pixel Spacing” in DICOM tag (0018,1164)

The CT IOD uses the *Image Plane Module* with pixel spacing defined in (0028,1130).

PACS Workstation/Viewer vendor may not be looking for pixel spacing in correct location.

DICOM Image Quality

- Grayscale Standard Display Function (DICOM Part 14)
 - Identifies a standard method to calibrate the luminance response of emissive (monitors), transmissive (film) and reflective (paper) media
- Softcopy Grayscale Presentation State IOD
 - Defines an object which can store or preserve the “state” of a referenced object (like an image)
 - Stores flip/rotate, window/level, annotations, masking or shutters, etc



Grayscale Standard Display Function (GSDF)

- Blume, Daly, and Muka "Presentation of Medical Images on CRT Displays: a renewed proposal for a display function standard," Proc SPIE 1897, 1993
- Blume, Hartwig "ACR/NEMA Proposal for a grayscale display function standard," Proc SPIE 2707, 1996

Grayscale Standard Display Function (GSDF)

- Why not just calibrate to a linear luminance response?
- Contrast sensitivity (ability to detect changes in luminance) varies with luminance
 - low levels very sensitive
 - can perceive difference of 0.005 Cd/m^2 at $\sim 0.05 \text{ Cd/m}^2$
 - high levels not as sensitive
 - can only perceive difference of $\sim 25 \text{ Cd/m}^2$ at $\sim 4000 \text{ Cd/m}^2$

Grayscale Standard Display Function (GSDF)

- Adopted a model of the Human Visual System (Barten model)
- Concept of "perceptual linearization"
 - Equal change in input pixel value (grayscale) should result in equal "perceived" change in output luminance

Grayscale Standard Display Function (GSDF)

- Barten's model fits, for a given luminance level, the change in luminance that an observer would "just-notice."
- This is a just-noticeable-difference or "JND"
- Each JND step results in a single observable change in luminance

Grayscale Standard Display Function (GSDF)

- At 0.0500 Cd/m^2 , the model predicts that a human observer will see a “just-noticeable-difference” (JND) if the luminance is increased to 0.0547 Cd/m^2

Grayscale Standard Display Function			
JND	L[cd/m ²]	JND	L[cd/m ²]
1	0.0500	2	0.0547

$\Delta\text{JND} = 1$

$\Delta\text{L} = 0.005 \text{ Cd/m}^2$

Grayscale Standard Display Function (GSDF)

- At $\sim 599 \text{ Cd/m}^2$, the model predicts that a human observer will see a “just-noticeable-difference” (JND) if the luminance is increased to $\sim 603 \text{ Cd/m}^2$

JND	Luminance	JND	Luminance
733	599.0744	734	603.0758

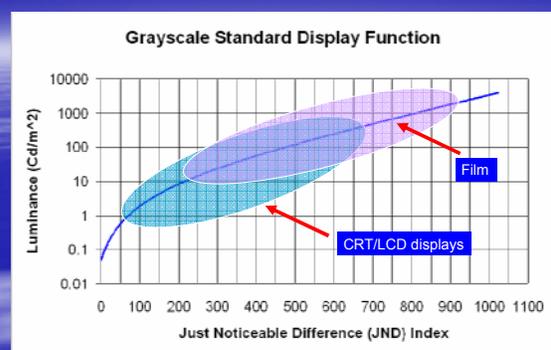
$\Delta\text{JND} = 1$

$\Delta\text{L} \sim 4 \text{ Cd/m}^2$

ΔL is $\sim 1000\text{x}$ greater than values at $\sim 0.05 \text{ Cd/m}^2$

Grayscale Standard Display Function (GSDF)

- Continue in this same manner to 4000 Cd/m^2 ...
 - DICOM Part 14 GSDF model has 1023 total JNDs covering range from 0.05 Cd/m^2 to 4000 Cd/m^2



DICOM Part 14 GSDF - emissive

- Know (measure) the minimum and maximum luminance (L_{min} and L_{max}) associated with min and max input digital driving level (DDL)

(Input DDLs are linearly related to input pixel values)

- Use the table in DICOM PS3.14 to lookup the JNDs that correspond to L_{min} and L_{max}

DICOM Part 14 GSDF - emissive

There are also analytical formulas that allow you to *calculate* the JND(L) and the L(JND)

Table lookups not required!

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“What is this IHE thing?”

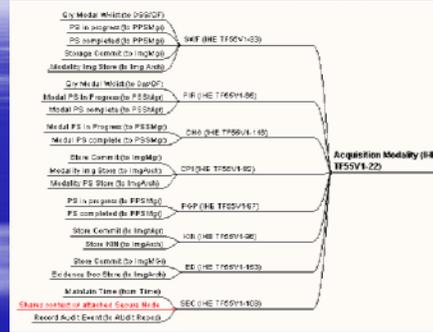
- An implementation guideline - not a standard
- Created in 1998, current Edition “Year 5”
- Builds on earlier standards - HL7 and DICOM
- Sponsors: RSNA, HIMSS, EAR (European Assoc. of Radiologists)
- Key Concepts as of IHE Year 5
 - 22 Actors (REG-ADT, Order Placer, Order Filler, Image Manager, Modalities, etc)
 - 46 Transactions among them (orders, results, etc)
 - 12 Integration Profiles (Scheduled Workflow, Patient Info. Reconciliation, Charge Posting, etc)

“What is this IHE thing?”

	N o d e a d i t i v i t y	A u d i t r e c o r	B i l l i n g	D i s t r i b u t i o n	E v e n t r e p o r t	E x c h a n g e	I m a g e	I m a g e	O r d e r	P o s t p r o c e s s i n g	P r i n t i n g	P r e s e n t a t i o n	R e p o r t g e n e r a t i o n	R e p o r t r e c e i v i n g	R e p o r t s e c u r i t y	T i m e
SWF	X			X	X	X	X	X	X	X						
PIR	X	X		X		X	X	X	X	X				X	X	
PWF	X			X	X	X	X	X	X	X						
RWF			X	X	X	X	X	X	X	X			X	X	X	
CHG	X	X	X	X	X	X	X	X	X	X						
CPI	X	X		X	X	X	X	X	X	X	X	X				
PGP	X			X	X	X	X	X	X	X						
KIN	X			X	X	X	X	X	X	X						
ED	X			X	X	X	X	X	X	X			X			
SINR				X	X	X	X	X	X	X			X	X	X	
ARI				X	X	X	X	X	X	X			X	X	X	
SEC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

IHE TF5.5 Vol. 1 Section 2.1

“What is this IHE thing?”



“Why is IHE Important?”

- DICOM and HL7 Conformance Statements no guarantee of interoperability
- “Validation Statements” would be better
- As the Expert on Dx Modality purchasing, how to you protect your institution?
 - RFP requires IHE Compliance
 - Purchasing Agreement states “Equipment will be Acceptance Tested on IHE profiles”
 - Have 30 return policy for equipment that does not conform

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"Free Stuff" DICOM Sleuthing Tools

- Mallinckrodt CTN (central test node)
 - NT/2000, Solaris command line tools
 - simple_storage (storage SCP)
 - send_image (storage SCU)
 - dicom_echo (dicom "ping" SCU)
 - dcm_dump_file (dump contents of a file)

<ftp://ftp.erl.wustl.edu/pub/dicom/software/ctn/>

"Free Stuff" DICOM Sleuthing Tools

- University of Oldenburg OFFIS
 - NT/2000, Solaris command line tools
 - storescp (storage SCP)
 - storescu (storage SCU)
 - echoscu (echo SCU)
 - dcmdump (dump contents of a file)
 - findscu (worklist management SCU)

http://www.offis.de/projekte/ig/dicom/soft-docs/soft01_e.html

"Free Stuff" DICOM Sleuthing Tools

- Agfa DICOM Validation Tool

www.agfa.com/healthcare

Very powerful, emulates

- storage SCP
- printer SCP
- worklist management SCP

"Free Stuff" DICOM Sleuthing Tools

- DICOM Image Viewers
 - NIH Image (rsb.info.nih.gov/nih-image/Default.html)
 - ImageJ (rsb.info.nih.gov/ij/)
 - Irfanview (www.irfanview.com)
 - Osiris (www.expasy.ch/www/UIN/html1/projects/osiris/osiris.html)
 - others at SourceForge.net

“Free Stuff” DICOM Sleuthing Tools

- Uses?
 - Agfa DICOM Validation Tool
 - Debugged SMS RIS Worklist Management that was not working with a GE Horizon LXI MR Scanner
 - Used every day in a script to send “automatic” print jobs of a test pattern to all DICOM printers
 - Capture storage associations to retrieve image samples for vendors
 - Used to confirm conformance of DICOM Part 10 CD-ROMS

“Free Stuff” DICOM Sleuthing Tools

- Uses?
 - CTN tools
 - “dicom_echo” - used in a script to wake up every ten minutes and verify that critical DICOM storage devices or servers are alive
 - “dcm_dump_file” - header dumps of images that were not properly displaying in viewers
 - “simple_storage” and “send_image” – used to receive studies then auto-forward to several destinations

“Free Stuff” DICOM Sleuthing Tools

- Uses?
 - OFFIS tools
 - “findscu” – used to test and debug SMS worklist management server that replaced a MITRA PACS Broker
 - Viewers (ImageJ, Irfanview, etc)
 - Examine and review images, test images, etc.

“What the Physicist Should Know” Summary

- Did we cover it all? No.
- What’s left
 - DICOM network configurations
 - Application entity title, IP address, TCP/IP port number
 - Like a phone call (name, number, and extension)
 - Supplement 55 Anonymization (HIPAA compliance)
 - No known “anonymizers” that you can currently buy that do COMPLETE Supp. 55 anonymization
 - Must remove PRIVATE elements, not just Supp. 55 items
 - Supplement 44 (US), and new CT/MR 3D Objects
 - Supplement 95, Auditing
 - more ...

“What the Physicist Should Know” Summary

- Further DICOM Information
 - <http://www.dclunie.com/>
- Further IHE Information
 - <http://www.rsna.org/IHE/index.shtml>
 - Mesa Validation Tools
 - <http://wuerlim.wustl.edu/mesa/>

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DICOM: Complex, but not “Mission Impossible”