Deploying a VNA with Integration of Multiple Clinical Specialties
–
DICOM Beyond Radiology

David A. Clunie, MBBS, FRANZCR(Ret), FSIIM

Consultant

PixelMed Publishing

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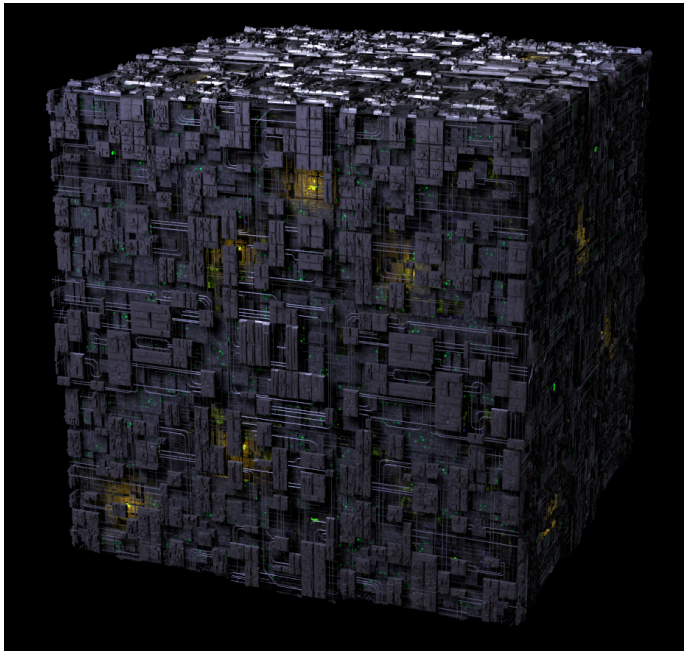
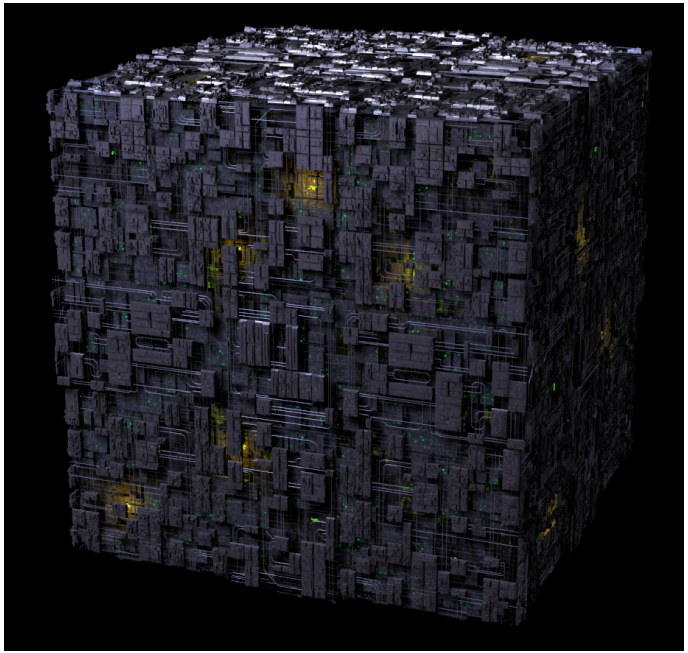
- Editor of DICOM Standard (NEMA/MITA Contractor)
- Other: Owner of PixelMed Publishing

Will you be assimilated?



DICOM℠
Digital Imaging and Communications in Medicine

Will you be assimilated?



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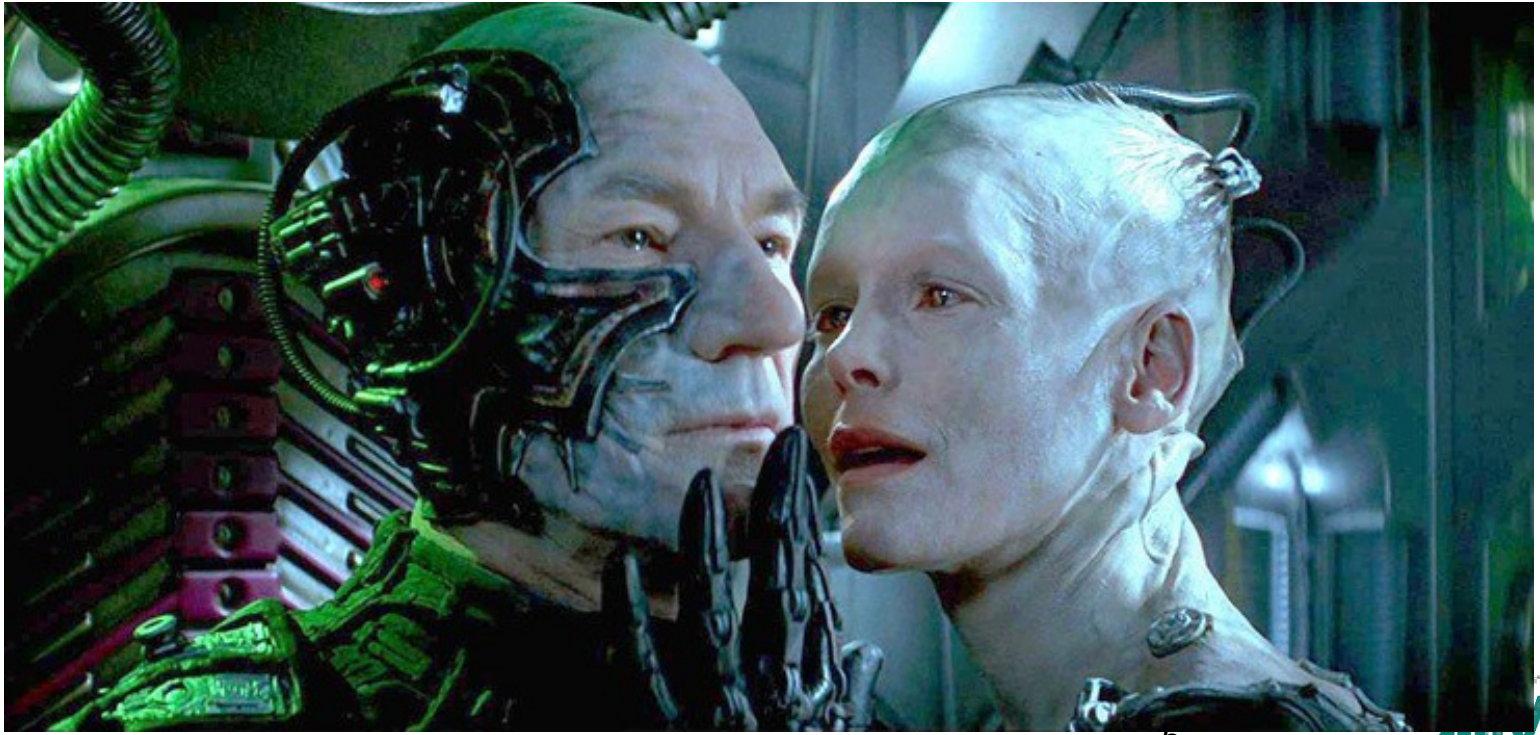
Digital Imaging and Communications in Medicine

"we will add your biological and technological distinctiveness to our own"

"your culture will adapt to service us"

"resistance is futile"

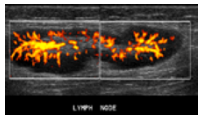
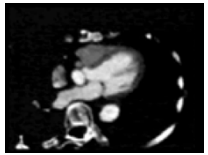
Why might you want to be?

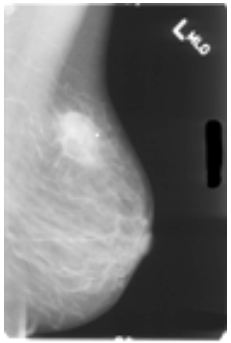


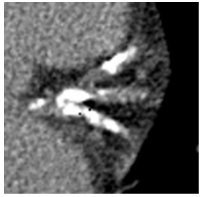
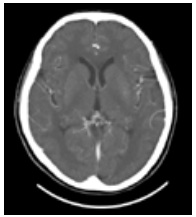
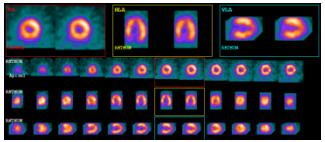
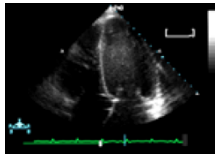
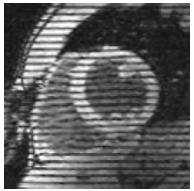
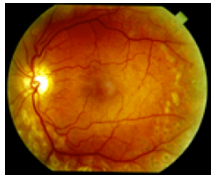
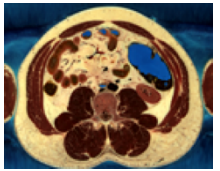
DICOM – Diversity from early on …

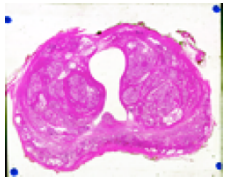
- DICOM has been around a very long time (1985 ACR-NEMA)
- DICOM has been doing more than radiology for a long time too
- Cardiology – 1995
- Radiotherapy – 1996
- Visible Light – 1998 – including Slide Microscopy
- Even before that – Secondary Capture RGB – 1993
- Increasingly specialty specific image types and metadata
- Whole Slide Imaging – 2010
- Ophthalmic Tomography Angiography – 2017

Old 2002 Slide (for Cardiologists)





Early Supplements

Supplement	Affected	Title	Status	Applies To
Supp 1	Parts 10	Media Storage and File Format For Media Interchange	Standard	1993
Supp 2	Parts 11	Media Storage Application Profiles	Standard	1993
Supp 3	Parts 12	Media Format and Physical Media Media Interchange	Standard	1993
Supp 4	Parts 3,4,6	X-Ray Angiographic Image Objects and Media Storage	Standard	1993
Supp 5	Parts 3,4,5,6,11	Ultrasound Application Profile, IOD and Transfer Syntax Extension	Standard	1993
Supp 6	Parts 3,4,6	X-Ray Flouroscopic Image Object	Standard	1993
Supp 7	Parts 3,4,6	Nuclear Medicine Image Object	Standard	1993
Supp 8	Parts 3,4,6	Storage Commitment Service Class	Standard	1993
Supp 9	Parts 2,3,4,5,6	Multi-byte Character Set Support	Standard	1993
Supp 10	Parts 3,4,6	Basic Worklist Management - Modality	Standard	1993
Supp 11	Parts 3,4,6	Radiotherapy Information Objects	Standard	1996
Supp 12	Parts 3,4,6	PET Information Object	Standard	1996
Supp 13	Parts 3,4,6	Queue Management Service Class	Standard	1996
Supp 14	Parts 2,5	Standard Extended SOP Classes and Unknown Value Representation	Standard	1996
Supp 15	Parts 3,4,6	Visible Light Image Object	Standard	1998

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→ Supp 15	Parts 3,4,6	Visible Light Image Object	Standard	1998

Recent Supplements

Supp 187	Parts 2,3,4,6,16,17	Preclinical Small Animal Imaging Acquisition Context	Standard	2015c
Supp 188	Parts 2,3,6,16,17	Multi-Energy CT Images	Comment	
Supp 189	Parts 2,3,4,6	Advanced Blending Presentation State Storage	Standard	2017a
Supp 190	Parts 2,3,4,6,17	Volume Rendering Volumetric Presentation States	Standard	2017a
Supp 191	Parts 2,3,4,6,16,17	Patient Radiation Dose Structured Report (P-RDSR)	Standard	2017a
Supp 192	Parts 2,3,4,6,16,17	Instance Approval Storage SOP Class	Ballot	
Supp 193	Parts 18	REST Notifications	Work	
Supp 194	Parts 18	RESTful Services for Non-Patient Instances	Standard	2016e
Supp 195	Parts 5,6,17	HEVC/H.265 Transfer Syntax	Standard	2016d
Supp 196	Parts 2,3,4,6,16,17	Segmentation Creation Template	Work	
Supp 197	Parts 2,3,4,6,16,17	Ophthalmic Tomography Angiographic (OCT-A) Image Storage SOP Classes	Standard	2017a

Recent Supplements – Image Types

	Supp 187	Parts 2,3,4,6,16,17	Preclinical Small Animal Imaging Acquisition Context	Standard	2015c
→	Supp 188	Parts 2,3,6,16,17	Multi-Energy CT Images	Comment	
	Supp 189	Parts 2,3,4,6	Advanced Blending Presentation State Storage	Standard	2017a
	Supp 190	Parts 2,3,4,6,17	Volume Rendering Volumetric Presentation States	Standard	2017a
	Supp 191	Parts 2,3,4,6,16,17	Patient Radiation Dose Structured Report (P-RDSR)	Standard	2017a
	Supp 192	Parts 2,3,4,6,16,17	Instance Approval Storage SOP Class	Ballot	
	Supp 193	Parts 18	REST Notifications	Work	
	Supp 194	Parts 18	RESTful Services for Non-Patient Instances	Standard	2016e
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→	Supp 197	Parts 2,3,4,6,16,17	Ophthalmic Tomography Angiographic (OCT-A) Image Storage SOP Classes	Standard	2017a

Recent Supplements – Compression

Supp 187	Parts 2,3,4,6,16,17	Preclinical Small Animal Imaging Acquisition Context	Standard	2015c
Supp 188	Parts 2,3,6,16,17	Multi-Energy CT Images	Comment	
Supp 189	Parts 2,3,4,6	Advanced Blending Presentation State Storage	Standard	2017a
Supp 190	Parts 2,3,4,6,17	Volume Rendering Volumetric Presentation States	Standard	2017a
Supp 191	Parts 2,3,4,6,16,17	Patient Radiation Dose Structured Report (P-RDSR)	Standard	2017a
Supp 192	Parts 2,3,4,6,16,17	Instance Approval Storage SOP Class	Ballot	
Supp 193	Parts 18	REST Notifications	Work	
Supp 194	Parts 18	RESTful Services for Non-Patient Instances	Standard	2016e
→ Supp 195	Parts 5,6,17	HEVC/H.265 Transfer Syntax	Standard	2016d
Supp 196	Parts 2,3,4,6,16,17	Segmentation Creation Template	Work	
Supp 197	Parts 2,3,4,6,16,17	Ophthalmic Tomography Angiographic (OCT-A) Image Storage SOP Classes	Standard	2017a

Recent Supplements – Reports

	Supp 187	Parts 2,3,4,6,16,17	Preclinical Small Animal Imaging Acquisition Context	Standard	2015c
	Supp 188	Parts 2,3,6,16,17	Multi-Energy CT Images	Comment	
	Supp 189	Parts 2,3,4,6	Advanced Blending Presentation State Storage	Standard	2017a
	Supp 190	Parts 2,3,4,6,17	Volume Rendering Volumetric Presentation States	Standard	2017a
→	Supp 191	Parts 2,3,4,6,16,17	Patient Radiation Dose Structured Report (P-RDSR)	Standard	2017a
	Supp 192	Parts 2,3,4,6,16,17	Instance Approval Storage SOP Class	Ballot	
	Supp 193	Parts 18	REST Notifications	Work	
	Supp 194	Parts 18	RESTful Services for Non-Patient Instances	Standard	2016e
	Supp 195	Parts 5,6,17	HEVC/H.265 Transfer Syntax	Standard	2016d
	Supp 196	Parts 2,3,4,6,16,17	Segmentation Creation Template	Work	
	Supp 197	Parts 2,3,4,6,16,17	Ophthalmic Tomography Angiographic (OCT-A) Image Storage SOP Classes	Standard	2017a

Recent Supplements – Subjects

→	Supp 187	Parts 2,3,4,6,16,17	Preclinical Small Animal Imaging Acquisition Context	Standard	2015c
	Supp 188	Parts 2,3,6,16,17	Multi-Energy CT Images	Comment	
	Supp 189	Parts 2,3,4,6	Advanced Blending Presentation State Storage	Standard	2017a
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	Supp 197	Parts 2,3,4,6,16,17	Ophthalmic Tomography Angiographic (OCT-A) Image Storage SOP Classes	Standard	2017a

Recent Supplements – Protocols

Supp 187	Parts 2,3,4,6,16,17	Preclinical Small Animal Imaging Acquisition Context	Standard	2015c
Supp 188	Parts 2,3,6,16,17	Multi-Energy CT Images	Comment	
Supp 189	Parts 2,3,4,6	Advanced Blending Presentation State Storage	Standard	2017a
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Supp 193	Parts 18	REST Notifications	Work	
Supp 194	Parts 18	RESTful Services for Non-Patient Instances	Standard	2016e
Supp 195	Parts 5,6,17	HEVC/H.265 Transfer Syntax	Standard	2016d
Supp 196	Parts 2,3,4,6,16,17	Segmentation Creation Template	Work	
Supp 197	Parts 2,3,4,6,16,17	Ophthalmic Tomography Angiographic (OCT-A) Image Storage SOP Classes	Standard	2017a

Add your biological, technological distinctiveness to our own

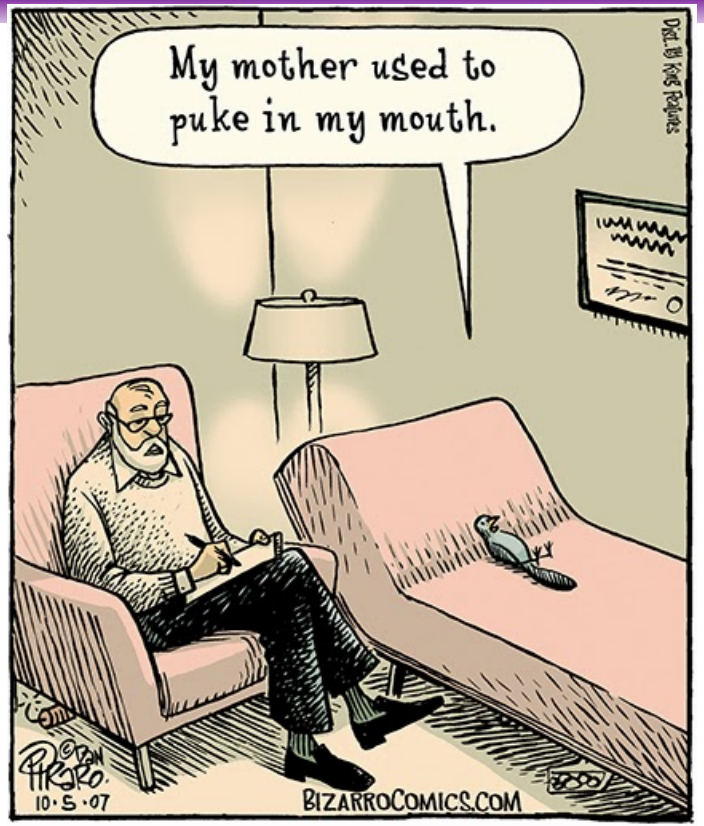
- New image types – modalities and clinical applications
- Non-image types, including specific reports and derived objects, especially for quantitative analysis results
- New subject types – veterinary, small animal research
- Also non-destructive testing (DICONDE), baggage security (DICOS)
- New protocols – not just HTTP (WADO-URI (2004)), but adapting to the RESTful trend in web services (WADO-RS (2011), STOW-RS, QIDO-RS, UPS-RS)

Your culture will adapt to service us

- Who are “you” and who is “us” (are “we”)?
- “You” – the modality/specialty specific “silo”
- “Us” – the enterprise (users & infrastructure)

- Standards (specifically DICOM) simplify the enterprise task – better, stronger, faster and hopefully cheaper too (? < $6m 1973 USD)

Store, Find & Regurgitate +/- View



Storing anything and everything

- … with DICOM …
- Specific SOP Class and IOD – e.g., Ophthalmic Photography
- Generic SOP Class and IOD – e.g., VL Photographic
- Anything at all SOP Class & IOD – e.g., Secondary Capture
- Distinguished by Pixel Data restrictions & metadata
- Pixel Data “payload” – uncompressed or compressed (e.g., JPEG-*, MPEG-*)
- Metadata (“header”) – composite (shared) and modality (clinical application) specific

Visible Light IODs and SOP Classes

- VL Endoscopic Image (IOD and Storage SOP Class)
- VL Microscopic Image
- VL Slide-Coordinates Microscopic Image
- VL Photographic Image

- Video Endoscopic Image
- Video Microscopic Image
- Video Photographic Image

- VL Whole Slide Microscopy Image

Ophthalmic IODs and SOP Classes

- Ophthalmic Photography 8 bit Image
- Ophthalmic Photography 16 bit Image
- Ophthalmic Tomography Image
- Ophthalmic Refractive Measurements (Lensometry, Visual Acuity, …)
- Ophthalmic Visual Field Static Perimetry Measurements
- Ophthalmic Thickness Map
- Wide Field Ophthalmic Photography Stereographic Projection Image
- Wide Field Ophthalmic Photography 3D Coordinates Image
- Ophthalmic Optical Coherence Tomography En Face Image
- Ophthalmic Optical Coherence Tomography B-scan Volume Analysis

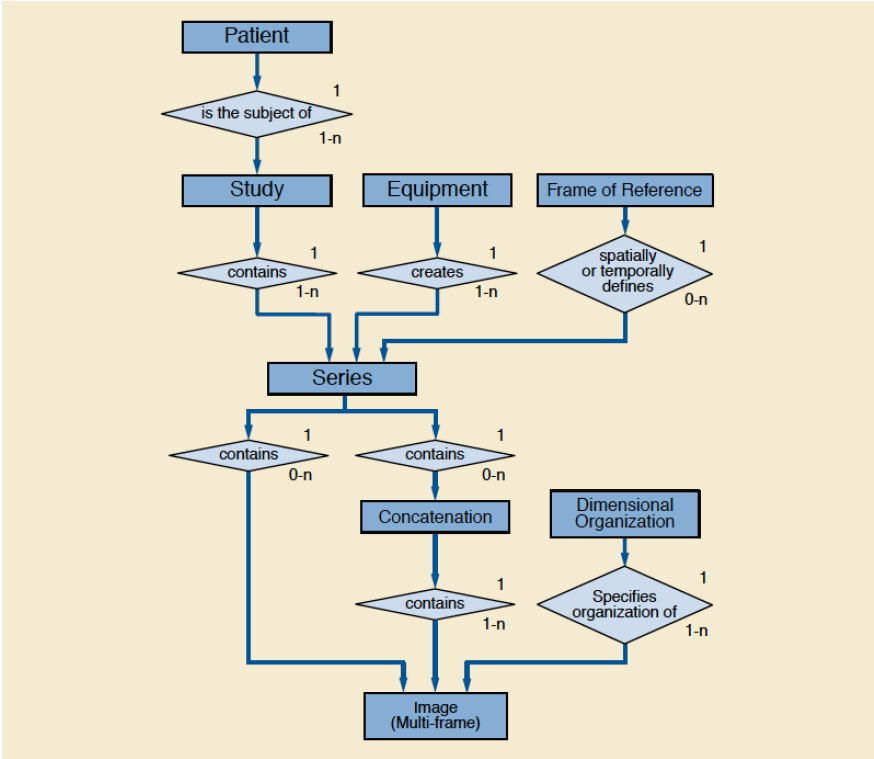
It’s the metadata, stupid

http://medium.com/digital-trends-index/its-the-metadata-stupid-12a4fc121e45#.4zhwdz5y0

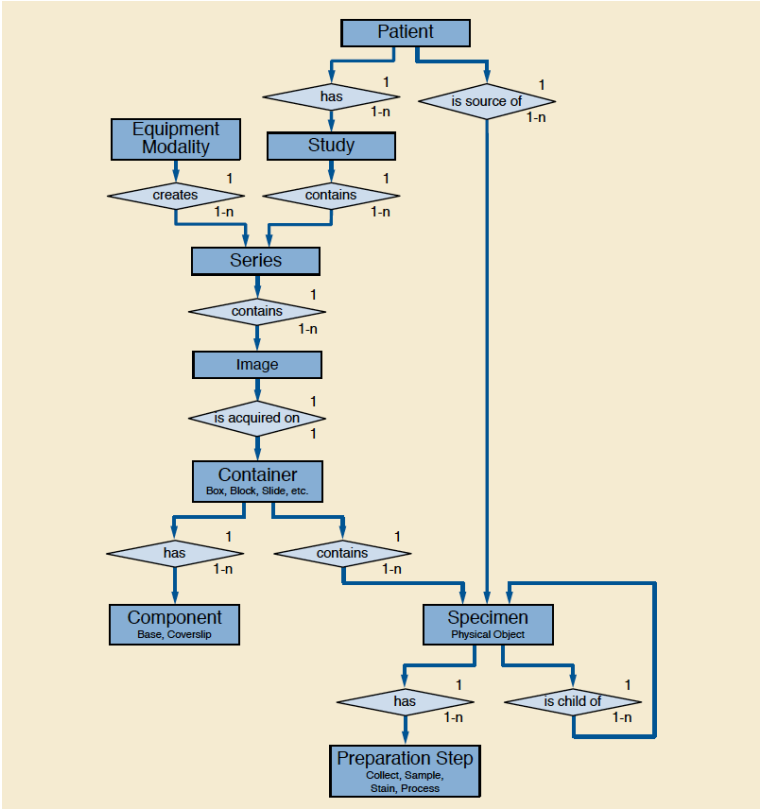
Composite Context

- All of the stuff that is the same across multiple images (files, instances) … i.e., of the DICOM Composite Information Model:
  - Patient … same for all instances for patient
  - Study … same for all instances for procedure
  - Series … new for each related acquisition or derivation
  - Equipment
  - Multi-Frame Dimensions
  - Frame of Reference … e.g., if same slide coordinates
- On reading … relevant to database/browser structure
- On writing … re-use from input, e.g., for analysis results

Composite Information Model



Extend the Model – e.g., for Specimen



Extreme Metadata – or lack thereof

- Every image needs the Pixel Data described (rows, columns, bit depth, etc.)
- Beyond that lot or a little, whatever is needed
- Bare minimum – some identifier to match some other system – recipient does the work
- Everything and the kitchen sink – detailed description of the patient's state, acquisition process, etc., using standard string values or codes – recipient is passive
- The latter is the norm in radiology

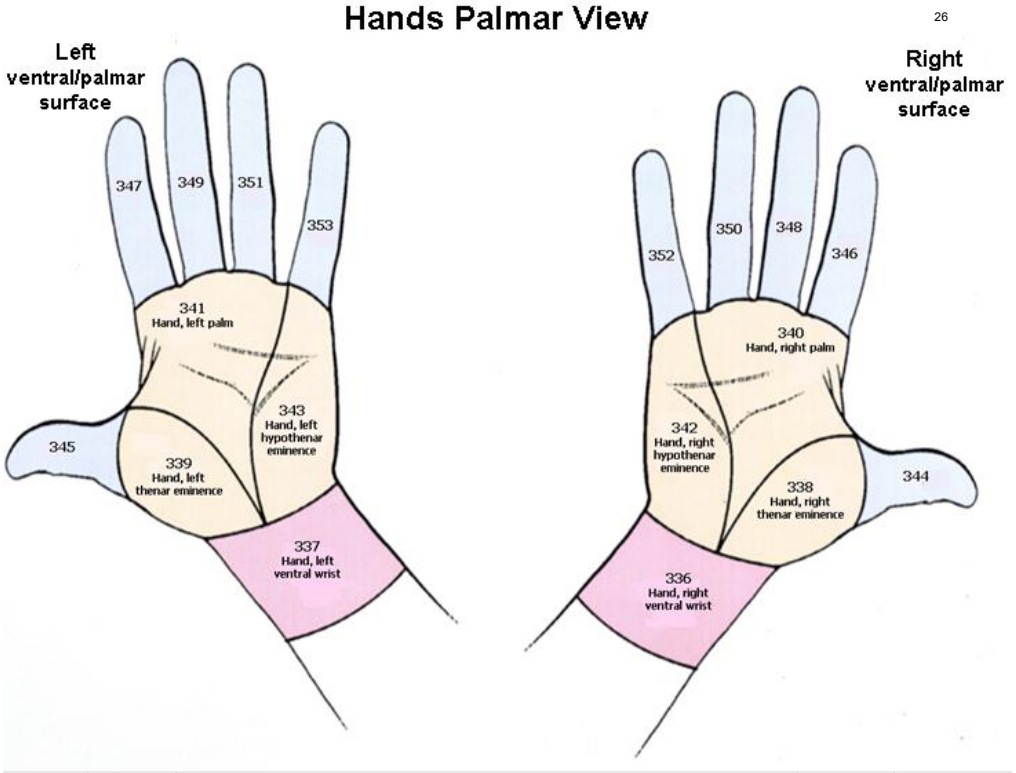
Minimum Chips

- As little as possible in one of the generic SOP Classes
- Very few required Type 1 elements
- Type 2 required elements may be “empty” if unknown
- Send Patient ID only (empty name, DOB, age, sex – server will lookup and coerce)
- Send Content (or Acquisition) Date and Time only – server (or user) can match to other records captured contemporaneously
- Absent/empty Accession Number, Admission ID, Service Episode ID
- Make up some (Study, Series, Instance) UIDs
- With STOW-RS, can even omit the Pixel Data description, and let the server figure it out from the JPEG payload

A little more than is strictly necessary

- Can do better by adding what is relevant to the recipient
- Textual descriptions (e.g., in Study/Series Description, Image Comments)
- Modality – more specific than “other”
- A little anatomy – may be hardwired (e.g., knee arthroscopy, colonoscopy, retinal fundoscopy) or user controlled (e.g., handheld skin lesion photos) – is best coded (e.g., SNOMED, FMA, clinical specialty codes such as NYU Melanoma CCG) rather than just text string
- Guiding principle – what can the recipient benefit from that is not too burdensome to capture?
- Radiology experience – rich metadata drives hanging protocols, prior pre-fetching, finding the right stuff in the study/series browser

Dermatology Anatomy – NYU, Mayo



Dermatology Anatomy – NYU, Mayo

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-CT Concept ID	UMLS Concept Unique ID	FMA ID	NYUMCCG Numeric Code	NYUMCCG Description	Mayo Numeric Code	Mayo Description
FMA	54343	Nail of left little Finger		C0926382	54343	335	Nail of the Little Finger of the Left Hand	335	Hand, left fifth fingernail
FMA	38284	Skin of anterior part of right wrist		C0829680	38284	336	Volar Right Wrist	336	Hand, right ventral wrist
FMA	38285	Skin of anterior part of left wrist		C0829681	38285	337	Volar Left Wrist	337	Hand, left ventral wrist
FMA	79168	Skin of right thenar eminence		C2338531	79168	338	Thenar Eminence of the Right Hand	338	Hand, right thenar eminence
FMA	79169	Skin of left thenar eminence		C2329983	79169	339	Thenar Eminence of the Left Hand	339	Hand, lef thenar eminence
FMA	38302	Skin of palm of right hand		C0829695	38302	340	Palmar Surface of the Right Hand	340	Hand, right palm
FMA	38303	Skin of palm of left hand		C0829696	38303	341	Palmar Surface of the Left Hand	341	Hand, left palm
FMA	79165	Skin of right hypothenar eminence		C2328058	79165	342	Hypothenar Eminence of the Right Hand	342	Hand, right hypothenar eminence
FMA	79166	Skin of left hypothenar eminence		C2334824	79166	343	Hypothenar Eminence of the Left Hand	343	Hand, left hypothenar eminence

The opposite extreme – rich metadata

- All sorts of stuff relevant to the interpretation
- Even if another local source, needed when image is exported
- Identification and description of the patient
- Other Patient IDs, age, height, weight
- Patient (or specimen) preparation, positioning
- Acquisition process (e.g., illumination, filtration)
- Special aspects of the technique (e.g., fluorescence)

Coded Acquisition Context

- Metadata on steroids
- Named Coded Sequence attributes for critical metadata
- Extensible name-value pairs for additional metadata
- Standard code sources, e.g., SNOMED, LOINC, NCIt
- External lexicons (re-use external experts' expertise, clinical systems' commonality)
- DCM (PS3.16) coded concepts defined when/until external source found
- Codes may change (better codes, harmonization)
- Value sets (context groups) grow (if extensible)
- Bidgood Jr. WD et al. Controlled terminology for clinically-relevant indexing and selective retrieval of biomedical images. Int J Digit Libr. 1997. http://www.schattauer.de/t3page/1214.html?manuscript=13388&L=1

A.32.8.3.1 VL Whole Slide Microscopy Image IOD Content Constraints

A.32.8.3.1.1 Optical Path Module

The Code Sequences within the Optical Path Sequence (0048,0105) of the Optical Path Module (see Section C.8.12.5) are constrained as follows:

Baseline CID for Illuminator Type Code Sequence (0048,0100) is CID 8125 “Microscopy Illuminator Type”.

Baseline CID for Illumination Color Code Sequence (0048,0108) is CID 8122 “Microscopy Illuminator and Sensor Color”.

CID 8122 Microscopy Illuminator and Sensor Color

Type: Extensible
Version: 20100824

Table CID 8122. Microscopy Illuminator and Sensor Color

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-CT Concept ID	UMLS Concept Unique ID
SRT	R-102C0	Full Spectrum	414298005	C1532530
SRT	R-102BE	Infrared	414497003	C1532326
SRT	G-A11A	Red	371240000	C1260956
SRT	G-A11E	Green	371246006	C0332583
SRT	G-A12F	Blue	405738005	C1260957
SRT	R-102BF	Ultraviolet	415770004	C1532472

Table CID 8131. Pathology Imaging Protocols

Coding Scheme Designator	Code Value	Code Meaning
DCM	112700	Peri-operative Photographic Imaging
DCM	112701	Gross Specimen Imaging
DCM	112702	Slide Microscopy
DCM	112703	Whole Slide Imaging
DCM	112704	WSI 20X RGB
DCM	112705	WSI 40X RGB

Table CID 8132. Magnification Selection

Coding Scheme Designator	Code Value	Code Meaning
DCM	112715	5X
DCM	112716	10X
DCM	112717	20X
DCM	112718	40X

Table CID 8133. Tissue Selection

Coding Scheme Designator	Code Value	Code Meaning
DCM	112719	Nominal empty tile suppression
DCM	112720	High threshold empty tile suppression
DCM	112721	No empty tile suppression

Why this matters

- Why not just save “consumer format” data in a content management system, and let it worry about the metadata?
- Export beyond the system (enterprise) – transfer, referrals
- Import from elsewhere – where does the metadata come from?
- Migrations – VNAs, CMS, EMRs go EOL just like PACS do – do you really want to repeat the pain of your last legacy PACS migration with its proprietary database and non-standard internal file format and proprietary compression?
- Mergers and acquisitions – when you get swallowed, your new owner will want to assimilate you, and standards (DICOM) help

From whence cometh the metadata

- Manual data entry sucks (and is error prone)
- It lives naturally in HIS, departmental IS, EMR
- Which broadcast (or can be configured to send) HL7 V2 on various “trigger events”
- Asynchronous stuff sucks (since it may come when the acquisition device is least expecting it) – devices may be “intermittently connected”
- A 3rd party can cache it and responds to queries for it – hence DICOM Modality Worklist was born
- Today one might reinvent it with queries on FHIR resources

Modality Worklist beyond Radiology

- DICOM MWL does NOT depend on their being an order
- A clinic visit can trigger a worklist entry
- Admission and Service Episode IDs can appear in work lists to provide matching to “encounters”
- Cardiology – typically not “ordered” and even if ordered, morph during the procedure (e.g., from diagnostic cath to interventional)
- Extensive VA use for ophthalmology, endoscopy, dentistry
- Joint VA/DoD DICOM Modality Conformance Requirements – http://www.va.gov/health/IMAGING/docs/Joint_DICOM_Req_Doc_V_3_0_upd.pdf
- List of VA Approved devices – http://www.va.gov/HEALTH/imaging/docs/VistA_Imaging_DICOM_Modality_Interfaces.pdf

VA Approved DICOM Devices

Supported Ophthalmic Photography Devices		
Manufacturer	**Model**	**Status**
Canon	CF1 Camera (MYD)	Supported
Canon	CR1 Camera (non-MYD)	Supported
Canon	CR1 Mark II (non-MYD)	Supported
Canon	CR2 (Platform-Retinal Imaging Control 3.2)	Supported
Canon	CR2 Plus (Platform-Retinal Imaging Control 3.2)	Supported
Canon	CX1 (Platform-Retinal Imaging Control)	Supported
Canon	EyeQ Pro	Supported
Canon	CR2 (Platform-Retinal Imaging Control 4.1)	Supported
Canon	CR-2 Plus AF (Platform-Retinal Imaging Control 4.1)	Supported
Carl Zeiss Meditec, Inc.	IOL Master 500	Supported [15,18]
Carl Zeiss Meditec, Inc.	VISUCAM	Supported
Carl Zeiss Meditec, Inc.	VISUPAC	Supported
Carl Zeiss Meditec, Inc.	FORUM	Supported
Chace and Associates Technologies, LLC	ZPIP	Supported
Escalon	Ophthavision	Supported
Estenda	JVN	Supported
Heidelberg Engineering	Spectralis HRA	Supported
Kowa	VKDICOM	Supported
Kowa	VK-2	Supported
Medflow	oiCapture	Supported [15]

VA Approved DICOM Devices

Supported Ophthalmic Coherence Tomography Devices		
Manufacturer	**Model**	**Status**
Carl Zeiss Meditec, Inc.	Cirrus HD-OCT 400/4000	Supported[18]
Carl Zeiss Meditec, Inc.	Cirrus HD-OCT 500/5000	Supported[18]
Carl Zeiss Meditec, Inc.	Cirrus Photo 600/800 (with Forum)	Supported[18]
Carl Zeiss Meditec, Inc.	Stratus 3000	Supported
Heidelberg Engineering	Spectralis HRA + OCT	Supported

VA Approved DICOM Devices

Supported VL – Endoscopy Devices		
Manufacturer	**Model**	**Status**
Endosoft (UTECH)	Endosoft Systems	Supported
Endosoft (UTECH)	Endosoft 6.0 (Platform: 6.0)	Supported[18]
Endosoft (UTECH)	EndoVault 1.3 (Platform: 6.0)	Supported[18]
Envisionier Medical Technologies, Inc	eGoManager	Supported
Global Media Group, LLC	CapSure 2.0	Supported[5]
Karl Storz	AIDA HD Connect	Supported
Karl Storz	OR1-AIDA Compact II	Supported
KayPENTAX	DSW (Digital Swallowing Workstation)	Supported
KayPENTAX	KDS (Digital Stroboscopy Workstation)	Supported
MedXchange	DRSHD – Digital Recording System	Supported
MedXchange	DRSHD – Digital Recording System v1.4	Supported
Olympus	EndoWorks	Supported
Olympus America, Inc.	Endoworks 7.4	Supported
STI	UltraSight HD	Supported
Stryker Endoscopy	SDC-HD	Supported
Stryker Endoscopy	SDC Ultra	Supported
Stryker	SDC3	Supported
Notes [18] DICOM Encapsulated PDF.		

VA Pioneers in DICOM Clinical Imaging

- Kuzmak PM, Dayhoff RE. Multidisciplinary HIS DICOM interfaces at the Department of Veterans Affairs. In: Proc SPIE Medical Imaging 2000: PACS Design and Evaluation: Engineering and Clinical Issues. 2000. Available from: http://dx.doi.org/10.1117/12.386432
- Kuzmak PM, Dayhoff RE. Integrating nonradiology DICOM images into the electronic medical record at the Department of Veterans Affairs. In: Proc SPIE Medical Imaging 2001: PACS and Integrated Medical Information Systems: Design and Evaluation. 2001. Available from: http://dx.doi.org/10.1117/12.435479
- Kuzmak PM, Dayhoff RE. Extending DICOM imaging to new clinical specialties in the healthcare enterprise. In: Proc SPIE Medical Imaging 2002: PACS and Integrated Medical Information Systems: Design and Evaluation. 2002. Available from: http://dx.doi.org/10.1117/12.467012
- Kuzmak PM, Dayhoff RE. Experience with DICOM for the clinical specialties in the healthcare enterprise. In: Proc SPIE Medical Imaging 2003: PACS and Integrated Medical Information Systems: Design and Evaluation. 2003. Available from: http://dx.doi.org/10.1117/12.480668
- Kuzmak PM, Dayhoff RE. Operational experience with DICOM for the clinical specialties in the healthcare enterprise. In: Proc SPIE Medical Imaging 2004: PACS and Imaging Informatics. 2004. Available from: http://dx.doi.org/10.1117/12.539855

Encapsulation

- What if there is no IOD/SOP Class and the content is “complex”
- Save it as Secondary Capture image?
- Save it as Encapsulated PDF (which contains vector graphics)?
- Also have Encapsulated CDA
- DICOM has very restrictive “encapsulation policy”
- Not proprietary formats (e.g., not Microsoft Word)
- Not images that can be transcoded (e.g., PNG images)
- Not compressed streams that can already be used as Transfer Syntaxes with normal image IODs (e.g., JPEG, J2K)
- Will extend when it makes sense (e.g., 3D printing … STL, etc.)

Compression in DICOM

- Compressing the Pixel Data
  - policy is to use (other) standard schemes, esp. ISO/IEC JTC1/SC29
  - lossless: JPEG lossless, JPEG-LS, JPEG 2000 reversible, RLE
  - lossy: JPEG baseline DCT, JPEG 2000 irreversible
  - video: MPEG-2, MPEG-4, H.265 (AVC)
- Pixel Data element value is an entire compressed “file”
  - e.g., an entire JPEG/J2K bit stream, less the JFIF/JP2 segment
- Compressing everything
  - “deflate” scheme (zip, etc.)
- Essentially independent of the IOD/SOP Class of the image
  - some common patterns, esp. ultrasound, cardiac XA
  - interaction with Photometric Interpretation (RGB v. YBR_FULL_422)

Even Video

- Specific VL IODs/SOP Classes added for video, which mirror the single frame objects, e.g., for endoscopy
- Size limit – 4GB of compressed bit stream per DICOM instance due to single fragment requirement – ?? could relax this
- Can split really long videos into separate instances
  - if divided between GOPs (“groups of pictures”), i.e., at each “I” frame, will be lossless
  - can formally manage relationship of parts – Concatenations
  - informally, can put in same series and use timing attributes to relate
  - can reassemble into single non-DICOM bit stream for recipient prn.

Color Consistency

- Less of an issue for radiology, cardiology
- DICOM Grayscale Standard Display Function (GSDF)
- ICC Profiles for consistency of color images
- Recipient can perform “color management” to map “device” profile of image to “display” profile of calibrated display
- Challenge: displaying grayscale and color images at same time
- ICC Medical Image Working Group (MIWG) is working on such issues, as well as calibration targets (e.g., slides for WSI), best practices

Protocols: C-STORE, STOW-RS

- Traditional DICOM protocols (C-STORE, C-MOVE/GET, C-FIND)
  - TCP/IP based but not HTTP port 80 so not consistent with contemporary developer expectations
  - have provided perfectly adequate performance for decades if implemented properly, and widespread toolkit support, so nothing wrong with reusing them for clinical images
- Can also use new family with same functionality using HTTP and RESTful principles (STOW-RS, WADO-RS, QIDO-RS)
  - entire PS3.10 DICOM file
  - separate metadata as JSON or XML
  - separate bulk data, e.g., extract Pixel Data as image/jpeg

DICOMweb – WADO, STOW, QIDO-RS

DICOMweb Cheatsheet

Study Resources and Actions

Verb	Path	Type	Description
POST	{s}/studies	Store PS3.18 6.6.1	Store instances
GET	{s}/studies?...	Query PS3.18 6.7.1	Query for matching studies
GET	{s}/studies/{studyUID}	Retrieve PS3.18 6.5.1	Retrieve entire study
POST	{s}/studies/{studyUID}	Store PS3.18 6.6.1	Store instances
GET	{s}/studies/{studyUID}/metadata	Retrieve PS3.18 6.5.6	Retrieve metadata
GET	{s}/studies/{studyUID}/series?...	Query PS3.18 6.7.1	Query for matching series in a study
GET	{s}/studies/{studyUID}/series/{seriesUID}	Retrieve PS3.18 6.5.2	Retrieve entire series
GET	{s}/studies/{studyUID}/series/{seriesUID}/metadata	Retrieve PS3.18 6.5.6	Retrieve series metadata
GET	{s}/studies/{studyUID}/series/{seriesUID}/instances?...	Query PS3.18 6.7.1	Query for matching instances in a series
GET	{s}/studies/{studyUID}/series/{seriesUID}/instances/{instanceUID}	Retrieve PS3.18 6.5.3	Retrieve instance
GET	{s}/studies/{studyUID}/series/{seriesUID}/instances/{instanceUID}/metadata	Retrieve PS3.18 6.5.6	Retrieve instance metadata
GET	{s}/studies/{studyUID}/series/{seriesUID}/instances/{instanceUID}/frames/{frames}	Retrieve PS3.18 6.5.4	Retrieve frames in an instance
GET	/{bulkdataReference}	Retrieve PS3.18 6.5.5	Retrieve bulk data

Workflow Resources and Actions

Verb	Path	Type	Description
POST	{s}/workitems {?AffectedSOPInstanceUID}	PS3.18 6.9.1	CreateUPS
POST	{s}/workitems/{UPSInstanceUID} {?transaction}	PS3.18 6.9.2	UpdateUPS
GET	{s}/workitems{?query*}	PS3.18 6.9.3	SearchForUPS
GET	{s}/workitems/{UPSInstanceUID}	PS3.18 6.9.4	RetrieveUPS
PUT	{s}/workitems/{UPSInstanceUID}/state	PS3.18 6.9.5	ChangeUPSState
POST	{s}/workitems/{UPSInstanceUID}/ cancelrequest	PS3.18 6.9.6	RequestUPS Cancellation
POST	{s}/workitems/{UPSInstanceUID}/ subscribers/{AETitle}{?deletionlock}	PS3.18 6.9.7	CreateSubscription
POST	{s}/workitems/1.2.840.10008.5.1.4.34.5/	PS3.18 6.9.8	SuspendGlobal Subscription
DELETE	{s}/workitems/{UPSInstanceUID}/ subscribers/{AETitle}	PS3.18 6.9.9	DeleteSubscription
GET	{s}/subscribers/{AETitle}	PS3.18 6.9.10	OpenEventChannel
N/A	N/A	PS3.18 6.9.11	SendEventReport

Payloads

XML

```
<NativeDicomModel>
  <DicomAttribute Tag="00080020"
VR="DT" Keyword="StudyDate">
    <Value
number="1">20130409</value>
  </DicomAttribute>
  <DicomAttribute Tag="00080030"
VR="TM" Keyword="StudyTime">
    <Value
number="1">131600.0000</value>
  </DicomAttribute>
  …
</NativeDicomModel>
```

JSON

```
{
    "00080020": {
        "vr": "DT",
        "Value":
["20130409"]
    },
    "00080030": {
        "vr": "TM",
        "Value":
["131600.0000"]
    },
    …
}
```

(these payloads are excerpts to show payload structure; these are not complete)

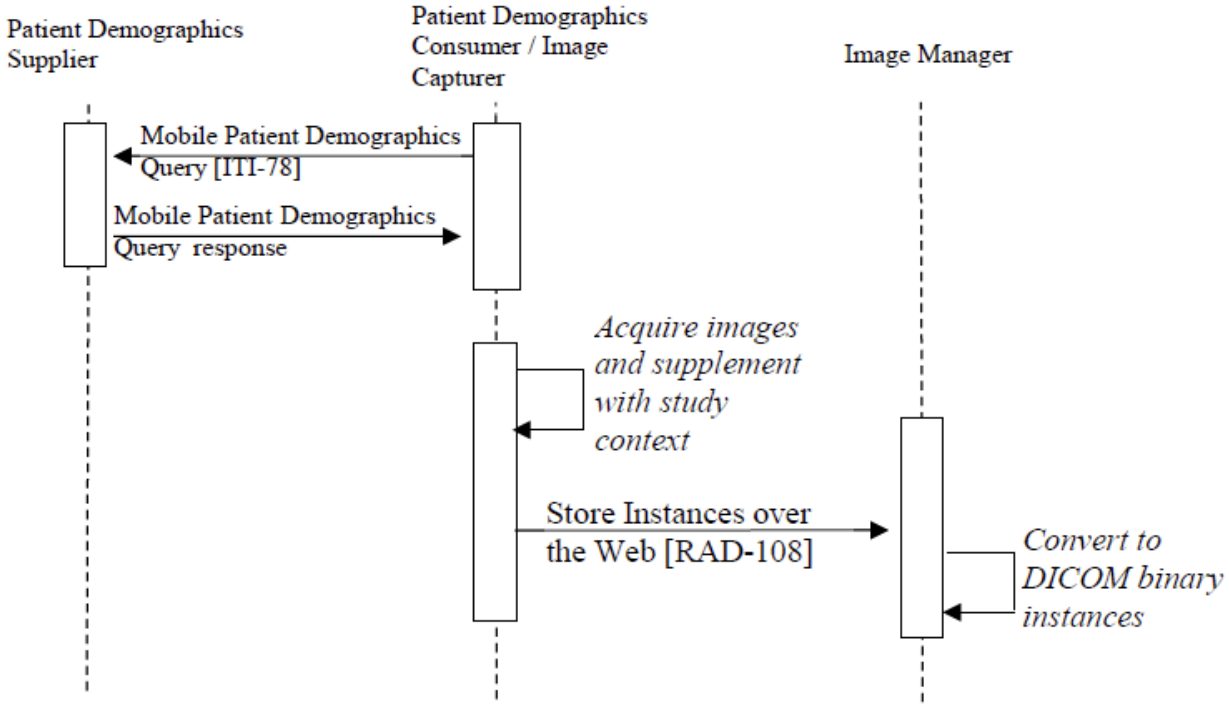
More Information

See http://dicomweb.org and Part 18 of the DICOM Standard, http://dicom.nema.org/standard.html.

IHE Web Image Capture with STOW-RS

- User identifies patient to the capture “app” somehow
  - e.g., scan barcode with ID and does mPDQ lookup of demographics
- User captures ordinary images or videos with app
- App builds minimal DICOM header with demographics, UIDs, dates/times, etc., and encodes it as JSON or XML
- App uses DICOM STOW-RS (HTTP POST) to send minimal header + image/jpeg, video/H265 (etc.) to server
- Server assembles DICOM instance out of what was supplied
  - can even extract Pixel Data module from image/video bit stream (rows, columns, etc.) since hard to do with some mobile camera APIs

IHE Web Image Capture with STOW-RS



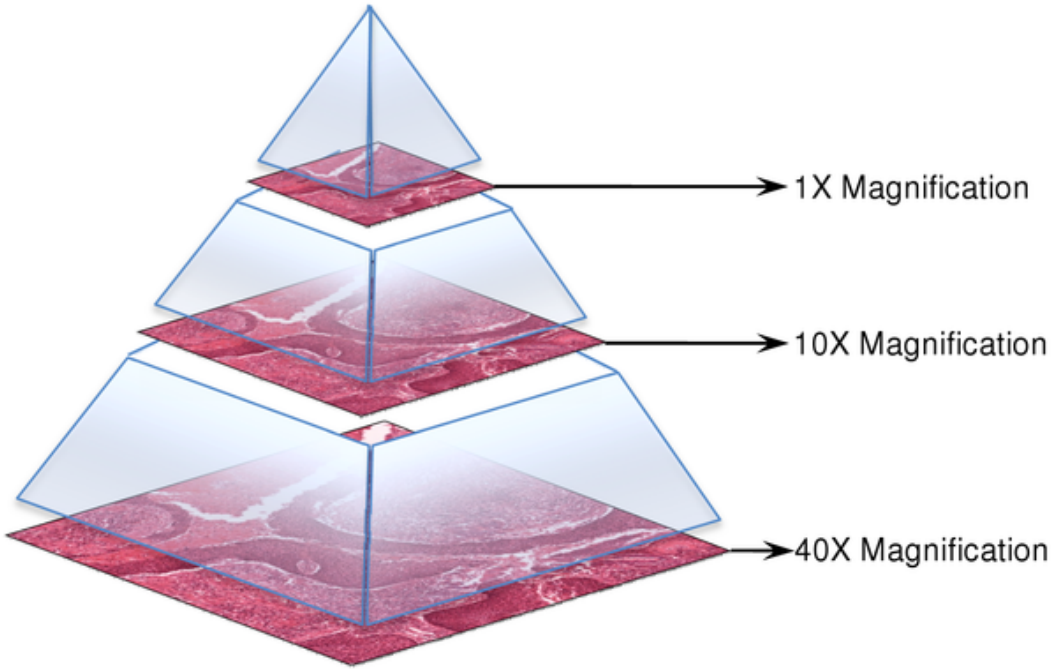
“Universal” Viewers

- View anything
- View from anywhere (any vendors’ DICOM archive/PACS)
- Standard protocol (DICOM, DICOMweb) used directly by viewer
- Proprietary protocol to thin server that talks standard protocol
- “Zero” footprint – absolute, almost, not even close to zero
- Performance – speed is ALL that matters to users – if anticipated can pre-fetch, worklist or visit list look ahead, versus on demand
- Avoid “A” is for “absent” syndrome (meant to be “archived”)
- Multiple specialty appropriate viewers (e.g., whole slide imaging)

Viewer Performance Challenges

- It is routine to “optimize” matched clients/servers from same vendor
- Standard protocols (e.g., DICOMweb) can be optimized too
- Can use a planned and expected sequence of operations
- With sufficient metadata in query to then select appropriate frames
- Appropriate server-side preprocessing/caching to “be ready” for the planned/expected next request
- Much harder to generalize across different vendors of client and server – nothing wrong with the standard, just how it is used
- Try before you buy to avoid disappointment
- Time to first (which?) slice/frame, time to scroll, zoom/pan
- On demand request versus anticipated (worklist, scheduled visit)

Digital slides stored in a pyramid



Wang Y, Williamson KE, Kelly PJ, James JA, Hamilton PW (2012) SurfaceSlide: A Multitouch Digital Pathology Platform. PLOS ONE 7(1): e30783. https://doi.org/10.1371/journal.pone.0030783
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0030783

One of these things not like the other

- Whole Slide Imaging (WSI) – DICOM standard for that too (Sup 145)
- Big + “Virtual Microscopy” navigation paradigm
- Think Google Maps or Microsoft Terraserver
- Pan around, zoom in and out, like moving a microscope stage and changing objective lenses
- Difference is the huge size of the high resolution layer (e.g., 200,000 x 256 x 256 tiles)
- No radiology modality is anything like that
- No other visible light modality is like that either
- Even if dedicated viewer needed, can still use standard archive, files and protocols (DICOM WSI file, metadata and frame level retrieval)

Other stuff that DICOM supports

- Radiotherapy objects (plans, structure sets, DVHs, treatment records,…)
- Waveforms (EKG and hemodynamic)
- Registrations
- Segmentations (rasterized and surface)
- Tractography Results
- Presentation States
- Structured Reports
- Structured Displays
- Hanging Protocols
- Acquisition Protocols
- Raw Data
- Stereometric Relationship
- Implant Templates
- …

Summary

- DICOM has long history of supporting “clinical” modalities
- More IODs/SOP Classes with specialized metadata can be added as requested
- Most contemporary PACS, all (true) VNAs can add new SOP Classes with simple configuration, and most are routinely “viewable” (even without specialized annotations)
- Common (consumer) compression formats match standard DICOM Transfer Syntaxes and are trivially transcoded, even videos
- Standard DICOM or newer WADO-RS protocols with JSON/XML are available to satisfy developer/deployment/security/performance requirements
- Use of DICOM allows for extensibility, scalability, reusability, portability and migratability
- The key is common composite context and metadata embedded within the instance/file
- DICOM data is truly managed data, not opaque files tenuously linked to metadata in a proprietary database