MICCAI 2017 – 21st Century DICOM for Quantitative Imaging Research

Why, What, and How

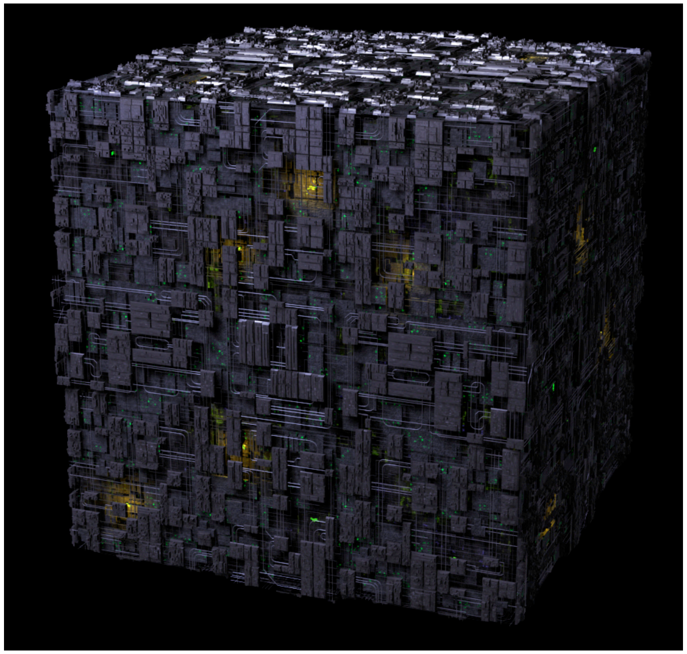
DICOM: Overview and historical perspective

David Clunie (dclunie@dclunie.com)
PixelMed Publishing

Background & Disclosures

- Owner, PixelMed Publishing, LLC
- Radiologist
- Independent Consultant
- Sub-contractor on NCI QIICR project
- Editor of DICOM Standard
- Formerly co-chair DICOM Standards Committee
- Formerly co-chair IHE Radiology Technical Committee

Will you be assimilated?



DICOM[SM]

Digital Imaging and Communications in Medicine

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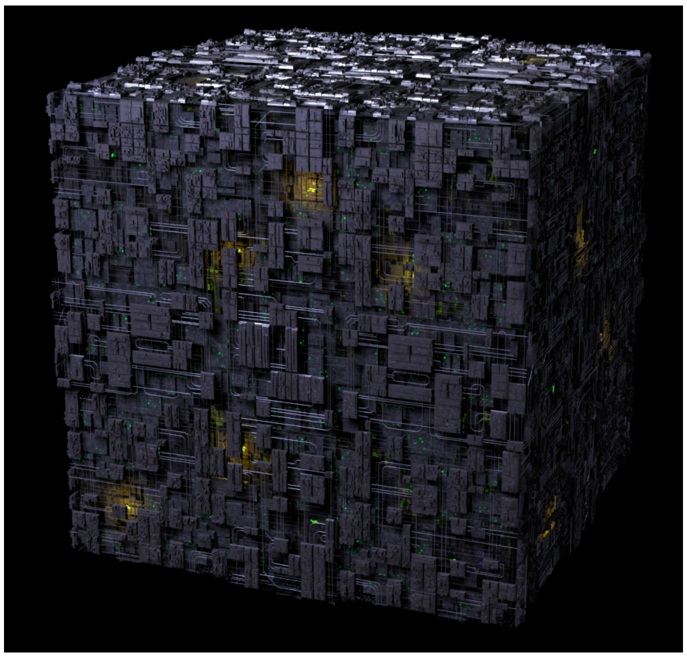


DICOM

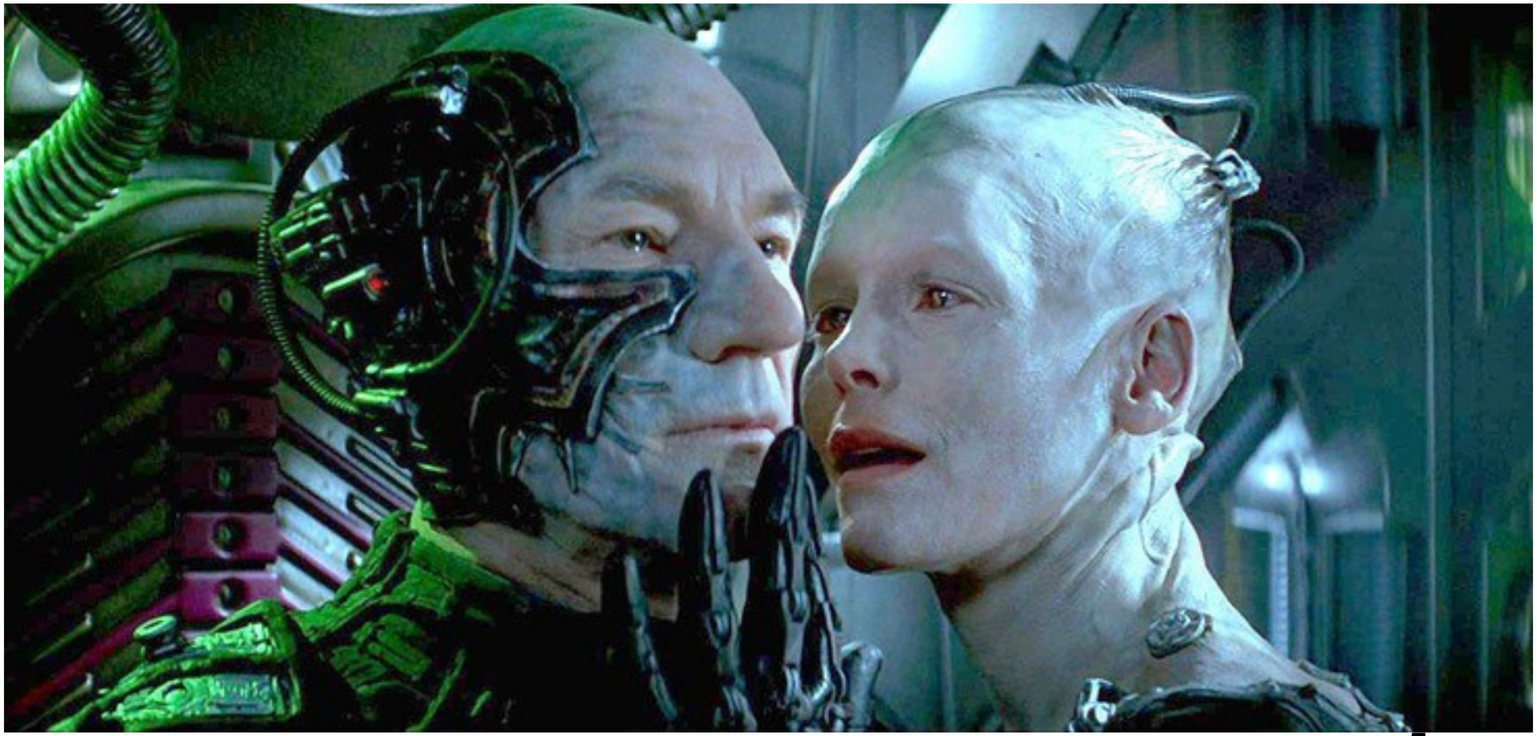
Digital Imaging and Communications in Medicine

“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?



Photoelectronic radiology department

M. Paul Capp, Sol Nudelman, Donald Fisher, Theron W. Ovitt, Gerald D. Pond, Meryl M. Frost, Hans Roehrig, Joachim Seeger, Donald Oimette
Department of Radiology, University of Arizona Health Sciences Center, Tucson, Arizona 85724

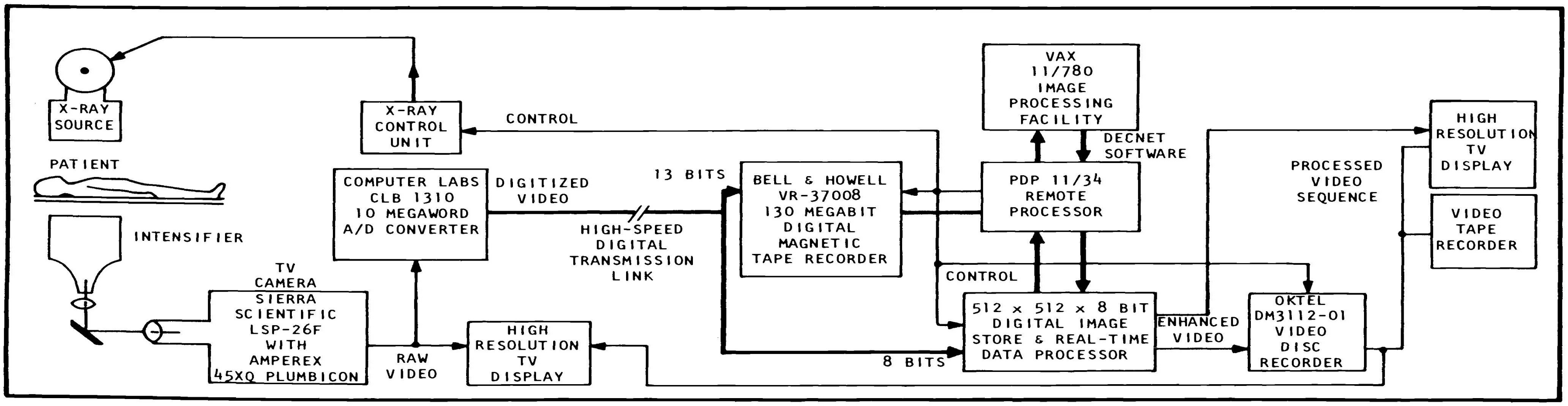
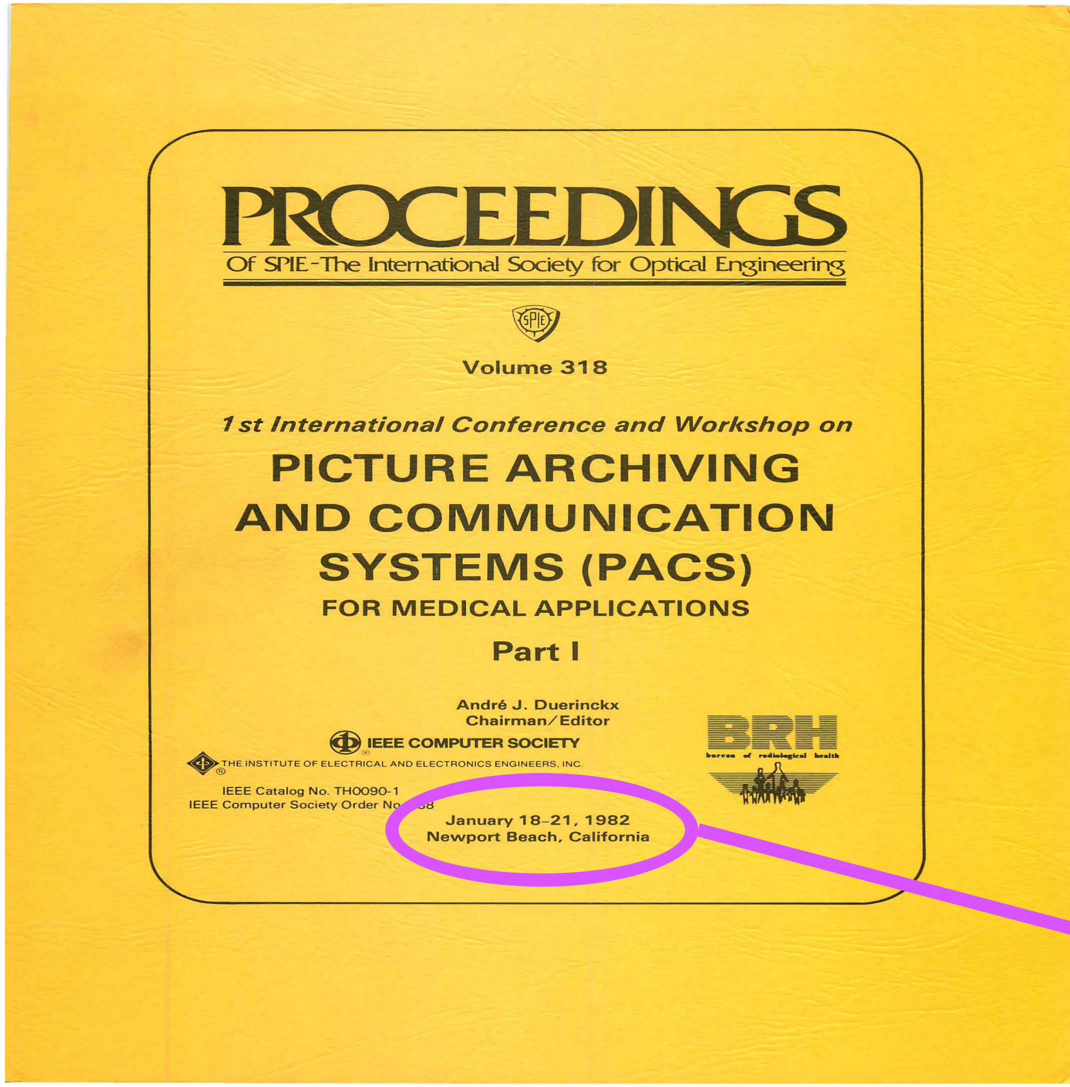


Figure 1. System block diagram of demonstration facility.



PROCEEDINGS

Of SPIE-The International Society for Optical Engineering

Volume 318

1st International Conference and Workshop on

PICTURE ARCHIVING AND COMMUNICATION SYSTEMS (PACS)

FOR MEDICAL APPLICATIONS

Part I

André J. Duerinckx
Chairman/Editor

IEEE COMPUTER SOCIETY

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

IEEE Catalog No. TH0090-1
IEEE Computer Society Order No. [illegible]68

BRH
bureau of radiological health

January 18–21, 1982
Newport Beach, California

1982

32 years ago – radiology PACS and DICOM ubiquitous 15-20 years later

DICOM – Brief History

- 1982 – 1st PACS Conference – session on standards
- 1982 – AAPM Report 10 – Standard Format for Image Interchange
- 1983 – ad hoc meeting between FDA, ACR & NEMA
- 1983 – 1st meeting of ACR-NEMA “Digital Imaging and Communications Standards” Committee
- 1985 – ACR-NEMA 300-1985 (“version 1.0”) issued
- 1988 – ACR-NEMA 300-1988 (“version 2.0”) issued
- 1990 – Inter-vendor testing of version 2.0 at Georgetown
- 1992 – Trial of DICOM (“version 3.0) at RSNA
- 1993 – DICOM 3.0 issued

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- 1982 – 1st PACS Conference – session on standards
- 1982 – AAPM Report 10 – Standard Format for Image Interchange
- 1983 – ad hoc meeting between FDA, ACR & NEMA
- 1983 – 1st meeting of ACR-NEMA “Digital Imaging and Communications Standards” Committee
- 1985 – ACR-NEMA 300-1985 (“version 1.0”) issued
- 1985 – IEEE 802.3 Ethernet (based on 1976 Metcalfe)
- 1986 – Aldus TIFF (version 3; prior versions drafts only)
- 1987 – CompuServe GIF
- 1988 – ACR-NEMA 300-1988 (“version 2.0”) issued
- 1990 – Inter-vendor testing of version 2.0 at Georgetown
- 1992 – Trial of DICOM (“version 3.0) at RSNA
- 1992 – JPEG (ITU T.81; ISO 10918-1 1994)
- 1993 – DICOM 3.0 issued

DICOM – Brief History

- ACR-NEMA versions 1 and 2
  - 50-pin 16 bit parallel interface
  - no network (assumed “network interface unit”)
  - layered
  - messages with commands and data
  - tag-value pairs
  - described patients, studies, images
  - described modality, acquisition, 3D position, etc.

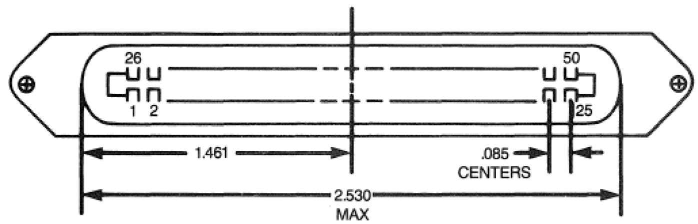


Figure 7-4
CONNECTOR—50 PIN FEMALE RECEPTACLE FRONT VIEW

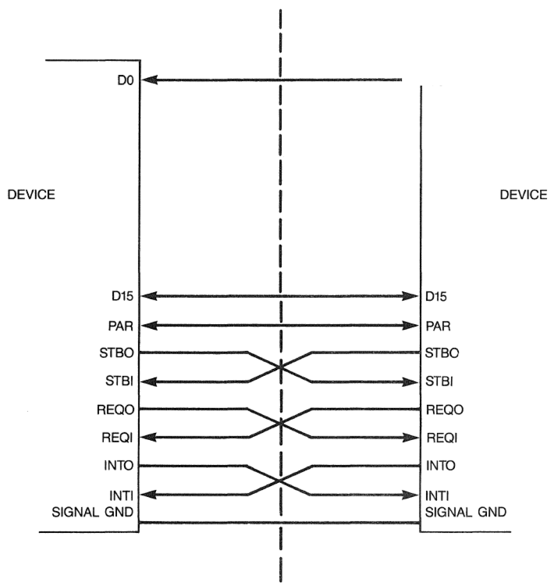


Figure 7-2
PHYSICAL AND LOGICAL INTERFACE

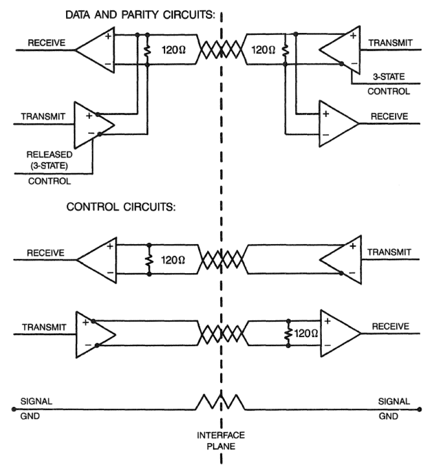


Figure 7-3
TYPICAL INTERFACE CIRCUIT

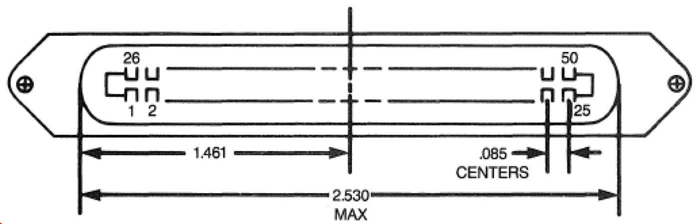
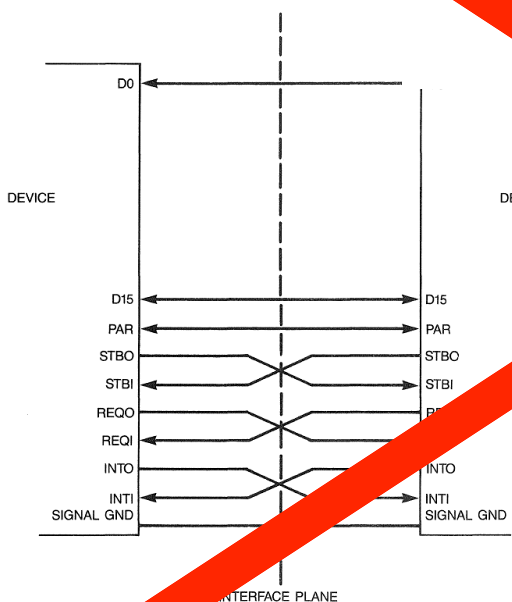


Figure 7-4
NECTOR—50 PIN FEMALE RECEPTACLE FRONT V



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PHYSICAL AND LOGICAL INTERFACE

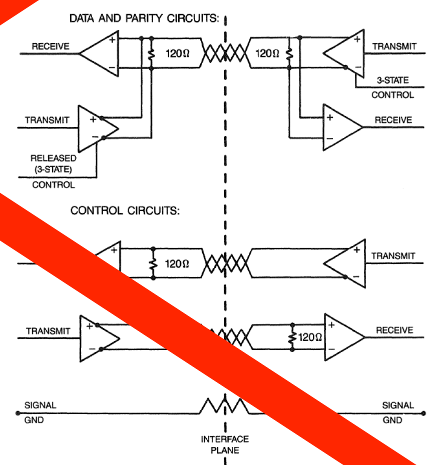

Figure 7-3
TYPICAL INTERFACE CIRCUIT

MESSAGE STRUCTURE
SEND_REQUEST

GROUP	ELEMENT	LENGTH	VALUE	MEANING	DESCRIPTION
0000	0000	0004 0000	0044 0000		Even number of bytes from the end of this field to the beginning of the next group
0000	0001	0004 0000	0190 0010		Even number of bytes from the end of this field to the end of the message
0000	0100	0002 0000	0001	"0001"	Command field = SEND_REQUEST
0000	0110	0004 0000	3231 4133	"123A"	Device generated message ID
0000	0200	0004 0000	4344 3148	"DCH1"	Logical address of sender
0000	0300	0004 0000	4341 3148	"ACH1"	Logical address of receiver
0000	0800	0002 0000	0000	"0000"	Data type = image
0008	0000	0004 0000	0084 0000		Group length
0008	0001	0004 0000	0140 0010		Message length
0008	0010	000C 0000	4341 2D52 454E 414D 3120 302E	"ACR-NEMA 1.0"	Recognition code
0008	0020	000A 0000	3931 3538 312E 2E31 3532	"1985.11.25"	Study date
0008	0030	0008 0000	3231 303A 3A35 3935	"12:05:59"	Study time
0008	0040	0006 0000	4D49 4741 2045	"Image"	Data set type
0008	0060	0002 0000	5244	"DR"	Modality
0008	0070	0004 0000	4241 4443	"ABCD"	Manufacturer
0008	0080	000E 0000	454D 4352 2059 4F48 5053 5449 4C41	"Mercy Hospital"	Institution ID

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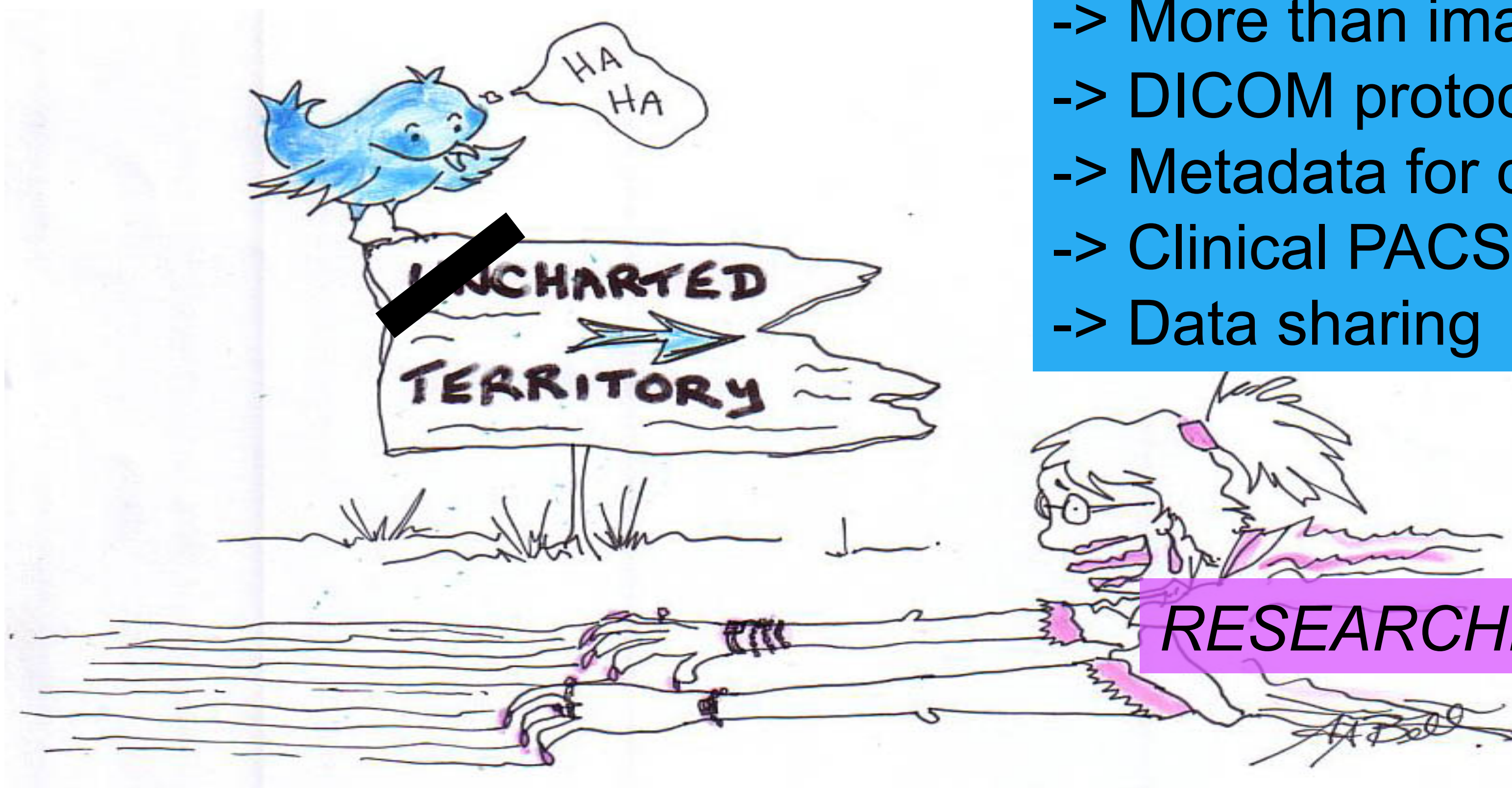
  - described patients, studies, images
  - described modality, acquisition, 3D position, etc.
- DICOM “3.0”
  - TCP/IP network protocol (and OSI semantics)
  - “object-oriented” description & conformance

https://supernaturalunderground.blogspot.com/2012/11/super-tweeting-with-royalty.html

-> DICOM files
-> More than images
-> DICOM protocols
-> Metadata for query
-> Clinical PACS
-> Data sharing



DICOM is essential for research too … esp. clinical adoption

What is DICOM?

- Application/modality specific Information Object Definitions (IODs) for data sets
- A standard file format in which to store data sets
- Data sets for images, parametric maps, segmentations, spectra, waveforms, point clouds, meshes, contours, annotations, transformations, reports, protocols, plans, … anything image-related
- Standard protocols to send, query for and retrieve data sets (and other things)
- A conformance documentation mechanism
- A data dictionary (elements, what they mean, how they are encoded)
- A controlled terminology (standard codes with standard definitions)
- Value sets (which standard codes to use in which contexts)

Interoperability

“the ability of two or more systems or components to exchange information and to use the information that has been exchanged”

IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. 1990

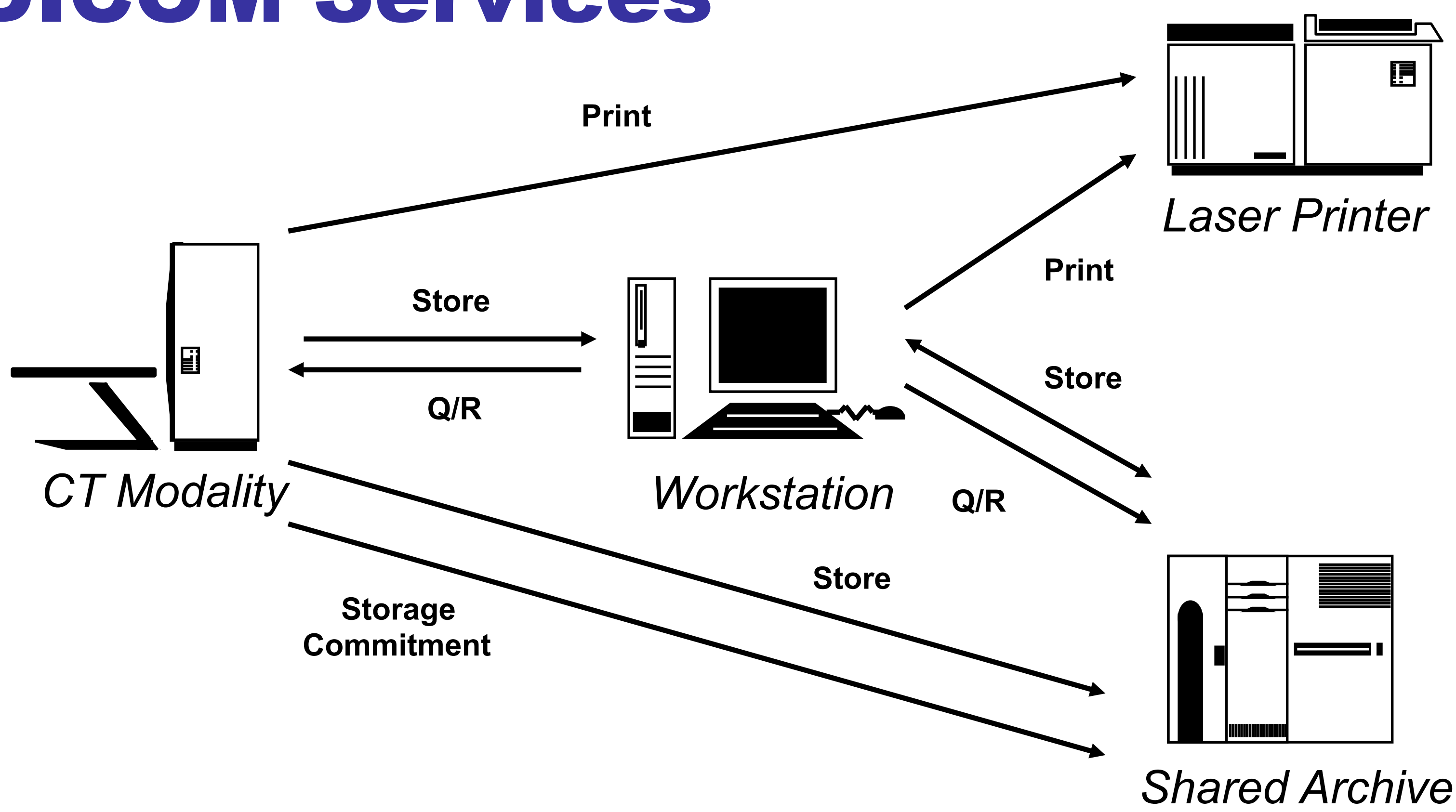
DICOM and Interoperability

- Conformance to DICOM
  - will guarantee network connection
  - will guarantee storage of object such as an image:
    - from modality to workstation
  - will NOT guarantee (but will enable) usability:
    - workstation will display image "correctly"
    - workstation can perform analysis
  - "use" facilitated by consistent mandatory attributes for:
    - identification, annotation, positioning, etc.
  - unbounded range of potential "uses"

DICOM and Interoperability

- Object oriented definition
  - data structures, e.g., MR image object
    - composite model of real world entities
      - patient, study, series
      - general image, specialized to MR image
  - services, e.g., image storage
  - together -> service/object pairs (SOP)
- Roles (user or provider) (SCU or SCP)
- Role + SOP Class -> Conformance

DICOM Services



Purchasing using DICOM Specs

- DICOM Conformance Statement
  - defines services
    - including modality/application specific storage classes
  - defines roles (user or provider)
  - defines other specific conformance issues
    - Transfer Syntax (encoding) - there is a default
    - limitations
    - configuration
    - physical network

Conformance Statement

CT Scanner – SCU (Client) Role

"This Application Entity provides Standard Conformance to the following DICOM v3.0 SOP Classes as an SCU:"

SOP Class Name(SCU)	SOP Class UID
CT Image Information Storage	1.2.840.10008.5.1.4.1.1.2
Modality Worklist Info Model - FIND	1.2.840.10008.5.1.4.31
Storage Commitment Push Model	1.2.840.10008.1.20.1
Basic Grayscale Print Management	1.2.840.10008.5.1.1.9

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Conformance Statement

Archive – SCP (Server) Role

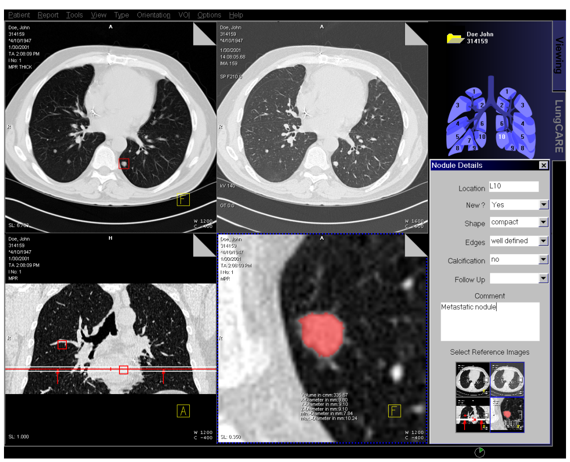
"This Application Entity provides Standard Conformance to the following DICOM v3.0 SOP Classes as an SCP:"

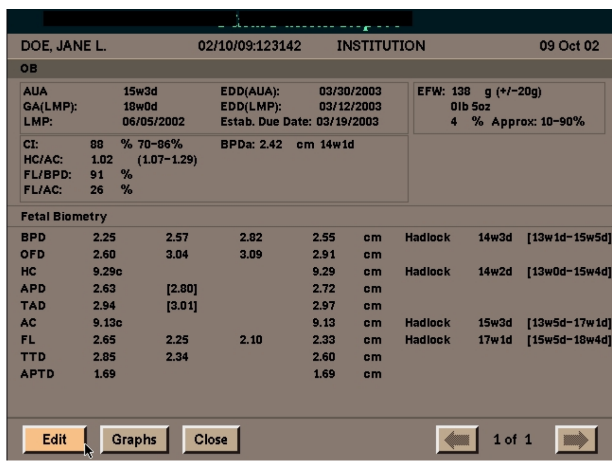
SOP Class Name(SCP)	SOP Class UID
Verification (Echo)	1.2.840.10008.1.1
CT Image Information Storage	1.2.840.10008.5.1.4.1.1.2
Study Root Query/Retrieve - FIND	1.2.840.10008.5.1.4.1.2.2.1
Study Root Query/Retrieve - MOVE	1.2.840.10008.5.1.4.1.2.2.2

Integration using DICOM

- Define primary functions
- Define boundaries between functions
- Identify equipment with functions
- Define primary services
- Define support services
- Identify DICOM service/role per device
- Match Conformance Statements


General Medical Hospital
Echocardiography Report


Nodule Details
Location
New ?
Shape
Edges
Calcification
Follow Up
Comment
Metastatic nodule
Select Reference Images
LungCARE


DOE, JANE L.
02/10/09:123142
INSTITUTION
09 Oct 02
OB
AUA 15w3d EDD(AUA): 03/30/2003
GA(LMP): 18w0d EDD(LMP): 03/12/2003
LMP: 06/05/2002 Estab. Due Date: 03/19/2003
EFW: 138 g (+/-20g)
0lb 5oz
4 % Approx: 10-90%
CI: 88 % 70-86% BPDa: 2.42 cm 14w1d
HC/AC: 1.02 (1.07-1.29)
FL/BPD: 91 %
FL/AC: 26 %
Fetal Biometry
BPD 2.25 2.57 2.82 2.55 cm Hadlock 14w3d [13w1d-15w5d]
OFD 2.60 3.04 3.09 2.91 cm
HC 9.29c 9.29 cm Hadlock 14w2d [13w0d-15w4d]
APD 2.63 [2.80] 2.72 cm
TAD 2.94 [3.01] 2.97 cm
AC 9.13c 9.13 cm Hadlock 15w3d [13w5d-17w1d]
FL 2.65 2.25 2.10 2.33 cm Hadlock 17w1d [15w5d-18w4d]
TTD 2.85 2.34 2.60 cm
APTD 1.69 1.69 cm
Edit
Graphs
Close
1 of 1


Doe Jane
Save Data
Reload Data

DICOM for Researchers – Ideal

- Same model as for clinical deployment
- Actually use DICOM network services and protocols to communicate to/from repositories (clinical PACS, research PACS)
- Use open source toolkits to do it
- Could take DICOM data straight from the scanners
- Send DICOM data back to the PACS for use with off-the-shelf devices/ software (viewers)
- All data is indexed in the PACS with standard metadata
- Research results become useful in a clinical context
- Hospital infrastructure support for archiving, security, training

DICOM for Researchers – Reality

- DICOM is often only used at the file level for input, +/- output
- Use open source toolkits to read and write DICOM files
- Can get files from off-the-shelf software that receives or sends files, or read from hard disk, CD, MOD, memory stick, etc.
- Any indexing is manual or using non-standard mechanisms
- Need to deal with “bunch of files” esp. if one slice/file (off modality)
- Research results useful if manually transferred to other standard-based tools (e.g., viewers)
- Manually deal with archiving, security, …
- Take advantage of standard encoding, metadata, compression, …

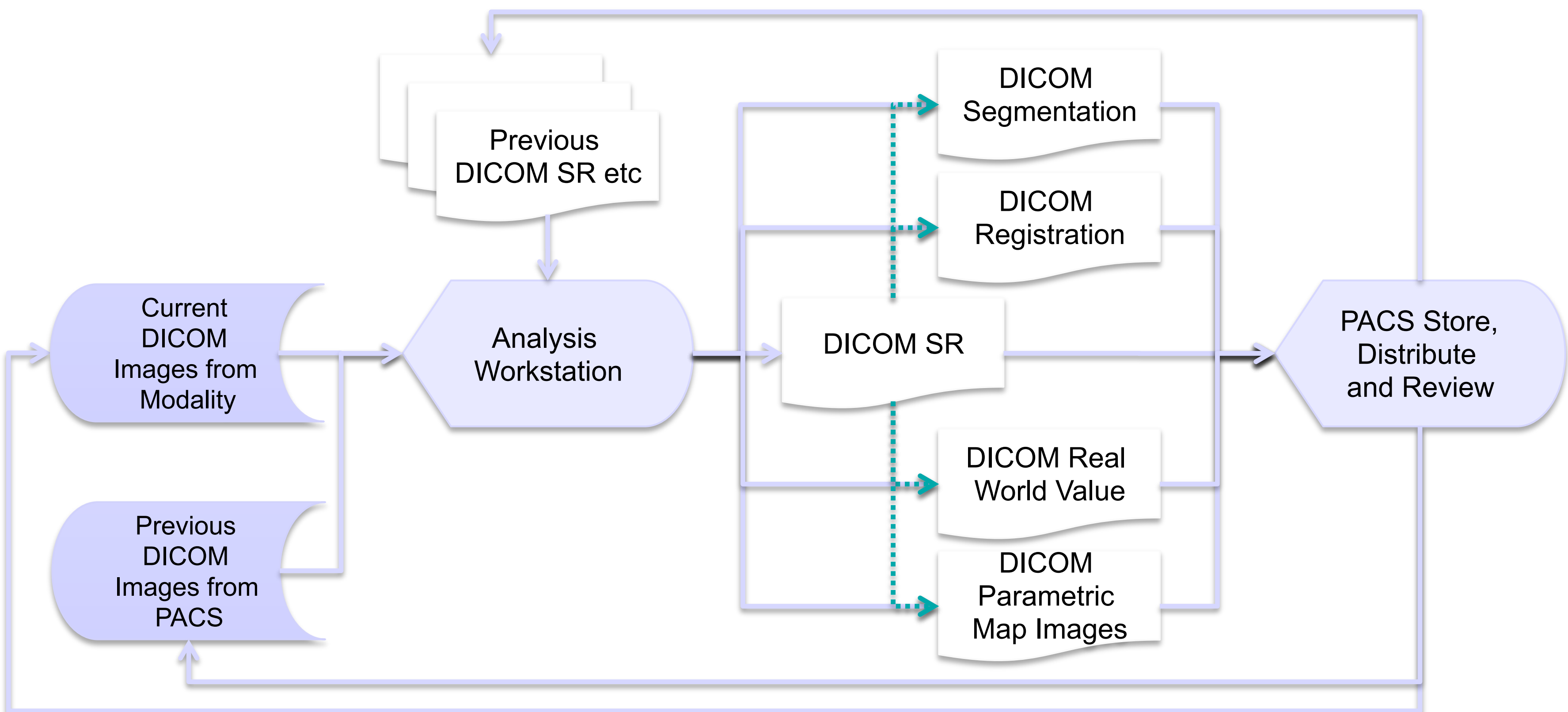
DICOM Files – What's in them?

- Images
- One slice per data set (file) or bunch of slices (enhanced multi-frame, e.g., a 3D volume, or 4D volume + time or other dimension)
- Images from scanner
- Images created by analysis
- Images that are intermediate work product shared between tools
- Images that are parametric maps (physical quantities)
- Images that are integers (scaled) or floating point
- Images that are pretty pictures (e.g., rendered fusions, screen shots)

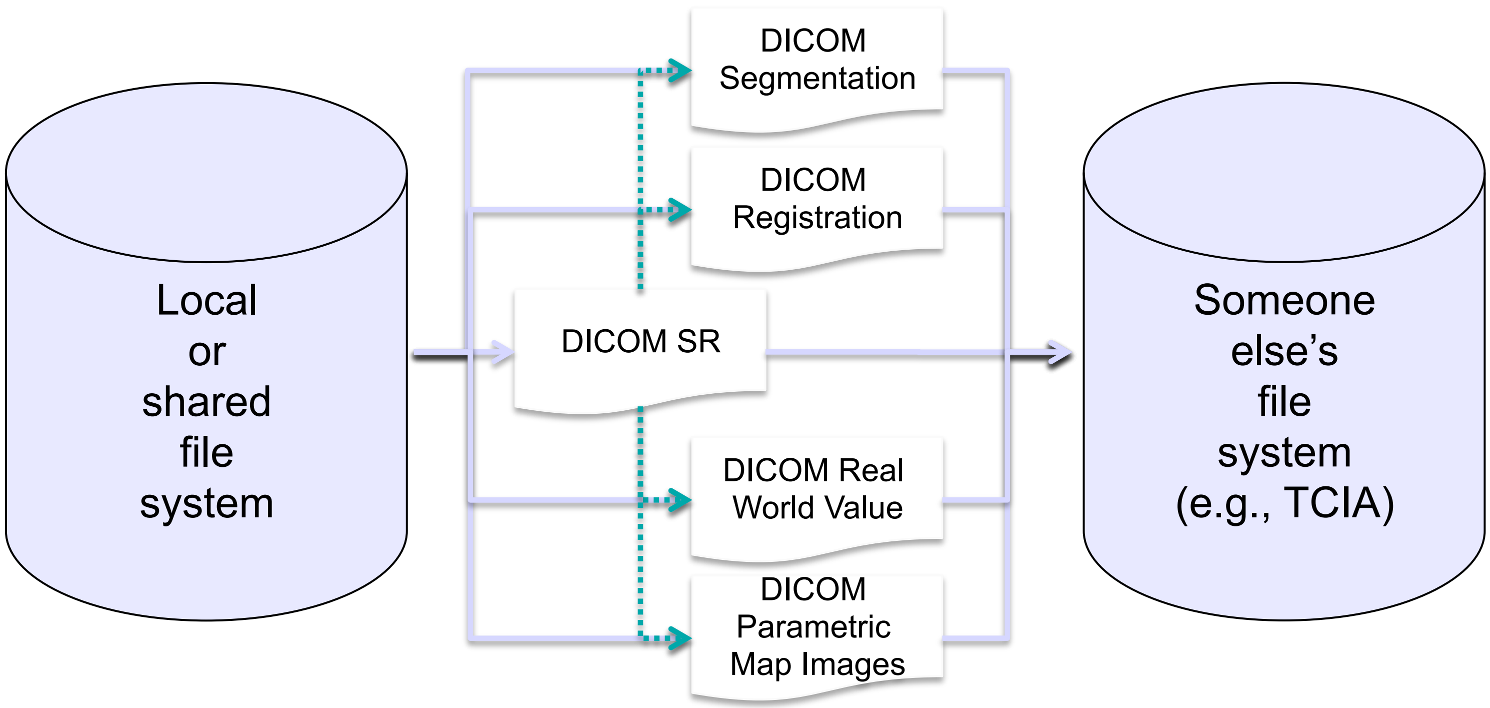
DICOM Files – What's in them?

- Non-images
- Registration transformation – rigid or deformation field
- Display instruction – presentation state
- Classification – Segmentation (rasterized, surface), Structure Sets – iso-contours (used in radiotherapy planning)
- Surface meshes and point clouds
- Structured data – Structured Report (SR) (e.g., measurements, categorical statements, annotations, contours)
- Pretty pictures – scanned documents, encapsulated PDF

Putting it all together … ideal



Putting it all together … files



DICOM Basics

- Bunch of “attributes” (data elements)
- Encoded in binary file as list of tag-value pairs
- Defined (but not encoded) as “modules” in “information object descriptions” (IODs)
- Very similar encoding to TIFF
- Pixel Data is just yet another attribute
- No fixed offsets – have to “parse” data elements sequentially – use a toolkit
- Are now standard XML and JSON alternative encodings defined for use with DICOM RESTful web services (WADO-RS)

How are DICOM files encoded?

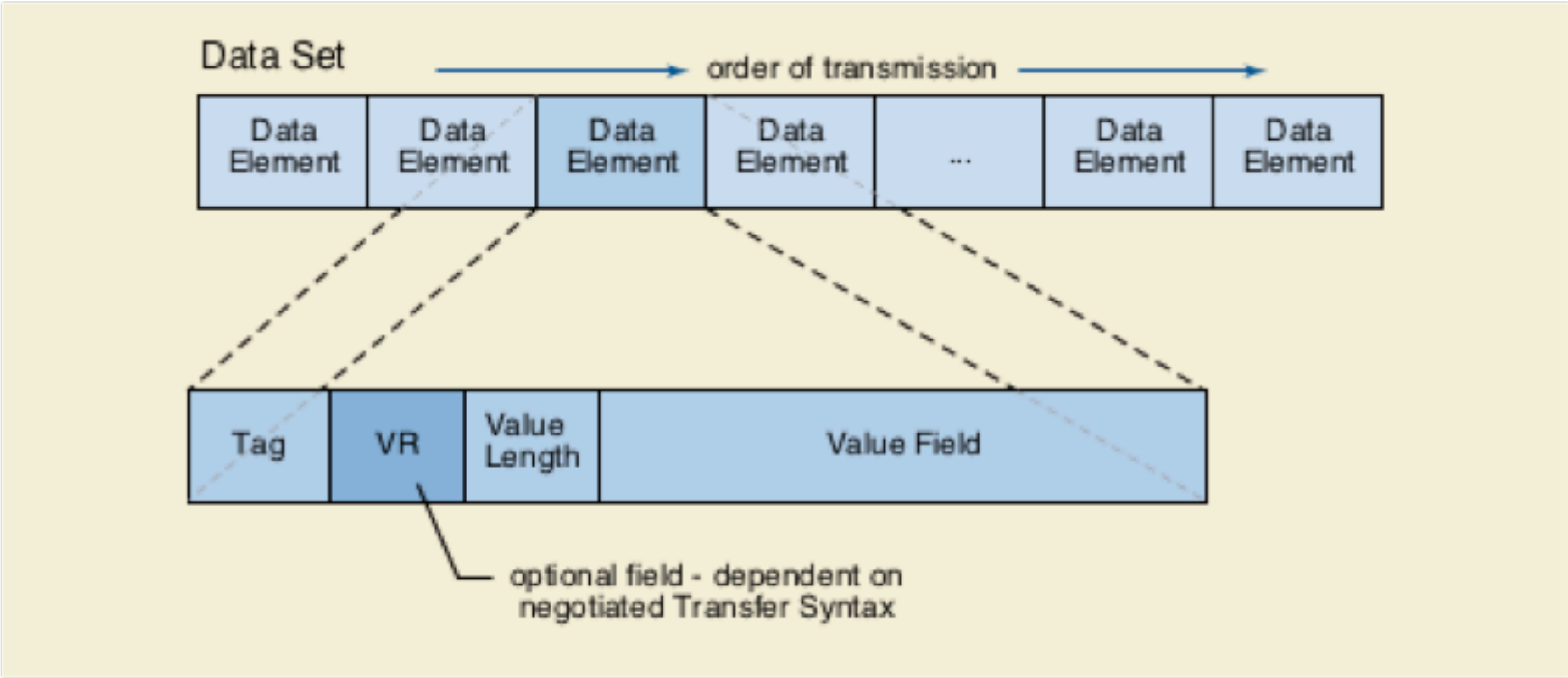


Image Plane Module

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 (first pixel 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.

MR Image Composite IOD

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
Series	General Series	C.7.3.1	M
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
Image	General Image	C.7.6.1	M
	Image Plane	C.7.6.2	M
	Image Pixel	C.7.6.3	M
	Contrast/bolus	C.7.6.4	C - Required if contrast media was used in this image
	MR Image	C.8.3.1	M
	Overlay Plane	C.9.2	U
	VOI LUT	C.11.2	U
	SOP Common	C.12.1	M

Example MR Image Dataset

```
(0x0008,0x0005) CS Specific Character Set   VR=<CS>   VL=<0x000a>  <ISO_IR 100>
(0x0008,0x0008) CS Image Type   VR=<CS>   VL=<0x0010>  <ORIGINAL\PRIMARY>
(0x0008,0x0016) UI SOP Class UID   VR=<UI>   VL=<0x001a>  <1.2.840.10008.5.1.4.1.1.4>
(0x0008,0x0018) UI SOP Instance UID   VR=<UI>   VL=<0x002e>
        <1.2.840.113619.2.1.2.1909421756.1.1.602501582>
(0x0008,0x0020) DA Study Date   VR=<DA>   VL=<0x0008>  <19890203>
(0x0008,0x0021) DA Series Date   VR=<DA>   VL=<0x0008>  <19890203>
(0x0008,0x0022) DA Acquisition Date   VR=<DA>   VL=<0x0008>  <19890203>
(0x0008,0x0023) DA Image Date   VR=<DA>   VL=<0x0008>  <19890203>
(0x0008,0x0030) TM Study Time   VR=<TM>   VL=<0x0006>  <092618>
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(0x0008,0x0032) TM Acquisition Time   VR=<TM>   VL=<0x0006>  <093302>
(0x0008,0x0033) TM Image Time   VR=<TM>   VL=<0x0006>  <093302>
(0x0008,0x0050) SH Accession Number   VR=<SH>   VL=<0x0000>   []
(0x0008,0x0060) CS Modality   VR=<CS>   VL=<0x0002>  <MR>
(0x0008,0x0070) LO Manufacturer   VR=<LO>   VL=<0x0012>  <GE MEDICAL SYSTEMS>
(0x0008,0x0080) LO Institution Name   VR=<LO>   VL=<0x001c>  <THOMAS JEFF UNIVHOSPITAL MRI>
(0x0008,0x0090) PN Referring Physician's Name   VR=<PN>   VL=<0x0004>  <HUME>
(0x0008,0x1010) SH Station Name   VR=<SH>   VL=<0x0008>  <FOR.IC0 >
(0x0008,0x1030) LO Study Description   VR=<LO>   VL=<0x0004>  <KNEE>
(0x0008,0x103e) LO Series Description   VR=<LO>   VL=<0x0006>  <COR T2>
(0x0008,0x1060) PN Name of Physician(s) Reading Study   VR=<PN>   VL=<0x0004>  <BODY>
(0x0008,0x1070) PN Operator's Name   VR=<PN>   VL=<0x0002>  <RB>
(0x0008,0x1090) LO Manufacturer's Model Name   VR=<LO>   VL=<0x000e>  <GENESIS_SIGNA >
(0x0010,0x0010) PN Patient's Name   VR=<PN>   VL=<0x000c>  <* GRX KNEE *>
(0x0010,0x0020) LO Patient's ID   VR=<LO>   VL=<0x0006>  <RSNA2 >
(0x0010,0x0030) DA Patient's Birth Date   VR=<DA>   VL=<0x0000>   []
(0x0010,0x0040) CS Patient's Sex   VR=<CS>   VL=<0x0002>  <M >
(0x0010,0x1010) AS Patient's Age   VR=<AS>   VL=<0x0004>  <034Y>
(0x0010,0x1030) DS Patient's Weight   VR=<DS>   VL=<0x000a>  < 90.718000>
(0x0010,0x21b0) LT Additional Patient History   VR=<LT>   VL=<0x0008>  <R/O TEAR>
(0x0018,0x0020) CS Scanning Sequence   VR=<CS>   VL=<0x0002>  <SE>
(0x0018,0x0021) CS Sequence Variant   VR=<CS>   VL=<0x0004>  <OSP >
(0x0018,0x0022) CS Scan Options   VR=<CS>   VL=<0x0004>  <NPW >
(0x0018,0x0023) CS MR Acquisition Type   VR=<CS>   VL=<0x0002>  <2D>
(0x0018,0x0025) CS Angio Flag   VR=<CS>   VL=<0x0002>  <N >
(0x0018,0x0050) DS Slice Thickness   VR=<DS>   VL=<0x0008>  <5.000000>
(0x0018,0x0080) DS Repetition Time   VR=<DS>   VL=<0x000c>  < 2000.000000>
(0x0018,0x0081) DS Echo Time   VR=<DS>   VL=<0x000a>  < 20.000000>
(0x0018,0x0082) DS Inversion Time   VR=<DS>   VL=<0x0008>  <0.000000>
(0x0018,0x0083) DS Number of Averages   VR=<DS>   VL=<0x0008>  <0.500000>
(0x0018,0x0084) DS Imaging Frequency   VR=<DS>   VL=<0x0010>  < 638746840.00000>
(0x0018,0x0085) SH Imaged Nucleus   VR=<SH>   VL=<0x0002>  <H1>
(0x0018,0x0086) IS Echo Number(s)   VR=<IS>   VL=<0x0002>  < 1>
(0x0018,0x0087) DS Magnetic Field Strength   VR=<DS>   VL=<0x0006>  <15000 >
(0x0018,0x0088) DS Spacing Between Slices   VR=<DS>   VL=<0x0008>  <6.000000>
(0x0018,0x0091) IS Echo Train Length   VR=<IS>   VL=<0x0002>  <0 >
(0x0018,0x0093) DS Percent Sampling   VR=<DS>   VL=<0x000a>  < 53.125000>
(0x0018,0x0094) DS Percent Phase Field of View   VR=<DS>   VL=<0x000a>  <100.000000>
(0x0018,0x1088) IS Heart Rate   VR=<IS>   VL=<0x0002>  <0 >
(0x0018,0x1090) IS Cardiac Number of Images   VR=<IS>   VL=<0x0002>  <0 >
(0x0018,0x1094) IS Trigger Window   VR=<IS>   VL=<0x0002>  <10>
(0x0018,0x1100) DS Reconstruction Diameter   VR=<DS>   VL=<0x000a>  <140.000000>
(0x0018,0x1314) DS Flip Angle   VR=<DS>   VL=<0x0002>  <0 >
(0x0018,0x1315) CS Variable Flip Angle Flag   VR=<CS>   VL=<0x0002>  <N >
(0x0018,0x1316) DS SAR   VR=<DS>   VL=<0x0008>  <0.052993>
(0x0018,0x5100) CS Patient Position   VR=<CS>   VL=<0x0004>  <FFS >
(0x0020,0x000d) UI Study Instance UID   VR=<UI>   VL=<0x0028>
        <1.2.840.113619.2.1.2.139348932.602501178>
(0x0020,0x000e) UI Series Instance UID   VR=<UI>   VL=<0x002a>
        <1.2.840.113619.2.1.2.596272627.1.602501541>
(0x0020,0x0010) SH Study ID   VR=<SH>   VL=<0x0002>  <2 >
(0x0020,0x0011) IS Series Number   VR=<IS>   VL=<0x0002>  < 1>
(0x0020,0x0012) IS Acquisition Number   VR=<IS>   VL=<0x0002>  < 0>
(0x0020,0x0013) IS Image Number   VR=<IS>   VL=<0x0002>  < 1>
(0x0020,0x0032) DS Image Position (Patient)   VR=<DS>   VL=<0x0020>
        <-70.000000\ 18.000000\ 75.000000>
(0x0020,0x0037) DS Image Orientation (Patient)   VR=<DS>   VL=<0x0038>
        < 1.000000\0.000000\0.000000\0.000000\0.000000\ -1.000000>
(0x0020,0x0052) UI Frame of Reference UID   VR=<UI>   VL=<0x002c>
        <1.2.840.113619.2.1.2.596272627.1.602501541.0>
(0x0020,0x0060) CS Laterality   VR=<CS>   VL=<0x0000>   []
(0x0020,0x0110) DS Temporal Resolution   VR=<DS>   VL=<0x000a>  <1120403456>
(0x0020,0x1040) LO Position Reference Indicator   VR=<LO>   VL=<0x0002>  <KN>
(0x0020,0x1041) DS Slice Location   VR=<DS>   VL=<0x000e>  <-18.0000000000>
(0x0028,0x0002) US Samples per Pixel   VR=<US>   VL=<0x0002>  [0x01]
(0x0028,0x0004) CS Photometric Interpretation   VR=<CS>   VL=<0x000c>  <MONOCHROME2 >
(0x0028,0x0010) US Rows   VR=<US>   VL=<0x0002>  [0x100]
(0x0028,0x0011) US Columns   VR=<US>   VL=<0x0002>  [0x100]
(0x0028,0x0030) DS Pixel Spacing   VR=<DS>   VL=<0x0012>  < 0.546875\0.546875>
(0x0028,0x0100) US Bits Allocated   VR=<US>   VL=<0x0002>  [0x10]
(0x0028,0x0101) US Bits Stored   VR=<US>   VL=<0x0002>  [0x10]
(0x0028,0x0102) US High Bit   VR=<US>   VL=<0x0002>  [0x0f]
(0x0028,0x0103) US Pixel Representation   VR=<US>   VL=<0x0002>  [0x01]
(0x0028,0x0120) XS Pixel Padding Value   VR=<SS>   VL=<0x0002>  [0x00]
(0x7fe0,0x0010) OX Pixel Data   VR=<OW>   VL=<0x20000>   []   # skipping ...
```

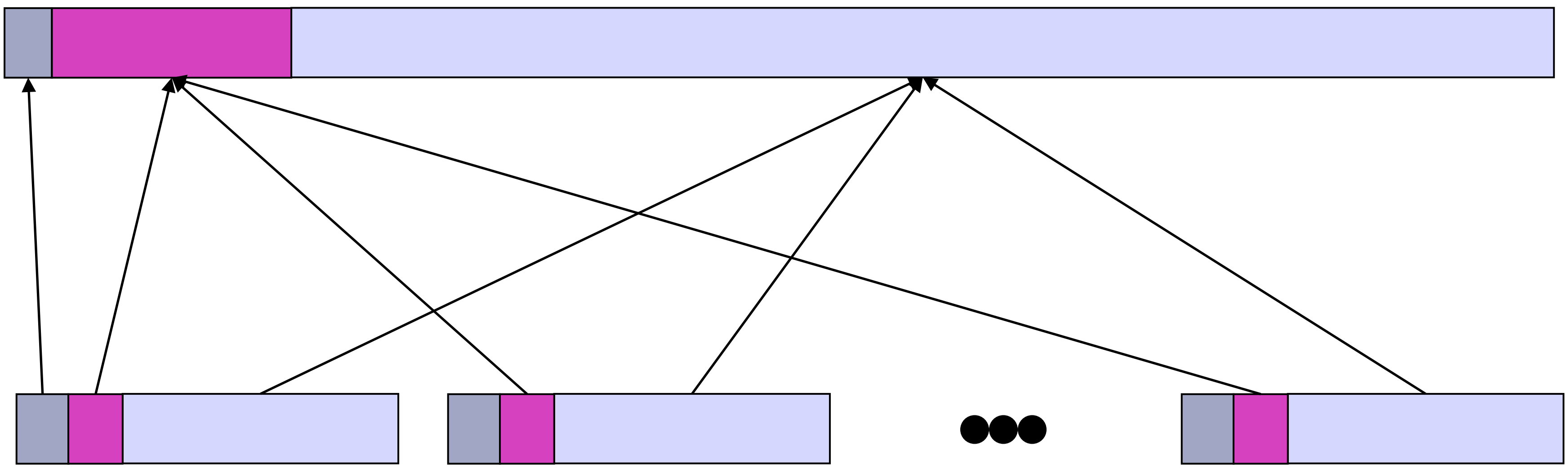
DICOM as XML

```
<?xml version="1.0" encoding="UTF-8" xml:space="preserve" ?>
<NativeDicomModel>
  <DicomAttribute tag="0020000D" vr="UI" keyword="StudyInstanceUID”>
    <Value number="1”>1.2.392.200036.9116.2.2.2.1762893313.1029997326.945873</Value>
  </DicomAttribute>
  …
</NativeDicomModel>
```

DICOM as JSON

```
[
  { "0020000D”:
    { "vr": "UI", "Value": [ "1.2.392.200036.9116.2.2.2.1762893313.1029997326.945873" ] }
  },
  …
]
```

Single vs. Multi-frame Encoding



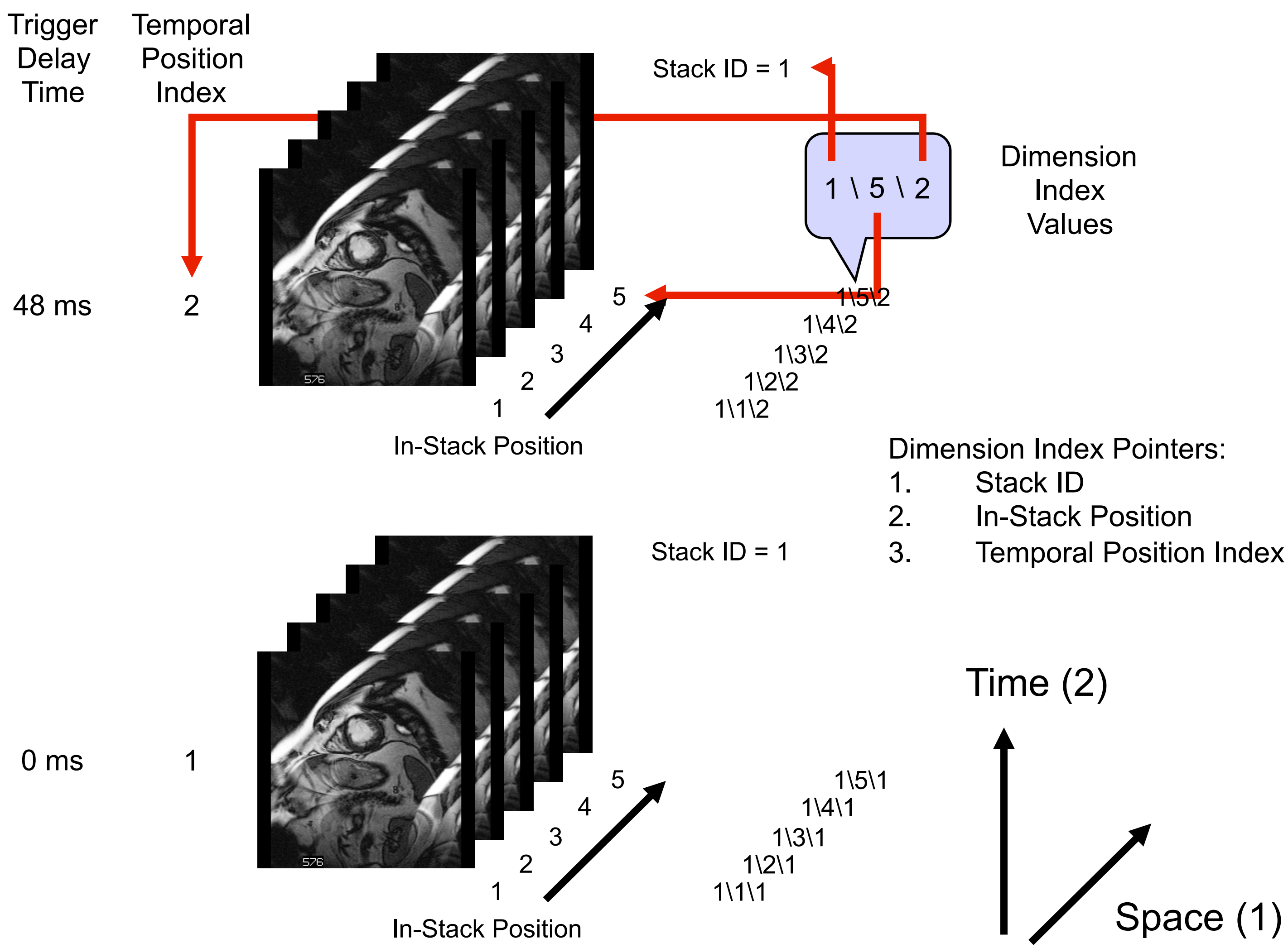
Shared attributes   Per-frame attributes   Pixels

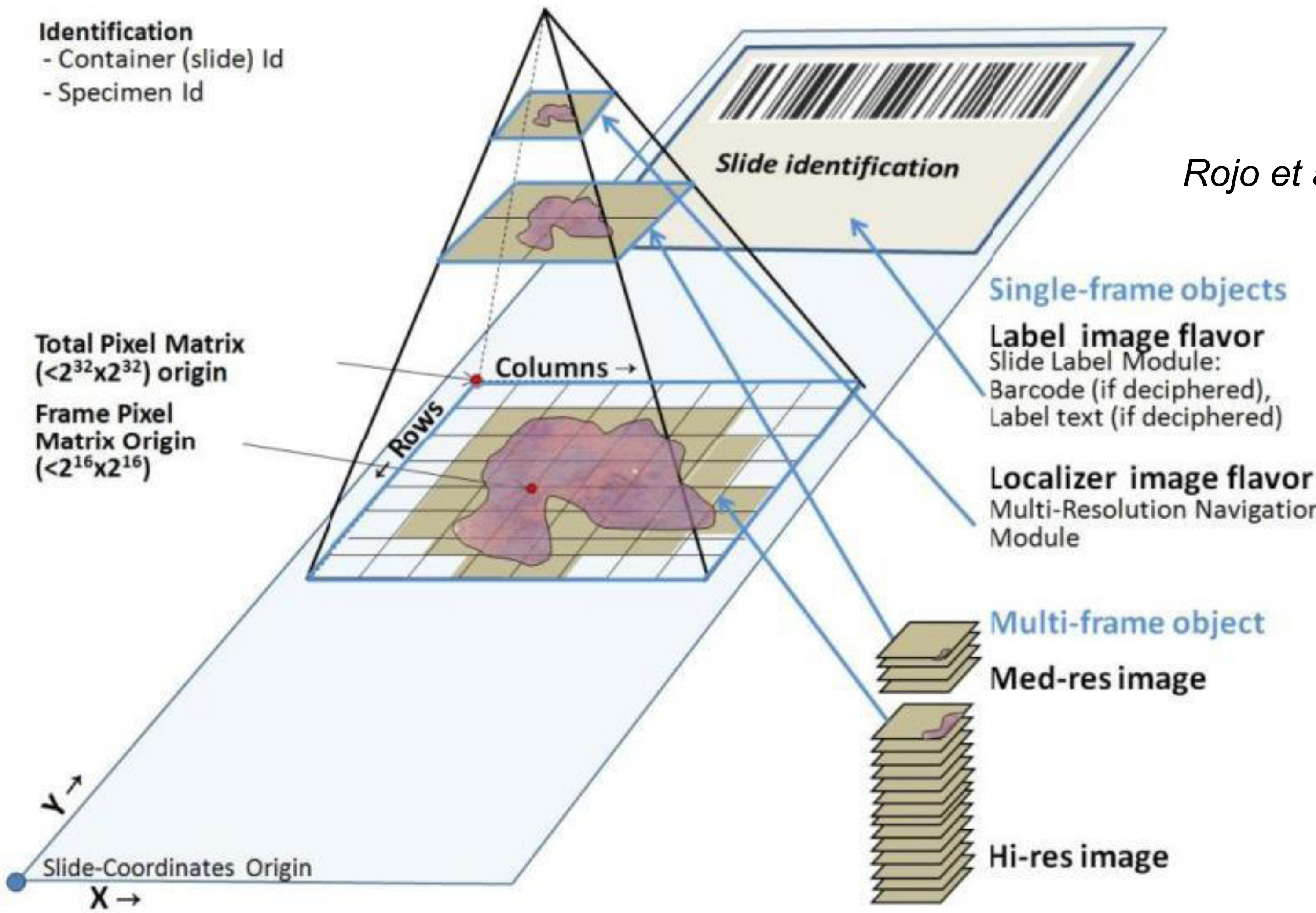
Enhanced Multi-frame Encoding

- Used by all new objects (e.g., segmentation)
- Fully defined modern equivalents for CT, MR and PET (produced by some vendors)
- “Legacy converted” objects defined for conversion of single frame objects (which don’t satisfy mandatory requirements of new objects)
- Even if vendors don’t use them, researchers can (toolkit, viewer support)
- Can take advantage of more detailed attributes and values

Creating DICOM Multi-frame

- From traditional single frame per slice DICOM encoding
- Poor: stuff all slices (with same Rows/Columns) into a file and describe them
- Better: merge all single frames in a series into one multi-frame
- Best: partition them based on common attributes, e.g., same acquisition, all parallel, equally spaced, etc.
- Essentially the same “find the single volume traversal” problem that traditional viewers face
- CT/MR/PET researchers like “volumes” and so do their tools
- Not all acquisitions were designed as “volumes”
- Modality-produced multi-frame: “dimensions” pre-defined and encoded

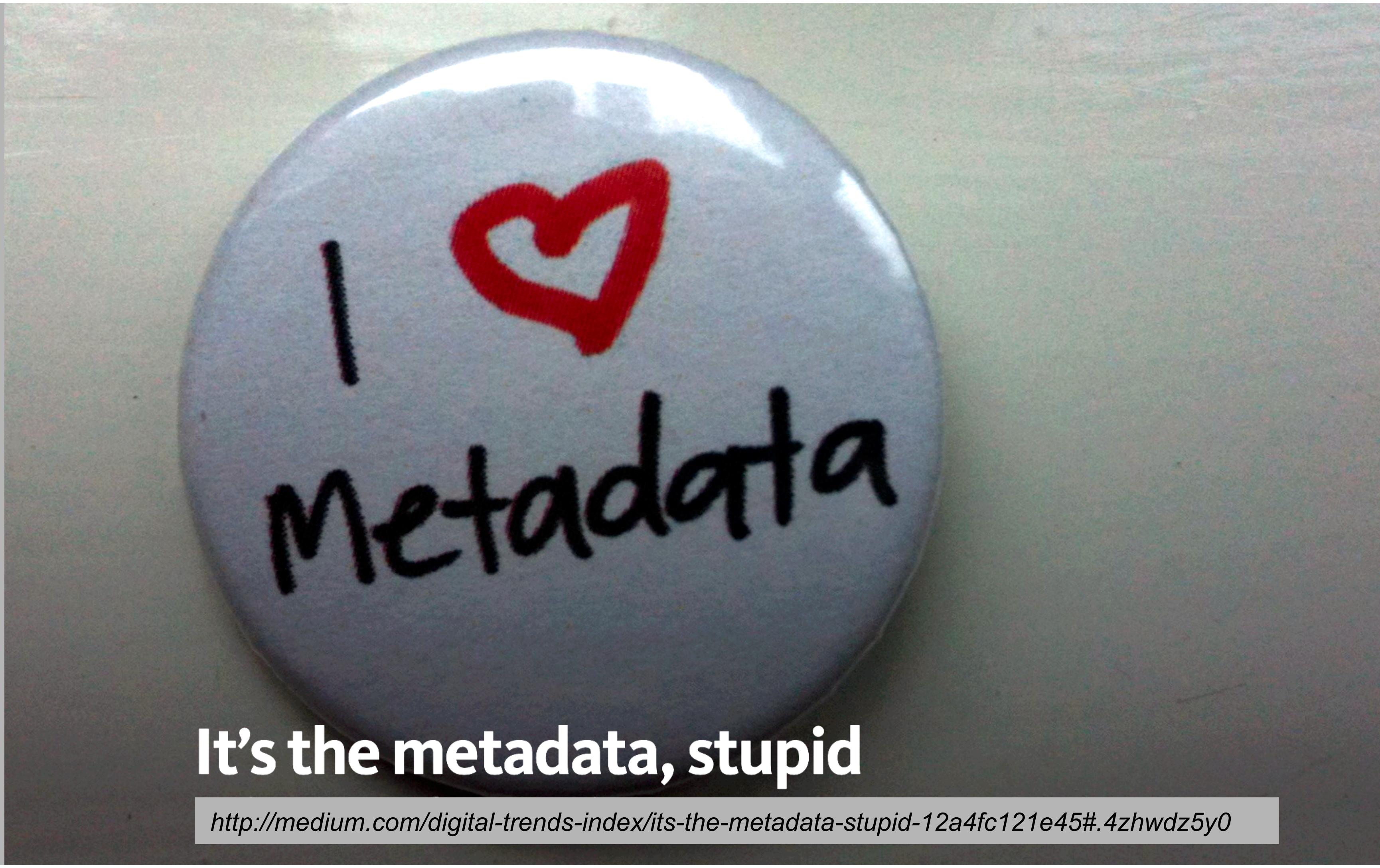

Trigger Delay Time
Temporal Position Index
Stack ID = 1
Dimension Index Values
1 \ 5 \ 2
48 ms
2
5
4
3
2
1
1\5\2
1\4\2
1\3\2
1\2\2
1\1\2
In-Stack Position
Dimension Index Pointers:
1. Stack ID
2. In-Stack Position
3. Temporal Position Index
Stack ID = 1
0 ms
1
5
4
3
2
1
1\5\1
1\4\1
1\3\1
1\2\1
1\1\1
In-Stack Position
Time (2)
Space (1)



Rojo et al. 2016

Why dwell on the new stuff?

- Common complaint about DICOM from researchers – too many independent files, organized differently depending on vendor
- Possible to separate “clean up” from “reading” steps
- Then specialists can write “cleaners” that can be used for pre-processing
- Algorithm developers can then focus on ingesting high quality, pre-cleaned DICOM multi-frame, rather than relying on lame/incomplete/buggy/broken/ obsolete DICOM toolkits built-in to their platforms
- Opportunity to extract private data elements (e.g., for DWI, fMRI, DCE/DSC timing) into standard attributes and standard values
- Corollary – research software can/should write multi-frame DICOM too
- DICOM binary format “too hard” – use API/library, but also XML, JSON
- Even have floating point pixel data now – DICOM Parametric Map object



It's the metadata, stupid

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

Standard Attributes & Values

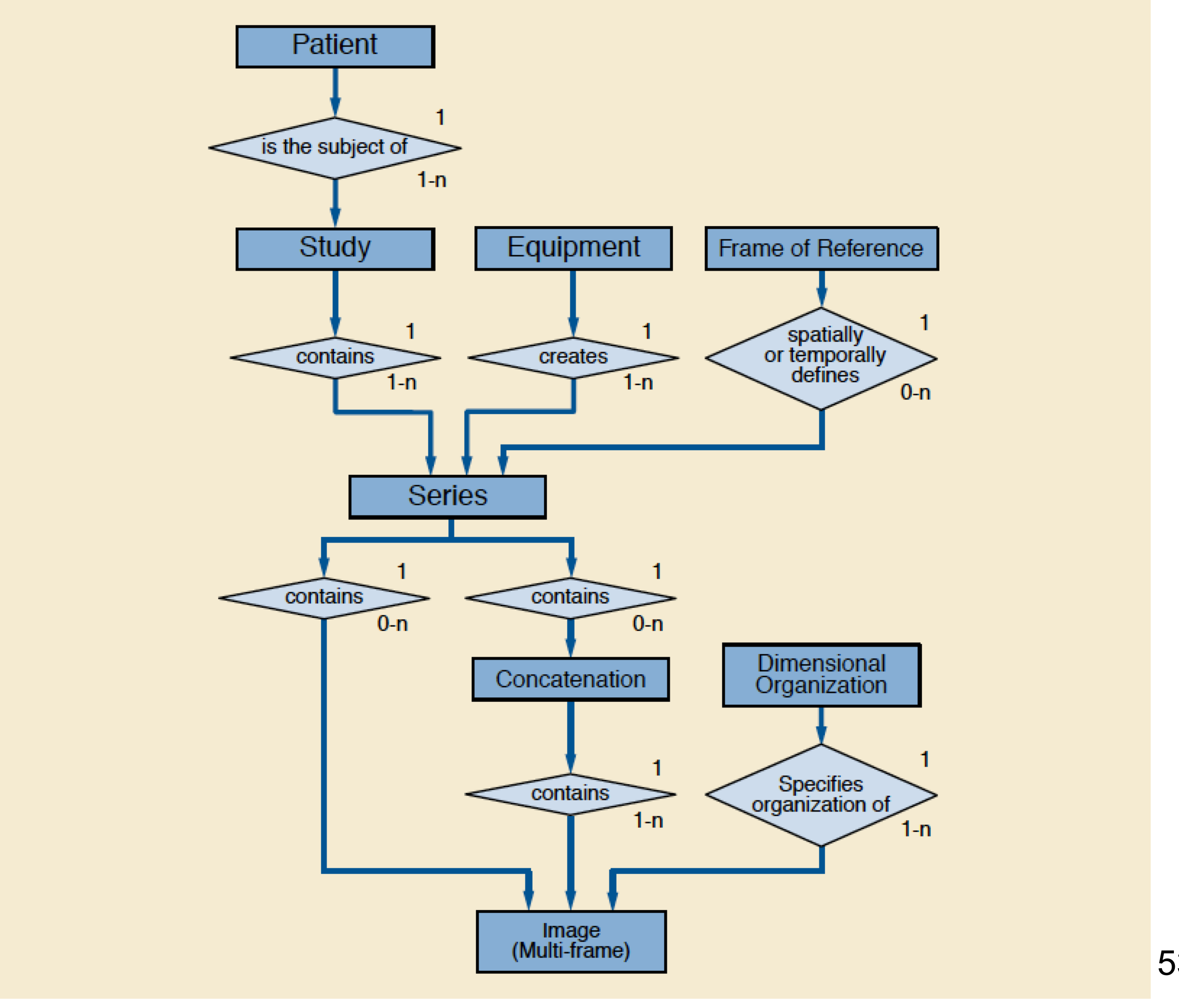
	MR	
SOP Class	**Original**	**Enhanced**
Attributes (Mandatory)	44 (2)	103 (94)
Terms (Enumerated)	38 (9)	228 (47)

MR Acquisition Contrast

- Original DICOM SOP Class
  - guess from echo and repetition time, etc.
  - depend on Series Description, Protocol Name
- Enhanced DICOM SOP Class
  - new mandatory frame level attribute: Acquisition Contrast
    - DIFFUSION, FLOW_ENCODED, FLUID_ATTENUATED, PERFUSION, PROTON_DENSITY, STIR, TAGGING, T1, T2, T2_STAR, TOF, UNKNOWN
- “Cleanup” tool could populate these (parse text, convert private)

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
- Garbage in, garbage out (GIGO)
  - if invalid on ingestion, if copied and not correct, will be invalid in output



Patient
is the subject of
1
1-n
Study
Equipment
Frame of Reference
contains
1
1-n
creates
1
1-n
spatially or temporally defines
1
0-n
Series
contains
1
0-n
contains
1
0-n
Concatenation
Dimensional Organization
contains
1
1-n
Specifies organization of
1
1-n
Image (Multi-frame)

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
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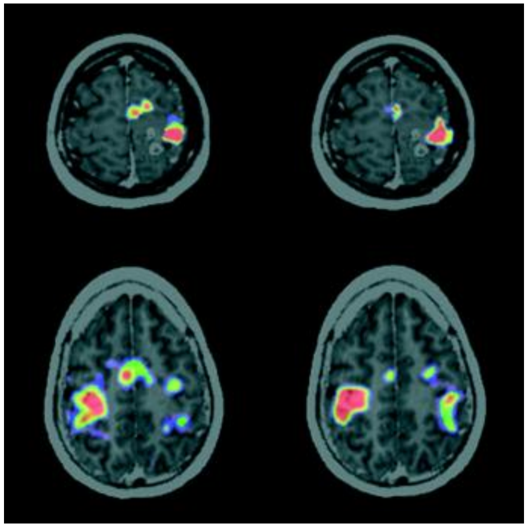
  - if invalid on ingestion, if copied and not correct, will be invalid in output

Composite Context & Research

- Needs to be de-identified
  - use research IDs to replace patient IDs, etc.
  - lots of open source tools and standards for this
- Research tools must *preserve & propagate*
  - into derived objects (images, SEG, REG, SR, etc.)
  - via intermediate objects (e.g., DICOM floating point parametric map, raw data instances)
  - save it somewhere and reuse it when converting to DICOM

Parametric Maps & Label Maps

- Per-voxel encoding of numeric or label values
- "Images", but not just "pretty pictures"
  - modality-specific or secondary capture; single or multi-frame
- Segmentations (alternative to label maps)
  - binary, probability, fractional occupancy
  - multiple segments (multiple labels)
- Parametric maps
  - pixel value "means something" – real world value map (RWVM)
  - integers +/- (linear) rescaling to floats (usable by any viewer)
  - "derived" images of modality-specific SOP Class
  - recently added floating point voxels and SOP Class (Sup 172)
- Leave "fusion" (superimposition) to application
  - e.g., PET SUV on top of CT
  - can use Blending Presentation State to specify what to fuse



Meyer P T et al. J Neurol Neurosurg Psychiatry 2003;74:471-478

Segmentations

- Used to encode tissue segmentation, functional segmentation, and artifact identification for quantification or visualization
- Segmentation of entire volumes, single slices, smaller sub-regions, 2D frames
- Alternative mechanism to encode ROI: voxel based, rather than contours
- Mechanism to encode “atlases”
- Coded description of segment category: anatomical or property based or both
- Encoded as a multi-frame image
- Each frame represents a 2D plane or a slice of a single segmentation category
- More than one segment category per instance
- Binary or fractional (probability or occupancy percentages)
- Spatial sampling, orientation, extent do not need to be same as source images
- Related to patient coordinate system via Frame of Reference

Segmentation Codes

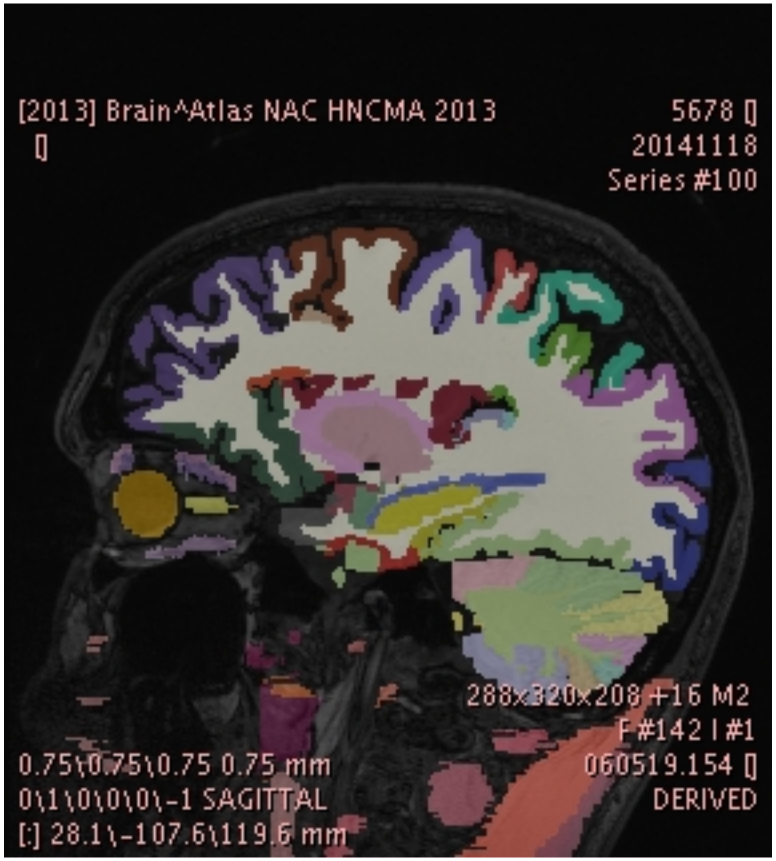
Table CID 7150. Segmentation Property Categories

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-CT Concept ID	UMLS Concept Unique ID
SRT	T-D0050	Tissue	85756007	C0040300
SRT	T-D000A	Anatomical Structure	123037004	C1268086
SRT	A-00004	Physical object	260787004	C0085089
SRT	M-01000	Morphologically Altered Structure	49755003	C0221198
SRT	R-42019	Function	246464006	C0542341
SRT	R-42018	Spatial and Relational Concept	309825002	C0587374
SRT	T-D0080	Body Substance	91720002	C0504082

Table CID 7159. Lesion Segmentation Types

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-CT Concept ID	UMLS Concept Unique ID
SRT	M-41610	Abscess	44132006	C0000833
SRT	M-35000	Blood clot	75753009	C0302148
SRT	M-3340A	Cyst	367643001	C0010709
SRT	M-36300	Edema	79654002	C0013604
SRT	M-35300	Embolus	55584005	C1704212
SRT	M-37000	Hemorrhage	50960005	C0019080
SRT	M-40000	Inflammation	23583003	C0021368
SRT	M-03000	Mass	4147007	C0577559
SRT	M-54000	Necrosis	6574001	C0027540
SRT	M-8FFFF	Neoplasm	108369006	C0027651
SRT	M-03010	Nodule	27925004	C0028259

DICOM Segmentation Example



- *Harvard Brain Atlas*
- *converted NRRD Label Map*
- *numerical voxel indices to DICOM Segmentation*
- *one bitmap per anatomical segment*
- *superimposed on differently sampled source MR image*

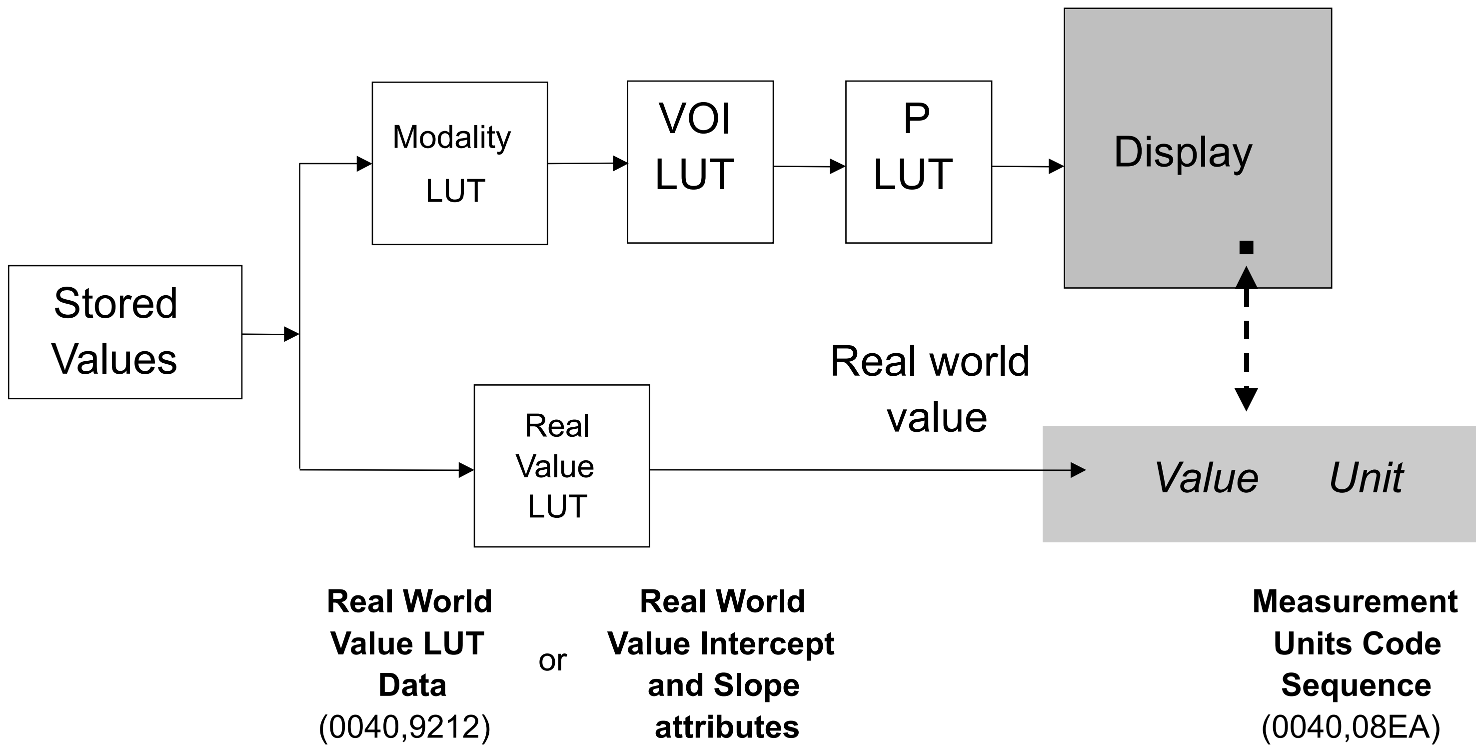
Parametric Maps

- Each pixel value has "meaning" in real world
- “Parametric" alludes to the meaning being the parameter of something
- Parameters of pharmacokinetic models: Ktrans of the Tofts model used in DCE-MRI
- Cerebral blood volume (CBV) or flow (CBF) in perfusion CT
- Normalized values on body size: SUVbw used in PET
- MR Diffusion parameters: Apparent Diffusion Coefficient (ADC)

Parametric Maps

- Can be encoded as:
  - “traditional” IOD-specific images of “derived” type (single/multi-frame)
  - new Parametric Map Storage SOP Class
- Parametric Map Storage SOP Class
  - integer or floating point (32 or 64 bit) pixels
  - single “sample” per frame (i.e., monochrome)
  - pseudo-coloring for rendering defined separately
  - leverages functional groups, dimensions, 3D positioning of enhanced MF
  - for intermediate files (to propagate composite context)
  - Real World Value Map mechanism defines “meaning” of parameter values

Real World Value Mapping



Real World Value Mapping

- Separate pipelines based on pixels
  - what to show on the display
  - what the pixel (voxel) “means”
- e.g., MR pixel values
  - signal intensity windowed for display
  - mapped to physical unit (e.g. phase contrast velocity)
  - code for “quantity” distinct from units (different quantities may have same units)
- Encoding options:
  - within image or separate object (e.g., derived later)
  - linear equation or LUT, applied to all/sub-set of range
  - point operation (applies to all voxels in slice/frame)
  - referenced from SR for ROI measurement

Real World Value Mapping

- Units:
  - Unified Code for Units of Measure (UCUM)
- Quantity defined (in an extensible manner) as:
  - (G-C1C6, SRT, "Quantity”)
  - (121401, DCM, “Derivation”)
  - (G-C036, SRT, “Measurement Method”)

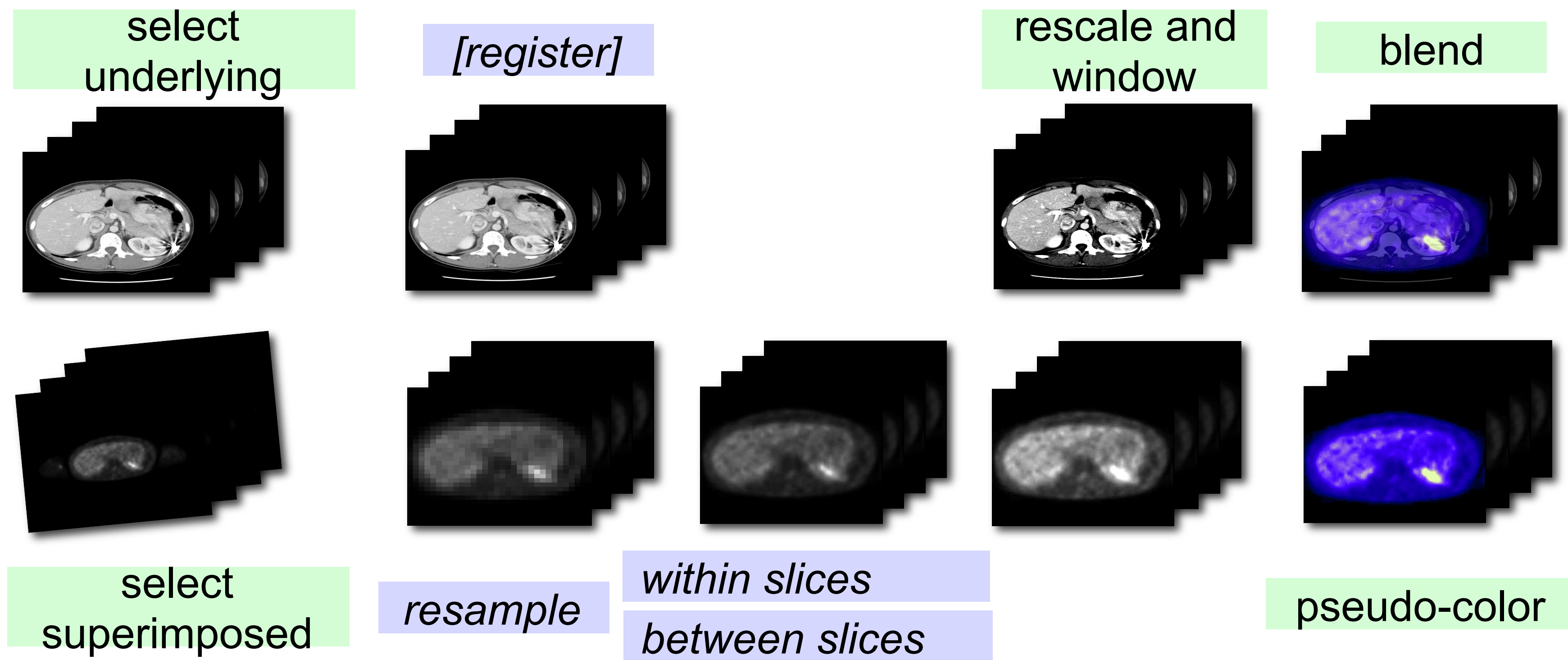
Real World Value Mapping

- E.g., Apparent Diffusion Coefficient (ADC)
  - Measurement Units Code Sequence
    - (mm2/s, UCUM, "mm2/s")
  - Quantity Definition Sequence
    - (G-C1C6, SRT, "Quantity") = (113041, DCM, "Apparent Diffusion Coefficient”)

Real World Value Mapping

- E.g., Apparent Diffusion Coefficient (ADC)
  - Measurement Units Code Sequence
    - (mm2/s, UCUM, "mm2/s")
  - Quantity Definition Sequence
    - (G-C1C6, SRT, "Quantity") = (113041, DCM, "Apparent Diffusion Coefficient")
    - (G-C306, SRT, "Measurement Method") = (113250, DCM, "Mono-exponential ADC model")
    - (113241, DCM, "Model fitting method") = (113260, DCM, "Log of ratio of two samples")
    - (113240, DCM, "Source image diffusion b-value") = 0 (s/mm2, UCUM, "s/mm2")
    - (113240, DCM, "Source image diffusion b-value") = 1000 (s/mm2, UCUM, "s/mm2")
    - (121050, DCM, "Equivalent Meaning of Concept Name") = "ADC mono-exponential log ratio B0 and B1000"

Blending Presentation State

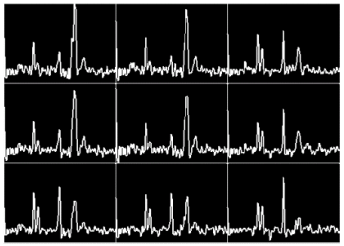


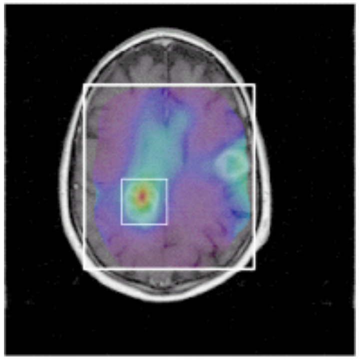
Registration & Fiducials

- Mapping between 3D coordinates
  - DICOM Registration – rigid matrix
  - DICOM Deformable Registration
- Location of specific points
  - DICOM Fiducial
- Used to save manual or automated results
  - save application state for further work later
  - re-use for other purposes (e.g., sync’d scrolling)

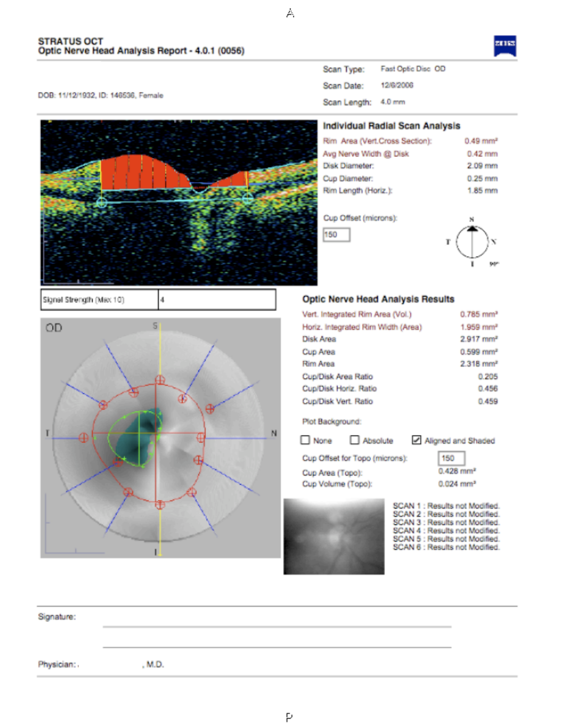
Other Bulk Data Storage

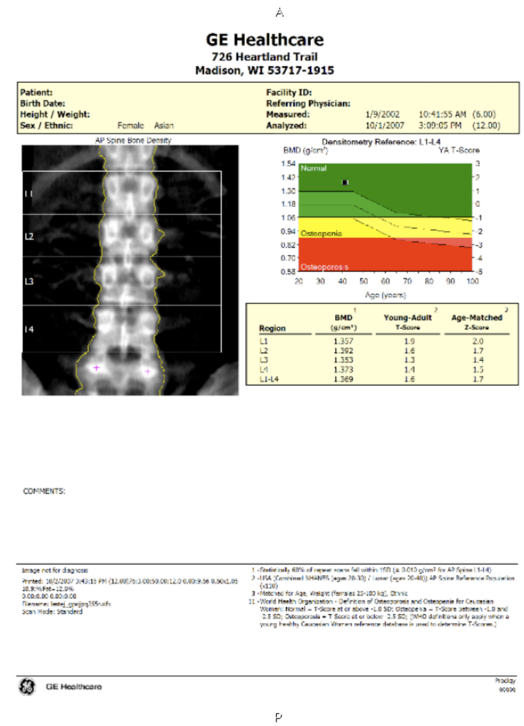
- Time-based Waveforms
  - ECG
  - Hemodynamic
  - Audio
- MR Spectroscopy
  - Single voxel
  - Multi-voxel
  - Multi-frame
  - Metabolite maps (CSI) as images
- Raw Data IOD





Encapsulated PDF Pretty Pictures





Better quality alternative to Secondary Capture Images, but semantics are lost

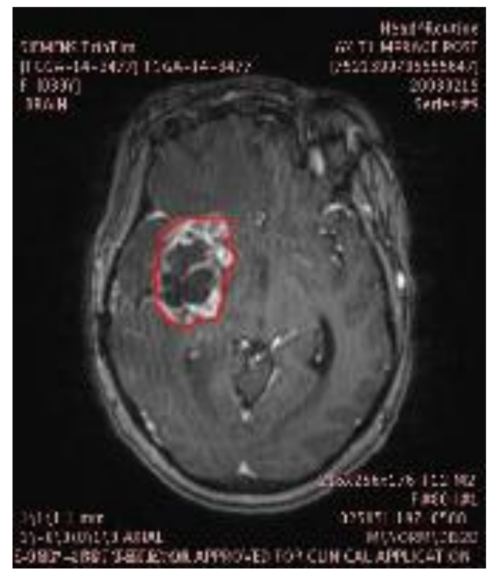
Measurements Results

- Regions of Interest (ROI)
  - contours and other image-related references
  - measurements, categorical assessments
- Per-voxel values
  - parametric maps (e.g., SUV, ktrans)
  - label maps and segmentations
- Intermediate re-usable work products
  - spatial registration (rigid & deformable)
  - fiducials
  - real-world values (quantities & physical units)

DICOM encoding of ROIs

- Private elements
  - evil & must be stopped
- Curves in image
  - weak semantics, old, retired
- Overlays in image
  - weak semantics
- Presentation States
  - weak semantics, PACS favorite
- Structured Reports
  - best choice, but more work
- RT Structure Sets
  - coordinates only
- Segmentations
  - per-voxel ROIs; use with SR

Date	Volume	Auto LD	Auto SD
20021207	27080	49	27
…	…	…	…



DICOM encoding of ROIs

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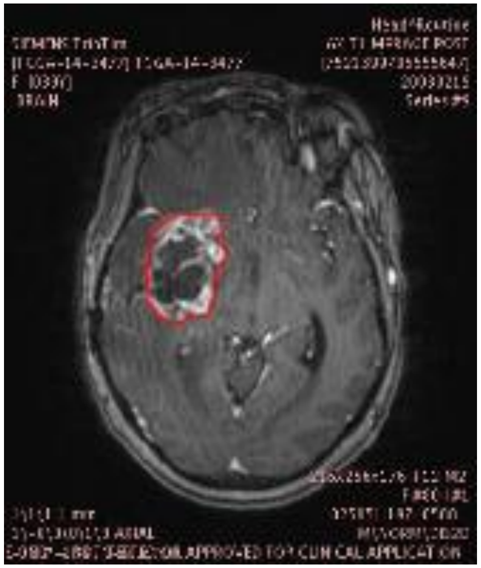
Date	Volume	Auto LD	Auto SD
20021207	27080	49	27
…	…	…	…



DICOM Structured Reports

- Hierarchical structure
  - codes, numbers, coordinates, image references, etc.
- Flexibility is constrained by templates
  - just as XML is constrained by DTD or Schema
- Standard DICOM binary representation
  - easily stored in PACS though general purpose visualization remains challenging
  - easily transcoded to XML or JSON for processing
- Widely used in existing quantitative modalities
  - echo-cardiography, obstetric ultrasound, radiation dose reporting
  - received and understood by voice reporting systems
- Easier to implement if good toolkit support
  - e.g., dcmtk provides abstractions in an SR API, XML conversion

TID 1500 Measurement Report

- Document title
- Image library
  - relevant characteristics of images used, e.g., radiopharmaceutical
- List of ROIs with measurements
  - planar, volumetric, other types
- List of qualitative (categorical) evaluations
  - i.e., coded questions, code or text values

ROI Measurement Groups

- Session (e.g., for multiple reads by same reader)
- Tracking identifier (e.g., "lesion 1") + UID
- Finding type (e.g., lesion, tumor, reference region)
- Time point (e.g., for longitudinal comparison baseline, prior, current)
- Measurement method (e.g. ”SUVbw") (common to all measurements)
- Target site (anatomic location) (common to all measurements)
- Coordinates, segmentation references, image references defining ROI
- List of measurements derived from the ROI
- List of qualitative evaluations

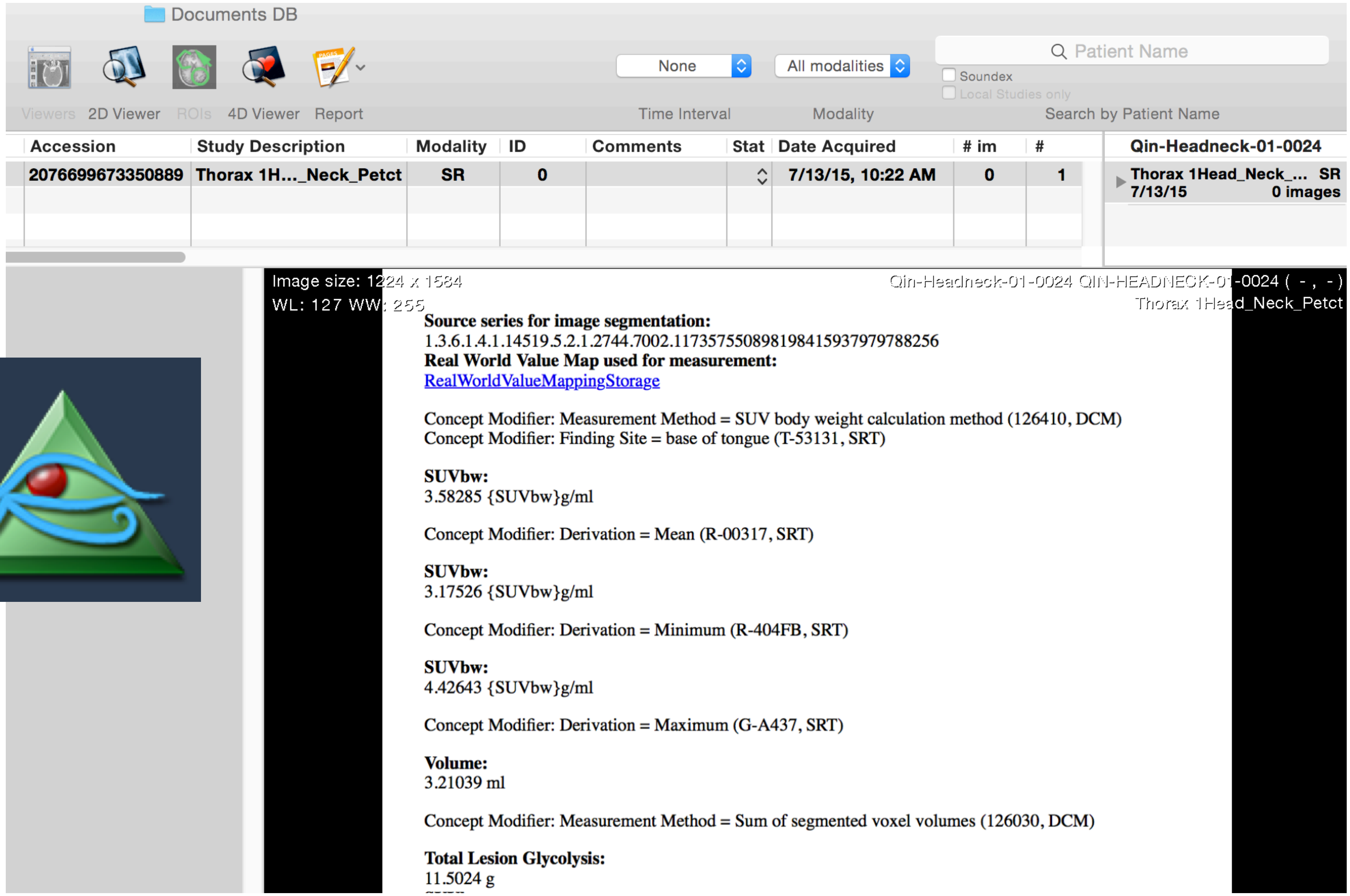
Each ROI Measurement

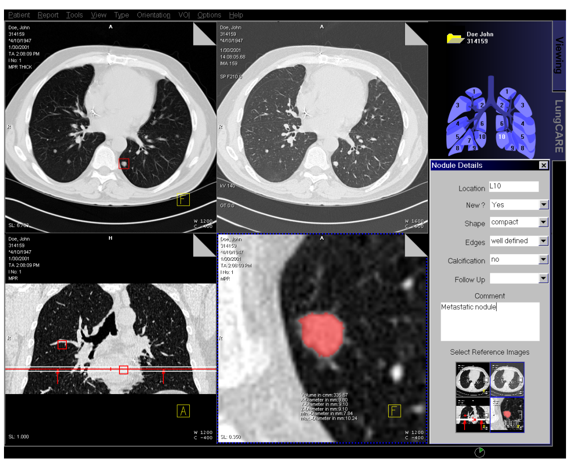
- Coded concept, numeric value, coded units (e.g., Volume = 33 mm3)
- Modifiers for concept name of measurement
- Measurement method (e.g. “SUVbw”)
- Measurement derivation (e.g., “mean”)
- Target site (anatomic location)
- Equation
- Reference authority
- Range authority
- Derivation parameter

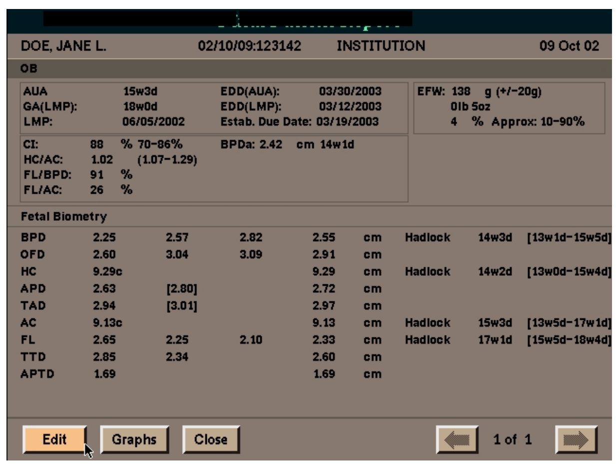
Table TID 1411. Volumetric ROI Measurements

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
1			CONTAINER	EV (125007, DCM, "Measurement Group")	1	M		
1b	>	HAS OBS CONTEXT	TEXT	EV (C67447, NCIt, "Activity Session")	1	U		
2	>	HAS OBS CONTEXT	TEXT	DT (112039, DCM, "Tracking Identifier")	1	M		
3	>	HAS OBS CONTEXT	UIDREF	EV (112040, DCM, "Tracking Unique Identifier")	1	M		
3b	>	CONTAINS	CODE	EV (121071, DCM, "Finding")	1	U		$FindingType
4	>	CONTAINS	INCLUDE	DTID 1502 "Time Point Context"	1	U		
5	>	CONTAINS	SCOORD	EV (111030, DCM, "Image Region")	1-n	MC	XOR Rows 7, 10	GRAPHIC TYPE = not {MULTIPOINT}
6	>>	SELECTED FROM	IMAGE		1	M		
7	>	CONTAINS	IMAGE	EV (121191, DCM, "Referenced Segment")	1	MC	XOR Rows 5, 10	Reference shall be to a Segmentation Image or Surface Segmentation object, with a single value specified in Referenced Segment Number
8	>	CONTAINS	IMAGE	EV (121233, DCM, "Source image for segmentation")	1-n	MC	XOR Row 9 and IFF Row 7	

- CONTAINS: CONTAINER: Imaging Measurements [SEPARATE]
  - CONTAINS: CONTAINER: Measurement Group [SEPARATE] (DCMR,1411)
    - HAS OBS CONTEXT: TEXT: Activity Session = 2
    - HAS OBS CONTEXT: TEXT: Tracking Identifier = primary tumor
    - HAS OBS CONTEXT: UIDREF: Tracking Unique Identifier = 2.25.321931685067302978142568823813987841964
    - CONTAINS: CODE: Finding = Neoplasm, Primary
    - HAS OBS CONTEXT: TEXT: Time Point = 1
    - CONTAINS: IMAGE: Referenced Segment = 1.2.840.10008.5.1.4.1.1.66.4 : 1.2.276.0.7230010.3.1.4.8323329.22968.1436800951.875753[Segment 1]
    - CONTAINS: UIDREF: Source series for image segmentation = 1.3.6.1.4.1.14519.5.2.1.2744.7002.117357550898198415937979788256
    - CONTAINS: COMPOSITE: Real World Value Map used for measurement = 1.2.840.10008.5.1.4.1.1.67 : 1.2.276.0.7230010.3.1.4.8323329.21218.1436800935.45195
    - HAS CONCEPT MOD: CODE: Measurement Method = SUV body weight calculation method
    - HAS CONCEPT MOD: CODE: Finding Site = base of tongue
    - CONTAINS: NUM: SUVbw = 3.58285 Standardized Uptake Value body weight
      - HAS CONCEPT MOD: CODE: Derivation = Mean
    - CONTAINS: NUM: SUVbw = 3.17526 Standardized Uptake Value body weight
      - HAS CONCEPT MOD: CODE: Derivation = Minimum
    - CONTAINS: NUM: SUVbw = 4.42643 Standardized Uptake Value body weight
      - HAS CONCEPT MOD: CODE: Derivation = Maximum
    - CONTAINS: NUM: Volume = 3.21039 Milliliter
      - HAS CONCEPT MOD: CODE: Measurement Method = Sum of segmented voxel volumes
    - CONTAINS: NUM: Total Lesion Glycolysis = 11.5024 Gram
    - CONTAINS: NUM: SUVbw = 0.253951 Standardized Uptake Value body weight
      - HAS CONCEPT MOD: CODE: Derivation = Standard Deviation
    - CONTAINS: NUM: SUVbw = 3.38131 Standardized Uptake Value body weight
      - HAS CONCEPT MOD: CODE: Derivation = 25th Percentile Value
    - CONTAINS: NUM: SUVbw = 3.49684 Standardized Uptake Value body weight
      - HAS CONCEPT MOD: CODE: Derivation = Median
    - CONTAINS: NUM: SUVbw = 3.72015 Standardized Uptake Value body weight
      - HAS CONCEPT MOD: CODE: Derivation = 75th Percentile Value
    - CONTAINS: NUM: SUVbw = 4.21502 Standardized Uptake Value body weight
      - HAS CONCEPT MOD: CODE: Derivation = Upper Adjacent Value
    - CONTAINS: NUM: SUVbw = 3.59184 Standardized Uptake Value body weight
      - HAS CONCEPT MOD: CODE: Derivation = RMS
    - CONTAINS: NUM: Glycolysis Within First Quarter of Intensity Range = 4.98963 Gram
    - CONTAINS: NUM: Glycolysis Within Second Quarter of Intensity Range = 4.30593 Gram


Documents DB
Viewers
2D Viewer
ROIs
4D Viewer
Report
None
All modalities
Patient Name
Soundex
Local Studies only
Time Interval
Modality
Search by Patient Name
Accession
Study Description
Modality
ID
Comments
Stat
Date Acquired
im
#
2076699673350889
Thorax 1H..._Neck_Petct
SR
0
7/13/15, 10:22 AM
0
1
Qin-Headneck-01-0024
Thorax 1Head_Neck_... SR
7/13/15 0 images
Image size: 1224 x 1584
WL: 127 WW: 255
Qin-Headneck-01-0024 QIN-HEADNECK-01-0024 (- , -)
Thorax 1Head_Neck_Petct
Source series for image segmentation:
1.3.6.1.4.1.14519.5.2.1.2744.7002.117357550898198415937979788256
Real World Value Map used for measurement:
RealWorldValueMappingStorage
Concept Modifier: Measurement Method = SUV body weight calculation method (126410, DCM)
Concept Modifier: Finding Site = base of tongue (T-53131, SRT)
SUVbw:
3.58285 {SUVbw}g/ml
Concept Modifier: Derivation = Mean (R-00317, SRT)
SUVbw:
3.17526 {SUVbw}g/ml
Concept Modifier: Derivation = Minimum (R-404FB, SRT)
SUVbw:
4.42643 {SUVbw}g/ml
Concept Modifier: Derivation = Maximum (G-A437, SRT)
Volume:
3.21039 ml
Concept Modifier: Measurement Method = Sum of segmented voxel volumes (126030, DCM)
Total Lesion Glycolysis:
11.5024 g

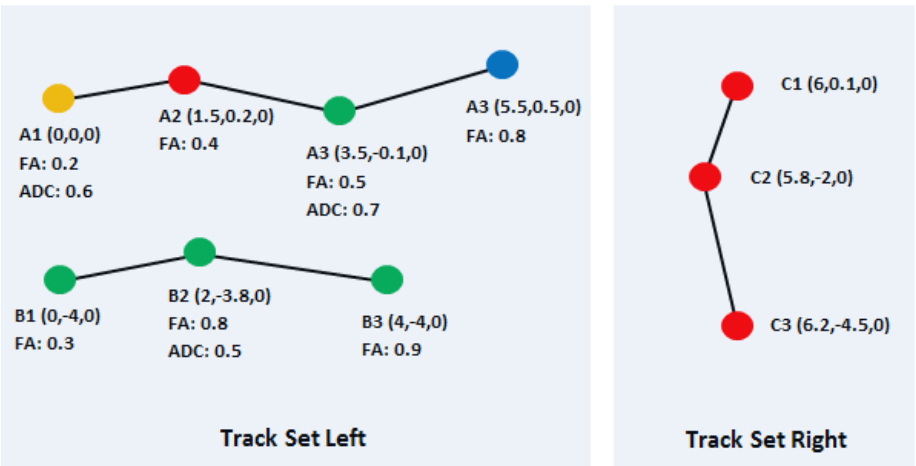

Nodule Details
Location L10
New ? Yes
Shape compact
Edges well defined
Calcification no
Follow Up
Comment
Metastatic nodule
Select Reference Images
LungCARE
Viewing


DOE, JANE L. 02/10/09:123142 INSTITUTION 09 Oct 02
OB
AUA 15w3d EDD(AUA): 03/30/2003
GA(LMP): 18w0d EDD(LMP): 03/12/2003
LMP: 06/05/2002 Estab. Due Date: 03/19/2003
EFW: 138 g (+/-20g)
0lb 5oz
4 % Approx: 10-90%
CI: 88 % 70-86% BPDa: 2.42 cm 14w1d
HC/AC: 1.02 (1.07-1.29)
FL/BPD: 91 %
FL/AC: 26 %
Fetal Biometry
BPD 2.25 2.57 2.82 2.55 cm Hadlock 14w3d [13w1d-15w5d]
OFD 2.60 3.04 3.09 2.91 cm
HC 9.29c 9.29 cm Hadlock 14w2d [13w0d-15w4d]
APD 2.63 [2.80] 2.72 cm
TAD 2.94 [3.01] 2.97 cm
AC 9.13c 9.13 cm Hadlock 15w3d [13w5d-17w1d]
FL 2.65 2.25 2.10 2.33 cm Hadlock 17w1d [15w5d-18w4d]
TTD 2.85 2.34 2.60 cm
APTD 1.69 1.69 cm
Edit
Graphs
Close
1 of 1

Extending DICOM

- Research is all about novel stuff
- May be able to reuse existing object
- nD arrays of non-image data encoded as images
- Add private data elements (attributes) to existing IODs
- Use private codes (e.g., for methods, techniques) in standard attributes
- Create private IODs/SOP Classes specific to the task
- Collaborations between academics and vendors work best
- Work with DICOM to define new standard IODs/SOP Classes
- Base it on DICOM – do NOT make up another encoding mechanism else infrastructure, tools and image base not reusable
- To include in DICOM Standard, must be open – not proprietary, patented

Tractography Results



>>Modifier Code Sequence	(0040,A195)		
Item 1			
>>>Code Sequence Macro Values	...	(G-A101, SRT, "Left")	*CID 244*
>Track Sequence	(0066,0102)		
Item 1 (First Track "A")			
>>Point Coordinates Data	(0066,0016)	0, 0, 0 1.5, 0.2, 0 3.5, -0.1, 0 5.5, 0.5, 0	Coordinates of A1, A2, A3, A4
>>Recommended Display CIELab Value List	(0066,0103)	47270/40385/52501/ 34751/53214/49924/ 57318/11632/54042 22077/53113/5901/	Colors of A1, A2, A3, A4
Item 2 (Second Track "B")			
>>Point Coordinates Data	(0066,0016)	0, -4, 0 2,-3.8, 0 4,-4, 0	Coordinates of B1, B2, B3
>>Recommended Display CIELab Value	(0062,000D)	57318/11632/54042	Color of B1, B2, B3
>Measurements Sequence	(0066,0121)		
Item 1 (Fractional Anisotropy (FA) values stored on each Track)			
>>Concept Name Code Sequence	(0040,A043)		
>>>Code Sequence Macro Values	...	(110808, DCM, "Fractional Anisotropy")	*CID 7263*
>>Measurement Units Code Sequence	(0040,08EA)		
>>>Code Sequence Macro Values	...	(1, UCUM, "no units")	*CID 82*
>>Measurement Values Sequence	(0066,0132)		
Item 1 (FA Values for each point on first Track "A")			
>>>Floating Point Values	(0066,0125)	0.2, 0.4, 0.5, 0.8	FA values of A1, A2, A3, A4
Item 2 (FA Values for each point on second Track "B")			
>>>Floating Point Values	(0066,0125)	0.3, 0.8, 0.9	FA values of B1, B2, B3
Item 2 (Apparent Diffusion Coefficient (ADC) values stored on each Track)			

Anti-Standards - Vendors

- Many systems do not go beyond images
  - mistaken perception that DICOM is only for images
  - hampered by lack of platform toolkit support
  - do not see value in “sharing” (or saving) results
  - users satisfied with secondary capture screen shots
  - believe it is sufficient to save/restore “state” locally
  - or hidden inside private data elements or SOP Class
  - so, “Yet Another Proprietary File Format” (YAPFF)

Anti-Standards - Academics

- Many academics don’t like DICOM
  - DICOM is “old-fashioned” (e.g., not originally XML based)
  - easier to make up your own format than to re-use
  - so, “Yet Another Academic File Format” (YAAFF)
  - legitimate legacy of working code predating DICOM
  - effort to retain required identifiers through pipeline
  - but policy (leadership, funding) is evolving favorably
  - e.g., QIN, QIICR, NWU, ePAD: DICOM segmentation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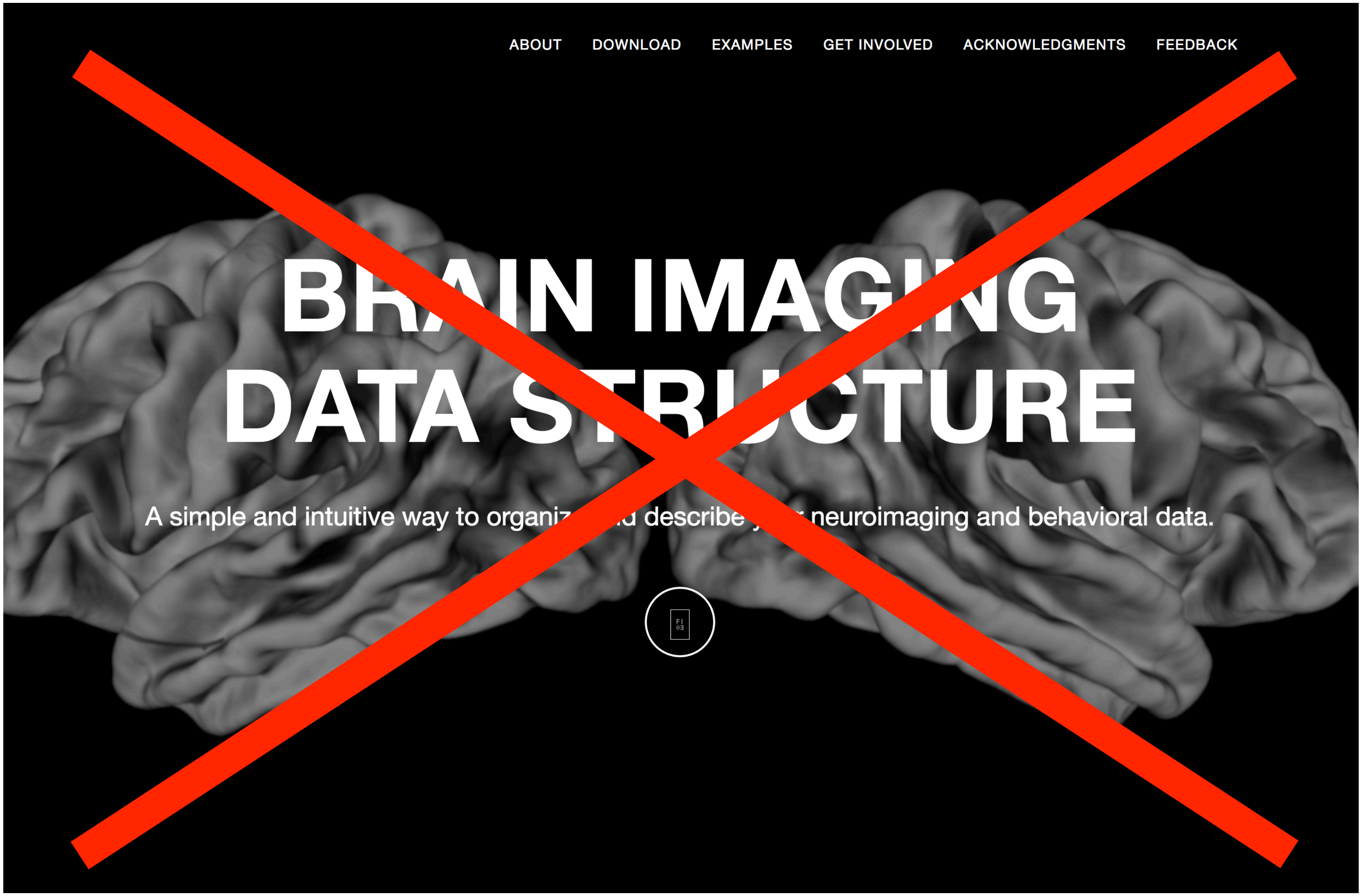
BRAIN IMAGING
DATA STRUCTURE
A simple and intuitive way to organize and describe your neuroimaging and behavioral data.


ABOUT
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DATA STRUCTURE
neuroimaging and behavioral data.

ISMRM Raw Data Format: A Proposed Standard for MRI Raw Datasets

Souheil J. Inati,[1] Joseph D. Naegele,[1] Nicholas R. Zwart,[2] Vinai Roopchansingh,[1] Martin J. Lizak,[3] David C. Hansen,[4] Chia-Ying Liu,[5] David Atkinson,[6] Peter Kellman,[7] Sebastian Kozerke,[8] Hui Xue,[7] Adrienne E. Campbell-Washburn,[7] Thomas S. Sørensen,[9] and Michael S. Hansen[7]*

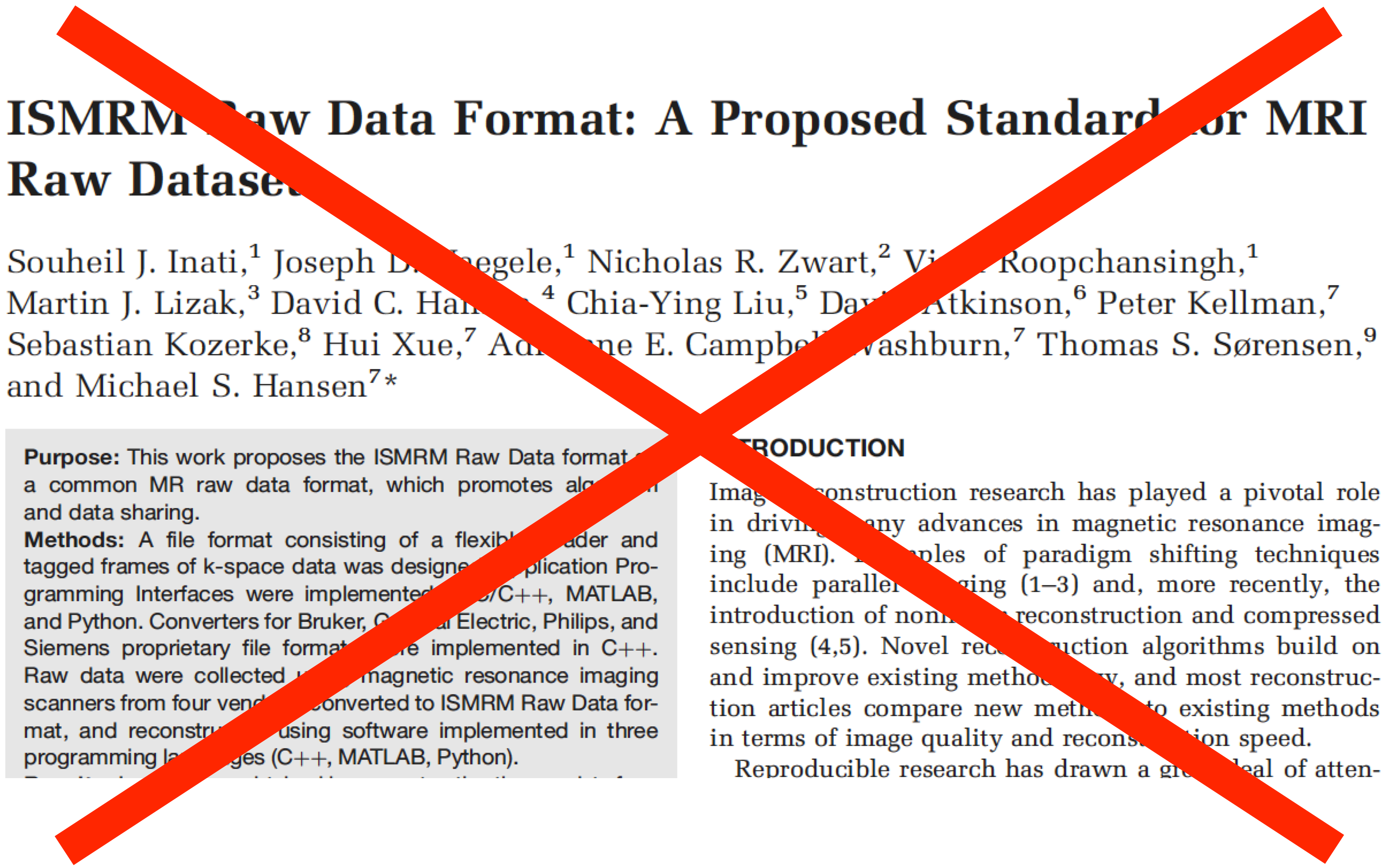
Purpose: This work proposes the ISMRM Raw Data format as a common MR raw data format, which promotes algorithm and data sharing.

Methods: A file format consisting of a flexible header and tagged frames of k-space data was designed. Application Programming Interfaces were implemented in C/C++, MATLAB, and Python. Converters for Bruker, General Electric, Philips, and Siemens proprietary file formats were implemented in C++. Raw data were collected using magnetic resonance imaging scanners from four vendors, converted to ISMRM Raw Data format, and reconstructed using software implemented in three programming languages (C++, MATLAB, Python).

INTRODUCTION

Image reconstruction research has played a pivotal role in driving many advances in magnetic resonance imaging (MRI). Examples of paradigm shifting techniques include parallel imaging (1–3) and, more recently, the introduction of nonlinear reconstruction and compressed sensing (4,5). Novel reconstruction algorithms build on and improve existing methodology, and most reconstruction articles compare new methods to existing methods in terms of image quality and reconstruction speed.

Reproducible research has drawn a great deal of atten-



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...RODUCTION

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The International Journal of Medical Physics Research and Practice

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Technical Note: Development and validation of an open data format for CT projection data

Baiyu Chen, Xinhui Duan, Zhicong Yu, Shuai Leng, Lifeng Yu, and Cynthia McCollough[a)]
Department of Radiology, Mayo Clinic, Rochester, Minnesota 55905

(Received 1 May 2015; revised 14 October 2015; accepted for publication 28 October 2015; published 12 November 2015)

Purpose: Lack of access to projection data from patient CT scans is a major limitation for development and validation of new reconstruction algorithms. To meet this critical need, this work developed and validated a vendor-neutral format for CT projection data, which will further be employed to build a library of patient projection data for public access.
Methods: A digital imaging and communication in medicine (DICOM)-like format was created for CT projection data (CT-PD), named the DICOM-CT-PD format. The format stores attenuation information in the DICOM image data block and stores parameters necessary for reconstruction in the DICOM header under various tags (51 tags to store the geometry and scan parameters and 9 tags to store patient information). To validate the accuracy and completeness of the new format,

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Anti-Standards, Bad Standards

- AIM
- Analyze
- GIPL
- MINC
- NIfTI, BIDS
- NRRD
- VTK

- BMP
- JPEG
- PNG
- TIFF
- NetPBM
- HDF
- NetCDF

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- AIM
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- GIPL
- MINC
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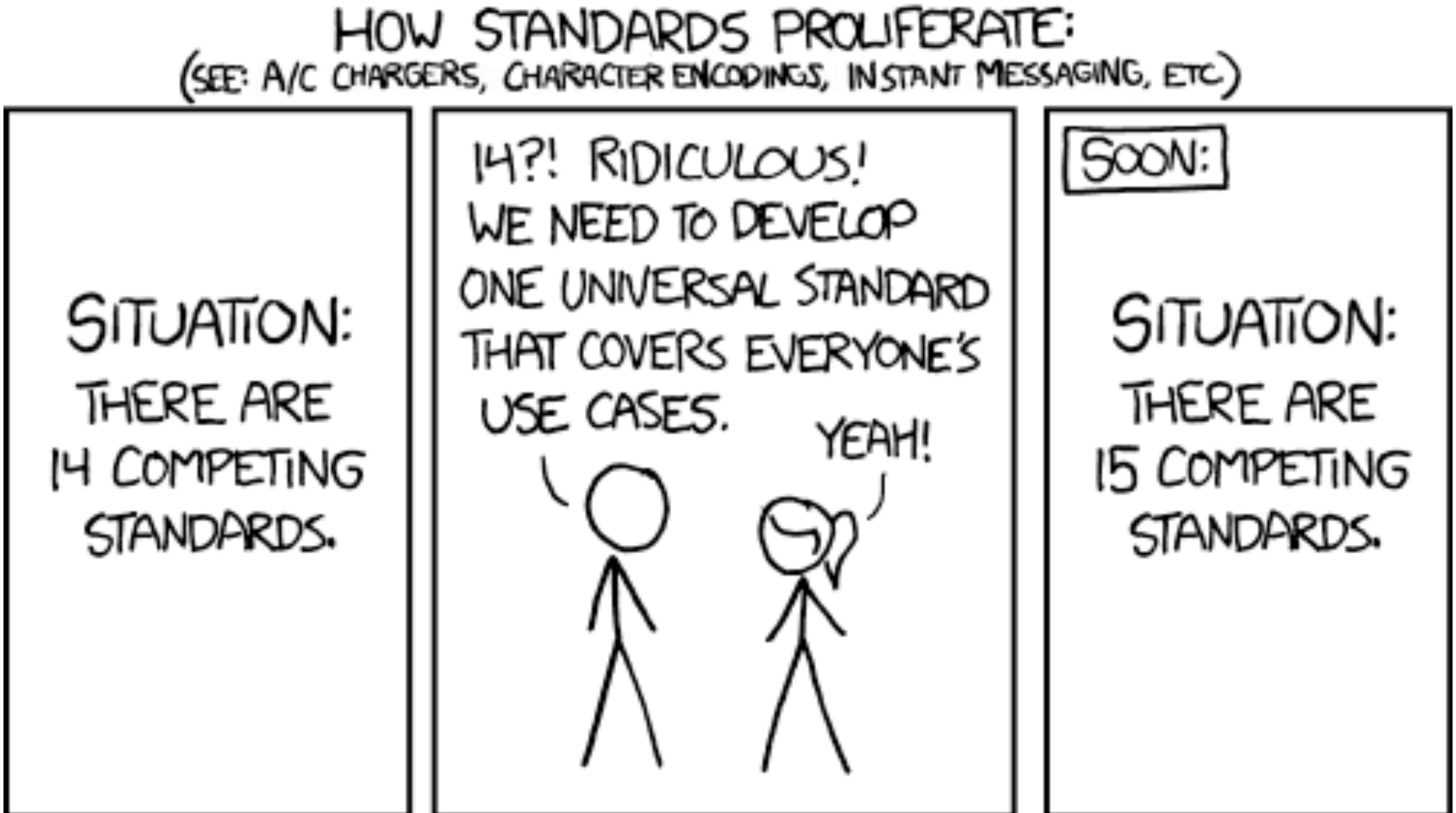
- NRRD
- VTK
- BMP
- JPEG
- PNG
- TIFF
- NetPBM
- HDF
- NetCDF

Translation to Clinical Practice

- "Bench to Bedside"
  - for research applications to reach clinical practice, tools and standards must be interoperable and commercially viable
- No place for YA[PA]FFs & generic (context-less) formats
  - no patient & workflow & analysis metadata
  - no support in PACS
  - little or no support in viewers & workstations
  - poorly documented
  - limited life – end of funding/product/vendor – end of support
  - anyone can use the word "standard" but that doesn't make it one


HOW STANDARDS PROLIFERATE:
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC)
SITUATION:
THERE ARE 14 COMPETING STANDARDS.
14?! RIDICULOUS! WE NEED TO DEVELOP ONE UNIVERSAL STANDARD THAT COVERS EVERYONE'S USE CASES.
YEAH!
SOON:
SITUATION:
THERE ARE 15 COMPETING STANDARDS.