SPIE Medical Imaging 2009

DICOM Research Applications - life at the fringe of reality

David Clunie

RadPharm, Inc.

RADPHARM
Princeton Radiology Pharmaceutical Research

Overview

- Range of research applications
- Clinical versus research context
- Commonalities and differences
- Types of image support & novel devices support
- DICOM versus proprietary research formats
- Non-image stuff
- Workflow
- De-identification
- Hosted applications
- Web services

Motivation

- Day job
  - large commercial oncology clinical trials
- Involved in
  - NCI caBIG in vivo imaging workspace projects
- Observing other groups struggling to
  - bridge clinical and research worlds
  - handle disparate information sources & sinks
  - leverage COTS and open-source technology

Types of Research

- Acquisition technology
- Image processing and analysis
- Biomarkers
- Drugs & in vivo devices
- Animal trials
- Clinical trials

Areas of Application

- Research
- Development

- Validation
- Verification
- Evaluation

Clinical versus Research

- DICOM is everywhere in clinical imaging
  - undeniable, unavoidable
  - medical IS folks get over it
- Not the same acceptance in research
  - whiners say DICOM is
    - too big, complicated, expensive, limited, slow, …
    - not XML
- Missing an opportunity
  - to leverage huge base of codified expertise & tools
- Still unavoidable for a lot of research

Clinical versus Research

- Research and clinical trials are “niche markets”
- Almost completely ignored by major medical device vendors
- Re-using COTS may require creative and novel workarounds
- Specialist 3rd party vendors often not DICOM aware or literate

Commonalities

- Involves use of images
- Acquire images
  - human or animal
  - in vivo or ex
- Process and analyze images
- Store intermediate work
- Store and distribute results
- Search and retrieval
- Repetitive non-trivial workflow

Differences

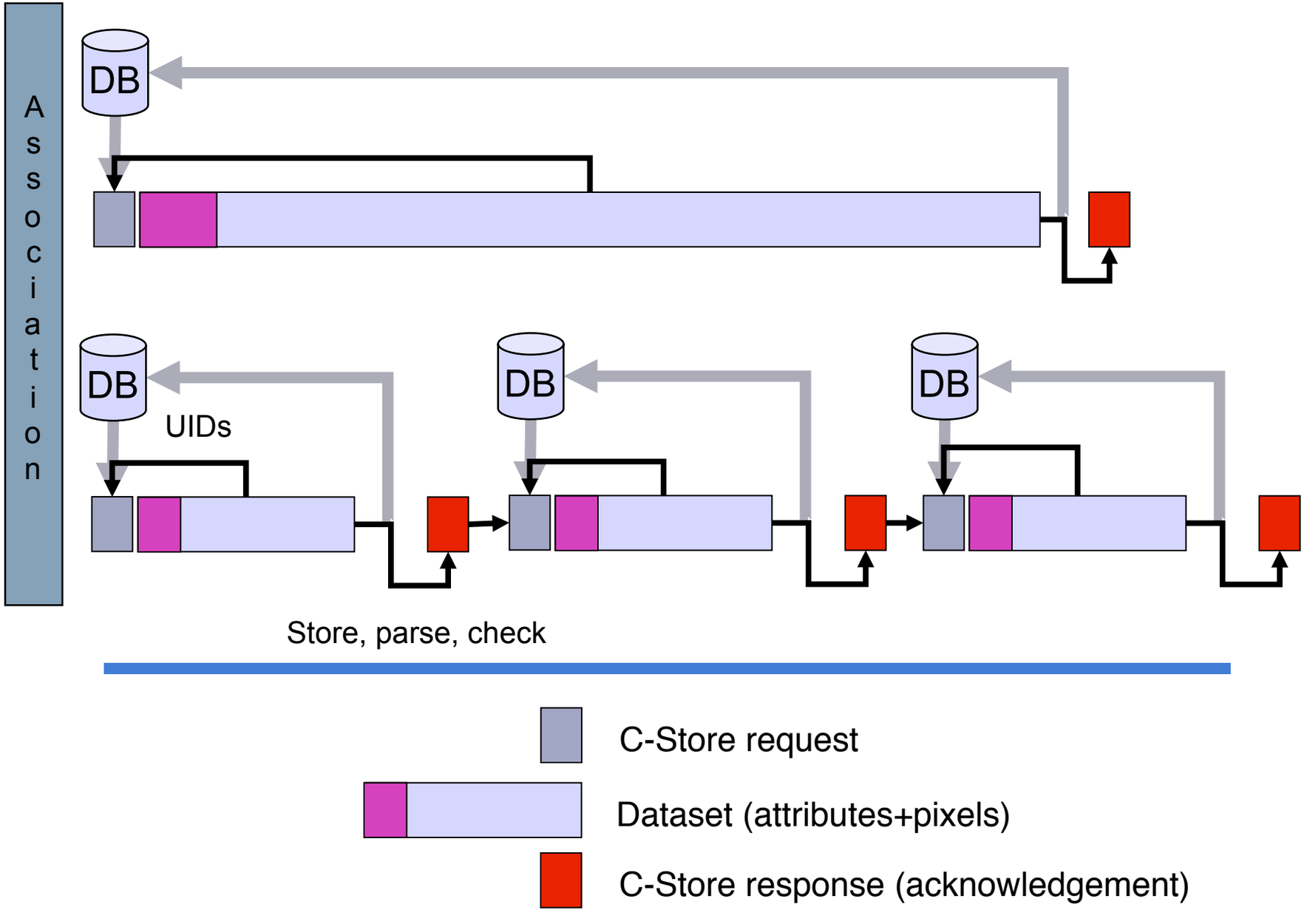
- Specialized acquisition technology
- Multi-subject acquisition (TMA)
- De-identified subjects
- Specialized processing & analysis
- Complex form of intermediate data
- Different search criteria
- Different (if any) regulatory burden
- Different workflow

Acquisition Technology

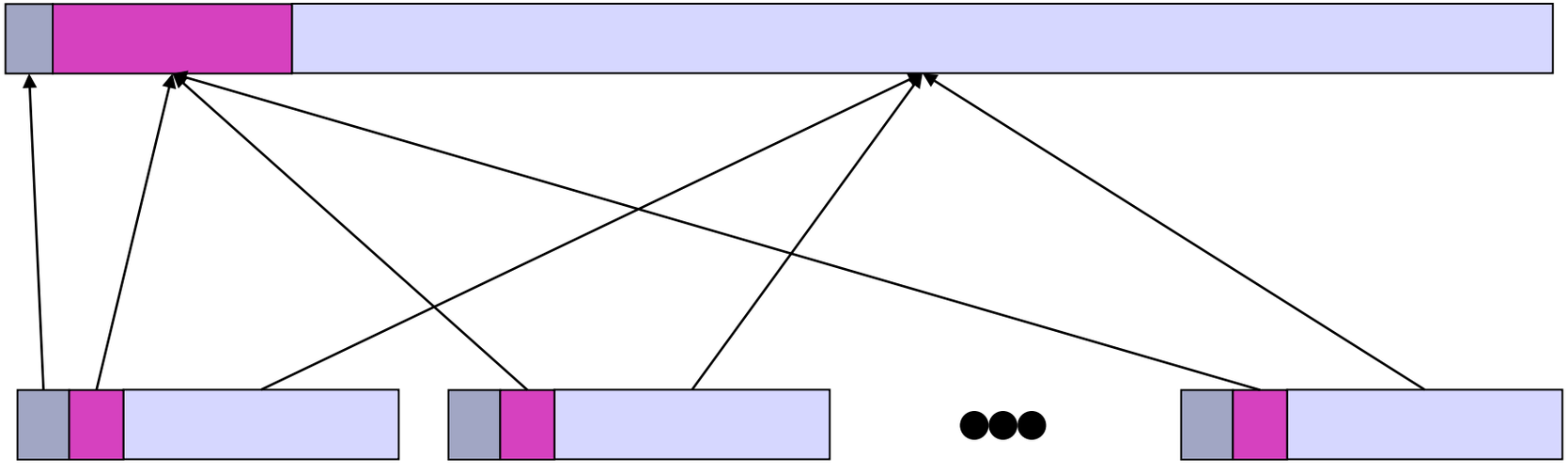
- Does DICOM have adequate coverage ?
  - to encode bulk (pixel) data
  - to manage data (demographics, etc.)
  - to describe acquisition
- Broad range of modalities
  - well beyond traditional radiology
- Improved secondary capture
  - multi-frame, vectors to describe dimensions
- Extensible with private attributes

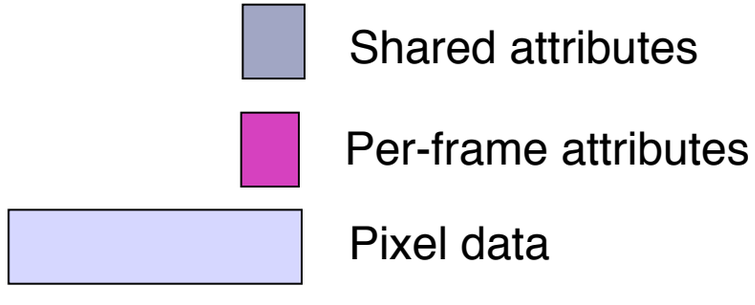
Acquisition Technology

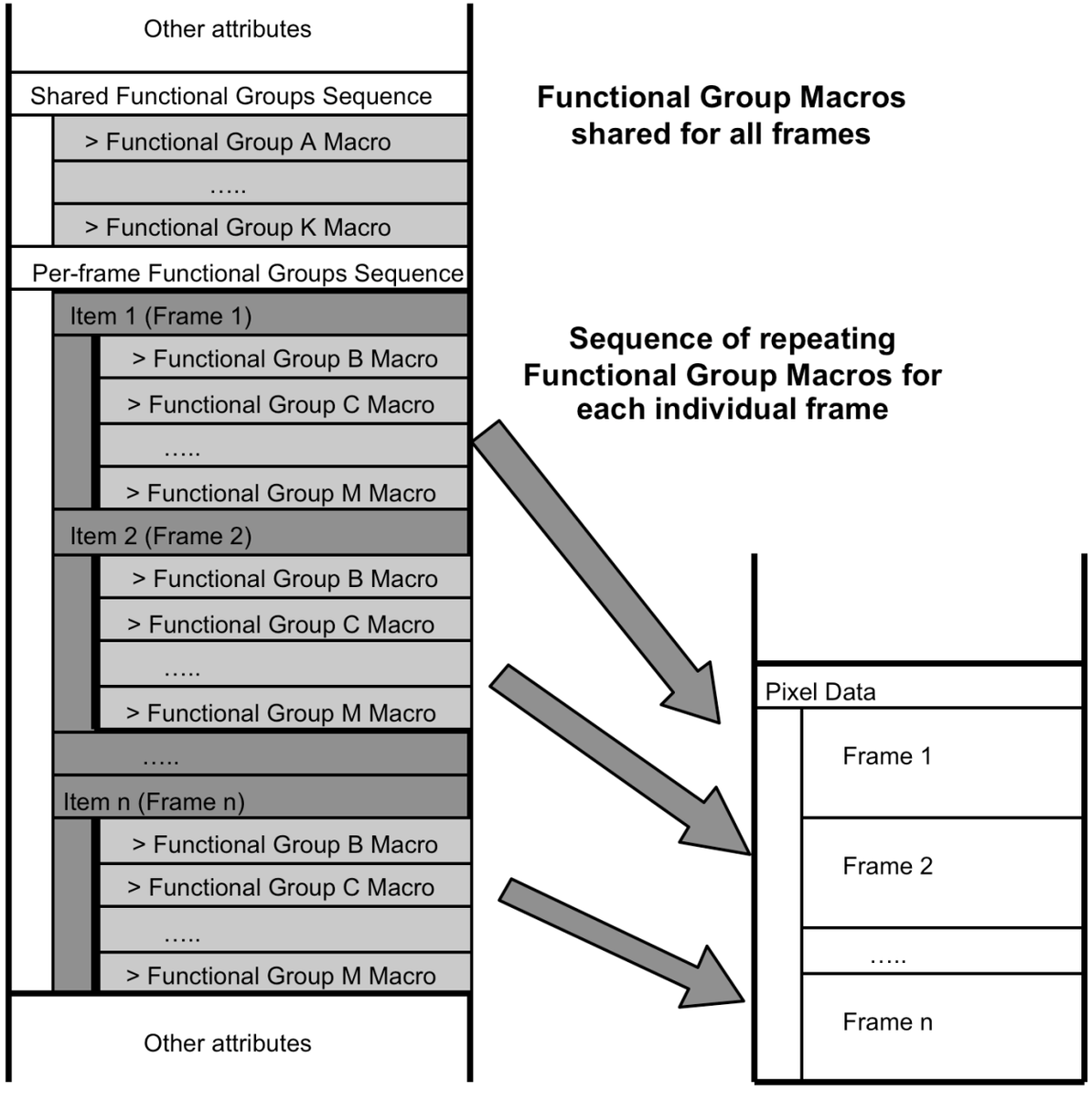
- Almost anything that is (or is like) an image
  - can be encoded in DICOM
  - should be encoded in DICOM
  - will be encoded in DICOM if from COTS device
- Use newer objects when possible
  - enhanced multi-frame family
  - more efficient access in single object
  - more robust descriptions (technique, timing)
  - extensible private functional groups

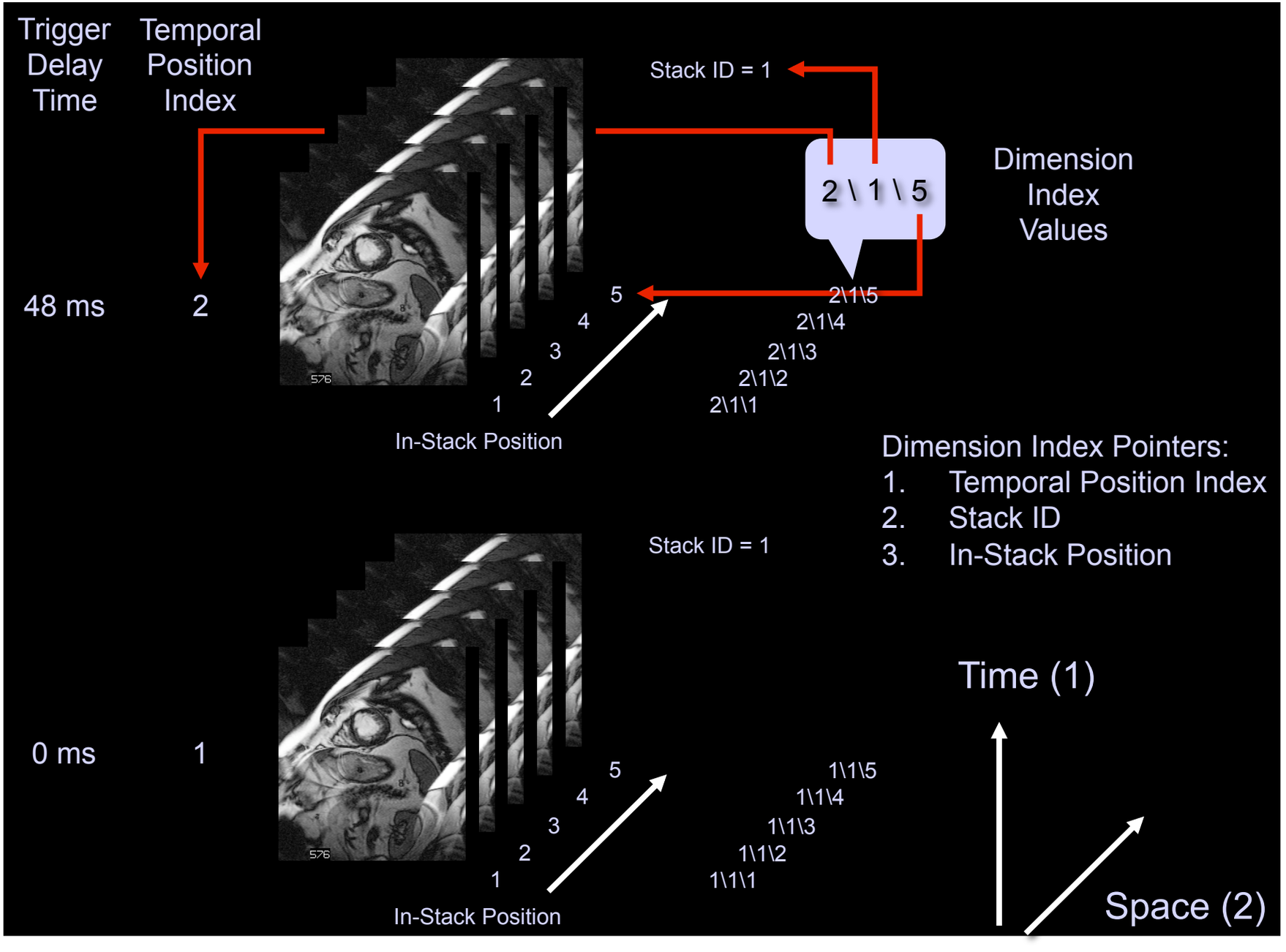

Association
DB
DB
UIDs
DB
DB
Store, parse, check
C-Store request
Dataset (attributes+pixels)
C-Store response (acknowledgement)

Multi-frame Functional Groups






Other attributes
Shared Functional Groups Sequence
> Functional Group A Macro
.....
> Functional Group K Macro
Per-frame Functional Groups Sequence
Item 1 (Frame 1)
> Functional Group B Macro
> Functional Group C Macro
.....
> Functional Group M Macro
Item 2 (Frame 2)
> Functional Group B Macro
> Functional Group C Macro
.....
> Functional Group M Macro
.....
Item n (Frame n)
> Functional Group B Macro
> Functional Group C Macro
.....
> Functional Group M Macro
Other attributes
Functional Group Macros shared for all frames
Sequence of repeating Functional Group Macros for each individual frame
Pixel Data
Frame 1
Frame 2
.....
Frame n


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

DICOM Enhanced Objects for Research Acquisitions

- Easier to keep data for a single "experiment" organized
- Slices all together in one object
- Can explicitly describe dimensions
  - generic: space, time, cardiac cycle position
  - specific: standard or private
- Supported by secondary capture
  - e.g., for novel modalities
  - as of CP 600

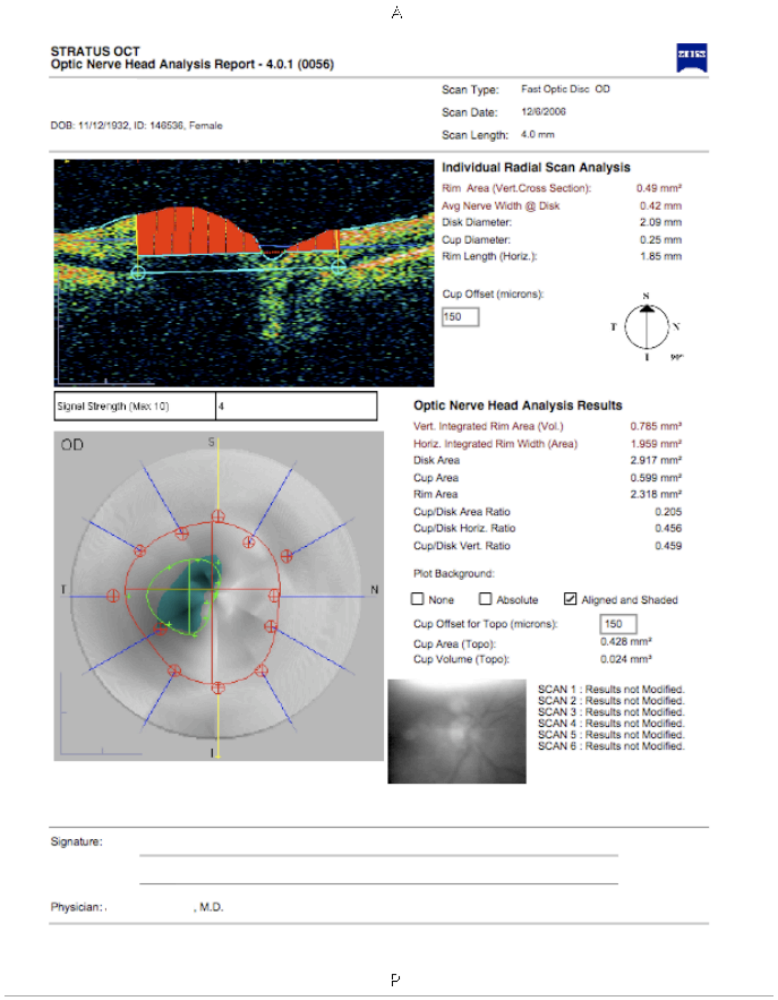
DICOM Enhanced Objects for Intermediate Work Storage

- To join processing pipeline components
- Same arguments apply as for acquisition
  - private frame descriptions and dimensions
  - e.g., real and imaginary frames
- Major gap is the absence of floating point pixel data representations
  - OF value representation (IEEE 32 bit float)
  - not defined for Pixel Data (7FE0,0010)
  - not supported by toolkits for Pixel Data

DICOM Output

- Emphasis on “Translational Research”
  - “bench to bedside”
- More modest goal for images
  - clinical distribution of research tool output
- Clinical systems (PACS)
  - all accept DICOM input
  - most will not accept non-DICOM input
  - almost none aware of research formats
  - DICOM encapsulated PDF is an option

Encapsulated PDF



A

STRATUS OCT
Optic Nerve Head Analysis Report - 4.0.1 (0056)

DOB: 11/12/1932, ID: 146536, Female

Scan Type: Fast Optic Disc OD
Scan Date: 12/6/2006
Scan Length: 4.0 mm

Individual Radial Scan Analysis

Rim Area (Vert.Cross Section):	0.49 mm²
Avg Nerve Width @ Disk	0.42 mm
Disk Diameter:	2.09 mm
Cup Diameter:	0.25 mm
Rim Length (Horiz.):	1.85 mm

Cup Offset (microns): 150

Signal Strength (Max 10)	4

Optic Nerve Head Analysis Results

Vert. Integrated Rim Area (Vol.)	0.785 mm³
Horiz. Integrated Rim Width (Area)	1.959 mm²
Disk Area	2.917 mm²
Cup Area	0.599 mm²
Rim Area	2.318 mm²
Cup/Disk Area Ratio	0.205
Cup/Disk Horiz. Ratio	0.456
Cup/Disk Vert. Ratio	0.459

Plot Background:

☐ None ☐ Absolute ☑ Aligned and Shaded

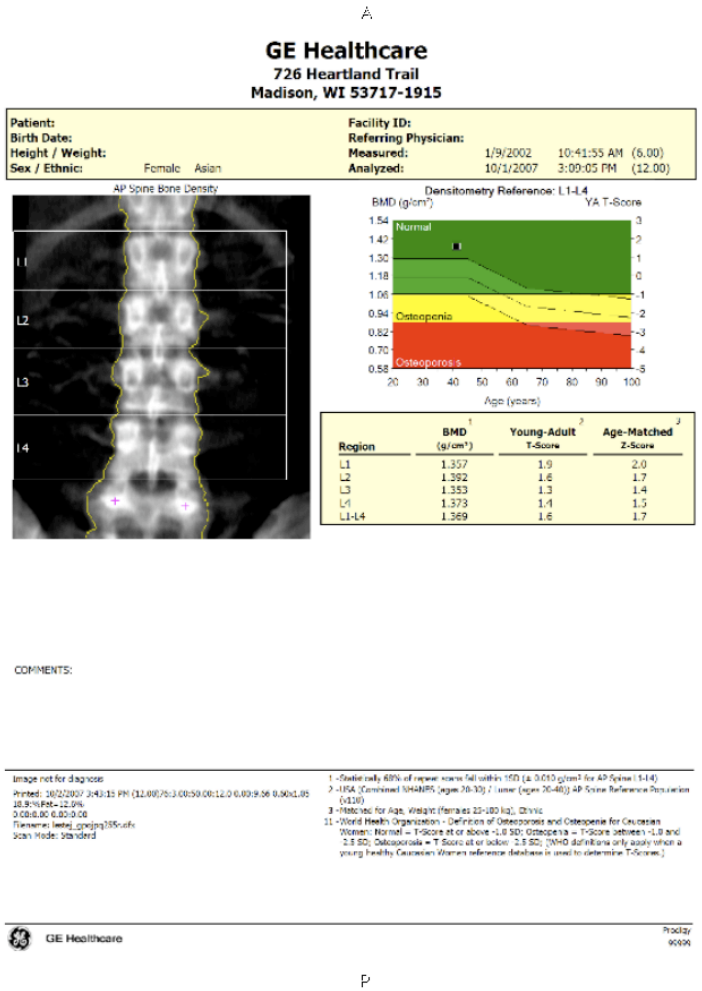
Cup Offset for Topo (microns): 150
Cup Area (Topo): 0.428 mm²
Cup Volume (Topo): 0.024 mm³

SCAN 1 : Results not Modified.
SCAN 2 : Results not Modified.
SCAN 3 : Results not Modified.
SCAN 4 : Results not Modified.
SCAN 5 : Results not Modified.
SCAN 6 : Results not Modified.

Signature:

Physician: , M.D.

P



A

GE Healthcare
726 Heartland Trail
Madison, WI 53717-1915

Patient:
Birth Date:
Height / Weight:
Sex / Ethnic: Female Asian
Facility ID:
Referring Physician:
Measured: 1/9/2002 10:41:55 AM (6.00)
Analyzed: 10/1/2007 3:09:05 PM (12.00)

AP Spine Bone Density

Densitometry Reference: L1-L4

Region	BMD [1] (g/cm²)	Young-Adult [2] T-Score	Age-Matched [3] Z-Score
L1	1.357	1.9	2.0
L2	1.392	1.6	1.7
L3	1.353	1.3	1.4
L4	1.373	1.4	1.5
L1-L4	1.369	1.6	1.7

COMMENTS:

GE Healthcare

P

Research Only Formats

- Medical equipment proprietary formats
  - largely gone – “DICOM inside”
- Research software proprietary formats
  - groups have pre-DICOM development history
  - lacking toolkits and expertise in early days
  - single file for entire 3D/4D volume convenient
  - every group develops better “framework”
  - floating point sometimes required
  - some use other standards (HDF, NetCDF)

Problems with Research Only Formats

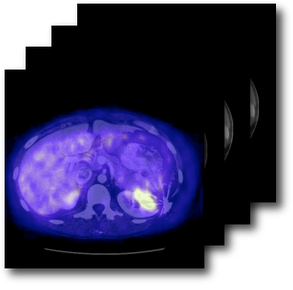
- Convert DICOM input from modalities
  - discard management & technique data
- Often no management metadata
  - organized in files & folders not database
  - build custom format-aware database
- Convert output to DICOM for PACS
  - inadequate meta-data to do it right
- Problems are surmountable
  - generic format agnostic data warehouse
  - just use DICOM in the first place ?

Non-Image DICOM Objects for Research

- Segmentation
  - raster – binary, fractional (occupancy, probability)
  - surfaces – mesh
- Registration
  - rigid – affine transform
  - non-rigid – deformation field
- Sorting and grouping
  - key object selection (KOS) document

Result Reporting
DICOM Objects for Research

- Numeric and structured results
  - structured report (SR)
- Image appearance
  - Grayscale and color presentation states

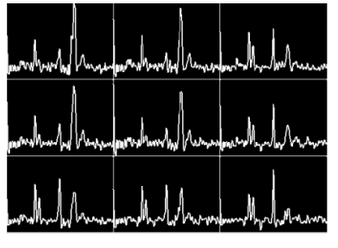


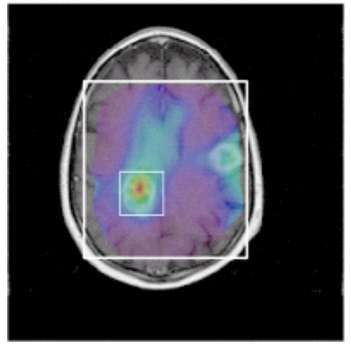
- Multi-modality image fusion
  - Blending presentation state

- Display Organization
  - Structured Display – specific images
  - Hanging Protocols – rules for classes of images

Other Bulk Data
DICOM Objects for Research

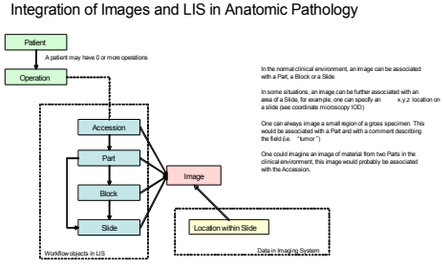
- Time-based Waveforms
  - ECG
  - Hemodynamic
  - Audio
- MR Spectroscopy
  - Single voxel
  - Multi-voxel
  - Multi-frame
  - Metabolite maps (CSI) as images





Storage Issues to Address or Work In Progress

- Floating point pixels
  - needed for research but no current work item
  - modality vendors convinced they don't need it
- More complex identification
  - specimen identification
  - recently completed
- Really, really big images (> 64k x 64k)
  - whole slide imaging
  - work in progress – pyramidal tiling approach



Research Workflow

- Needs
  - small volume research often unmanaged and ad hoc workflow
  - reliability of repetitive tasks rapidly reduces as scale increases
  - multi-center phase III clinical trials demand rigorous workflow control
- Reliable and consistent
  - identifiers and status
  - sequence of operations

Research Workflow

- Solutions in DICOM
  - Worklists & Performed Procedure Step
  - Modality, General Purpose, Unified
- Solutions in IHE
  - Teaching file and Clinical trial Export (TCE)
  - Import Reconciliation WorkFlow (IRWF)
- Equally applicable to
  - novel device acquisitions
  - transfer from sites to central labs

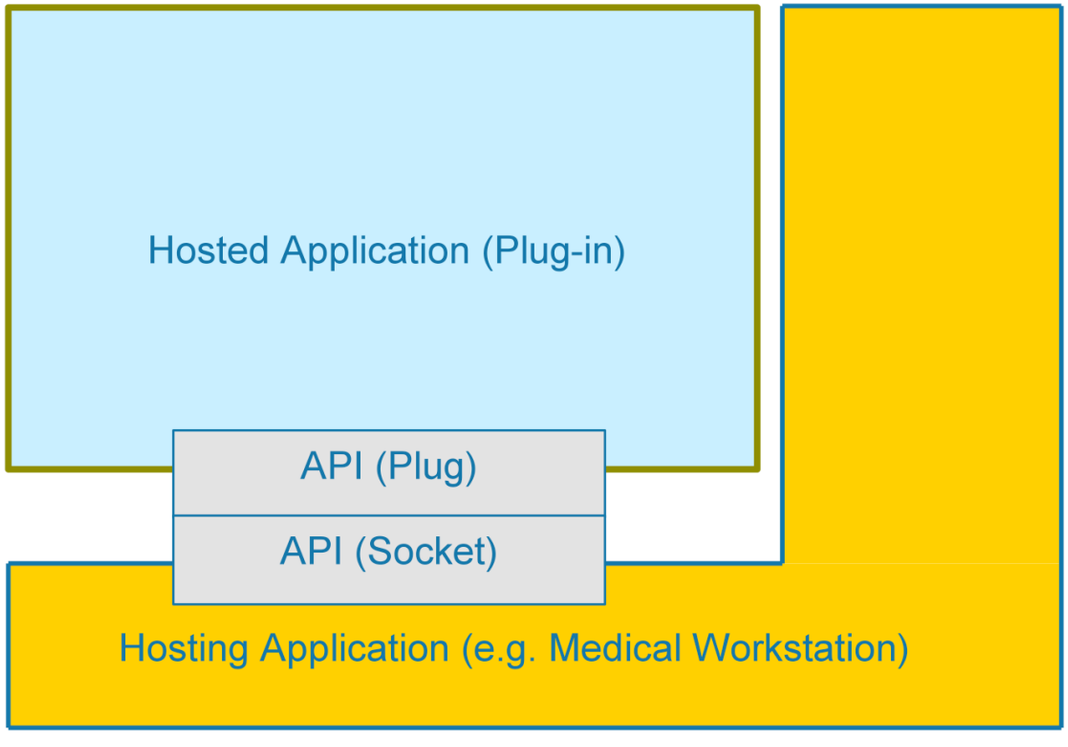
De-identification

- Privacy is important
- Individual researchers are not lawyers
- IRBs are not always consistent
- Use-cases vary
  - need body weight for PET, not for other stuff
  - need dates for longitudinal studies
- Researchers don’t know all DICOM attributes
- DICOM standard on de-identification
  - what to do with which attributes when

Research and Application Hosting

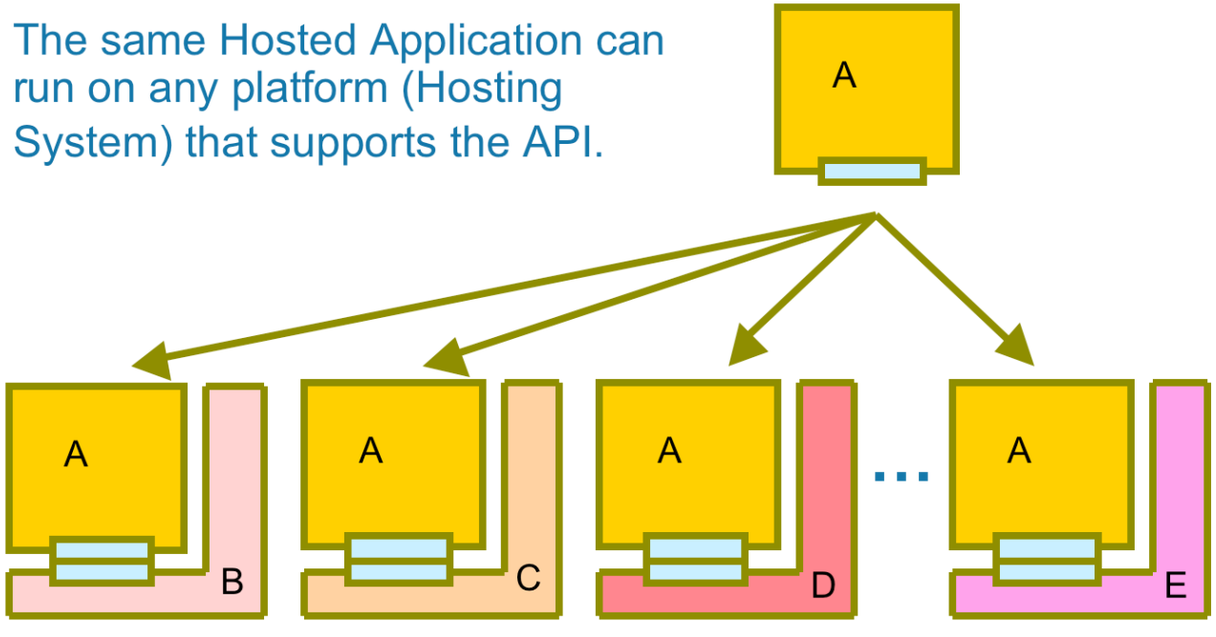
- Goal is reuse of existing infrastructure
  - engineers build the hosts
  - scientists write the application that is hosted
  - more rapid translation for clinical use and sale
- Hosts take care of
  - workflow
  - data selection, retrieval and persistence
- Hosted applications
  - do the processing +/- user interaction

Hosted Applications



Hosted Applications

The same Hosted Application can run on any platform (Hosting System) that supports the API.



Hosted Applications

- Platform neutral hosting
  - Web Services end points on local host
- Bulk (pixel) data transfer
  - via URI's which may be local files
  - memory-mapped files for efficiency
- Meta-data interfaces
  - binary – entire original file
  - native – XPath query of DICOM attributes
  - abstract – N dimensional model

DICOM, Web Services and Research

- DICOM is almost a quarter century old
- Wide area distribution infrastructure services have improved
- “X” buzzword has become “WS-*”
- Genuine reasons to share SOAP-based persistence, transport and security infrastructure
- Adapt to support generic IHE XDS
- SOAP MTOM/XOP transport of ordinary DICOM files
- Complex remote queries over web services
- New working group formed

Conclusion

- DICOM is good for research too
- DICOM is here to help
- DICOM can accommodate specific needs
- DICOM has a clinical trials working group
- DICOM is branching out into uncharted water
- DICOM wants to be buzzword compliant too

… even at the fringe of reality