DICOM Research Applications
- life at the fringe of reality

David Clunie
RadPharm, Inc.
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
Multi-frame Functional Groups

- Shared attributes
- Per-frame attributes
- Pixel data
Functional Group Macros
shared for all frames

Sequence of repeating Functional Group Macros for each individual frame

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

Pixel Data

  Frame 1
  Frame 2
  ......
  Frame n
Temporal Position Index

Trigger Delay Time

48 ms  2

In-Stack Position

Stack ID = 1

Dimension Index Pointers:
1. Temporal Position Index
2. Stack ID
3. In-Stack Position

Time (1)

Space (2)

Dimenion Index Values

2 \ 1 \ 5

0 ms  1

In-Stack Position
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
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 Application (Plug-in)

API (Plug)

API (Socket)

Hosting Application (e.g. Medical Workstation)
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 URIs 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