New Enhanced Multi-frame DICOM CT and MR Objects to Enhance Performance and Image Processing on PACS and Workstations
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Greater Expectations

- Previously, users content with viewing + annotations
- Increasingly advanced applications
  - Hanging protocols, MPR, 3D, virtual colonoscopy
  - Perfusion, diffusion, functional MR, spectroscopy
  - Cardiac cine, CT and MR fluoroscopy
  - Lung CAD
- Such applications are often vendor-specific
  - Performed on console or same vendor’s workstation
  - Depend on private attributes
- Want advanced application interoperability
- Support in multi-vendor PACS workstations
- Distributing “screen saves” on PACS insufficient
Why are new objects needed?

- CT and MR objects more than 10 years old
  - Technology on which they are based probably more than 15 years old
- Pre-date many technological advances
  - Helical CT & fast spin echo pulse sequences
- Explosion in data set size -> performance?
  - Multi-detector CT and functional MR
- Expectations beyond simple viewing
  - Hanging protocols & advanced applications
New Multi-frame CT & MT

- Potential performance gain during transfer & loading
- Easier access to organized multi-slice data
- Preservation of intended semantics of acquisition (e.g. a volume set, a cine run)
- More extensive, up-to-date acquisition parameters
- Additional features for special acquisition and analysis types
  - color values, e.g. for functional data overlaid on structure
  - real world value mapping, e.g. ADC, velocity
- Specialized data interchange, and central archiving
  - Spectroscopy and raw data
Performance Opportunities

- New multi-frame object does not change
  - TCP connection establishment
  - Association establishment
- Common header information is not repeated
  - But reduction is negligible compared to pixel data size
- Reduced latency (delay) between storage requests
- Creates opportunity for inter-slice (3D) compression
- Extremely implementation-dependent
Dataset (attributes+pixels)

C-Store request

C-Store response (acknowledgement)
Association

DB

UIDs

Store, parse, check

C-Store request

Dataset (attributes+pixels)

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DB

C-Store response (acknowledgement)
Dataset (attributes+pixels)
C-Store request

Association

UIDs

Store, parse, check
CTA - 548x512x512 (275MB) File read/transfer/save (GB Ethernet)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tbody>
<tr>
<td>Multi Frame</td>
<td>11.14111111</td>
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<tr>
<td>Single Frame</td>
<td>16.905</td>
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Lossless JPEG 2000 Compression (Alexis Tzannes, Aware, 2003)

<table>
<thead>
<tr>
<th>Slices in 3rd dimension</th>
<th>Compression Ratio</th>
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<tr>
<td>single</td>
<td>2.073490814</td>
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<tr>
<td>all</td>
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</table>

- 127x256x8 7.9MB
- 449x512x16 224MB
- 620x512x16 310MB
Organizational Features

- Multi-frame pixel data
- Comprehensive, mandatory, coded attributes
- Shared and per-frame functional groups
  - Compact & makes explicit what doesn’t change
- Dimensions
  - \textit{a priori} hints as to how the frames are organized
- Stacks
- Temporal positions
- Concatenations
  - Reasonable size chunks, viewing in batches as acquired
Multi-frame Functional Groups

- Shared attributes
- Per-frame attributes
- Pixel data
Concatenations
Robust Application Support

• More technique-specific attributes
  – Majority of them mandatory for original images

• More technique-specific terms
  – Categorizing acquisition types
  – Describing acquisition parameters

• Less dependence on private attributes

• Better organization of data
<table>
<thead>
<tr>
<th></th>
<th>CT</th>
<th>MR</th>
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<tbody>
<tr>
<td>SOP Class</td>
<td>Original</td>
<td>Enhanced</td>
</tr>
<tr>
<td>Attributes (Mandatory)</td>
<td>18 (0)</td>
<td>41 (39)</td>
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<tr>
<td>Terms (Enumerated)</td>
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<td>Original</td>
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<td>Attributes (Mandatory)</td>
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<tr>
<td>Terms (Enumerated)</td>
<td>38 (9)</td>
<td>228 (47)</td>
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</tbody>
</table>
CT Image Type Value 3

• Original SOP Class
  – AXIAL or LOCALIZER

• Enhanced SOP Class
  – Common to CT and MR
    ➢ ANGIO, FLUOROSCOPY, LOCALIZER, MOTION, PERFUSION, PRE_CONTRAST, POST_CONTRAST, REST, STRESS, VOLUME
  – CT-specific
    ➢ ATTENUATION, CARDIAC, CARDIAC_GATED, REFERENCE
Organization of Data

• Shared and Per-frame Functional Groups
  – Each functional group contains attributes that likely vary as a group, e.g. Pixel Measures, Plane Orientation, Velocity Encoding, etc.

• Dimensions
  – Specify intended order of traversal, such as space, then time (e.g., for cardiac cine loops)

• Stacks
  – Groups of spatially-related slices, repeatable

• Temporal Position Index
Dimensions

Start with a dimension of space.

A set of contiguous slices through the heart.
Add dimension of time (delay time from R-wave).

Sets of contiguous slices throughout cardiac cycle.
Temporal Position Index

Trigger Delay Time

48 ms

2

Temporal Position Index

Stack ID = 1

Dimension Index Values

1 \ 5 \ 2

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

In-Stack Position

In-Stack Position

Stack ID = 1

Time (2)

Space (1)
Temporal Position Index

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

Time (2)

Space (1)

48 ms

0 ms

In-Stack Position

In-Stack Position

Stack ID = 1

Stack ID = 1
Dimension Index Pointers:
1. Trigger Delay Time
2. Stack ID
3. In-Stack Position

In-Stack Position

Stack ID = 1

Dimension Index Values

2 \ 1 \ 5

Space (2)

Time (1)
Organization of Data

• Goal is to reduce the work that the receiving application has to do to “figure out”
  – How the data is organized
  – Why it is organized that way
• Without preventing use of the data in unanticipated ways
  – E.g. 3D on a dataset not intended as a volume
• Two levels
  – The detailed shared & per-frame attributes
  – The overall dimensions, stacks and temporal positions
Color Information
Spectroscopy

Storage of Spectroscopy Data

Metabolite Maps
But when?
NEMA Initiatives

• MR test tools, images and spectra available
• CT test tools and images in development

• Implementation testing & demonstration
  – In conjunction with SCAR
  – May 2004 - call for participation
  – Dec 2004 - commitment by vendors
  – Jun 2005 - SCAR demonstration
Not Just MR & CT?

• Need for new multi-frame PET object
  – Currently single slice
  – Much renewed interest in PET-CT fusion
  – To be assessed during SNM June 2004 meeting

• X-ray angiography work in progress
  – Support for digital detectors
  – New acquisition types
  – Tomosynthesis
Summary

• Primary goal of new CT & MR objects is to support inter-operability of advanced applications
  – between multiple vendors
  – between modalities, workstations & PACS
• New objects simplify the task of a receiving application by providing guidance through multi-dimensions
• Adoption requires commitment by modality, workstations and PACS vendors
• DICOM, NEMA & SCAR promoting collaboration