# The New Enhanced Multiframe CT and MR DICOM Objects

*David Clunie, MB, BS*
*CTO, RadPharm*
*Bangor, PA 18013*

*Bradley J Erickson, MD PhD*
*Dept Radiology, Mayo Clinic*
*Rochester, MN 55902*
*(507) 284-8548*

**Outline**

1. Describe the nature of the problems the new CT and MR objects address
2. Describe the new objects, and how they can be used to improve clinical practice
3. Describe efforts at testing the new objects and validating inter-operability

**Introduction**

The DICOM CT and MR image objects are now more than a decade old. While they have served the imaging community well, they are now outdated by comparison with the rapidly advancing capabilities of CT and MR technology. Consequently, much of the important information needed to support advanced applications is not represented in standard attributes in DICOM encoded images, compromising the ability to interoperate between equipment from different vendors. Also, as individual CT and MR studies have become significantly larger, work on improving the performance of transfer mechanisms has been necessary. The DICOM Standards Committee recognized that addressing such issues required more than incremental improvement of the existing objects, and has added a new family of objects to address the new CT and MR requirements.

**Image Features.**

Since the advent of routine spin echo MR imaging of the central nervous and musculoskeletal system to obtain morphological information, there have been many new clinical applications defined. Not only has MR imaging been extended to many other areas of the body and types of pathology, but also more sophisticated pulse sequences that take advantage of specific structural or functional phenomena have been devised. Hence it is now common to see in clinical use such pulse sequences as fat suppression and other forms of chemical shift imaging, fluid suppression, velocity encoding, time of flight imaging for angiography, diffusion and perfusion imaging. Yet more advanced applications, such as diffusion tensor imaging for fiber tract mapping and functional imaging based on changes in susceptibility related to oxygen metabolism, have yet to find common clinical use, but are important research tools. The potential for time-based imaging for routine cardiac imaging is also now approaching.

Such developments post-date the simplistic descriptions of pulse sequences and acquisition strategies that are described in the existing DICOM MR image object. A plethora of additional optional attributes could have been added to the existing object, to attempt to standardize the description of the myriad private attributes that are currently used by vendors to support advanced applications in non-interoperable ways. However, it was realized that additional attributes alone were insufficient to describe how to navigate the relatively more complex dimensions of description that such new applications required. Accordingly, it was agreed to define a new MR object that not only defines new attributes, but also new organizational structures to support applications.

The new organizational structures include explicitly defined dimensions, stacks based on position and indices of temporal position. These are intended to convey from the modality to the application those dimensions are available and important, not only for sorting for display but also for volume rendering and volumetric analysis, as well as for more complex analyses. This approach considerable simplifies the amount of guess work required of a receiving application, which would formerly have had to analyze all of the available descriptive, positioning and temporal attributes to attempt to divine the intentions of the creator of the image set, or indeed even which images constituted a single set.

The requirements for CT are less demanding than MR in a sense, there being a less rich variety of mechanisms of contrast. However, the mechanical characteristics of modern gantries combined with novel reconstruction techniques, as well as the opportunities provided by the sheer speed of acquisition, provide for many new applications. Specifically, CT angiography, perfusion, gated cardiac imaging and fluoroscopy are now possible. The old DICOM CT object contained no attributes or organizational information for such applications. Indeed it was not even possible to define the helical scan pitch or number of detectors in the old object, and this information was relegated to private attributes. This situation is rectified in the new CT object, which makes use of the same infrastructure devised for the enhanced MR applications. Note especially that where there is commonality between CT and MR, exactly the same attributes and mechanisms have been used.

In addition to common descriptive and organizational mechanisms, the CT and MR image objects share new mechanisms to unambiguously define the grayscale pipeline and grayscale output space (which is the DICOM grayscale standard display function), to map pixel values to real world values independently of the grayscale rendering (e.g. to units such as velocity or time), to add limited color functional information over the top of structural information, and to synchronized with respect to time-based waveforms (such as separately encoded ECGs), and cardiac, respiratory and bulk motion.

Also, for both CT and MR, considerably emphasis is placed on the use of coded rather than free text information, particularly in order to facilitate the use of hanging protocols. This extends to the coding of administered contrast information, the presence of which can be defined down to the individual frame level, the intent being to support the automated generation and display of slices acquired during different phases of contrast administration (e.g., arterial, portal venous, etc.).

A common complaint about the earlier objects was that much of the interesting information was in optional attributes, and that vendors could not be relied upon to populate these. Accordingly, the new objects make the majority of attributes mandatory or conditional based on their presence making sense, and provide a consistent set of terms or codes to use for their values. For example, in the original CT object there were 18 technique attributes of which none were mandatory; in the enhanced object there are 41 of which 39 are mandatory or conditional. Similarly in the old MR image object there were 44 technique attributes of which two were mandatory, in the enhanced image object there are 103 of which 94 are mandatory or conditional.

**Non-Image Objects**

A specific MR application that has been poorly supported up until now is MR spectroscopy. Whilst some of the information obtained through spectroscopy can be represented as an image, specifically metabolite maps, typically one acquires spectra that need to be represented in a different manner, if the receiving application is to be able to process the information and allow the user to interact with it. Up until now, if spectroscopy information is required beyond a single vendor's modality and spectroscopy workstation, the approach has been to render the spectra as a graph, take a snapshot of it and save it to the PACS as a secondary capture image. The limits the usefulness of the information, and accordingly DICOM has added a specific new non-image object to encode the spectroscopy data and its accompanying information. This object shares the description of the acquisition technique to the extent possible with the enhanced MR multi-frame image object. It supports both two and three dimensional frequency resolved spectra for single and multiple voxels. Whilst it is understood that MR spectroscopy is not in wide clinical use, the standard now offers an opportunity to share the data in a standard form as well as to store and manage it in the PACS.

Likewise, whilst there is little interest in standardizing the form of the raw data acquired during MR and CT examinations, it often needs to be stored in order to be reconstructed in a different manner at a later date. Until now, this could only be achieved using the modalities' own local archive media, and in a proprietary manner. DICOM has added a modality and vendor neutral Raw Data object to address the need to store this information in a conventional PACS archive, together with the necessary patient identifying and management information, without the need to understand the raw data payload itself.

**Performance Enhancements**

Modern MR and CT scanners are now capable of producing studies that contain thousands of slices. The original DICOM approach used for CT and MR called for each slice to be transferred as a separate data set. This means that after each slice is sent on an association, there is a delay waiting for a response before sending the next. This is acceptable when the number of slices is small and the transfer medium is slow relative to the delay waiting for a response, but as the speed of networks increase, particularly on wide area networks with high latency, the approach of sending one slice at a time has a greater impact, which is exacerbated as the number of slices per study increase.

Whilst it is certainly possible to mitigate these problems by more complex implementations of the existing DICOM network protocols that use multiple simultaneous associations or asynchronous operations, pragmatically it is simpler to send more slices before waiting for an acknowledgement. Accordingly, since new objects were already required to address the new CT and MR applications, it was appropriate to choose a multi-frame rather than single frame image object. This choice provides an opportunity for implementers to improve network transfer performance without adopting more complex approaches.

Since the descriptive information is contained within a single image object, the shared information does not need to be replicated for each slice. Compared to the bulk of the pixel data, the descriptive information is very small, hence this factoring out of common information has a negligible impact on the size of the object or transfer performance. It does however have a major advantage in terms of recognizing that the information is indeed shared, and does not vary per frame.

Experimental tests of the new multi- frame objects with large CT studies over a fast network have shown the potential for performance gains of around 30% in terms of transfer time, when compared against well optimized single frame transfer implementations. It is expected that as implementations mature, the advantages may increase further. Indeed, well-optimized implementations of the DICOM multi-frame object should be capable of approaching the theoretical limits for transfer over a raw TCP/IP socket, a limit that no protocol, standard or proprietary, can exceed.

Practically speaking however, it must be recognized that other factors tend to dominate transfer time in the real world, such as the manner in which the slices are made available by the sending application and the time it takes for the receiving application to process them (for example insert them in its database). Accordingly, the new DICOM multi-frame objects must not be regarded as a panacea in this regard.

Transferring an entire very large multi-frame object as a single entity creates the risk that the transfer will fail and need to be restarted from the beginning. Further, it may be desirable to transmit early parts of the examination before the entire data set is available. Accordingly, in conjunction with the ability to send CT and MR slices as large multi-frame datasets, a mechanism has been added to subdivide these large single instances into smaller components as parts of what is referred to as a "concatenation."

## Compression

Compression of images, whether lossless or lossy, takes advantage of the ability of the encoder to recognize redundancy within the data. Hence it is well known that a compression scheme that is aware that data is a two-dimensional image can exploit more redundancy and achieve better compression than with one dimension. By extension, the ability to take advantage of redundancy in a third or fourth dimension of space of time should allow greater compression. When slices are transferred as one single frame image at a time, this opportunity is lost. The new multi-frame image objects allow the use of multidimensional compression schemes, such as that defined in JPEG 2000.

Preliminary results of 3D compression using JPEG2000 suggest a benefit of between 10 and 40% in lossless compression over 2D compression with the same scheme, and perhaps greater benefits for lossy compression. Further, these benefits can be obtained across a modest number of adjacent slices rather than having to compress the entire 3D volume at once.

Accordingly, in addition to adding mutli-frame CT and MR image objects to the DICOM standard, new transfer syntaxes are being added to support the multi-dimensional form of JPEG 2000, as well as a means to selectively retrieve portions of the compressed bitstream using the new JPEG Interactive Protocol (JPIP).

**Interoperability and Deployment Issues**

Anything that is new, particularly something that replaces the old, takes time to adopt. Further, new devices that use only the new objects will be incompatible with devices that use only the old objects.

Accordingly, a concerted effort is required to educate and motivate the vendors that create CT and MR images, such as modality vendors, and those that consume CT and MR images, such as PACS and workstation vendors, to recognize the benefits to the users and to implement the new objects within the same time frame. Accordingly, SCAR, NEMA and DICOM are working with the vendors to provide tools and an infrastructure for developing, testing, validating and demonstrating the new objects. Those test tools and sample images together with open source code that are not already publicly available, will be available to everyone after SCAR 2005. They have developed with funding by multiple vendors participating in a voluntary effort.

Emphasis has been placed on developing a freely available validator that will check objects for compliance with the new standard definitions. This will help developers and encourage vendors to do better with respect to compliance, an onerous task given the sophistication of the new objects,. It will also allow users themselves to check the compliance of the devices that they are considering purchasing, or are having difficulty integrating.

Regardless, it will still likely be necessary for all vendors to support both the old and the new CT and MR image objects in their equipment for some time to come. However, users can expect that in the future, increasingly advanced functionality across different vendors’ equipment is likely to be possible in an interoperable manner only with the new objects.

Finally, CT and MR are not the only modalities for which new and increasingly sophisticated applications are being defined. Already work is nearing completion on a new DICOM digital angiography and fluoroscopy image object that shares the same infrastructure as the enhanced CT and MR images. A decision has been made to define a new enhanced PET multi-frame image object, a particularly pressing need given the synergy between CT and PET that is now dominant. There is also strong consideration of redirecting work on new Ultrasound image object development to also use the CT and MR multi-frame infrastructure. Future work on images to encode the results of analysis, such as segmentation objects, will likely use the same approach. More complex applications, such as for interchange of intermediate functional MR analysis results are also under consideration by groups involved in such research.