American Society for Echocardiography Software Suite for Verification and Playback of Ultrasonic Ciné-Mode Images

S Claesen*, G Heart*, W Li†, A Bharath*,S Chandra†, R Kitney*, CF Dewey†Jr, JD Thomas‡

*Imperial College of Science, Technology and Medicine London, UK
†Massachussetts Institute of Technology, Boston, ‡Cleveland Clinic, Ohio, USA

Abstract

The imminent balloting of the draft DICOM 3.0 module on ultrasound represents a major step forward in the progress of digital storage formats for echocardiography. In this paper, we discuss a software suite soon to be released into the public domain for reading, parsing and verifying DICOM 3.0 ultrasonic objects. The software is designed to allow the user to verify that a file consisting of digital ultrasound data, claiming DICOM 3.0 conformance, does in fact adhere to the standard. A graphical user-interface for the software suite is also provided, allowing the playback of ciné mode images in real-time on standard computer hardware, and across a TCP/IP network.

1   Introduction

The lack of a widespread standard for the digital formatting of medical images is recognised as a substantial obstacle to digital medical imaging. The well known problems of reading disks recorded on one manufacturer's scanner, and displaying the images on the analysis or viewing console of another has long been a sought after goal. A widely accepted standard for media and storage specification would provide an answer to this issue. Networking of scanners onto a Local Area Network (LAN) using industry standard protocols is also a desirable goal, so that ubiquitous, low-cost hardware may be used to communicate with the scanner for maintenance, control, image downloading and remote image viewing.

Standards for the formatting and storage of medical images would also allow an explosion of technological advances in the medical imaging field. For instance, the encoding of imaging parameters within an image file would allow the development of robust measurement tools for analysing images and for image processing operators to display and enhance images.

While a wide variety of such tools, including histogram modification, edge enhancement, and so on, already exist, they all suffer from the requirement that they are very image specific. This means that a particular image operator, designed for enhancing or analysing an image of one particular modality and in one particular scanning configuration, will generally function optimally *only* on that image type. Such specific operators will give poor, or even erroneous results if scanning parameters are changed. It is obvious that more general image analysis and enhancement tools, which can recognise the imaging modality, the orientation of the scan and other important parameters and act accordingly, are required. The almost infinite variability of biological images, coupled to the large number of imaging modalities and scanning modes, makes the development of such general-purpose automated image analysis tools currently intractable. A necessary requirement, therefore, is that some contextual image information be encoded with the image, in a manner that is uniform across all imaging modalities and manufacturers. The encoding of such information would allow the design of reasonably robust automated analysis, display and measurement systems, providing a rich software environment of tools for medical research.

2   Introduction to DICOM 3.0

The American College of Radiology's collaborative effort with the National Electrical Manufacturers Association led, in 1992, to the first parts of the DICOM 3.0 standard being approved. The standard, developed in a modular fashion, attempts to address the very issues related to digital image formatting, storage media and network transmission outlined above. By the end of 1993, most of the parts of the standard, covering information object definitions for Computed Tomography, X-Ray imaging and Magnetic

Resonance Imaging had been balloted and approved. In addition, the standard at this time covered protocols for network transmission, and in particular, a well-defined collection of PACS (Picture Archiving and Communication Systems) network services[3].

Recently, the DICOM group formed the Ad-Hoc Ultrasound Committee to look at the extension of the standard to encompass ultrasonic imaging. The rough organisational structure emerging from this effort was as follows.

At the "coarsest" level of storage is a list of DICOM storage files. Within each DICOM file may be a number of DICOM 3.0 objects. Each of these objects in turn consists of a number of rigidly defined modules, organised at the **Study Level** for managing the patient and general study information, and the **Series Level** which contains information on images, time-sequences of images and series of images[1].

A clear statement on the requirement of some modules in an object is provided. Thus, some of the modules are mandatory for DICOM conformance, while others are conditional, depending on the type of the object.

In accordance with the development of the previous parts of the evolving standard, the Ultrasound Ad-Hoc Committee agreed to demonstrate a prototype implementation of the standard whilst the drafting of the standard was still in progress.

The reasons for selecting this approach were multifold. First, it allowed the committee to find any obvious failings in the specification of the standard. Such failings might include redundant pieces of information, information objects that were not fully specified, and potential conflicts which would be difficult to spot in the drafting phase. Secondly, because of the direct participation of the manufacturers in the demonstration, errors in the *implementation* of the standard on the various vendors' machines could be identified and rectified at an early stage in the product development cycle.

Finally, the early demonstration at the American Society of Echocardiography in June of 1995 was seen as a valuable educational tool for publicising the benefits to the ultrasound community of the DICOM 3.0 formatting standard.

3 DICOM Verification Software

The International Consortium for Medical Imaging Technology has written software for the detailed verification of all DICOM 3.0 ultrasound files. The software is able to provide detailed parsing information, depending on the level of "verbosity" specified by the user.

The verification process also provides a statement of apparent conformance, based on the allowable rules and syntax of a DICOM 3.0 ultrasound object. In the event of non-conformance, the software issues an error message, providing further details on the precise nature of the error. The detailed parsing includes looking for unknown element types, unknown value representations, incorrect element types, incorrect value multiplicity, incorrect table lengths and many other common errors. In addition, detailed error checking for image data storage, both compressed and uncompressed is performed. In all, currently over 200 detailed conformance violations are recognised and reported.

The software exists in the form of stand-alone command-line executables for the DEC AlphaStation under OSF/1. ANSI compliant, fully documented C source code is also available. A Motif-based graphical user-interface is also provided. The software suite, including the graphical user interface has successfully been ported to 5 different UNIX platforms. The stand-alone command-line verification software has been compiled on a much wider range of machines and operating systems, including the PC under MS-DOS.

The display subsystem is entirely X11-R5 based, allowing a user sitting at any X-terminal, including a standard PC running an X server, to view the images and sequences.

The software is expected to be placed in the public domain towards the end of September, 1995, by which time the final balloting of the draft ultrasound supplement is expected to be concluded. More formal announcements are expected to be made at various meetings, including the American College of Cardiology meeting in March, 1996. Distribution of the software is expected to be via Internet, with CD-ROM's of the reference filesets available for purchase at cost.

4 Software and Hardware Demonstration Platform

At the 1995 conference of the American College of Cardiology, held in June in Toronto, the first unveiling of the DICOM 3.0 verification and display tools took place. The demonstration was organised by the American Society of Echocardiography, with the specific purpose of raising awareness of the DICOM 3.0 standard, and particularly of the emerging ultrasonic supplement.

The software suite described in detail in **Section 3** was mainly demonstrated on a DEC AlphaStation 200/166 with a 24-bit display and 96MB RAM running

DEC OSF/1 V3.2. The supported media formats included a 5¼" magneto optical disks, 3½" magneto-optical disks and an ISO 9660 compliant CD-ROM [2]. DICOM directories could be created for all of the writeable, removable media types, and the software successfully read images from all media types.

In addition to the software, a "golden" fileset was also demonstrated, consisting of some 160 studies stored on magneto-optical disk and CD-ROM. These studies represented images from 8 major ultrasound equipment manufacturers, including examples of B-mode stills, B-mode ciné loops, colour Doppler, stress-echo and M-mode scans. The image formatting standards supported included uncompressed, RLE compressed and JPEG lossy compression. Photometric interpretations included RGB colour, 16-bit palette colour, 8-bit palette colour and monochrome 8-bit.

In addition to demonstrating different levels of message display during the parsing and verification process, the demonstration included the display of up to 6 full-sized, 24-bit, full frame-rate ciné ultrasound loops, including some running at 30 frames/second on a single display.

In order to illustrate the colour reduction algorithms, and the portability of the system to hardware with lower display and memory specifications, a second DEC AlphaStation, with an 8-bit display, was also demonstrated reading, verifying and displaying the reduced colour images.

5   Conclusion

The DICOM 3.0 standard represents the first formatting standard that is likely to have significant and lasting impact on the field of medical ultrasonic imaging. Examples of the power of the standard are apparent even from the aforementioned demonstration suite: the frame rate is read automatically from the file, so that the digital ultrasonic image sequence is replayed to the viewer at the correct display rate; the photometric interpretations are noted from the file, so that the correct velocity calibrated colourbars are displayed alongside colour Doppler images; from a collection of images, one can quickly parse all images for clinical information, and create a database of patients, studies or diagnoses. These software features represent clear examples of the utility of the DICOM model for image storage, which is an object-oriented data model.

We anticipate that the "golden" filesets will become a valuable teaching resource. The system has been succesfully executed on a UNIX computational server, with a number of display clients running during a teaching session at M.I.T. A similar system is expected to be installed at Imperial College in the near future, for use by the medical school and local researchers.

Perhaps more importantly, the existence of the software suite represents a very useful resource both to those involved in building their own DICOM viewers, database and image analysis tools, and to hospital instrumentation groups involved in evaluating the conformance of ultrasonic scanners to the DICOM 3.0 digital image formatting standard.

References
[1] Thomas, J.D. "The DICOM Image Formatting Standard: What It Means for Echocardiographers", *Journal of American Society for Echocardiography*, 8, pp 319-327, 1995.
[2] Dewey, C.F. Jr., Thomas, J.D., Bharath, A., "DICOM Demonstration for the American Society for Echocardiography", *Internal Report, International Consortium for Medical Imaging Technology*, December, 1994.
[3] "Overview of the RSNA 1993 DICOM Demonstration", Report by *Mallinkrodt Institute of Radiology*.

Address for correspondence:

Dr. A. A. Bharath
Centre for Biological & Medical Systems
Level 1
Mechanical Engineering Building
Imperial College
Exhibition Road
London SW7 2BX
E-mail: a.bharath@ic.ac.uk