Overview of the DICOM Standard

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Abstract - *Digital technology has in the last few decades entered almost every aspect of medicine. There has been a huge development in noninvasive medical imaging equipment. Because there are many medical equipment manufacturers, a standard for storage and exchange of medical images needed to be developed. DICOM (Digital Imaging and Communication in Medicine) makes medical image exchange more easy and independent of the imaging equipment manufacturer. Besides the image data, DICOM file format supports other information useful to describe the image. This makes DICOM easy to use and the data exchange fast and safe while avoiding possible confusion caused by multiple files for the same study.*

Keywords - *DICOM, Medical Imaging, Mammography*

1. INTRODUCTION

During the last thirty years there has been a large development of digital technology. Computers have entered almost every aspect of our lives, so naturally they have become more and more important in medical applications. Many medical imaging methods used today mostly rely on computer processing. Computers are used not only to store or display images but also to make images or 3D models from the input series of data. Data are obtained from imaging devices that use complex methods, for example: CT, MRI, SPECT, PET. Also there has been a large, more or less successful, development of Computer-Aided Diagnosis (CAD) methods [1, 2]. Because of many directions in development of medical imaging equipment, it was very important to make a standard for connection and information exchange between medical appliances. Since there are many of manufacturers that make medical imaging equipment with different approaches, having a standard makes interchange of the images and medical data more easy. DICOM (Digital Imaging and Communication in Medicine) is a standard that specifies a non-proprietary data exchange protocol. Current version (3.0) is published by NEMA (National Electrical Manufacturers Association) in 1993. This standard is developed by workgroups every year to satisfy virtually any medical branch [3]. This paper describes the DICOM Standard and problems in medical image displaying using non-proprietary workstations.

2. HISTORY OF THE DICOM

As the development of digital computers and equipment started in the 1970's an idea of using digital imaging equipment in medicine has become a reality. ACR (American College of Radiology) and NEMA (National Electrical Manufacturers Association) formed in 1983 a joint committee whose mission was to develop a standard for connection of displays and similar devices to medical imaging equipment from different manufacturers. The first version named ACR/NEMA Standard Version 1.0 was published in 1985. Two revisions of the standard, in October 1986 (No. 1) and in January 1988 (No. 2), followed the initial version 1.0. In 1988 new material was included in the new revision of the standard and version 2.0 was created. Both versions 1.0 and 2.0 allowed point-to-point connection and that represented a problem for modern communication networks which do not use absolutely dedicated channels. Because of that a new revision of the standard had to be presented. In 1993 a new version, named DICOM Version 3.0, was released. DICOM Version 3.0 uses networked environment instead of point-to-point connection environment for imaging system connections. This allows cost-effective connections over large geographical areas with the use of a prebuilt network infrastructure. Since its release in 1993 DICOM Standard has been revised many times, mostly on yearly bases. Research in different medical fields is done by different workgroups, each with specific area of research. The DICOM Standards Committee nowadays creates and maintains international standards for interchange of digital medical imaging and associated data. It has become a leading standard used by all major vendors of diagnostic medical equipment. If not already, DICOM will soon be used in every medical branch that utilizes imaging, for example: cardiology, mammography, radiology, surgery, endoscopy, dentistry, pathology, etc. Today DICOM allows effective medical imaging storage and transfer over large geographical areas, making a basis for picture archiving and communication systems (PACS) [3]-[7].

3. TECHNOLOGICAL OVERVIEW

DICOM Standard is consisted of several layers in relation to ISO OSI network model. DICOM is independent of the physical layer because it does not define a physical connection. Upper Layer Protocol (ULP) is defined inside the DICOM Standard. It is an abstract protocol that defines data encapsulation and is higher than level five of the ISO OSI model. At the application layer there are five primary areas of functionality:

- Transmission and persistence of complete objects (such as images, waveforms and documents),
- Query and retrieval of such objects,
- Performance of specific actions (such as printing images on film),
- Workflow management (support of worklists and status information) and
- Quality and consistency of image appearance (both for display and print) [3].

DICOM was developed to make medical images and associated data standardized for easier interchange. Besides that, DICOM defines network oriented services for transfer or printing of the images, media formats for data exchange, work-flow management, consistency and quality of presentation and requirements of conformance of devices and programs. Information Object Definitions (IODs) are introduced in the standard to define attributes that describe a certain characteristic of the image. IODs have a well-defined meaning and their attributes precisely describe type of the object, data of the patient, performed procedures or reports as well as the technical information about the medical imaging device used in the procedure. Technical information includes the name of the imaging device manufacturer, device serial number and other details about the device. For example, data that are included for a mammography device are exposure time, field of view, X-Ray tube current, anode material, compression force, detector ID and temperature, etc. These attributes vary when comparing devices from different manufacturers and different modalities (CT, MRI, mammography, etc.). There are also private attributes that can be used by equipment vendors to save proprietary data that can not be used by other manufacturer's workstations [4].
DICOM Standard also defines network services that are used for information transfer. To make a transfer both stations have to support the same service and objects. Two stations that support the same services and objects are called Service-Object Pair Class (SOP Class). There are many other services that allow to query and retrieve objects with certain characteristics. One of the important services is DICOM Print, which allows transferring data for printing over the network. For data transfer and communication DICOM specifies a network protocol utilizing TCP/IP. That protocol defines the operation of Service Classes beyond the simple transfer of data, and provides a mechanism for uniquely identifying Information Objects for transferring across the network. Information Objects are defined not only for images but also for patients, studies, reports, and other data groupings. It is important to mention that the DICOM Standard does not define hardware interfaces for equipment connection. Instead it provides support for information exchange based on upper layer protocol (ULP) of the ISO OSI network models that are independent of the physical network and therefore can be used in different network setups.

DICOM Standard consist of 16 parts:

PS 3.1: Introduction and Overview
PS 3.2: Conformance
PS 3.3: Information Object Definitions
PS 3.4: Service Class Specifications
PS 3.5: Data Structure and Encoding
PS 3.6: Data Dictionary
PS 3.7: Message Exchange
PS 3.8: Network Communication Support for Message Exchange
PS 3.10: Media Storage and File Format for Data Interchange
PS 3.11: Media Storage Application Profiles
PS 3.12: Media Formats and Physical Media for Data Interchange
PS 3.14: Grayscale Standard Display Function
PS 3.15: Security and System Management Profiles
PS 3.16: Content Mapping Resource
PS 3.17: Explanatory Information
PS 3.18: Web Access to DICOM Persistent Objects (WADO)

During the development of the standard, parts 9 and 13 have been retired [9]. Basic topology of the DICOM Standard is shown in Fig. 1.

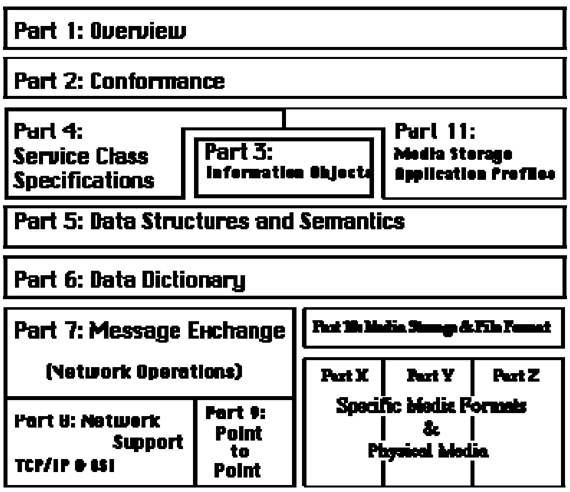


Fig. 1. Basic topology of the DICOM Standard

DICOM is large and complex standard because it has to be well suited for different medical branches. It is developed by 26 workgroups that develop only small portion of the standard. Workgroups are divided as shown in Table 1 [3, 4, 8].

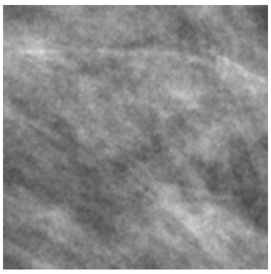
Table 1. DICOM workgroups

No.	Name	work items
WG-01:	Cardiac and Vascular Information	Develops standard for interchange of digital cardiovascular images, physiologic waveforms and core clinical information
WG-02:	Projection Radiography and Angiography	Develops and maintains objects in the domains of 2D and 3D X-Ray imaging
WG-03:	Nuclear Medicine	Develops standards for nuclear medicine and PET images
WG-04:	Compression	Tracks progress of JPEG2000 image compression standard, prepares a work item for 3D image compression
WG-05:	Exchange Media	Develops a standard for interchange media (DVD, UDF file format).
WG-06:	Base Standard	Maintains the overall consistency of the DICOM Standard
WG-07:	Radiotherapy	Develops and maintains radiotherapy information objects of the DICOM Standard
WG-08:	Structured Reporting	Maintains and develops the DICOM Structured Reporting (SR) specification and collaborates with DICOM workgroups in development of codes and controlled terminology and templates for biomedical imaging applications
WG-09:	Ophthalmology	Develops a work flow of eye-care environments and addresses all the issues related to imaging in ophthalmic applications
WG-10:	Strategic Advisory	Considers the issues and opportunities related to the strategic evolution of DICOM Standard
WG-11:	Display Function Standard	Develops services related to display and presentation of images
WG-12:	Ultrasound	Develops DICOM Standard to meet the needs of the ultrasound and echocardiography specialties, provides support for the 3D ultrasound image acquisition and processing
WG-13:	Visible Light	Adopts DICOM Standard for still and motion Visible Light color or monochrome images
WG-14:	Security	Develops extensions for secure information exchange
WG-15:	Digital Mammography and CAD	Develops support for breast imaging and Computer-Aided Detection (CAD)
WG-16:	Magnetic Resonance	Develops a new MR object with more descriptive attributes
WG-17:	3D	Extends the DICOM Standard for handling 3D and other multi-dimensional data sets that are not specific only to certain modality
WG-18:	Clinical Trials and Education	Extends the DICOM Standard to support clinical trials and research using medical images
WG-19:	Dermatologic Standards	Provides support for cutaneous imaging
WG-20:	Integration of Imaging and Information Systems	Develops DICOM and Health Level 7 (HL7) standards for image-related information where the consistent use of both standards is of prime concern
WG-21:	Computed Tomography	Develops and extends CT image objects to support technological and clinical advances in CT
WG-22:	Dentistry	Addresses the issues related to imaging and reporting of image-based studies in dental and maxillofacial applications
WG-23:	Application Hosting	Develops specification for interfaces between hosted application system and a DICOM host system
WG-24:	Surgery	Develops DICOM objects and services for Image Guided Surgery (IGS)
WG-25:	Veterinary Medicine	Develops attributes to support identification and description of veterinary patients
WG-26:	Pathology	Extends DICOM Standard to support Pathology images (cytopathology, surgical pathology, clinical pathology and autopsy pathology studies)

3.1. DICOM images

Image displaying under DICOM Standard does not define how images are displayed or annotated. Besides the image data, DICOM includes data structures that are of importance to the image. Those structures are placed in a header that contains object's description, patient's data, name of the institution and other information such as performed procedures or reports. Information Object Definitions (IODs) are the most important components of data structures. IODs are tables of attributes that define information objects. Information objects are models that are abstracted versions of real-world objects, for example "patient" is an information object that has "patient name" and "patient ID number" as attributes. DICOM Standard supports different types of images for different medical applications. For X-Ray imaging intensity images are used, while for some Computed Tomography applications color images are often used. DICOM supports multi-dimensional multi-frame images. Data compression relies on widely used compression standards like JPEG, JPEG Lossless, JPEG 2000, or MPEG-2 for multi-image (video) sequences [10]. Different medical applications require different level of image quality. Mammography images require very high resolution, so the compression used is mostly lossless because small details need to be preserved. That is the reason why mammography image files are large even though images are grayscale. Fig. 1 shows the influence of compression on detail loss.

(a)



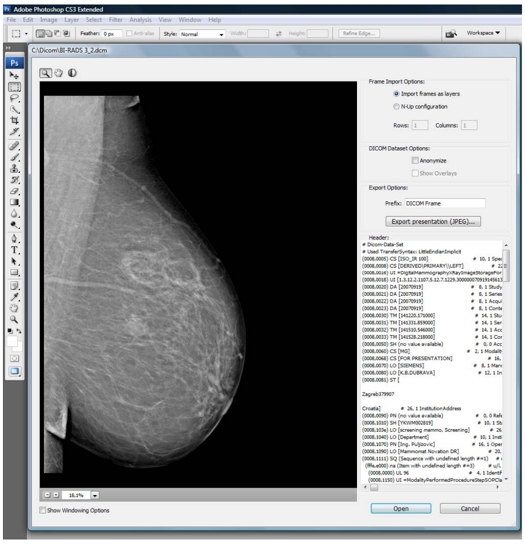
(b)

(c)

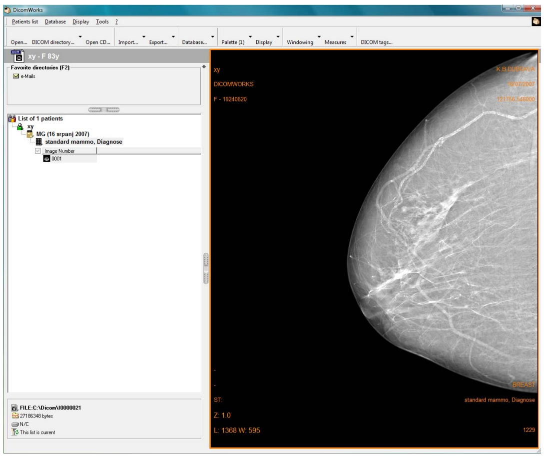
Fig. 1. (a) entire mammography image with position of the segment, (b) segment of uncompressed image, (c) segment of 25:1 JPEG compressed image.

3.2. Viewing DICOM images

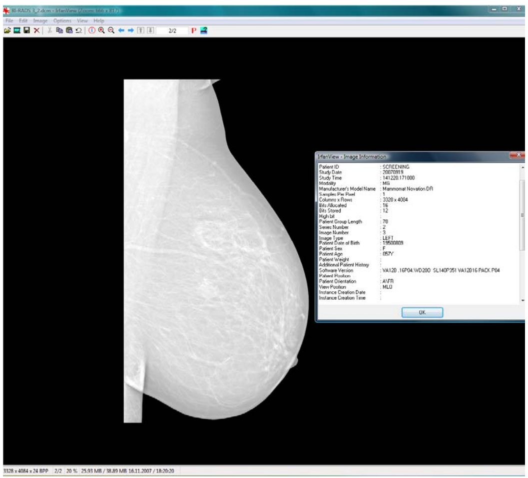
DICOM images are meant to be viewed on different workstations or personal computers (PCs). Images can be grayscale or color. Bit depth and compression applied to the image is explained in the header of the image. That ensures that the image will be correctly displayed regardless of equipment's manufacturer. In recent years many different, third-party, DICOM viewers have been developed. Plug-ins for image processing software, like Adobe Photoshop, have also been developed. Idea for including support in image viewers is to make possible for patients to view DICOM images at home with no need to ship the images with a dedicated viewer on a CD-ROM or other media type. DICOM viewing software can be divided into two main categories: proprietary viewers that are supplied with the medical imaging system; and third-party DICOM-viewing software for individual PCs [10]. Some of the most popular non-proprietary viewers available for free download are: DicomWorks [11], Osiris [12] and IrfanView [13] as the popular all-format image viewer. Merge eFilm is a complete DICOM image workstation and it is not a freeware, but it allows other advanced features besides just image and header displaying. Adobe has developed a plug-in for its Photoshop CS3 [14] that makes possible to view DICOM images and header information and export images to different file formats. Because Photoshop is a powerful tool for image editing, it allows good adjustments of contrast and brightness of the image. Functions have been made for reading DICOM images and headers in Matlab [15]. Matlab's function for reading the DICOM header is helpful because it shows all the information stored, which is not the case in other viewers. However, it is not suitable for general use because it requires some programming knowledge. The problem that most non-proprietary viewers experience is setting the optimal "window" for displaying the image. Optimal "window" defines the range of amplitudes in the image that are displayed on the entire range from 100% black to 100% white. Problem with "windowing" happens because different imaging devices produce different range of amplitudes and images are stored as, for example, 12-bit images. If the "window" is set too narrow, contrast of the displayed image will be set too high and vice versa. Because of that problem some viewers allow applying manual settings of the desired range of amplitudes that should be displayed. Fig. 2 shows DICOM mammography images displayed in different viewers. Obvious problem of setting optimal range of displayed amplitudes is visible in Fig. 2 (c).



(a)



(b)



(c)

Fig. 2. Screenshots of DICOM mammography images opened in: (a) Adobe Photoshop, (b) DicomWorks, (c) IrfanView.

Some research has been done in the field of mobile devices and the possibility to display DICOM images on handheld computers or mobile phones that support application upgrades through Java [16]. DICOM image viewers can also be divided into stand-alone or complete Picture archiving and communication systems (PACS). PACS are digitalized archives consisted of one or more computers in a network that offer image storage and exchange. They are suitable because they take up less space, allow quicker search by different queries and there is no degradation in quality of the images caused by ageing.

3.3. Advantages and disadvantages of DICOM

DICOM has standardized the exchange of medical information. The general idea was to provide a standard for cost-effective interconnection of different medical systems to provide a transparent and easy to use environment. It is very important to have a standard which is being used in all hospitals for the same or similar examination processes. A unique standard helps in avoiding problems that occur if patient moves from one hospital to another. DICOM also provides interconnectivity between diverse medical systems. That made the DICOM Standard stand in front of other separate standards developed by manufacturers of medical equipment. DICOM's big advantage also lies in supporting all medical branches, and that makes it so comprehensive. Different workgroups that work in development of DICOM Standard are in charge of developing only a small part of the standard that is specific to their line of duty. DICOM also has an advantage when compared to storage of analogue images and data because it takes up less space for digital storage and digital data are easy to transmit over the large geographical area. Analogue data in some cases suffer from quality degradation caused by limited durability of the media and this is not the case with the digital data. Considering that problem DICOM offers a possibility to convert analogue data to DICOM digital format.

DICOM defines all the attributes that should be included in each modality. Those data fields can be required or optional. A major disadvantage of the DICOM Standard is the possibility for entering probably too many optional fields. This disadvantage is mostly showing in inconsistency of filling all the fields with the data [17]. Some image objects are often incomplete because some fields are left blank and some are filled with incorrect data. Another problem occurs when displaying an image on a device that is made from different manufacturer, because different imaging equipment uses different amplitude ranges and same number of allocated bits. In that case image can be displayed as underexposed or overexposed with poor contrast, so those parameters should be adjusted manually.

4. CONCLUSION

DICOM is one of the most ambitious medical image standards. It is developed to make image data standardized and easy to share between the equipment from different manufacturers. Many workgroups that are gathered to develop the standard are divided in a way so that each workgroup develops only a small specialized part of the standard. This organization structure is very efficient, because each workgroup is in charge of different areas with as little aliasing between them as possible. DICOM Standard is developed to make possible a further expansion and easy upgrade of some parts that constantly develop. That is a very important possibility, because today imaging standards develop very fast as well as the medical imaging equipment. Even though there are some obvious disadvantages, for example in the case of defining required data in the headers of images, DICOM has proved to be a very complete and, most of all, helpful standard for medical imaging archiving and exchanging.

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