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System for Digitalization of Medical Images Based on DICOM Standard*

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Abstract: According to DICOM standard, which defines both medical image information and user information, a new system for digitalizing medical images is involved as a part of the main system for archiving and retrieving medical databases. The basic characteristics of this system are described in this paper. Furthermore, the analysis of some important DICOM header's tags which are used in this system, are presented, too. Having chosen the appropriate tags in order to preserve important information, the efficient system has been created.

Keywords: Digital image processing, DICOM standard, DICOM header, Telemedicine, ASP.NET, SQL server.

1 Introduction

Development of numerous systems for medical image acquisition, as well as various methods for application in diagnostic, gave rise to improvement of integrated systems which will be able to provide acquisition and communication, namely distribution of medical images both within local area networks and worldwide via Internet, reaching the remote users.

In contrast to the modern systems for acquisition and communication through medical images [1, 2], where each medical image is digitalized first and than is ready for archiving and distribution via computer network, the previous systems used to archive the images at physical medium, e.g. films, so the communications and the analysis of them were impossible by wider auditorium. The result of such inefficient systems was the huge amount of important information for further research stored under inappropriate conditions, because of limited durability of film, as a medium for their archiving. Therefore, fast retrieving medical database, transfer, storage and viewing of medical images was not plausible.

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During the process of digitalization of the old medical image archives, it has become possible to provide efficient access to the longstanding databases. Hospitals and other health institutions can use this new technology without spending extra money for buying additional new equipment for analysis and further research. The outcome is also considerably enlarged medical databases [3]. By introduction of the old medical image archives into digital record, it is ensured their integration within the modern systems for communication through medical images and information, such as PACS (Picture archiving and communications system) [4] and HIS (Health information system). The integration of digital archives within the systems mentioned above is understood through adequate standardization of the whole process of medical image digitalization, archiving and communication. DICOM (Digital Imaging and Communication in Medicine) standard represents the group of standards regulating manipulation, archiving, printing and transfer of medical images. It also includes defining of the file format of recorded image and network communication protocols. The use of this standard enables hardware from different producers to be a part of the same system.

The difference between DICOM file format and the rest of them is in adequate grouping the information which is important for the patient enabling their permanent connection with medical image. In this way the more efficient archiving of all the relevant patient data is achieved. All the relevant patient data related to medical image are stored in the header of DICOM file as a various tags. There are a large number of different tags which can be defined and written down by DICOM standard. Also, the process of digitalization of medical files and their archiving into database in order to comply with DICOM standard can be really difficult because of manually inputting the great amount of relevant information. Consequently there is a need for choosing the appropriate tags and attributes which will be enough for proper patient representation. Additionally, the input and retrieving efficiency of medical databases should be improved.

In this paper, the proposed system for medical image digitalization and their input into appropriate database is presented. Furthermore, the way of selecting the appropriate tags into DICOM header file is specially analyzed in order to develop the efficient system for archiving and retrieving medical image databases.

This paper is organized into four sections. After the introduction, in section two, the main hardware characteristics of the realized system and the DICOM header description are given. The medical image database description and the list of relevant information stored in DICOM header are presented in section three. Finally, plans for further research and system development are given in section four.

2 Proposed System Architecture

The system realized in this paper is illustrated in Fig. 1. Despite the fact that the system is based on PACS in general [5], the system is quite different because the part of the system which is responsible for medical image acquisition is not included in this case. The proposed system consists of several blocks. Firstly, there is an image high resolution digitalizer with a software which is responsible for image formatting according to DICOM standard [4, 6]. Secondly, the server for archiving database is also included, then the application server and finally the client computer.

The medical image database is designed to satisfy several requests for system efficiency and its applicability. Additionally, the database scalability is very important parameter which was considered during the process of database design. The consequence is the fact that the database is able to be changed in order to suit different requests for advanced information archiving if it is necessary. Because of adequate data indexing, fast access all information in database is ensured, as well as fast and efficient medical database retrieving.

Database design also enables transparent export of data and their suitable exchange between databases which are created by different manufacturers. It is certain that the database absolutely provides all specified requests for medical image archiving according to DICOM standard.

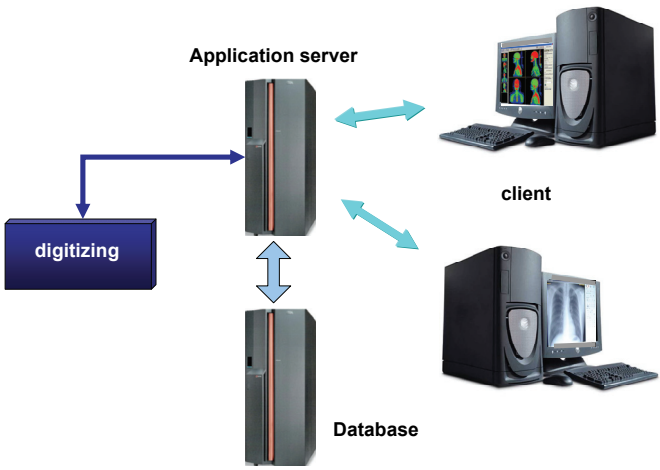

Fig. 1 – *Described system*.

Software which provides access to the database is realized as a WEB application at three different levels [7]. The first level represents the communication with database, the second level contains work logic, while the

third level provides graphic interface. The level of software realization which ensures communication with database represents the lowest level. It also enables functional data access, as well as capability to adjust to the various types of database. This part of realized software provides adaptability of the system as a whole to the databases of various manufacturers through changing the small part of implemented software. The medium level represents the software wherein the work logic of application is realized. Furthermore, it provides basic functionalities which this application offers.

The level with graphic interface enables the user interactive work with the system. Graphic environment offers the user full control over the functionalities of application.

During the realization of database design, licensed software was used for creation Microsoft SQL database, as well as Microsoft Visual studio for realization of WEB application in ASP.NET technology.

WEB orientation of the whole system caused the specific requirements in the design of software to protect some private medical data of patients. The implementation of this database also provide a reliable data transmission for telemedicine in accordance with HIPAA [8] rules.

In the applications that access the database, software has been implemented in a way to allow viewing of images in DICOM format. It provides basic functionality, good visibility and easy manipulation of images with them, in terms of zoom, image rotation, changing brightness, contrast and other changes.

Additionally, well-organized information system is very important in keeping the relevant information related to the treatment of patients in medicine. This is especially important in the transmission of medical images and text information. Different manufacturers can generate images and data of different formats, and if these formats are not compatible, there is a big problem in their exchange and processing.

Today there are two main standards that define the method of storage and keeping all necessary data related to the image and the patient, as well as medical image processing by itself, then retrieving medical image database and data transfer protocols between health institutions in the computer networks. These are the HL7 (Health Level 7) [9], and DICOM standard. DICOM standard defines the format of which digital record is done and medical image stored, obtained by different acquisition techniques.

The DICOM format consists of a field in which the image is placed, but previously recorded in a certain way depending on the type of medical treatment. Then the DICOM format includes the header in which information, related to the type and size of the image, patient data, type of disease, and treatment methods that are recommended, is stored. Data, or tags in the DICOM

header are generally divided into public and private data. Public information is the data to which medical staff and administration have right to access. Some of these data could be name of the patient, or place and year of patient birth. Besides the public, there are private information to which only certain people like specialized doctor of the patient have right to access. These information like patient data related to a history of diseases may become private previously determined by the doctor. There are also tags that carry information related to medical image processing method and the results given treatment.

Table 1

Showing some DICOM *tags in the header of the* AGFA CR.

(0008,0020):	Study Date	:21/06/06
(0008,0022):	Acquisition Date	:21/06/06
(0008,0060):	Modality	:CR
(0008,0070):	Manufacturer	:AGFA
(0008,0080):	Institution Name	:HCSC
(0008,1010):	Station Name	:ADCC2
(0008,103E:	Series Description	:lumbar AP
(0010,1010):	Patient's Age	:020Y
(0018,0015):	Body Part Examined	:LSPINE
(0018,1004):	Plate ID	:U13-35
(0018,1401):	Acquisition Device Processing	:60025la712Ra
(0018,1403):	Cassette Size	:35CMX43CM
(0018,1404):	Exposures on Plate	:342
(0018,5101):	View Position	:AP
(0018,6000):	Sensitivity	:4.00000000E+02
(0019,1010):	Image processing parameters	
MENU=60025 CC=0 MC=3.00 EC=0.00 LR=2.00 NR=4.00		
(0019,1013):	Sensitometry Name	:NK5
(0019,1015):	Dose monitoring list	:1.54
(0020,0013):	Image Number	:1
(0020,1002):	Images in Acquisition	:1
(0028,0010):	Rows	:3730
(0028,0011):	Columns	:3062
(0020,1002):	Bits Allocated	:16
(0028,0010):	Bits Stored	:12
(0028,0011):	High Bit	:11

It is very difficult to save and organize all relevant data in the DICOM header, previously obtained from the various software packages for visualization of the clinical images. Different health institutions depending on the type of disease and the type of diagnosis, organize storage and archiving of useful data in a way that is acceptable to them. In terms of defining standards of storage of relevant data there is a field for innovation and research.

Furthermore, it is obvious that within the very specific medical field there is a problem in defining standards for the storage of certain data. The problem is interesting especially in radiology (X-ray systems) where is necessary to save tags related to the dosage of radiation [10]. The ultimate goal is to enable automatic recording of doses of radiation applied to the patient, its comparison with the reference values and alert if the measured values exceed the limits of tolerance.

By the relevant information in radiology, which is stored in the DICOM header, medical staff is allowed to properly control the specific parameters related to the dosage amount of radiation that patient has received during the fluoroscopically guided procedures in radiology. In this regard, it has been made a great effort to standardize the tags which should be placed in private and public part of the DICOM header. Some tags are standardized by the manufacturer, while some additional tags, related to a radiation, are additionally placed in a separate header field and it allows more detailed calculations in order to better treatment of patients [10]. The organization of data stored in the database is also defined. **Table 1** and **Table 2** are showing the organization of tags in the DICOM header by some manufacturers.

Table 2
Showing some DICOM *tags in the header of the* AGFA CR.

Relevant DICOM tags GE Chest flat panel		
(0008,0020):	Study Date	:27/06/06
(0008,0030):	Study Time	:11:34:12
(0008,0033):	Image Time	:11:35:42
(0010,0020):	Patient ID	:768507
(0010,0040):	Patient's Sex	:M
(0010,1010):	Patient's Age	:085Y
(0018,0015):	Body Part Examined	:
(0018,0060):	KVP	:125
(0018,1150):	Exposure Time	:5
(0018,1151):	X-ray Tube Current	:250
(0018,115E):	Image Area Dose Product	:0.83556
(0018,1190):	Focal Spot(s)	:0.6
(0018,1405):	Relative X-ray Exposure	:61
(0018,7060):	Exposure Control Mode	:AUTOMATIC
(0018,7062):	Exposure Control Mode Descript: AEC_left_and_right_cells	
(0028,0010):	Rows	:2022
(0028,0011):	Columns	:2022
(0028,0100):	Bits Allocated	:16
(0028,0101):	Bits Stored	:14

3 Recording Medical Images According to DICOM Standard

The database of digitized medical images of described system was created in a way that the minimum of information in the DICOM header is defined which is necessary to describe each image properly, The same thing is done on a database server. Information which describes medical images is divided into two parts and allows the user easier retrieving [11]. The first group of tags consists of the required information (tags) that is necessary to input, represented the minimum information that must write down to each digitized image. Also, identification of images is done using the number and the name of the patient, and based on data related to digital image format as a number of species, columns, etc. The second part consists of an optional information (tags) that provide additional information about the patient, the image and details of the acquisition itself.

Table 3
The View of used DICOM *tags in the header*.

Demanded tags

(0020,0013)	Image Number
(0010,0010)	Patients Name
(0028,0010)	Rows
(0028,0011)	Columns
(0028,0100)	Bits Allocated
(0028,0101)	Bits Stored
(0028,0102)	High Bit

Optional tags

(0008,0020)	Study Date
(0008,0030)	Study Time
(0018,0015)	Body Part Examined
(0020,0032)	Image Position Patient
(0020,0037)	Image Orientation Patient
(0010,0020)	Patient ID
(0010,0030)	Patient's Birth Date
(0010,0040)	Patient's Sex
(0008,0060)	Modality
(0008,0070)	Manufacturer
(0008,0080)	Institution Name
(0008,0081)	Institution Address
(0008,1030)	Study Descrption
(0008,103e)	Series Description

Defining these two groups of information (tags) is caused by the desire of designers to optimally adapt the relevant database to some information that is available during the digitization of medical images and their archiving. It is also considered the possibility that during the digitization of medical images there is no enough information about the images from supporting documents in the previous archives. In Table 3 demanded and optional information entered in the header of each DICOM file of digitized medical image is shown. As it can be seen, the amount of optional information is grater than the amount of demanded information.

The dedicated tags include the number of image obtained in the process of digitization, the name of the patient, the number of rows and columns of digitized image, the number of bits reserved for recording the values of the sample pixels, then actual number of bits used for recording the value of the sample pixels and the actual value of the highest bit position in the results of the sample pixel values in reserved set of bits.

The optional tags are used to further identify the patient through a unique identifier and adding the data for gender and age. The acquisition of the medical image was described with more information which includes information like: the time and date of performance of acquisitions; part of the body that is captured; image position of patient; the orientation of patient; modality of acquisitions. A special two tags give a brief description of the acquisition itself and the description of a series of recordings. As the useful information, some tags are provided to identify the institution in which acquisitions has made and provide the contact address of the institution.

The mentioned information are simultaneously entered in the DICOM header file and stored in the database on the server. The information on the server is available for access and retrieval by the user, if this is in accordance with the rights of access to certain information. The database is scalable and able to provide extension and additionally inputting of more relevant information if there is a need.

It can be concluded from the **Table 3**, that the amount of information required for storage into database during the process of medical image digitizing is not huge. The consequence of that is faster and easier operation by the staff who perform the process of digitalizationemissions.

4 Conclusion

The system for medical image digitization, as well as medical image archiving and retrieving the relevant databases is presented in this paper. The great importance is given to the analysis of the type and amount of information, which is important to record and archive into database and header of DICOM

file. For each digitized medical image, the group of relevant information which should be memorized into DICOM header is proposed. The proposed group is presented as an optimal group of relevant information of the aspect of a whole system of application.

The system for medical image digitization, archiving and medical database retrieving has been developed in cooperation between two educational Institutions, ICT Collage in Belgrade and The faculty for electrical engineering in Belgrade, as a result of their participating on the project approved by The Ministry of Science and Technological Development in 2008/2009. The aim of this research was giving students the opportunity to learn more about modern technology applied in telemedicine.

Additionally, it is supposed that the research will bring many benefits to hospitals and other health institutions, because of increasing the efficiency in medical image processing, as well as efficient archiving and retrieving medical databases. The system capability to offer multiple access to the medical database with all relevant information about the patients, independently of their location, will raise health care on higher level, specially in small rural environments. Also, the proposed system should make possible to prolong the validation of some old equipment for medical image acquisition based on physical medium, which do not have ability for advanced implementation of image digitization.

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