INTEGRATED, RADIOLOGICAL DATABASE STRUCTURE

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Abstract: The rapid development of medical imaging requires proper preparation of medical database structure for multimedia information acquired during a patient visit. This paper presents a study on integrated structure of a radiological database based on DICOM, HL7 standards and on medical coding systems. Conclusions are based on the Radiological Information System project prepared for the Institute of Radiology, Medical University of Gdansk.

Keywords: medical database, DICOM, HL7

1. Introduction

Application of imaging techniques for medical diagnostics and therapy planning has become a daily practice in medicine. Development of modern technologies and their introduction to hospitals generates huge datasets of digital data. According to estimates of some radiological departments the production of digital data is more than a few GB per a day. The proper management of such huge data collections requires preparation of effective patient management system. Patient management system for medical imaging departments can be organised as it is presented in Figure 1. All functional parts of the system should be integrated to create appropriate model of reality.

Presented functional parts of a patient management system are described by ordered, logical structures connected with the specific event. This means that each event in the process can be represented as a set of storing elements (e.g. tables) in the database. It is important to pay special attention to a database structure design,

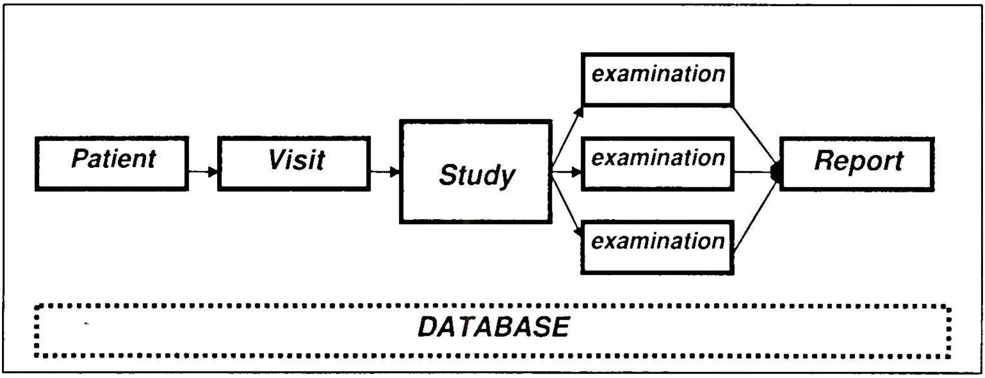

Figure 1. Model of the integrated patient management system

taking into consideration the following items:

— existing patient management system,
— a set of attributes required by law, standards and local needs,
— possibility of co–operation with existing information systems,
— possibility of data coding according to international and national medical coding systems.

Unfortunately, most of the existing medical database systems and medical information systems in Poland have been designed only with the first and partly second constrain. Such applications are not "open" in the medical information technology environment and will not provide possibilities for:

— co–operation, communication and exchange of data and knowledge with other local and global medical information systems and modalities,
— statistical analysis of data sets according to international and national coding schemes of diseases (a lack of common reference system for knowledge exchange),
— development of medical information systems (e.g., HIS — Hospital Information System, RIS — Radiological Information System, etc.).

The process of effective data structures designing for medical databases has to consider existing standards of medical data formatting, especially those dedicated to medical imaging of data sets. There are two fundamental standards in medical information technology today: Digital Imaging and Communication in Medicine — DICOM; Health Level 7 — HL7 [1, 2].

During the last 10 years two fundamental standards for medical data formatting and exchange have been established. HL7 and DICOM define basic modules and attributes, which can be used to create information object (message) representing real event (e.g., patient visit, examination, etc.). Both standards describe also a process of information objects exchange in the network environment. Here only data formatting information in both standards is presented.

First the Health Level 7 standard has been defined. The HL7 presents methods of data formatting, messages construction and exchange for text–based medical data. Unfortunately the standard does not describe modules and attributes to store medical image data. The lack of the common standard of medical image data formatting was a real problem in medical imaging systems integration. The solution for all problems connected with interoperability of modalities were planned to be solved by application of a new standard for medical imaging — DICOM.

2. DICOM standard for radiological database designing

This new international standard was created by American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA) in co–operation with international organisations and medical companies [1]. First chapters (9 chapters, 9 books) were published in 1993, next in 1995, and the last one in 1998. Currently, the DICOM standard version 3.0 consists of 14 chapters; more are under development (a version is the same even if the standard is enlarged).

The main goals of the DICOM standard are:

- to promote communication of digital image information, regardless of device manufacturer,
- to facilitate the development and expansion of picture archiving and communication systems (PACS) that can also interface with other systems of hospital information e.g. HL7 standard,
- to allow the creation of diagnostic information data bases that can be interrogated by a wide variety of devices distributed geographically.

The basic class defined by the DICOM standard is a SERVICE class. This class contains subclass called Service–Object Pair Class (SOP), which describes relation between data object (data object = implementation of data structures) and their services (e.g., write, send, etc.). All data objects (patient data, study data, image data, etc.) are defined by IOD — Information Object Definition. IOD groups data in special thematic Information Entities and Modules. Each module is defined by a set of attributes (Figure 2). Each attribute is described by a simple structure called Data Element. Data Element consists of a unique identifier (TAG: Group and Group Element), a data type specification (VR– Value Representation), a length of pure data values in bytes (VL — Value Length) and a set of bytes constructing data value. Information to be collected in DICOM is then composed by a stream of Data Elements. The DICOM standard defines catalogues of data types, encoding methods, etc.

A Data Element is the basic structure presented by the DICOM standard, and is used to store real object (event) attributes (Figure 3). Attribute, according to DICOM, is an elementary value representing a real object or event. Each attribute is labelled by a unique code TAG. As it is required in medicine, all codes stored with attribute values have a description with a specific (e.g. language specific) codes directory [1]. The standard coding scheme is build with three basic elements: a code

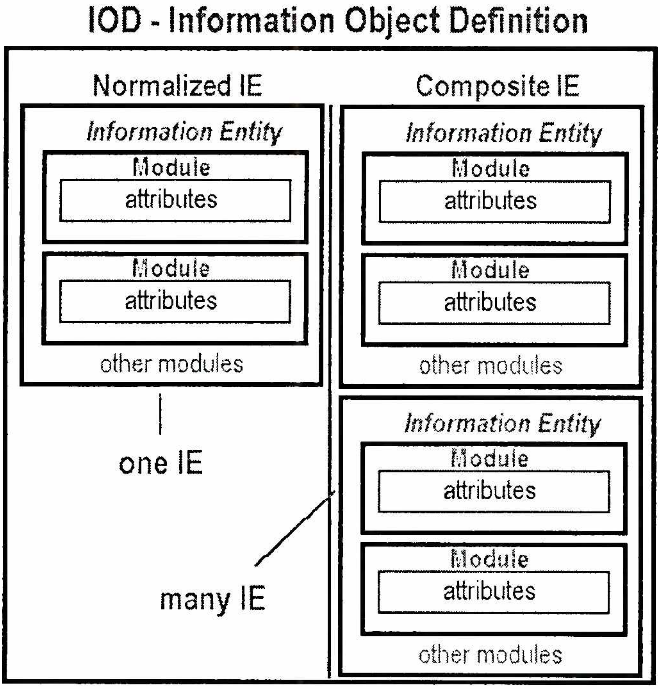

Figure 2. *Structure of IOD*

TAG	***data type VR***	***value length***	***value***

Figure 3. *Structure of Data Element in the DICOM standard*

value, a codes directory and a code meaning (Figure 4). In some situations Data Element value can store a code which is then interpreted by an external codes directory (e.g., ACR case codes, diseases codes, etc.). In medicine coding is extremely important and enables data and knowledge exchange, statistical analysis (epidemiology), patient data security, etc. Especially American College of Radiology codes and SNOMED (Systematized Nomenclature of Human and Veterinary Medicine) DICOM Microglossary (SDM) are important in medical imaging. With SDM it is possible to map DICOM codes to terms defined in Unified Medical Language — UML.

Figure 4. *Application of codes in medical databases*

In DICOM the most important coding is constructed by a TAG value. TAG value consists of two bytes representing logical, thematic group of elements and two bytes indicating a particular element of the group. Each TAG is strictly defined and is presented in the data dictionary, which is one of the DICOM chapters. This helps to reduce data structure size and enables to interpret codes in different languages. Data Element (attribute) in the DICOM standard is an element of medical record for a given information object. TAG can be used as an address of attribute value. With a given address an attribute is tied to a specific column in the medical database table. Storing attributes require definition of data types. Each column in the medical database table should be defined by a description (e.g. TAG — code meaning), a data type specification (e.g. text, number, date, etc.) and a domain of the data type (e.g. text [20], integer, etc.). TAG code allows to tie a data element with a given value representation. DICOM defines the catalogue of data types and domain called Value Representation. Each element in data directory (TAG) has strictly defined VR. This gives opportunity not to include Value Representation in the Data Element. Definitions of data types are a real problem in designing of data exchange systems (information systems). Medical database structure design process has also to take into account this problem. It is especially important to enable mapping of DICOM VR to popular DBMS data types like those defined in SQL standard specifications (e.g., SQL 1992, SQL 1995).

A set of attributes forms a data record in a medical database. Each data record (IOD, in the DICOM standard) should be represented by a unique identifier. Identifiers (in DICOM SOP UID — Unique Identifiers) label a medical database data record and its creator (a device, a medical doctor, etc.). This means that unique identifier is also constructed with specific, standardised codes. It should be underlined that DICOM methodology is object oriented: an object is an instance of a medical record (in DICOM an instance of the IOD class). Creation of a new object is equal to create a new record in the database. In DICOM each object can have special activity defined by methods (services: store, send, print, etc.). This means that creation of the medical structure according to the presented requirements can be directly developed to a medical information system in a given hospital or in other healthcare institution.

DICOM standard is widely adopted in medicine today, but:

- its compatibility is offered as an option to modality, which is a cost element that can be rejected during ordering decision,
- its conformance is described in the "Conformance statement" document, which means that two systems can be compatible with the DICOM standard but not with each other.

3. Message structures in the HL7 standard

HL7 standard, which stands for Health Level 7 (7^{th} level of ideal communication model defined by ISO — application level), is an application protocol for electronic exchange of medical data in a networked environment. The standard defines sets of messages and data formats, whose implementation enables communication of medical systems. The HL7 standard is described in 11 chapters. The most important for the medical database structure designer are:

6. *Observation Reporting — Clinical Observation Report Messages;*
7. *Master Files — Healthcare Application Master Files;*
8. *Medical Records/Information Management — Document Management Services and Resources;*
9. *Scheduling — Appointment Scheduling.*

In appendices of HL7 standard a description of data dictionaries for messages is presented. Data dictionaries can be used to define medical record data types and to create and HL7/DICOM data conversion interface.

Fundamental idea of the communication system presented by HL7 is the events processing. In a case of an event (trigger event) generation, the event is detected and interpreted. According to the type of an event appropriate action is performed. There are different events possible and defined in the standard (e.g., patient in the reception, report ready, etc.). An event can be also generated as a system query. Each event must be acknowledged by a special message. The query event doesn't need to be acknowledged — the answer for the query is the only acknowledgement. There are different query mechanisms that can be used: data filtration, query languages, e.g. SQL, etc. The basic data exchange element defined in the HL7 standard is a message. All messages are classified in different types, according to the kind of information they transport. Each message is composed of data segments, which are the fundamental data record in the HL7 standard. Similarly to a database record a segment describes logically ordered data elements, e.g. Message Header, Patient ID, Patient Visit, etc. Each segment is identified by a unique (Segment) ID, defined by three characters at the beginning of the segment. The first character in the Segment ID code is 'Z'. A segment is a set of fields, which are constructed by characters. Transmission of an empty field means no change required, transmission of the NULL value ("") means delete the field. All possible segments are defined in the HL7 standard and the code set is presented in the appendix.

4. Conclusions

Standards, which define data types, data element structures, record formats and methods of data coding should be considered in the designing process of the integrated, radiological database structures. According to the Figure 1, which presents different activities connected to a patient management in a healthcare unit, it is possible to construct a frame of medical database structures. Each functional part, e.g. patient, visit, examination, etc., should have an appropriate structure of a medical record (class, table, etc.) according to coding methods defined by standards, data types and attribute representations. In an integrated radiological database the following data records should be implemented: patient records (personal data, personal ID, etc.); visit records (date, visit number, etc.); study records (problem identification, medical doctor data, etc.); examination records (exam number, exam type, modality information, exam data — e.g. pixels, etc.); result records (diagnosis, disease code, therapy planning, visit schedule, etc.). With each record (class) some activity can be connected. Activity generated by an object (event) can be also included in the structure of the medical database (the simplest solutions are binary state records, e.g. patient after exam YES/NO). Dynamic database created with such structures can enhance workflow management in a given radiological unit. Properly established procedures are fundamental to run a fast and precise patient management system. Taking into consideration all the requirements made in this paper it is possible to create a good structure of medical database which will fulfil basic conditions of modern computer assisted applications in medicine. The results of the analysis presented here were used to design an integrated, radiological database structure for the Institute of Radiology, Medical University of Gdansk. The project of the system claims that the organisation of database tables and the relations between them should be used as it is presented in Figure 5.

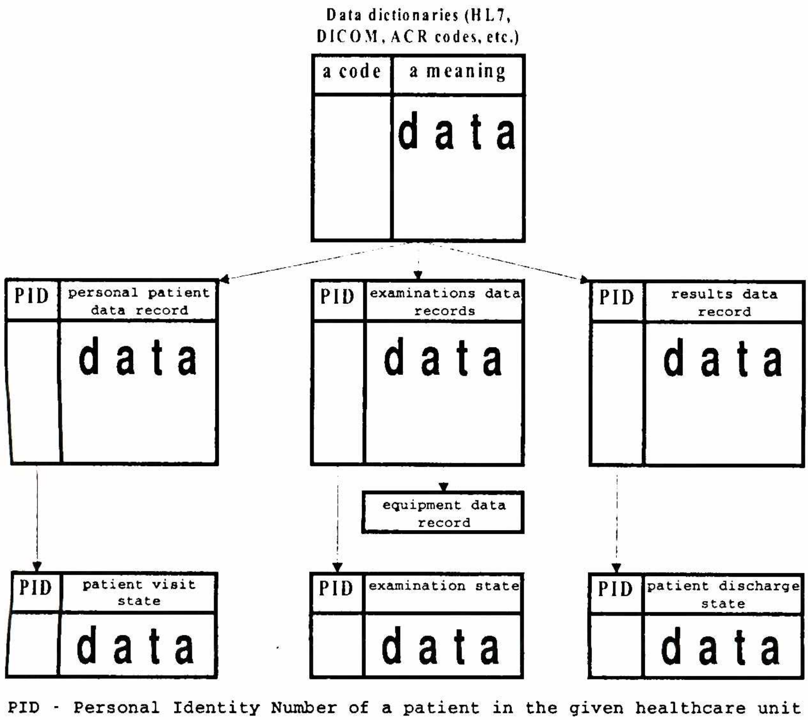

Figure 5. Structure of tables and relations between them in the radiological database project for the Institute of Radiology, Medical University of Gdansk

The implementation of the designed structure is created in the Microsoft SQL Server 6.5. Database clients are constructed with the Java programming language with the application of Java DataBase Connectivity (JDBC 2.0).

References

[1] ARC–NEMA PS3 SET — Digital Imaging and Communication in Medicine, 1995
[2] HL7 V2.3 — Health Level Seven Group, 1997