MRIMS: A new Middleware Connective Level for RIS and PACS

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Abstract: - Information sharing between the RIS, HIS, and reporting systems is addressed by HL-7 standard designed specifically to facilitate text-based information systems' communication. DICOM, on the other hand, was designed to address the sharing of images between different vendors' equipment with little regard for sharing patient information. Hence, another application is required to broker the communication between the PACS and the information systems. Since patient and examination information changes frequently, it is critical to keep the databases involved in transactions synchronized. MRIMS is a complete solution that synchronizes medical imaging and clinical information workflow, by means of creating, viewing and distributing a report, regarding a patient and his/her medical examinations. It ensures the integration between HL7 and DICOM standards by implementing a new protocol model for communication compatibility between those two standards. Specifically designed for the imaging centre or hospital enterprise, this integrated solution will automate processes at every point of patient search, image acquisition, diagnostic reading, and results delivery

Key-Words: Medical information systems, DICOM, Health Level 7, radiology information system, picture archiving communication system, multimedia document, workflow management

1 Introduction

The department of radiology today services all diagnostic and in many cases interventional and radiotherapeutic—imaging needs, of the entire healthcare organization. The medical information that is produced and transferred, and also the administrative and workflow management data constitute a crucial component of the electronic medical record. The whole of this information is the result of a number of activities that are applied during the radiology department's process. These are in general patient registration, appointment scheduling, examination, medical reporting, and imaging examination data archiving. Nowadays, as the IT has become the main mean of automating the every day events and information management in the area of healthcare, two different but not independent systems are in charge for the above activities: radiology information system (RIS) and picture archiving and communication system (PACS) [1].

1.1 What is the question for RIS and PACS?

RIS and PACS seem to be two autonomous systems. However, it is a fact that they implement the interface between the standard workflow of the radiology department and the human resource that participate to it. Each of them is responsible for a number of functions that are distinct and if we follow strictly their definitions they are not covered. They should participate as different actors and with distinct roles during the radiology departement's workflow. The already developed systems (RIS and PACS) are in the majority of them hybrid solutions and overlap each other in the functions that they provide. Thus, the application of the two systems in the same place becomes dysfunctional and requires high operational costs [2].

Even if we consider the case of two systems not covering each other, it is undoubted that the communication between them is necessary. The RIS is the "port", through of which and after the appropriate procedures, the PACS public the imaging exams with the appropriate format, in the "world" beyond the radiology department [3], [4], [5], [6]. For this communication a number of extra specifications rise from the features of the two information systems.

First of all, the two domains of information that each of them administer include some common data. For the proper coordination of them and the correct provision of their services the synchronization of the two distinct data stores is required. This is a sophisticated issue as the integration between the RIS's and PACS's data elements should not affect the processes of each of them and the complexity level concerning the end-user interface.

The second fundamental issue regards the used protocols and the guarantee of compatibility between the communication data and the applied standards. From the one hand, most PACS solutions are based on the technical standard Digital Imaging and Communication in Medicine protocol

(DICOM). From the other, Health Level Seven (HL7) is the protocol that determines the rules for transferring and formatting the information during RIS processes. Currently existing subsystems that act as middleware translators between DICOM files and HL7 messages are stand-alone applications, which are managed directly by user and are not included in either PACS or RIS. This results in more complexity inside the radiology department, which additionally affects the overall time of everyday workflow, due to the fact of its none-automated nature and that the users are most possible not used with such applications.

1.2 A solution for bridging the gap

The requirements that are described in the previous section are covered by the proposed solution, called Middleware Radiology Information Management System (MRIMS). This is an intermediate system between RIS and PACS and its special features result following a two-stage methodology. During the first stage the Case Model of the system is defined. This model is comprised by two diagrams: the Workflow Case Diagram (WCD), which specifies in detail the exact point of the overall workflow in which RIS and PACS need to exchange data and the Use Case Diagram (UCD) that presents the step-by-step administration of this information and the participants as well. The second stage of designing the MRIMS includes the detailed specification of the Communication Model. This model describes the architecture which the communication between the two systems is based on. It is constituted by three distinct levels, with different roles, that transact each other in order to proceed the events that the Case Model defines, applying the rules of data format and transfer of HL7 and DICOM protocols.

Implementing those models, we developed a multimedia radiology information management system using the advanced computing technologies and evaluated the performance of the application. This application was implemented including the optimal workflow management system and distributed components with the following architectural design features:

- Separation among graphical user interface (GUI), workflow process and application logic;
- Full RIS/PACS integration;
- Enterprise interoperability;
- Role-dependent GUI;
- Legacy component reuse;
- Dynamic configuration of workflow processes

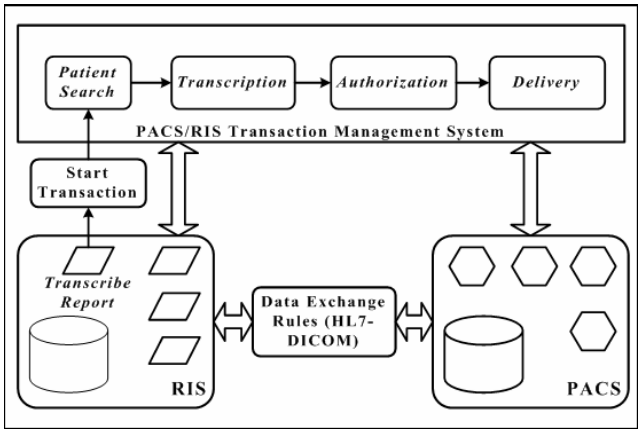

Fig. 1: MRIMS Workflow Case Diagram

2 The Case Model

The goal during designing and implementing the MRIMS is to develop the interface between the two systems. In this first phase, structuring the Case Model we simulate the workflow of their transactions with a set of diagrams that manages the individual procedures within an integrated, autonomous management system. For this purpose we define the WCD and the UCD.

2.1 The Workflow Case Diagram

In Fig. 1 the WCD is presented. It accepts as inbound information the request of RIS for the transcription of the clinical report of a patient and for a specific imaging examination. The outbound result is a completed transcribed and authorized report, delivered to the corresponding placer of the initial examination. The intermediate steps of the workflow define the basic modules of MRIMS and they support the functions of patient search, transcription, authorization and delivery [7]. During the execution of these the transaction with RIS's and PACS's information domains is necessary. The details of each function are analyzed using the UCD.

2.2 The Use Case Diagram

The UCD analyses the WCD in detailed actions, triggered by different actors. The main participants are "Radiology Application User –RAU", the "Radiology Physician –RP' and the "Clinical Physician –CP". The Fig. 2 presents the general use case diagram of the model, showing the allocated steps and the participation of the actors.

2.2.1 Patient Search

The request 'Transcribe Report' of RIS, signals the start of the process. The first step is a *Patient-Based Search* throughout a patient log file. When this action is completed, then the chosen patient's folder

data are acquired automatically from the RIS-data store (*History Folder View*) and the user is notified for the existence of a medical report for a selected exam of that patient. If a report exists for the selected medical examination, a preview of that report is available (*Report Viewing*). If selected, then the demographic data of the patient, the diagnosis and the attached medical images are presented.

2.2.2 Transcription

In case a report does not exist, then the user is provided with the option of creating a multimedia document, based on the data registered into the PACS and RIS Databases (*Create Report*). The relevant clinical data of the selected examination and the patient data are retrieved from the RIS Database (*RIS Related Data Add*). The medical images and the physician's diagnosis are retrieved from the PACS Database (*PACS Related Data Retrieve*).

2.2.3 Authorization

The authorization function performs the electronic medical doctors' confirmation of the content of the multimedia clinical report (*Report Viewing, Data Confirmation*). The digital signature of the conducting medical doctor or doctors substantiates the validness of the produced 'document' (*Digital Signature Validation*), and then the report is considered as totally completed and ready for submission.

The digital signature is the upper level authorization process, during of which the system interacts with the user, which is a radiology physician. In a lower level, internal automated procedures that support the MRIMS services, verify the integrity and quality of the including data, after of which the radiology application user is authorized to deliver the medical report. During the first stage of this process a special implemented protocol is responsible for the management of the transactions between the application programs and the warehouses of RIS and PACS. Secondly, the status of the multimedia report is traced and managed by a signaling process, which is self-activated. (*Data Confirmation*)

2.2.4 Delivery

After the authorization procedure is completed in both levels, the electronic multimedia report is considered as valid to be transmitted to the corresponding placer of the incoming referring (*Send Report*). Again, a second signaling process is responsible for the notification of the clinical physician for the delivery of the requested report (*Signaling*). At this point the referring physician views the full report, as to make his own decision (View *Authenticated Report*).

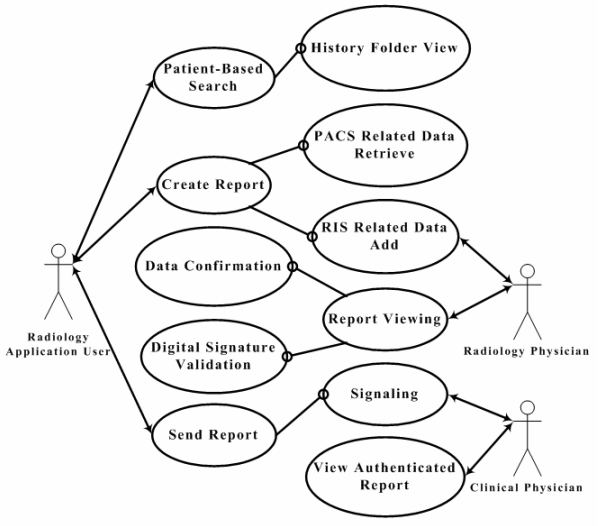

Fig. 2: MRIMS Use Case Diagram

3 The Communication Model

The communication model of MRIMS (Fig. 3) is based on the structure, communication rules and transferred information of DICOM and HL7 protocols. HL7 is a protocol that develops the standards for the electronic interchange of clinical, financial and administrative information among independent health care computer systems. Its scope is beyond imaging and is an event based standard. Additionally, HL7 is made up of segments and their attributes are always text strings, encoded with specific rules and the segment data can change depending upon trigger event. DICOM, on the other hand, is a client/server protocol, made up of tags which data never changes within the same study. Its scope is only imaging and is mainly an action based standard.

MRIMS manages the challenge of integrating these two and apply the encoding and communication rules of both. It considers the transactions described in the previews section with the Case Model, as a synchronous exchange of information and a sequent performance of events, both relied on a three-stage architecture. The three stages of the applied communication model are the Master Files (MFs), the Middleware Protocol Mechanism (MPM) and the Meta-Data Node (MDN) [8].

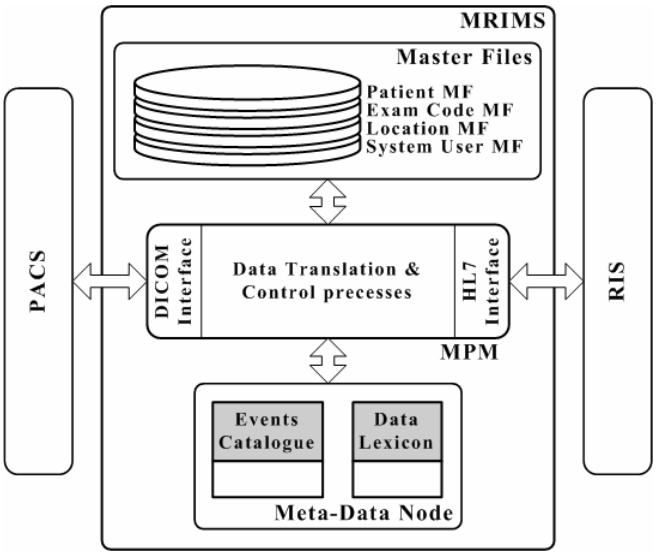

Fig. 3: MRIMS Communication Model

The Master Files specification is based on the open-architecture approach that we apply for the medical information systems, regarding the division of the workflow functions and the specification of communication modes during their cooperation [9]. The MFs are the common reference files that are managed by the MRIMS and required for supporting the provided services, maintaining the whole performance, synchronizing the various application sites and control the status and routing of the transferred data. Their structure and content is based on a number of initial assumptions taking as given the worst case study that RIS and PACS are not designed to work together.

1. PACS and RIS have their own data stores
2. Each data store involves its own patients and users catalogues
3. The patients and the users of each application system has primary identifications numbers, which differs, even though regarding the same people
4. The two application systems use the same types of imaging examinations
5. The referrings that arrive to RIS for scheduling the exams are the same with those that arrive to PACS
6. The structure of the PACS information is based on the DICOM modules and this of RIS on HL7 classes

The System User Master File provides all the required information regarding the users of the MRIMS. In this master file the external identification numbers (registration codes in RIS and PACS data stores) of the users regarding both systems and their primary MRIMS codes are involved. The Location Master File 'maps' the sites that supply the radiology department with exams requests, as well the sub-departments of the radiology department. The Exam Code Definition Master File contains all the types of examinations that are served in the radiology department and are used as definitions by all the sites contained in Location Master File. The Patient Master File is the main patients' catalogue in the perspective of registering the external IDs of the patients and integrating them, identifying the information that regards the same persons.

The second informational part of MRIMS is the Meta-Data Node and contains two main directories, the Events Catalogue and the Data Lexicon. The Events Catalogue identifies all the allowed events that occur for the performance of the MRIMS transactions and specifies the interface of each such event. The structure of the events' definition includes a number of parameters. The name clause identifies the event. The object-type clause can have the values of 'query', 'data-event' or 'MF-process'. The 'query' and 'data-event' events perform the transactions with the database of RIS and PACS and the 'MF-process' events allocate the exchange of data between the MPM and the MFs. The inbound clause contains all the semantic information needed to implement the managed transaction. The outbound clause indicates the returned data elements (if they exist) and the error status ('non-error' or 'ErrorID'). Finally, the description clause contains a human-readable textual definition of the event. An example of such an event is the PatIdentification event:

Name	PatIdentification
Type	query
Inboubd	'PID-MRIMS' or 'PID-RIS' or 'PID-PACS'
Outbound	'PatFirstName', 'PatLastName',..., 'ErrStatus'
Description	'The elements of patient's identity are retrieved from the RIS or PACS database, according to the inbound parameters'

The Data Lexicon is a table which contains the used field names translated to HL7 segments and DICOM tags. Each event that requires the analysis of a HL7 message, reading a DICOM file or even pass from the one protocol to the other in order to serve a transaction, references to this table to bind the information and make the proper conversions. The Table 1 presents a part of the Data Lexicon.

The Middleware Protocol Mechanism serves the communication of RIS and PACS through of MRIMS, applying a set of cascaded events in three stages, for both directions of communication. The three steps include processes that implement the DICOM compatible MRIMS interface, the HL7 compatible MRIMS interface and the internal processes of translation and control.

Table 1: The Data Lexicon of MDN translates the MPM fields to segments (HL7) and tags (DICOM)

Field Name	HL7 Segments	DICOM Tag
Patient Name	PID-5	(0010,0010)
Primary Patient ID	PID–4	(0010,0020)
Requested Procedure - Name	OBR-4	(0040,1001) (0032,1060)
Requested Procedure - Code	OBR-4	(0032,1064)
ClinicalReason for Exam	OBR-13	(0032,1030)
Requesting Physician	ORC-12	(0008,0090) (0040,1010) (0032,1032)
Performing Technologist	OBR-34	(0040,0006)
Report Status	OBR-25	(4008,0212)
Report Text	OBX-5	(4008,010B)
Interpreting Radiologist	OBR-33	(4008,010C) (4008,0102) (0008,1060)
Supervising Radiologist	OBR-32	(0008,1060)
Verifying Radiologist	ZRR-4	(4008,0114)
ETC.		

The Data Translation and Control processes are responsible for the performance of MRIMS transactions in a low level and is totally in charge for the administration of information. The triggering events of these processes are the requests that the actors address. For the service of RIS and PACS communication they state the appropriate requests to the corresponding interfaces and manipulate the responded data properly. The internal processes actually perform the functions of the Events Catalogue and make the translation of the data fields, using the Data Lexicon's definitions. Additionally, they transact with the MFs properly, as to confirm the identities of participants, fill the communication data and execute the authorization and authentication rules for the MRIMS users. Finally, this part of MPM takes on the signalling procedures, the total surveillance of the modules and the management of information status.

The DICOM interface sends the appropriate queries that have been built by internal processes to the PACS and waits for the response, which includes the corresponding DICOM file and its context. The modules of the formatted file are recognized, read by the interface and the included attributes pass from the interface to the proper internal processes for further administration [10].

The HL7 interface establishes the appropriate communication mode for the transaction with RIS. The transferred data are encrypted HL7 messages and serve either queries or orders from the MRIMS to RIS. Following the opposite direction the returned messages include the queries' results or acknowledgements for the validation status of the messages or the information. Procedures for the configuration, synthesis, cryptography, recognition, analysis, service, correction and transfer of messages are included. The initial requests are made by internal processes and the results are placed back to them for the completion of the served transaction.

4 Implementation

MRIMS is implemented using emerging technologies in programming language, distributed computing, workflow management, and databases. RIS and PACS data-stores are Oracle databases, the interface is built using the Visual Studio tools and libraries and we used PL/SQL language for the data manipulation commands. The HL7 messages and DICOM files are transferred with TCP protocol.

In Fig. 4 the end-user interface of MRIMS is depicted. The first form is used for *patient's search* and view of *reports catalogue*. From this form the end-user triggers the start of 'Transcription'. The second form implements the 'View Report' and 'Transcription' functions.

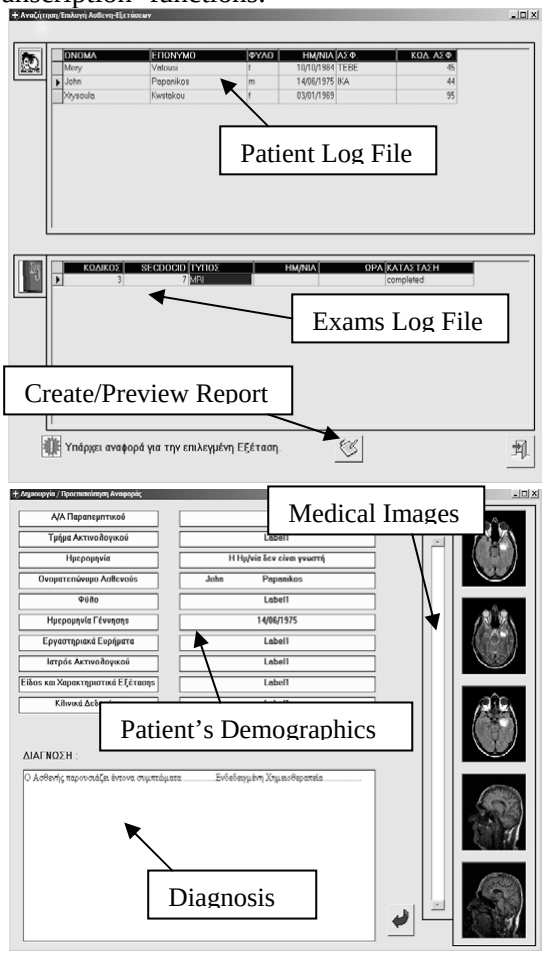

Fig. 4: MRIMS end-user interface

The graphic area of the user interface is composed of work spot, work overview, and patient overview areas. Role-dependent GUI is one of our fundamental design goals. In the design, the role-dependent GUI is realized by using role-dependent graphical components for patient and exam selection, pre-exam viewing, and report composition and overview. Other components, such as work list display or navigation, are role-independent.

Each service should provide operations for any display components to acquire data with operation returns in presentation-ready formats. The application is composed of automated procedures of those services for data transfer and relational database access. The external data transfer service acts as a gateway to access radiology information through HL7, DICOM, and other proprietary non-DICOM protocols. Images from PACS are retrieved by the data transfer service using the DICOM protocol, as is the signed diagnosis document file. Any relevant data, including patient demographic data and history file, are automatically acquired from the RIS database.

5 Conclusion

A known problem with PACS is communicating to all of the "actors" in the process that the images have gotten to the "next step." Typically, the PACS does not communicate a status message back to the RIS that the images have been committed to storage or are being acted upon. MRIMS solves this issue, by addressing, this service class as an automated procedure of the application. In the integrated RIS/PACS, the requirement is that events are tracked and status messages are communicated and recorded in the database. The value of this is that all users are aware of the status of clinical workflow. The value of the integrated RIS/PACS is to provide a single database that manages the image and information workflow of a radiology department. In addition to acquiring, storing, and displaying radiology text-based and image information, the integrated RIS/PACS solution creates worklists, tracks events and updates the status of the orders, maintains awareness of all of the analogue and digital information, eliminates paper-based information, and manages all of the clinical and business processes. In theory, the cost of ownership and complexity is reduced by eliminating the number of required interfaces, reduces or eliminating the number of databases, hardware, and vendors involved. The term "in theory" is stressed because currently there are only a small handful of examples of comprehensive, single database integrated RIS/PACS.

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