# Hospital Information System using HL7 and DICOM standards

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*Abstract:* In the medical world of nowadays, the information systems and the standardization of the transmission protocols have been gaining more and more importance. Therefore, the integration of different kinds of medical software applications has become mandatory. In order to achieve this, the HL7 – Health Level Seven standard has been developed, which offers a set of rules and algorithms related to the medical field. This paper illustrates the use of HL7 and Web Services to form an integrated medical pilot system, specially adapted to the Romanian sanitary system.

*Key-Words:* - HIS-Hospital Information System, HL7 – Health Level Seven, eHeatlh, DICOM, Web Services, XML

## 1 Introduction

Informational systems and the standardization of data transfer protocols have become an important part of nowadays medical world. Software applications have become an indispensable tool for the specialist engaged in the medical act. In this sense, the use of information and communication technology has influenced greatly the fast and reliable (also secure) transmission of medical data throughout informational systems, shortening the required processing times.

The increasing use of IT&C in the medical world also demanded for new protocols that would facilitate data transfer (between different software application) and data storage in a common format. Likewise, several organizations have undertaken this difficult task of medical digital data standardization, among which the National Electrical Manufacturers Association (NEMA) and American College of Radiology (ACR) are the most important ones. Their efforts concentrate mostly in the development of the **DICOM (Digital Imaging and Communications in Medicine) standard.** It has all started in the 1970's with the increasing use of CT scanners and other image-based diagnostic devices that opened the way for large – scale deployment of software applications in the medical field and thus the need to interface machines and applications manufactured/ produced by various companies was born. This translated into the need to specify a common image format for all medical imaging devices.

- In 1983, ACR and NEMA delegated a committee to solve this problem and propose a standard that would allow the following:
- Data exchange concerning generated digital medical images between devices produced by different manufactures;
- The development of PACS (Picture Archiving and Communication Systems);
- The development of medical databases able to be interrogated using (geographically) distributed software applications;

In 1985 version 1.0 of the DICOM standard was published by ACR and NEMA, followed by 2 revisions in October 1986 and January 1988. Version 2.0 of the standard was issued also in 1988 and added a set of commands for the displays, by introducing a new image identification scheme based on „data-elements" for a better characterization of the image parameters [2].

The last published version, 3.0, issued in 2000, contains a large number of changes and additions with respect to the previous ones. The DICOM standard facilitates medical imaging equipments inter-operability by specifying:

- A set of protocols that complaint devices must respect;
- The commands' semantics and syntax as well as the associated information format that can be transmitted using the protocol.

In a heterogeneous system, in order to integrate medical equipments supplied by various manufactures, the use of DICOM and HL7 standards is compulsory. DICOM, as previously presented, is mainly dedicated to medical imaging, whereas **HL7 (Health Level Seven)** covers more general aspects of medical digital data processing and management. HL7 is used for the transmitting data related to patient charts and files but also associated documents and audio recordings. The number „7" refers to the „application" layer, the 7$^{th}$ one from the OSI (Open Systems Interconnection) model system representation [1].

The HL7 standard was first published in 1987 by a group of medical equipment manufacturing companies. Version 2.0 succeeded in 1988, followed by versions

2.1, 2.2, 2.3 and 2.3.1 in 1990 to 1999. In 1994 ANSI (American National Standards Institute) officially recognized it as an industry standard. Currently, version 3.0 is on its way, with a draft already released.

The main objective of the HL7 standard is to produce a set of specifications that allows free communication and exchange of data between medical software applications in order to eliminate or reduce incompatibility among different applications. To achieve this, the following measures have been proposed:

- the standard must support information exchange between systems implemented in a large variety of development environments (technical) and communication environments. Its implementation must be possible in all the major existing programming languages.
- immediate, single transaction, transfer must be available in the same time as file sharing/transfer based on multiple-transactions;
- the highest degree of standardization must be obtained when compared to the most often encountered cases of elements formatting; the standard must comply with the specific necessities of each medical field. Accordingly, the standard comprises situation specific tables, definitions and segments that can be customized (Z-segments)
- the standard must cope with variations suffered in time due to inherent technical progress and evolution;
- the standard evolution must be based on the experience already gained and on already existing and well known industrial protocols. Favors given to certain producers or companies must be avoided by all means.
- HL7 makes no presumptions related to the architecture of the medical informatics system, and does not try to resolve the architectural differences present in medical informatics systems. Due to this reason, HL7 cannot have a „plug and play" interface.
- a first interest of the HL7 workgroup was to use the standard as soon as possible. Once published, HL7 was voted and recognized as a standard by American National Standards Institute (ANSI) and Accredited Standards Organization (ASO).
- currently, the cooperation with other standardizing organization from the medical field (ACR/NEMA DICOM, ASC X12, ASTM, IEEE/MEDIX, NCPDP, etc.) has become a priority for HL7 and focus on a better development of medical informational systems has contributed to the group's joining to the ANSI HISPP (Health Information Systems Planning Panel) process, ever since its debut, in 1992.

The two standards, DICOM and HL7, form the basis of the informational integration of software based medical processes. In November 1998, Healthcare Information and Management Systems Society (HIMSS) and Radiological Society of North America (RSNA) founded the **Integrating the Healthcare Enterprise (IHE)** forum, with the declared goal of helping the integration of software application from various medical fields and domains. Its main objective is to ensure that in the course of the medical act all the information necessary in the decision making and taking processes are accurate and available in time for the medical specialist. Its purpose is not to define new standards, but to promote the use of the existing ones, namely DICOM and HL7. Currently the main focus is on radiology. The DICOM and HL7 standards provide the necessary means and technology for developing software applications, while IHE supervises their adoption into real-life medical world. IHE provides support for the users of medical software applications by ensuring a better access to information and eliminating, as much as possible, confusions or misunderstanding when acquiring such applications.

From the medical software application development point of view, the IHE specifications facilitate fast and safe releases of new products as well as simple mechanisms for implementing interfacing options with other, already existing ones.

## 2 General overview of the HL7 standard

The HL7 standard addresses software developers and medical equipments manufactures with the declared goal of unifying the way the information present in medical units and institutions is transmitted, exchanged and/or stored, based on a common format, agreed by all involved parties [6]. There are other standards dedicated to the medical sector, each having a very well defined domain and focus: pharmacy, medical devices, medical imaging, and insurances. HL7 is, on this matter, dedicated to the processing and management of administrative and clinical data [3]. The HL7 focuses on the following fields/domains:

- Patient management – admit, discharge, transfer patient (ADT);
- Queries, resources (rooms, beds, devices, etc.), patient scheduling;
- Scheduling of medical procedures, results, clinical trials;
- Financial administration;
- Medical documents;
- Medical records;
- Medical treatments;

Taking into considerations the great variety of applications involved in the process of the medical act and the requirement that these have to exchange information/data between them, it is obvious that many of such communication interfaces would greatly benefit from using a standardizes approach [5]. The HL7 standards comes exactly to solve this problem and ease the burden of message passing and data exchange between various applications by providing a very precise structure under which this must happen.

The „Level Seven" syntagm from the standard's name indicates that this standard belongs to the seventh layer of OSI (Open Systems Interconnection) model, also called the application layer.

Therefore, medical applications can use several communication protocols, and at application level they will communicate using the HL7 standard. The most used communication protocol for HL7 is TCP/IP. The OSI model when deploying TCP/IP for communication is illustrated below:

| OSI Model | |
|---|---|
| 7 | Application Layer **HL7** |
| 6 | Presentation Layer |
| 5 | Session Layer |
| 4 | Transport Layer |
| 3 | Network Layer |
| 2 | Data Link Layer |
| 1 | Physical Layer |

| TCP/IP Model | |
|---|---|
| 7 | Application Layer **HL7** |
| 6 | Doesn't exist |
| 5 | Doesn't exist |
| 4 | Doesn't exist |
| 3 | Doesn't exist |
| 2 | Host-to-Network |
| 1 | |

| | |
|---|---|
| HL7 Application (client or server), Telnet, DNS, FTP, SMPT, POP3, HTTP, etc. | Application |
| TCP UDP | Transport |
| IP | Network |
| LAN, WAN, Radio with packets | Physical and Data Link |

Fig.1 Comparison between OSI and TCP/IP models

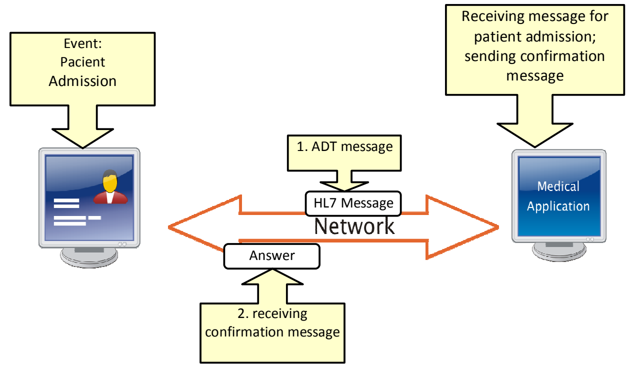


Fig. 2 Example of using HL7 messages

A medical application that uses the HL7 standard will send to another application a "HL7 type" message generated as a result of some medical event occurring in the current activity: admit patient –A01, transfer patient – A02, discharge patient – A03, etc. If the application receiving the messages also complies with HL7 regulations, then it can be certain that there will be no missing information, all information received will be interpreted the right way and a proper response will be issued back. Thus, the exchange of information made would be coherent and efficient [1].

The HL7 standards define a number of messages that cover all activities specific to medical units. The HL7 messages are characterized by the *message* type, made up of a 3 character code. Message types are organized by different domains/fields (e.g. admit, discharge, transfer, clinical trials scheduling, etc). A HL7 message is made up of: segments, fields, components and sub-components.

The *segment* is a union of fields. Each segment begins with a three-character literal value that identifies its type within a message. A group of segments forms a message. The HL7 standard clearly specifies what segment types can form a certain message type.

Each segment is composed of several *fields*. Not all fields within a segment are mandatory. The compulsory fields are defined by the HL7 standard. A HL7 field has the following characteristics:

- data type
- predefined maximum length
- unique ID
- name
- optionality
- HL7 predefined table
- when the standard permits, the fields can be repeated

The HL7 fields are composed of one or more *components*. *Subcomponents* are used when dividing components is needed.

## 3 The architecture and functionalities of the SIMIMED

This software application is a result of a very good collaboration in medical software research field between Technical University of Cluj-Napoca and PixelData Company. The project aims to develop a pilot HIS integrated system using the latest standards available (HL7 and DICOM), adapted to the particular case of the Romanian National Health System and compliant with the EU requirements. Figure 3 presents the main functionalities of the SIMIMED application.


Fig. 3 - SIMIMED packages overview

The SIMIMED application contains a packet of software modules that provide 4 service categories:

- The **HIS integrates system**: is made up from a server application and client applications distributed by sections/departments. The system uses the 3 tier architecture. The communication between client and server is based on the http/https protocol. The HIS application is used for saving information in the database, client application management and database querying. The server connects to the Microsoft SQL Server database using an ADO connection and uses the web service principle loaded by the IIS server; each service is workflow – oriented. The HIS client applications offers the client a friendly and intuitive graphical user interface that allows the user to input or retrieve data into/from the SIMIMED system. It is implemented in C# and communicates with the server using the http/https protocol [7].
- **Datacenter** – is a server application that manages the data stored in the common database by all the HIS applications running in different hospitals/institutions. This is intended to store medical data to be used by researchers. The storage center will be developed based on the Microsoft SQL server technology. The HIS servers running at the medical institutions involved in the project will send data to the storage center. In the data exchange process between the HIS servers and the Datacenter the HL7 together with the TCP/IP protocol are used. Due to the fact that the data stored will be used mainly for research purposes, no information that would allow patient identification will be stored.
- The **web application** – is a web-client application that allows access to the data stored in the Datacenter. It will be used by the researchers, students and PhD students to study different cases classified by the Datacenter. The access is controlled by the data center administrator, who is entitled to issue access accounts based on username/password pairs.
- The **AdminTool** application – is a web application used for remote administration of the HIS server, and allows for quick and in time support in case of malfunctions.

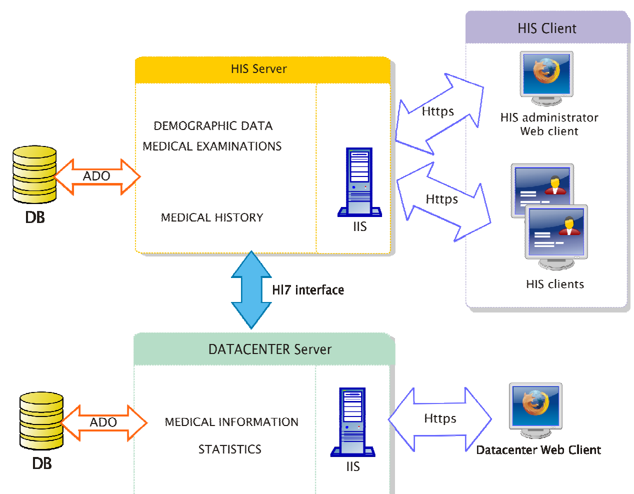


Fig. 4 SIMIMED system architecture

The SIMIMED HIS client contains six important modules: Patient List, Patient Demographic, Examinations, Surgery, Patient History and Schedule.

**Patient List module** allows to retrieve a list with all the registered patients and some basic information about them like sex, location, status, diagnosis, hospitalization date and criteria.

**Patient Demographic module** contains the graphical controls to add/edit/search demographic data of a patient. Using this module one can add/modify visits, document upload/download documents, add/modify transfers or other type of information (allergies, antecedents, and medical history), health insurance, and patient discharge.

**Examinations module** allows the editing of information regarding examinations taken on a patient, and contains a visit list and 4 tab-controls: *general clinical examinations* – for general information (height, weight, general condition), *examinations* – for surgery procedures, *specialty examinations* (ex. oncology, radiology), *and evolution and treatment*. Data in each tab-control is loaded from the server based on the selected visit, and can be modified if the selected visit is the current one.

**Surgery module** contains components regarding surgery intervention. We can edit information related to intervention date, operating physician, assistants, medical equipments or tools used and the list of surgery interventions in the selected visit.

**Patient History module** contains in a single tab-control all the relevant information regarding patient visits: the list of visits, list of surgery interventions, medications, documents, allergies, transfers.

**Schedule module** is used by physician to schedule meetings with patients, interventions and other events. This module will contain a reminder for upcoming and important events.

## 4 Implementation of the SIMIMED

The main technologies and concepts used in the implementation process of the SIMIMED HIS, are:

- Service Oriented Architecture (SOA) - provides methods for systems development and integration where systems package functionality as interoperable services, by means of loose coupling and using the Web Service Description Language (WSDL) [4].
- Web Services – is a realization of SOA, which relies on web standards such as SOAP, HTTP and XML to communicate. The Microsoft implementation of web services is Windows Communications Foundation (WCF), through which service endpoints are created in SIMIMED [8],[9],[10].
- SQL Server 2005 is used as database support for the project.
- ADO.NET – for data access and manipulation [11],[12],[13].
- Windows Forms – API for creating user interfaces.

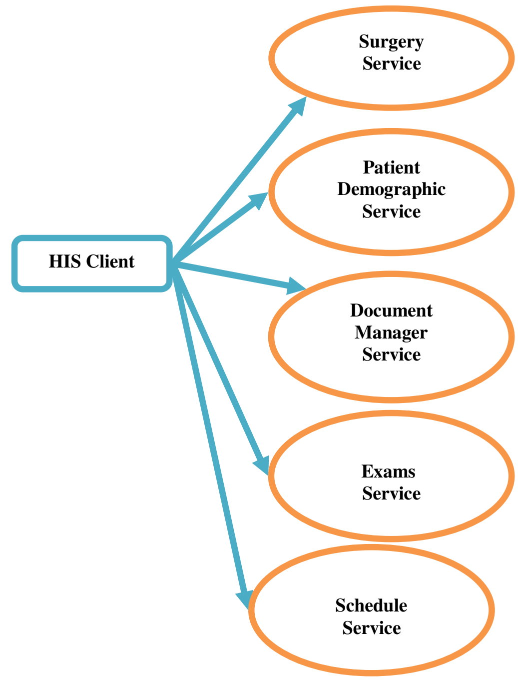


Fig. 5 Implemented web services

The Server application is built up by separate and independent web services (figure 5). Each web service has several methods to serve the client with the corresponding information in a given client module.

The *PatientDemographic* service contains the web service methods that are related to the demographic and admission/transfer/discharge information of patients. The most important ones are methods for adding/modifying patient, visits and transfers entries, as well as releasing a patient, searching patients and related information.

*DocumentManager* service – provides the means to upload and download any kind of document, using streamed transfer

*Surgery* service – defines the methods necessary for surgery intervention related information transfer, like: adding new intervention, returning the list of all interventions from a visit, adding medical personnel to operators list.

*Exams* service – provides the methods related to patient's examinations during a visit: add/modify/delete examinations, add/update general information for general clinical examinations, add/update specialty examinations, add/update evolution and treatment.

*Schedule* service – contains methods for scheduling patients' hospitalizations and interventions.

On the client side, the application is split into panels, each one focusing on different types of medical information. Six panels have been implemented so far:
- one for listing patients and some basic information

- one through which patient demographics, visits, releases, transfers allergies and insurance can be managed
- one for managing different kinds of examinations for each patient visit
- one for surgery intervention management, including selection of operating staff.
- one for listing the patient's history
- one for scheduling interventions and hospitalization periods and locations

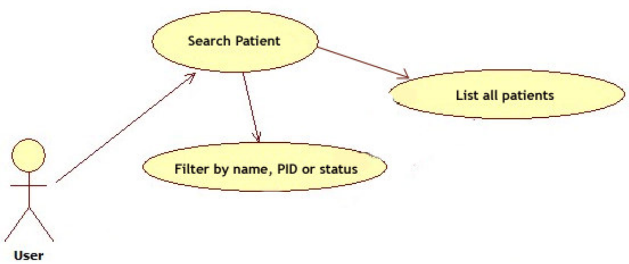


Fig. 6 - Use case diagram for PatientList

Fig. 6 represents the operations that can be performed by the user on the PatientList panel:

- Search a patient by name, surname, CNP or status and display some basic information
- List all patients' basic information

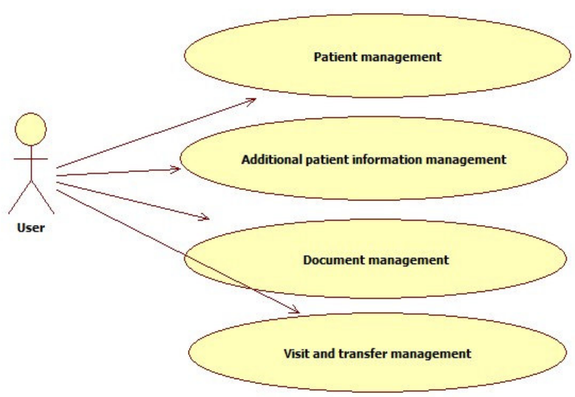


Fig. 7 - Use case diagram for PatientPanel

Using the PatientPanel, as can be seen on Fig.7, the user can perform the following operations:

- Patient management: adding a new patient entry, editing existing ones, and search for existing patients in the database
- Visit and transfer management: adding new visits for existing patients, adding intra-hospital transfers for visits, closing a visit either by releasing the patient or in case of patients
- Document management: adding/deleting any kind of document to a patients file
- Additional patient information management: including patient allergies and medical background information

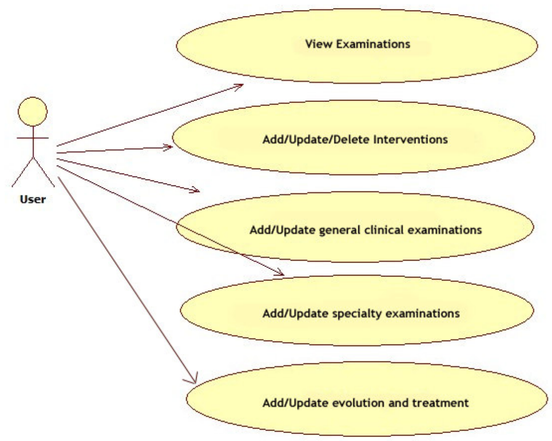


Fig. 8 - Use case diagram for ExamsPanel

As it can be seen in Fig.8, the user can do several operations on the ExamsPanel:

- View examinations for a selected patient visit
- Add/Update/Delete interventions: the user can add new examinations, update or delete the existing ones for an active visit
- Add/Update general clinical examinations: the user can add or modify the results of a general examination for an active visit
- Add/Update specialty examinations: the user can add or modify the results of specialty examinations for an active visit
- Add/Update evolution and treatment: the evolution and treatment of a patient can be easily monitored using this tab; a 72 hour diagnosis can also be set in this section

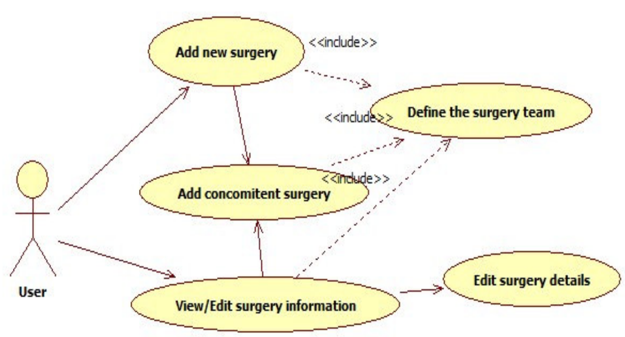


Fig. 9 - Use case diagram for SurgeryPanel

Fig. 9 represents the possible operations that can be performed by the user on the SurgeryPanel:

- Add new surgery: adds a new surgery intervention entry, which includes the definition of the surgery team, and can include adding a concomitant surgery intervention
- View/Edit surgery information: the user can view the surgery interventions for a selected patient, and can edit the active one

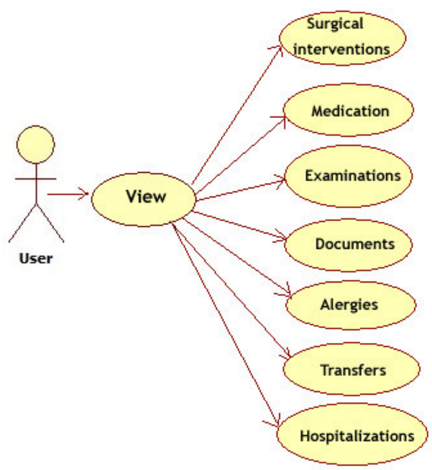


Fig. 10 - Use case diagram for PatientHistoryPanel

Fig.10 illustrates the operations that can be done on the PatientHistoryPanel:

- View for a certain patient all surgical interventions, hospitalizations, medication, examinations, documents, allergies and transfers

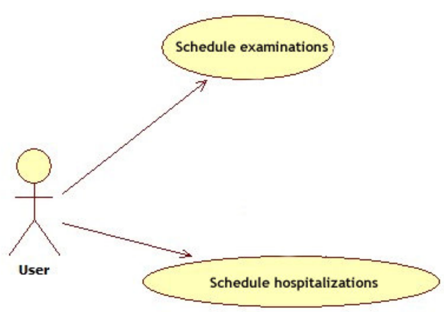


Fig. 11 - Use case diagram for SchedulePanel

Fig.11 represents the operations that can be done on the SchedulePanel:

- Schedule hospitalization: schedules the date and location of a patient's hospitalization
- Schedule examinations: schedules the date , location, procedure and doctor for an examination of a hospitalized patient

## 5 Integration interfaces

The Hospital Information System called SIMIMED has a special interface for integration with radiology department using HL7 and DICOM standards. The Hospital Information System can send orders for imaging procedures to imaging centers using HL7 interface. The HL7 messages are ADT – for patient information and ORM – for order/procedures information. The Radiology Information System (RIS) knows to read the HL7 messages and store the information about patients and orders for image acquisition, processing and results.
After the radiologist final signed, his report the Hospital Information System receives the signed report in two ways:

a. Using HL7 messages - using ORU (Observational Results (Unsolicited)) messages. The RIS sends ORU messages to SIMIMED HIS contained the result and additional information, like: patient name, procedure name, name of radiologist, date of final signature.

b. Using DICOM standard – the SIMIMED HIS can receive the result using DICOM PDF encapsulation.

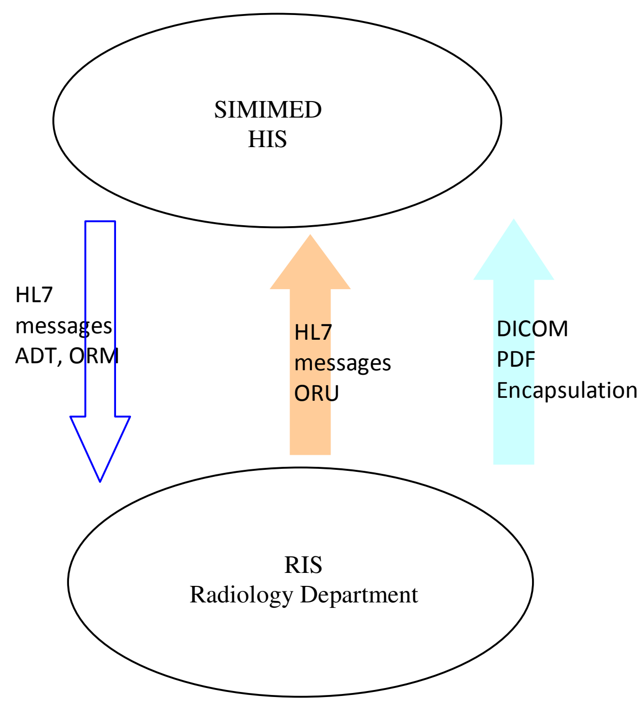


Fig. 12 – HIS/ RIS interface

# 6 Results

In the current development stage of the SIMIMED system, we have successfully implemented graphical user interface components for HIS client and web services for the HIS server, offering the users the possibility to manage patient demographic information, along with administration of visit, transfer information, examinations, surgery intervention details and schedules.

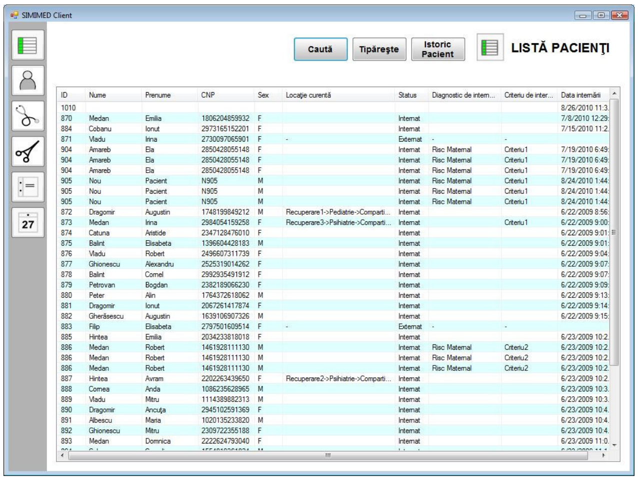


Fig. 13 - UI for patient list

Figure 13 shows the user interface for viewing a list of registered patients. The patients can be searched and filtered by name, surname, CNP and status.

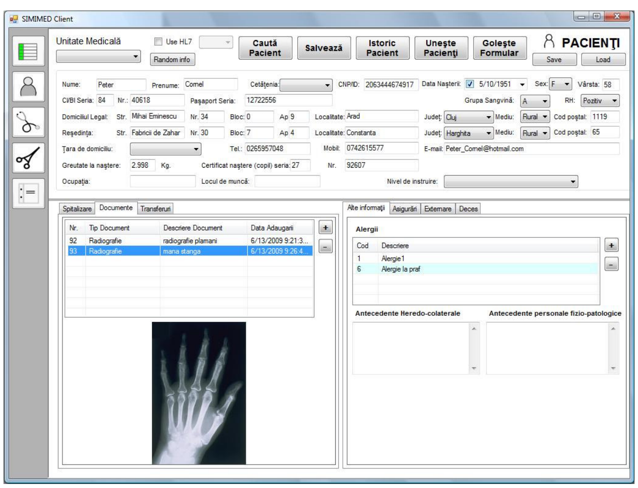


Fig. 14 - UI for patient demographics and transfers

Figure 14 presents the user interface for patient management and surgery information management. The user can create a new patient entry, search for a certain patient in the HIS server, add or modify transfer information and to enter release information, and also add or delete patient documents. All these operations can be performed by the user using the panel presented in Figure 7.

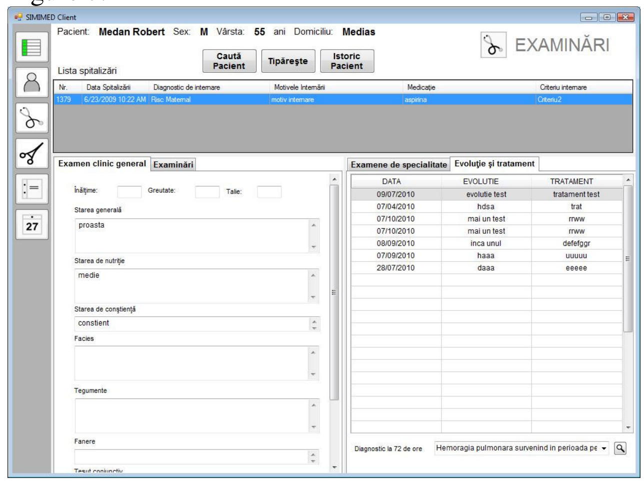


Fig. 15 - UI for patient examinations

Figure 15 shows the user interface for managing examinations information. Using this panel, the user can edit general clinical examination information, procedures, specialty exams results and evolution and treatment for a certain active patient visit. For the closed visits, the information provided is read-only.

In Figure 16 is presented the UI for surgery information management. Using this interface the user can add new surgery entry, which includes defining the surgery team, intervention details, concomitant surgery information and also view information regarding past surgeries that the patient had suffered.

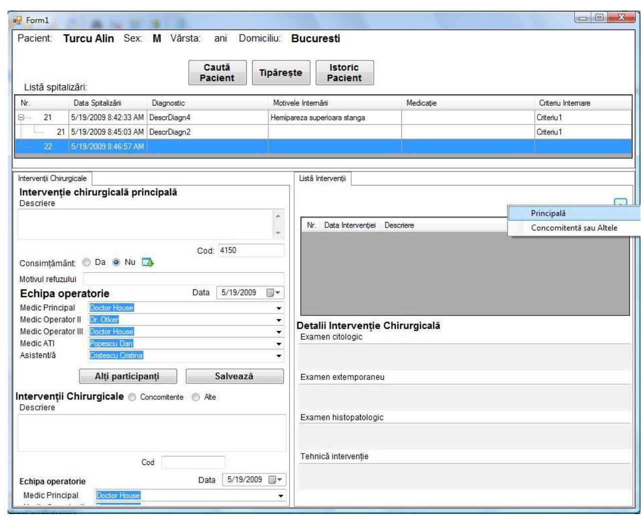


Fig. 16 - UI for surgery interventions

A HL7 interface has been added to the panel in Figure 16, which allows the creation and parsing of HL7 versions 2.6 and 3.0 messages, for basic demographic information.

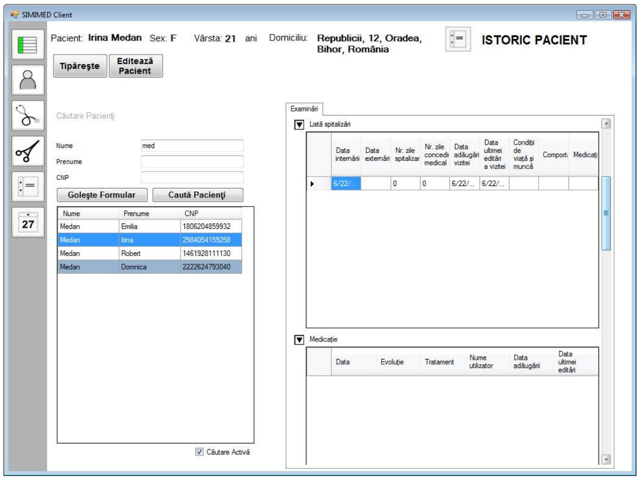


Fig. 17 - UI for patient history

Figure 17 illustrates the user interface for viewing the patient's history. The user has the possibility to search for a patient and view all of its transfers, hospitalizations, examinations, surgical interventions, medication, allergies and documents. The user can also be redirected to the patient demographic panel, for further editing of patient's information.

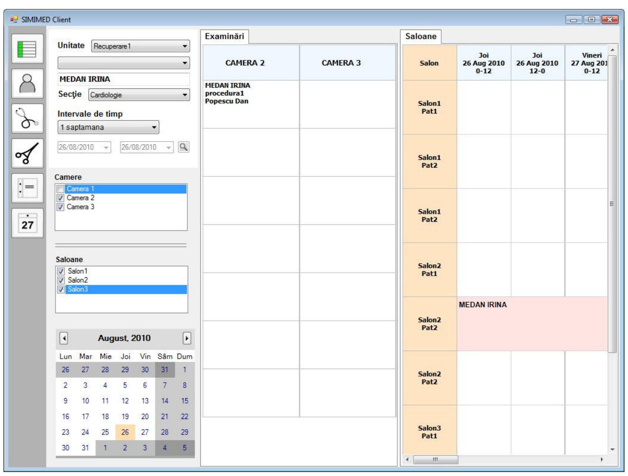


Fig. 18 - UI for schedule

In Figure 18 is presented the user interface for scheduling hospitalizations ( the tab on the right) and examinations ( the tab on the left) . The user can select the desired date and location and search for a patient to schedule. The displayed period can also be customized, the default one being one week. After scheduling a hospitalization, the user can also schedule examinations for the patient. Options for cancelling or rescheduling are also available.

# 6 Conclusions

This project aims to integrate the informatics domain with medical/hospital domain to improve the efficiency of both medical and administrative staff of a hospital.

The software architecture of the project is an open one, making use of WebServices and HL7 standard WebServices make the service endpoints to be easily used by other developers with reduced development time. Also it allows the system's developers to easily change the endpoint (like the transmission layer, the authentication method, the encryption used, etc.).

In the current stage of this project, the architecture of the SIMIMED HIS and Datacenter systems are defined, based on the current medical data management, and on the feedback from medical doctors. Its architecture is based on the SOA paradigm.

The database structure is completely designed and implemented, based on the currently used medical chart in Romanian healthcare.

At this time patient management, surgery information management, examinations, patient history and scheduling features are implemented on both the HIS server and client modules. Also basic HL7 messaging was developed.

The look and feel of the client application is very close to the designer's expectations, by putting a lot of effort in modifying and creating WF user controls to obtain the desired behavior. The result is a user friendly and simple to use client application that doesn't require sophisticated computer skills.

Currently only business logic errors are handled, the rest of errors, related to networking problems, memory resources, file access, etc. will be implemented later on.

The HL7 messaging needs to be extended to include the same features as the services on the HIS Server.

Software applications used in medical centers must be modular and scalable in order to meet the needs of beneficiaries. To ensure the proper integration of various software modules it is necessary to use HL7 and DICOM standards which provides a set of rules and algorithms specific to the medical field.

The system is still in development process, most certainly will change and add some features based on the physicians' feedbacks.

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