OraHealthX ImaginX A next generation cost effective medical imaging workflow management platform

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***Abstract* — Currently, several traditional IT systems exist for supporting workflows of medical imaging departments. However, there is the recognized need for the next step; an integrated and low cost open architecture platform which can manage various kinds of healthcare workflows. The implementation of such solutions can be achieved by intelligent integration of existing systems, the use of web technologies, the utilization of available web services and web semantic ontologies. Based on this approach, this paper presents an advanced, integrated web platform that is generic, agnostic, knowledge based, mobile oriented and supports all medical imaging workflows, complying at the same time with international standards and initiatives. Furthermore, the utilization of knowledge management techniques and semantic web ontologies facilitate prognosis and diagnosis procedures, increase productivity and improve the accuracy and reliability of medical diagnosis.**

Keywords – Medical Imaging; RIS; PACS; Semantic Image Annotation; Medical Ontologies

I. INTRODUCTION

The absence of an integrated IT solution in a radiology department has been proved to be the cause of some serious problems. For instance, radiology departments that use conventional film are facing several limitations and risks. For example, the expensive film can be printed only once and there is a possibility of loss or theft. In addition, radiology units that decide to archive medical images using individual, non-centralized PACS from various modality vendors have a lot of interoperability problems. Moreover, Radiology departments with traditional RIS/PACS systems force users to work locally, without taking advantage of web and mobile technologies for online access and image or data distribution [1, 2].

Over the past decade, the healthcare industry has experienced dramatic advancement in IT and medical imaging systems. For the exchange and management of digital medical images and information, international standards were established, in particular DICOM and HL7 [3, 4]. In addition, the development of the IHE initiative [5] facilitates a more efficient, predictable, and functional integration between disparate systems [2]. This enables the development of information systems that are modality vendor independent and are able to interoperate with all modalities that are compatible with these standards. Nowadays, web and mobile technologies, web services and semantic web ontologies [6] are mature enough to help us provide next generation healthcare services and to enable the use of mobile devices in a secure manner [7].

The recognized needs and the problems that are caused by the diversity of information systems in healthcare units and the lack of integration among them, combined with our experience and evolution of Information Technology initiated the development of OraHealthX, a smart integration platform generator for supporting workflows of medical diagnosis and disease prediction. This platform is generic, agnostic and knowledge based as it utilizes knowledge management features and semantic web ontologies. It is also configurable as it generates a complete, minimal, seamless and secure user interface for every needed functionality and content. It should also be noted that it is mobile oriented by design since the mobile features evolve natively [7, 8].

This paper presents the ImaginX, a configuration of the OraHealthX platform regarding the management of diagnostic imaging workflows. The proposed system inherits all OraHealthX base features and among others it is scalable, user-friendly, fast, modular and affordable, complying with standards such as HL7, IHE, CPOE and DICOM. ImaginX is web based and provides mobile functionality in critical areas so as to support efficiently the radiologists' and clinicians' work. It's the next step in medical imaging workflows' integration as it operates as a single point of access and all functionality and communications are transparent to users. Moreover, the integration of semantic web technology provides an open, standards-based, computer-interpretable framework on which the system's architecture and design is based.

ImaginX differentiates in the fact that it is not just a collection of interoperable applications, but a highly integrated, knowledge based, configurable platform that provides even more functionality with reduced costs and user effort. Different installations of ImaginX can interface with each other, with standard web technologies, creating a network (grid) where each node can search and order exams on the connected sites. It has also the ability to automatically accept exam orders from third party systems (HIS, RIS, etc.) by using standard protocols (HL7) and to provide to those systems the results of the exams.

It started as an implementation of the OraHealthX platform to support all traditional workflows of a radiology department. Since 2013 ImaginX operates in the Radiology Department of the University Hospital of Larissa (UHL), Greece where, in collaboration with the department's staff, it was primarily

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adapted to serve the department's specific needs. Further development of key components comprising a next generation medical imaging platform was developed subsequently. ImaginX has been accepted and embraced by its' users at UHL, as it is used on a daily basis, since its' installation. User Acceptance Testing methodologies are planned to be applied in the UHL and in future installations as well.

II. Architecture

A. *Framework*

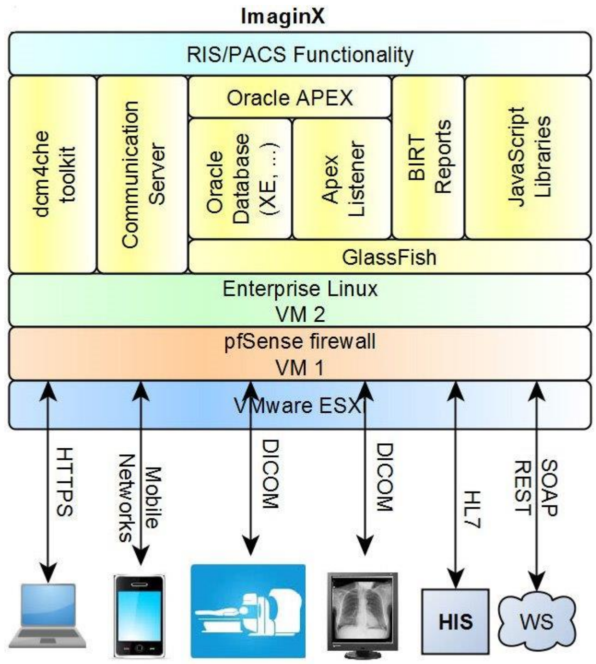

Figure 1. Physical Architecture Diagram

By design, ImaginX conforms to commonly accepted standards. It applies virtualization technologies (VMware ESXi [9]) to simplify the necessary infrastructure, it is installed in virtual machines and it is cloud ready. It is web based and uses open source / no-cost license software, which complies with international certificates and it is based on a leading technology. In particular, at the database level ImaginX uses Oracle [10]. At the level of the application server ImaginX uses the GlassFish [11], a full-featured enterprise ready and widely accepted application server. The application is developed with Oracle Application Express, a browser based rapid application development framework for developing rich interactive web and mobile applications. For paper reports the platform uses BIRT reports [12]. For archiving and communicating with DICOM images the dcm4che toolkit [13] is used, a well-known open source implementation of the DICOM standard that also collaborates perfectly with diagnostic viewers like OsiriX [14], etc. ImaginX implements basic DICOM services such as modality worklist, modality performed procedure step, send images. It also interacts with third party systems through the HL7 protocol and web services. The platform is also multilingual.

B. *Security*

The ImaginX platform is protected by an integrated pfSense [15] firewall and the web server is SSL encrypted. Users login to the application by utilizing their username and password. Password and login control policies are applied. A regular scenario regarding security involves encryption of passwords, a minimum of 8 characters that should include one number, one lower case letter, one upper case letter and one special character. All users are forced to change their passwords upon initial login and every six months thereafter. All users will be automatically logged out after 60 minutes of inactivity. Authenticated users will be presented with different web interfaces, menu items and system operations based on their respective user role such as doctor, technologist, typist etc. The system uses the Role Based Access Control (RBAC) approach to restrict system access to authorized users. Data Anonymization policies are applied so as to remove private data from users with limited data access for either view clinical data or export data for research.

C. *Interoperability*

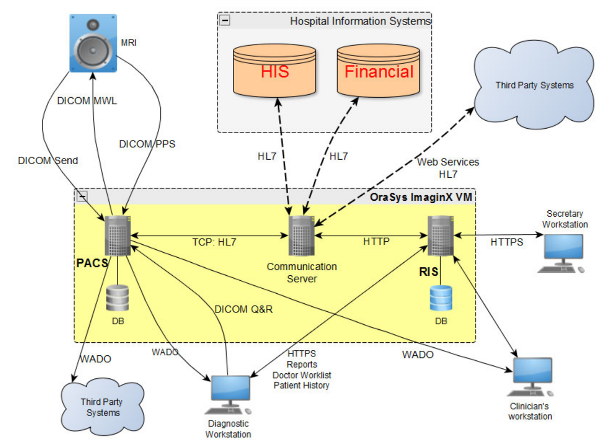

Figure 2. Interoperability Diagram

The HL7 protocol (version 2.3 or above) [4] is used to retrieve and request Clinical Information from other systems (HIS, LIS), and to handle exam orders. The system interacts with all modalities that support DICOM integration standard [3]. System workflow processes and transactions are in conformance with the IHE profiles [5]. Web Services are used to provide / consume data to / from other systems (e.g. National Registries / Exam Referrals).

III. Platform Functional Components

A. *RIS (Radiology Information System) Functionality*

RIS provides all functions for managing and planning imaging exam orders. Patient Record is the basic component for recording patients' health events like allergies, diseases, operations, medications and medical examinations. The primary use of such data is to provide clinical information to other systems like Clinical Information Systems (CIS). Another use of such data (commonly anonymized for privacy reasons) is for clinical research. In addition, this component encapsulates an essential feature; Patient Timeline, a modern technology that gives to the doctors, the opportunity to make a fast clinical decision as it presents the patient's medical history in a visual form. Typically the RIS, as an information system of the radiology department, receives patient data from the HIS. The system supports full patient record management in case there is no HIS, plus it interacts with national registries using web services so as to obtain certified patient data based on national identification codes (e.g. SSN).

Study work-list is used to manage imaging exam orders. The orders can be created either inside the department such us inpatient or emergency or outside it as outpatient appointments. An order has a status, which automatically changes at every transaction. The system provides the DICOM Modality Work List (MWL), so the modality can automatically be updated and therefore re-inserting data is not required in the modality console. When an examination (procedure) is completed, images and diagnosis are automatically associated with the order. When an order is completed, it will be included in the Patient Record with its results (Report, Clinical Images).

During diagnosis radiologists have several support modules to help them in clinical decision making: Patient Timeline is a module which displays all Patient medical history and the Comparison Module which automatically searches for prior studies which were performed on the same body region. In addition, for reporting medical image findings, the system provides a special rich editor which embeds many custom plugins such as predefined report templates, spell checking and radiology lexicon with semantic ontology annotation features, using international vocabularies. Radiologists can create many study reports by either typing or by dictating into a digital dictation system. Because of high complexity, the application provides to users the ability to adjust the screen modules according to each user's job.

B. *PACS Functionality*

PACS is used to store Medical Images. Users can query for medical images, retrieve images and display them. Additionally, if a new modality is connected in the network the images produced can be managed and stored in the PACS with a minimum effort. ImaginX integrates a PACS subsystem which is vendor neutral and interoperates with existing third party IT systems through HL7 and DICOM standards. It offers web and smartphone interfaces (front-end) for functions such as patient search, access to and managing of images. It is DICOM and IHE compliant [3, 13].

C. *Image Viewing Functionality*

ImaginX incorporates and collaborates with various kinds of viewers in order to provide radiologists and clinicians all necessary tools for viewing imaging exams from any place with Internet access. The types of viewers supported are the following:

Pure Web Based Viewer: A web based DICOM viewer, which uses 100% web technologies (HTML / CSS / JavaScript). The web based DICOM viewer provides functions such as contrast, zoom, rotate and measurement tools. It also provides functions for showing all series and images for quick and easy access.

Mobile Viewer: The platform features mobile viewers that provide access to imaging exams through smartphones and tablets.

Light Viewer: ImaginX supports viewers such as WEASIS.

Diagnostic Viewer: OsiriX [14] is one of the most advanced and widely used DICOM viewers. ImaginX is OsiriX Ready as it cooperates perfectly with it, and provides full functionality.

D. *Mobile Functionality*

ImaginX embeds features that support mobile functionality and online access to specific tasks with the use of smartphones, regardless of screen size and operating system. Modern smartphones and tablets provide high image resolution and ImaginX has the required functionality for supporting remote access to medical images from such devices when an emergency diagnosis is needed or a first clinical decision.

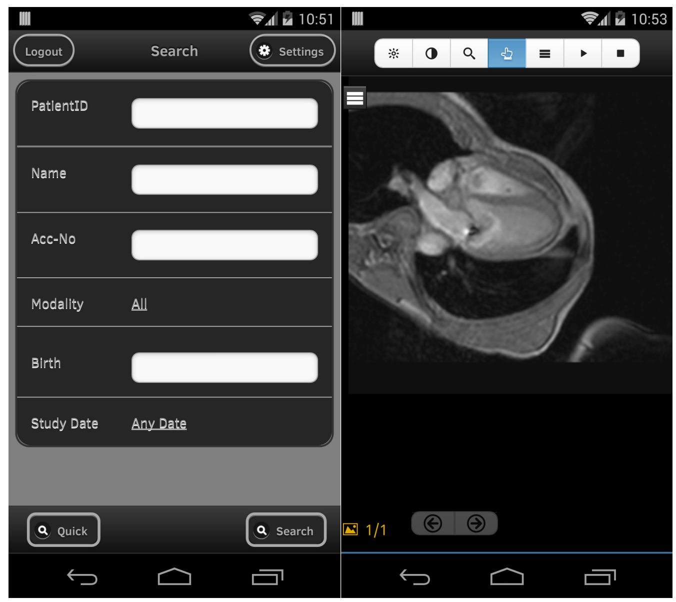

Figure 3. Search and View Patient Medical Images via mobile screen

IV. DEMONSTRATION: USAGE SCENARIO

ImaginX integrates seamlessly the main workflow regarding management of radiology examinations, as described by the IHE Initiative. Below it is demonstrated a work case of the installation in the University Hospital of Larissa (UHL).

For scheduling an imaging exam (e.g. an MRI), the physician requests it from a workstation, which can be located anywhere in the medical center (HIS). This order automatically generates in the RIS a Patient Record, containing demographic and clinical information according to the HL7 standard rules. A major problem that arises in this stage is the lack of a unique identifier such as SSN (Social Security Number) in order to eliminate or at least minimize cases of different medical records for the same patient. To eradicate this issue UHL uses a national web service that provides all patient data via SSN. So the physician inserts in the system only the SSN and all patient data are filled automatically.

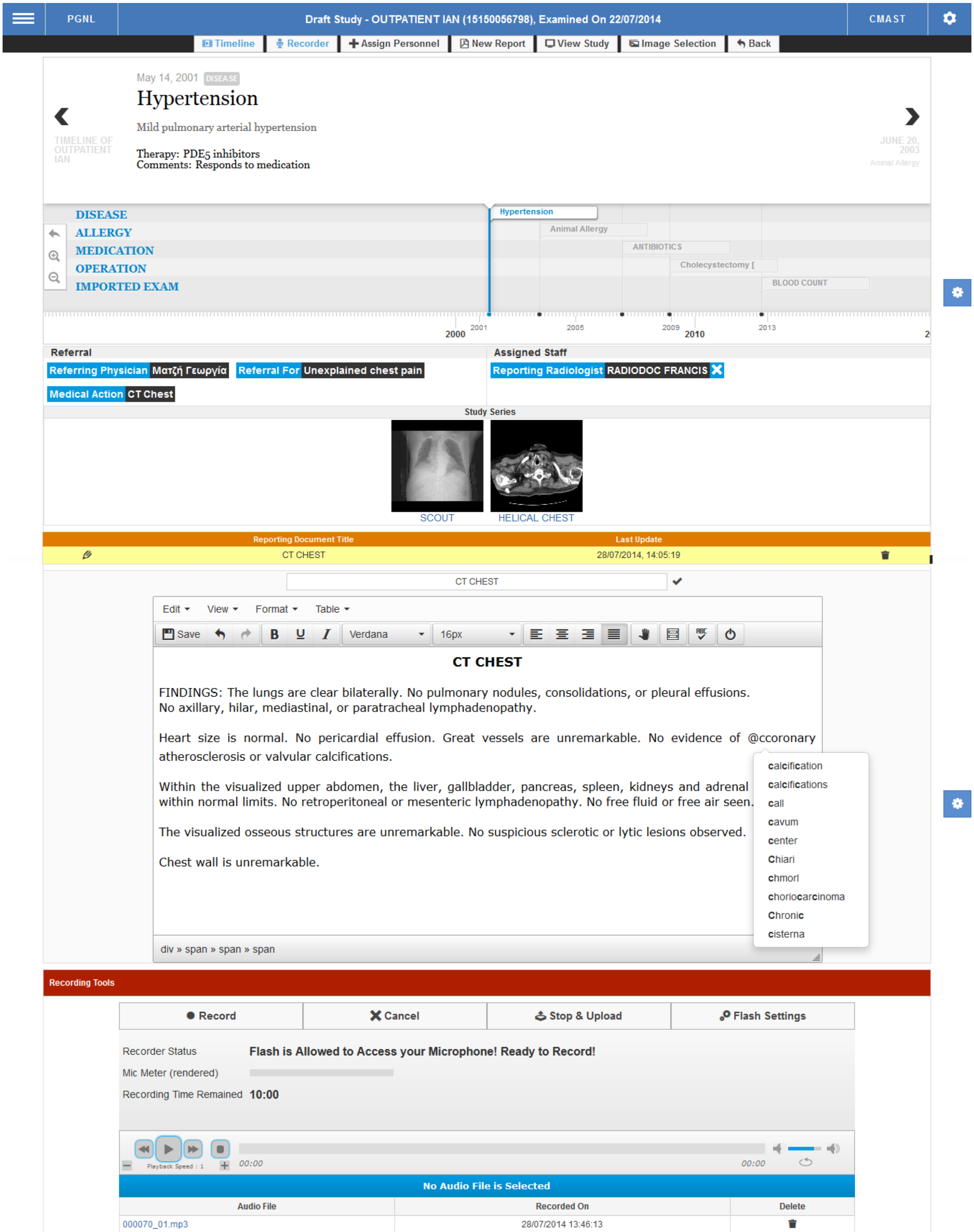

Figure 4. Diagnosis Medical Images Screen

The list of studies to be scheduled becomes automatically available to the radiologists at their workstations. The modality operator (technologist) selects the order without typing anything on the modality console (Greek Texts are transformed according to official Greek standards). During the exam radiologists can be updated with the exam status (Started - In Progress - Completed). Finally, the modality sends the Images to the image archiving system (PACS). After the examination the radiologist uses DICOM Viewers to diagnose the findings in the images and create the study report by either typing into a rich text editor or by dictating into a digital dictation system.

Finally, when the physician completes the study report, it is automatically included in the Patient Record. The system has features for notifying users or patients by e-mail or SMS.

V. Discussion and Conclusions

The traditional definitions for PACS and RIS no longer apply. The healthcare requirements have led to the need for more sophisticated and efficient systems, which should include workflow and model issues. ImaginX offers healthcare providers the potential for long-term cost savings in radiology services (e.g. gradual elimination of expenses for film processing and storage), it increases the ability for radiologists to grow the services they provide, to include advanced visualization in routine practice and to increase the efficiency and quality of reporting and patient care workflow [2].

OraHealthX is an open architecture platform designed to manage various kinds of healthcare workflows. HPVGuard, a software platform to support Management and Prognosis of Cervical Cancer, is another project that was generated and developed under that platform [16]. The scalability and multi-configuration features that are embedded, make the OraHealthX platform suitable to be used in other clinical specialties such us cardiology, pathology, dermatology, ophthalmology, surgery, oncology where there is also the need for imaging informatics applications and the need to support clinical decision services.

Future work focuses on developing services either embedded or remote, especially in the fields of clinical reporting, clinical prediction and semantic data analysis. Some of these services are:

- "dicomizing" images captured from smartphones,
- embedding a voice recognition feature in the diagnosis recording module,
- the development and evolvement of a custom-made pure web based cross platform viewer,
- utilization of semantic web technologies for radiology report and radiology image annotation [6, 17]. The primary objective is, annotated data to be available for navigation by other systems that use semantic technologies, in order to help physicians to better understand radiological images and reports, radiologists to compare similar studies so as to improve diagnosis procedures and organizations for conducting research [18].
- Support high-end post processing services, including CAD Analysis, WM Tractography, Biomarker Quantification with whole lesion Histogram Analysis [17, 19].

The use of web technologies, helps physicians acquire better clinical information in order to produce more accurate and efficient diagnoses. The use of semantic technologies provides information from clinical cases that help physicians search similar incidents and can also be used for research [20].

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