Image Management in an Integrated Electronic Health Record Environment

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For the past few years, CMI-HTA of ICS-FORTH has been deploying HYGEIAnet, an integrated regional health telematics network on the island of Crete. HYGEIAnet has been designed to support continuity of care and the provision of quality healthcare services, based on information and communications technologies, across all levels of the health system hierarchy (i.e. pre-hospital emergency care, primary care, home care, and hospital care).

In the above effort, the main challenge has been the design and development of an Integrated Electronic Health Record (I-EHR) environment, which supports the consistent and authenticated access to personalized clinical information, including diagnostic medical images, over the Internet in order to facilitate evidence-based medical decision-making. In this environment, medical images originating from different clinical departments at healthcare facilities all over Crete are managed and accessed, as segments of the I-EHR of a patient, based on the Digital Imaging and Communications in Medicine (DICOM) standard. The I-EHR environment is built on top of an underlying Health Information Infrastructure (HII) that enables the provision of advanced health telematics services at a regional level, based on a federation of autonomous and self-consistent clinical information systems. These information systems have been optimized with respect to the requirements of different medical specialties and levels of care, and to manage corresponding segments of a patient's EHR. The HII also provides the tools for integrated and secure access to the distributed health information space.

This paper focuses on the methodology used to integrate diagnostic medical images in the I-EHR environment. A description of tools, required in order to enable the authorized access to medical image data and related meta-data, is provided. This information is transferred to the system of an authorized and certified requester, and can be reviewed using appropriate viewers available through the I-EHR Human Computer Interaction (HCI) environment.

INTRODUCTION

In developing HYGEIAnet (see Figure 1), the regional health telematics network of Crete, CMI-HTA of ICS-FORTH has applied image management techniques (1) in a number of medical departments that produce images (e.g. radiology, ophthalmology, etc.) in order to give solutions to the task of managing these digital imaging examinations, based on the DICOM standard. At the same time, CMI-HTA has designed and developed an I-EHR environment, which provides the basis for consistent and authenticated access to clinical information over the Internet in order to support decision-making (2). This environment is based upon an underlying HII that provides a set of supporting services, thus enabling the provision of advanced health telematics applications at a regional level based on a federation of autonomous and self-consistent clinical information systems. It also provides the necessary tools for integrated access to clinical information, which is kept where it is produced and is maintained by the systems that are optimized with respect to the corresponding medical specialty (3, 4).

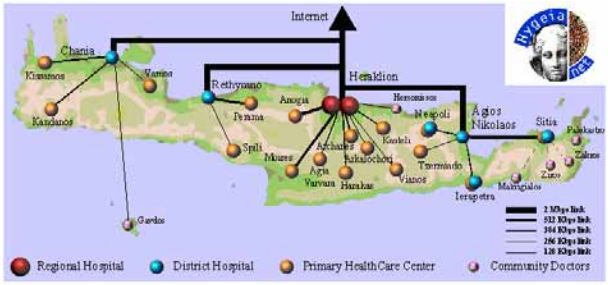

Figure 1. HYGEIAnet, the regional health telematics network of Crete.

In order to link the distributed segments of one's EHR, appropriate pieces of information have to be indexed (e.g. patient identification/demographics, encounter information, accession numbers, etc). Certified users that need access to clinical information (either the report or the examination itself) use these links. Clinical information may include images from different imaging modalities such as X-ray, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (US), etc. This information is transferred to the place of the certified requester (hospital, medical office, home, etc.) and can be reviewed using appropriate viewers through

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the I-EHR Human Computer Interaction (HCI) environment (5) (see Figure 2).

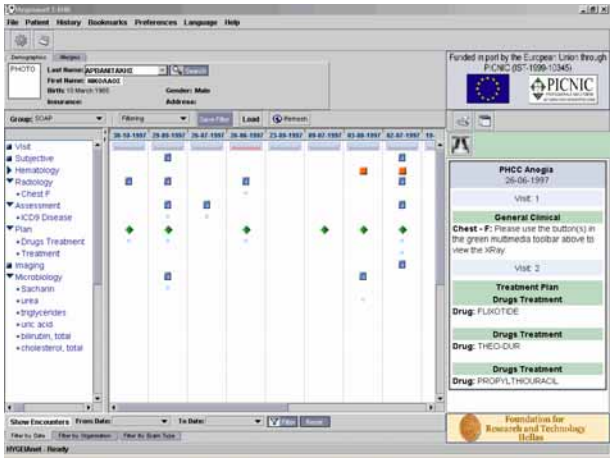

Figure 2. The I-EHR end user HCI environment.

This paper describes the methodology used to integrate diagnostic medical images in the I-EHR environment and the tools required in order to enable authorized access to medical images and related meta-data by general practitioners and clinical specialists. The following section describes the I-EHR infrastructure components of HYGEIAnet. The Image Management section that follows explains how DICOM imaging is linked to the I-EHR environment. The concluding section discusses open issues and potential benefits related to image management in an I-EHR environment.

I-EHR INFRASTRUCTURE

Today, there is no universal way, process, standard, or format for the exchange and integration of an individual's entire health record even if it is assumed that complete information is acquired and managed in an efficient manner. This is mainly because healthcare is usually delivered within certain organizational boundaries and information produced at each site is managed by isolated autonomous clinical information systems. Message based communication of Electronic Health Record (EHR) data is used today extensively to facilitate remote examination ordering and the acquisition of results. Despite the fact that this approach works well when the number of clinical information systems involved is kept relatively small, when their number increases the resulting complexity becomes non-manageable.

The most realistic approach towards the I-EHR relies on the existence of an underlying HII that consists of cooperating software components and a reference architecture to support clinically significant health telematics services (6). Efforts that have been related to the development of a federated approach towards the I-EHR have involved a number of projects in Europe and the United States (US), as well as several standardization activities such as those of the technical committee for medical informatics of the European Committee for Standardization (CEN/ TC 251) (7), Health Level Seven (HL7) (8), the Object Management Group (OMG) (9), and the American Society for Testing and Materials (ASTM) (10).

All efforts toward establishing integrated health information networks involve the adoption of an architectural framework to be used as a point of reference for the exchange of all electronic information, in order to support the interconnection of the individual cooperating service centers. This involves the development of environments for information exchange among regional healthcare networks, based on agreed information exchange protocols for the medical domain. It also involves and requires the definition of the medical and operational procedures for sharing resources and expertise so that patient mobility and improved care practices can be supported effectively.

Components of the HII

Essential components that are required for the proper delivery of integrated health telematics services include, above all, public interfaces (e.g. HL7 and DICOM) for the efficient communication of information. These interfaces can support functional integration of healthcare processes in and across individual healthcare facilities, promoting cost-effective healthcare delivery and continuity of care.

Important software components to be considered include those for patient identification (ID), I-EHR indexing, resource location, terminology mapping, user profile management, and security (for authentication, encryption, access control and auditing). In addition, a standardized component is required for accessing directly the complete, original (physician generated), clinical information at the place of origin. Today, as far as imaging in medicine is concerned, DICOM (11) is well accepted as a standard by the majority of actors in the healthcare sector.

Patient Identification

Patient identification plays an important role within any health system, since it enables the tracking of patient information. A variety of information may be used to identify a certain individual. This includes demographics (e.g. address, place of birth, etc.), biometrics (e.g. finger print, photograph, blood type, etc.) and several IDs issued for other purposes (e.g. social security number, driving license number, health insurance number, passport number etc.).

All identification systems produce IDs that do not have any meaning outside the specific ID domain for which they have been issued and this contradicts the real (and existing) need for efficient collection and correlation of health records through multiple organizations. Furthermore, a certain percentage of the population is not of

local origin and, therefore, may have not been assigned a permanent ID, as their existence may never have been recorded. Another reason why patient identification services are required at a national level, even in the presence of unique citizen identification, is the fact that legacy systems exist and, therefore, a migration plan ought to be in place in order to support their incorporation in a single ID domain in a standardized way.

Last but not least, any modification of key patient demographic information (e.g. health insurance status, patient address, contacts, etc) ought to be instantly propagated to other systems that should be updated.

The OMG Person Identification Service (PIDS) (12) is currently deployed in HYGEIAnet, as it is able to handle all the above issues.

I-EHR Indexing

I-EHR indexing addresses the need for indexing segments of the I-EHR produced and maintained at different nodes of a regional health information network. Although the identification of individuals within and across domains is addressed through PIDS, the I-EHR Indexing Service (IS) is intended to complement its capabilities in locating and providing summary data about existing records and to satisfy certain types of criteria.

More precisely, the IS supports the following: 1) locating EHR information in a distributed healthcare environment and identifying certain properties of this information (such as type, size and availability of information, its format, count of matching instances, etc.), 2) filtering of information by patient, provider, information type, time frame etc., 3) retrieval of extensible and different location types such as the Uniform Resource Identifier (URI), the Interoperable Object Reference (IOR), the DICOM study instance Universal Identifier (UID), etc., 4) access to alternative locations (e.g. organizational, virtual, physical etc.). Using the IS, information, wherever it may reside, can be accessed by a plethora of fixed and mobile devices, as well as different platforms.

The IS can also be extended to accommodate locally defined and namespace-qualified location types. Each IS location carries relevant information including computational and engineering specifications. Thus, the IS is configurable to be compatible with the relevant standard of preference (e.g. the Subjective-Objective-Assessment-Plan (SOAP) model in primary care, which is encounter centered). It also supports two alternative representations for indexed information: full content (e.g. reason of contact) and coded values (e.g. type of information for which information exists). The former representation requires large data stores and communication bandwidth (high redundancy) for maintaining consistency, while the latter requires that the IS maintains simple indices to the clinical observations and uses a more flexible access control mechanism.

Clinical Observations

According to (13) the term Clinical Observation refers to "*any measurement, recording, or description of the anatomical, physiological, pathological, or psychological state or history of a human being or any sample from a human being, and any impressions, conclusions, or judgments made regarding that individual within the context of the current delivery of healthcare*".

All observations share a few common features. For example, they are all related to a specific subject of care (e.g., patient, organ, population) and represent a snapshot of that subject at a particular time or over some specified interval of time. They are made or recorded by an instrument or a healthcare professional in some clinical context and carry some degree of confidentiality.

Observations can be quantitative or qualitative and include vital signs, clinical laboratory results, trends in measured values, impressions from a clinical exam, correlation of several qualitative impressions, acquired images, and derived images.

The role of the OMG COAS that has been adopted in HYGEIAnet is to support direct access to the clinical information systems in which the complete, original (physician generated), clinical information is kept.

Resource Management

Resource location services are useful for identifying available resources and the means for accessing them. In this context, the established Health Resource Service (HRS) of HYGEIAnet is responsible for identifying the availability of resources, such as participating organizations, existing devices, healthcare professionals, or software. It also provides the means for accessing them. This component is used as a repository of location information and the place where potential clients (users, components, applications) are directed in order to identify and locate the offered components/ services in the distributed environment of a health information network.

Examples of resources include pharmacies on-duty, hospitals and clinics, clinical information systems, methods and technologies available for accessing primary information, and protocols for exchanging information with them. The HRS also provides information about equipment/ devices available at certain facilities, as well as used by certain categories of people, together with the corresponding equipment/ device characteristics.

It is difficult to anticipate every potential kind of resource that exists or may exist in the future and would

be of interest. Therefore, the implementation of the HRS is as generic as possible, without imposing any constraints that could limit its use when future demands for new resources appear. In addition, the information managed by the HRS for each resource is expressed in a generic manner. An important consideration has to do with the fact that the attributes for each type of resource vary significantly. For example, for a web server it is important to know the host name, address and port number, while for a physician the name, address (contact information) and specialty constitute important information.

Security

The amount of protection each health information network is prepared to pay for depends on the value of the assets and the threats that need to be countered. However, the process of determining which security controls are appropriate and cost effective is quite often a complex and sometimes a subjective matter. For example, in the region of Crete, security is implemented by means of the HYGEIAnet Virtual Private Network (VPN) and an authentication server, compatible with the overall architecture, utilizing digital signatures that are enforced by means of smart cards.

Although security is enforced at a regional level, there are constraints on how systems are constructed in order to ensure adequate separation of objects, so that they do not interfere with each other. The separation of user functions (duties) ensures that the damage an individual user can do is limited. Therefore, although authentication is performed at a regional level through the authentication server, access to the I-EHR environment is controlled according to appropriate permission settings, imposed by a specially tailored rule-editor (14). Authorization is granted according to per-system, per-time range, and per-type-of examination criteria.

IMAGE MANAGEMENT

Image management solutions, as well as solutions for the integrated workflow of ordering, scheduling and performing a diagnostic imaging procedure, or producing and making available reports in HYGEIAnet, are based on the recommendations of the Integrating the Healthcare Enterprise (IHE) technical framework (15). Departmental Radiology Information Systems (RIS) are being developed and installed that support the scheduling of ordered diagnostic imaging procedures and their assignment to a variety of modalities (CT, MRI, US, Computed Radiography (CR), and secondary capture). Imaging modalities produce DICOM images that are stored in the appropriate Archive Manager. Image query and retrieval support is provided to radiologists for the review of a study, while the report for a given study is produced, archived and managed by the corresponding Report Manager. As soon as a signed report is ready, it is also made available by the Report Manager to all authorized individuals. The overall approach is consistent with the IHE technical framework guidelines and, more specifically, it implements the *Scheduled Workflow* IHE integration profile and part of the *Simple Numeric Report* IHE integration profile.

The above is the most frequent case of making the radiological report available to interested parties (order placers). In certain cases, the radiological study in a DICOM format must be made available to an interested party as soon as it is acquired or created. As part of the overall approach towards an I-EHR, the ability to have access to such information is provided, given proper identification. To achieve this, the departmental RIS implements the *Access to Radiology Information* IHE integration profile. Key transactions for this integration profile are *Query Image* and *Retrieve Image*. The I-EHR environment implements the *Image Display* IHE actor in order to be able to use the above transactions.

Based on the above approach and given a certain context in I-EHR, a patient is identified through PIDS, his health record segments are indexed through IS, located through HRS, and accessed through COAS. In case medical imaging is also involved (e.g. the patient has had a CT examination), the information identifying the specific medical imaging procedure is already available in the I-EHR environment. This information originates from the Departmental RIS and includes *Accession Number* and *Study Instance UID* query keys. These query keys are used by the *Query Image* and Retrieve *Image* IHE transactions to either get information for the particular study or initiate its transfer from the remote Image Archive to a local temporary archive for review purposes (see Figure 3).

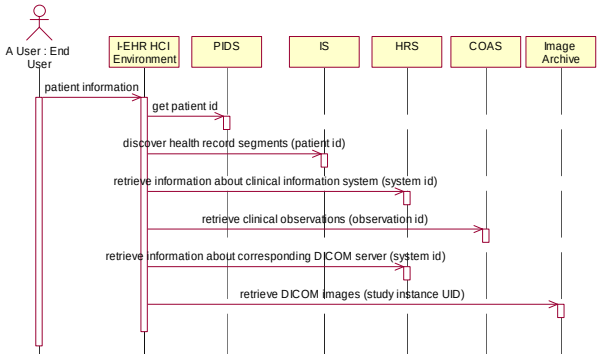

Figure 3. The sequence of events involved in accessing a DICOM series of images.

This transfer may take a long time based on available bandwidth and the number of images that comprise the study. However, pre-fetching strategies can be applied to provide solutions to this problem. The pre-fetching of diagnostic imaging examinations can be automatically triggered by other information systems deployed at regional level. Then, the DICOM viewer installed at the client machine is used to review the imaging examination (see Figure 4).

Figure 4. The DICOM Viewer.

CONCLUSIONS

The healthcare environment is currently undergoing substantial changes with Information and Communications Technologies (ICT) taking on a leading role. Making medical expertise a shared resource and providing support for continuity of care, while taking into account the increasing population mobility, are giving rise to the requirement for the creation and consistent use of a lifelong, active I-EHR for every citizen (16). Segments of the EHR can be distributed at regional, national, and international level. Therefore, secure access to the I-EHR by all authorized users, anywhere and anytime, is a prerequisite to the provision of evidence-based medical care at the point of need and at all levels of the health system hierarchy (i.e. pre-hospital emergency care, primary care, home care, and hospital care).

Diagnostic imaging examinations contribute significant information content to the I-EHR of a citizen and, due to the volume of data they produce, define to a large extent the requirements for its design, implementation and access. Image management and communication in an Integrated Electronic Health Record environment, addressing the needs of regional health information networks, extends the range of current PACS installations in accordance with the emerging distributed (virtual) healthcare organization and the need for seamless care across organizational boundaries.

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