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Interactive Radiology Teaching File System: the Development of a MIRC-Compliant and User-Centered e-Learning Resource*

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Abstract — **Radiology teaching usually employs a systematic and comprehensive set of medical images and related information. Databases with representative radiological images and documents are highly desirable and widely used in Radiology teaching programs. Currently, computer-based teaching file systems are widely used in Medicine and Radiology teaching as an educational resource. This work addresses a user-centered radiology electronic teaching file system as an instance of MIRC compliant medical image database. Such as a digital library, the clinical cases are available to access by using a web browser. The system has offered great opportunities to some Radiology residents interact with experts. This has been done by applying user-centered techniques and creating usage context-based tools in order to make available an interactive system.**

I. Introduction

Case-based learning[1] is a valuable and effective methodological approach which is used in Medicine teaching. In Radiology, teaching activities usually employ systematic and comprehensive set of medical images and related information (clinical cases), in order to make available an expert knowledge database. According to Vannier[2], a comprehensive collection of medical images and related information is an important resource for medical education and the dissemination of knowledge.

Currently, image-based teaching files exist in many Radiology departments and they are useful, e.g. to illustrate relevant teaching points. For many years, the teaching of Radiology has been accomplished by using case-based files. The earliest practices were dependent on film-based images with some relevant clinical information (e.g. patient's clinical condition). By using film-based images, there are great obstacles related to creating, maintaining, tracking, storing, and sharing clinical cases. However, with the popularization of digital – digitalized and film-less radiology, and the increasing use and establishment of the digital picture archiving and communication systems (PACS) – good opportunities to design teaching file solutions has been achieved.

In order to analyze medical image and recognize normal and abnormal findings, radiologists need to learn by using a comprehensive clinical dataset. They are expected to master on several cases which have normal features and normal findings. On the other hand, they should also master on other cases which have abnormal findings which could represent a specific disease.

In this way, libraries (or repositories) with representative radiological images, documents and media are highly desirable in Radiology teaching programs. To achieve this, open medical archives have been created for Radiology teaching and some of them are available on the Internet, e.g. MyPACS.net[1] and AuntMinie[2]. In addition, there are other in-house teaching file solutions also available on the Internet. Currently, computer-based Radiology teaching file systems are widely used as an educational resource.

Looking at the importance of images for teaching Medicine, the Radiological Society North America (RSNA) has worked on the development of the Medical Imaging Resource Center (MIRC). The MIRC initiative aims to facilitate the creation of repositories for medical images and related information, as well as to investigate and propose standards to be used in the development of teaching file and dataset exchange[3].

Some articles document techniques for creating teaching files by means of providing conditions to organize and make available educational cases [2][4]. Others have focused on standards for archiving and sharing medical images and related information[5][6]. Nevertheless, it can be noted that it is important to devote efforts in order to make the users aware with useful resources. For example, context-based tools which are designed for clinical information retrieval and provide user-centered graphical interfaces.

By using experiences reported in other studies[7][8], in this work, an user-centered Radiology ETF system is developed such as an instance of MIRC compliant medical image database. The main focus has been on offering a set of user-centered application concerning usage contexts.

II. Materials and Methods

The ETF system should be available to all Radiology department members. They are from diverse working groups and have very diverse interests; hence they may use the same clinical dataset in different contexts (e.g. healthcare's daily routine and Medicine teaching). In this way, the development of this ETF started thinking on how to make available a system to collect and document relevant clinical cases useful to Radiology learning. Similar to an e-learning environment, the usage of this ETF should enrich the users' training or experience. This has been done by applying user-centered techniques and creating usage context-based tools.

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[1] http: //www.mypacs.net
[2] http:// www.auntminnie.com

A. System Requirements

According to Wong and Tjandra[9], when a medical image database is designed, there are a set of issues which requires attention. Some of them are: clinical data distribution (e.g. they could be stored in heterogeneous and not integrated systems), interoperable interfaces to other clinical applications, heterogeneous datasets archiving, clinical dataset processing and analysis, clinical data security and confidentiality, and clinical dataset standardization and compliance.

In this context, it should be noted that a suitable infrastructure for medical image database should offer a set of features, such as[7]: identify datasets, offer customized query and retrieve tools, and carry out images on-demand; archive datasets from medical daily routine, and provide means to accomplish new analyses comparing with other datasets; provide distributed access; provide tools for image viewing and case authoring; provide context-sensitive and role-based user access[10]; offer tools for medical image de-identification; retrieve clinical cases from PACS and electronic patient record systems (the ETF may be integrated into clinical workflow and offer vendor-neutral case input); the datasets should be reviewed by experts; rapid query processing, summarizing contents found in several repositories; and context-based tools for medical image viewing and clinical dataset retrieval.

B. Conceptual View

Kohli and Bradshaw[11] state: *"educating radiology is a complex procedure that requires hours of self-study, an enriching didactic environment, and extensive clinical experience"*. Looking carefully at this statement, this ETF has been planned such as a system which presents a summarized and interactive electronic book of relevant clinical cases. Such cases integrate information from multiple sources.

Each clinical case is a set of anonymous clinical information objects, such as: patient's demographic information, visits, laboratory tests, radiological images and reports. Similar to a digital library, the clinical cases are available to access by using a web browser.

By using a set of customized services, regarding to radiologist's usage contexts, a medical image database infrastructure[7] provides interactive and integrated access to all dataset at the moment of image interpretation. In this way, in order to reach well-informed conclusions, the users may examine all available datasets, access the medical literature and compare a clinical case with another (or others) similar clinical case(s).

First of all, a medical image database system was designed aiming to archive images and related information. In this task, it was identified three important issues concerning medical knowledge. They are[7]: (1) parameters used during image acquisition process (e.g. imaging modality, the body region examined, the functional system under investigation, and the reasons to study it); (2) images' regions of interest and existing findings; (3) set of information about findings – and their properties – as well as the relationship among these findings.

Concerning methodological approach used in teaching activities, in this work, the case-based learning[1] was selected. This approach has been widely used in Medicine teaching and it has offered great opportunities to Radiology residents learn and master using a comprehensive database of clinical cases.

The main component of this ETF system is a database which archives a set of clinical cases. This database specifically archives clinical datasets usually stored in heterogeneous information systems and, sometimes, not integrated. In this way, the ETF has been designed to become a resource which can be used in medical education and the dissemination of knowledge.

This ETF can be accessed from any personal computer connected to the Internet and by a range of users (e.g. Medicine students, Radiology residents, and medical imaging researchers).

The case authoring is a documentation process which is based on seven main stages usually applied on clinical investigation and assistance processes. These stages – adapted from [12] – are: (1) the clinical investigation begins when a problem (symptoms) is reported by the patient; (2) the causes of that problem are hypothesized; (3) a set of information about patient's clinical condition is collected (e.g. laboratory tests, radiological examinations, etc); (4) these information are analyzed; (5) the treatment is planned and conducted; (6) the response to the treatment (results) is analyzed; and (7) the conclusions are drawn and a follow-up is recommended.

In order to track treatments and archive expert knowledge, all relevant events observed in that stages should be stored into the ETF's database. Each one of these events will be reviewed by experts (editors) who will assess their contents. This is aimed at providing high quality and peer-reviewed content.

The basic usage workflow is summarized in the figure 1.

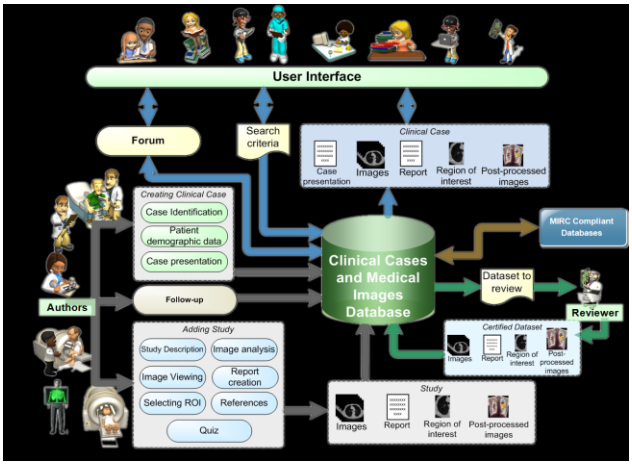

Figure 1. Schematic and basic usage workflow proposed by Santos and Furuie[7].

With the introduction of digital medical imaging devices, great opportunities have been offered for creating ETF systems. Some of them offer open access and free content for use. In addition, it should be noted that some databases have clinically and didactically relevant contents. This ETF has been prepared to access and share clinical cases by using MIRC services[13-15].

C. *Indexing and Retrieval Information from Radiology Reports*

In general, the Radiology report summarizes notes on existing findings in the images. Putting it in simple, the report is mainly composed of: *findings* (what could be noted); *discussion* (findings' meaning and their effects); *conclusion* (suggested diagnosis) and *key images* (relevant images in the study and/or regions of interest).

Looking at the purposes of this ETF system, information retrieval is an important feature. Especially in an e-learning environment, efficient retrieval mechanisms are needed (e.g. when the user are looking for similar cases).

Firstly, it was created an indexing mechanism (Figure 2) which automatically organizes expert and relevant information found in text-based radiological reports. The indexing process is used to identify concepts found in clinical documents. After parsing, the identified concepts are expressed in an acceptable terminology. This has been done by using controlled vocabularies (e.g. Radlex and ACR).

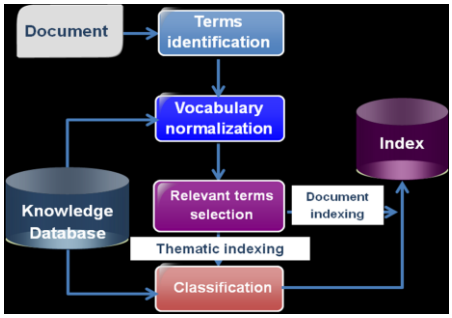

Figure 2. Schematic diagram of text-based document indexing.

Secondly, retrieval mechanisms (Figure 3) were created in order to make feasible to retrieve clinical information using customized queries.

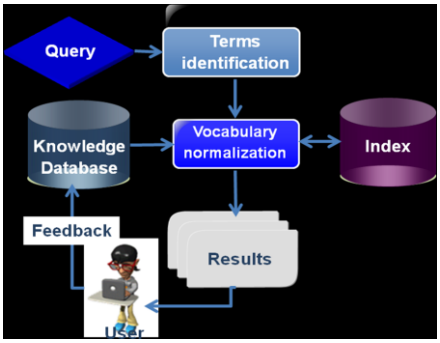

Figure 3. Schematic diagram of clinical information retrieval.

D. *Architecture and System Implementation*

The main components which are parts of the system's architecture are shown in the figure 4. They are: (1) *clinical case and medical image database*: it archives clinical datasets using a flexible data model which allows to use them on different clinical and teaching contexts; (2) *learning management system*: it offers an e-learning environment which provides access to similar clinical cases and provides links to the medical literature; (3) *query, retrieve, and viewing tools*: it offers integrated access to all relevant clinical datasets; and (4) *usability framework*: this component offers context-based and user-centered tools.

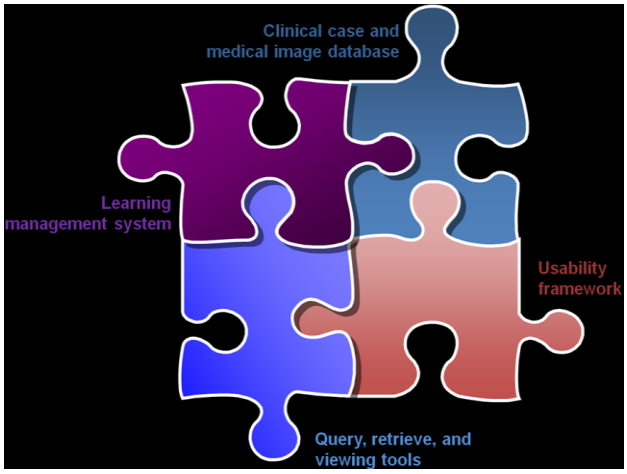

Figure 4. ETF's main components.

This ETF system is implemented such as an Internet portal. By using this concept, the development has offered a good solution in order to bring several capabilities of distributed computing. In this way, the clinical case and medical image database component has been implemented such as a distributed image database. In addition, the proposed architecture is enabled to be integrated to existing medical image databases (featured by MIRC interoperability[3]).

All system's features have been offered in a collaborative infrastructure, where groups and/or people interested in medical images can exchange clinical datasets. Thus, they have access and can use datasets and experience from other groups and/or mastered radiologists.

The set of applications is based on open medical standards (such as Digital Imaging and Communication in Medicine – DICOM – and Health Level Seven – HL7) and implemented by using open source development tools (such as Java, Java Server Pages, PostgreSQL, etc). The Unified Modeling Language (UML) has served as language used in the application modeling process.

Aiming to achieve requirements of diverse users' groups, the user-centered development lifecycle[16] has been applied. In addition, a graphic user interface manager was constructed in order to present clinical information to the diverse users' groups according to their usage contexts.

III. RESULTS

The main results are summarized in the following groups:

- *Radiology learning tools*: fifteen frequent users (students and mastered radiologists) have tested the ETF system; there are around of 715 complete clinical cases; the system has offered great opportunities to some students interact with experts.
- *Clinical case query and retrieval tools*: the automatic indexing mechanism has enhanced the query and retrieve processes; this mechanism organizes many clinical documents in short time with consistency and no bias; on the other hand, the retrieval mechanism provide means to retrieve useful information for different usage contexts; DICOM images can be retrieved from workstations for post-processing.
- *Exchanging datasets with public medical image repositories*: by using MIRC data model, the ETF system has been enabled to interoperate and exchange clinical cases with MIRC repositories.
- *Applications' usability*: we have archived users' interaction and created models aiming to increase the system's usage by means of proposing steps to be undertaken.

Currently, new tools have been created in order to help other developers to use and contribute with new features. The next step involves: (a) availability of a large and diverse set of clinical cases; (b) make the application available to other groups, install and test it in other scenarios, such as in the clinical routine workflow; and (c) apply and test the integration profiles published by Integration Healthcare Enterprise (IHE).

IV. DISCUSSION AND CONCLUSION

This work has represented an opportunity to investigate some of main requirements to take into account when medical and ETF systems are implemented and used. In this task, diverse actions are required regarding to planning, organizing, human resource management, services offered, customized services, and creating access and usage polices related to clinical information.

In this way, it is useful to remember some issues mentioned by Shneiderman[17] and confirmed in this work: *"the old computing was about what computers could do; the computing is about what users can do. Successful technologies are those that are in harmony with users' needs. They must support relationships and activities that enrich the users' experience"*. And he[17] continues: *"technologies are most appreciated when users experience a sense of security, mastery and accomplishment. Then these technologies enable users to relax, enjoy, and explore"*.

In conclusion, ETF systems are an important component of Radiology learning process. The current implementation has shown that creating clinical cases repositories on networked computer environments seems to be a good solution providing means to review information management practices in electronic environments and create customized and context-based tools for users connected to the system throughout electronic interfaces. It can be noted that it is important to devote efforts in order to make the users aware with useful resources. Moreover, in Radiology teaching, usability, peer-reviewed and high quality datasets are essential.

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