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Casimage Project

A Digital Teaching Files Authoring Environment

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Abstract: The goal of the Casimage project is to offer an authoring and editing environment integrated with the Picture Archiving and Communication Systems (PACS) for creating image-based electronic teaching files. This software is based on a client/server architecture allowing remote access of users to a central database.

This authoring environment allows radiologists to create reference databases and collection of digital images for teaching and research directly from clinical cases being reviewed on PACS diagnostic workstations. The environment includes all tools to create teaching files, including textual description, annotations, and image manipulation. The software also allows users to generate stand-alone CD-ROMs and web-based teaching files to easily share their collections. The system includes a web server compatible with the Medical Imaging Resource Center standard (MIRC, http://mirc.rsna.org) to easily integrate collections in the RSNA web network dedicated to teaching files. This software could be installed on any PACS workstation to allow users to add new cases at any time and anywhere during clinical operations. Several images collections were created with this tool, including thoracic imaging that was subsequently made available on a CD-Rom and on our web site and through the MIRC network for public access.

Key Words: teaching files, database, PACS, DICOM, MIRC

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With the introduction of the PACS in radiology, classic teaching files based on printed films become rapidly obsolete and incompatible with the digital environment of modern radiology departments.[1,2] The development of a digital teaching files system is facilitated by the widely accepted DICOM and PACS standards, allowing the radiologist to benefit from the advantages of digital teaching files—edit and share images collections anywhere and anytime through online or off-line access (Internet, CD-ROM). To be successful and widely adopted, a digital teaching files system needs to include 3 main functions: (1) to provide an easy and convenient way of importing images from different sources, (2) to allow simple editing and annotation of the images and associated description, and most importantly, (3) it must provide a convenient and easily accessible way for sharing and distribution of image collections to remote users. These 3 functions represent a chain of events that should fit in the daily clinical workflow to allow the authors to work efficiently, while allowing the users easy and convenient access to these collections at any time from any location. Existing commercial software programs for creating collections of images often do not support DICOM image communication standard and are often not designed to coexist with an existing clinical PACS. This is why we elected to develop our own system: the Casimage project.[3] This system is designed as a generic image database-authoring tool and is based on the integration of commercially available software components running on any personal computer. The stand-alone version is available as a freeware for MacOS or Windows operating systems. The client/server version is provided under a license fee due to the utilization of a commercial database engine on the server side.

MATERIALS AND METHODS

We elected to use a commercially available relational database development environment—4th Dimension by ACI S.A., version 6.8.4.[4,5] This database engine can be implemented on either a Windows or MacOS operating system. The database structure is defined in 4 relational tables (author–collection–case–image). These tables represent the hierarchical structure of the database: one author has one or many collections. Each collection can contain an unlimited number of cases, which can be individually described by textual fields and many images. Each case is represented by a unique user-defined key image (Fig. 1). For each table, the database struc-

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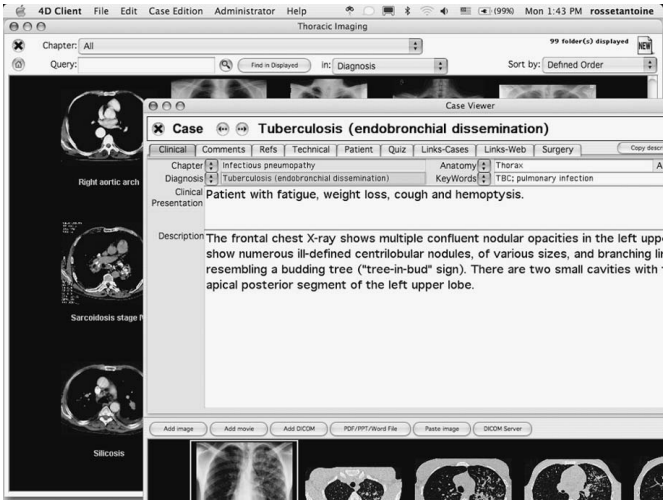

FIGURE 1. The front window displays a case with several images. The back window displays a collection containing several cases, represented by key images.

ture will consist of a list of specific textual fields. Images, however, are not stored in the database but are saved as individual files in a separate folder in order not to overload the index file of the database and affect its performance. Images are stored in the JPEG (Joint Photographic Experts Group) file format for still images,[6] and in QuickTime file format for dynamic sequences.[7] We use the lowest compression rate for JPEG files to minimize image deteriorations due to compression[8–10] and MPEG (Moving Picture Experts Group)[11] compression for QuickTime files. File size is limited to 10 MB to maintain adequate performance. We did not set any limitation to the size and spatial resolution of the images themselves. In the client/server configuration, the database server is the core of the system and is accessible remotely from any computer including directly from the PACS workstations if needed (Fig. 2). The client software used for authoring and editing the image collections can run on Mac OS and Windows operating systems, and it connects to the server through standard TCP/IP protocol. The server also provides a web-based interface for review of the image collections from any web-browser on the network.

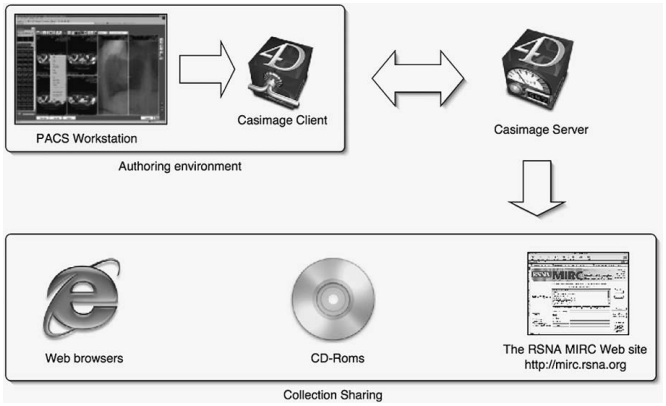

FIGURE 2. Architecture of the Casimage network.

IMAGES IMPORT

The first function to be offered by our system is the ability to import images, from a PACS or from any digital source, directly into the image database. In our department, we have been using for the last 3 years a commercial DICOM-based PACS from which the images of all modalities are saved and retrieved for clinical interpretation. We developed 2 different ways of importing DICOM images into our digital teaching files system:

1) Direct import of stand-alone DICOM files: We developed a 4th Dimension plug-in that converts a DICOM file to a JPEG file. It comprises an interactive tool that allows the user to adjust image setting of window level and width before the conversion into an 8-bit JPEG image. This plug-in uses our own DICOM C/C++ software library, Papyrus 3.0.[12] The Papyrus toolkit developed at the University of Geneva is available in the public domain[13] and is written in ANSI (American National Standard for Information) C,[14] and thus compatible with most C/C++ compilers.
2) Retrieval of images through the DICOM communication standard protocol: We implemented on our server a "DICOM listener" software that we developed in the Java programming language. This software supports a DICOM "STORE Service Class Provider." It is written in Java language and is available as freeware.[15] It allows any user of our PACS to send a DICOM data set directly to our digital teaching files system using DICOM Query-Retrieve communication protocols available today on most imaging devices and PACS workstations.[16] These images are then converted from DICOM format to JPEG with our Papyrus plug-in software.[12]

The software also supports the majority of standard multimedia file formats (JPEG, TIFF, BMP, and Photoshop), with the use of 2 commercial plug-ins for 4th Dimension: QPix and QmediaLight.[17] These plug-ins convert all these multimedia file formats to JPEG, and handle QuickTime files.

Finally, our system supports a copy/paste function: many PACS interpretation software allows the user to copy the image displayed onto the clipboard. The user can then simply paste the image from any viewing application directly into the server database[18] (Fig. 3).

AUTHORING ENVIRONMENT

Once the images are imported in the database, the user can edit all text data as well as the images in the client software environment. The text is separated in different fields to keep the same structure in all collections. The text data can be edited

FIGURE 3. Screenshot of Casimage client software running in front of a PACS software (Centricity from General Electric). Users can copy (**white arrow**) and paste (**black arrow**) images from PACS to Casimage.

and copied from word processing software to benefit from grammatical and spelling corrections and then pasted back into the database. The client software includes simple image editing functions, such as change of spatial resolution, cropping, and contrast/brightness setting (Fig. 4). A set of graphical tools is available if the user wants to add annotations like arrows, text, and regions-of-interests (ROI) on images. These annotations are saved as graphics overlays independent from the images themselves, allowing users to hide or display them at will, facilitating the creation of quizzes. Using the copy/paste function the user can also copy images from the database to any image editing software to do more complex changes to the images, such as applying special filters. Furthermore, the images can be directly copied from the image database into presentations software programs such as PowerPoint to be included in didactic presentations.

COLLECTIONS SHARING

For review of the collection stored in the database, the system offers 3 modes of data sharing allowing users to remotely access and review these teaching files anywhere at anytime:

1) A web server (HTTP protocol) allows any web browser to consult the cases in the database through any standard web-browser without the need of any additional software (Fig. 5).
2) By generating off-line hybrid CD-ROMs (MacOS and Windows) containing selected cases exported from the database that can be displayed and reviewed on any personal computer with a CD-ROM drive. Each CD-ROM contains a run-time version of our 4th Dimension client software, thus avoiding the need of any pre-installed application on the computer. The advantage of CD-ROMs is that they can be replicated in large number of copies to be distributed to users or students at a relatively low cost.[19]
3) A MIRC web server (HTTP/XML protocol) that allows connection of the Casimage server to the MIRC network sponsored by the Radiologic Society of North America (RSNA).[20] The MIRC network proposes a standard for teaching files database. It allows users to search and browse through a large number of different teaching files servers on the Internet (Fig. 6). One other advantage of this standard is to allow users to import and export cases from a teaching files server to another one, avoiding reliance on any proprietary format.

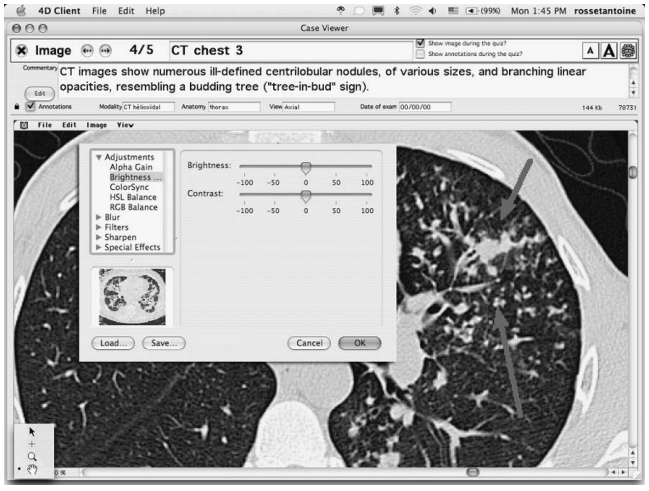

FIGURE 4. Image editing capabilities of the Casimage software.

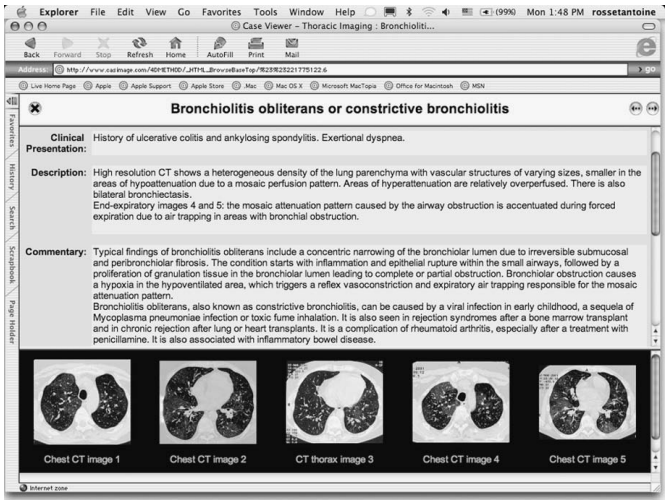

FIGURE 5. Graphic User Interface of the Casimage web site.

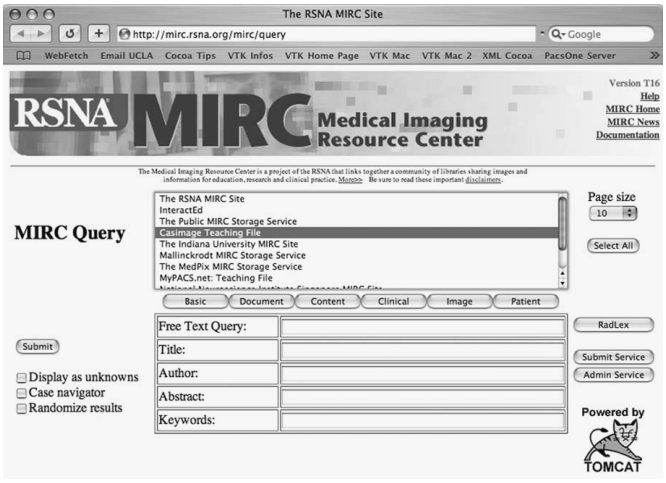

FIGURE 6. Medical Imaging Resource Center (MIRC) web site.

RESULTS

To validate the use of the system in our clinical operations, we elected to develop a thoracic imaging collection, based on cases available on our PACS. This collection is composed of 99 different cases, illustrated by 382 images. This collection was developed in less than 6 months by a radiologist during his daily clinical activity.[21] This initial collection allowed us to tune up the system for best performance and quality in a clinical environment. We then deployed the system on all PACS workstations of our department. Many members of the department successfully developed additional individual collections very rapidly. This tool is now part of the standard resources used for teaching and training of students and residents at the University Hospital of Geneva. Several faculty members have been assigned to maintain and update "official" pre- and post-graduate teaching collections that are used as part of the general curriculum of the medical school. After being operational for about 3 years, over 50,000 images were entered in the system so far, corresponding to approximately 7600 teaching files cases. At the current stage of the project, users add an average of 500 images per week in our system. We also produced 9 CD-ROMs on selected topics for wider distribution to students and residents and for presentations in international meetings and conferences. Our public web server offers access to selected reviewed collections from our institution (http://www.casimage.com) (Fig. 5). It records an average of 500 connections per day, and users from more than 200 different countries have visited our web site so far.

The Casimage environment is available to other institutions, through our web site,[3] as a stand-alone version or as a client/server version. At this date the stand-alone version has been downloaded more than 3000 times, and 5 institutions have already installed the client/server version in their radiology departments, working on different commercial PACS like Centricity from General Electric,[22] DirectView PACS from Kodak,[23] MagicView from Siemens,[24] and I-SoftView from Cedara.[25]

DISCUSSION

The transition from traditional films to PACS is a challenging and often difficult path. In an academic environment, the transition to the digital world is not limited to the clinical implementation of the PACS but also affects significantly the teaching and academic role of a radiology department. The benefit of using a PACS in clinical routine is to provide better tools supporting teaching and training tasks that are part of the academic mission of a university hospital.[1] This extension of PACS functionality usually cannot be achieved at the same time as the migration to a digital PACS environment; most current commercial PACS do not offer the tools needed for the creation of teaching files of selected clinical cases. In clinical PACS, the search for an examination is mostly done by the patient's demographic data, not by keywords or ACR codes. It is usually not possible to index or retrieve specific pathologies or clinical findings in a conventional PACS. In most clinical settings, there are also limitations and constraints imposed by security and confidentiality requirements: it is often difficult to share the same software and database environment used clinically simply by restricting access to the patient's demographic data for teaching purposes. The selection of a PACS should always consider the needs and requirements of academic and research tasks that often require an in-depth evaluation of the needs and functionalities that the system must have to support sharing clinical data for teaching and education purposes while maintaining full compliance with policies and regulations on patient confidentialities and data security.[26] In our system, image data are anonymized and only the author of the particular case can have access to patient demographics if needed.

ADVANTAGES OF A DIGITAL TEACHING FILES SYSTEM

Advantages of a complete digital environment for teaching files are numerous:

1) The transfer of digital information. Built on a client/server architecture, the transfer of information is transparent to the user. A user can consult a case from anywhere at anytime.[27] In the case of a user wanting to move a large volume of data, he can create a stand-alone CD-ROM, allowing moving more than 2000 radiologic images on a low-cost media that can easily be sent by mail.[9]
2) Users can consult the database with interactive query features,[28] like quizzes. They benefit also from powerful searching functions with logical operators (AND, OR, IF).
3) Since cases and images are stored in a database with a fixed structure, it is easy to re-use existing collections to build new collections or export them from one project to another.
4) A complete authoring environment greatly facilitates the task of preparation and creation of a teaching database: the

radiologist selects his image directly on the PACS during his clinical work and copies selected images in the digital system.[29] The clinical history, comments, legends, and annotations can be added directly or at a later time in the database through the interactive authoring software. Thanks to a client/server architecture, every newly created case is immediately available on the network for other users to review.[30] There is no need to use multiple software components to create a case, and to publish the results.

5) With the emergence of multicentric and national efforts for federating large numbers of existing teaching databases like the MIRC initiative proposed by the RSNA,[20] exchange and creation of large collections from different institutions is now possible.

SECURITY

With powerful functions of transfer and copy of clinical information, security and data confidentiality are major concerns that were addressed in our authoring environment. Maintaining data confidentiality is achieved by restricting the access to the patient's demographic data to the main author of a given case. Data security is obtained by limiting the ability of any individual to modify or alter the data. For maintaining these 2 rules, a strict identification procedure with an individual password is enforced.[18] For each collection there is a unique administrator, and possibly multiple co-administrators, who can see the patient's demographic data and edit or modify a case. The system stores patient identification to allow subsequent updates of the cases with additional exams and images that may be acquired at a later time. When users log in for remote consultation under generic or anonymous login, they only have access to de-identified data with no access to the patient demographic data.

To increase the security of patients' data, we usually recommended to set up an independent web server with anonymized image data for Internet distribution of teaching databases. We installed an Internet server outside our intranet network, without a link to the intranet database server. All collections that are accessible through the Internet are copied manually after extraction of all patient demographic data. Only the Internet server is connected to the MIRC network.

KEYS TO SUCCESS

The success of such projects relies mainly on the motivation and satisfaction of the users.[30] The creation and maintenance of a teaching files database often represent additional work to the radiologist's clinical activity. The digital teaching files system should facilitate and support the user motivation to spend time on collections creation. The author should see in the system a practical and powerful tool, and not a succession of incomprehensible and complex procedures. We put a particular effort into designing the system to minimize the number of steps required to create and store a case. Authors' creativity and motivation are inversely proportional to the complexity and awkwardness of a system.[26] We wanted the system to be easily accessible from everywhere at any time, allowing both the authors and the users to be able to work on the image collections remotely from any place in the department. The client/server architecture facilitates the implementation of a wide distribution and easy remote access. This offers a higher degree in flexibility and convenience where authors can select images on the PACS stations during their clinical interpretation, and then in a later time edit the selected cases from another workstation or from a standard personal computer. This ease of access adds to the convenience and motivation for creating teaching files, which often tends to be rapidly exhausted after the initial enthusiasm of the creation of a complete collection.

One major concern of many users creating a collection is to be sure that his work will be visible and used by others. It is often frustrating for authors that prepare large collections of teaching files when they have no easy way to distribute their work and make it accessible to others. By offering off-line and on-line access through CD-Rom, Internet, and MIRC network, our system offers the maximum visibility.

OUTLOOK

We are currently evaluating some advanced image and pattern recognition tools such as Content-Based Image Retrieval (CBIR)[31] algorithms as an extension for our teaching files database query mechanisms to complement text-based search. These algorithms allow users to find a case in a large collection by similarities in shape, texture, and other visual patterns found in the images. Instead of relying on keywords and codes to retrieve images and cases, one would select one or several template image(s) of what to search for and the system will automatically search the database for all images that have some degree of visual similarity with the query image(s). We are currently evaluating an existing open source image retrieval system: GIFT—GNU Image Finding Tool[32]—that we have adapted to specific medical image features from particular imaging modalities (more importance on gray-scale features and textures than on colors and changes in the user interface).

We recently made available a web site to give a demonstration of the CBIR functionality: http://viper.unige.ch/~muellerh/demoRSNA/index.php. This demonstration allows showing of random images from the collection and choosing images for starting queries with examples. More information on this medGIFT project can be found at http://www.sim.hcuge.ch/medgift/.

We are also working on an extension of the software that should connect multiple Casimage servers to allow multiple users from different institutions to work on the same collections while having separate physical storage of their own data. This work still requires adequate network protection and data

security mechanisms to be put in place to avoid security and confidentiality violations.

CONCLUSION

With the evolution of digital imaging and emergence of digital teaching tools, it is vital for an academic radiology department to implement a robust and convenient digital teaching files system. Existing commercial solutions for creating image collections are often not suitable for radiologic applications, and usually do not provide adequate PACS integration. For these reasons we elected to develop our own digital teaching files system and image collection database system. The system is built on 3 main functions: (1) The images import function fully integrated with our PACS workstations, as well as compatibility with other standard multimedia image formats (JPEG, TIFF, BMP, etc.). (2) The authoring features to edit images and texts associated to a case. (3) And finally, the data sharing and distribution with the creation of stand-alone and multi-platform CD-ROMs; with a web server for online-access using any web browser, such as Internet Explorer or Netscape, and with the MIRC standard compatibility for sharing on the MIRC network.

The system has been implemented and is accessible from every computer of our department, and the rapid growth of database content was a clear evidence of the success and acceptance of the system by the users. The storage of selected interesting cases in the image databases became a natural and common trend among our radiologists during their daily clinical routine. They particularly praised the convenience of doing so directly from the PACS workstations while reviewing images for clinical diagnosis. The ability of generating on-line teaching files as well as off-line CD-ROMs motivated numerous members of our department to add comments and complete collections of cases in specific domains to generate comprehensive collections that were edited and distributed in large numbers to other institutions and in international meetings and conferences.

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