Casimage project : integration of a multimedia teaching and reference database in a PACS environment

Rosset, Antoine

Casimage Project : Integration of a Multimedia Teaching and Reference Database in a PACS Environment

Antoine ROSSET
Département de Radiologie
Hôpital Cantonal Universitaire de Genève
Rue Micheli-du-Crest 24
1211 Genève 14

DOCTORAT EN MEDECINE

Thèse de :
Monsieur Antoine ROSSET
originaire de Thônex (GE)

Intitulée :

« Casimage Project : Integration of a Multimedia Teaching and Reference Database in a PACS Environment »

La Faculté de médecine, sur le préavis de Monsieur François TERRIER, professeur ordinaire au Département de radiologie, autorise l'impression de la présente thèse, sans prétendre par là émettre d'opinion sur les propositions qui y sont énoncées.

Genève, le 19 décembre 2002

Thèse n° 10301

Peter SUTER
Doyen

Table des matières

Résumé en français

Le but de cette thèse était le développement d'un environnement digital de création et de partage de collections de cas en imagerie médicale. Cet environnement devait s'adapter et s'intégrer au PACS (Picture Archiving and Communication System) fonctionnant avec la norme DICOM (Digital Imaging and Communications in Medicine), actuellement utilisé en radiologie. La finalité de ce projet était de remplacer par un système 100% numérique les collections classiques sous forme de films imprimés.

Ce système de collections de cas, nommé Casimage, est basé sur un moteur de base de données, permettant l'accès aux données, à la fois depuis Internet ou Intranet (http://www.casimage.com), ainsi que depuis des CD-ROMs. Le logiciel fonctionne en mode client/serveur permettant à toutes les stations PACS de s'y connecter et d'y transférer des images rapidement, grâce au support de la norme d'images DICOM.

Le système a été déployé avec succès au sein du département de Radiologie de l'Hôpital Cantonal Universitaire de Genève.

Introduction en français

Ces dernières années, avec l'évolution et l'intégration de l'informatique dans le domaine de l'imagerie médicale, une norme est apparue pour permettre à toutes les modalités radiologiques de communiquer entre elles et de partager les images produites à travers des réseaux informatiques. Les systèmes permettant d'échanger et de stocker les images médicales s'appellent « Picture Archiving and Communication System » (PACS). Ces systèmes répondent tous à la norme « Digital Imaging and Communications in Medicine », les rendant compatibles entre eux. Un PACS a pour but de permettre l'exploitation clinique des images produites dans un département de radiologie. Les images et les examens sont sauvegardés dans un format de fichier particulier décrit dans la norme DICOM. Ce format DICOM contient aussi bien l'image elle-même et ses paramètres, mais également les informations relatives aux patients (nom, âge, sexe, antécédents, etc.). Les examens peuvent donc être entièrement lu et analysé sur des stations informatiques, ne nécessitant plus l'impression des images sur des films radiologiques. La mise en place de cette technologie fut un grand challenge pour un grand nombre de d'hôpitaux : le flux de travail et l'organisation des départements sont en effet radicalement modifiés. Cette mutation permet un travail à la fois plus rapide, mais également de meilleure qualité grâce à tous les outils informatiques de traitement des images.

Le passage au PACS a également un très important impact sur le rôle d'enseignement d'un département universitaire de radiologie. L'enseignement de la radiologie est bien sûr basé sur un apprentissage théorique des signes radiologiques, mais s'appuie énormément sur des collections de cas (« teaching files » en anglais) pour démontrer et entraîner l'œil des étudiants. La radiologie est par essence une science de l'image, seule la pratique de l'image permet d'apprendre la radiologie. Avec le PACS, les images n'étant disponibles que sous forme digitale, les anciennes collections de cas sous forme de films deviennent désuètes et ne reflètent plus la pratique courante des radiologues d'aujourd'hui.

C’est pour cette raison qu’il était indispensable de développer de nouveaux outils pour l’enseignement de l’imagerie médicale, s’adaptant à la norme PACS.

Le passage de collections de cas classiques à des collections de cas digitales offre de nombreux avantages : 1) un accès ubiquitaire et instantané grâce aux technologies d’Internet, 2) une capacité de transport incomparable à un coût réduit par l’utilisation des CD-ROMs, 3) des outils interactifs pour la recherche, la création de QCMs ou encore la manipulation des images.

Un tel système de collections digitales doit inclure trois principales fonctions desquelles va dépendre son succès : 1) des fonctions d’importation d’images qui permettent le support de différentes sources, comme le format DICOM, les scanners à plats, appareils photos digitaux, etc. 2) des fonctions permettant l’édition des images médicales, notamment le réglage des intensités de niveaux gris, indispensable pour les modalités de type CT ou IRM, ainsi que des fonctions d’édition des textes associés à ces images (sémiologie, commentaires, références, etc.) 3) et enfin, des fonctions de partage de ces collections par leur consultation à travers des navigateurs Internet ou par la production de CD-ROMs. Ces trois fonctions vont permettre à l’auteur des collections de travailler de façon optimale, puis à l’étudiant de consulter ces cas facilement et dans de bonnes conditions.

Après une étude de marché et l’essai de plusieurs logiciels, nous nous sommes rapidement aperçus qu’il n’existait pas de solution commerciale satisfaisante. Les logiciels existants ne sont pas ou mal adaptés à la norme PACS, y compris au format DICOM. Ils ne s’intègrent donc que très difficilement dans les environnements informatiques PACS. C’est pour cette raison que nous avons décidé de développer notre propre solution informatique pour le support de ces collections de cas : le projet Casimage.

La première étape était le choix technologique. Ce choix s’est bien sûr porté sur un logiciel de base de données permettant à la fois de gérer des textes et des images. Les performances de la base de données étaient également un point critique, puisque ces images radiologiques sont souvent de résolution spatiale et dynamique élevée. Un autre critère était le support des outils relatifs à

Internet (serveur http, java, javascript). Le logiciel 4th Dimension de la société ACI S.A. a été retenu. Il avait comme autre avantage d'intégrer un environnement de développement nous permettant de développer les fonctions spécifiques d'intégration avec le PACS ainsi que le support du format radiologique DICOM. Le développement a pris 6 mois à temps complet. Le premier prototype a ensuite été déployé au sein du département de radiologie, avec un serveur central, tournant sous MacOS X Server, et le déploiement de plusieurs logiciels de type « client » à la fois sur les stations d'interprétation PACS et sur les ordinateurs personnels des radiologues. Ces logiciels « client » fonctionnent aussi bien sur les systèmes MacOS que Windows. Ces logiciels « client » permettent aux radiologues de gérer les collections dont ils sont responsables, avec des outils d'édition des images et du texte. Le partage et la distribution de ces collections sont assurés par le serveur http intégré au logiciel 4th Dimension. Il permet à n'importe quel ordinateur de l'hôpital de consulter ces collections par l'intermédiaire d'un navigateur Internet du type Internet Explorer ou Netscape. L'autre mode de consultation est le CD-ROM. Durant cette première année d'utilisation, nous avons produit quatre CD-ROMs : trois pour la formation post-graduée (Ultrasons Doppler, Imagerie Musculaire, Imagerie Ostéo-Articulaire) et un pour la formation pré-graduée (Imagerie Médicale pour étudiants). L'avantage du CD-Rom par rapport à la consultation avec un navigateur Internet est de permettre à l'étudiant de travailler chez lui. En effet, la consultation d'images de haute résolution prend actuellement un temps relativement long si l'utilisateur ne possède pas une connexion haut débit, comme disponible au sein de l'hôpital.

En environ une année d'utilisation, l'adoption du système Casimage au sein de l'hôpital a été un succès. Le système est utilisé par plus de quarante médecins. La fréquence de connexion journalière est d'environ 40. Les utilisateurs rajoutent environ 300 images /semaine dans la base de données. La base de données contient actuellement 25'000 images pour 4'000 cas. Les clefs du succès de ce projet résident dans l'intégration du logiciel au PACS. En effet, l'utilisateur peut créer des nouveaux cas en quelques manipulations de souris et il n'a pas besoin de changer d'ordinateur pour le faire, Casimage est entièrement

accessible depuis les stations PACS. Le travail de création de cas ne produit donc pas de surcharge de travail et il peut être fait durant le temps d'interprétation des examens cliniques.

À la suite de l'enthousiasme rencontré en radiologie, le projet Casimage est actuellement étendu aux autres départements travaillant avec l'image : la chirurgie orthopédique, la chirurgie viscérale, la dermatologie, la pathologie et l'ophtalmologie. Étant donné que Casimage supporte également des séquences animées du type AVI ou MPEG, les chirurgiens sont très intéressés à créer des collections de films illustrant les différents types d'opération, par exemple.

Dans les possibilités d'évolution du système, nous entamons une réflexion pour l'intégration de fonctions de type CBIR (Content Based Image Retrieval) qui permettent à l'utilisateur de chercher une image selon des critères objectifs de l'image et non pas uniquement selon le texte décrivant ces images.

Introduction

With the introduction of PACS in radiology, classic teaching files based on printed films become rapidly obsolete and incompatible with the digital environment of modern radiology departments (1). With the recent developments of PACS (2) and the evolution of standards such as DICOM (3), the development of a digital teaching files system is facilitated, allowing the radiologist to benefit from the advantages of digital imaging technology to edit and share image collections: anywhere and anytime through on-line or off-line access (Internet, CD-ROM), with means for quick and easy data replication of multimedia data sets, in an interactive environment providing powerful and convenient tools for query and data retrieval. A digital teaching files authoring environment should include three main functions, on which will depend its success: importing images from different sources, editing images and associated description, and finally sharing and consultation of image collections. These three functions represent a chain of events that must allow the author to work efficiently, then allowing the users easy and convenient access to these collections. No satisfactory commercial solution is available today. Existing software programs for creating collections of images often do not support DICOM imaging standard and are often not designed to coexist with an existing clinical PACS. This is why we decided to develop our own system. 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 computers.

Materials and Methods

For the development of our digital teaching files authoring and storage system, we chose a commercially available relational database development environment: 4th Dimension by ACI S.A., version 6.7.1(4, 5). This software was installed in a client/server mode on a Macintosh computer (G4 800 MHz processor, 372 MB RAM, 80 GB Hard Disk), with Mac OS 10.1 as the operating system. The database structure was defined in four relational tables (author-

collection-case-image) with a One-To-Many relation between them. For each table, we defined a list of specific fields (Table 1). Images 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 file format (Joint Photographic Experts Group (6)) for still images, and in MPEG file format for dynamic sequences (7). We use the lowest compression rate for JPEG files to minimize image deteriorations due to compression (8, 9, 10) and MPEG (Moving Picture Experts Group (11)) compression for QuickTime files. We did not set any limitation to the size and spatial resolution of the images. File size is limited to 10 MB for reasons of performance. The database server is the core of our system (Fig. 1). Users can connect to the central database in a client/server mode. The client software is also developed with the 4th Dimension environment and can run on Mac OS and Windows operating system and it connects to the server through standard TCP/IP protocol.

Data Import

The first function to be offered by our system is the ability to import images, from our PACS or from any digital source directly into the image database. In our department, we have been using for 2 years a commercial DICOM-based PACS from ImageDevice (12), from which the images of all modalities are saved and retrieved for clinical interpretation. We developed two ways to import DICOM images into our digital teaching files system:

1) From a DICOM file: we developed a 4th Dimension plug-in that converts a DICOM file to a JPEG file. It allows the user to select custom window level and width before the conversion. This plug-in uses our own DICOM C/C++ software library, Papyrus 3.0 (13). The Papyrus toolkit developed at the University of Geneva is available in the public domain (14) and is written in ANSI C (American National Standard for Information (15)), and thus compatible with most C/C++ compilers.

2) Using the DICOM communication standard protocol: We installed on our server a “DICOM listener” software, that we developed in the Java programming

language. This Java DICOM listener is also available in the public domain (16). It allows any user of our PACS to send a DICOM data set directly to our digital teaching files system (17). These images are then converted from DICOM format to JPEG with our Papyrus plug-in software (13).

Since some images do not come from our PACS, but can, for example, be scanned from hard-copy or films, we also support the majority of standard multimedia file formats (JPEG, TIFF, BMP, Photoshop), with the use of two commercial plug-ins for 4th Dimension: Qpix and Qmedia (18). These plug-ins convert all these multimedia file formats to JPEG, and handle QuickTime files.

Finally our system supports a Copy/Paste function: our 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 into the server database (19) (Fig. 2). Depending on the application used to copy images from, this function can be limited by the display resolution and thus may require high resolution displays for copying high resolution images like projectional x-rays.

Data Editing

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 (Fig. 3). The text data can also be edited in a word processing software in order to benefit from grammatical and spelling corrections and then pasted back into the image database. The client software also includes simple image editing functions, such as change of spatial resolution, cropping, and contrast/brightness setting (Fig. 4). 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, removing part of the image or adding arrows or legends on an image.

Data Sharing

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

1) A web server (HTTP protocol) that allows any web browser to consult our collections (Fig. 5) through any standard web-browser without the need of any special software.

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. 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 (20).

Discussion

The use of our digital teaching files system was rapidly adopted by many members of the department who successfully developed large collections of images. All radiologists in our department have an access to the database with their own “personal” collection(s). This tool is now part of our standard resources used for teaching and training of students and residents, and faculty members are assigned to maintain and update “official” pre- and post-graduate teaching collections, such as MRI muscle tumor, bone pathology, Doppler ultrasound, emergency neuroradiology, and tumors in neuroradiology. After being operational for about one year, over 25’000 images were entered in about 4’000 teaching files cases. At the current stage of the project, users add about 200 images per week in our system. We also published 3 CD-ROMs for students and residents and presented them in international meetings and conferences. Actually, we did not evaluate the impact of these new digital teaching files on users. It would be certainly interesting to evaluate students’ feedbacks, by example.

The transition from the traditional use of analogue films to digital images 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. Apart from the benefit of using a PACS in clinical routine, an additional benefit 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 can usually not be achieved at the same time as the migration to a digital PACS environment: most current commercial PACS do not offer tools for the creation of teaching files of selected clinical cases. In clinical PACS, the search for an exam is generally by patient's data, not by keyword or ACR codes. It is usually not possible to index or retrieve specific pathologies in a conventional PACS. In most clinical settings there are also limitations and constraint 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 (21).

Advantages of a digital teaching files system

The advantages of a digital environment for teaching files compared to film-based environment are numerous:

1) The most important advantage is the cost effectiveness of a digital system. While it requires expensive computer equipment, it is possible to limit the cost by sharing the same computers for software dedicated to the PACS and for

software for the digital teaching files system. The additional cost will then be limited to the software and its maintenance. On the other hand, traditional film-based collection generates continuous and increasing costs with the size of the collection: the duplication of a film costs approximately 1 $US per film, compared with a CD-R costing less than 1 $US, but which can store up to 2000 JPEG images (if images are stored at a medium resolution of 800x800 in the highest quality mode). Film collections also require significant storage space and are more difficult to transfer from one location to another. For large image collections that exceeds a few thousands images, the digital system clearly provides a financial advantage (22).

2) Another advantage of digital image collections is the ability to duplicate the data very easily without any loss of quality and information. A digital collection can thus be duplicated and distributed to other institutions at relatively low cost.

3) The transfer of a digital collection is extremely easy compared to a film-based collection. In our system we have two modes of digital transfer: by digital network, allowing the user to transfer more important volumes of data from one site to another (23), without any physical transport; or by CD-ROM, allowing the user to move more than 2000 radiological images on a low-cost media that can easily be sent by mail (9).

4) With a digital system, it is possible to add some interactivity to the teaching files (24). The user benefits from powerful searching functions with logical operators (AND, OR, IF) and from the possibility to search targeted fields as anatomy or ACR Codes. The interactivity also allows self-evaluation tests and quizzes to be incorporated.

5) A digital system greatly facilitates the task of preparation and creation of a teaching database. By contrast, the creation of a film-based collection is a complex and time consuming task, requiring several steps: once the image is chosen, it is necessary to have a copy made by a technician, to dictate the case comments to a secretary and finally to gather and classify the case in a library. A digital system simplifies these steps into one single step: the radiologist selects his image directly on the PACS and copies it in the digital system (25). The user

can also enter his comments, legends and annotations directly in the database authoring software. Thanks to a client/server architecture, every newly created case is immediately available on the network, for other users to review (26).

Technology choice

The technology choice is one of the keys to success for a digital system. First of all, it is important to choose an adequate database management system (DBMS). Using the generic functions of a DBMS, the user will be able to search, sort and classify his data, according to the preset fields and tables. The DBMS must be able, however, to perform these functions without performance limitation with large volumes of data. The DBMS represents the core of the system around which fundamental functions of import, edition and sharing are developed and its choice is key for the implementation of a successful system.

Many characteristics of the digital system depend of the DBMS choice:

- Its ease of use through a simple Graphical User Interface (GUI)
- Its compatibility with other systems through its ability to import and export data
- Its adaptability to be cross-platform and system-independent
- Its sharing capacities through the support of Internet protocol.

We elected to use the 4th Dimension DBMS from ACI SA because it was found to best support the requirements listed above: it has a robust database engine with no limits on the data size; it can manage images and animated sequences with the help of plug-ins; it functions in a transparent way with Mac OS or Windows; it offers a programming language for the development of specific functions like the DICOM support; it includes a powerful tool for the creation of the GUI; it includes an HTTP server for data sharing on Internet; and finally it functions in a transparent way in client/server mode for the use in a network, and in local mode for the creation of stand-alones CD-ROMs. The whole system is developed with the same tool, thus avoiding problems of interfacing between several different software packages. The use of a single tool also provides the

most optimal performance and facilitates the transfer of the data from one site to another.

System development

Based on 4th Dimension database management system, the development of import functions, editing tools and data-sharing functions took approximately 6 months for a full-time software developer. The first stage of the development was the definition of the 4 relational tables (Table 1). These 4 tables represent the 4 hierarchical levels in which the data are structured: the highest level is the « administrator » table. This table contains information of each person having access to the system (password, phone numbers, email and department). This table has a relation with one or more « collections » tables. A table « collection » represents a whole collection; it is defined by the name of the collection and the type of the collection (teaching, search and personal). Each table « collection » has then a relation with one or more tables « case ». The table « case » contains all the medical data: patient name, clinical presentation, image description, commentary, references, ACR codes, pathology, etc. And finally, each table « case » has a relation with one or more « image » tables, which define the image name, specific commentaries about the image and the link with the image file. The tables and fields definition is an important stage, which must be made with the input from the users. The users cannot modify these tables once they have been created. Any changes in these tables generate new development and re-programming of the database. Moreover if fields are added or modified, while data are already present in the database, the risk of loosing data consistency is quite high. For example, the new fields will not be filled in the old data, and the modified fields will not correspond to the data already present.

After defining the database structure, we have developed the necessary import functions to allow the integration with our PACS. It was important for our project that the system allows a complete integration with the PACS infrastructure,

and allows importing image data from the PACS with a limited number of steps. To achieve such integration, we installed the client software (the proprietary client developed with 4th Dimension) on each PACS diagnostic workstation in our department. The advantage of having the PACS software and the teaching files software on the same computer used for clinical interpretation is that it avoids unnecessary “double browsing” to retrieve the image data: when the user sees an interesting exam during his interpretation work, he can quickly copy and paste this image with the proper window level and window width settings (Fig. 2) (19, 29). This eliminates the need for searching for this exam subsequently using different software to retrieve and transfer the images. Simplicity and rapidity of this step is a key of success and acceptability by the users, it motivates users to add new cases to the digital teaching files system on a regular basis (27). In addition to this easy copy/paste function, the user can also do a standard “DICOM Send” function from the PACS software to our Java DICOM Listener installed on our digital teaching files server. In that mode the user must then set the window level and width in the client software, and the DICOM image will then be converted in the JPEG format at the original resolution of the DICOM image. This method requires more steps than the copy/paste function but allows to send image sets from any DICOM-compliant source. This copy/paste function was found to be the most easiest import method in our department. As all images do not necessarily originate from our PACS, it was equally important to support additional standard file formats: it is therefore possible to import an image in JPEG, TIFF or a BMP format.

We have elected to store images in JPEG file format for several reasons: JPEG allows a very advantageous quality/size ratio, with a compression ratio of about 90% (10), with few image distortions in high quality mode (8); its use is ubiquitous, supported by all multimedia software (Microsoft PowerPoint, Adobe Photoshop); it is the image standard format that is widely used for the Internet and world wide web applications(28); and finally, it does not contain « hidden » confidential data, unlike DICOM files which can contain the patient’s specific metadata (29). The JPEG file format is actually the standard most widely used for

teaching files system (8, 10, 9, 19, 23, 25, 26, 28, 30). A disadvantage of JPEG is that the pixel depth is only of 8 bits allowing for only 256 shades of grays on grayscale images. Therefore it is not possible to change the window level and window width defined by the author, once this image is in the database. A solution to this problem could be to use an alternative format like the more recent PNG file format provided that its use spreads as much as the JPEG file format in the general consumer market (8).

After the import functions, we have developed the editing functions for images and textual data. We have used the graphic user interface (GUI) tool of 4th Dimension: the client software, which allows to communicate and interact with the central database server. This client software takes advantage of a user friendly GUI offering the full set of standard GUI features such as buttons, popup menus, hierarchical lists, drag and drop functions, icons, etc. It was designed to be very intuitive. The user sees all cases and images stored in the database as small thumbnail images. The user can edit all different fields and tables of the database simply by pointing and clicking in the given field. For certain fields (anatomy, ACR codes, etc.), we have added the possibility to use pre-defined lists with the most frequently used values (19). The user can also edit and modify the images with the basic image processing functions (zoom, crop, contrast/brightness). Our experience showed that these basic functions are sufficient for most cases. If a user wants to do a more complex image processing and editing, he can transfer any image to more advanced commercially available image processing software programs.

The last component of our system was the development of data sharing functions. The data sharing is the final and most important stage of a teaching files system. An image collection is useful only if it can be easily shared and reviewed by the greatest number of users. We have used two characteristics of 4th Dimension for facilitating data sharing: the first is the ability of making a stand-alone application running either on Macintosh operating system or Microsoft Windows systems. The second mechanism uses the feature of sharing the database on the Internet with the integrated web server.

The stand-alone applications allow us to generate CD-ROMs of specific collections. This sharing mode on CD-ROM is complementary to on-line Internet access. It offers the advantages of easy transfer of a very large data volume (650 MB) on a small and affordable media. Off-line media such as CD-ROMs also offer better performance compared to on-line access over the web that can be relatively slow depending on the bandwidth of the network access.

The access to the data on-line allows a continuous update of the database collection and real time access to newly updated cases. Every new case that is entered in the database becomes available immediately to other users for review. The convenience and flexibility of data sharing over the Internet is unmatched by any other technology (30, 31). The access to databases through Web pages using standard HTML allows users to retrieve and review images from the database using standard web browsers. The web pages GUI is simple and uses the same principle of the client software developed with 4th Dimension (32): the user navigates in the collections with small thumbnail images (Fig. 5). An example of this web access is available on our public web site: http://www.casimage.com.

Security

Security and data protection rely on two basic requirements: 1) it is necessary to maintain patient confidentiality by protecting the access to the patient's demographic data. 2) It is necessary to prevent other persons from modifying or altering the data. For these two reasons our system required the set up of a user identification procedure with a password (19). Only the author will be able to see the patient's demographic data of a case being edited. It is important that 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. Authors must also be cautious to remove any patient's name appearing on an image, like an ultrasound screenshot. With the identification procedure, the system authorizes data modification only by the owner and author of that case. The system authorizes also an anonymous login without access to the patient demographic data.

In order to increase the security of patient's data, we have set up an independent web server for Internet distribution of teaching databases. This Internet server is located 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.

Keys to success

The creation and the maintenance of a teaching files database often represent additional work to the radiologist's clinical activity. The success of such projects depends mainly on the motivation of the users (26). This motivation depends on such questions: Can I make effective use of an image collection and generate a publication or a scientific paper out of data extracted from a collection? Is there a possibility of publishing a collection as a teaching file or a reference image database? Will I learn something in doing it? Are there some users interested in this collection?

The digital teaching files system cannot answer these questions, but it certainly can facilitate and support the user motivation to achieve these goals. The author should see in the system a practical and powerful tool, and not a succession of incomprehensible and complex procedures. The system must 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 (21). The system must also be accessible from everywhere at anytime. Thanks to the client/server architecture and to the cross-platform compatibility, the access to our system is possible from any computer in our department. The author can therefore select images on the PACS stations, and then in a second time edit the selected cases from his desktop computer. This ease of access adds to the convenience and motivation for creating teaching files, which often tends to be exhausted after the initial enthusiasm of the creation of a complete collection.

Outlook

We are currently evaluating several improvements to the system. First of all we would like to add options that allow drawing regions of interest (ROI) and annotations on the images. Concerning the data security, we are also evaluating the use of watermarking technologies to label the images, to offer images traceability and to prevent the illegal use of images without the author's agreement. And finally we are investigating the Content Based Image Retrieval (CBIR) algorithms as an extension for our teaching files database query mechanisms.

In the outlook of this project, it is also important to evaluate the possibility of migrating our data (images and texts) to another platform and software. It is important to not definitively rely on specific software, like the 4th Dimension DBMS. What would happen if the software company that develop and support 4th Dimension disappears? This is why we developed the possibility to export at any time the entire database in "Extensible Markup Language" (XML) (33) format for texts and in JPEG and MPEG files for images and sequences. The XML format allows us to quickly re-import all data in a new DBMS.

Conclusion

A digital teaching files system is vital for an academic radiology department equipped with a PACS. Existing commercial solutions for creating image collections are often not suitable for radiological applications. These systems are usually difficult to integrate with a PACS. For these reasons we developed our own digital teaching files system and image collection database system. We chose a database development tool that allows rapid design and development of multimedia, user-friendly authoring programs supporting web-based as well as stand-alone applications. With this software we developed the three main functions of our system: 1) the data import function fully integrated with our PACS workstations, as well as compatibility with other standard multimedia image formats (JPEG, TIFF, BMP, etc.). 2) The data editing features through a simple and powerful client software, connected to the database server remotely. 3) And

finally, the data sharing and distribution with the creation of stand-alone and multi-platform CD-ROMs, and with a web server for online-access using any web browser, such as Internet Explorer or Netscape.

The system implemented in a clinical setting was rapidly adopted by all our faculty member 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 appreciated the convenience of doing so 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 collection of cases in specific domains to generate comprehensive collections that were edited and distributed in large numbers to other institutions and in internationals meetings and conferences.

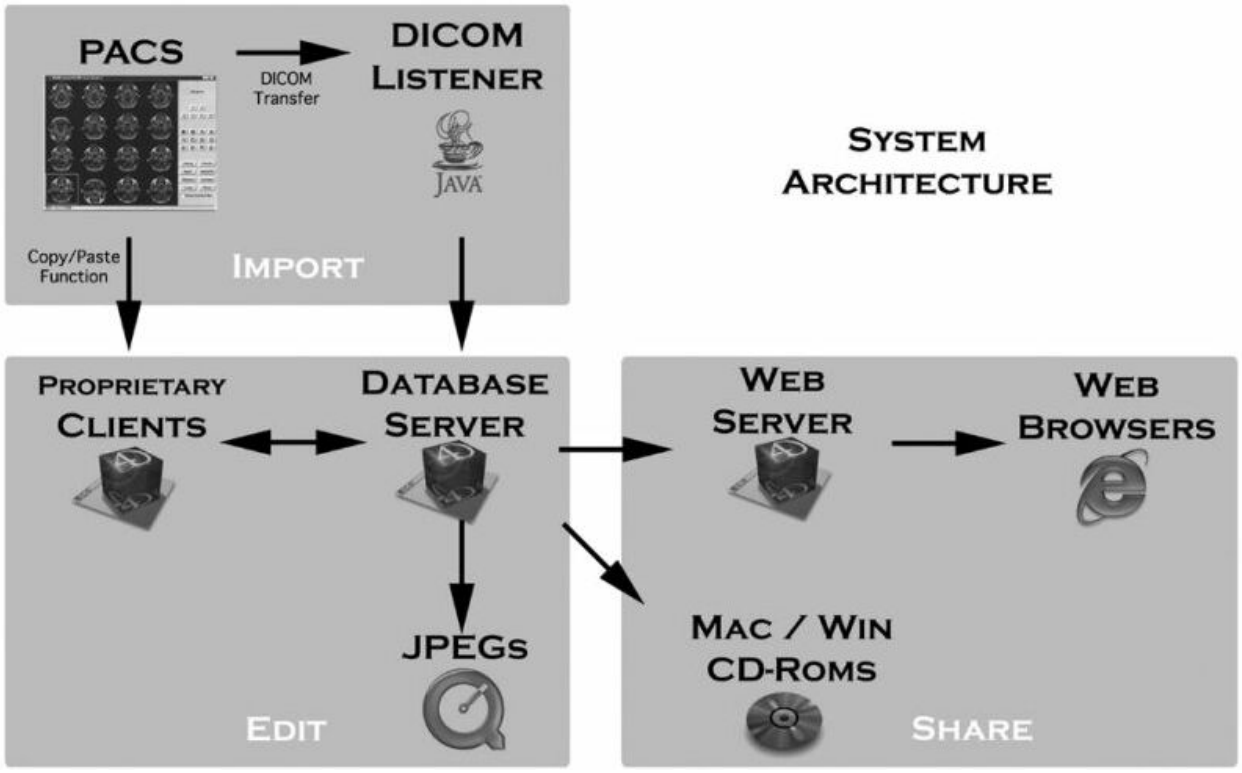
Acknowledgments

My personal thanks to Professor Osman RATIB, from UCLA, Los Angeles, for his help to write this document.

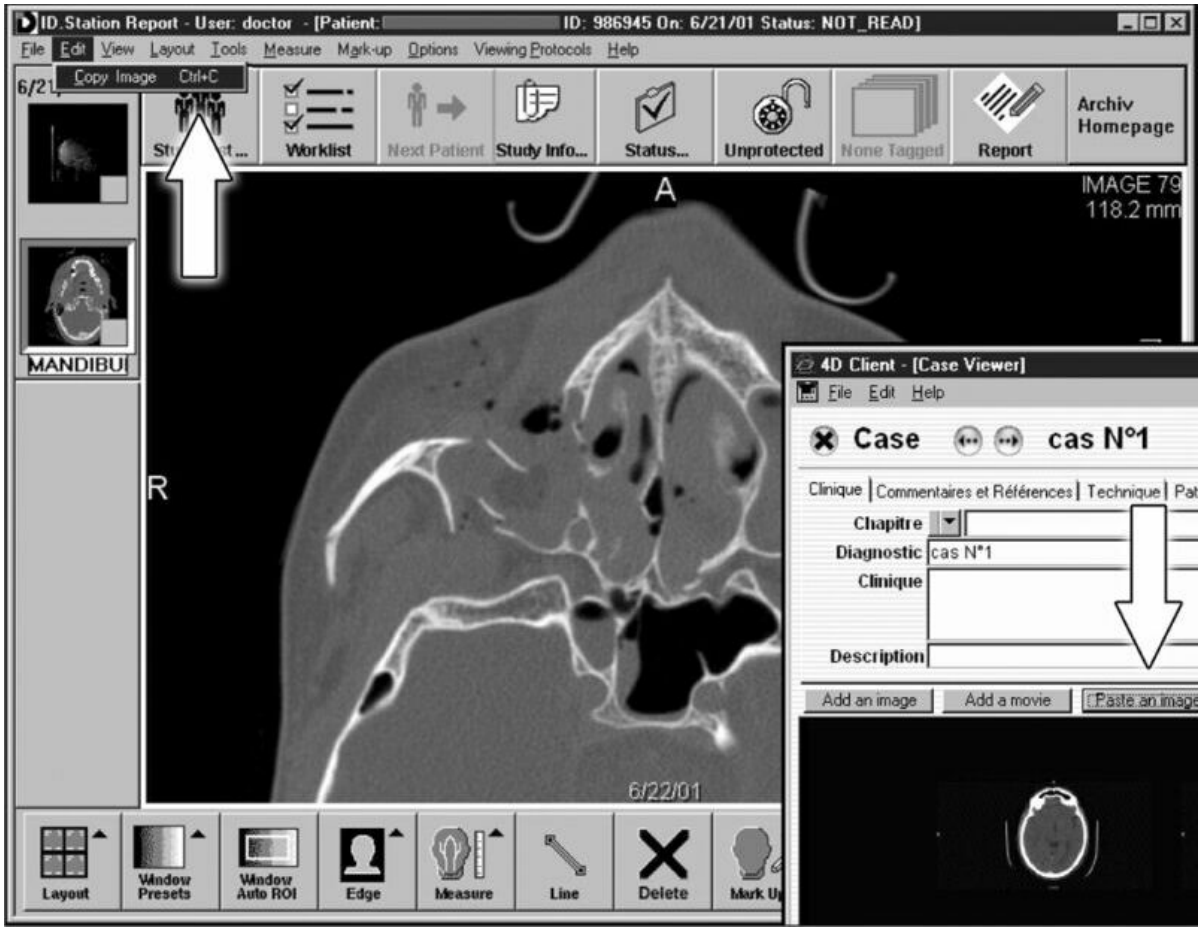
This development was funded by the Geneva Health Department grant #PL7512.

Figures

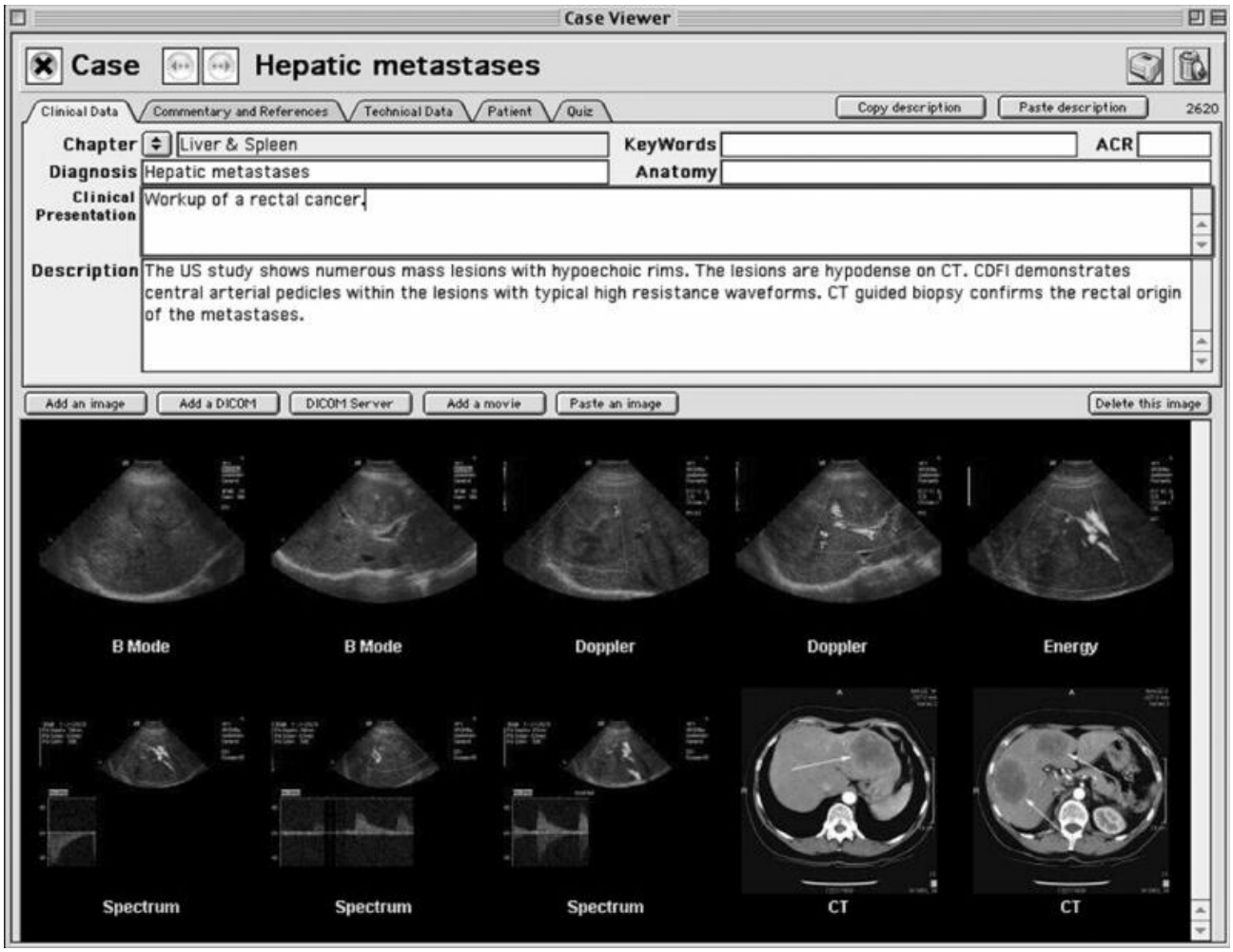
1. Architecture of the digital teaching files system



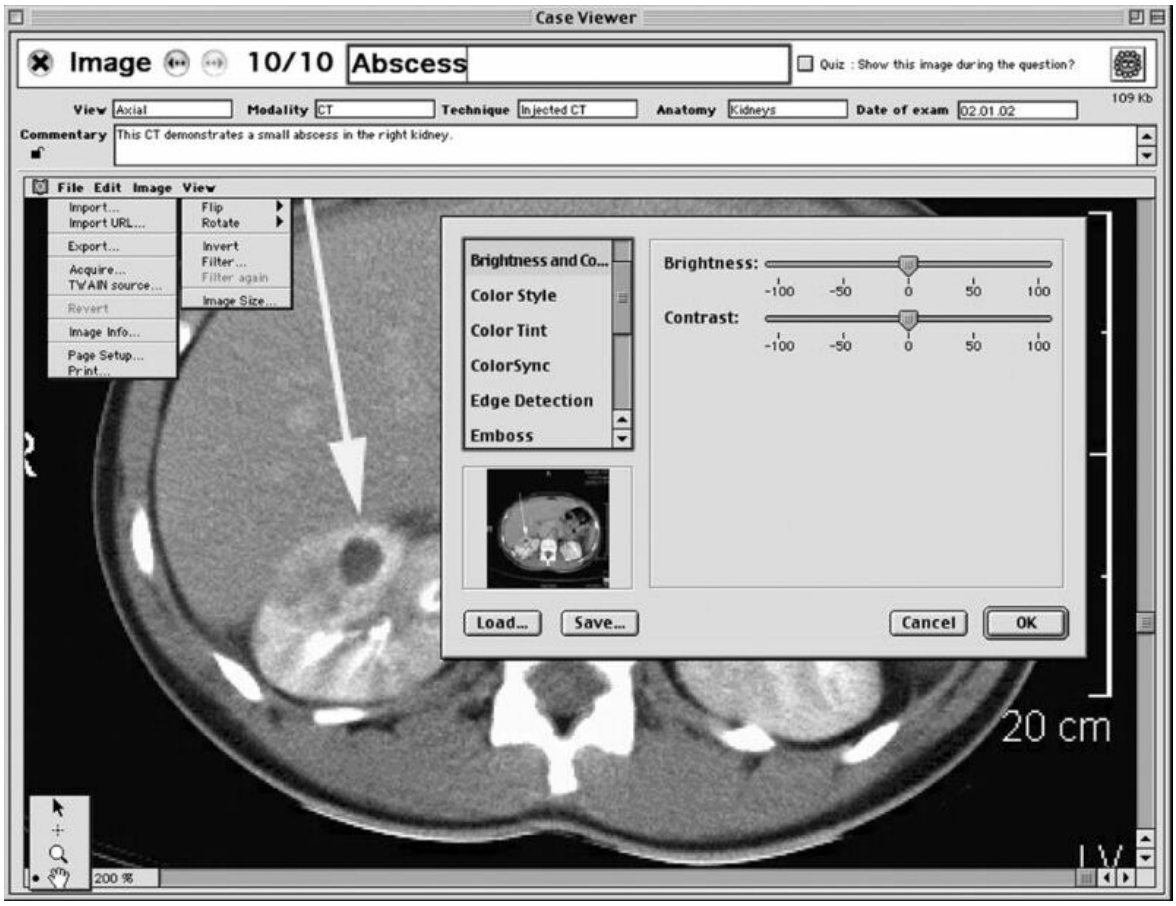
2. Screenshot of 4D user interface for case input to teaching and reference database running on PACS workstation



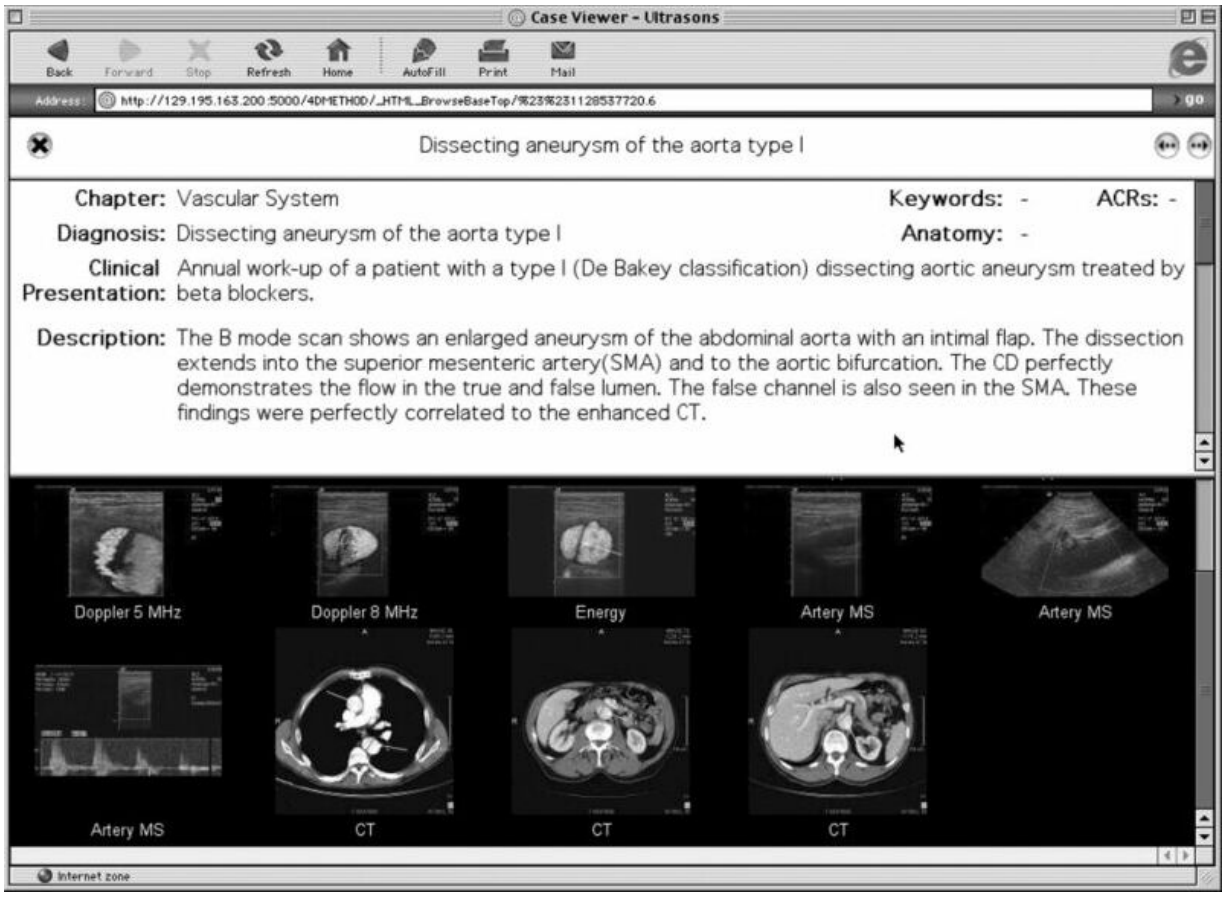
3. Graphic User Interface of the client software used to edit collections



4. Image editing capabilities of the client software



5. Graphic User Interface of the web server



Tables

Tables and fields of the Teaching Files relational database

1. Administrator	2. Collections	3. Cases	4. Images
Administrator	Administrator	Administrator	Administrator
Phone	Collection name	Collection name	Collection name
Email	Compression	Case ID	Case ID
Department	Level	Title	JPEG File ID
Hospital	Area	Clinical Presentation	Image title
Password		Diagnosis Description	Modality
		References	Technique
		Commentary	Anatomy
		Anatomy	Commentary
		ACR Codes	View
		Patient name	
		Patient Sex	
		Patient birthday	
		Patient age	

References

1. Wiggins RH, Davidson H, Dilda P, Harnsberger R, Katzman G. The evolution of filmless radiology teaching. J Digit Imaging 2001; 14:236-237
2. Ratib O, Ligier Y, Bandon D, Valentino D. Update on digital image management and PACS. Abdom Imaging. 2000; 25(4):333-340
3. National Electrical Manufacturers Association. Digital Imaging and Communications in Medicine (DICOM). Rosslyn, Va: National Electrical Manufacturers Association, 1996; PS 3.1-1996-3.13-1996.
4. ACI S.A., USA. Software Company. http://www.4d.com
5. Nayrolles P, Arguillère T, Lafeuille LO, Keromen C. Le Guide 4D Expert. Eyrolles 2000. ISBN 2-212-09163-X
6. Hamilton E. JPEG file interchange format, version 1.02. Available at: http://www.w3.org/Graphics/JPEG/jfif3.pdf Accessed February 20, 2002.
7. Apple Computer, Inc. Software Company. Quicktime Definition available at: http://www.apple.com/quicktime Accessed February 20, 2002.
8. Wiggins RH, Davidson C, Harnsberger R, Lauman J, Goede P. Image File Formats: Past, Present, and Future. Radiographics 2001; 21:789-798
9. Tran TH, Roach NA, O'Kane PL, Thune M. Creating a digital radiographic teaching file and database using a PC and common software. AJR 2000; 175:325-327
10. Kurihara Y, Okuhara Y, Narita Y, Kitazoe Y, Sawada A, Yoshida S, Geshi H. Fast image accessing based on an analysis of the picture archiving and communication system in Kochi Medical School. Comput Med Imaging Graph 1998; 22:439-445
11. MPEG Home Page, Moving Picture Experts Group, http://mpeg.telecomitalialab.com. Accessed February 20, 2002.
12. Image Device GmbH, Germany. Software company. http://www.imagedev.com Accessed February 20, 2002.
13. Ratib O, Hoehn H, Girard C, Parisot C. PAPYRUS 3.0: DICOM-compatible file format. Med Inform (Lond) 1994 Apr-Jun;19(2):171-8
14. Papyrus Toolkit, Digital Imaging Unit, Geneva University Hospital. http://www.expasy.ch/UIN/html1/projects/papyrus/papyrus.html, Accessed February 20, 2002.
15. ANSI C, American National Standard for Information. http://www.lysator.liu.se/c/rat/title.html, Accessed February 20, 2002.
16. Casimir Tool, Digital Imaging Unit, Geneva University Hospital. http://www.expasy.ch/UIN/html1/projects/Casimage/casimir/casimir.html, Accessed February 20, 2002.
17. Fernandez-Bayo J, Barbero O, Rubies C, Sentis M, Domoso L. Distributing Medical Images with Internet Technologies: A DICOM Web server and a DICOM Java Viewer. Radiographics 2000; 20:581-590

18. Escape Inc. Greece. Software company. http://www.escape.gr, Accessed February 20, 2002.
19. Khorasani R, Lester J, Davis S, Hanlon W, Fener E, Seltzer S, Adams D, Holman L. Web-based Digital Radiology Teaching File: Faciliting Case Input at Time of Interpretation. AJR 1998; 170:1165-1167
20. IdemInformatique S.A., Switzerland. Software company. http://www.ideminfo.ch, Accessed February 20, 2002.
21. Calboun P, Fishman E. Developing a Computer-assisted Instruction Program: A Process Overview for the Radiologist. Radiographics 1997; 17:1277-1291
22. Hien Dieu Tran T, Roach N, O'Kane P, Thune M. Creating a Digital Radiographic Teaching File and Database Using a PC and Common Software. AJR 2000; 175:325-327
23. Wangel M, Niemitukia L, Katia T, Soimakallo B. WWW- an effective way of teaching radiology. Comput Methods Programs Biomed 2001; 66:91-98
24. Maleck M, Fischer M, Kammer B, Zeiler C, Mangel E, Schenk F, Pfeifer KJ. Do Computers teach better? A Media comparison study for case-based teaching in Radiology. Radiographics 2001; 21:1025-1032
25. Goldberg D, DeMarco JK, Parikh T. Internet-Based Interactive Teaching File for Neuroradiology. AJR 2000; 175:1371-1373
26. Mehta A, Dreyer KJ, Montgomery M, Wittenberg J. A World Wide Web Internet Engine for Collaborative Entry and Peer Review of Radiologic Teaching Files. AJR 1999; 172:893-896
27. Siegel E, Reiner B. Electronic teaching files: seven-year experience using a commercial picture archiving and communication system. J Digit Imaging 2001; 14:125-127
28. Houldsworth A. Tuning your images for the Web: JPEGs. Available at: http://www.zdnet.com/devhead/stories/articles/0,4413,1600556,00. Accessed February 20, 2002.
29. Maldijan J, Listerud J. Automated Teaching File and Slide Database for Digital Images. AJR 2000; 175:1249-1251
30. Richardsoin ML. A World-Wide Web radiology teaching file server on the Internet. AJR 1995; 164:479-483
31. Tellis MT, Andriole KP, Avrin DE, Arenson RL. Web Technology in the Integration of a Digital Teaching File at the Diagnostic Workstation. J Digital Imaging, Vol 11, No 3, Suppl 1 (August), 1998: pp 117-119
32. Scalzetti EM. Radiology Teaching file cases on the World Wide Web. J Digit Imaging 1997; 10:209-211
33. Extensible Markup Language (XML). Available at: http://www.w3.org/XML/. Accessed December 20, 2002.