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Web-based distribution of radiological images from PACS to EPR

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Abstract

Medical images are currently created digitally and stored in the radiology department's picture archiving and communication system (PACS). Reports are usually stored in the electronic patient record (EPR) of other information systems, such as the radiology information system (RIS) or the hospital information system (HIS). But high-quality service can only be provided if the EPR data is integrated with the PACS digital images. The clinician should be able to access both systems' data in an integrated and consistent way as part of the regular working environment, the HIS or the RIS. Additionally, this system should allow for teleconferences with other users, e.g., for consultations with a specialist in the radiology department. This paper describes a web-based solution that integrates the digital images of the PACS, the EPR/HIS/RIS data and a built-in teleconferencing functionality. The integration has been successfully tested with three different commercial RIS and HIS products.

Keywords: PACS; HIS; EPR; Teleradiology; Image integration; Webviewer; DICOM

1. Introduction

Medical images are usually digitally created and stored in the radiology department's picture archiving and communication system (PACS). An important requirement is the

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distribution of digital images and reports as a single unit throughout the entire hospital. The workflow in the hospital shows that images are required and must be directly accessible in the electronic patient record (EPR). The goal is to have the complete medical information of a patient available in one consistent application and not in several information systems.

Because there are many different types of clinical workstations, we need applications that can run on any computer and operating system. Web-based programs that have a simple but powerful user interface are very flexible in this respect and can easily be controlled by other hospital (HIS) or radiology information systems (RIS). A web-based application for displaying and processing medical images must be very flexible for integration with various RIS or HIS electronic patient records (EPR). The interface must be easy to adapt to the other information systems.

Saving time is as important as improving the quality and speed of the personnel's communication. Therefore, it should be possible to discuss images in synchronized teleconferences among clinicians or in an interdisciplinary exchange, e.g., between clinicians and radiologists, for either consultative purposes or to discuss diagnostic and therapeutic measures. The web-based application must be able to synchronize with the professional radiology workstation as well as other web applications but without requiring personnel to leave the regular work environment or to launch external or additional programs.

Not only radiologists but clinicians also need to process medical images using level/windowing, measurements, etc. Therefore, the clinical application of image display must also provide for it.

2. Method

Since 1996, the Steinbeis-Transferzentrum Medizinische Informatik in Heidelberg has been developing the CHILI radiology system in cooperation with the German Cancer Research Center in Heidelberg [1]. This product started as a teleradiology system and evolved into a fully functional radiological reporting workstation so that today, CHILI provides the functionality of a PACS [2]. Because it has not been possible to make the images available to other information systems on the clinical workstation so far, it was decided to develop a web-based CHILI/Web application that runs on any computer without dependence on a specific operating system. Additionally, it must provide a simple interface that can be used or invoked by other programs such as the EPR.

Several prototypes in the Java programming language, which runs on different platforms, were developed and tested by our team during the last 4 years. As a result, we gathered considerable experience with that particular programming language, development tools and, for most part, the limitations of Java. However, it was only recently that client computers became sufficiently fast and the development tools sufficiently mature for developing and using a client-based active Java solution to display and process the huge DICOM data sets during the clinical routine.

The graphical user interface of this newly developed CHILI/Web application is similar to the "classic" CHILI workstation (see Fig. 1). It was developed using the Java

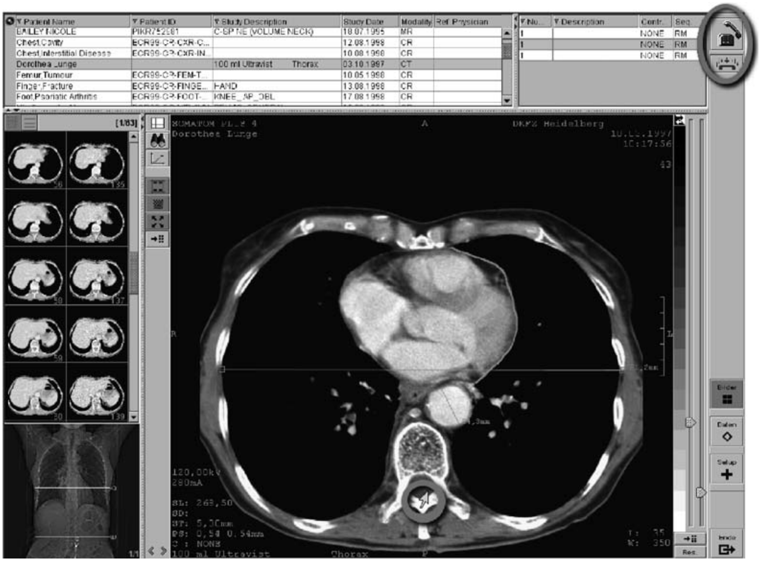

Fig. 1. CHILI/Web with database in teleconference mode (see mouse pointer of conference partner and open telephone).

application programming interface (API) Java-Swing [3], which has developed very rapidly in recent years so that good intuitive graphical user interfaces are easily adapted to existing environments.

Fast processing of large medical image sets has always been a crucial issue in Java. The Java Advanced Imaging (JAI) API solves this problem [4]. This API provides new and good functionality with the Java programming language, which makes image processing simpler and more useable. With its fast rendering concept, JAI enables very rapid display of huge images that consume large amounts of memory, e.g., images in the CR modality (tested with CR image, 5928×4728 pixel, 56 MB). Furthermore, it was optimized to show large series of images, e.g., up to 500 or more images per series.

CHILI/Web supports many image formats like DICOM, TIFF, JPEG and PIC. A dedicated parser was designed and implemented to read images in DICOM and PIC formats [5,6]. Now, it has become easy to add other formats.

On the server side, CHILI/Web is using the existing classical CHILI components to communicate with the PACS and DICOM modalities. The *CHILI infrastructure* provides the database and images to the webserver, and the client program loads the data and images from there. With this approach, we can simply reuse existing components that were integrated into the CHILI system. If the system with the EPR itself stores images, it does not need the CHILI database. The interface also permits loading images from other sources.

For accessing the database on the webserver, the program contains a fully functional database viewer with methods of finding and sorting data from the PACS database. The images are cached on the web server. The client program loads the images either using HTTP [7] or its own CHILI/Web protocol. Optionally, the data stream can be encrypted

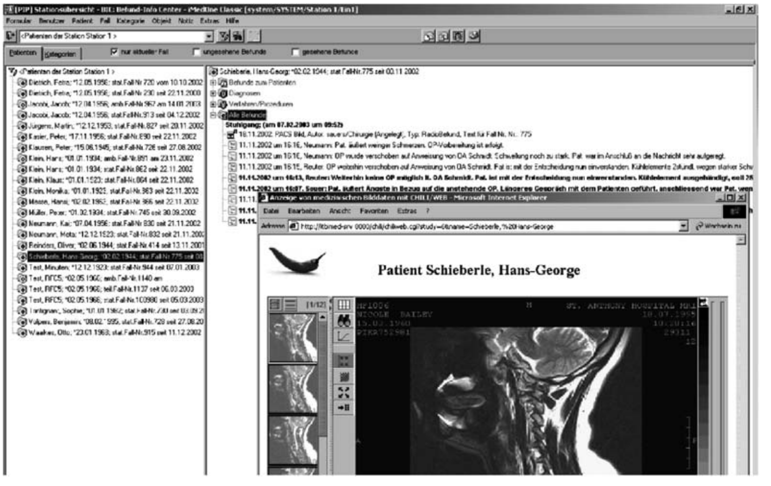

Fig. 2. CHILI/Web integrated with iMedOne (ITB AG, Cologne, Germany).

with the SSL3/TLS secure socket layer protocol [8]. The CHILI protocol also supports lossless and lossy compression such as GZIP, JPEG and JPEG2000 [9]. This saves bandwidth in large or slow networks and can provide a 10 Mbit/s network with the virtual speed of a 100 Mbit/s network—an important issue in legacy environments.

The developed application provides simple but powerful interfaces for integration with HIS or RIS. Other systems can control the way in which the user interface appears to the user: the calling information system can determine if CHILI/Web should display one specific image, a series of images or a study with thumbnails without a database interface. However, if necessary, it can be launched using a database browser. Of decisive importance is that the calling system has control of the appearance and that the application appearing is embedded into an HTML page with built-in functionality (see Fig. 2).

For security purposes, users must *authenticate* themselves to be able to use the program—unless they are using it in a secure environment. The authentication mechanism uses its own authentication database or existing systems such as the network information system (NIS) [11] or lightweight directory access protocol (LDAP) [10]. This important feature avoids separate authentication for each information system, saves the user significant amounts of time and ensures a unified authentication infrastructure.

3. Concept

CHILI/Web is a viewing component for medical images with a large set of *standard image processing functions*. It is integrated in and configurable through other systems like HIS/RIS, connected to the PACS and has synchronized teleconferencing as an additional option. The web-based program runs in an internet browser (see Fig. 2) or as a standalone application (see Fig. 1). No propriety systems, such as ActiveX (Microsoft), are required. Support by the Java Runtime Environment is the only prerequisite [12].

The developed application can load *different image formats*. Usually, it reads DICOM images but JPEG and TIFF are also supported. It can display gray value images as well as RGB color images, especially multiframe sequences such as ultrasound Doppler sequences.

The *lightbox* shows a thumbnail for each available image. This gives the user an overview of the existing data and improves navigation within the data because the thumbnails can be clicked to display the original image. Images of more than 8 bits can be displayed using the *level/window* concept. Modality-specific presets can be applied as well as interactive selection of appropriate values. Images can be *zoomed*, *panned*, *inverted*, *rotated* and *flipped*. Zooming in on regions of interest (ROI) is possible in different sizes and resolutions with the electronic *magnifying glass*. The *gray value* of single pixels can also be displayed. *Measurements* are possible for distances, areas, means and standard deviations of ROIs of different shapes, such as circles, rectangles and polygons. *Angles* can be calculated with three- and four-point angles. Finally, the information in the DICOM header as well as image orientation (H–F, L–R, A–P) and a centimeter scale can be displayed.

CHILI/Web provides the possibility of performing *synchronized teleconferences* with synchronized mouse pointers, images and functions on the images. Teleconferences are possible between CHILI/Web clients or by using the classical professional CHILI workstation in the radiology department. The communication partners can have different CHILI programs (classic or web), hardware (e.g., computer and monitor size) and operating systems (e.g., Linux, Mac, Windows). Only synchronization commands are passed by the teleconference protocol (and not images) to save network bandwidth and to speed up the teleconference. It was for this purpose that the CHILI middleware system was implemented in Java.

The EPR of an RIS or HIS can use different parameters to invoke and control CHILI/Web. Most systems are able to start external programs using the parameters. This ability is used to integrate our application. In that case the other system calls a URL with parameters, e.g., study ID, patient ID or the relative image addresses, on the web server. A dynamically generated HTML page contains the Java Applet and the URL parameters are passed to the applet during dynamic generation. Then, the generated HTML page is displayed in the browser window inside the clinical application (EPR). CHILI/Web starts, checks the parameters and begins to load images in the background. The applet is cached in the RAM, so that it is possible to switch rapidly from one patient to another.

CHILI/Web has been successfully integrated and tested in the following commercial medical information systems:

- IS-H*Med (GSD, Berlin, Germany),
- iMedOne (ITB, Cologne, Germany) (see Fig. 2), and
- Medos 8.30 (Medos, Langenselbold, Germany)

In our experience, real integration and testing needs 2–5 h without any changes in the CHILI/Web code. Since this is not much time, we can say that integration is simple and fast.

Another important integration function is displaying the report (stored in the RIS or HIS) in CHILI/Web. In this case, the information system protocol has to be used to retrieve the report and display it together with the images in the browser. The standard protocol of CHILI/Web for this purpose is again HTTP, which is simple and well defined. For security aspects, it provides an active ticket solution, which means the program creates a ticket and includes it in the query. The ticket is then checked by the other information system (e.g., RIS) before the report is delivered. This solution has been successfully tested with the RIS of Medos.

Currently, CHILI/Web is in clinical use at the German Cancer Research Center in Heidelberg and in a few other hospitals.

4. Discussion

Several web-based systems have been developed in Java for the purpose of image distribution in recent years, e.g., [13–16]. Nevertheless, only a few can integrate images in PACS with clinical workstations and even fewer are really integrated with HIS/RIS [13]. A comparison shows that no other system has the ability of this simple integration with clinical workstations and the teleconferencing feature, and especially of a webviewer with a professional reporting workstation. Handels et al. [15] developed the only other webviewer with teleconferencing functions, but it is a rather academic prototype that is not integrated with clinical information systems.

The web-based implementation shows that simple integration with other programs like HIS or RIS is not only possible but also necessary. With this approach, it is easy to distribute images from the radiology department to other locations in the clinic without requiring expensive radiological workstations. This helps to improve the quality of radiological services and enhances the clinical workflow.

5. Conclusion

The implemented CHILI/Web application fulfills the requirements for distributing medical images and integrates them with the electronic patient record. A simple integration of existing information systems enables the user to work in a consistent environment without the need to switch between different applications, including logging in again, etc. The images are called up by functions in the EPR and displayed in the same work place. The integrated teleconferencing feature improves the quality of medical treatment and care because consultation with experts becomes as easy as a telephone call.

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