Design and Implementation of World Wide Web-Based Tools For Image Management in Computed Tomography, Magnetic Resonance Imaging, and Ultrasonography

Christopher J. Henri, Richard K. Rubin, Robert D. Cox, and Patrice M. Bret

This article describes our experience in developing and using several web-based tools to facilitate access to and management of images from inside and outside of our department. Having recently eliminated film in ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI), a simple method was required to access imaging from computers already existing throughout the hospital. The success of the World Wide Web (WWW), the familiarity of end-users with web browsers, and the relative ease of developing user interfaces virtually dictated that such an approach be pursued in our case. The resulting web-based tools allow validated users to search our Digital Imaging and Communications in Medicine (DICOM)-compliant archive servers for specific exams; to download image data from a remote site; to request the retrieval of data from long-term storage; to view images, and to perform certain DICOM routing operations. The existing infrastructure of the Internet has allowed us to develop a low-cost system capable of being used for teleradiology. Since low-level, machine-specific interface programming was avoided, these tools were developed rapidly and are easily adapted. The familiarity of browser-based interfaces has facilitated user acceptance, and the benefit of platform independence minimizes software portability concerns.

Copyright © 1997 by W.B. Saunders Company

KEY WORDS: World Wide Web, DICOM, filmless radiology, PACS.

THIS ARTICLE describes the design and implementation of a World Wide Web (WWW) browser-based application to facilitate access to and management of image data from within and outside our department. The need for such a system arose from our efforts to eliminate film in computed tomography (CT), magnetic resonance (MR) imaging, and ultrasonography, while continuing to provide the clinicians outside our department with a simple means of accessing and viewing the images.

The design of the system was shaped by the experience we gained in operating our own mini picture archiving and communication system (PACS) in ultrasonography that has been filmless now for more than 18 months (see our companion article¹ in this issue). A significant constraint, particularly with CT and MR imaging, was to use the existing infrastructure comprising a hospital-wide network of personal computers (PCs) that was

not designed to support a sophisticated imaging network. Although our department is primarily Macintosh-based (Apple Computer Co, Cupertino, CA), the same is not true for the rest of our institution, nor in the hospitals within our community. Thus, cross-platform portability and connectivity were concerns we had to address. A high level of user acceptance was deemed critical to the success of the project, so the user interface was designed to be easy to learn and operate yet powerful enough to satisfy the varied demands of those interacting with it. The success of the WWW, the familiarity of end-users with web browsers, and the relative ease of developing user interfaces virtually dictated that a WWW interface be developed in our case.

METHODS

Background

Our departmental PACS was developed entirely in-house with the exception of our diagnostic review workstations (one Advantage Windows and seven Advantage Review workstations) that were purchased from General Electric (GE Medical Systems, Canada). We have taken a modular approach to designing the system that includes making use of public domain software running on low-cost PCs. (For a more complete description of the system, see our companion articles^{1,2} in this issue.) We have one MR imaging and three CT scanners, all of which support the American College of Radiology—National Electrical Manufacturers Association (ACR-NEMA) Digital Imaging and Communications in Medicine (DICOM) standard as users of the Storage service class. (Two of our CT scanners required third-party interfaces to provide DICOM output.) The principal components of our PACS include three modality servers (one for MR imaging and two shared by the three CT scanners), one database server, one long-term archival server that coordinates recording of data on CD, one retrieval server for restoring data from CD, and one teleradiology server. Each of these is a 200-MHz Pentium Pro running the LINUX operating system (Red Hat Software Inc, Durham, NC). The DICOM capabilities of these systems were derived largely from the

From the Department of Diagnostic Radiology, McGill University, Montreal General Hospital, Montreal, Quebec, Canada.

Supported by Sterling Diagnostic Imaging, Inc, Canada.

Address reprint requests to Christopher J. Henri, PhD, Department of Diagnostic Radiology, Montreal General Hospital, 1650 Cedar Avenue, Montreal, Quebec, Canada H3G 1A4.

*Copyright © 1997 by W.B. Saunders Company
0897-1889/97/1003-1029\$3.00/0*

Mallinckrodt Institute of Radiology DICOM Central Test Node (CTN) software.³ We have introduced several modifications to enhance the database facilities, to support CD-based archival, and to incorporate some automatic routing of images.

System Design and Specifications

Web-based access to the PACS is provided through the WWW server. The functionality that was deemed necessary included the ability to download images for remote viewing, view images within the WWW browser, move images to desired workstations within the department, and print images (on paper). To perform any of these tasks, the user first must identify the required data. Thus, an implied element of the system was a "master database" that could be searched for a given patient, study, or series.

For the sake of simplicity, it also was decided that the user should not have to know whether the desired data are currently on-line (i.e., available on one of the archive servers) or where the data presently reside. Additional specifications that affected the system design and implementation included making it possible to print or move groups of patients, studies, or series; being able to specify multiple destinations (for moving) or to select from multiple (paper) printers; and making the data available for viewing or downloading immediately after acquisition.

Security had to be adequate, but not so complex that it would deter users. Because security measures were already in place for our institution's hospital information system (HIS), and everyone was familiar with this approach, we chose to adopt the same method of using user-names and passwords. Our implementation, however, has included a significant amount of logging to help quantify system usage. We also added hostname verification to provide a lower level of security.

Implementation

The WWW interface and search tools use HTML forms to interact with Perl CGI scripts. File conversion functions for downloading and in-line viewing purposes were written in C and C++. All database interactions use mini-SQL; the same database used in the CTN software.

The highest level of interaction occurs as the user executes a search for one or more patients. Because our master database is structured hierarchically (i.e., Patient→Study→Series→Image), the resulting search tools follow a similar logical flow. The initial search provides a list of patients that match the search criteria, then one or several patients can be selected and a list of associated studies presented. To facilitate viewing the results, the user may re-sort them by patient name, patient identification number, study date, or study description (each achieved by a single button-click). Search results are listed in scrollable HTML-form "select" windows. This allows multiple results to be selected and requires minimal overhead for HTML format tags; a significant advantage compared with using HTML tables. At the study level, the user may select one or more of the results displayed then choose to list the associated series, or move the selected studies to one or more of our departmental diagnostic workstations. (The latter function is available only to authorized users.)

At the series level, there are similar re-sorting capabilities, and users are able to select series to either view within the

browser, download to their own computer, move to one or more of the departmental diagnostic workstations, or print on one of a few paper printers. This latter function is performed in the background by converting the images from their native DICOM format to Postscript then spooling the data to the selected printer.

To shelter the end-user from details concerning the whereabouts of image data, the best server to provide the data is chosen automatically. If a request from a CD is necessary, the user is notified of the expected delay and asked either to confirm or cancel the request. Compact disk retrieval, image conversion, and routing details are also transparent to the user.

To provide immediate access to images after acquisition, we have implemented software to forward automatically a copy of each image to one or more destinations using the DICOM protocol. The teleradiology server is a mandatory destination for every image acquired, and is a DICOM Storage service class provider. As an image arrives, instead of storing a single copy in a raw DICOM format, we save copies in two different formats. The first is a simple JPEG version of the image that is used for browser-based viewing. The second is a DICOM part 10 format called *Papyrus* and is viewed using freely shared software called *OSIRIS* (developed by Digital Imaging Unit at the University Hospital of Geneva^{4,5}). The *Papyrus* file format allows images from the same series to be grouped together in one file; a convenience that facilitates downloading. This process is controlled by a modified version of the CTN software that does the conversions and updates the corresponding *Papyrus* file with each new image. The choice to use *OSIRIS* for remote viewing was based on its sophistication and the fact that versions exist for both Macintosh and PCs. This latter aspect provides the desired element of platform independence.

RESULTS AND DISCUSSION

The system has successfully met the specifications that it be platform independent and easy to use. Requests for support have been minimal, which may in part be due to our having distributed a simple "How to . . ." sheet to the anticipated users. It is too soon to provide results that quantify the use of each facility (e.g., in-line viewing, downloading, printing, and so on), but we have designed an elaborate logging system to do so in the future.

One unanticipated benefit of the system is its ability to be used for daily pre-fetching operations. In fact, the design improved upon the pre-fetching scheme that had been used as part of our mini-PACS in ultrasonography. The key differences between the two lie in the ability to now select multiple patients, studies, or series, and to have the data automatically forwarded to the appropriate destinations on the network. The latter feature is achieved by specifying the retrieval server as the destination for the restored data. When data are received on the retrieval server (from one or more

archival servers or when restored from CD), they immediately are re-transmitted, based on their study description, to the appropriate diagnostic workstation(s). We presently are developing an HL7 interface between our PACS and our institution's HIS, and expect to automate pre-fetching when complete.

The system was designed to allow searches of various levels of complexity, making use of SQL's inherent capabilities. Thus, a further benefit is its potential for use as a research and teaching tool. We have yet to provide public access to the system, but we hope to do so in the near future.

CONCLUSIONS

Our original motivations to use WWW-based technology seem to have been well-founded. Although the design was based on experience gained during 18 months of operating a mini-PACS in

ultrasonography, the system was implemented rapidly and has been easy to maintain. Most importantly, given our limited resources, it has required a minimum of support in terms of user training. Ultimately, the system has turned out to be a key component of our PACS, which has allowed us to eliminate film in CT, MR imaging, and ultrasonography. Based on this success, we have begun work to integrate our PACS with our institution's HIS. We see several opportunities to use a similar Web-based approach to solve problems in that area, not the least of which is a method to enable simultaneous access to images and reports. Although we once considered this goal out of reach, it now seems inevitable.

ACKNOWLEDGMENT

We thank Francois DeBlois for implementing the original "proof of concept."

REFERENCES

1. Henri CJ, Cox RD, Bret PM: Implementation of a filmless ultrasound mini-PACS: Experience after one year of use. Presented at the 14th Symposium for Computer Applications in Radiology, 1997
2. Cox RD, Henri CJ, Bret PM: CD-based image archival and management on a hybrid radiology intranet. Presented at the 14th Symposium for Computer Applications in Radiology, 1997
3. Moore SM, Hoffman SA, Beecher DE: DICOM shareware: A public implementation of the DICOM standard, in Jost RG (ed): Medical Imaging 1994—PACS: Design and Evaluation, vol 2165. Bellingham, WA, The International Society for Optical Engineering (SPIE), 1994, pp 772–778
4. Ratib O, Hoehn H, Girard C, et al: *Papyrus* 3.0: DICOM compatible file format. Med Inform 19:171–178, 1994
5. Ligier Y, Ratib O, Logean M, et al: *OSIRIS*: A medical image manipulation system. M.D. Computing Journal 11:212–218, 1994