SESSION VIII

Web Technology in the Integration of a Digital Teaching File at the Diagnostic Workstation

Wyatt M. Tellis, Katherine P. Andriole, David E. Avrin, and Ronald L. Arenson

WITH RECENT advancements in picture archiving and communication system (PACS) technology has come the desire to establish independent, digital "high-interest" case file (HICF) archives for research and educational purposes. Each "high-interest" case consists of relevant images as well as associated demographic and clinical data, and each case is categorized using the coding system developed by the American College of Radiology (ACR). One of the main issues in the development of HICF archives has been the appropriate time for the creation of the cases, which involves the designation of relevant images and transfer of image and associated data.

Our previous implementation of the HICF archive uses a proprietary client/server suite, developed at the University of California at San Francisco (UCSF), to transfer image and demographic data from the on-site PACS to the HICF archive after readout. This procedure has several limitations including the inability to window and level the images before they are entered into the HICF and limited access to the PACS. Also our previous studies have demonstrated that the moment of diagnostic interpretation provides the optimal time for HICF creation.¹

To this end we have developed an interface that seamlessly integrates the diagnostic workstation with the HICF and provides a user friendly procedure for creating high-interest cases. The interface consists of two components, a web based process that handles the transmission of the demographic and clinical information and a Digital Imaging and Communications in Medicine (DICOM) process that transfers the image data. Our decision to use this architecture was influenced by the fact that this solution uses off-the-shelf technology and well established transfer protocols, mainly the hypertext transfer protocol (HTTP) and DICOM. This paper will address the specific issues involved in creating a link between a diagnostic workstation and an HICF.

MATERIALS AND METHODS

The HICF archive is a 4th Dimension (4D) v6.0 object-oriented, relational database (ACI US, Cupertino, CA) running

under Windows NT 4.0 (Microsoft Corp., Redmond, WA). The host machine is a 166 MHz Pentium with 64 MB RAM and a 2 GB hard drive. 4D was chosen for this application because of our previous work in developing an HICF archive¹ as well as for its cross-platform capabilities, its inherent multitasking architecture which is independent of the operating system (OS), and its application program interface (API) which permits the development of third party "externals" that give the database additional functionality. The database consists of three tables (Fig 1): one containing the clinical and demographic data for each case, a second containing the image series description (accession number, modality, etc.) and a third containing the images. The demographics table is related to the image series table through a one to many relationship, where there are many image series for one case. The same relation exists between the image series table and the image table, where there are multiple images per image series.

For this application, one external, the Internet Tool Kit (Foresight Technology, Inc., Fort Worth, TX), was required to provide the Transmission Control Protocol/Internet Protocol (TCP/IP) capabilities needed for the database to act as a web server. The web server consists of two types of tasks (referred to as "processes" within 4D): a master process (MP) that handles most of the TCP/IP operations, such as opening listening streams and listening for incoming connections, and a slave process (SP) that handles the actual HTTP requests. When the MP first starts it, opens a set number (N) of listening streams and spawns N/3 SPs. It then continues to loop through the streams checking for an incoming HTTP connection. Once spawned the SPs immediately notify the MP, by way of a message queue, of their availability to handle a request and pause until they are needed. When the MP finally detects an incoming HTTP connection, it scans the message queue for the first available SP and wakes this process. It passes a pointer to the stream with the HTTP connection by way of a second message queue, and then continues looping through the streams checking for more connections. The MP also opens a new listening stream to replace the one that was used, so as to maintain a constant number of available streams. In the mean time the SP reads the HTTP request header and sends an appropriate HTTP response, which can include either a web page or image. Once the request

From the Laboratory for Radiological Informatics, Department of Radiology, University of California at San Francisco.

The assistance of Scott Sloka and Mahalingam Lingam of Mitra Inc. with the modification of the IMPAX RS 3000 workstation is greatly appreciated.

Address reprint requests to Wyatt M. Tellis, 789 48th Avenue, San Francisco, CA 94121.

*Copyright © 1998 by W.B. Saunders Company
0897-1889/98/1103-1034\$8.00/0*

Fig 1. HICF Database Structure.

has been processed, the SP closes the stream, notifies the MP of its availability and pauses itself, completing the cycle. A third type of process, a create HICF process (CP), handles the actual creation of an HICF. This type of process is independent of the web server and is only started when a request to create an HICF is received.

In order for the HICF archive to receive DICOM images, a separate application was developed using the DICOM Tool Kit for Windows NT (Mitra Inc., Waterloo, Ontario, Canada). This application acts as a DICOM service class provider (SCP) and is responsible for handling all DICOM associations and requests. It also converts DICOM image data, which is usually 12-bits/pixel, into 8-bits/pixel, grayscale, Macintosh (Apple Computer, Inc., Cupertino, CA) PICT images. The PICT format is used because it is 4D's internal image format. During the conversion, the window and level settings selected by the radiologist are applied to the image data to ensure the appropriate rendering of the image. The PICT images are then outputted to a folder which is periodically checked by each CP running in the archive.

The display station (DS) used in this setup is a specially modified RS 3000 IMPAX workstation (Agfa, Ridgefield Park, NJ). The station contains a modified display process that is responsible for sending images to the SCP mentioned above as well as invoking the web browser used to display a customized web page form. The browser is Netscape Navigator 3.01 (Netscape Corp., Mountain View, CA).

The process of creating a high interest case file begins at the DS when the radiologist creates a summary series containing images to be entered into the HICF archive. At this time the radiologist adjusts the window and level of the images to suit his/her preferences. After preparing the images the radiologist then invokes the web browser (by clicking a button) which displays a form requesting pertinent clinical information (Fig 2A). The form displayed by the browser is generated by the web server processes mentioned above, and contains the demographic data pre-entered. The demographic data is transmitted to the web server through the uniform resource locator (URL) used by the browser to retrieve the form. To assist in filling out the form all ACR codes are available in a searchable, scrolling list.

After completing the form, the radiologist submits it back to the server (Fig 2B) which prompts it to spawn a new CP. The CP then generates and sends a reference id to the DS (Fig 2C).

All remaining transactions now occur in the background. When the DS receives the reference id it sends all the images in the summary series to the DICOM SCP (Fig 2D), which converts them to PICT, and places them in a folder. Each PICT file is labeled with the reference id, which was encapsulated within the DICOM header of each image. The newly created CP begins to check the folder for images matching the reference id. When it has found all the images it begins to assemble the HICF by first creating a record in the demographics table and entering all the information provided on the web form. It then imports the images into the image table (Fig 2E) and creates an entry in the image series table to link the images to the demographic data.

RESULTS

The current setup addresses two of the main issues that arose with our previous implementation of the HICF. First, the issue of window and level has been resolved since the settings of the radiologist, and not a preset value, are used during the conversion of the images from DICOM to PICT. Second, there is no longer a delay in retrieving images. The prior implementation relied on a proprietary protocol to query and retrieve image from the PACS. Since these queries had the lowest priority they were frequently rejected by the PACS controller. The new implementation sends the images directly from the DS without having to query the PACS. One feature that the HICF currently does not support is the ability to have multiple modalities within the same case. This is a limitation of the DS since a summary series cannot contain different modalities.

Fig 2. Setup. Key: (A) Send create HICF form to display station; (B) Submit form back to web server; (C) Send reference id to display station; (D) Send images in summary series to DICOM SCP; and (E) Images imported into HICF

DISCUSSION

The implementation described above relies on single user 4D to host the archive. In order to make the HICF accessible to multiple users within the Department of Radiology, a switch to 4D Server (ACI US, Cupertino, CA) is required. We are currently evaluating the performance and stability of 4D Server and plan to begin beta testing in the Section of Neuroradiology shortly. For the next

generation HICF we are actively investigating the possibility of providing web access to the cases, which would remove the need for 4D Server.

REFERENCES

1. Avrin DE, Andriole KP, Arenson RL: Integration of a Digital Teaching File at the Diagnostic Workstation. Symposium for Computer Assisted Radiology (SCAR), 1996; pp. 56-61.