A Cost-Effective Web-Based Teaching File System

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Teaching files are common in radiology. Although there is an increasing role of digital technology in radiology departments, today's teaching files have not yet seen the application of this new technology. This may have been due in part to poor or incomplete implementation in many commercial software packages. We have demonstrated that by utilizing free software from the Internet, a web-based teaching file system, which is easy to use, low cost, and secure, can be created.

KEY WORDS: Teaching files, web-based, PHP, DICOM, SSL

TEACHING FILES are common in a radiology department. They are utilized by radiologists and clinicians to maintain a record or a copy of interesting cases. These teaching cases are typically utilized for instructional purposes or for use in presentations. Conventionally, these uses required the films to be copied and stored in some organized fashion in order to allow easy retrieval. This system is costly, inefficient, requires large amounts of physical space, and can be difficult to maintain. It also does not allow for easy incorporation of cases into electronic format for presentations. With the increasing role that digital imaging and picture archiving and communication systems (PACS) have had in the radiology department, it is clearly evident that teaching files will need to move in a similar direction.¹⁻⁸ Sadly, many PACS vendors have either not added this functionality or the implementation is less than ideal.⁷ We propose a web-based solution that provides an easy-to-use, low-cost, and effective solution that can be added onto most PACS systems.

The common means for a teaching file creation and storage system is by making physical, hardcopies of the films. This is time-intensive,

costly, and requires some form of written or electronic database in order to maintain a record of the specifics of the case and where it is located. As well, the image must then be converted into an electronic format to be utilized in an electronic presentation. This digitization of existing cases overcomes many of the limitations of the prior manner for teaching file creation and usage.² However, although it is an improvement, it is not a feasible solution for new cases. The scanned or photographed image will never be as accurate as the original digital image.

An improvement on this would be to have the user copy the images onto a removable electronic media at the PACS workstation. This would alleviate the need to convert the images into an electronic format later, and the physical space required would be much smaller. The downfall, however, of this approach is that the media can be damaged or lost. In addition, the number of images stored on some types of media is severely limited. A large number of disks would be created in a very short time. For

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long-term storage, the images could be copied onto a hard drive or CD-ROM. A database must be then updated manually to keep track of the cases. The final limitation to this approach is that in order to share cases with other clinicians, a copy of the information must be created and physically or electronically transferred to the other individual. Because of these limitations, this approach makes it a poor option for most radiology departments.

Another approach is to use screen capture of images from the PACS workstations and send them over the hospital intranet to a webserver.^{1,3,5,6} This approach, however, limits the spatial and contrast fidelity of the copied image. An improvement on this would be to save the image in the native DICOM format with its inherent improved spatial and contrast resolution. The need to save storage space by saving images in formats other than DICOM is significantly decreased due to the rapidly decreasing cost of hard drive storage.

A locally developed improvement was created to overcome these limitations. Software was obtained from the Internet that provided the DICOM storage class functionality from the University of Oldenburg (<http://www.offis.uni-oldenburg.de>). This software was installed onto a personal computer (PC) that was on the PACS network. This PC also acted as an image server. Images could be selected at a PACS workstation, sent to the webserver, and stored in the DICOM format. A database record of each case was updated as images were received. The user interface was written in Java and was installed on each user's personal computer. Security was provided using a VPN client when connecting into the server. The major limitation of this system was difficulty with installing and maintaining the VPN clients. The client software lacked the ability to preview the images. We felt an improvement could be made.

METHODS

A review of the software currently available was performed and it was determined that the Image Archive software developed at the Mallinckrodt Institute (<http://wuerlim.wustl.edu/DICOM/ctn.html>) could be used as a starting point. The Image Archive software has the ability to store DICOM images and write information to a MySQL database (<http://www.mysql.com>). Additional features were

required. We wanted to allow the users to enter classification codes or words that could be used to search for cases at a later date, if desired. Also, the DICOM headers had to be anonymous for privacy issues. Therefore, the source code was obtained and these features were written in. A comment field is editable at our Kodak Cemax-Icon and Efilm workstations. This field can be edited by the user, and up to five comma-separated codes, classifications, or descriptive terms can be entered to describe the case. This field, together with other DICOM tag fields, is sent in each image transfer to the archive. This information, as well as details about the case (submitting user, date submitted, etc) are parsed out by the Image Archive software and are stored in the database. When the user submits a case to the archive, he/she can select to send the entire case or only selected images.

The MySQL database used by the archive software required an additional table to track information about the case. This table was created and the archive software was rewritten to update information to this table.

Apache was chosen for the webserver (<http://www.apache.org>). The webserver, by nature, is installed in the demilitarized zone of the firewall; in this location it is possible to be attacked by outside Internet users. Therefore, it was decided to remove the database to a separate server that resides behind the firewall, as shown in Figure 1. The webserver connects to this database server as required to obtain information about the cases. If desired, the teaching webserver could be hosted on an intranet. This setup would alleviate the requirement for two separate servers. The archive/database server could host the webserver as well.

The web-based interface was developed in the server-side scripting language PHP (<http://www.php.net/>). PHP is free software, has a rapid development environment, and is easy to interface with MySQL. An additional MySQL database (also stored on the database server) is used to store user login names and passwords. For security the user is required to log into the web site via a secure socket layer protocol (SSL). SSL provides us with mutual authentication, data encryption and data integrity. This secure transmission is utilized to further protect any confidential information. Once the user is logged in, he/she can search, view, edit, and delete cases.

As cases are submitted to the Image Archive, they are designated as private cases and only the submitting user can search, view, and edit the case. The case can be designated as a shared resource at the web interface and can then be searched and viewed by all. Thumbnail images for the interface are converted on-the-fly through the PHP scripted pages from the DICOM format to a JPEG format using the free image conversion software developed at the University of Oldenburg (<http://www.offis.uni-oldenburg.de>). The images can be downloaded in either DICOM or JPEG format. The images from a case can be combined into a single compressed file and downloaded. The images can also be viewed under limited different window and level values. The user can upload additional clinical photos, images, or video clips to the webserver. A group of images from an individual series can be grouped together and converted into an AVI movie. The user can then download this movie file.

The flow of information through the teaching webserver is also shown in Figure 1. The PACS network sends cases to

Fig 1. A pictorial representation of a typical installation. The direction and type of data flow is depicted by the arrows.

the archive/database server, which runs the archive software as well as the database server. The archive software extracts the information from the DICOM header and writes it to the database. The archive software then removes any patient demographic data from the DICOM header of the image file. This anonymous file is then forwarded onto the webserver computer. The webserver runs the Apache server as well as an additional archive software process, Simple Storage. This software, from the Mallinckrodt Institute, acts as a limited DICOM storage class provider. When the webserver serves the images to a browser, it obtains the database information about the case from the database server via TCP/IP.

In order to minimize the potential risk of loss of information from hardware failure, the images are duplicated in the system. The archive/database server maintains copies of the original images sent from the PACS workstations. The webserver has a copy of the original images without the demographic data. The MySQL database is archived every night by a simple shell script and stored on a separate networked computer. If a catastrophic failure of the webserver were to occur, the images could be resent to it from the archive/database server. If the archive/database server were to fail, the images could be sent to it from the webserver, and the database restored from the archived copy.

The webserver software was installed onto a 466 MHz PC running Red Hat Linux version 7.3 with 128 Mbytes of RAM and 40 Gbytes of hard drive capacity. The database server was installed onto a 1200-MHz PC running Red Hat Linux version 8.0 with 128 Mbytes of RAM and 40 Gbytes of hard drive capacity. Although the sizes of the hard drives appear small, they can store up to 70,000 images. Additional hard drive storage can be added as required.

RESULTS

The system was installed and utilized on a trial basis for approximately 3 months. During this time, two radiologists and three residents submitted over 200 cases. The system has been found to be fast, secure, and responsive to the

Fig 2. Screen capture of the login page.

Fig 3. Screen capture of the main search page. The user can enter text to search for as well as limit the results by modality and/or shared cases.

needs of the submitting physicians. The PHP interface has allowed for rapid debugging and for adding new features. Figures 2–7 are screen captures of the web interface. The remaining radiologists and residents will soon be added to the system.

CONCLUSION

The proposed system overcomes many limitations of the current method for storage and organization of teaching cases. The proposed system runs on low-cost PCs that run Linux, Apache, and MySQL. The operating system

Fig 4. Screen capture of the advanced search page. The user can search on additional criteria.

Fig 5. Screen capture of the results page. The user can see a thumbnail image of the case as well as additional information. If the user is the owner of the case, he/she may delete the case or edit details about the case.

and applications are free from the Internet. Our modification to the software and instructions on installation are available at <http://sourceforge.net/projects/radwebserver>. No modification to the software of the PACS workstations is required. The system is easy to set up and maintain. The PHP interface is easily modifiable to allow revisions or changes. This makes the system flexible and adaptable to future needs. The proposed approach allows for easy

Fig 6. Screen capture of the edit page. The user can edit the descriptive codes for the case. The case can also be designated as a shared case. Additional images or video clips can be uploaded and added to the case. On the bottom of the page, thumbnails of each of the submitted images can be viewed.

Fig 7. Screen capture of the view page. The user can view details of the case as well as download all of the images compressed into a single file. The user can also create and view a movie of images from a series. The individual images from the case can be viewed at the bottom of the page. The individual images can be downloaded as DICOM files or as JPEG images.

storage, classification, viewing, editing, and sharing of teaching cases. Future work will include developing a Java applet to allow image manipulation with real-time windowing and leveling. Finally, although this system is an improvement, an ideal solution would be to

have the teaching file functionality added into the PACS software itself.

REFERENCES

1. Ernst RD, Kawashima A, Tamm E, et al: A high-quality, low-cost, internet/intranet-based digital imaging database. Available at http://ej.rsna.org/EJ_0_96/0056-97_fin/tfile1.htm. Posted November 1997

2. Galvin, JR, D'Alessandro, MP, Kurihara, Y, et al: Distributing an electronic thoracic imaging teaching file using the Internet, Mosaic, and personal computers. *AJR Am J Roentgenol* 164:475-478, 1995

3. Halstead, MJ, Moskovitz, J, Johnson, N, et al: A simple method of capturing PACS and other radiographic

images for digital teaching files or other image repositories. *AJR Am J Roentgenol* 178:817-819, 2002

4. Langer SG, Berger RM: Goals and methods for radiology teaching files. Available at http://ej.rsna.org/EJ_0_96/0011-96/TF-RSNA.htm. Posted July 1996

5. Maldjian, JA, Listerud, J: Automated teaching file and slide database for digital images. *AJR Am J Roentgenol* 175:1249-1251, 2000

6. Richardson, ML: A world-wide web radiology teaching file server on the Internet. *AJR Am J Roentgenol* 164:479-483, 1995

7. Seigel, E, Reiner, B: Electronic teaching files: seven-year experience Using a Commercial Picture Archiving and Communication System. *J Digit Imaging* 14(2):125-127, 2001

8. Wiggins, RH, Davidson, HC, Dilda, P, et al: The Evolution of filmless radiology teaching. *J Digit Imaging* 14(2):236-237, 2001