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WEB technology — the future of teleradiology?

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Abstract

With the widespread use of the Internet, standard browsers are widely available in radiological and clinical departments. So far the limited speed of the Internet has made teleradiology via the Internet too slow for practical use, but many hospital LANs are now connected to the world wide web through high speed access. The new JavaScript technology has made it possible to view examinations with web browsers as simple images instead of sending the full examination data. The full data from the examination remains on the server in the radiology department. If changes in window, level, size, zoom factor etc. are required, corrections are made locally in the web browser with JavaScript, and a new simple image is sent from the server. Web browser technology is now offered by most PACS companies and a new de facto standard for image viewing is emerging. © 2001 Elsevier Science Ireland Ltd. All rights reserved.

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1. Introduction

Teleradiology is a tool for sending images obtained by a modality of radiology and for viewing them at a distance. Inside the hospital, images can be viewed in other departments, by clinicians or even in the radiologist's own office only a few meters away from the department. Between hospitals, teleradiology can be used for teleconsulting, getting old images for comparison or for illustrating a reported finding. It can be used for on duty reporting from the radiologist's home or for sending images to rare users like specialists in remote locations.

The three major problems of teleradiology are speed, security and image quality. It has till now been based on dedicated equipment that needed special workstations and software, using point-to-point connections or mobile equipment. Television links have delivered images of poor quality with analog–digital conversion problems and have needed an active sender interaction. Receiving has been limited to passive viewing without means for postprocessing the image.

2. The Internet

With the widespread use of the Internet, standard browsers are now widely available in radiological and clinical departments and most radiologists are familiar with the Internet for

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gathering information, e.g. from the MedLine database. So far the limitations in speed have made teleradiology via the Internet too slow for practical use, but many hospitals are now connected to the World Wide Web (WWW) by local area networks (LAN) instead of telephone lines, and the national core connections of the web are constantly increasing in transfer speed. Outside the hospitals, ISDN [1] and ADSL [2] have made telephone line connections increasingly faster, and technologies for using power lines, cable-TV or satellites for private Internet connections are emerging. The advantages of the Internet solution are obvious. It is platform-independent; Mac, PC or Unix is of no importance. The browser software is free and familiar to most users, so that no further training is needed. The Internet is overall and always available, making the teleradiology independent of time, place and equipment. Post-processing is now possible with JavaScript applets.

3. The Java Script

Java is a computer language for open cross-platform environment programming. It was first announced by SUN Microsystems [3] and Netscape [4] in December 1995, and later endorsed by most major players of the Internet industry including Microsoft [5]. JavaScript enables programmers to integrate Java-based programs, so called applets, into WWW home pages so they may be run from any Internet browser. An applet can give the end user the full interface of the Java program that takes over the entire screen. The program is not running in a frame in the browser, but it is using the whole monitor area, although it is in fact running over the Internet connection.

Java technology makes it possible to view examinations with web browsers as simple images instead of sending the full examination data. Java lets one view the examination first as small and fast transmittable thumbprints. Selected images can then be requested in full size but still sent as simple images of low data size. The full data of the examination remains on the server in the radiology department. If changes in window, level, size, zoom factor, etc. are required, corrections are made locally in the web browser by a Javascript procedure, and a new simple image is sent from the server. Distance and region of interest (ROI) measurements are also possible.

4. Web problems

Speed is a major obstacle in using the Internet for teleradiology, but speed is improving. The standard PC modem is now using a speed of 56 kbps when only a year ago the standard was 28.8 kbps or less. ISDN offers a speed up to 128 kbps and ADSL will bring the speed up to 4 Mbps downstream on normal phone lines. The type of image is of immense importance too — a digital 2 K by 2 K 16-bit chest X-ray consists of a data volume of 8 MBytes and is normally used with a front and a side projection giving a total data volume of 16 MBytes for the most commonly used examination. These data would take 1 h 16 min to be sent on a 28.8 kbps modem. A Computer Tomography (CT) scan of the brain with a 512×512 eight-bit matrix giving a 0.25 MBytes data volume takes only 16 s per slice and a 20-slice examination can be transmitted in just 5 min 20 s by ISDN [6]. So the Internet may at this point be useable for CT, Magnetic Resonance Imaging (MRI) or Nuclear Medicine (NM), but is still too slow for conventional radiology like chest X-ray or skeletal images. The Java Script technology solves some of this speed problem — instead of sending the full image data to the end user, only a smaller compressed image in JPEG file format [7] is sent using less than 10% of the original data volume. The data for the full image remains on the server, and if the user wants another view of the image, e.g. another window/level setting, then a new JPEG image is transferred — a full 20-slice brain CT scan can in this way be viewed anywhere around the world in just 32 s by ISDN.

The security issue is of vital importance for the use of patient information in a hospital. The browser technology can be used in a hospital intranet inside the LAN firewall or as a point-to-

point dial-up connection to the hospital network using a modem pool at the entrance of the hospital firewall. With direct modem connections, security can be increased by 'dial back' modems or with the use of hardware identification like CryptoCard [8]. At the server level, the individual users can be limited to predefined folders and patient files, giving user-dependent access to sensitive data. If the connection to the hospital is part of an open Internet, user name and password identification can be optimised with JavaScript protocols for identification with a crypted masterkey. With this so-called 'Symmetric-key cryptography' the key is unique to the user name, password and the user's computer and is sent by ordinary mail prior to the first connection to the hospital — in this way unauthorised monitoring of the Internet traffic cannot give enough information to identify this as an accepted user to the server.

A major and unsolved problem is display quality. Standard PC monitors have quite sufficient resolution to view CT or MRI images, but are not good enough for 2 K conventional images. Though segment enlargements or pixel compression may overcome some of this problem, the major difficulty is display quality. With users spread out over the Internet, there is no way the server can know what kind of monitor the image is being viewed at, it may even be on a laptop computer. Whereas monitors in a PACS installation should be replaced every 3–5 years, web computers are out of range for the image quality check. Monitors often need a warm-up period of 15–30 min before they are reliable in image quality, whereas a web computer may be just turned on to view an examination sent to the on-call doctor's home during the night.

5. Commercially available products

Web browser technology is already offered by many PACS companies as well as some manufacturers of MRI and CT units. In my own department we are using the NetView software from Philips [9] connecting a CT scanner and a MRI unit to a Unix workstation containing the NetView webserver software. With any Internet browser we can see the examinations inside the hospital LAN or from outside calling a modem pool at the hospital firewall. We have not yet made use of crypted access over the Internet. NetView (Fig. 1) offers most of the functions mentioned above, but the window/level function is just a correction of brightness and contrast not a genuine resampling of image data. We use this web browser-based teleradiology for viewing brain CT scans in emergency cases transmitting the images to the on-call radiologists using ISDN and their own PCs or laptops.

Other companies have Webserver applications available like the GE WebLink [10] or Siemens MagicView [11], but only a few can be seen in working demonstrations on the Internet. Company mergers and take-overs have been very intensive on the PACS market over the last few years. Applicare [12] who is marketing the RadWorks WebViewer (Fig. 2) together with Picker [13] have been bought by GE.

Dupont became Sterling and is now owned by Agfa [14]. 3M became Imation and their PACS division Cemax-Icon [15] was bought by Kodak [16]. Now former Elscint developed Impex Web 1000 in alliance with Agfa and formed the Impax Technologies Inc. together with Mitra [17]. Mitra produces the market leading PACS broker. Almost all PACS manufacturers use the Mitra broker including all the above mentioned companies plus companies like Toshiba [18] and Fuji [19].

Fig. 1. NetView from Philips.

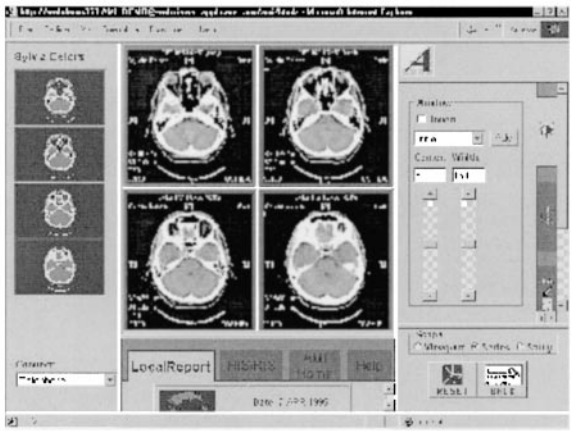

Fig. 2. RadWorks WebViewer from Applicare.

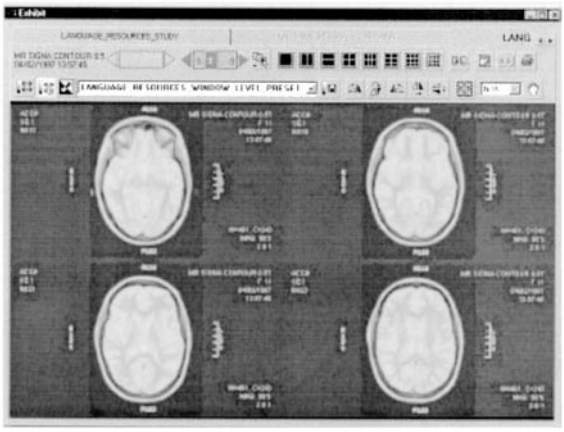

Fig. 3. Exhibit from Mitra.

Therefore the Webviewer product from Mitra called Exhibit is of major interest (Fig. 3). It is a development of both Applicare/Picker/GE and Elscint/Agfa with partners like Kodak/Cemax-Icon, Siemens and Fuji. It may be a new market standard with all major X-ray film manufacturers and major PACS producers involved.

The demonstration version at the homepage of Mitra allows true window/level adjustments in real time viewing and has an image printing facility directly from the browser to your own printer.

6. Future developments

In the future, teleradiology will be based on the Internet using low-cost equipment and hopefully with a de facto standard software. It will be integrated into the hospital PACS and may use private LAN, direct modem pool connections or be crypted. Taking the main idea of the Internet to the limit, the entire PACS could be web-based. If the Radiology Information System (RIS) knows where and when an examination was performed, then the data do not need to leave the modality at all. Distributed modality archives on the web controlled by RIS could form the core of a virtual PACS archive. The computing power of low-cost equipment like PC and Mac computers is quite sufficient for most viewing needs and larger Unix workstations can be integrated when needed for 3D reconstructions or virtual endoscopy. The weak points are monitor quality and speed of the Internet.

References

[1] www.whatis.com/isdn.htm
[2] www.whatis.com/adsl.htm
[3] java.sun.com/
[4] home.netscape.com/
[5] www.microsoft.com/java/
[6] www.toshiba.com/tams/corp/itr.html
[7] www.jpeg.org/
[8] www.cryptocard.com/
[9] www.medical.philips.com
[10] www.ge.com/medical/xray/
[11] www.siemens.de/med/shs/
[12] www.applicare.com/
[13] www.picker.com/
[14] medical.agfa.com/
[15] www.cemax-icon.com/
[16] www.kodak.com/US/en/health/medicalSci.shtml
[17] www.mitra.com/
[18] medical.toshiba.com
[19] www.fujimed.com/medical/medical.html