# Computers in Radiologic Education

# The Internet, World-Wide Web, and Mosaic: An Overview

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**Technology is revolutionizing education. Global networks, powerful personal computers, and user friendly, graphically oriented software are creating a new infrastructure that promotes rapid, efficient access to information. Images, text, audio, and video can be integrated into interactive multimedia presentations, providing a hierarchy of knowledge that can be traversed by the click of a mouse. The extensive use of images in our arena makes radiologic education a major beneficiary. Because the components (text, images) of educational presentations are stored electronically on a network rather than on the printed page, an individual component can be linked and bundled into as many different presentations as desired. Furthermore, components of information can exist on different computers throughout the world and yet be linked by software into a single presentation.**

Imagine sitting at a personal computer. A mouse click initiates a continuing medical education session, retrieving cases that are stored on a remote computer system. Click: a chest CT showing a lung mass appears on the screen. Click: information regarding the current staging criteria for lung cancer is displayed. Click: an electronic form appears, asking the radiologist to determine the exact staging of the lung tumor. Click: the form is electronically submitted for scoring, and the next case is retrieved and displayed. While this scenario may seem futuristic, the Internet, network computers, and free computer software called Mosaic make all of this possible today.

## The Internet: An Existing Prototype of the "Information Superhighway"

The Internet is an international network of computers that uses standardized protocols for the exchange of information. The Internet connects government agencies, universities, and industry. The exact size of the Internet is difficult to determine, but current estimates are 2.3 million computers in 130 countries [1], 30 million individual users, and a growth rate as high as 2 million additional users per month. The Internet is not owned by any company or government agency. Volunteer groups establish protocols and general policies, but there is no Internet president or policeman. Traditionally, the Internet has been used for three functions: electronic mail, file transfer between computers using file transfer protocol (FTP), and remote access to mainframe computers. A variety of information is available to the public on the Internet, including government reports, public domain software, digital pictures, and computer-related technical information, all of which can be accessed from any computer (including a personal computer) that is connected to the Internet. The Internet is the prime conduit for electronic mail around the world.

Although the early Internet linked computers in government offices or university laboratories, this stereotype no longer applies. Access for business and industry has expanded as new commercial uses for the Internet have been introduced. The public can access the Internet, using a telephone modem connection, via commercial providers of connectivity. Such connections provide full access to the Internet, although the transfer of information is slower than with higher speed, direct connections such as Ethernet. For example, a single MR image, which might take 5 sec to transfer by Ethernet, could take 60 sec with a high-speed modem. Newer, faster network technology, such as asynchronous transfer mode (ATM), can transfer multimegabyte images in less than 1 sec. Although today this technology is cost-effective only for special applications, ATM (or some descendant thereof) will eventually provide high-speed connections to individual households.

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The goal of the National Information Infrastructure, the "information superhighway" of the future proposed by the Clinton administration, is to make information widely available on a diverse range of subjects. Envisioned applications such as digital movies on demand and interactive home shopping will require network connections capable of transferring large amounts of data. The telephone and cable television industries are competing to upgrade existing Internet connections and to extend high-speed connections to the home. In this scenario, the Internet will be updated and transformed to serve as the National Information Infrastructure.

How much does the Internet cost? University faculty and students with Internet access will often tell colleagues they have free access, but in fact the university pays a telecommunications company for an Internet connection. In a typical university radiology department, an Internet-linked computer might first be linked to a local area network in the department; the local network in turn is connected to a university-wide network, which is ultimately connected (usually by an intermediate facility) to the high-speed Internet backbone that links our national supercomputing centers. Using the Internet, an individual can connect to computers around the world almost as easily as to computers in the next office. Although the connection is not free, much of the information available on the Internet is free.

### The World-Wide Web

The original purpose of the Internet was the sharing of information among scientists in academic and government institutions. Efficiency and accuracy were emphasized. The concept of user friendliness was not a priority. Multimedia documents containing text, images, and digital movies did not exist. Cryptic commands based on the UNIX operating system were required to access the Internet. Frequently, although a document could be retrieved from a dissimilar computer, incompatible document formats prevented the document from being correctly displayed on other computer systems.

The difficulties caused by incompatible documents on different computer systems prompted CERN, the European Particle Physics Laboratory in Switzerland, to establish the World-Wide Web (WWW) in 1989. This web was a consortium of computer users who implemented a standardized, nonproprietary syntax termed HyperText Markup Language (HTML) for composing documents. The HTML syntax combines text with embedded formatting commands (the markup components) (Fig. 1). Via these markup components, HTML provides a standardized method for including images, movies, and audio in complex documents that will display correctly on a variety of different computers including the Apple Macintosh (Apple, Cupertino, CA), IBM-compatible personal computers using Microsoft Windows (Microsoft, Redmond, WA), and graphical workstations running under the UNIX operating system.

HTML is an implementation of the hypertext concept. In a hypertext document, any phrase, icon, or portion of a displayed image can serve as a symbolic link to additional information. An HTML author uses hypertext links within and among documents to provide logical, hierarchical access to a body of interrelated information. When a link is invoked by the click of a mouse, the user's computer retrieves and displays the appropriate related information. This information can contain links to even more information. Because HTML supports the display of text, digital images, audio, and digital movies, many people use the term "hypermedia" to describe the features provided by HTML. Key features of the World-Wide Web are that linked information can reside on any computer on the Internet, and that a single HTML document can include links that reference items on one or many geographically distant

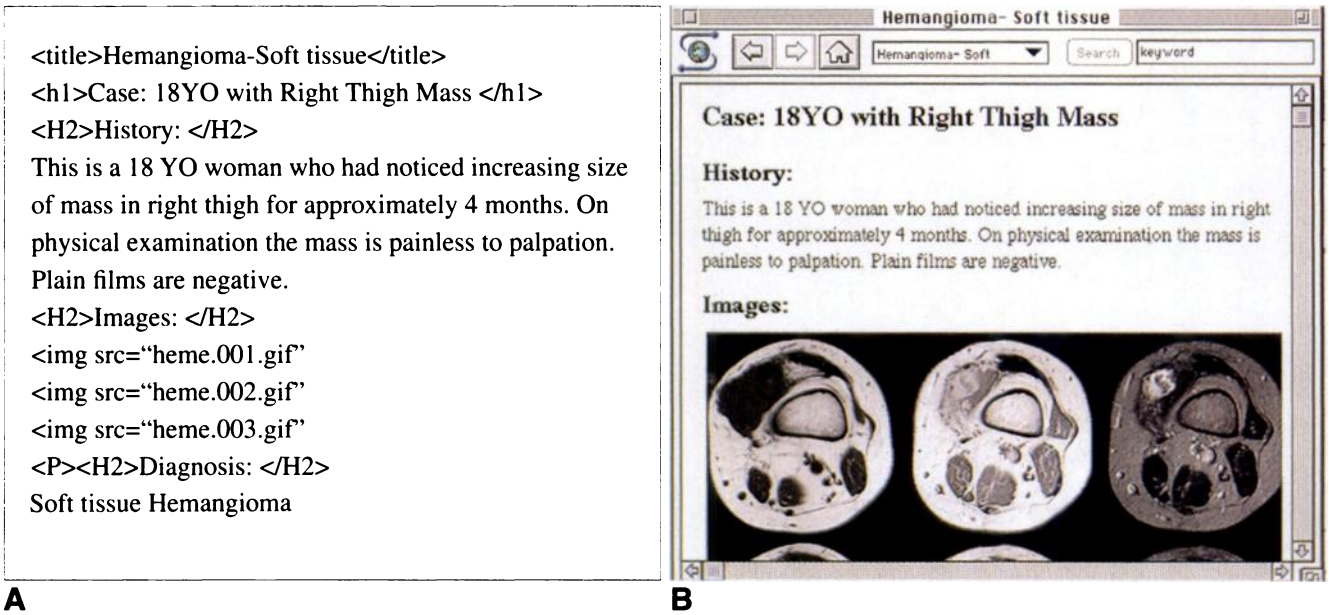


**Fig. 1.—HyperText Markup Language (HTML) documents provide for efficient integration of text and images.**

***A*, Sample HTML document. Format combines text and markup commands in same document that is retrieved and interpreted by Mosaic browser. Heme.001.gif, heme.002.gif, and heme.003.gif are names of computer files that contain MR images displayed in *B*. YO = year-old.**

***B*, Teaching file document on soft tissue hemangioma, created with HTML document shown in *A*, as seen by user. Mosaic ensures correct display of complex documents on variety of computer systems.**

computers. The capability to integrate images into documents, link text to images, and link images to text, makes hypermedia and its implementation on the Internet attractive for radiologic applications. An HTML radiology teaching file can provide the clinical histories and case explanations maintained on one computer, with the images retrieved from a library on another computer located elsewhere.

The World-Wide Web is based on the client-server exchange of information. In the context of the WWW, the "server" (host computer) on the Internet contains information that can be retrieved by a "client" (user's computer). A personal computer can effectively function as a client because relatively little processing is used to retrieve and display a document. The client computer has software, termed a "browser," which retrieves and displays information from the server. One of the best-known and most popular browsers for the WWW is Mosaic. Running on the user's computer, Mosaic retrieves an HTML document from the server and interprets markup commands embedded in the document. The interpretation and execution of these markup commands result in the display of a visually appealing, interactive, easily navigable document.

In order for the WWW to remain functional, every HTML document and every component linked to that document must be uniquely identified in the massive network of computers that comprise the Internet. To cope with this requirement, the concept of the uniform resource locator (URL) was developed. A URL gives the location of an HTML document (or linked component) and the name of the document or component. In computer parlance, a URL is the combination of an Internet computer's address and a file name. Most WWW servers have established one or more default HTML documents, each of which is called a "home page." To connect to a WWW server, only the Internet address of that server is necessary. Home pages are retrieved by default and processed locally by the browser software to provide an interactive, hypermedia introduction to whatever is available on the server system. For example, the URL that "opens the door" to the University of Iowa's Virtual Hospital is "http://vh.radiology.uiowa.edu/" (Table 1).

**TABLE 1: World-Wide Web Radiology Information Resources**

| Institution | Uniform Resource Locator |
|---|---|
| Brigham and Women's Hospital, Department of Radiology | http://count51.med.harvard.edu/bwh.bwhrad.html |
| Harvard University's Joint Program in Nuclear Medicine Teaching File | http://count51.med.harvard.edu/jpnm/tf.html |
| Indiana University, Department of Radiology | http://foyt.indyrad.iupui.edu/homepage.html |
| Mallinckrodt Institute of Radiology | http://www.mir.wustl.edu |
| Medical College of Wisconsin: CHORUS (Collaborative Hypertext of Radiology and Ultrasonography) | http://chorus.rad.mcw.edu/chorus.html |
| Pennsylvania State, Department of Radiology | http://www.xray.hmc.psu.edu/home.html |
| Robert Wood Johnson Medical School/Laurie Imaging Center | http://130.219.15.246/ |
| Society of Nuclear Medicine: Computer and Instrumentation Council | http://gamma.wustl.edu/tf/caic.html |
| University of Arizona Radiology Department | http://zax.radiology.arizona.edu |
| University of California Davis, Department of Radiology | http://www-radiology.ucdmc.ucdavis.edu/ |
| University of Florida Radiologic Anatomy | http://www.med.ufl.edu/medinfo/rademo/raintro.html |
| University of Iowa's Virtual Hospital | http://vh.radiology.uiowa.edu/ |
| University of Leeds (England) Centre of Medical Imaging Research | http://agora.leeds.ac.uk/comir/comir.html |
| University of Miami, Department of Radiology | http://iitcsun10.med.miami.edu/ |
| University of Pennsylvania, Department of Radiology | http://mipgsun.mipg.upenn.edu/ |
| University of Pisa (Italy) Institute of Radiology | http://www.rad.unipi.it:7080/IRMosaicHome.html |
| University of Texas at Arlington, Magnetic Resonance Imaging Group | http://www-mri.uta.edu/ |
| University of Texas–Southwestern, Radiology Imaging Center | http://visual-ra.swmed.edu/ |
| University of Washington, Department of Radiology | http://www.rad.washington.edu/ |
| University of Western Ontario (Canada) | http://johns.largnet.uwo.ca/med/index.html/ |

### Mosaic: WWW Browser Software

Several WWW client applications are available to provide hypermedia access to servers on the World-Wide Web. A popular application is Mosaic, developed by the National Center for Supercomputing Applications (NCSA, Urbana-Champaign, IL). The Mosaic software is free, available directly from NCSA (anonymous FTP to ftp.ncsa.uiuc.edu). Versions are available for X-Windows (UNIX), Microsoft Windows, and Apple Macintosh computers. Commercial versions of Mosaic are being developed by other parties. Other WWW browsers include macWEB and windowsWEB (EINet, Austin, TX), Cello (Cornell University, Ithaca, NY) for Windows, and Lynx (University of Kansas, Lawrence, KS), the last of which can be used on computers with nongraphical user interfaces. A recent addition to the list of available clients, Netscape (Netscape Communications, Maountain View, CA, http://home.mcom.com/), is optimized for those using modems to access the Internet. Netscape can be used without cost by individuals associated with an educational institution or nonprofit organization and by others for a nominal liscense fee.

Hypermedia facilitates the discovery of information. Mosaic provides a user friendly, graphically oriented interface based on the hypermedia concept to WWW servers on the Internet. Users with minimal computer experience can learn to navigate the Internet in less than 10 min. The user browses through hypermedia screens containing links to information located around the world. The user does not have to be concerned with the network addresses or geographical locations. With Mosaic, navigation is entirely accomplished though mouse clicks (Fig. 2).

Links to additional information are represented by short phrases of highlighted (colored) text, by icons, or by a region within a displayed image. Mosaic's user interface is similar to the well-known Macintosh program, HyperCard (Apple), which uses the metaphor of cards arranged in a stack. However, with Mosaic the "stack" is the entire Internet, and the "cards" can reside on computers located anywhere on the Internet. Like a HyperCard "home card," a home page is displayed

whenever the program is started (Fig. 3). The user can employ the home page available from the NCSA or a home page from any WWW server on the Internet, or the user can create a personal home page (stored locally) containing references to his or her favorite WWW servers.

Mosaic has several value-added features. For example, Mosaic maintains a list of documents just viewed, thus providing for backward as well as forward navigation through a series of hypermedia documents. The user can maintain one or more "hot lists" of interesting WWW resources for future reference. A mouse click adds the currently displayed document to a hot list. Mosaic can also place personal annotations on documents. The annotations are stored locally; when the same document is again retrieved from the server, the locally stored notes are available via a hypermedia link displayed at the end of the document.

Potentially the most exciting feature of Mosaic and the WWW is the implementation of electronic forms (computerized versions of hard-copy forms) that enable the transfer of information from the client back to the server. For example, Mosaic can display an image, the radiologist responds by completing an electronic form, and the response is transmitted to the server. The potential applications are numerous. Electronic forms provide a method to search remote teaching files for specific cases or to globally search the medical literature. Electronic forms can also be used for testing and credentialing.

## Limitations of Internet and Mosaic

The main limitation of the Internet is the lack of universal Internet access. Direct Internet access, either using Serial Line Internet Protocol or Point-to-Point Protocol, is required to use Mosaic. This level of access is currently available at most universities but is uncommon in community hospitals, clinics, and individual homes; however, it is likely that high-speed network access to homes will become available over the next several years. The widely accessible network services of America on Line (Vienna, VA), Prodigy (White Plains, NY), and CompuServe (Columbus, OH) have varying levels of Internet access but do not offer access to the WWW. However, America on Line announced that it will provide WWW access in the near future. Modem access can be frustrating because of the slow speed of data transfer for HTML documents and associated images.

A problem for network administrators is that WWW servers contain more images than do traditional Internet file servers. Images are huge compared with text files, and their transfer requires increased network capacity. The number of users of the Internet is rapidly increasing, straining its capacity. The "information superhighway" is intended to provide widespread, high-speed connections that will upgrade the limited capacity of today's Internet.

## Applications in Radiology

Why should the radiology community be interested in the capabilities of the World-Wide Web and Mosaic? The answer in one word is images. While early Internet documents were largely text based, HTML documents provide for the efficient integration of text and images. Teaching files [2], textbooks, and radiology journals are examples of existing resources that can be digitized and made available though the WWW (Fig. 1B). Teaching files can be enhanced by including references to data bases of medical information (Fig. 4). Electronic distribution of radiology journals has already been proposed [3]. One can envision access to refereed scientific papers, including digital illustrations, within days rather than months after acceptance for publication. Mosaic also benefits authors interested in developing computer-based learning programs. With the standards established by the World-Wide

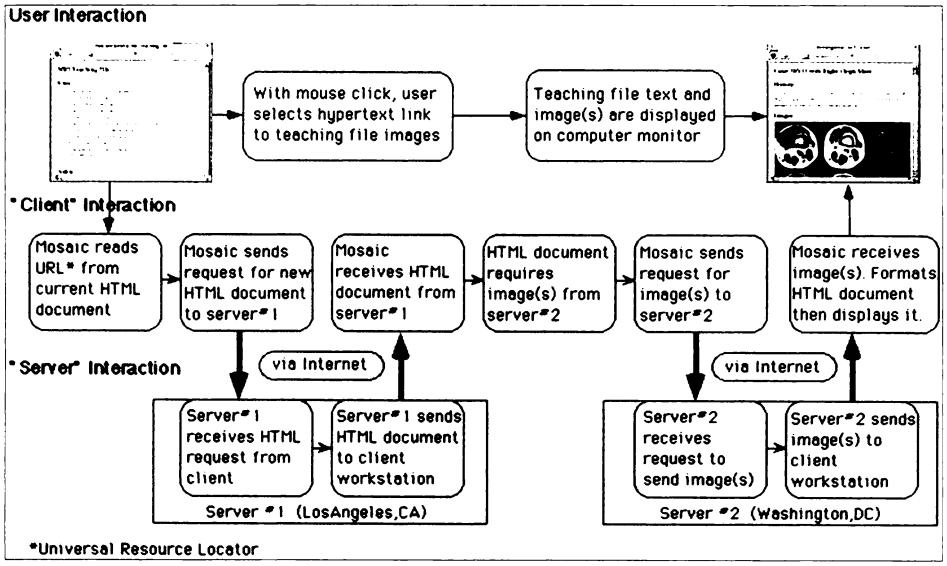


**Fig. 2.—Mosaic in operation, retrieving teaching file document that includes link to radiologic images. In this schematic example, user selected teaching file case from list, initiating series of actions by Mosaic mostly unseen by user. Basic steps are (1) interpretation of link invoked by user's choice, (2) retrieval of information specified by link, and (3) generation of graphical display containing text, images, and sometimes digital movies and/or audio. HTML = HyperText Markup Language.**

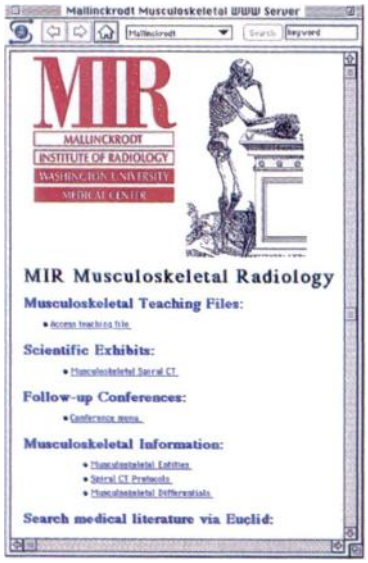


**Fig. 3.—Musculoskeletal teaching file home page. Both text and graphics can be incorporated in home page screens.**

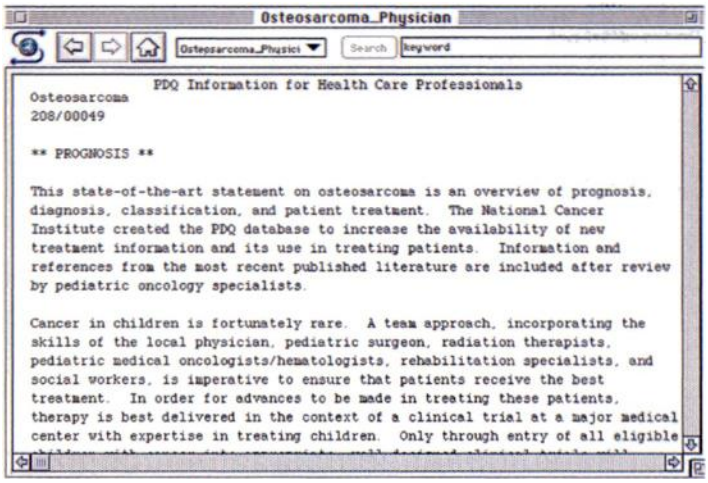


**Fig. 4.—Current cancer treatment information via Internet. National Cancer Institute's World-Wide Web server (Bethesda, MD) provides up-to-date information from its CancerNet data base. Link to this display was in osteosarcoma teaching file document stored on author's computer in St. Louis. PDQ = Physician's Data Query**

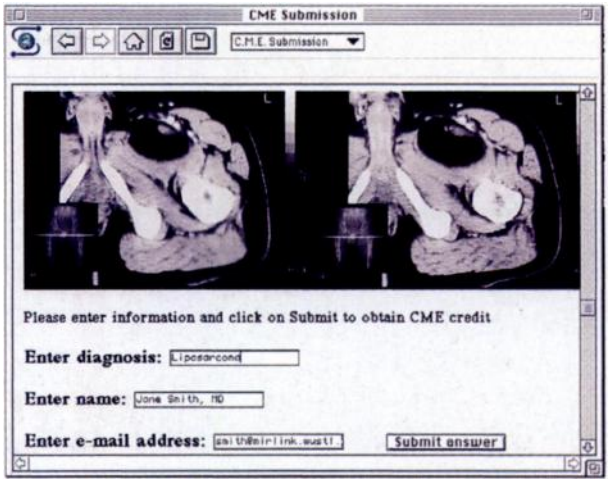


**Fig. 5.—Prototype of continuing medical education (CME) interface. Electronic forms capabilities of Mosaic allow users to submit responses to host computer. In this example (a CME application), user views diagnostic images and clinical history (*not shown*), then electronically submits diagnosis for scoring and CME credit.**

Web, considerations of user interface and cross-platform computer compatibility are effectively addressed. Electronic forms provide a method to assess the effectiveness of teaching materials that are based on the WWW and Mosaic.

For academic radiology departments, the cost of developing and maintaining traditional teaching files is substantial. In the transition to computer-based teaching files, the American College of Radiology has focused on videodisc storage of teaching file images, with CD-ROM versions under development. Network distribution of teaching files will be the next phase in this transition. Continuing medical education is an ideal WWW application that is facilitated by electronic forms (Fig. 5). Programs like Mosaic ensure proper presentation of educational material on a wide variety of personal computers.

Scientific exhibits are among the highlights of national radiology meetings. Given the time constraints at meetings, it is often difficult to fully explore these exhibits. Scientific exhibits are expensive to create and transport. As an alternative, an electronic exhibit can be established to which authors would digitally submit their work. These exhibits would be available for viewing on workstations during the meeting and via the Internet after the meeting. The cost of electronic exhibits should be substantially less than for comparable poster exhibits. Exhibits stored on a WWW server would be a valuable resource to the worldwide radiology community. A recent poster exhibit [4] has been transformed into HTML format to demonstrate the feasibility of this approach (URL for this document is http://wuerlim.wustl.edu/draxa/www/exhibit/toppanel.HTML).

The World-Wide Web and Mosaic give us a glimpse at the future of radiologic education. The many emerging applications are exciting. However, much assessment and refinement of this evolving technology are yet to come.

## REFERENCES

1. The Internet Society. *Latest Internet measurements reveal dramatic growth in 1994.* Press release. The Internet Society, Reston, VA. Aug. 4, **1994**
2. Richardson ML, Rowberg AH, Gillespy T, Frank MS. An on-line digital Internet teaching file server. *AJR* **1994**;162:1239–1242
3. Fishman EK, Ney DR, Brody WR. The *AJR* of the future: electronic publication and distribution. *AJR* **1993**;160:413–415
4. McEnery KW, Miller MM, West OC, Wilson AJ. Musculoskeletal trauma evaluation with spiral CT. *AJR* **1994**;162(3) [suppl]:252