Empowering Radiologic Education on the Internet: A New Virtual Website Technology for Hosting Interactive Educational Content on the World Wide Web

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Objective: We describe a virtual web site hosting technology that enables educators in radiology to emblazon and make available for delivery on the world wide web their own interactive educational content, free from dependencies on in-house resources and policies. **Materials/Methods:** This suite of technologies includes a graphically oriented software application, designed for the computer novice, to facilitate the input, storage, and management of domain expertise within a database system. The database stores this expertise as choreographed and interlinked multimedia entities including text, imagery, interactive questions, and audio. Case-based presentations or thematic lectures can be authored locally, previewed locally within a web browser, then uploaded at will as packaged knowledge objects to an educator's (or department's) personal web site housed within a virtual server architecture. This architecture can host an unlimited number of unique educational web sites for individuals or departments in need of such service. Each virtual site's content is stored within that site's protected back-end database connected to Internet Information Server (Microsoft Corp, Redmond WA) using a suite of Active Server Page (ASP) modules that incorporate Microsoft's Active Data Objects (ADO) technology. Each person's or department's electronic teaching material appears as an independent web site with different levels of access—controlled by a username-password strategy—for teachers and students. There is essentially no static hypertext markup language (HTML). Rather, all pages displayed for a given site are rendered dynamically from case-based or thematic content that is fetched from that virtual site's database. The dynamically rendered HTML is displayed within a web browser in a Socratic fashion that can assess the recipient's current fund of knowledge while providing instantaneous user-specific feedback. Each site is emblazoned with the logo and identification of the participating institution. Individuals with teacher-level access can use a web browser to upload new content as well as manage content already stored on their virtual site. Each virtual site stores, collates, and scores participants' responses to the interactive questions posed on line. **Conclusion:** This virtual web site strategy empowers the educator with an end-to-end solution for creating interactive educational content and hosting that content within the educator's personalized and protected educational site on the world wide web, thus providing a valuable outlet that can magnify the impact of his or her talents and contributions.

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RADIOLOGIC EDUCATION has faced several challenges in recent years. Larger work loads per radiologist, decreased time and money available for education, and the migration from film-based radiology to digital radiology have combined to stymie many department's intentions to maintain or expand their internal educational resources such as radiologic teaching files. Many radiologists who embarked on the creation of web-centric digital teaching files with great enthusiasm in the mid-1990s have discovered that it takes time, money, and usually the support and cooperation of information systems personnel at their institution to maintain an educational web site. Further complicating this issue has been a lack of software tools and web-centric technology specifically designed to empower radiologic education on the web. We describe a new virtual website hosting technology called a "Universal Education Server" that enables educators in radiology to emblazon and make available for delivery on the world wide web their own interactive educational content, free from dependencies on in-house resources and policies. A complementary authoring technology is used for creating and storing this interactive educational content. This suite of technologies is collectively referred to as EDACTIC for "Education Delivered and Composed Through Internet Communication."

MATERIALS AND METHODS

EDACTIC includes graphically oriented authoring software designed for the computer novice to facilitate the input, storage, and management of domain expertise within a database system. The authoring software, as used for radiologic education, has been customized to also serve as a digital teaching file manager, and is joined operationally with its complementary web deliv-

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0897-1889/01/1402-1028\$35.00/0

doi:10.1053/jdim.2001.23832

ery and virtual server technology at the database level. The authoring software runs in the Microsoft Windows (Microsoft, Redmond, WA) environment and is compatible with Windows 95, 98, Millennium Edition, NT, and Windows 2000. The software can function as a stand-alone application or in a local area network (LAN) environment where the database is shared among authors. Content can also be authored locally and uploaded to a remote website. Information is entered into the system in a case-centric fashion; that is, one record in the database typically represents one teaching file case. The software employs a variable-length, loosely structured record format that also facilitates its use for storing thematic material, as well as other formats of content. It is primarily the context in which the educator uses the application, and the way in which material is entered, that determines whether the content within will be case-centric, thematic, or otherwise. For example, one or more home pages for a hosted site can be created and maintained by the authoring software. These are records that are composed (and flagged) to function as top-level pages. They are stored in the data base along with all educational cases and any other special-purpose "cases" (eg, records) than an author might want to create.

An image management facility enables the integration of imagery with each case. The software is compatible with images of Windows Bitmap (BMP), Graphics Interchange (GIF), Joint Photographer expert Group (JPEG), and Digital Imaging and Communications in Medicine (DICOM) formats. The image management module contains facilities for both interactive and batch mode functions such as zooming, sorting, renaming, cropping, resizing, watermarking, and reorienting images, as well as creating "thumbnail" images that correspond to their full-sized counterparts. Images are stored external to the database as individual graphic files within a folder hierarchy maintained by the software. References to image files are stored within each database record. A built-in search engine supports menu-driven, Boolean combinations of natural-language queries that can encompass any or all elements of a record. The authoring software also supports, for intended delivery over the world wide web, the storage and choreography of several other types of content such as free-form stylized text and interactive multiple choice or true-false questions accompanied by immediate feedback to the user. An internal meta-language, invisible to the author but stored with the content, was invented to represent the choreographic directives that drive the sequencing and interactivity of the content when transmitted over the world wide web.

A separate software system is used to retrieve content having been stored in a database by the authoring system, convert this content in to web pages, and transmit these pages over the world wide web. There are no static hypertext markup language (HTML) files. Rather, the delivery software dynamically converts content retrieved from the database into HTML per the choreographic directives stored with the content. This delivery system is essentially an Active Server Page application (Microsoft), comprised of a collection of modules that include software scripts written in VBScript (much like Visual Basic) and Java. This application connects to a teaching-file database using Microsoft's ActiveX Data Objects (ADO) technology. The delivery system runs in the Microsoft Windows environment in conjunction with Internet Information Server or Personal Web Server (depending on the specific operating system),

and is compatible with Windows 9x, Millennium Edition, NT, and 2000. The web pages generated by the delivery system are designed to be compatible with any common web browser (eg, Internet Explorer, Netscape Navigator, Opera). The delivery software can be installed on the same computer on which the authoring system is installed and used in stand-alone mode (eg, on a laptop computer that is not connected to the internet) in which the delivery software and a locally installed web server generate and transmit web pages to a web browser also running on the same computer. An author typically uses this capability to interactively preview exactly what his or her material would look like were it actually being transmitted on the internet.

The delivery technology exploits the hierarchical storage architecture used by the authoring software to maintain the database and associated imagery. For example, a single mapping directive can link the delivery software to a particular database and all underlying full-sized images and thumbnail images associated with cases in the database. All images are stored external to the database, and all intrinsically browser-compatible images (eg, JPEG and GIF) are thus web-ready and fully accessible to the delivery software. When the delivery software fetches a record from the database, processes it, and generates web pages that contain either images or links to images, the delivery software "knows" exactly where the images are stored relative to a web browser's perspective, and thus can dynamically generate the appropriate HTML along with any associated links such that coherence is maintained within and across cases (ie, records) retrieved from the database.

In its simplest implementation, the delivery software can be mapped to a single database and its associated hierarchy of folders containing images. The user sees a single website that itself can contain an unlimited number of case-based or thematic presentations. When the delivery software is configured as a Universal Education Server, an entry-level page is presented that requires log in with user name and password (Fig 1). An underlying table contains authentication information (eg, names and passwords to validate users), as well as the mapping directives to dynamically point the software to the correct

Fig 1. Entry-level log-on screen for Universal Education Server as implemented at Massachusetts General Hospital.

database and image repository for each virtual site. Associated with the authentication data for each user are directives that convey a user's level of access to a site (student v teacher level), as well as a reference to the logos used to emblazon the web pages generated for a particular virtual site. Thus, for example, any department can provide read-only student-level access to its constituency by circulating a single username-password combination that gives student-level access to the department's virtual site. One or more additional username-password combinations can be maintained for those (teachers) with privileges to upload content or modify certain characteristics of content in the database such as visibility. Students and teachers are greeted with different home pages. The teacher's home page (Fig 2) is rendered by the Universal Education Server software and is the same for all virtual sites. However, the home page presented under student-level access for each virtual site is administered and controlled by individuals with teacher-level access to that site (Fig 3). Regardless, students and teachers alike who visit a virtual site will see web pages branded with the logo of the institution that manages and maintains the site. Any number of virtual sites can be hosted within a Universal Education Server, including independent sites for sections and individuals within the same department.

The authoring software supports the transfer of content from a locally maintained database to a remote virtual site hosted within the Universal Education Service. A packaging facility integrated with the authoring software will on demand place all content (text, images, choreographic directives) for a given case into a single compressed file. The packaging facility can create both "full" and "incremental" packages. A full package contains all content for a case. An incremental package contains only changes made to a case's content, including new or modified images, since the most recent full package was made. This

Fig 2. Teacher-level home page, logged in under SUNY Stony Brook Department of Radiology. Upload facility displayed at bottom of figure.

Fig 3. Student-level home page, logged in under SUNY Stony Brook Department of Radiology (A) compared to student-level home page when logged in under the New England Roentgen Ray Society (B) on the same Universal Education Server.

strategy facilitates fast uploads of small, incremental changes often made to the content of a case once all images have been uploaded within a full package. The Universal Education Server exposes an upload facility (Fig 2) to users logged in with teacher-level access to a virtual site. With a simple "click and paste" operation, the user can package a case, switch from the authoring software directly to the upload facility displayed in his or her web browser, and initiate an upload. Software continually running in the background on the Universal Education Server immediately detects and processes a newly arrived package, placing the data for an arriving package into the appropriate database and placing any accompanying images

into their appropriate storage area so that all associations between images and data are maintained.

RESULTS AND DISCUSSION

The Universal Education Server has been successfully deployed within teaching hospitals, radiologic organizations, and radiology web portals. The highest-volume site (the Education Section of *AuntMinnie.com*) currently receives approximately 1 million page views per month and between 6,000 and 7,000 log-in sessions per day. In this particular implementation, user-level access is provided to the internet community via direct entry to customized subsites on the Education Section (ie, there is no user-level log in provided through the Universal Server itself). However, the content on this site is maintained remotely via teacher-level access to a Universal Education Server which maps to different subsites on the Education Section such as the Case of the Day and RadiologyIQ sections.

The Universal Education Server offers several benefits that can facilitate an educator's role and magnify his or her talents and contributions. The technology enables educators in radiology to publish on the world wide web their own interactive educational content on a protected web site free from dependencies on in-house technol-

ogy and politics. Frustrating "fire wall" restrictions that can cause obstacles for web-centric teaching files are bypassed. All that is necessary for creating educational content and publishing it on a hosted site is the authoring software (which can be used off line), a web browser, and an Internet connection. A special version of the web delivery software is installable on an author's own computer(s) to facilitate review of exactly what his or her educational content will look like when actually posted on a Universal Education Server. Each person's or department's electronic teaching material appears as an independent web site with different levels of access—controlled by a username-password strategy—for teachers and students. Should a department choose to install the Universal Education Server internally and host their own content, one such server installed on one computer can host as many independent educational sites as a department desires. Each virtual site stores, collates, and scores participants' responses to the interactive questions posed on line, thus facilitating more formal educational initiatives such as distance-learning curricula and continuing medical education.