Beyond the Electronic Textbook Model: Software Techniques to Make On-line Educational Content Dynamic

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Objective: We describe a working software technology that enables educators to incorporate their expertise and teaching style into highly interactive and Socratic educational material for distribution on the world wide web. **Materials/Methods:** A graphically oriented interactive authoring system was developed to enable the computer novice to create and store within a database his or her domain expertise in the form of electronic knowledge. The authoring system supports and facilitates the input and integration of several types of content, including free-form, stylized text, miniature and full-sized images, audio, and interactive questions with immediate feedback. The system enables the choreography and sequencing of these entities for display within a web page as well as the sequencing of entire web pages within a case-based or thematic presentation. Images or segments of text can be hyperlinked with point-and-click to other entities such as adjunctive web pages, audio, or other images, cases, or electronic chapters. Miniature (thumbnail) images are automatically linked to their full-sized counterparts. The authoring system contains a graphically oriented word processor, an image editor, and capabilities to automatically invoke and use external image-editing software such as Photoshop. The system works in both local area network (LAN) and internet-centric environments. An internal metalanguage (invisible to the author but stored with the content) was invented to represent the choreographic directives that specify the interactive delivery of the content on the world wide web. A database schema was developed to objectify and store both this electronic knowledge and its associated choreographic metalanguage. A database engine was combined with page-rendering algorithms in order to retrieve content from the database and deliver it on the web in a Socratic style, assess the recipient's current fund of knowledge, and provide immediate feedback, thus stimulating in-person interaction with a human expert. **Results:** This technology enables the educator to choreograph a stylized, interactive delivery of his or her message using multimedia components assembled in virtually any order, spanning any number of

web pages for a given case or theme. An educator can thus exercise precise influence on specific learning objectives, embody his or her personal teaching style within the content, and ultimately enhance its educational impact. **Conclusion:** The described technology amplifies the efforts of the educator and provides a more dynamic and enriching learning environment for web-based education.

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MANY EDUCATIONAL websites for radiology have come to resemble each other, using a more or less static electronic-textbook model that provides little dynamic interaction. Radiologists have discovered that keeping an educational website interesting and up to date requires substantial effort. Exacerbating this is the dearth of software tools and database technology specifically designed to empower radiologists as educators on the web. We describe a new graphically oriented interactive authoring system, which in its simplest implementation serves as a digital teaching file manager, that enables the computer novice to create and store within a database his or her domain expertise in the form of choreographed, interactive, electronic knowledge. A complementary web server application delivers this content on the web in a Socratic style to assess the recipient's current fund of knowledge and provide immediate feedback, thus simulating in-person interaction with a human expert. This suite of technologies is collectively referred to as EDACTIC for "Education Delivered and Composed Through Internet Communication."

MATERIALS AND METHODS

The authoring system was developed within Microsoft's Visual Studio software (Microsoft, Redmond, WA) framework. Visual Foxpro, a database management application and member of the Visual Studio suite, served as the primary development tool. Some ancillary software libraries were created with Visual C++. The software runs in the Microsoft Windows environment and is compatible with Windows 95, 98, Millennium Edition, NT, and Windows 2000. The application is distributed as a self-installing executable file that can be downloaded via the internet and installed as a stand-alone or local area network (LAN) application. The software employs a variable-length, loosely structured record format that facilitates its use for processing case-based, as well as thematic material. On startup,

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Fig 1. Startup screen of authoring system displays the roster of content currently in database. In this case-based example, patient's names have been partially obscured to protect confidentiality.

the software displays a roster of content within the database (Fig 1). A record in the database can contain, among other things, a teaching file case, a thematic presentation, a quiz (ie, interactive questions only), an electronic chapter, or any combination thereof. 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 a record will be case-centric, thematic, or otherwise.

The most distinguishing feature of the authoring system is its ability to store not only educational content, but also choreographic information (used by the web delivery software) to specify and control the sequence and style in which the content is delivered to intended recipients on the web. An internal metalanguage, invisible to the author but stored with the content, was invented to represent these choreographic directives. A data structure referred to as an EduScript is used to internally implement this metalanguage as a structured sequence of interactive objects such as thumbnail images that automatically zoom to their full-sized counterparts, interactive true-false or

multiple choice questions, and stylized, graphically oriented text objects, which are essentially web page "snippets" represented internally with hypertext markup language (HTML). Using the integrated EduScript editor (Fig 2), an unlimited number of these interactive objects can be chosen from a predefined gallery, inserted into the EduScript, and sequenced in any desired order. Many of the interactive objects, such as dynamic questions and so-called what-you-see-is-what-you-get (WYSIWYG) stylized text objects, have their own built-in editors as well. The WYSIWYG editor (Fig 3) provides a look and feel much like Microsoft Word. Every record in the database contains its own EduScript as one of its elements. Whenever a record's EduScript is empty, the content of the record is displayed on the web using a default presentation template that incorporates standard information elements of history, findings, diagnosis, and discussion.

The authoring system also supports the creation of an unlimited of supplemental web pages, referred to as EduPages that can be stored with each record. These function as ancillary

Fig 2. EduScript editor. Gallery of available interactive objects is depicted by push-buttons along left side of form. User has double-clicked the second item (a free-form, unformatted text item) in the EduScript and is editing text for this item in the smaller foreground window.

Fig 3. Graphically oriented text editor in authoring system uses HTML to represent visual content. Here author is editing a so-called WYSIWYG EduScript item pertaining to aortic dissection.

information objects to which content anywhere within a record (eg, a text snippet or thumbnail image) can be linked. A built-in EduPage management module provides a graphically oriented interface for organizing and accessing EduPages within each

record. EduPages themselves are edited with the same WYSIWYG editor (described above) that is used to create stylized, graphically oriented text objects for an EduScript.

When the subject matter of a record is case-based, discrete

Fig 4. Built-in image editor in authoring system. Author is using the editor in "cookie cutter" mode to select, crop, resize, and watermark individual images from a digitized film sheet. Small foreground window awaits author's confirmation of intended editing actions.

items such as the name of the case, identification number, modalities used, contributor, reviewer, and mechanism of establishing the diagnosis can be tracked. To facilitate the retrieval and review of inbound case material, patient identification information can be stored for internal only in protected elements that are not transmitted over the Internet. The user interface employs the familiar parlance of "history," "findings," and "diagnosis" to reflect the more general concepts of "problem," "evidence," and "solution" that are represented within the underlying data model. An integrated coding module expedites the assignment of diagnostic codes to the subject matter. An image management facility enables association of imagery with textual material. 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. A built-in image editor (Fig 4) is optimized to facilitate the processing and production of web-ready content using images obtained from digital cameras and film scanners. 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. The image management module can be configured to also automatically invoke and use commercially-available image-editing software such as Photoshop or Paint Shop Pro. 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 preceding paragraphs have focused on the authoring system, whose function is to create and store interactive educational content intended for distribution over the world wide web. A separate "delivery system" is used to retrieve content having been stored in a database by the authoring system, convert this content into dynamic web pages, and transmit these web pages over the world wide web (see <http://education.auntminnie.com>). The authoring system and delivery system are joined operationally at the database level. The delivery system is comprised of a collection of Active Server Page (Microsoft) modules that include HTML, as well as software scripts written in VBScript (much like Visual Basic) and Java. 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) as well as several popular operating systems such as Windows, Linux, Unix, and Macintosh. The delivery system 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 system 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 instantly and interactively preview exactly what his or her material would look like were it actually being transmitted over the Internet.

RESULTS AND DISCUSSION

The authoring and delivering systems described herein have been successfully deployed within teaching hospitals, radiologic organizations, and radiology web portals. The highest volume site currently receives approximately 1 million page views per month and between 6,000 and 7,000 log-in sessions per day. The flexibility inherent in the authoring system facilitates the creation and delivery of educational content tailored to meet specific objectives of the educator. For example, in addition to creating case-based material for a digital teaching file, the same technology has been used to create thematic material appropriate for chapters in an interactive on-line textbook and to create interactive Q&A presentations that simulate a written examination (see <http://education.auntminnie.com/auntminnie/ambrdrw/>).

Academic radiology has been subject to economic factors that have resulted in larger work loads per radiologist with decreased time and money available for education. Regardless, the migration of content from a hard-copy-oriented teaching environment to a digital one is laborious, as is the creation of new educational content within a filmless environment when one also considers the effort required to integrate expert-level knowledge with medical images. A static electronic-textbook model for on-line education provides little dynamic interaction and can be more fatiguing than actually reading a textbook. We believe that the future of academic radiology requires that radiologists as educators, and teaching hospitals as educational institutions, become more efficient in terms of their educational productivity and the subsequent impact of their efforts. The technologies described here are intended to facilitate and amplify the efforts of educators and to also provide a more interactive and enriching learning experience than the ubiquitous electronic textbook model seen on-line today.

Because the authoring system serves as both a digital teaching file manager and a tool for creating choreographed interactive content, its user interface can be switched between beginner, intermediate, and advanced mode. Beginner mode is designed for users who want only digital teaching file functionality, ie, to store and categorize case material comprising images and the corresponding

history, findings, diagnosis, and discussion for the case. Advanced mode is for creating choreographed, interactive material intended to span several web pages. Such material when delivered on the web typically includes one or more series of images interspersed with stylized text, interactive questions with real-time feedback, and links to ancillary web pages.

The system is designed not only to dynamically interact with an intended audience on the web, but also to assess and track a user's current fund of knowledge with respect to the material presented. An EduScript can contain any number of interactive questions of either true-false or multiple choice format. When an interactive question is rendered on a web page, each available response presented for the question is accompanied by an active hyperlink, and thus each chosen response results in the immediate display of specific feed-

back that conveys whether or not the response was correct. The feedback also usually conveys, at the author's discretion, additional explanatory material that can itself contain links to EduPages or images associated with the case, as well as links to other records (eg, cases, chapters) in the database or links to any URL. The delivery system tracks a user's response and logs to a database whether or not the user was correct the first time he or she tried to answer the question. The delivery system can be also be configured to require that a user seek the correct answers for questions posed before the user is credited with having completed the material. Thus, in addition to superseding the static electronic textbook model with a more engaging and stimulating learning environment for an educator's intended audience, such an infrastructure also avails itself to formal initiatives in distance learning and continuing medical education.