A method for interactive medical instruction utilizing the World Wide Web

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We describe the implementation of interactive medical teaching programs in radiology and histology which utilize the Internet's World Wide Web (WWW). The WWW standard hypertext interface allows for simple navigation between related documents but does not provide a method for student tracking or question queries. Electronic forms, a recent feature of the WWW, provide the means to present question documents to remote clients and track student performance. A feature of our approach is dynamic creation of HTML documents based upon interaction with database applications. The approach allows multiple simultaneous, yet asynchronous interactions by geographically dispersed students upon the same instructional database and is scalable, providing the capability for multiple image/document servers. The security of the database is assured given that it is not accessible through the Internet.

INTRODUCTION

As originally conceived the World Wide Web (WWW) provided an efficient method for electronic distribution of multimedia documents.[1] For medical computer aided instruction (CAI) integration images and text is essential for effective instructional programs.[2,3] The original implementation of the WWW is based upon hypertext links between pre-existing documents. All accessible documents and their contained hypertext links are specifically formatted given the conventions of hypertext mark-up language (HTML).

The WWW's Hypertext Transfer Protocol (HTTP) is stateless meaning that no information is retained by the server computer regarding a given user's prior interactions. This situation presents a problem for those interesting in creating interactive instructional lessons across the Internet. Most local CAI programs rely upon state information to create/control the instructional presentation. In static hypertext environments, as one navigates through linked documents there is no method for the server computer to alter the presentation or direct the student to specific resources as would have been displayed in a high quality CAI program. In some ways, static hypertext is analogous to "electronic page turning" which was criticized in initial implementations of CAI.

A recent addition to the standard features of the WWW are "electronic forms" which provide the capability to transfer user responses to specific questions from the client to the server computer. They also allow state information to be retained by the server computer or saved in a "hidden field" within the form returned to the client. In the context of medical education, electronic "forms" give educators the means to create self-assessment routines and provide specific instructional feedback. The server computer required for this processing need not be a complex UNIX system. All this interactivity can be implemented on an office Macintosh computer with access to the Internet.

Although the conventions of HTML require precise document formatting, a document need not pre-exist on the server. HTML documents can be dynamic, created "on the fly" upon the request of the client to the server. In our applications, the returned HTML documents reflect an interaction with a pre-existing database interfaced exclusively though electronic forms. Rather than educational programs containing static links to existing HTML documents, there is a paradigm shift in that the HTML documents reflect the information within the database. This provides the means to create a dynamic educational environment similar to current local CAI programs but with access to the resources of the entire Internet.

To initiate investigations of network accessible medical education through the WWW, we developed projects for the histology curriculum and for radiology instruction. These areas were selected

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because of their dependence upon high quality medical images and established conventional self-instructional models.

METHODS

WWW server and database interface

The main project "web" server was established on a Power Macintosh 7100 running WebSTAR (Starnine Technologies, Berkeley, CA). This server processed all document requests, created the HTML documents though the use of Common Gateway Interface (CGI) applications and returned them to the client application. Local student stations were equipped with the WWW client Netscape (Netscape Communications, Mountain View, CA).

CGI applications process form submissions, interact with ancillary applications such as databases, and return the results as a HTML document to the server (FIGURE 1). While CGI applications can be written in a variety of programming languages including C, C++, PERL, for this project AppleScript was chosen given pre-existing scripts for database interaction. The specifics of CGI creation are covered elsewhere.[4] Filemaker Pro was selected as the database application primarily due to its AppleScript support which provides query capabilities to the database without need to directly access the program interface. An advantage to the Filemaker program was that it was already in use by the authors and required no unique adaptations to interface to the WebSTAR server. The documentation needed to create these scripts is included with WebSTAR software or is available through the WWW.[5]

Radiology Project

The format for the radiology presentation was as a magnetic resonance imaging "Case of the Week". A clinical case was selected from an existing film based teaching file. Images from the case were reloaded onto a Siemen's (Iselin, New Jersey) MRI scanner from an optical clinical archive and transferred by an Ethernet Local Area Network to a Macintosh computer. The public domain program Image (National Institutes of Health, Bethesda, MD) allowed conversion of the image into .PICT format. DeBabelizer (Saucalito, CA) was selected to convert the images into .GIF format which provides display by all WWW clients.

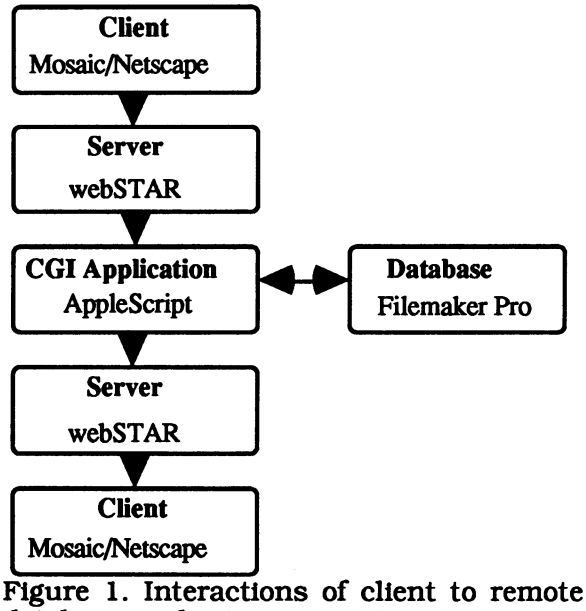

Figure 1. Interactions of client to remote database application computer.

In the radiology database, information entered included diagnosis, image names, image description, case discussion, and multiple choice questions. All information in the database is stored as standard text documents and not in HTML format. This provides for easy editing by secretarial personnel with no knowledge of HTML formatting. Upon a client request, the server CGI application accesses the database text and adds the necessary HTML formatting (Figure 2).

Diagnosis
Image names
Image description
Labeled image names
Questions - up to five
Didactic information

Figure 2. Radiology database format

In the current "unknown" presentation, initially only selected diagnostic images and clinical history are displayed. A diagnosis is entered, passed to the server and recorded in separate user database. A second HTML page is returned to the client which contains the correct diagnosis, an image with findings labeled, a description of the findings, and several multiple choice questions. Answers are submitted and graded. The final HTML page lists the correct answers, number of correct answers, and provides pertinent teaching points regarding the diagnosis. The date,

A. Question as stored in database (simple text document):
Regarding osteosarcoma:
The most common location is in the distal femur
The tumor occurs commonly near joints of long bones.
It is the most common bone tumor in teenagers
All of the above
None of the above

B. HTML formatting of question (HTML created by CGI):

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<B>Regarding osteosarcoma:</B>
<OL><LI><input type="radio" name="Q1"value="1">The most common location is in the distal femur
<LI><input type="radio" name="Q1"value="2">The tumor occurs commonly near joints of long bones. .
<IL><input type="radio" name="Q1"value="3">It is the most common bone tumor in teenagers
<LI><input type="radio" name="Q1"value="4">All of the above
<LI><input type="radio" name="Q1"value="5">None of the above</OL>
```

C. HTML formatted question as displayed by client software (as viewed by user):

Regarding osteosarcoma:
1.❑ The most common location is in the distal femur
2.❑ The tumor occurs commonly near joints of long bones.
3.❑ It is the most common bone tumor in teenagers
4.❑ All of the above
5.❑ None of the above

Figure 3. **A.** The question document is stored in simple text form in the database. **B.** A CGI application automatically converts the text into HTML documents at the time of question request. **C.** The HTML formatted question is displayed by the client software. This process ensures precise HTML formatting and spares authors the tedium of the extensive HTML coding required for question delivery via in electronic forms.

exact time and length of interaction and user answers are recorded in the user database. Currently, assessment of the user's diagnosis is performed manually, not at the time of interaction. As a self-assessment module, it is expected that the user can determine if their answer was correct based upon the correct diagnosis. The CGI application automatically evaluated responses to the multiple choice questions .

Histology Project

The histology project involved the conversion of a non-interactive 35 mm slide-tape self-study program to electronic format with capability for student self-assessment. The modules assisted first year medical students in preparation for the microscopic identification portion of their histology laboratory course. This source material consisted of approximately 400 high quality histology images and audio descriptions. Printed transcripts of the audio descriptions were also available.

The 35-mm slides were digitized using the Photo CD (Eastman Kodak, Rochester, MN). DeBabelizer allowed reading the PhotoCD disks, placement of a copyright notice, renaming, and saving in .GIF format in a single batch process. Two image resolutions are available. The entire histology image database is 152 mB in size.

A Filemaker database includes a separate record for each image which includes image cell type, image name and descriptive information. Additional fields are available for future expansion including standard coding such as SMOMED and National Library of Medicine Metathesaurus. The availability of this coding anticipates linking these images to other teaching applications.

The histology program has both a REVIEW and QUIZ module. In both modules the student is presented with a listing of all the slides types available (bone, lung, etc.). The student selects either a specific tissue type or range of tissue types. If the student selects review, a HTML page is created which includes the slide descriptive information as well as the server location of the histology image. This HTML document is returned to the client with options to view

the next/prior slide in the series or return to main menu.

In the QUIZ mode, the electronic form presents an unknown histology image and contains a field to type in the name of the cell type. The form is submitted to the server. The CGI application processes the user's answer and incorporates it into the returned HTML document which identifies the image and presents the associated descriptive text.

Given of the complexity of free text entry processing, and the purpose of this module as self-assessment, the student is asked to grade their own answer as correct or incorrect. The student's self-assessment is recorded and passed unbeknownst coded in a hidden field included within the next form. To assist in the instructional effectiveness, if an incorrect identification is noted by the student, that image is recorded and given a higher priority to re-appear as one of the next 3-10 HTML pages. Upon the user quitting their review, a document is returned stating the number of images viewed and the number and percentage correct.

Like the radiology database, given the paradigm of database interaction a variety of different presentation formats can be implemented. One will simulate the current histology laboratory examination. A specific list of slides will be viewed, providing the student a comparison with the performance of their peers. With this planned module formal student evaluation could be implemented.

RESULTS

Radiology Project

The project was successful in its implementation of the teaching file approach with capability for self-assessment. Multiple users from around the world were able to interact with the system and correctly interpret the available diagnostic images. In repetitive testing, the server was able to analyze user responses and return a formatted HTML document in 5 seconds or less. The total case retrieval time depends upon the bandwidth of the user's Internet connection. Average image size was 30 kB or less with usually 4 images available (120 kB total). With a 14.4 modem, nominal image transfer was 1 kB/sec necessitating a total transfer time of 120 seconds. With Ethernet connection nominal image transfer time was 10 kB/sec with case transfer time of less than 20 seconds for diagnostic image transfer.

Histology Project

The histology project was able to provide students with interactive lessons in both review and self-evaluation mode. All HTML documents were created by the computer and the utilization of the program, especially heavy during pre-examination preparation demonstrated that the forms approach was able to successfully manage multiple student submissions. Nominal time for HTML document retrieval was 5 seconds or less, even during high load periods. Base image size was approximately 100 kB. As all student stations utilized Ethernet connections nominal image transfer was 10 kB/sec which provided display in 10 seconds or less.

DISCUSSION

With the availability of widespread access to Internet resources it is likely that many medical education projects will occur in the future. We acknowledge several excellent examples at other institutions which utilize static HTML documents to provide access to subject material.[6-7] Examples also exist of dynamic access to radiology teaching files.[8] The features of forms based assessment, as utilized in our development, have only begun to be exploited by medical applications.

Utilization of a database interface for dynamic HTML page creation provides efficient framework for creation and maintenance of a WWW-based educational resource. The adoption of a database interaction paradigm arose from legitimate concerns that producing separate documents would become unwieldy and labor intensive. As example, initially for the histology project over 400 unique HTML pages were created. As the review module presents to HTML pages in a sequential "slide show", whenever a single image was added or deleted, this required the editing of the multiple HTML pages. Questioning of the effort needed to maintain an accurate collection of HTML pages, led to the search

for alternative methods which resulted in the adoption of the current database interaction methods.

As the instructional presentation is mediated by the CGI applications future instructional module implementations only require changes in the CGI application. For instance, interaction with the radiology database could be as known cases with the didactic information given before asking the questions. This planned format would allow testing of learned information rather than pre-existing knowledge of the present module.

Unlike the traditional CAI model of the single user/single computer, the WWW provides the capability for multiple, geographically dispersed students to view the same instructional material from a single server. These interactions can occur simultaneously and are asynchronous in that each student can view the material at their own speed. For a given user, with dynamic HTML there may not be any detectable difference in the WWW presentation than from that of a traditional CAI program. The student may not even be aware that the presented HTML pages are tracking interaction with the program. However, from the developer's perspective it is possible to incorporate a variety of resources into educational modules. An unlike a CD-ROM or videodisc presentation these WWW-based programs can be continually updated by simply changing the information within the instructional database.

Bandwidth limitations currently limit the practicality of this approach to those users with Ethernet connections to the Internet. Authors have noted that users will not tolerate waiting more than 20 seconds for information to be displayed.[9] For a modem such a delay will be routinely experienced. In our current efforts bandwidth requirements are not a major concern because all students stations have Ethernet network connection and ATM fiber optic networks are being installed

Cost considerations, especially in today's health care system must be raised in the initiation of any education project. Either videodisc or CD-ROM programs are alternatives to the present system. The WWW, videodisc, and CD-ROM presentations require multimedia capable computers. The utilization of the WWW eliminates the need to produce or make copies of either CD-ROM or videodiscs. In the radiology application we anticipate a continually growing resource ideally suited for network distribution. In addition, with the WWW, the case is available for review the instant that a reference record is saved in the teaching database. We anticipate benefits to the core medical curriculum as the image database is expanded to pathologic processes and current clinical material can be added to the database.

The selection of the Macintosh computer as the server platform is in keeping with the cost considerations of this project. While some may advocate implementation of WWW servers exclusively on a UNIX platform, the Macintosh is just as capable. A recent survey found that 20% of the current WWW servers are Macintosh-based.[10] A hidden cost in any educational software development are the personnel required to maintain the computer hardware. While specialized technical personnel are often a prerequisite to maintain a UNIX server, the Macintosh has no such requirement. The WebSTAR educational price is $300 with the remaining software such as Filemaker and AppleScript already found on many Macintosh computers. The Netscape client software preferred by the application is free to educational institutions.

The security of the instructional database is a primary concern. The selection of the Macintosh sever platform provides security features which prevent direct access to the instructional database or user information. The instructional database files are outside of the server's directory tree and therefore inaccessible. Future expansion of the program will place the database on a second computer which will communicate to the main server via Appletalk but have no software installed for direct Internet access. When it becomes universally available, encryption technology will be incorporated into our instructional programs. Although this technology is designed to keep user credit card transactions secure, it can also provide confidentiality for a medical student's exam

preparation as well as a physician's self-education activities.

The capacity for future project expansion is also an important consideration. The current approach is designed to be scalable. As images require greater bandwidth than HTML text documents, multiple image servers could be located within and outside of the sponsoring institution. As a feature of dynamic HTML documents, the main server can create documents which references images on a geographically appropriate server or keeps the user away from a malfunctioning or overloaded image servers. This capability would be very difficult to manage with pre-existing HTML documents.

An acknowledged limitation of our current efforts is the lack of formal assessment of the utility of our educational programs. We have only anecdotal data regarding the educational success of these programs. In general the response to these programs has been universally positive. We anticipate, that this technology will equal prior efforts in computer assisted instruction and has the potential to surpass these efforts given the diversity of information that will be available through the WWW.

Potentially the most important aspect of this approach is that the same presentation platform provides medical students, residents, and practicing physicians a common link to educational resources. It is likely that a variety of medical practice information resources will be accessible via the WWW. Formal studies will be needed to validate the short and long term benefits of the WWW for medical education.

CONCLUSION

We have successfully demonstrated that the WWW is capable of presenting interactive instruction and allowing self-assessment via the Internet. Current bandwidth limitations limit the practical ability to incorporate high quality diagnostic images to non-Ethernet connections. With the development of high speed fiber optic networks this limitation should be only a temporary. inconvenience As the WWW provides the medical student with tools for self-learning and self-assessment, utilizing the WWW for medical education could form the basis for lifelong learning by physicians. Further study will be required to determine the most effective utilization of this emerging technology for both undergraduate and graduate medical education.

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