CoVis geosciences web server: an internet-based resource for the k-12 community

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COVIS GEOSCIENCES WEB SERVER:
AN INTERNET-BASED RESOURCE FOR THE K-12 COMMUNITY

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1. INTRODUCTION

It would not be an exaggeration to suggest that the World-Wide Web (WWW/Web) has captured the imagination of computer users like no other software in the history of computers. The Web includes standard formats for sharing text, graphics, sound, and video, all of which can be indexed and searched by all networked machines, along with standard protocols for communication between computers. As a result, computers are increasingly becoming communication tools, whereas before computers were mainly regarded as compute engines. Electronically linking an estimated 30 to 50 million users to a vast body of information, the Web is causing academic institutions, government organizations and large and small companies to rethink their communications strategies. The Web is not only the quintessential bulletin board, but also a way to share documents, applications, and information between groups around the world.

The Web's ubiquitous availability has unleashed a cultural revolution in the use of computers in K-12 and higher education, helping to bridge the gap between classroom exercises and the practices of the broader community. In a way, the Web is the great equalizer. For example, over 250 Web sites now offer a variety of weather and climate information to anyone on the Internet. A user with an entry-level personal computer and a built-in high-speed modem now can gain access to data and products previously available only to the professional meteorologist with deep pockets. Many of the online resources that have been created are valuable to students and teachers.

As impressive an achievement as this is, to date, however, most resources on the Web have not been developed with the specific goal of fostering learning communities. A vast majority of the Web servers can be categorized as *information servers* that simply provide access to a collection of documents/ products/ data/tools to a general audience. Another notable weakness of the so-called first generation Web servers is that they are by and large providers of static information, lacking the ability to let users interact with the information they browse. Nor is the information customized for the end user. This lack of interactivity, dynamic generation and customization critically hinders the effective use of the Web in a classroom setting.

It is clear that, to facilitate the development of *educational servers* that are set up to support explicitly learning communities, a distinctive architecture is needed (Fishman et al., 1995). While information servers assume a general user who is interested in their products at the other end, an educational server has to target its resources to a specific audience of students and teachers with the goal of fostering interactive learning. As articulated by Fishman et al, an educational Web server should include the following features:

1. Supplementary educational material
2. Activity structures
3. Support for assessment
4. Student commentary and authoring forum
5. Contact information
6. Mentoring databases
7. Powerful search engines

In this paper, we offer a partial description of an educational Web server now under development as part of CoVis, a national science education collaboratory of investigators from Northwestern University (NU), the University of Illinois at Urbana-Champaign (UIUC), the Exploratorium Museum in San Francisco, and students and teachers from CoVis schools around the nation (Pea 1993; Ramamurthy et al., 1995). The goal of CoVis is to support K-12 science education, using methods modeled after the collaborative practice of scientists. It is realized that the computing and communication revolution has ushered in a new era in networked multimedia interpersonal computing. The CoVis project is a blueprint to inform educators,

researchers, and policy makers on the effective and sustainable use of interpersonal, collaborative media in science education.

2. COVIS GEOSCIENCES WEB SERVER

The CoVis project has developed an Internet-based educational server, the CoVis Geosciences Web Server (http://www.covis.nwu.edu/) to enhance geosciences education in the K-12 community. The resource is now available to CoVis classrooms and soon will be made available to the Internet audience. This server is intended to both provide support for project-based learning activities in CoVis classrooms and to serve as the mechanism for carrying out many of the activities listed under the educational Web server. Although the basic functions of this server have been mapped out so that it meets the current needs of teachers, students, and scientist mentors who participate in CoVis, we believe the development of any educational server is an evolutionary process. As such, everything from the overall design to its layout and organization of materials will undergo periodic re-evaluation and is subject to change.

The CoVis Geosciences Web Server will have the following primary interlocking components:

A database describing activities in earth and atmospheric sciences
Access to online data sets that will be used by many of the activities described in the database
Scientific visualization and analysis tools that are specifically designed to help students ask questions about the online data sets
Curricular materials that explain concepts underlying the activities, data, and visualization and analysis tools
A database of mentors who are available to assist students working on CoVis activities
A student-teacher facility to promote interaction and collaboration within and outside CoVis, as well as a forum for commentaries and authoring.

The different components of the server will be tightly integrated with one another. In addition, a high degree of interactivity is of course required for this server to achieve success. Community participation is also a key element for it will determine the growth of the database of activities, the range of data sets, ideas and techniques for using tools, curricular materials, and even the membership in the mentor database. Although the bulk of the material on the server will initially focus on atmospheric science topics, we expect that it will grow to include a broad range of earth science topics with active community participation.

While we will not go into detail on all aspects of the CoVis Geosciences Web Server here, we will describe some of its key components:

Mentor Database

The mentor database serves a central function in helping to bridge the gap between the community of students and teachers, and the community of scientists and other knowledgeable people outside the classroom's traditional boundaries. Creating these bridges is one of the most important areas in which the Web can be useful to the educational community.

The mentor database provides a sort of learning and teaching "ride board." In the student union of most college campuses, there are ride boards with postings of rides requested and rides being offered. In a mentor database, there will be a broad range of student projects being conducted at any moment in time, and a broad range of expertise offered by scientists and others who volunteer to help advise students on their projects[1] and activities. We recognize that we are not the first to attempt to create an online database of resources for classroom use. The Electronic Emissary Project at the University of Texas at Austin is an example of such a database, designed to be accessed through a Telnet session.

What CoVis is building is an environment that simplifies and integrates access for mentors and other materials in a unified, web-based environment.

The CoVis mentor database will be populated by volunteers. Although the majority will be members of larger scientific organizations, such as national energy labs or university departments, there is the opportunity for anyone with a particular interest or expertise in earth and atmospheric science to join. In either case, it is paramount that being a mentor not pose an unreasonable burden on these volunteers, either in time spent mentoring or in administrative overhead.

On a ride board, volunteers avoid burdensome requests by stating the precise terms in which they are able to offer help. The CoVis mentor database will be structured to do the same thing. Using a forms-based interface on the Geosciences Web Server, potential mentors will be asked to specify not only their particular areas of expertise, but also the manner in which they would like to interact with students, including time spans and mode of communication. For example, a mentor might specify that she is an expert in ocean-floor seismic activity, is interested in working

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[1] The projects don't take place *inside* the database -- the database is used to support projects that take place in the classroom.

with a small group of students over an extended period of time, and can be contacted via e-mail, telephone, or fax. Another mentor might specify that he knows a lot about weather prediction, but is only available to answer short questions, and prefers to be reached via e-mail or videoconferencing.

Teachers will be responsible for making and maintaining appropriate matches between mentors and students. When a teacher thinks that students are working on a project that could benefit from outside mentoring, he or she will call up the database and complete a form that asks for a specification of the project topic, age level, number of students, start and end dates of the project, and other information believed to be pertinent to the request. The database will return a list of potential mentors, and the teacher may then search their full database records in order to make decisions about possible matches. If a mentor agrees to take on a particular student project, the database will be updated to indicate that they are currently unavailable as a mentor to others. This mechanism will help prevent mentors from feeling bombarded or overworked.

Because activities and analysis tools are integrated in a web-based environment, mentors have a unique opportunity to participate in student work. When the Web is coupled with a specialized collaboration and project inquiry tool like the CoVis Collaboratory Notebook (O'Neill and Gomez, 1994), mentors have access to the entire scope of student work, and can offer feedback and advice as they see fit.

Scientific Visualizers

The goal of CoVis is to support K-12 science education, using methods modeled after the collaborative practice of scientists. This is accomplished by providing access to some of the same data and tools used by research scientists. The initial efforts have been concentrated in the environmental and atmospheric sciences.

The CoVis Weather Visualizer and Greenhouse Effect Visualizer (http://www.atmos.uiuc.edu/geosciences/ visualization/visualization.html) are a supporting piece of the overall CoVis project. Their task is to provide real, observable data to support K-12 education, e.g., classroom activities such as general meteorology education and weather prediction, or support for special student projects outside the classroom. The Greenhouse Effect Visualizer was described by Gordin et al (1995). Here we describe the Weather Visualizer.

The design criteria for the Weather Visualizer were:

- Provide reasonably fast access to customizable requests

- Present a useful yet manageable set of options
- Use a framework that is easily obtainable and familiar to the user

The first criterion was chosen in order for the user to actively participate in the learning process. While it would be easy to provide a "canned" set of pregenerated products, the spontaneous and investigative nature of the learning experience would then be greatly diluted. As mentioned earlier, there are hundreds of Web servers that provide access to pregenerated products.

The second criterion was selected so as to present the most useful and commonly used set of choices and data, without overwhelming the user with a bewildering and arcane jumble of options. By keeping choices basic, maximum effort could be spent viewing and learning about the end product, rather than trying to decide what to look at.

The last criterion was chosen in order to maximize the accessibility and understandability of the tool, and to use resources that may have already been available or familiar to the CoVis community. To this end, the Web was chosen for several reasons. By using current WWW technology, existing viewing (browser) software that features a (hopefully) familiar user interface could be used. In addition, use could be made of the existing Internet infrastructure. Choosing a web-based application also meant the Weather Visualizer would immediately be usable on a wide range of hardware platforms with little or no additional implementation effort, and would allow updating the software without the need to continually distribute new versions.

The introductory document of the Weather Visualizer consists of a graphical panel of seven main categories of weather topics, as well as some introductory text. The seven categories are Surface Observations, Upper Air Observations, Upper Air Soundings, Cross Section Analyses, Radar Summary, Satellite Imagery, and Forecast Data.

Each main section contains one or more subsidiary HTML forms or documents that present choices and solicit input as to which meteorological parameters to display. When selection of the parameters is completed, the form is processed, resulting in the return of the image, plot, or textual data requested. Typical end products would be a map of US surface observations, radar echo summary, and frontal analysis superimposed on an infrared satellite image background; a table of forecast model output statistics; or a Stuve thermodynamic diagram.

An additional feature of the subsidiary pages and forms is generous use of Helper sections, which use the hypertext functionality of HTML to explain what the

various parameters and map items mean, and how the items or products are typically used in interpreting the data. A companion paper (Hall et al., 1996) and the next section describes the CoVis learning modules from which the Helper sections were developed.

The documents presented make use of common features of the Web's HyperText Markup Language (HTML) HTML 2.0 specification, a few of the proposed HTML 3.0 features or extensions, and version 1.1 of the Common Gateway Interface (CGI). Processing of the HTML forms is done using the Common Gateway Interface in the form of scripts written in the Perl language. These scripts interpret the user input from the form, translate that input into the appropriate actions, and format and return custom HTML documents that present the results of the request. Much of the underlying processing is performed by programs from the WXP package, which was developed at Purdue University and is distributed by the Unidata Project. The server itself runs an up-to-date version of the HTTP daemon developed at the National Center for Supercomputing Applications at the University of Illinois.

There are certain limitations to using the Web to present the data. These limitations to some extent altered the design and implementation of the Visualizer, and served to make clear some of the existing issues with serving potentially large amounts of data interactively to even a relatively small number of simultaneous users. Certain of the underlying operations entailed fairly intense computation, and as few as a couple dozen simultaneous requests for such data slowed the server down to unacceptable levels. To this end a few tasks, such as remapping satellite imagery for use as surface observation backgrounds, were performed as the data was received so as to be available for quicker use when requested. This substantially raised the number of requests that could be processed simultaneously, while still preserving the interactivity and customizable nature of the Visualizer.

A related issue is one of HTTP daemon design and computer operating system constraints. Current HTTP daemons seem to be optimized to handle relatively short-lived requests that are not CPU-intensive, such as reasonably small HTML documents and images. This is in stark contrast to typical Weather Visualizer requests, which can result in spawning long-lived computer processes that are potentially CPU-intensive. In this case, the actions of the HTTP daemon can more quickly cause a strain on operating system resources such as number of processes active, process page and swap space, and other limited operating system resources. Several methods to alleviate these problems have been contemplated, but as of September 1995 none had been implemented.

Hypermedia Educational Modules

Another important component of the CoVis Geosciences Web server is the section on web-based hypermedia educational modules (http://www.atmos.uiuc.edu/covis/modules/html/module.html).

An educational Web server, particularly one targeted toward students engaged in project-based science learning, must provide supplementary educational material that will aid students in conducting their projects. This type of material differs from the standard prearranged sequences of material found in most textbooks in one important respect: it is organized so that students can directly access the relevant helper material they need to solve the problem at hand. This is analogous to what adults do when they consult a how-to book in order to solve an infrequent problem. If you need to know how to fix a leaky faucet, an entire course in plumbing would be too time-consuming and provide far more information than you need to complete the task.

As such, the hypermedia educational modules are designed to play an integral role in this new approach to science learning. Through the use of color diagrams, video and audio, scanned images and text, these modules introduce and discuss essential concepts in atmospheric sciences as they arise in project-based science inquiry.

Early web-based modules focused on topics such as Pressure, Forces and Winds, and Interpretation of Weather Maps and Satellite Images. Recently completed modules deal with topics such as Atmospheric Optics, Cloud Classification, and Severe Storms. Colorful slides depicting these phenomena have been scanned in and are accompanied by descriptive audio, text, and schematic diagrams. The Guide to Atmospheric Optics, for example, introduces students to an array of optical effects from rainbows to sundogs and sunsets to mirages. Schematic diagrams and text explain mechanisms responsible for the development of phenomena like reflection and refraction. The Storm Spotters Guide contains an impressive collection of slides and descriptive text designed to educate students about severe weather.

Other hypermedia modules have been developed on: 1) Fronts, where students learn about the various types of fronts and their influence on the weather, 2) Midlatitude Cyclones, where students investigate the evolution of cyclones from cyclogenesis to dissipation, examine surface and upper-level features, while relating this to an "actual" case study on the infamous "Storm of the Century", 3) Weather along Coastlines, concentrates on land/sea breezes and their role in the development of

lake effect snow, and 4) Weather Forecasting. The forecasting module carefully steps through the processes meteorologists use when preparing a forecast, introduces general forecasting methods, interprets key weather maps and images and provides valuable tips to improve the student's forecasting ability. Since all our completed modules are Internet accessible, their usage is not limited to the CoVis project, and, in fact, are being accessed daily by users across the network. Their feedback and comments have also helped shape the design of current and future modules.

In addition to providing self-contained hypermedia educational modules on a variety of topics, we are integrating tightly the contents of these hypermedia modules with other sections of the CoVis Geosciences Web Server. One example is the integration of hypermedia module pages into the new Weather Visualizer. The visualizer allows users to generate customized weather images from real-time weather data. Also included are built-in helper sections to provide useful information about the weather features available in the visualizer (for example, fronts, radar, etc.) and are accessible by simply clicking on the word in question. For example, if the user clicked on "Frontal Analysis," module pages comprised of descriptive text and images would be accessed that not only introduce the various types of fronts, but also clarify how to identify fronts on weather maps, and their importance in interpreting the weather. The purpose of the helper sections is to equip the user with the knowledge and skills required for valuable and correct interpretation of images generated by the weather visualizer.

3. DISTRIBUTED WEB SERVERS

So far, we have described the CoVis Geosciences Web Server as a single entity. However, one of the truly exceptional attributes of the Web is that it provides a transparent and seamless integration of online resources anywhere on the Internet. The contents of a virtual Web server can be distributed across any number of computers physically located in different locations on the network. And in a national collaboratory such as CoVis where project partners come from different disciplines bringing diverse expertise, and are located in different geographical locations, it is possible to develop and maintain the individual components of the Geosciences Server in a distributed manner.

Another important advantage of this paradigm is that other members of the Internet community can both participate and contribute material to the virtual Web server by simply linking any material they develop to the Geosciences Web Server. For instance, if an expert in Hydrology at a non-CoVis site develops web-based educational material on the Hydrologic cycle and River Flows, that material, with the permission of the

original author, can immediately be made available on the CoVis Geosciences Web Server. This model provides an elegant way to expand both the audience as well as the scope of the material available on an educational server.

In keeping with this spirit, the project partners at UIUC and NU have developed two Geosciences Web servers, targeted toward their respective audiences. The NU CoVis Geosciences Web Server (http://www.covis.nwu.edu/) will be the principal server for CoVis and K-12 communities. The UIUC Geosciences Web Server (http://www.atmos.uiuc.edu/geosciences/ geosciences.html) will target its content toward a broader Internet audience. It should be added that the UIUC group operates The Daily Planet™ Web-server (Wilhelmson et al., 1995) and The Weather Machine Gopher server (Ramamurthy and Kemp, 1993), which together receive over 200,000 requests daily. Because of this important difference in the audience for the two servers, the structure and organization of material on the two servers are also somewhat different.

While the NU CoVis Geosciences Web Server will be the clearing house for the CoVis community and as such it has to maintain a high-level of stability so as to be useful in a classroom setting, the UIUC Geosciences Web Server will continue to explore and experiment with cutting-edge digital library and information technologies. As new tools for exploration of atmospheric sciences data are developed, they will appear on the UIUC server at first. After extensive stability tests are conducted, they may be made available on the NU Geosciences server, if they are useful within the CoVis context.

4. CONCLUDING REMARKS

Despite the ubiquitous availability of Web servers, the challenge of providing useful educational resources via the Internet is becoming ever increasing. A great number of Web servers provide access to static products (images and text), providing very little interactivity for a student. Another notable void is in the availability of sophisticated web-based analysis tools and prototype simulation models. For example, there is an acute need to develop prototype interactive models like SimEarth™ that are Web based. As the sophistication and complexity of these tools and models increase, the need to interface information technology tools like Netscape™ or NCSA Mosaic to compute servers becomes that much more critical. This has important implications for the future of NII and HPCC.

This raises another important aspect of the Web, the issue of scalability. As more and more clients access these servers, the demands on a given server are not

likely to be met merely through increases in processor speeds or additional machines. In the current Web architecture, the bulk of the compute power on a client is left untapped when accessing a server. If the number of clients keeps increasing disproportionate to increases in server capacity (which is axiomatic), then the clients at some point will have to share in the workload for the load to be sustained.

The recent introduction of the Java environment by Sun Microsystems shows considerable promise in alleviating such scalability-related bottlenecks. In a Java environment, programs, which are written in a C++-like Java language, can be executed on any client that is running a Java-based Web browser. It is important to add that Java is platform independent, and Java-based Web browsers are expected to be available on a number of platforms (Unix, Windows 95, Windows NT and Macintoshes) in the near future. A companion paper by Wojtowicz et al. (1995) outlines how we plan to make effective use of the Java environment in the CoVis Weather Visualizer.

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