Impact of World Wide Web, Java, and Virtual Environments on Education in Computational Science and Engineering

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Abstract

The World Wide Web (WWW) on the Internet has been recognized as an effective environment to create new distributed applications that have the potential to bring instruction beyond the bounds of the classroom. The availability of browsers (e.g. Mosaic, Netscape, Hot Java) has enormously simplified the access to the WWW, and there have been numerous initiatives to take advantage of this new technology for teaching. This work will illustrate recent developments of tools for engineering education and technology transfer which take advantage of WWW browsers, Java applets, and virtual reality. We have developed modules based on WWW browsers incorporating educational and research software, including advanced visualization, which find use for multimedia classroom presentations accessible by Internet users, and which can also improve interaction among academic groups and industry. Therefore, the material is suitable for asynchronous distance learning and technology transfer. Examples of interactive WWW applications include device simulation, semiconductor band structure calculation, numerical techniques, and electromagnetics.

Introduction

The World Wide Web (WWW) can provide an extremely useful platform for interactive learning and distance education [1,2,3]. Students in computational science can be provided with complete software modules that can enhance the learning process and provoke creativity and enthusiasm. Research programs can be easily integrated in the curriculum and also made available, with very similar procedures, to industry. In addition, software modules can be built to simulate the interface with virtual instruments or even control real instruments, such as a remote camera or microscope.

The software structure of educational modules can consist of a wide variety of ingredients such as conventional research programs in FORTRAN or C/C++, client-server Perl programs, data-sets from supercomputing simulations, and interactive Java applets. The visualization is an important part of the software modules. It can be achieved through popular commercial packages such as Matlab and AVS [4], or the Java graphic libraries. The Virtual Reality Modeling Language (VRML) is also now available on WWW browsers and modules can be organized as virtual environments, providing a new powerful way to view complex data sets where the user is completely embedded in the scene.

The rapid expansion of computer and network technologies can offer cost effective environments to bring education outside the traditional bounds of the classroom but it is crucial for educators to keep up with the technological evolution and translate it into constructive educational tools. These endeavors will not only enhance the learning experiences but may also make them more entertaining.

In the following sections, we illustrate a range of WWW based interactive applications developed at the University of Illinois to improve the engineering curriculum, integrate education and research, and at the same time strengthen mechanisms for industrial interaction and training.

Asynchronous Learning Tools

Education on demand (Asynchronous learning) is ideally served by interactive computer environments that can be built on the WWW. The recently introduced capabilities of Java offer new and improved means Java applets to create tutorials of engineering concepts. An important feature of Java is the complete hardware transparency, which makes the heterogeneous collection of computers and networks, on which WWW is based, a virtually seamless environment. Figure 2 shows examples of Java applets that are being developed to teach advanced electromagnetic concepts to engineering students, in this case transmission lines and antenna theory. The use can interactively modify. any parameter associated to a given system and immediately view the changes in behavior. For instance, in a transmission line the user can modify the load impedance, add stubs on the line with selectable position and admittance, and view the effects on line matching through a range of plots which can be selected from a menu (Fig. 2a). A built in Smith chart is automatically updated according to the user's input to reinforce the conceptual understanding. In this way students can experiment with an unlimited amount of problems in a very efficient way. Figure 2b shows an other example, where the radiation pattern and the current distribution on a dipole antenna are automatically update when the antenna length is varied.

Virtual environment technologies have matured to a point where they can facilitate interactive research and teaching applications. The virtual environments of NCSA at the University of Illinois include the CAVE (Cave Automatic Virtual Environment), ImmersaDesk, and Infinity Wall. Virtual environment software applications have been developed at the University of Illinois to research diverse topics, including the study of living organisms through computer simulation, four-dimensional hyperspace, climate data, modeling of human heart, molecular dynamics, virtual urban landscapes, and more. While the traditional computational tools offer the user an opportunity to run simulations, the connection to actual physical environments is not immediately available through such tools. Virtual environments provide the user a higher degree of realism through creation of physical environments as well. For example, the user could be immersed inside the Brillouin zone of silicon and study the detailed features of the computed band structure and interactively browse through a virtual reality representation of the data set..

Actual equipment can be linked to WWW environments to achieve remote instrumentation control capabilities, thus opening a wide range of possibilities for education and research. The ability to control a remotely located instrument allows users to perform experiments which would be difficult, if not impossible, otherwise. The instruments can vary from video cameras to sophisticated research equipment such as telescopes or Magnetic Resonance Imaging (MRI). The recent NCSA "chickscope project" (*http://vizlab.beckman.uiuc.edu/chickscope)* has been successfully used as a curriculum innovation in primary to high school classes. The project allowed students to control a Magnetic Resonance Imaging machine, located at the Beckman Institute of the University of Illinois, through a standard WWW browser from their classrooms to study chicken embryology. Efforts are under way in our group to develop a Java-based front-end to remotely control a Scanning Tunneling Microscope for research and teaching activities.

Many new WWW educational modules are being developed to further enhance the teaching of engineering courses, by incorporating simulation software and visualization. Some examples are available for demonstration at the URL: *http://www-ncce.ceg.uiuc.edu*.

Technology Transfer and Industrial Interaction

The same WWW-based approaches can be applied to education in a broader sense, where training and technology transfer of software can be effectively delivered from academic institutions to industry. A joint effort between our group at the University of Illinois and collaborators at Purdue University is under way to realize environments that can also be used by company members to evaluate new research software packages in order to facilitate the technology transfer process. WWW interactive interfaces simplify the porting issues and can be very effective for rapid training of users. This effort is sponsored in part by the Semiconductor Research Corporation (SRC).

A dedicated WWW server has been developed at the University of Illinois to experiment with technology transfer environments. The server software is realized with the Perl language [5] and it handles the user requests, runs the application software, supports data manipulation and visualization, checks and manages system resources, maintains user accounts, and sends e-mails to the users about the location of URLs containing the results at the end of simulation. A basic block diagram of this customized Perl server is shown in Figure 1. Since large research codes are accessible in this environment, this arrangement is necessary, because results cannot be obtained in real time, so programs are executed in the background, to avoid idle times when accessing the system through a WWW browser. Although this system was originally designed for specific interaction with industrial partners, one can readily use an identical approach to introduce large research codes in the university curriculum. Because of the considerable resources involved with the execution of these programs, a security system has been put in place, so that access to the software is limited to users who are assigned a password.

The research software on the SRC server include semiconductor bandstructure solvers, Monte Carlo device simulators, Schrödinger solvers for quantum structures, and others (educational modules are at URL: *http://www-ncce.ceg.uiuc. edu* and the SRC related modules are at URL *http://ncce-src.ceg.uiuc.edu*).

The colleagues at Purdue University have implemented a distributed server called "Computational Electronics Hub", where users can access software resident at different sites through WWW browsers. For demonstration, some of our modules are also accessible through this interface at URL *http://jacoby.ecn.purdue. edu:8000.*

Acknowledgments

This work was supported by a Research-Curriculum Development grant from the National Science Foundation (NSF EEC 93-15536), the National Center for Computational Electronics (NSF ECS 91-22768). and the Semiconductor Research Corporation (contract SRC 95-SJ-406). Numerous discussions and interactions with N. Kapadia, Dr.M. Lundstrom and Dr. J. Fortes of Purdue University are gratefully acknowledged.

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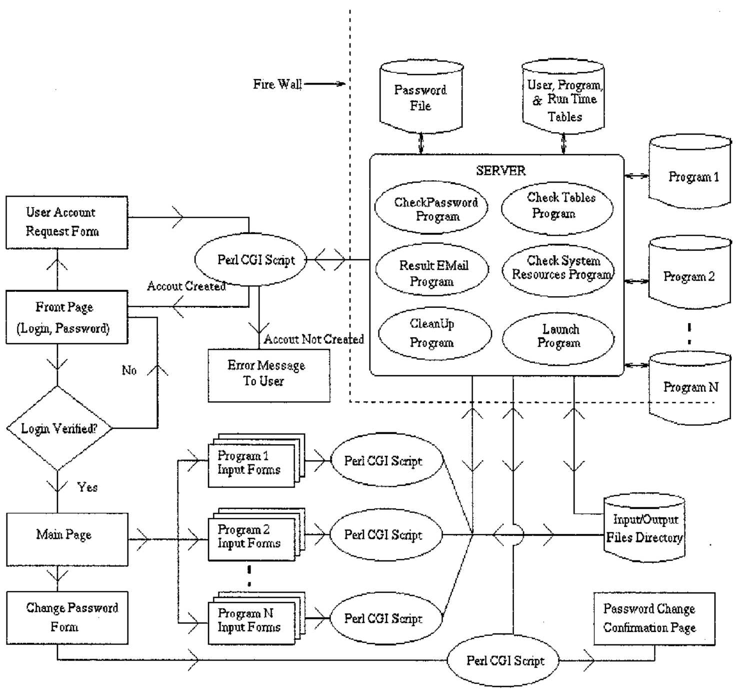
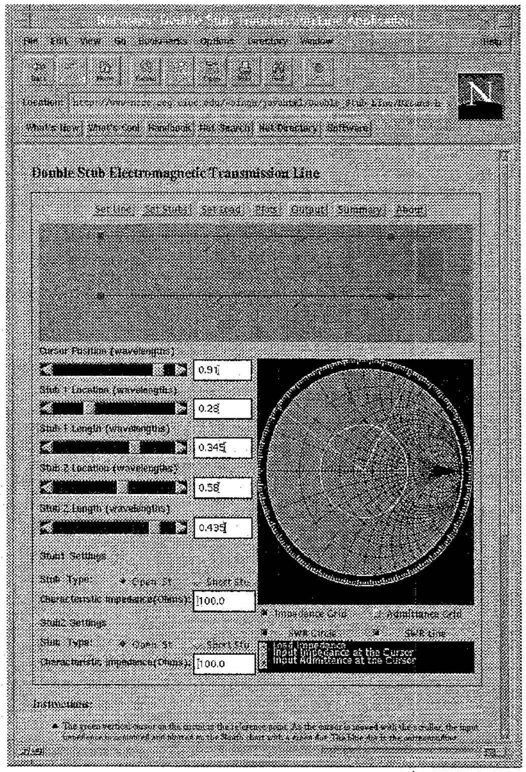


Figure 1: *Block diagram of the customized server for the Semiconductor Research Corporation designed for technology transfer.*



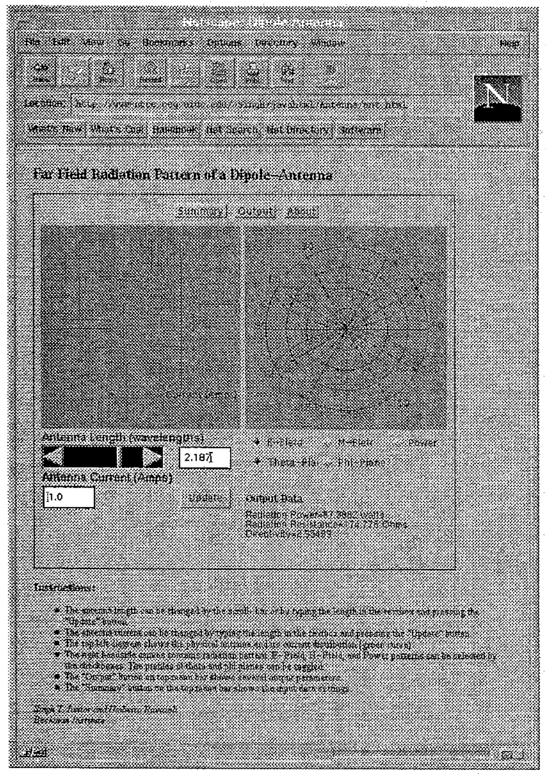


Figure 2: *Interactive Java based tutorials for teaching of: (a) electromagnetic transmission lines and (b) dipole antenna theory.*