

Internet-based Simulation and Virtual City for Engineering Education

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Abstract

This paper presents the results of integrating a virtual city into the ongoing program “Sooner City” at the University of Oklahoma. One of the objectives of the “Sooner City” program is to develop multiple multimedia modules over a series of basic courses to help civil engineering students better understand engineering topics and how they are integrated together in a real engineering task. In order to aid students in visually understanding the 'Big Picture', a 3D virtual city is built over the web by integrating the results of all the simulations. The virtual city is viewable on the Internet so that they and others can see their design ideas in a graphically correct 3D view. The virtual city concept also allows the engineering students to learn design with a true 3D perspective without the high cost of actually building the design (which is actually not possible with many engineering topics such as buildings). Both the steel structure module and the surveying module are discussed in this paper. Interactivity in these modules is emphasized using simulation, animation, sound, and CGI. The students use these two modules by reading the information sections, which include text and relevant graphics, and exploring the simulations. The virtual city integrates the simulations and the 3D virtual world into one environment. The simulations work as interfaces of the virtual city and the results of the simulations are visually showed in the 3D virtual city, which means that the virtual city is not fixed and can be updated and changed. To develop the virtual city and the multimedia modules, Internet technologies such as Shockwave, CGI-Perl, JavaScript, and VRML were employed.

Introduction

In addition to its rapid growth, the functionality of the Internet is expanding tremendously. Currently, it is normal to conduct e-commerce such as online shopping over the Internet. However, the Internet is not just for e-commerce, it can also be utilized for advanced educational methods that involve collaboration, visualization and distance learning. On November 16, 1999, Cisco CEO John Chambers delivered a keynote

address to a Comdex audience in Las Vegas at which he talked about taking advantage of e-learning as the “second wave” of the Internet [1]. Through e-learning, employees will have life-long learning opportunities and they will be able to learn whatever they want when they need it. E-learning or internet-based education provides a new and excellent way to present knowledge to the users since there is no schedule limitation and no space limitation. By taking advantage of the Internet, concepts and theories can be explained with the help of text, animation, graphics and simulations. Internet-based education or training can be accessed by every user in every corner of the world if an Internet connection is available, which is particularly beneficial to remote users.

In order to make use of the unique features of the Internet for education, a program called Sooner City was initiated at the University of Oklahoma in 1998 [2]. One of the goals of the program is to allow students to build certain segments of a virtual city upon completion of appropriate undergraduate courses in civil engineering. The end result is a complete virtual city that includes designs from all of their coursework. The completed city will be viewable on the Internet at the end of four years. Students learn engineering concepts while building virtual cities. Simulations and related engineering concepts are delivered on the Internet. First, the students learn engineering concepts through text description and related graphics. Then they explore simulations and build virtual cities through the use of simulations. Each simulation has been programmed to allow the user to build a segment of the virtual city at the completion of that simulation.

In this paper, four main topics will be covered. They are a literature review, Internet technologies used in the Sooner City program, internet-based multimedia modules, and implementation of the virtual city. Finally, this paper concludes with a discussion of the potential application of the virtual city and future work of the program.

Previous Work

Universities are one of the leading forces in developing the Internet infrastructure technologies, and one of the first to adopt these technologies for educational purposes. Soon after the creation of the Web, universities started to employ the Web as a new educational tool to educate students and provide training service to the public. There are numerous ways to use the Web for education such as information delivery, virtual laboratory, web-based simulation and online course.

Information Delivery

The Web is an efficient way to deliver a large amount of information, such as online textbooks, online manuals, and other course materials. These web-based books are similar to traditional books, but in addition to text, they usually also offer audio clips, video clips, simulations and reference links. Another advantage is that keyword searches are provided in these electronic books. A hyper-textbook written by Kenneth R. Koehler offers an overview of physics for students of biology and chemistry [3]. The first edition of this hyper-textbook has been translated into Japanese. At the University of Oklahoma, manuals about the use of Oracle databases are placed on the Web so that the students taking the database course can access them.

Virtual Laboratory

To resolve the problem of accessing an expensive or dangerous experimental apparatus such as laser devices and robots, the virtual laboratory can be set up over the Web. Jack and Karlesky at Grand Valley State University developed a virtual manufacturing laboratory, which allows students to access robots, CNC (Computer Numerical Control) machines, DAQ (Data Acquisition) cards and other equipment utilizing the Web [4]. Students are able to transfer data to the apparatus, control the apparatus, and observe the progress of the experiments using a live video link.

Web-based Simulation

Although it is generally agreed that the use of simulations in engineering education is beneficial to students, simulations are not widely used due to relatively small target user groups, the cost of development, and distribution problems. With the introduction of the Internet technologies, these problems can be minimized. There are numerous web-based simulations in the literature. An example is "Mallard" which was developed by Mike Swafford and Donna Brown at the University of Illinois at Urbana-Champaign [5]. Another example is to use Virtual Reality Modeling Language (VRML) to teach design over the Internet [6]. At Heriot-Watt University, UK, an ongoing project called Multiverse provides a standard interface for various internet-based simulations and reduces the cost of developing simulations [7].

Online Course

Since the Web provides unprecedented flexibility and multimedia capability to deliver course materials, more and more courses are being delivered through the Web. At the University of Tennessee, a graduate-level Finite Element course was offered as a video-streamed lecture over the Web [8]. The Fundamental in Engineering Review project at the University of Oklahoma is a paradigm that uses the Web as a delivery way to offer online review [9]. David R. Wallace and Philip Mutton from MIT investigated the effectiveness of web-based lecture and they found that students using web-based lectures performed better than students taking classroom-based lecture [10].

However, it is found that most current internet-based educational applications do not present 3D objects even though 3D visualization is essential in teaching most engineering ideas. If 3D objects can be presented on the Internet and be interactively changed, it will be beneficial to the students. In this paper, the idea of presenting 3D objects on the Internet and interactively changing them on the Internet is presented.

Internet-based Technologies

There are many Internet technologies available in the market that can be used to develop Internet-based applications. The most popular are Hypertext Markup Language (HTML), Extensible Markup Language (XML), JavaScript, Java, Shockwave, Virtual Reality Modeling Language (VRML), Streaming Video Technology, Active Server Pages (ASP), Practical Extraction and Report Language (Perl), and databases. In this project, HTML, JavaScript, VRML, Shockwave and Perl were chosen to develop the internet-based multimedia modules and the virtual world. These technologies were chosen because they

are well defined and most web sites use them to develop Internet-based applications. In the following paragraphs, these chosen Internet technologies are discussed in detail.

HTML

HTML is the basic vehicle that delivers text information over the Internet. Other Internet technologies are used only to add interactivity, animation and 3D worlds to the basic HTML pages. HTML is a tag-based document formatting language, which can be read by any web browser. One advantage of HTML pages is that it is particularly easy to update the contents. All of the information sections of the internet-based modules were created using HTML.

JavaScript

Although HTML is good in delivering static text information over the Internet, it cannot be used to distribute dynamic information. JavaScript was developed to help add interactivity to HTML pages [11]. The interactivity includes dynamically creating HTML pages, controlling the browser, transferring information from one HTML page to another, and interacting with the user. The content of the pages can be based on the input of the user, which makes HTML pages distinct from traditional books. For example, in order to manage the different users in the surveying module (discussed later), JavaScript was used to transfer the user name and user ID from page to page.

Shockwave

JavaScript is excellent in adding text-oriented interactivity to static HTML pages. It is difficult to use JavaScript to perform complicated, graphic-oriented simulations. To construct complicated simulations over the Internet, other technologies can be employed such as Shockwave. To develop Shockwave simulations, the user needs to use a multimedia program called Director and to export the Director movie as a Shockwave movie. Then the Shockwave movie can be embedded into the HTML pages and the user can play the Shockwave movie in the browser with the help of the Shockwave plug-in, which is now bundled with Internet Explorer and Netscape. Shockwave utilizes compression techniques to reduce the file size and downloading time. Shockwave is a basic Internet technology used to develop internet-based multimedia modules in the Sooner City program.

VRML

Shockwave is good at performing 2D simulation, but it is not strong in 3D simulation. In order to present a 3D world over the Internet, an efficient 3D modeling language is needed. VRML is a good choice because it is a platform-independent standard for viewing 3D worlds over the Internet. VRML supports interactivity, animation, modification, and hyperlink, which makes it suitable to navigate 3D worlds. Furthermore, VRML uses easy-to-understand text to describe the 3D model, allowing the VRML file to be edited in any text editor. One good example of VRML is the OU Campus Tour created by Tee Theng Tan and Mike Bradford, from the Engineering Media Lab, at the University of Oklahoma [12]. Both the steel structure and surveying module discussed in this paper use VRML to present 3D objects on the Internet.

CGI-Perl

Generally speaking, in a complicated internet-based application, only client-based interactivity is not sufficient for a truly dynamic learning environment and server-side programming (Common Gateway Interface or CGI scripting) is needed to allow the user to exchange the data with server. The Perl programming language is one of many languages that can perform CGI functions. Perl can obtain data from HTML form pages and Shockwave, process the data, and send the results back to the user. The surveying module extensively utilizes the CGI-Perl to allow students to upload data to the server, process the data using the Shockwave, and construct the 3D world.

Internet-based Multimedia Modules

Simulations are created based on specific engineering topics. Each simulation and its relevant engineering topic are composed of one module, which is independent to each other. Currently, three modules have been finished; a traffic engineering module, a steel structure module and a surveying module. The traffic engineering model was discussed in detail at the 1999 ASEE conference [2].

Steel Structure Module

The steel structure module was designed for the Graphics and Design course and was first used in the spring of 1999. Students who took this course used this module to help them understand the basic concepts of steel structures as they learned the CAD. Since the students were assumed to have little knowledge about the steel structures, only the basic concepts were covered in this module. The module had two sections; general background information and an interactive simulation.

The information section includes seven subtopics - introduction, code, beam, column, joist, decking, and connections. The basic layout of the information page is shown in Fig. 1. Text, graphics, real world photos, and 3D model are used to present the information to the students. In these different media, VRML was used to present 3D connection models (Fig. 2). With VRML, students are able to navigate in the virtual world, rotate, zoom in, zoom out the connections, and see details of the connections, all of which are helpful in deepening the understanding of the connection structures.

**Steel
Structure**

Topics
[Introduction](#)
[Code](#)
[Beam](#)
[Column](#)
[Joist](#)
[Decking](#)
[Connections](#)

Multimedia
[Simulation](#)

Links
[Sooner City](#)
[EML](#)

Introduction



Fig. 1 Steel structure (University of Oklahoma, Norman, OK)



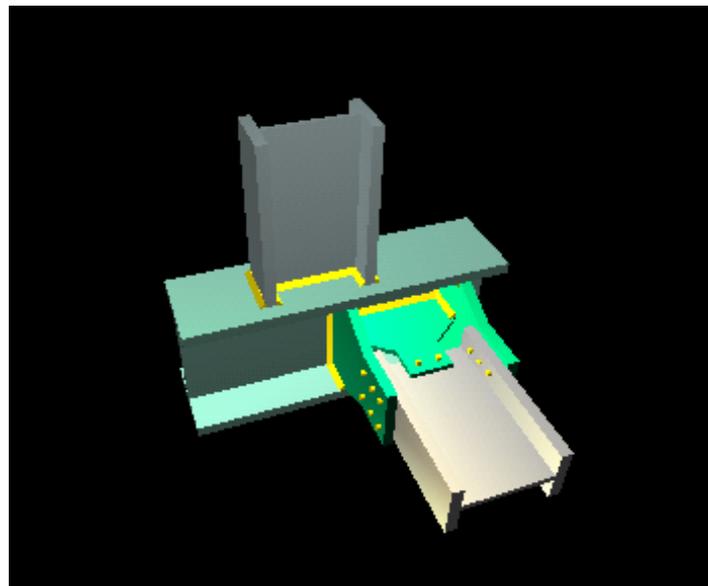
Fig. 2 Steel structure (University of Oklahoma, Norman, OK)

Steel structures are commonly used for both low- and high-rise building construction since the steel structures have desirable properties, such as high strength, uniformity, elasticity, and ductility. The high strength of steel per unit of weight means the dead loads of the structure will be small. This is important for tall buildings, and for structures having poor foundation conditions. The properties of steel not changing appreciably with time indicate the uniformity of the steel. Steel is elastic up to fairly high stress, which means the design assumptions are close to the steel behaviors. Furthermore, steel can withstand extensive deformation without failure under high tensile stresses. This fact is of great importance for the steel structures subjected to normal loads and sudden shocks.

Another reason for the common use of steel structures is that they are economical and can be assembled quickly. As main members of the steel structures, such as beams, columns, and tension members, are fairly simple and precisely laid down by specifications, the steel structures are reasonably inexpensive. Because of the use of standardized elements in the steel structures, they can be assembled quickly.

The essential task of the structural designer is to determine the member shape, size, and arrangement of the steel structure so that it has sufficient strength,

Fig. 1 Layout of Information Page in Steel Structure Module



A 3D VRML illustration showing a detailed view of a steel connection. It features a vertical column (grey) and a horizontal beam (light blue) meeting at a joint. The connection is highlighted with yellow and green, showing the internal components and bolts. The background is black.

Fig. 2 Connection illustration using VRML

The internet-based simulation (Fig. 3) for this module simulates the steps to design a single bay steel structure. The purpose of this module was to provide an easy-access tool for students to experience the design process for steel structures using the information they had learned. The main features of this simulation are as follows:

1. Building types, building size, live and dead loads, codes, safety factors and yield stress can be selected or typed in.
2. Clicking on one of the two icons representing joists creates joists. The number of joists can be changed.
3. Clicking on the force icon generates a point force. The point force is moved by a 'click-and-drag' motion and will snap to the beams or joists. The magnitude of the force can be modified by double clicking the force.
4. The type of beam or column can be selected through double clicking the specific beam or column.
5. Clicking on the "Calculate" button performs the stress calculation. If the maximum stress of any member is larger than the allowable stress, the member is shaded red to depict failure.
6. If the "Results" icon is clicked, the stress results of members can be viewed.
7. The user can deposit a steel structure in the Virtual City (discussed later) if the "Submit" icon is clicked.

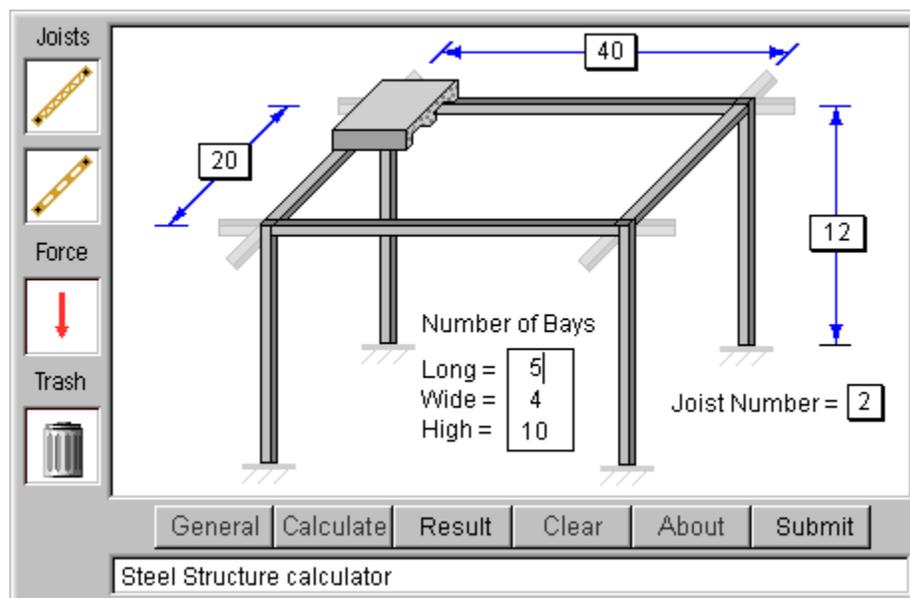


Fig. 3 Steel structure simulation

Surveying Module

The Surveying Module was designed for the Engineering Surveying course and was used in the fall of 1999. The motivation for this module was to provide an Internet-based data processing tool for the engineering surveying course. Previously, to process surveying data, students used a specific software program to generate 2D contour plots. However,

by integrating a number of Internet-based technologies, a surveying simulation was developed to generate 2D contour and visually present 3D surfaces on the Internet. The idea of generating 2D contour and demonstrating real 3D surface at the same time was realized by integrating Shockwave and VRML technologies. CGI-Perl is also used to read in data from Shockwave simulation, generate a VRML file and send the VRML file back to the user's browser.

The simulation uses irregular field data, which is gathered by conducting surveys over an area. Since surveying points are irregularly distributed over the field, the resultant data is not uniform along the x and y direction. However, to plot the contour of the data, regular data has to be used, which means that the steps in the data along x and y direction are uniform. An algorithm called *Shepard's Method* is employed to calculate the regular data points from the irregular data points. Then, a contour-plotting algorithm draws the contour and CGI-Perl generates the VRML file on the server, which is shown on the user's browser (Fig. 4).

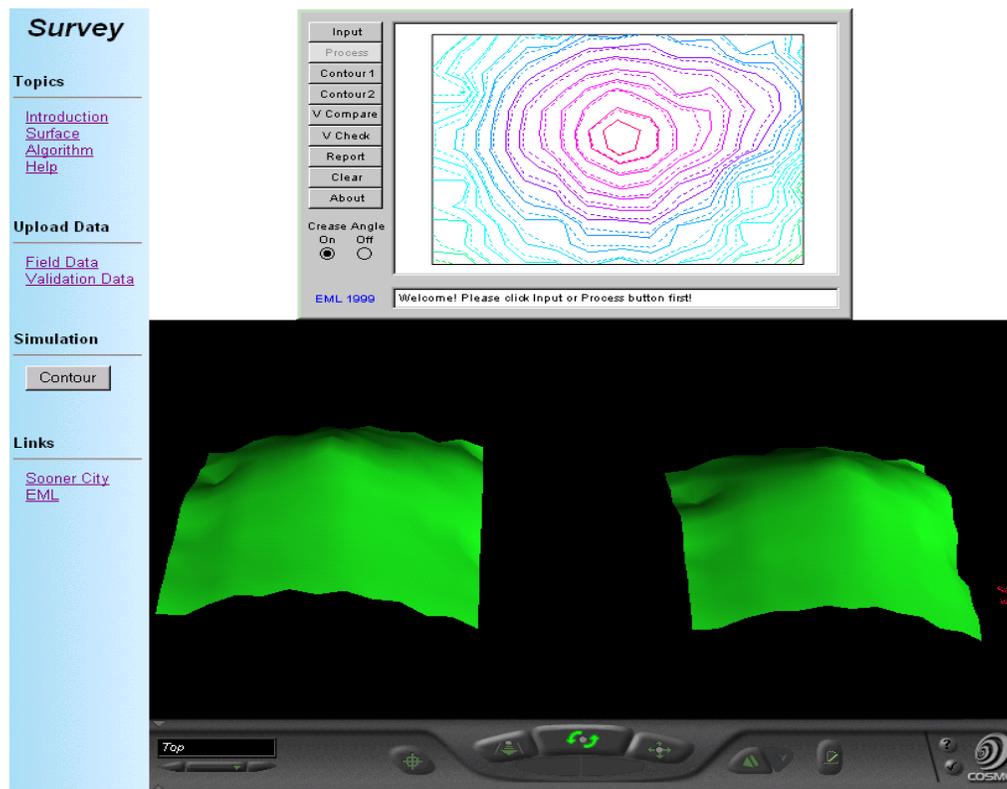


Fig. 4 Surveying Module

The design of the surveying module is similar to the steel structure, which also includes two sections, information and simulation. However, in order to use this surveying simulation, students are required to provide necessary information to set up an account on the server. After the accounts are established, the students are able to upload the field

survey data to the server, and the simulation can process the data, plot the contour, and generate the 3D surface world based on computational results. To compare the difference using the same algorithm with different parameter values, two generated surfaces are presented in the VRML world and two contours are plotted on the simulation. This is to show that the same algorithm with different parameter values may result in different contour lines and surfaces.

Virtual City

The Virtual City is a 3D world (Fig. 5) containing various structures such as buildings, bridges, and highways. These structures are created and deposited in the Virtual City by the corresponding simulations of different modules. In this way, the Virtual City ties the multimedia learning modules together in an innovative format. Linking the learning modules together in this manner permits the user to view the objects relative to one another. The user can then see how each object fits into the “big picture” (Fig. 6). This implementation was accomplished by integrating the shockwave simulation module and VRML into the same web page.

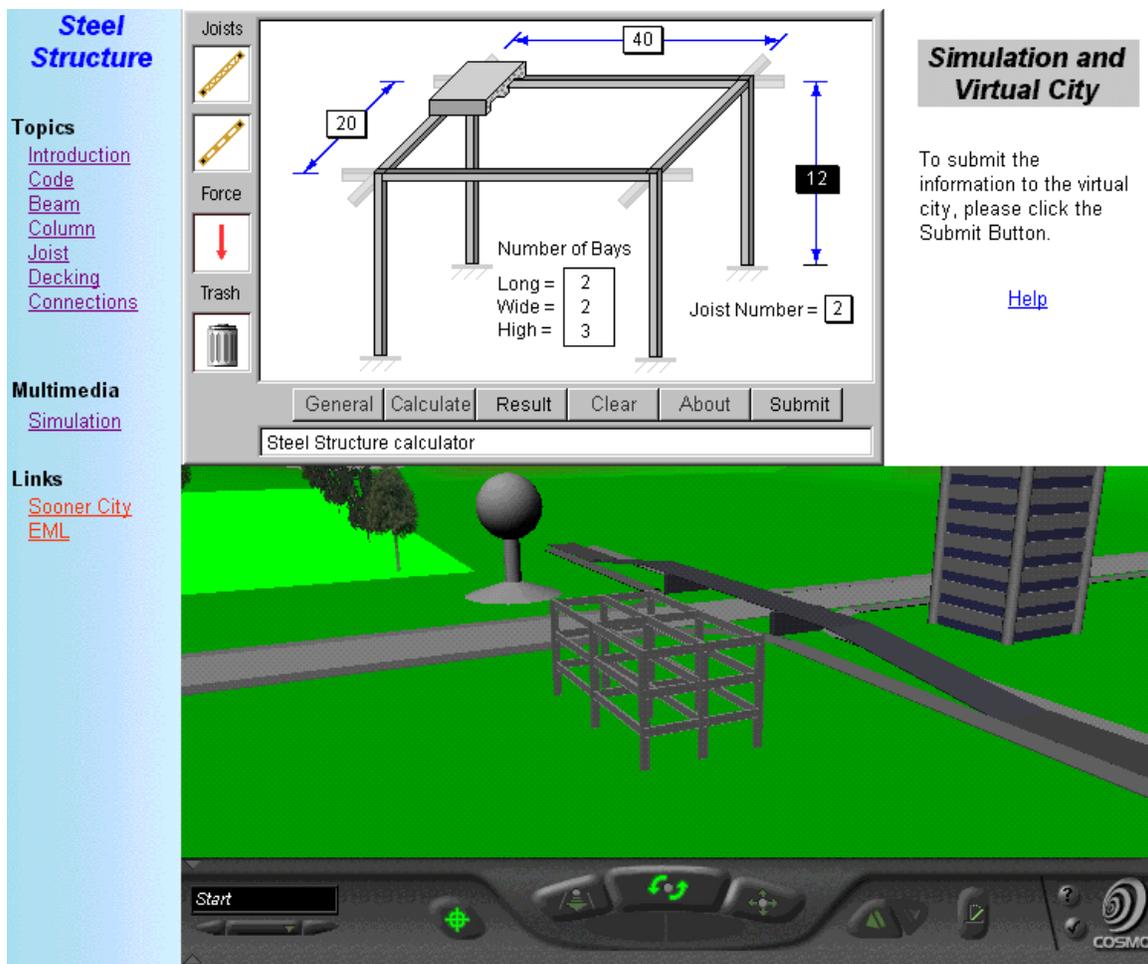


Fig. 5 Illustration of the virtual city integrated with the simulation

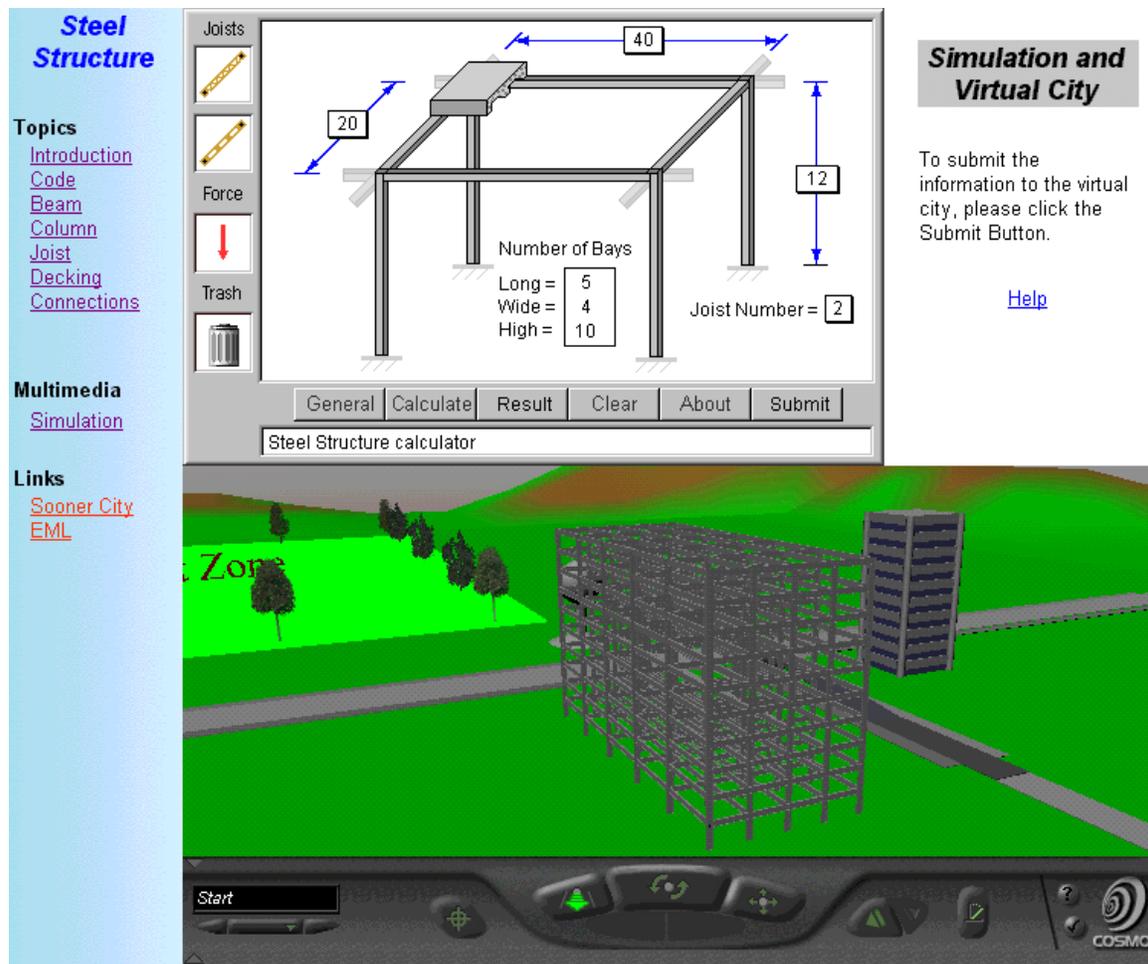


Fig. 6 The Virtual City with Modified Steel Structure

Virtual City Implementation

The basic idea of implementing a virtual city over the Internet is divided into three steps. First, the user explores the simulation and provides the basic data of the structure, which is going to be created by that simulation. Then, the simulation sends the data to the server, starts the Perl script to interpret the data, and generates a new structure in VRML format. Thirdly, the Virtual City is updated by downloading the newly created structure. At this point, the user can see a structure with different dimensions in the Virtual City (Fig. 6). It is important to note that all of the data transmission and subsequent VRML model in the lower section of the screen is all done automatically. The user does not have to upload files, transfer data or learn a complicated 3D modeling language. Furthermore, this can be done on any computer that has access to the Internet.

There are two different ways to access the Virtual City and simulations. The first way allows the users to access the Virtual City when they are using specific modules. The users learn relative engineering topics by reading information section. When they decide to explore the simulation, the simulation and the Virtual City are presented at the same

time. In other words, the Virtual City is integrated in each multimedia module (Fig. 5 and Fig. 6). The users can deposit the structure easily and see the end result immediately. The second way allows the users to navigate all the simulations in one HTML page (Fig. 7). The left side is the menu list, which includes all of the simulations. When a simulation is selected, it is displayed in the right topside. Once a simulation has been selected, it retrieves the users saved information if available. If the user has no previously saved data the simulation will use the default data set of information.

A key aspect of this Virtual City is that each student builds and maintains his or her own world. There is not just one Virtual City, but also one for each student. Only the owner of the world can change and add to the city, but others can view them on the web. In the manner, students can collaborate with other students and with the instructor. At the end of the four years, the student can also use the Virtual City as a visual portfolio of their design work during their engineering education career.

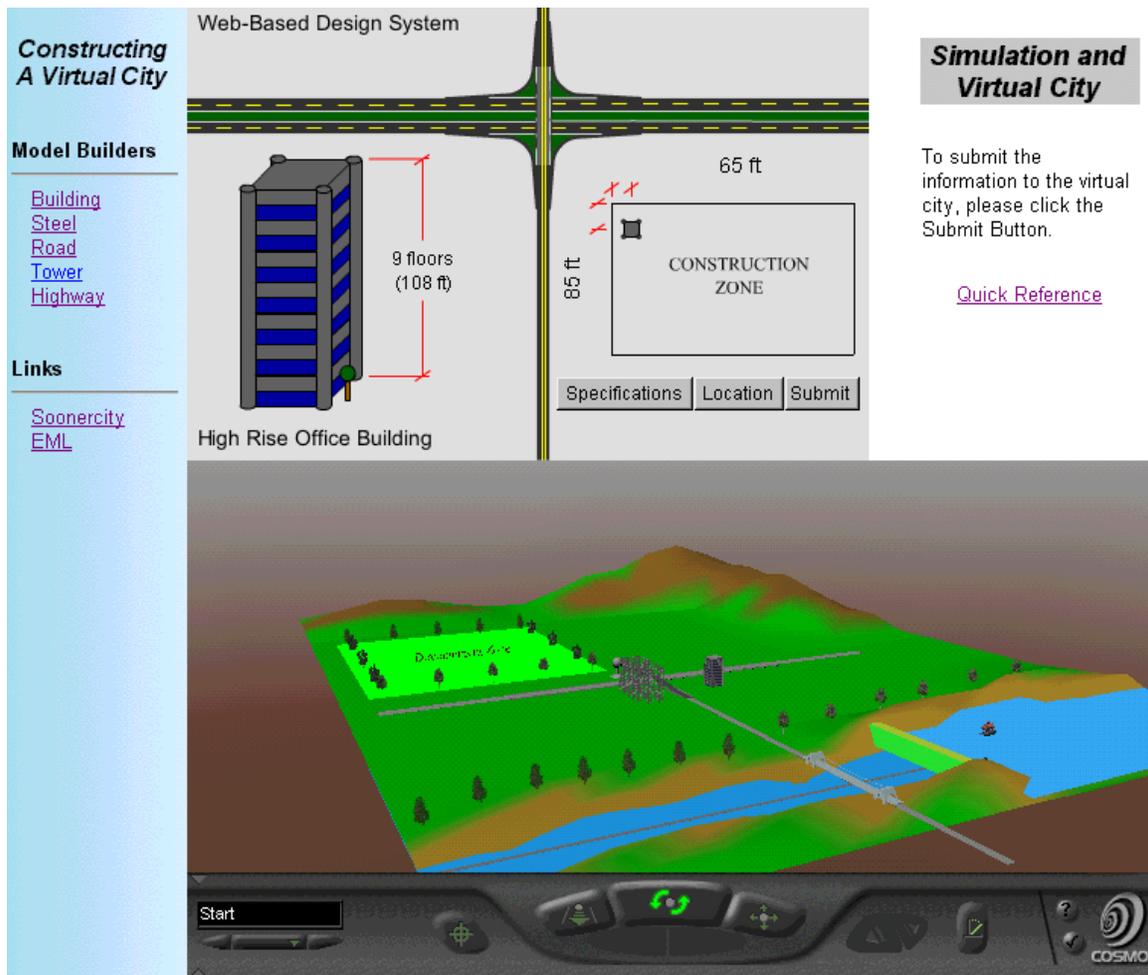


Fig. 7 An overview of the Virtual City

Since each user maintains his/her own city, the user is required to create an account on the servers by providing necessary information. To provide an easy and quick testing to new users, a guest account is created. Anyone can use the guest account to explore the Virtual City but it should be noted that the guest account is always changing by different guests.

Future Applications

The technology developed for the Virtual City extends far beyond applications for civil engineering. For example, it has tremendous potential for mechanical engineering. The Virtual City technology could be used to assemble parts of a virtual machine interactively over the Internet as an educational learning experience. The technology used to collaborate and construct 3D virtual objects is essentially free, similar to actual web pages. It is planned that more complex worlds will be built by engineering students in the future as this program develops and more simulation modules are implemented in other engineering courses. Currently, the transportation and steel building modules construct different objects in the Virtual City.

Summary

Internet-based education or e-learning has potential advantages compared to traditional education since it is less expensive, easy-to-access, easy-to-update and platform-independent. The two multimedia modules and the Virtual City discussed in this paper are examples of how to conduct internet-based engineering education over the Internet. The virtual cities are being built when the students are learning specific engineering topics. This helps the students to better understand these topics since 3D visualization is provided for these topics. The students can interactively modify the virtual cities, which allow the students to experience the effects of changing 3D virtual cities. The virtual cities are viewable on the Internet so that they and others can see their design ideas. The Virtual City concept also allows the engineering students to learn design with a true 3D perspective without the high cost of actually building the design.

The idea of implementing the Virtual City has the potential application not only for engineering education, but also for internet-based engineering design because 3D objects can be created and modified over the Internet. The future work will include applying the idea of implementing the Virtual City to internet-based engineering design.

Acknowledgements

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