Design Education over the Internet using VRML

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Abstract

Over the past few years the World Wide Web or the Internet has made its impact on almost all fields of human life, from business and entertainment to shopping and communicating with people all over the globe. Virtual Reality Modeling Language or VRML for short is a tool specifically designed for creating 3D virtual worlds on the World Wide Web. These synthetic worlds give us the ability to visualize objects on the computer screen almost as if they were in the real world and also view them from all possible angles and directions.

The VRML environment is viewed on the Internet using web browsers. This paper describes the application of VRML and the Internet in imparting design education to engineering students. The VRML based design environment is a real time design environment i.e. the students can experiment by changing the values of design parameters and get the feedback immediately as the design model updates on the computer screen. This design environment also allows the user to conduct design analysis of the model. Since this method uses the Internet as the collaboration medium, it allows multiple users to log on to the VRML design world at the same time from different locations. Thus team projects and collaborative efforts for better understanding the design process are possible by the use of this technology. Working professionals and engineers who may not be able to attend traditional classes due to their full time jobs can use this web-based method to study online. An additional benefit is the design projects can be easily archived for viewing and use by students in future courses.

Introduction

It is well known that courses in design form an important part of the curriculum for students majoring in mechanical, aerospace and civil engineering. In design courses students are taught to analyze problems using various equations and theories for computing forces, stress, strains and displacements [1]. Since the design problems concern real world objects such as shafts, gears, pulleys etc., a visual representation of the design model enhances the understanding of students taking the design course. Since the purpose of VRML is for making computer and Internet-based 3-D models it is an important technology that can be used by students to visualize their design model thereby enabling them to better understand the design. Modern CAD programs also have good

display properties but are expensive and require training to enable the students to use them.

Computer based mechanical engineering design education is now standard and is being integrated into all courses in undergraduate education. The spread of computers in imparting engineering education has seen the creation of numerous useful software and programs to help students in learning, understanding and applying the knowledge gained. The Internet or the World Wide Web is a good source for vast amount of information for research and education. Over the last few years the Internet has seen an explosive growth, both in the amount of users and new technologies being developed to harness the power of the Internet for various applications. With the increase in bandwidth and emerging 3D technologies for the Internet, high end graphics games are being played by groups of players at different locations via the Internet. Virtual environments having modern buildings, space shuttles, fighter planes and solar systems are now available for the Internet users to experience and explore online [2,3]. The Internet is also being used for designing mechanical parts [4].

The purpose of this project is to impart design education to the engineering students using the World Wide Web as a medium. This web based online methodology is used to supplement the classroom teaching. The reasons for utilizing the Internet and VRML for design education are the ubiquitous, inexpensive, efficient nature of the Internet as a medium of information and the 3-D display capabilities of VRML. VRML models also known as VRML worlds are easy to construct and can be manipulated using programming. VRML has very good display properties like color, texture etc. VRML models are constructed using a simple text editor like Notepad. Thus they are economical to use for education purposes. There are also specialized VRML software like Cosmo Worlds and VR Creator that enable the user to quickly create the models. Thus the users can select from among the above mentioned tools depending on their budget and use. This paper will describe in detail how VRML and the Internet can be utilized for engineering education.

Internet Technologies

To view VRML files over the Internet a program called a Web Browser is needed. The function of this browser is to retrieve and display contents from other computers that are being accessed on the Internet. Two popular browsers are Internet Explorer from Microsoft Corporation and Netscape Navigator from Netscape Communications that are available for free downloading at their respective web-sites. The Internet has become one of the major tools for exchanging information and is used extensively by universities, companies and individuals to exchange information and data. The Internet is a huge network of computers and therefore can respond to user inputs. Since the information on the Internet is viewable from any computer that has got an Internet connection there is no restriction on the physical availability of students in classroom.

The Internet can also be used as a medium for design education since it is very easy to use, inexpensive and accessible by anyone with an Internet connection. The Internet is

one of the key technologies of the future and research is being carried out to improve it capabilities and expand its applications.

Virtual Reality Modeling Language

With the rapid proliferation of the Internet, a number of years ago there was a strong need to develop a technology for creating and viewing 3-D objects and worlds on the Internet. This was the driving force behind Silicon Graphics, Inc. developing the Virtual Reality Modeling Language (VRML). It was initial released in 1995 and has undergone a series of modification since then. VRML was develop expressly as an Internet standard and thus works well with all Internet browsers for creating and displaying 3-D objects.

VRML is used for this research since it is easy to learn and apply to practical problems. Also VRML is cost-effective compared to other 3-D CAD programs. The user can interact with the 3-D objects by using zoom, rotate, seek, tilt and walk through features of VRML. A VRML file is basically an ASCII text file that can be created and edited using any text editor or word processor [5]. Whenever a web browser reads the instructions for building a virtual model from a VRML file, it builds the model and displays it on the computer screen.

The VRML world building instructions are similar to other 3D file formats, such as AutoCAD's DXF format in that each object in the world has its own parameters to control its location and size within the world's space and coordinate systems. VRML uses polygons to build the 3-D objects but only the surface of the model is built as a series of connected polygons referred to as polygonal mesh. VRML allows the user to perform geometric transformations such as scaling, rotation and translation on the 3-D objects. The users can also apply different colors and textures to the 3-objects created using VRML. They can navigate in the VRML world and look at the objects from different viewpoints and locations. Thus the user can interact dynamically with the objects. VRML also allows the addition of sound, background, lights and animation to the 3-D objects.

Since VRML was designed for use on the Internet it allows multiple users to access the same 3-D worlds simultaneously. VRML reuses the points, which share common edges, faces or vertices and also colors, textures, shapes thereby reducing the redundancy. Also since VRML transmits instructions for building the 3-D objects instead of transmitting entire images the files can be loaded and viewed quickly. This is one of the strong points of VRML. The ability of controlling VRML objects with a programming language such as PERL or JAVA allows the user to create new models by changing the parameters used to create the model.

To view VRML documents over the Internet a VRML helper application or plug-in called a VRML player must be installed in the browser. The player is actually a third party program that can be downloaded from the vendor, similar to other browser plug-ins. Some of the more common VRML players are Silicon Graphics' CosmoPlayer, Sony's Community Place, Intervista's World View, and Dimension X's Liquid Reality.

Common Gateway Interface (CGI) and PERL

In addition to sharing design modules, it is important that the designers have the ability of modifying the design. Thus, in this project there was a need for the user to be able to input data for the design generation. This data input by the user was then used for performing the computations and generating a new VRML file for the model. To accomplish this real-time design modifications over the Internet, CGI scripts were used for providing an interface between the user i.e. client and the server computer from where the VRML file was generated and loaded[6].

The CGI standard also provided the external program with as much information as possible about the server and the browser, in addition to any information that may be known about the user. The CGI standard serves as the gateway for many types of clients and servers and being multilingual it provides translation services between dozens of browser types, Web servers and operating systems.

Perl (Practical Extraction and Reporting Language) is one of the programming languages that can be used for CGI applications since it meets the functional requirements of a behavior language for VRML. One of the advantages of Perl is that it is platform independent and is therefore ideal for CGI applications. In particular, Perl is powerful for reading arbitrary text files, extracting information from those files and printing reports based on that information. Perl is an interpreted language i.e. there are no compilers required for it[7]. The Perl interpreter is available freely on the Internet for downloading and can be easily ported to a variety of systems.

HTML

In addition to the previous Internet technologies, Hypertext Markup Language (HTML) must was still be used to tie information together and act as the frame work for web pages. It is basically a scripting language that marks up a page with formatting commands [8] that can be used on the Internet. These commands are then interpreted by a Web browser and sent to the computer screen. Currently, HTML pages are the standard skeletal system of the Internet and span a wide range of applications from personal home pages to professional business service. HTML is used for generating the forms that collect the design data from the user and send it to the CGI scripts on the server.

Examples of using VRML and Internet Technologies for Engineering Design

The examples chosen for design using VRML and Internet technologies are selected to demonstrate the potential of VRML design using the Internet. The example of thick cylinder demonstrates the geometric change and color coding capabilities of this technology. The hard disk design is an example of making design changes to a complete product. The third example shows the use of this technique for design analysis using the FEA method.

Design Analysis for a Thick Walled Cylinder

The example of a cylinder is chosen since it has many common applications such as containing liquids and gases under pressure. They are also used in boilers to produce

steam from water for energy generation purposes. Also the example of a cylinder demonstrates to the students the calculations of stress and variations of stress across the cylinder walls.

A thick walled cylinder is one in which the thickness of the cylinder is greater than one twentieth of the internal diameter of the cylinder[9]. Such a cylinder is used for containing fluids under very high pressures or to withstand a large external pressure. The thick cylinder differs from a thin one in that the pressure distribution across the wall of the cylinder is not uniform.

For the online design, the student defines the geometry of the thick cylinder by specifying the inner and outer radii of the cylinder (Fig. 1) directly on the web page. The internal and external pressures are also set by the user in the appropriate text fields. Depending on the material of the cylinder, the properties are submitted by the student. In case a student wants to determine the thermal stress due to a temperature gradient from the inner radius to the outer radius the coefficient of thermal expansion for the material of the cylinder and the temperature gradient can be submitted for computation. The computations are performed after the data is entered and results are displayed in the browser window. Thus a student using the design can check his manual computation for the stresses with the values from the program.

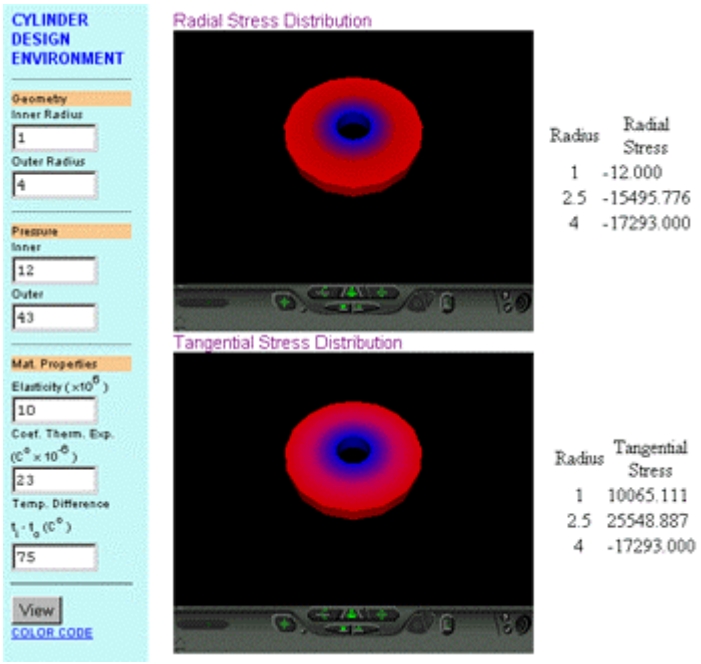

Fig. 1 Stress Visualization in a thick cylinder

The design module is operated using a web browser window. The design environment web page is divided into two frames. In the left frame the user input has the options to input the various dimension and design parameters. The user can then submit the data to the server. The data submission is done using an HTML form.

The data is send to the server using a CGI script. The Perl program then processes the data, computes the results and generates the new VRML design. The results are posted on the right side frame of the web page. After the user submits the design parameters calculations are performed by the PERL script. These calculations are used for generating the VRML model of the cylinder and computing the stresses. The stresses are color coded and displayed across the walls of the cylinder. This enables the student to easily visualize the stresses in the cylinder.

One of the advantages of using VRML for the cylinder design module is that the student can view the 3-D object from all possible directions. This enables the student to easily visualize the design and associated stress distribution.

Hard Disk Design

The VRML based design on the Internet has also been applied to design an actual product - a computer disk drive. The test model used for this application is Barracuda 9LP, a computer disk drive manufactured by Seagate Technology, Inc. The main components of the disk drive are the magnetic housing, read-write arms, disk pack, spindle axis and outer casing.

The disk drive fulfilled the need for a less complex model but still one which could serve as an excellent example for an engineering model since this whole research is focussed on engineering design. The outer case is approximated to a rectangular casing to make the design simple. The parameters of the case such as the height, width and depth are variables. The read-write arm, e-block, flex circuit and the magnet housing are not modeled in detail again keeping the concept of simple design in mind. The parameters of these components are not variables but their positions alter according to change in radius and number of disks.

The virtual design environment is designed to operate in a browser window. The browser window is divided into two frames to organize the window more easily and to facilitate the data flow within the system. As shown in Fig. 2, left hand side frame consists of five fields for entering input values to change the design of the disk drive. Two fields allow the user to change the parameters of the disk and three other fields allow changing the parameters of the case. The parameters for the disk are the number of disks and radius while the parameters for the case are height, width and depth.

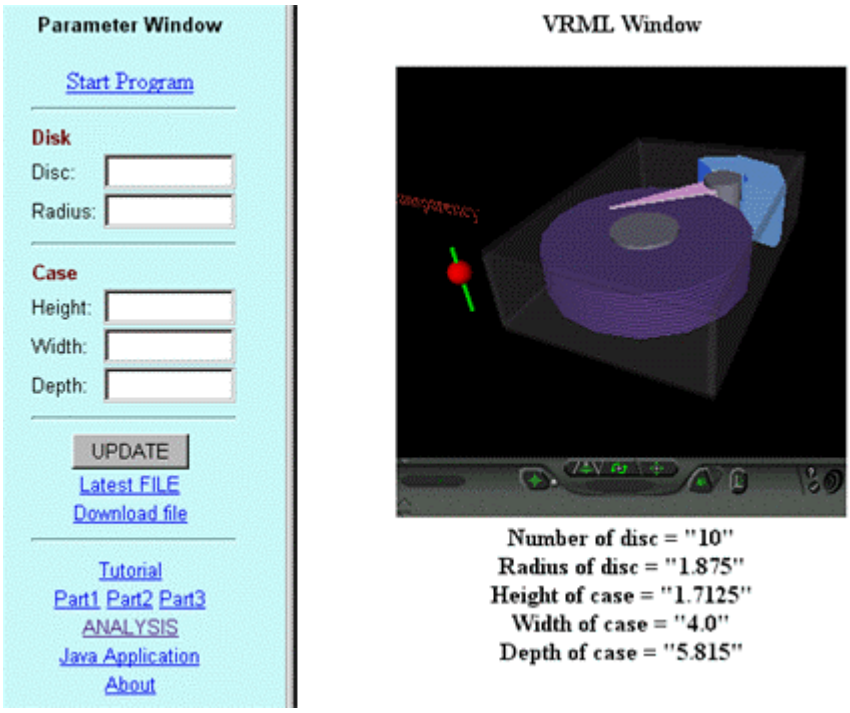

Fig. 2 Hard disk design

The left side frame consists of a link to start the application. This link inside the HTML page is designed to execute a Perl file on the server. This Perl file generates two files, which are targeted to the right hand side frame. The Perl file first opens a VRML file and writes the data needed to generate a disk drive with the given specifications into the file. The Perl file also generates an html file that contains the extension for the VRML file generated. So, once the link, “Start Program” is clicked using the mouse of the computer the VRML file is seen inside the VRML browser on the right hand side frame of the Internet browser. Also seen are the specifications of the disc drive such as number of disks, height, length and depth of the case. This keeps track of the specifications of the current design and helps the user to make design changes.

Finite Elements for a Simple Plate

The VRML based design on the Internet is also used for demonstrating a simple finite element analysis. This research is an attempt to prove that interactive analysis could be performed over the Internet and thus the model was relatively simple. The selected FEM model is a thin plate of unit thickness[10, 11].

The application is intended to work on an Internet browser window, which is divided into frames as shown in Fig. 3. The left side frame consists of fields to specify the nodes on which the forces are going to be applied, magnitude of forces and the directions of the forces. There are a total of six fields and a button to activate the CGI script. The script is written in Perl, and does the actual calculations. The VRML file that contains the FEA (finite element analysis) results along with the contour plot and color bar is loaded on the right side frame. There is a link to start the application and also a link to view the latest

file that contains the latest stress analysis results. Initially, the link “Initial model” has to be clicked to view the unanalyzed model. There are two fields to enter the two nodes on which the user wishes to apply the forces. Even if the user decides to apply forces only on one node, values should be entered on both the fields. For example, if the force were to be applied only on node 10 then the first field would contain the value 10. The second field can contain any other node value except the number 10.

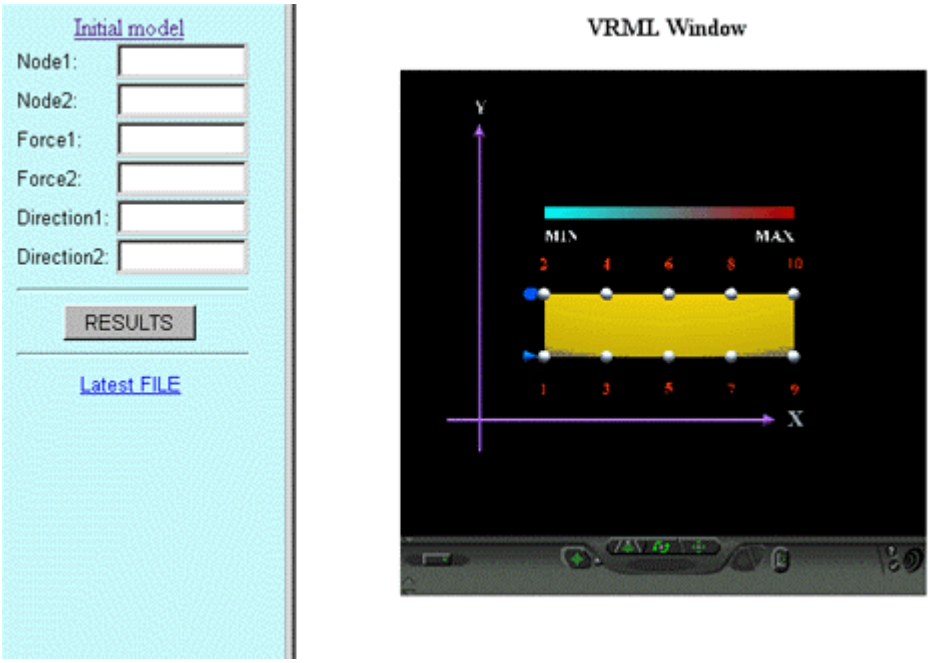

Fig. 3 Finite elements for a simple plate

The next two fields in the left side frame are reserved for entering the magnitude of the forces that are going to be applied on the model. The unit for the forces is pound. If only one force is applied, then zero must be entered into the “force” field for one of the nodes. The next two fields are filled with the directions of the forces being applied. Again if force is being applied at only one node, the second field must still contain either x or y but since the magnitude is zero, it will have no effect. Then the “UPDATE” button is clicked to view the points of maximum and minimum stresses. There is also a link “Latest FILE” to view the latest VRML file containing the results of the latest stress analysis being done on the model.

Summary and Conclusions

The use of VRML based design on the Internet opens a new avenue for engineering education. The virtual design environment showed that design on the Internet is possible and is inexpensive. The examples discussed in this paper were designed to work on the Internet and therefore tools that could facilitate transfer of data over the Internet were chosen. Software code was written using Perl to collect input from the user and process

them to deliver the desired output. VRML was used to present the data in a 3-D format on the web.

This paper demonstrated the potential of design on the Internet. The students can do collaborative design on the Internet. There is no restriction on the time and place for the students to use the design module. The students are able to better visualize their designs using the 3-D capabilities of VRML. Further research applications of the VRML method of design could be in using it to train personnel in industries.

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