A Low Cost Collaborative Environment for Student Product Design

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Abstract

The process of new product development or new product introduction has been changed due to the concept of concurrent engineering and globalization. It requires frequent interactions among various design teams and customers. Therefore a collaborative environment has to be established to handle all the interactions and communications in production design. In this paper a low cost collaborative environment is used for product design. This primitive but innovative collaborative environment can be applied in the teaching of product design. The instructor, student team members, and even industrial partner can participate in the product design together. Team members at different locations and times can collaborate through the web-based environment and provide feedback to each other. This approach can provide students with better inputs to their design, better use of information technology, and better interaction with potential industrial collaborators.

Introduction

As product design cycle time shortens ever faster, the method of design changes accordingly. Computer-based technologies have greatly changed the way design engineers work. The first technological element was the use of high-powered personal computers (PCs). With PCs, design engineers have access to Computer-Aided Design (CAD) software right at their own desks. Personal computers and CAD packages replaced drawing boards, pencils, and T-squares. The second change is the emerging use of the Internet or Intranet by engineers that enables them to collaborate with partners at far-flung locations. The third technology is virtual reality (VR) that allows users to enter design works and interface in three dimensions (3D).

Three-dimensional CAD software has been used extensively due to its power in creating 3D solids. Adding the third dimension has taken out the guesswork of how a product might look and behave. The on-screen solid models can be seen and analyzed long before they get to the shop floor. Schmitz (1994) indicated that the next step in the product development process was animation. Animation enables designers to see how their designs will look and work on screen.

Most of the state-funded universities and colleges have very limited equipment budget to purchase high power computers. And because of the complexity of the CAD software packages,

regular PC computers cannot meet the requirements of CAD software packages. Moreover, professional copies of CAD software packages cost an average of $5,000 to $20,000 per license. There are very few state-funded institutions of higher learning which can afford such luxurious state-of-the-art design laboratories to educate ten to twenty students at one time. Therefore, in most cases, professors have to invest in the $200 to $300 student version CAD packages with moderate speed PCs to teach Introduction to CAD. The authors have actually observed two students sharing one workstation in CAD classes in certain state-funded universities.

The advent of Internet and Intranet allows engineers to communicate with each other in a cooperative process (often called "collaborative engineering") on the same project to come up with the best design. In fact, this engineering environment pulls in all engineers, product managers, manufacturing engineers, and marketers to the same project. They all have access to the system. However, problems arise for students in the design class in terms of collaboration. The first problem is that most collaborative environments now available for product design focus on the collaboration between different designers who work on different parts of the same product. This type of collaborative environment requires that all members in the collaboration not only have certain software programs such as CATIA or Pro/ENGINEER, but certain knowledge in the use of these programs as well. Since students are learning to use these CAD software packages, the knowledge of these programs relies on their learning capabilities. And most of the students cannot afford to purchase a copy of the student version for their home PCs. In some metropolitan universities (such as one where one of the authors teaches), most of the students are commuting and are working either part-time or full-time outside classes. It is very difficult to coordinate team design schedules for a group of 3-4 students finding common times to meet at the CAD laboratory. And while the students are away from school they cannot design nor can they be aware pf the other team members' design concepts and work.

Another problem exists when service-learning elements or real-world design projects are assigned to students who are then placed in a disadvantaged situation. A better scenario would occur if the company has the financial resources to purchase an expensive professional version of the CAD software package and students can use this professional system in their design work. However, in Pro/ENGINEER, for example, the CAD files generated are not exchangeable between professional and student versions.

The principal notion behind Virtual Reality (VR) based systems is to provide an intuitive and easy-to-use environment for engineers, designers, and others. Through the Internet, 3D CAD and VR could bridge the communication gap between people on design teams to allow them get involved and accomplish product design in a collaborative approach. Schmitz (1995) agreed that VR offers an opportunity to take further steps toward improving communication between the designer and the others involved in the design process. The VR package such as eye phones and headpieces, headphones and earphones, data gloves and touch sensors, and software for developing virtual worlds are extremely expensive. A complete system offered by VPL Research or W. Industries Ltd. starts at $55,000 and can reach up to $250,000. Therefore, VR is not something that students can enjoy.

In this paper a low cost collaborative environment is proposed for product design. This primitive but innovative collaborative environment can be applied in the teaching of product design. The

instructor, student team members, and even industrial partner can participate in the product design together. Team members at different locations and times can collaborate through the web-based environment and provide feedback to each other. Multiple users can use the system at the same time providing that the computer server has enough bandwidth to handle the traffic. This approach can provide students with better input to their design, better use of information technology, and better interaction with potential industrial collaborators.

Virtual Reality and Virtual Reality Modeling Language

According to Benno (1998), the initial use of virtual reality seemed valuable only to scientists and engineers who had highly specialized needs. It was developed for potential military applications where development cost was not an issue initially. The first commercial companies entering the VR application field were the companies with the most capital to spend, such as aerospace and automobile manufacturers. McDonnell Douglas, for example, has been using VR to help design an improved engine housing for F-18 fighters. Volvo has been using VR to demonstrate the safety of its cars by allowing passengers to experience crashes in a stationary vehicle.

The Virtual Reality Modeling Language (VRML) is a dynamic 3D scene description language that can include embedded behaviors and camera animation and bring 3D worlds online. The original goal of VRML was to change the Web from a text-based interface to a 3D-based interface. Users can view the contents of a graphic file as well as navigate to other 3D worlds or HTML pages using VRML. It contains a rich set of graphic primitives that provide a common file format that can be used to describe various 3D scenes and objects. VRML 2.0 now gains international endorsement and provides a guarantee of specification stability, which will promote content compatibility to drive the growth of 3D on the Internet. Users in different parts of the world can view it simultaneously, as long as they are on the Web using either Netscape Navigator or Microsoft Internet Explorer.

Notess (1996) indicates that one of the most active directions of growth on the Internet has been in its multimedia and interactive capabilities. One way to make interactive capabilities more exciting is to use dynamic effects. Rather than presenting static graphical information, web designers can bring the Web pages to life by adding JavaScript in the creation of a collaborative environment. The JavaScript programming language makes multimedia and interactive capabilities available to Internet users.

With the use of VRML, the web is being extended to 3D. And JavaScript can broadcast the graphics over the Internet. This powerful combination shows that VRML and JavaScript provide extensive support for large-scale virtual environments. Newer versions of the web browsers come with multimedia plug-ins such as the Cosmo player that can run the VRML file so that users can view graphical images virtually.

Collaborative Environment

Figure 1 shows the steps to establish a collaborative environment using Pro/ENGINEER, VRML, JavaScript, and Cosmo Player. A simple pyramid is used to illustrate the procedure. It is

necessary to determine the critical variables that would be modified in the design project at the beginning of the collaborative environment. The variables for the pyramid are the dimensions of the base of the pyramid. The design cycle is complete when other team members are capable of modifying data and transmitting them back to the original designer through the Internet. This project uses a VRML plug-in, Cosmo Player 2.10, to view the VRML file. With Cosmo Player users can easily navigate and manipulate 3D scenes created in VRML. Cosmo Player is free from Silicon Graphics and can be downloaded from http://www.cai.com/cosmo/. There are many VRML browsers available besides Cosmo Player. The users can decide the appropriate plug-ins for different platforms from http://www.web3d.org/vrml/browpi.htm.

A 3D CAD software package is needed to generate the original design file. Since both Pro/ENGINEER and CATIA have the option to export the design as VRML file, designer can choose either platform to design the 3D object. Pro/ENGINEER student version is used in this case. The challenge to the student designer is that he/she must learn the basics of web page design and JavaScript in order to create a dynamic collaborative environment and to receive feedback from other team members and/or private company facilitators.

Model Building

The pyramid model is designed by Pro/ENGINEER 3D CAD software and then exported the object as VRML file. JavaScript is used to create the function of verifying the password, getting the input data, generating the new design, and feeding back the new design data to the original designer. HTML is used to create the web pages where the original and new designs can be displayed and reviewed at sites of other team members as well as participating companies at the time and place of their choice.

```
┌─────────────────────────────┐
│   Create Object in 3D CAD   │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│       Convert to VRML       │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│    Display in Cosmo Player   │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│   Create HTML and JavaScript │
└─────────────────────────────┘
              │
              ▼
┌──────────────────────────────────┐
│  Embed VRML, HTML, and JavaScript │
└──────────────────────────────────┘
```
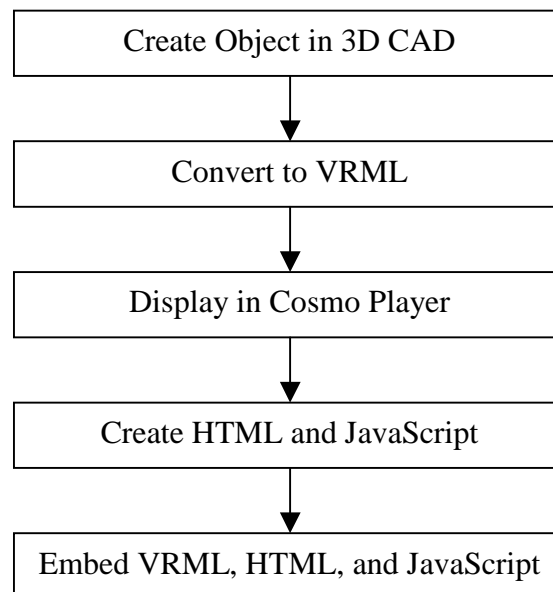
Figure 1. Establishing Collaborative Environment.

To simplify the process, Pro/ENGINEER creates a pyramid solid. The design file is then exported as Pyramid.wrl to allow the VRML browser to display it. The Pyramid.wrl file instructs VRML to create a pyramid in the browser. Figure 2 is the pyramid displayed in the Cosmo Player. The designer has to decide what variables the team members are allowed to modify before embedding the Pyramid.wrl file in JavaScript. The coding of the JavaScript is shown in the following:

```
// WritePlugIn
// function will open a document of the type of
// plug-in and write directly to it
function DisplayWorld() {

        X0 = document.ValueForm.X0.value
        Z0 = document.ValueForm.Z0.value
        X1 = document.ValueForm.X1.value
        Z1 = document.ValueForm.Z1.value
        X2 = document.ValueForm.X2.value
        Z2 = document.ValueForm.Z2.value
        X3 = document.ValueForm.X3.value
        Z3 = document.ValueForm.Z3.value
        X4 = document.ValueForm.X4.value
        Z4 = document.ValueForm.Z4.value
        X5 = document.ValueForm.X5.value
        Z5 = document.ValueForm.Z5.value
        X6 = document.ValueForm.X0.value
        Z6 = document.ValueForm.Z0.value
        X7 = document.ValueForm.X1.value
        Z7 = document.ValueForm.Z1.value
```

sExpression = "DEF Cameras Switch { whichChild 0 DEF Default PerspectiveCamera { position -0.0810269 0.101985 0.0793689 orientation -0.327221 -0.940454 -0.092052 0.872112 focalDistance 0.184715 } DEF FRONT PerspectiveCamera { position 0.05 0.05 0.151793 orientation 0 0 1 0 focalDistance 0.191793 } DEF TOP PerspectiveCamera { position 0.05 0.241793 -0.04 orientation -1 0 0 1.5708 focalDistance 0.191793 } DEF RIGHT PerspectiveCamera { position 0.241793 0.05 -0.04 orientation 0 1 0 1.5708 focalDistance 0.191793 } DEF BOTTOM PerspectiveCamera { position 0.05 -0.141793 -0.04 orientation 0 -0.707107 0.707107 3.14159 focalDistance 0.191793 } DEF BACK PerspectiveCamera { position 0.05 0.05 -0.231793 orientation 0 1 0 3.14159 focalDistance 0.191793 } DEF LEFT PerspectiveCamera { position -0.141793 0.05 -0.04 orientation 0 -1 0 1.5708 focalDistance 0.191793 } } ShapeHints { vertexOrdering COUNTERCLOCKWISE shapeType SOLID faceType   CONVEX } Group { Switch { whichChild 0 Group { DEF Rep_0 Group { DEF Geom_0 Separator { Geom_Type { DEF Poly_Geom_Data Group { " + CreateCoordinate(X0, 0, Z0, X1, 0, Z1, X2, 0, Z2, X3, 0, Z3, X4, 0.1, Z4, X5, 0.1, Z5, X6, 0.1, Z6, X7, 0.1, Z7) + " Normal { vector [0 -1 0, 0 1 0, 0 0.37 0.928, 0.894 0.446 0, 0 0.37 -0.928, -0.894 0.446 0,]} NormalBinding { value PER_VERTEX_INDEXED } Separator { IndexedFaceSet{ coordIndex [1, 0, 2, -1,3, 2, 0, -1,]   normalIndex [0, 0, 0, -1,0, 0, 0, -1,]   }

} Separator { IndexedFaceSet{coordIndex [5, 4, 6, -1,7, 6, 4, -1,] normalIndex [1, 1, 1, -1,1, 1, 1, -1,] } } Separator { IndexedFaceSet{ coordIndex [4, 0, 7, -1,1, 7, 0, -1,] normalIndex [2, 2, 2, -1,2, 2, 2, -1,] } } Separator { IndexedFaceSet{ coordIndex [7, 1, 6, -1,2, 6, 1, -1,] normalIndex [3, 3, 3, -1,3, 3, 3, -1,] } } Separator { IndexedFaceSet{ coordIndex [6, 2, 5, -1,3, 5, 2, -1,] normalIndex [4, 4, 4, -1,4, 4, 4, -1,] } } Separator { IndexedFaceSet{ coordIndex [5, 3, 4, -1,0, 4, 3, -1,] normalIndex [5, 5, 5, -1,5, 5, 5, -1,] } } } } } } } } } "

```
  document.ValueForm.Result.value=sExpression
  parent.LowRgt.document.open("", "World",
       "scrollbars=yes,width=500,height=400")
  parent.LowRgt.document.open("x-world/x-vrml")
  parent.LowRgt.document.writeln("#VRML V1.0 ascii")
  parent.LowRgt.document.writeln(sExpression)
  parent.LowRgt.document.close()
}
// WritePlugIn
// function will open a document of the type of
// plug-in and write directly to it
function SendWorld() {
```

All the coded lines above are related to the VRML file generated by the Pro/ENGINEER and modified to its present form. It was tedious work to write the codes the first time. However, after testing the model successfully, designers can use these lines as a template to modify other design parts with minimum effort.

After the Pyramid.wrl is created, the designer needs to use HTML to create the web pages for the web-based collaborative environment. The first HTML file is Index.htm and a password is required to login. The second file DesignPyramid.htm is the main collaborative page that contains three frames called LowRgt, LowLft, and Top, as shown in Figure 3. The LowRgt frame shows the original pyramid design. The LowLft frame generates team member's new design. The Top frame allows users to modify the variables of the design. There is a "Confirm" button whereby team members may send their new designs to designer via email after modifications. The collaborative design cycle is complete after the original designer receives the feedback from team members or participating companies.

The most critical steps in the collaborative environment are to create JavaScript and embed the JavaScript into HTML files. The JavaScript plays two roles in the collaboration. The first role, embedded in the Index.htm, is to control the user's login. Team members are permitted to enter into the collaborative environment if they have the correct password. The authors do recognize that a typical web designer can easily view the source codes and find out what the password is. However, the password function is not a key issue in our study but the collaborative environment. A safer way is to use Java Applet to hide the passwords in a log file. Again, an advanced level web designer can also hack into the log file and retrieve the passwords. Therefore, the best way to ensure network security for general web users is to use either ASP, CGI, or JAVA in coding the passwords, which is beyond the scope of this study. The following

codes are inserted in the index.htm file to allow users to login from remote sites. Please note that the password is given in the message display window for demonstration purpose.

Figure 2. Pyramid shown in Cosmo Player.

Figure 3. Web Frames in DesignPyramid.htm.

```
//JavaScript Functions
//
// Following functions verify the Passsword
function password() {
    Ret = prompt('The password is: password',"");
```

```
        if(Ret=="password") {
            location = 'DesignPyramid.htm';
        } else {
            alert("Please try again")
        }
}
// - End of JavaScript - -->
</SCRIPT>
```

The other role, embedded in the DesignPyramid.htm file, is to load the variables and generate the new VRML file. A default email address was set so that team members can send their modifications back to the original designer. The detailed procedure is shown below:

1.   Team members use Netscape Navigator to browser the website created by designer.

2.   Team members login by entering proper password to browse the DesignPyramid.htm page, as shown in Figure 4.

3.   The original design is displayed in the lower left frame of the DesignPyramid.htm page. The top frame, enlarged in Figure 5, shows the default data and allows users to enter their modifications to the original design. Click on the "Preview" button will show the new design in the LowRgt frame. For example, if a user enters "1.0" in X1 and X2 (originally "2.0") and also "-1.0" in Z2 and Z3 (originally "-0.8"), while keeps other values the same and then presses "Preview."   A new different shaped pyramid will be generated and displayed in LowRgt frame, as shown in Figure 6.
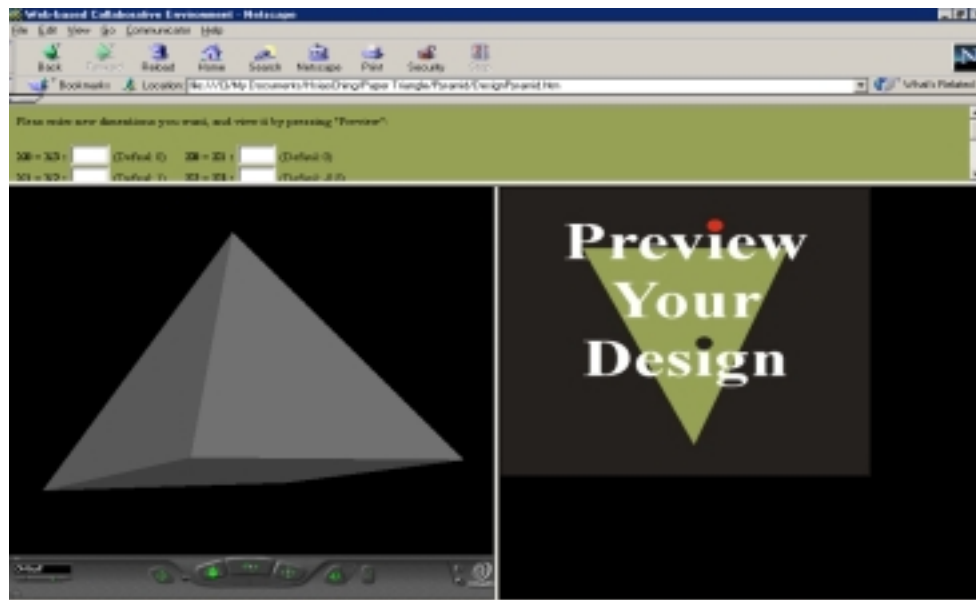
Figure 4. DesignPyramid.htm in Netscape.
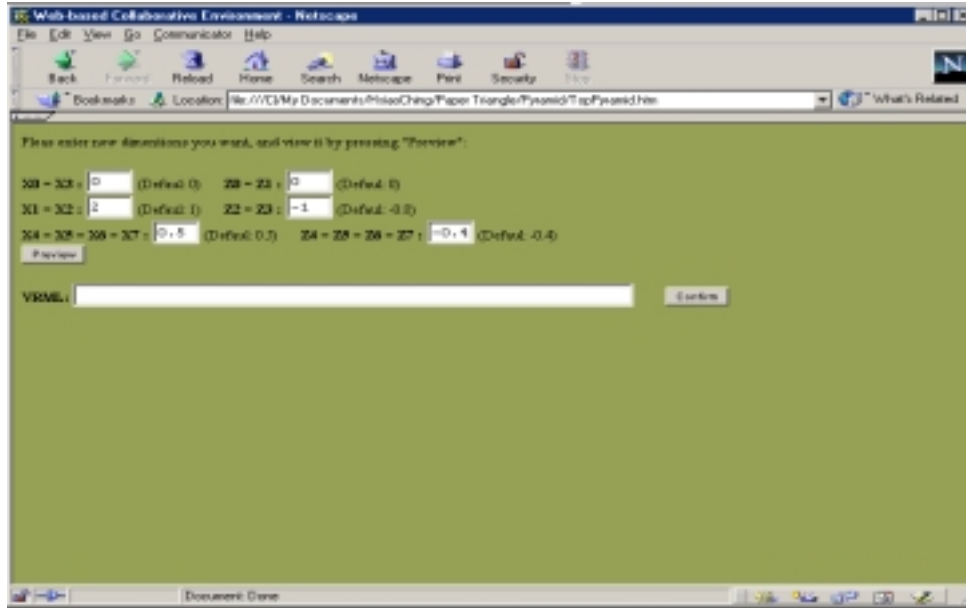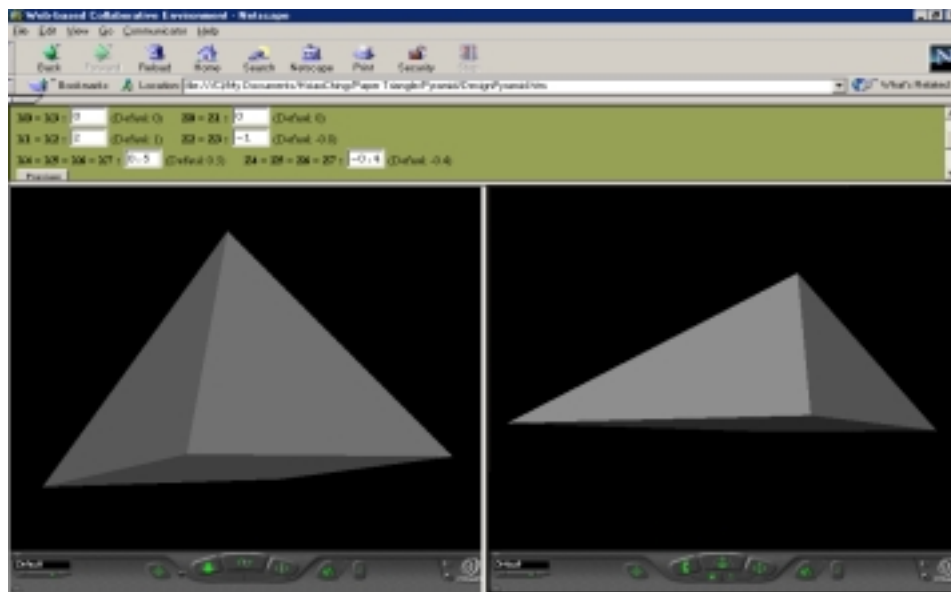
Figure 5. Data fields.
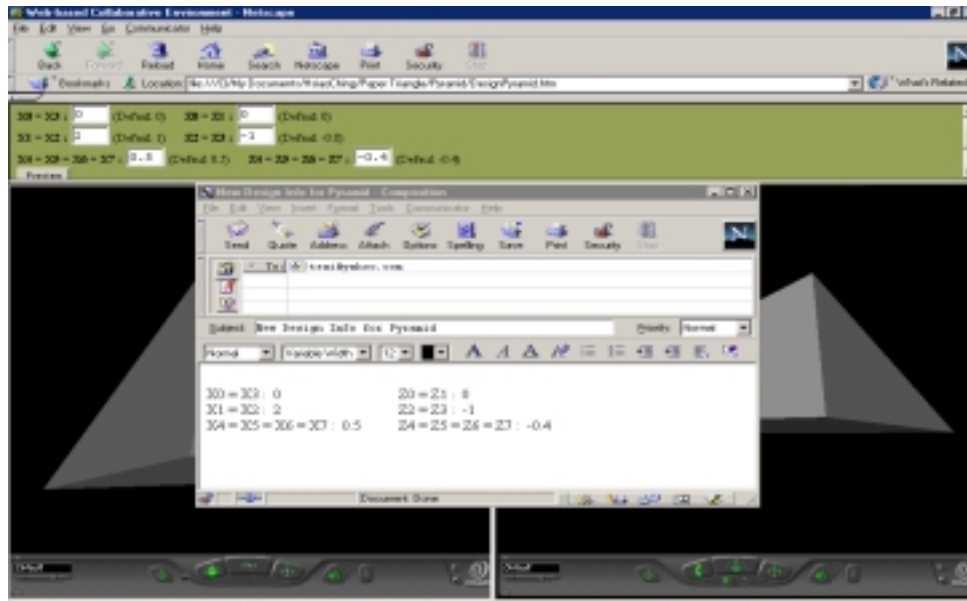

Figure 6. New Design Generation.

Figure 7. Feedback email.

Conclusions

Using web-based collaborative environment in product design is an inevitable trend for student team design, especially involving companies in a low budget operation.   Traditional product design process is not able to meet the fast-moving pace of current technological world that requires teamwork among members. A low-cost and innovative virtual collaborative environment can help to solve this problem in student team product design. Student team members can access others' designs by viewing the VRML results in Internet anywhere and anytime and send feedback to the original designers without ever being present in the CAD laboratory at the same time as other team members. This approach not only saves tremendous meeting time (and the difficulty in arranging it) but also provides flexibility and productivity while each team member is reviewing designs and sending feedback to the others.

This web-based collaboration approach using VRML for student team product design is very easy to use. However, it does present two technical limitations to the designers. Since VRML is exported from Pro/ENGINEER, it generates many lines and may take the designer quite some time to locate exactly where the codes are need to be changed by other team members so that JavaScript can be coded accordingly. Therefore, at the present time, this approach is limited to simple 3D designs only. The other limitation is that the student designer must know how to design web pages to embed all the design files and feedback information, a knowledge that requires at least a few weeks training to be done efficiently. We expect that when major CAD software companies recognize the values in collaborative designs, they will develop output options that will export 3D CAD files into VRML, web pages, and generate JavaScript codes to enable feedbacks to change dimensions, texts, and colors in the Internet environment.

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Biographical Information

Dr. Paul Cheng-Hsin Liu is currently an Associate Professor in the Department of Technology in the College of Engineering, Computer Science, and Technology at the California State University, Los Angeles. He holds a Ph.D. in Industrial Engineering from Auburn University. Dr. Liu has a strong background in Manufacturing Processes, Automation, Statistical Quality Control, Virtual Reality, and others. He is a member of SME, IIE, ASQ, and IEEE. He is Certified Manufacturing Engineer (CMfgE) by SME, and Certified Quality Engineer (CQE) by ASQ.

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Gladys Hsiao-Ching Tsai has a Master Degree and B.S. degree in Industrial Design. She has about ten years of experience as an industrial designer of various products. She has tremendous experience in product design utilizing CATIA, Pro/ENGINEER, and AutoCAD. She designed several tennis rackets for ProKennex when she was in Taiwan, one time the largest tennis racket manufacturer in the world, and received the Taiwan National Image Award in 1992 and 1995. Additionally, her designs also helped the company to acquire several multi-national patents in 1993 and 1994. Gladys also represented her former company several times in attending the ISPO Show (International Trade Fair for Sports Equipment and Fashion), the largest sporting goods show in Europe, and was highly praised by her customers. She is now working as senior product designer for an engineering company in Southern California.