Simple, low cost 3D Stereo Visualization Technique for mechanical engineering learners

R. S. KAMATH
Shahu Institute of Business Education and Research
Kolhapur, India
rs_kamath@rediffmail.com

R. K. KAMAT
Shivaji University
Kolhapur, India
raj_kamat@yahoo.com

ABSTRACT
Virtual reality technology is the interesting area in computer application research. Students are interested in cutting-edge technologies like virtual reality (VR), and VR has many potential uses in education. However, building VR applications has proved challenging due to both cost and technical skill barriers. Through a series of experiments in VR, we have developed method of bringing an important facet of VR, stereoscopic display, to mechanical students in a simple, cost-effective way. The computer based 3D stereo visualization techniques plays an important role in developing high-performance mechanical components. This paper describes our approach for development of less expensive 3D visualization technique for mechanical engineering learners.

Keywords: *VRML, Parser, Renderer, Passive Stere*

INTRODUCTION

The mechanical components are designed using modeling software like Cad/Cam, Catia, Pro/E, I-deas, and Solid Works etc. The modeling software is designed to assist a parallel engineering approach to mechanical engineering product design, 3D modeling, analysis and manufacturing application (Pratt 1995). It is extensively used in the design of tools and machinery in the manufacture of components and also mainly used for detailed engineering of 3D models and 2D drawings of physical components (Balc & Campbell, 2004). After designing the object in modeling software, the model can be exported into different ASCII file formats. The visualization system enables easy generation of realistic 3D animations using supported data file formats. In our development VRML (Virtual Reality Modeling Language) file format is specifically considered.

Three-Dimensional Stereovision is a feature of Virtual Reality which adds reality to computer generated scene, where any three dimensional scene can be viewed using stereo glass to get 3D effect (Doug et al., 2006, Lehner & DeFanti, 1997). The 3D visualization system provides mock-up to enable designers to obtain a more realistic feeling. Technology trends include an expansion of 2D visualization to an increasing use of 3D visualization. The visualization tool developed in our research is an ASCII text file driven system to visually simulate the modeled operation in 3D virtual space. With a low cost PC, and very inexpensive red/blue glasses, the students can view these interactive 3D visualizations in stereo (Mohamed 2008, Magnenat & Thalmann, 2006).

VISUALIZATION FEATURES

In the course of this work a cost effective software platform has developed for easy visualization of the mechanical components without much intricacies of the sophisticated computing platform (Ostones et al., 2004). Interactive immersive low cost 3D visualization of CAD model is the major outcome of this research. To enhance the effectiveness of this visualization suite, the following features are facilitated,

- Parsing of ASCII files (Eg.VRML) generated by modeling software by fetching the data required for visualization
- The ability to generate and display high quality images of mechanical components
- Allows the user to experience 3D stereo vision with low cost passive technology
- Enhance the visualization by implementing additional visualization features like texture mapping, walkthrough, cut section
- The tool should be able to change viewing angle and viewing mode
- Provision of editor for selection of different light sources, material properties, color
- Option for rotation, translation, scaling of the model on the screen

TECHNICAL CHARACTERISTICS VRML FILES

Building of this VR application started with the study of VRML Files. VRML is a scene description language (Carey & Bell, 1997). Most of the modeling software can export their data files in to VRML format thus making our visualization system independent of any modeling software (Harald & Didier, 2007). VRML is a 3D interchange format defines semantics of object's descriptions such as hierarchical transformations, geometry, viewpoints, light sources, material properties etc. It is a standard language for the animation and 3D modeling of geometric shapes. It is a simple language for describing 3D shapes and interactive environments. Shapes of the 3D objects are described in terms of triangulated data. Vertices and edges of 3D polygons are specified with surface details. VRML files are not compiled, but parsed by a VRML browser. VRML files are commonly called worlds and have the *.wrl extension. The features of VRML are simplicity, highly optimized, support for file interchange format, compos ability and scalability.

VRML File Format

VRML is a text file begins with header line #VRML. Following the header is a hierarchical description of the model. It contains vertices and edges for 3D polygon which are specified along with color, material, light, texture, shininess and so on. A sample ASCII file of the CAD model in .wrl format is shown in the figure 1. The datasets are organized from point by point followed by polygon's vertices references. To get the vertices arranged in triangles, the co-ordinates have to be taken according to the point references. This requires the rearrangement of vertices for the display. There are two versions in VRML, 1.0 and 2.0. The structure of a VRML Files has 3 basic elements,

1. A header which tells the browser that the file is VRML and which version also. A header line is mandatory.
2. Comments are preceded by #.
3. Nodes generally contain,
   - The type of node. Nodes always are in Capital letters.
   - A set of curly braces {.....}
   - A number of fields, all or some of which are optional.
   - Fields with that can have multiple values require braces [...].

```
#VRML V2.0 utf8
#dodec.wrl #
Viewpoint { description "Initial view" position 0.0 0.0 9.0 }
NavigationInfo { type "EXAMINE" }
Transform {
 translation -1.5 0.0 0.0
 children Shape {
  appearance DEF A Appearance { material Material { } }
  geometry DEF IFS IndexedFaceSet {
   coord Coordinate {
    point [
      1.0   1.0   1.0,
      1.0   1.0  -1.0]}
   coordIndex [
    1, 8, 0, 12, 13, -1,
    4, 9, 5, 15, 14, -1,
    2, 10, 3, 13, 12, -1]
   color Color {
    color [
     0.0 0.0 1.0,
     0.0 1.0 0.0]}
   colorPerVertex FALSE
   colorIndex [0, 1, 1, 0, 2, 3, 3, 2, 4, 5, 5, 4 ]
  }}}
```

Figure 1: Part of .wrl File of the CAD Model.

Details of VRML Scene Graph Nodes

VRML file is used to describe shape of the 3D object in terms of triangulated data. It is a text file format where vertices and edges for 3D polygon can be specified with appearance details. It is a standard language for the animation and 3d modeling of geometric shapes. The objects in a VRML file are called nodes. The structure of VRML form by arranging the nodes hierarchically called as scene graph. The Scene Graph structure of a VRML file has shown in the figure 2. VRML scene graph maintains following details about the model:

- Shape nodes describe actual geometry and appearance
- Property nodes modify geometry
- Grouping nodes cause groups of objects to be modified as one object
- Primitives are predefined basic shapes i.e. cube, sphere, cone and cylinder
- Material node specifies material properties like ambient, diffuse, specular, emissive, shininess, transparency
- Transform node consists of all the transformation functions like translation, rotation, scaling
- Light node is used to specify light effect
- Sensors defines basic user interaction and animation primitives
- Scripts allow the world creator to define arbitrary behaviors, defined in any supported scripting language

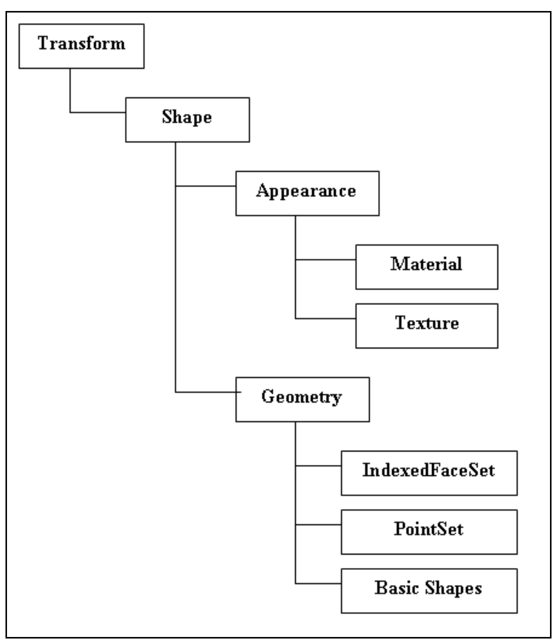

Figure 2: Scene Graph Structure of VRML File.

DESIGN ASPECTS OF VISUALIZATION SYSTEM

This visualization suite is a VC++ application which demonstrates 3D interface for VRML models. This interface can be used to represent complex datasets in 3D with additional visualization facilities. This suite reads a smooth three dimensional object that has been approximated by triangles. The program reads in this triangle mesh, calculate normal for each triangle, and display the object with lighting enabled. The user will be able to manipulate the model using the mouse. The triangle meshes for each object are stored in either VRML format, the program reads these files and display them in OpenGL.

This visualization suite loads .stl or .wrl file as an input, parses the file and then displays the model on the screen (Seth et al., 2005). Develo1pment of this software is categorized into two stages,

1. Parsing – reading the inputted .stl or .wrl file, extracting the details from inputted file which are required for visualization. Parser stores the details of the model as a scenegraph structure. The code is written in C/C++ to perform parsing.
2. Rendering – setting the graphics environment and displaying model on the monitor with support of additional visualization features. Data sets of the model available in the structures are passed to OpenGL for rendering.

```
OffsetToString(viewpoint) // pointer to locate the position in buffer
Allocate the memory for data structures
Scan the material properties, save it into structure
OffsetToString(point)
Each vertex's x, y, z co-ordinates are read from the buffer stored in data
structure according to their CoordIndex
        vertex[i][0]=x;
        vertex[i][1]=y;
        vertex[i][2]=z;
OffsetToString(IndexeFaceSet)
Each polygon's coord-indices are read from the buffer and stored in data
structure
        face[i][0]=v1;
        face[i][1]=v2;
        face[i][2]=v3;
If the vrml file contains color, light source, viewpoint etc details, these
details are saved in respective data structures.
If the vrml file contains more than one component same thing continues for
remaining.
```

Figure 3: Pseudo code for VRML File Parser.

Parser

This Visualization application reads VRML file consisting of a list of triangles which represent the object to be built in rapid prototyping. Translating an object from the VRML format generated by CAD systems to the VR space is facilitated by the wealth of information held in these files. These files consist of a list of triangles in 3D space. Each triangle definition contains coordinates in 3D space for each point of the triangle as well as other details about the CAD model. This format is ideal for Virtual Reality since the representation of objects in VR is itself a tessellated representation. Parser module receives VRML file as input and creates display structure after parsing. Figure 3 explains pseudocode for VRML file parser implemented in our research.

Renderer

Rendering, is the process of creating and displaying image on the screen. Regarding the object the triangulated details are present in VRML file (Yap et al., 2008). Initially shapes are constructed from geometric primitives, thereby creating mathematical descriptions of objects. Next arranging the objects in three-dimensional space and select the proper point for viewing the composed scene takes place. After this calculation of color, material, light and texture of the object is done. OpenGL, an application program interface used as a software development tool for graphics application. It provides direct control over fundamental operations of graphics. It provides primitive set of rendering commands that can be used to display the CAD model. Since the .wrl file represents the model in mesh form, GL_TRIANGLES command is used for rendering. Figure 4 shows the part of the VRML display program implemented in our work. Figure 5,6 are the snapshots of the outputs of visualization tool developed in our research.

```
for(int i=0;i<no_face;i++)
{
 x=0;
 glBegin(GL_POLYGON);
   glNormal3d(normal[i][0],normal[i][1],normal[i][2]);
   while(x<3)
   {
    glVertex3d(drawv[l][0],drawv[l][1],drawv[l][2]);
    l++;
    x++;
   }
 glEnd();
}
```

Figure 4: Sample Code for VRML File Display.

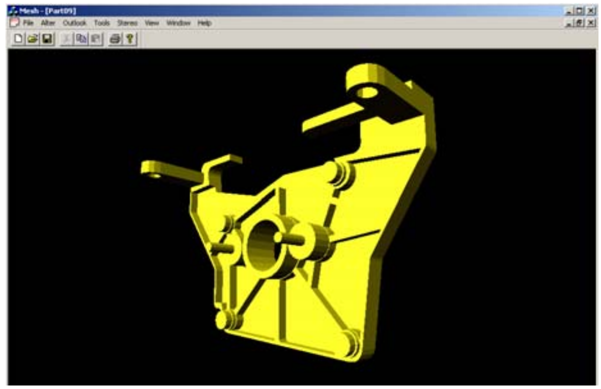

Figure 5: Display of VRML 1.0 Model.

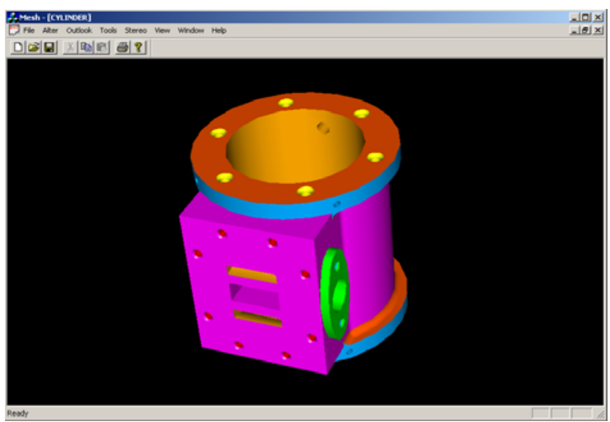

Figure 6: Display of VRML 2.0 Model.

COST EFFECTIVE 3D VISUALIZATION OF CAD MODELS

Stereoscopic display is a fundamental part of virtual reality (Robertson et al.1997). It is an effective way to enhance insight in 3D scientific visualization. This visualization suit demonstrates how a low end, inexpensive viewing technique can be used as a trick to produce the same effect as high-end stereo viewing. This low cost stereo technique is called as passive stereo (Kamath & Kamat, 2010). The model rendered in this tool provides depth as its parameter along with height and width. This enables the rotation of model, to view the model from any angle. Even though stereo offers 3 dimensions of viewing angle, the image is generally viewed on a 2D plane (Iqbal et al., 2007). The 3rd dimension is visualized by wearing stereo enabled glasses. Special 3D glasses to trick the viewer's eyes into seeing the virtual environment in three dimensions. An anaglyph is a method of viewing stereoscopic images using red-blue colored spectacles. The left view in blue (or green) is superimposed on the same image with the right eye view in red. When viewed through eye ware of corresponding colors but reversed, the 3D effect is perceived.

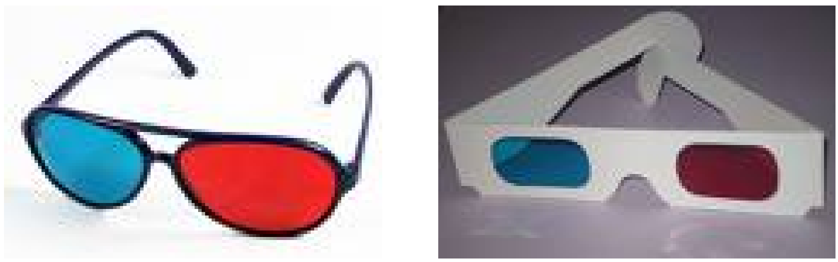

Figure 7: Red Blue Glasses for Passive Stereo used in this Research.

Time Parallelism Technique for 3D Vision

In this research, time parallelism technique is used to achieve passive stereo vision. Time-parallel methods present both eye views to the viewer simultaneously and use optical techniques to direct each view to the appropriate eye. This method requires the user to wear glasses with red and blue lenses or filters. Both images were presented on a screen simultaneously; hence, it is a time-parallel method.

The real trick is figuring out the best way to present the left and right eye images to just the left and right eyes, respectively. In passive stereo technique to view the 3D scene Red-Blue Anaglyph is used. Left and right eye images are combined into a single image consisting of blues for the left eye portion of the scene, reds for the right eye portion of the scene, and shades of magenta for portions of the scene occupied by both images. The viewer wears a pair of glasses with red over the left eye and blue over the right eye. Each eyepiece causes the line work destined for the other eye meld into the background and causes line work destined for its own eye to appear black. The key fact of stereo viewing is to generate two views of the scene, one from each eye position. This can be achieved by maintaining separate drawing buffers for the left and right eyes. Both the images are drawn on the screen. Left eye sees one image and the right eye sees another image. Combination of this in brain gives the 3D effect. The human brain processes received information from two eyes and displays 3D visualization system (Zorriassatine et al., 2003). The figure 8 shows the snapshot of VRML model in passive vision mode. It is an anaglyph output of this visualization tool.

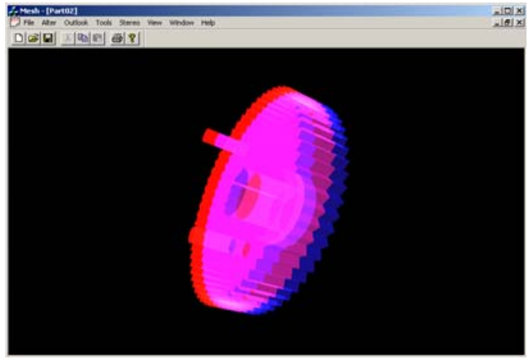

Figure 8: Passive Stereo Vision of VRML Model.

CONCLUSION

We have demonstrated a simple, low-cost technique for bringing VR involving stereoscopic display into the class-room. With a combination of inexpensive hardware and simple-to-use software, students can also enjoy the excitement of programming eye-popping 3D visualizations.

In the current implementation, this visualization suite is able to browse the VRML files. The 3D scenes are rendered by reading .wrl, with an inclusion of properties: applying various lights, material colors, options for solid, wire frame, points and lines viewing, texture mapping, transformation, different camera views etc. A stereoscopic display is a prime part of this implementation that accounts for virtual reality. The passive stereo is a low cost 3D visualization technique. It enables the user to enter a world of Virtual Realism.

This visualization suite offers affordable 3D interface for mechanical engineering students. It involves viewing and manipulation of 3D models, of manufactured components and large assemblies of products. It is a key part of product lifecycle management. Product visualization typically provides high levels of photorealism so that a product can be viewed before it is actually manufactured.

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REFERNCES

Balc, B. & Campbell, R. (2004). *From CAD and RP to Innovative Manufacturing*, Computing and Solutions in Manufacturing Engineering – CoSME 2004.

Carey, R. & Bell, G. (1997). *The annotated VRML 97 Reference Manual* http://accad.osu.edu/~pgerstma/class/vnv/resources/info/AnnotatedVrmlRef/appd.htm

Bowman, D.A., Chen, J & Chadwick, A. (2006). New Directions in 3D User Interfaces. *The International Journal of Virtual Reality, 5(2),* 3-14.

Wuest, H. & Stricker, D. (2007). Tracking of industrial objects by using CAD models. *Journal of Virtual Reality and Broadcasting, 4.*

Iqbal, M., A. H. M. Samsuzzoha, M. S. J. Hashmi, (2007). Modeling and Visualization of A 3D Mechanical Workshop. *Journal of Mechanical Engineering, vol. ME37.*

Kamath, R.S. & Kamat, R.K. (2010). Development of Cost Effective 3D Stereo Visualization Software Suite for Manufacturing Industries. *Indian Journal of Science and Technology,* (*3*), 564-566.

Lehner, V. D. & DeFanti, T. A. (1997). Projects in VR: Distributed virtual reality supporting remote collaboration in vehicle design. *IEEE Computer Graphics and Applications, 17(2),* 13–17.

Hamada, M. (2008). An Example of Virtual Environment and Web-based Application in Learning, *The International Journal of Virtual Reality, 7(3),* 1-8.

Magnenat, N. & Thalmann. (2006). Interactive Virtual Humans in Real-Time Virtual Environments. *The International Journal of Virtual Reality,* 5(2), 15-24.

Ostones, R., Abbott, V. & Lavender, S. (2004). Visualization techniques: An Overview – Part 2. *The Hydrographic Journal, 114,* 3-9.

Pratt, M., (1995). Virtual Prototyping and Product Models in Mechanical Engineering. *In Virtual Prototyping—Virtual Environments and the Product Design Process,* pp. 113-128.

Robertson, G., Czerwinski, M & Dantzich, M. (1997). Immersion in Desktop Virtual Reality. In *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST 1997).*

Seth, A., Smith, S.S., Shelley, M & Jiang, Q. (2005). A Low Cost Virtual Reality Human Computer Interface for CAD Model Manipulation, *Spring.*

Yap, H., Zahari, T., Liew, S, Ghazilla, R., Ahmad, O. (2008). *Development of a 3D CAD Model Conversion and Visualization System using Lexical Analyzer Generator and OpenGL*, APIEMS 2008 Proceedings of the 9th Asia Pasific Industrial Engineering & Management Systems Conference.

Zorriassatine, F., Wykes, C., Parkin, R., Gindy, N., (2003). A survey of virtual prototyping techniques for mechanical product development. *Journal Proceedings of the Institution of Mechanical Engineers*, *Part B: Journal of Engineering Manufacture*, *217(4)*, 513-530.