

An Effective Stereo Visualization System Implementation for Virtual Prototyping

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Abstract — Virtual Reality technology is becoming an increasingly popular in diverse areas from scientific data analysis to entertainment. An important feature of this technology is the Stereoscopic display of computer-generated images to produce three-dimensional visual effects. The visualization tool is an ASCII text file driven system to visually simulate the modeled operation in 3D virtual space. Stereovision improves the manufacturing process by analyzing the product before its actual manufacturing. The goal of the virtual prototyping environment is to decrease product development time and costs and also to increase quality by providing continuous computer support for the development cycle. This paper addresses implementation of 3D stereo visualization system which serves in virtual prototyping for productivity improvement in Manufacturing Processes.

Keywords—Passive Stereo Vision, STL File, VRML File, Immersion, Virtual Reality, Stereoscopic Display

I. INTRODUCTION

Presently manufacturing industries try hard to be most efficient and cost effective in the market. The development of physical prototypes, their verification for assembly, disassembly and maintenance tasks has been critical. Reduction in product development cycle time and cost are important area of focus. Stereo Visualization technology is a major contributor to achieve this goal. The Virtual Prototypes will give an opportunity to experiment with innovative designs, gain greater insight earlier in the development cycle, make quantifiable improvements, and make sure that products will work as intended before investing a significant amount of time and money for creating physical systems. Stereo Visualization helps for improving products, correcting processes, reducing design-to-manufacturing time, and reducing product costs. [13]

A. Problem Statement

Physical prototyping is a major bottleneck in rapid product design. It slows down the product development process. Also, after a prototype has been built and tested, a significant amount of time is spent in creating instructions for performing assembly and service. Virtual prototyping is found to be an alternative for product development difficulties. It enables to troubleshoot problems within existing designs and to significantly reduce the risk associated with developing new designs. [4] Since virtual prototyping is an important activity in product development, the virtual reality in this track got lot of attention.

The mechanical components are designed using modeling software like Cad/Cam, Catia, Pro/E, I-deas, and Solid Works etc. Modeling software 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. After designing the object in modeling software, the model can be exported into different ASCII file formats. The ASCII file contains geometry and non-geometric information about the model. Non-geometric information like kinematics constrains, material weight, etc., are not required for visualization. The visualization system enables easy generation of realistic 3D animations using supported data file formats. In this research specifically considered file formats are STL (Stereo Lithography) and VRML (Virtual Reality Modeling Language).

B. Objectives

The manufacturing industries maintain CAD database for models. After the design of the model, it can be exported in to ASCII format. [1] The visualization solution accesses geometric data which are required and presents it in a useful fashion. Means it provides immersive, stereoscopic access to that database and renders the model in 3D so that user can able to see a stereoscopic model as if it is physically there. Virtual prototyping for manufacturing assembly provides various studies related to manufacturing and depending on that one can take the decision.

As an example the VRML file Cylinder.wrl generated from I-Deas having the size 456KB. This file contains nearly 150KB of data that are not needed for visualization. Execution of such file in stereo mode in modeling software results in slow operation on general purpose computer. But visualization suite reported here fetches only the required data sets for visualization, thus makes the suit efficient.

II. RELATED STUDY

Objectives of Stereo Visualization in Virtual Prototyping are improving products, correcting processes, reducing design-to-manufacturing time, and reducing product costs. It is the concept of displaying visualizations to audiences using 3D and high-resolution technology. The present research work focuses on the cost effective 3D Stereoscopic visualization suite affordable to everyone. This section presents background of Virtual Prototyping, role of Stereo Vision in Manufacturing

industries, and the details about CAD data which is considered as input for this software.

A. Virtual Prototyping

Virtual prototyping is a computer-based engineering method that consists modeling a mechanical system, visualizing its 3D view under real-world operating situation, and refining the design through iterative process former to building the first physical prototype. [7] It uses 3D modeling and engineering data to visualize and analyze designs without making physical prototypes. In the development cycle it allows engineers to visualize their full-system design ideas on the computer, with realistic 3D models. It enables manufactures identify design related problems in beginning. Physical prototype will be built at the end. The reduction of the time to market of a product is a major contribution of VP in manufacturing.

The simulated virtual manufacturing environment generated by virtual prototyping enables to develop and optimize production, assembly, machining, and other manual and mechanized manufacturing processes eliminate the need for physical product prototypes. [12] Immersion is the great reason to attract manufacturing engineers. Here the brain is interacting with visual information. The benefit is that better understanding of the model before its actual manufacturing which reduces number of iterations in design.

B. Stereovision in Manufacturing

In the field of manufacturing industries, the distinctive advantage of Stereo Visualization application compared to traditional way of planning is that this technology allows the user to feel his presence in the assembly environment without actually being present. [2] It provides an alternative way for traditional iterative process of repeated development of hardware prototypes for experimentation and performance evaluation. Simulation is a powerful tool to analyze the product during manufacturing process. Stereovision is integrated with product development process in manufacturing industry. [6] The visualization setup helps in visualization of the components, assemblies and the entire engine in 3D and performs walkthrough, flythrough, assembly visualization etc. The advantage of using virtual prototype in an immerse design virtual reality environment are currently being studied by few large manufacturing companies.

Following tasks are performed in manufacturing environment for virtual simulation,

- Importing the ASCII format of CAD model created in modeling software
- Software tool parses the ASCII file and displays this model on the screen
- Model displayed on the monitor viewed by wearing stereo glasses to get 3D effect
- Finally output analysis, verifying the product virtually
- Walk-through and impact assessment of components and assemblies

- Finally manufacturing the actual product

C. CAD Data

Initially models are designed under CAD system. Modeling software can export these designs into ASCII format. The formats of the text file considered in this research are STL and VRML. This text file defines description of the object in terms of triangulated data. All the details of the object such as vertices and edges of the polygon; surface color, material, lighting, shininess etc are represented in triangulated fashion. The text file generated by CAD system represented as 3D model on the screen by using the information present in the file. Visualization tool reads these details present in ASCII file and renders the model on the screen. Even though these files contain huge details about the model, visualization software imports only the required data, required for visualization.

III. STRUCTURAL DESIGN

Fig. 1 shows the data pipeline from the CAD system to the Virtual Prototyping system. CAD systems are the source of most of the data. The objects designed under CAD system are exported to ASCII format. The visualization tool explained in this paper accepts these ASCII files as input. The tool displays the model in 3D for virtual prototyping by executing following modules,

- Parsing - reading the inputted .stl or .wrl file, extracting the details from inputted file.
- Retrieval – retrieves only the geometric information which is required for visualization.
- Calculate Normal – normal vector defines the orientation relative to the light sources.
- Storing – fetched details about the model are stored as a scenegraph structure.
- Tessellation - tiling of the collection of facets with no overlaps and gaps.
- Rendering – OpenGL, the graphics tool used for rendering the model on the screen
- Stereo vision - produces three-dimensional visual effect of the CAD model on the screen.

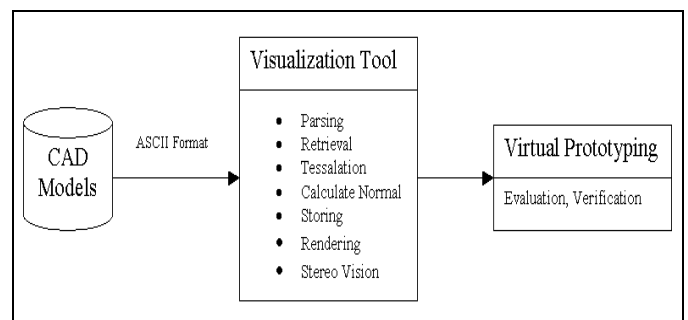


Figure 1. Data Pipeline from CAD to Virtual Prototyping

The visualization tool discussed in this paper has used OpenGL for stereo rendering. OpenGL is a software interface to graphics hardware, used for VR graphics. It consists of number of distinct commands, which are used to specify the objects and operations needed to produce interactive three-dimensional applications. [8]

IV. METHODOLOGY

Visualization is a tool for interpreting image data fed into a computer and generating images from complex multidimensional datasets. [5] Stereovision is a feature of visualization software, which adds reality to computer-generated scene. The methodology adopted in this software is mainly divided into two modules, Parser and Renderer. The key component of this visualization software is parsing the ASCII files generated by modeling software and to render the corresponding image on screen.

A. Parser

The Models designed in CAD software are exported into ASCII format, STL or VRML. This software suite imports the datasets and processes the same for visualization. Parser module accepts VRML, STL files as input and creates display structure after parsing. These display structures contains the geometric details about the model which are required for rendering. Fig. 2 explains the algorithm for the implementation of STL files. Fig. 3 explains the algorithm for the implementation of VRML files.

Pseudocode for STL file Parser,

```

START
OffsetToString(facet normal) // pointer to locate the position in buffer
Scan a word into word buffer
Normal vector's x, y, z co-ordinates read from the buffer and stored in the
array 'norm', stores normal vector of all the triangles.
    ReadWord() and copy to norm[i][0]
    ReadWord() and copy to norm[i][1]
    ReadWord() and copy to norm[i][2]
OffsetToString(vertex)
Scan a word into word buffer
Triangle's first vertex's x, y, z co-ordinates are read from the buffer and
stored in the array 'v1'.
    v1[i][0]=x;
    v1[i][1]=y;
    v1[i][2]=z;
In same way x, y, z co-ordinates of all the vertices are read from the buffer
and stored in v1, v2 and v3. The array v1 contains the coordinate's values of
the first vertex of all the triangles. v2 contains the coordinates values of the
second vertex of all the triangles and v3 contains the coordinates values of
the third vertex of all the triangles.
END
    
```

Figure 2. STL File Parser

Pseudocode for VRML 1.0 file Parser,

```

START
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.
END
    
```

Figure 3. VRML File Parser

B. Renderer

Rendering, is the process of creating and displaying image on the screen. The object's triangulated details are present in VRML and STL file. It is difficult to see the shape of the object clearly when only points are displayed. Lines to form a mesh or wire frame then connect the points. The wire frame clearly shows a group of polygons. It is important to note that polygons have only one side. A polygon's face is the side from which its normal points away from the polygon. To produce the appearance of solid objects the shading has done to individual polygons.

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. The final rendered image consists of pixels drawn on the screen. The graphics tool OpenGL is used in this implementation for all the phases of display. [8]

The display structure created by parser contains details about the model. These data used by renderer for the display of the model on the screen. This software supports the additional features to enhance the visualization. The process of rendering the component on the screen and implementation of various additional features are explained below,

Drawing the Model- STL and VRML files are triangular representation of 3D object. Each triangle is defined with its normal and three vertices. These values are taken from data structures for the display. In case of STL files, data present in a triangle is same as the structure of GL_TRIANGLES. This has simples task of displaying the model, by directly taking the data from data structures. VRML encloses all the visualization

details of the model. 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.

Transformation - Transformation options like Rotation, Panning and Zooming of the model on the screen are enabled. Fig. 4 explains the algorithm for the implementation of transformation options.

Set Material Properties – This feature allows selecting the required material properties and lightings. The standard specified materials are put up and the provision is given to the user to select whichever material he likes. The selected material is then applied for the object. One of the more interesting aspects of working in 3-D is that to visualize how the design will look like. The realistic effect can be achieved by adding lighting and materials to the design. Applying the materials makes the model to look exactly the way how it is required. Fig. 5 explains the algorithm for configuring material properties.

Pseudocode for transformation options,

```

START
The model displayed on the screen can be translated by holding mouse Left Button Down and moving the mouse.
    glTranslated(m_xTranslation,m_yTranslation,m_zTranslation)
The model displayed on the screen can be Zoomed by holding mouse Right Button Down and moving the mouse.
    glScalef(m_xScaling,m_yScaling,m_zScaling);
The model displayed on the screen can be Rotated by holding mouse Left and Right Button Down and moving the mouse.
    glRotatef(m_xRotation, 1.0, 0.0, 0.0);
    glRotatef(m_yRotation, 0.0, 1.0, 0.0);
    glRotatef(m_zRotation, 0.0, 0.0, 1.0);
END
    
```

Figure 4. Transformation option for the model

Pseudocode for setting material properties,

```

START
Material properties such as Ambient, Diffuse, Specular and shininess values are defined for gold, silver, chrome, emerald, perl, copper, brass, bronze etc
Desired material properties are specified to the model by,
    glMaterialfv(GL_FRONT, GL_AMBIENT, matAmbient);
    glMaterialfv(GL_FRONT, GL_DIFFUSE, matDiffuse);
    glMaterialfv(GL_FRONT, GL_SPECULAR, matSpecular);
    glMaterialf(GL_FRONT, GL_SHININESS, shine * 128.0f);
    Draw(), draw the model
END
    
```

Figure 5. Setting Material Properties

Display Mode – This feature provides options for rendering the model in various modes i.e. solid, wireframe and point,

- Solid – The default mode in which object has rendered. Here the object has filled up and it gives the viewer the feeling that it is made of hard solid.
- Wireframe – Only the wire mesh is displayed with no part of it being filled up as in the solid mode. It displays the triangularly linked vertices
- Point – Only the vertices are displayed without connecting them to one another

Fig. 6 explains the algorithm for implementation of changing display modes.

View - The viewer can view the rendered model through different angles along different axes. Different camera views displays the model's front, back, left, right, top, bottom and isometric view,

- Front – Default placement of the 3D scene, i.e., viewed along the XY plane
- Back – Along the YX plane
- Top – Along the XZ plane
- Bottom – Along the ZX plane
- Left – Along the ZY plane
- Right – Along the YZ plane
- Isometric – Along the three axes having a mutual inclination of an angle of 45. Isometric view is the simplest way to give a 3D representation of 2-D drawing.

Fig. 7 explains algorithm for implementation of changing camera views.

Pseudocode for various display modes,

```

START
The drawing mode is specified before drawing the polygons by
    glPolygonMode(GL_FRONT_AND_BACK,m_Mode);
        Point - m_Mode = GL_POINT
        Line - m_Mode = GL_LINE
        Solid - m_Mode = GL_FILL
END
    
```

Figure 6. Display Modes

```

START
  Model is rotated according to the required viewpoint.
  Front - Model is displayed in original viewpoint.
          glRotatef(0.0,0.0,0.0,0.0);
  Back - model is rotated along 180 deg along Y axis,
          glRotatef(180.0,0.0,1.0,0.0);
  Top - model is rotated along 90 deg along X axis
          glRotatef(90.0,1.0,0.0,0.0);
  Bottom - model is rotated along 270 deg along X axis
          glRotatef(270.0,1.0,0.0,0.0);
  Left - model is rotated along 90 deg along Y axis
          glRotatef(90.0,0.0,1.0,0.0);
  Right - model is rotated along 270 deg along Y axis
          glRotatef(270.0,0.0,1.0,0.0);
  Isometric - model is rotated along 45 deg along X, Y and Z axis
          glRotatef(45.0,1.0,1.0,1.0);
END
    
```

Figure 7. Camera Views

V. STEREOSCOPIC DISPLAY

Stereoscopic display is a fundamental part of this research to produce three-dimensional visual effects. [3] When the humans see the world, each eye constructs slightly different view. By combining these two views suitably, viewer's brain reconstructs a true three-dimensional view. This principle is used in this research to achieve 3D effect. Stereo vision provides depth cues, which gives better visual effects to the user than 2D projection. The model viewed in this software, has depth as one of its parameters. Thus software allows rotation of an object to view the item from any angle.

A. Implementation

The main idea of stereo viewing is to generate two views of the scene, one from each eye position. The position of the eyes is specified in terms of eye separation parameter. Having separate drawing buffers for the left and right eyes does stereo display. 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. Fig. 8 shows parallel view and view frustum produces a single view plane and overlapped images.

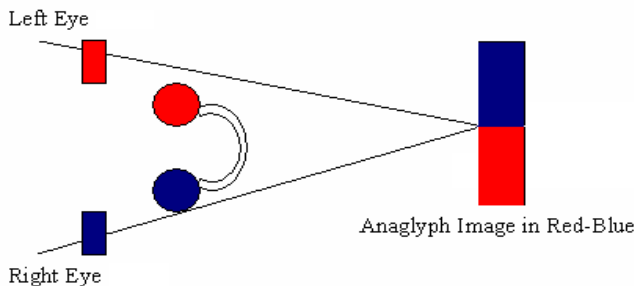


Figure 8. Passive Stereo Vision –Image drawn in Red & Blue

B. Display Technology

Stereo is a direct method of obtaining 3D structure of visual world, which makes it attractive for applications. Here the three-dimensional scene can be viewed using stereo glass to perceive 3D effect. Even though the image is generally viewed on a 2D plan, stereo offers 3D of viewing angle. The third dimension is implied rather than exhibited.

The cost effective stereo visualization technique implemented in this research is Anaglyph. [1] It is a passive stereo method in which two images of the same object displayed on the screen, one for each eyes view. Typically, the left eye image is projected in blue and the right eye is either red. Viewers wear glasses having a red filter over the left eye and a blue filter over the right, so that each eye only sees the intended image. This is very easy to produce with no special equipment and can be viewed on a computer monitor or from a projected image using inexpensive cardboard glasses. This research work demonstrates how a low end, inexpensive viewing technique can be used as a quick trick to produce many of the same affects as high-end stereo viewing.

The other techniques for stereovision are,

- Active stereo requires a high-speed system with stereo supported graphics card, infrared emitter and LCD shutter glasses. It produces an excellent stereo effect and is generally used in high-end VR environments. But the problem with active stereo is that it is very expensive because of its hardware requirements.
- Polarized Stereo is a passive stereo technique in which two projectors are used for the single screen, one for each eye's view. Polarizing filters are placed in front of each projector lens. The projectors project two images onto a specially coated screen, which reflects the polarized light correctly. Then users wear polarizing glasses where each lens only admits the light from the corresponding projector. It enables the user to view 3D image. It uses LCD projectors.

When visually immersed within a virtual environment, it creates a natural temptation to touch virtual models but there is nothing to touch and to feel. But, the user's sense of immersion can be greatly improved by embedding some suitable hardware components, such as data gloves, which enable the user to sense.

VI. CONCLUSION

Before manufacturing the actual component it is possible to represent model on the screen, translate, rotate, scale and assembled with other parts. Stereovision allows the designer to view virtual object represented by CAD drawings to get better visual effect because of 3D. User can perform walkthrough, viewing the object from various angles that are not possible in 2D. A 3D immersive visualization system changes the dynamic of manufacturing process by observation rather than by applying physical prototyping.

This study verifies the feasibility of virtual prototyping simulation to improve the production applicable to the manufacturing industries. Stereo visualization plays an

important role in virtual prototyping. By incorporating Stereo Visualization along with other Virtual Reality techniques, manufacturing industries can save lot of time and effort in developing products.

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