The Use of VRML to Integrate Design and Solid Freeform Fabrication

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ABSTRACT

The Virtual Reality Modeling Language (VRML) was created to put interconnected 3D worlds onto every desktop. The 3D VRML format has the potential for 3D fax and Tele-Manufacture. An architecture and methodology of using VRML format to integrate a 3D model and Solid Freeform Fabrication system are described in this paper. The prototype software discussed in this paper demonstrates the use of VRML for Solid Freeform Fabrication process planning. The path used from design to part will be described.

1. INTRODUCTION

The STL or Stereolithography format, established by 3D System, is an ASCII or binary file used in Solid Freeform Fabrication (SFF). It is a list of the triangular surfaces that approximate a computer generated solid model. This file format has become the *de facto* standard for rapid prototyping industries. But STL format has the limitation of visualization, communication and sharing information among different places. In the recent years, Tele-Manufacture has become a new area in the design and manufacture research. Researchers try to create an automated rapid prototyping capability on the Internet (Bailey, 1995). In order to improve the communication and information exchange through Internet, a new data format is needed for SFF. Bauer and Joppe (1996) suggested to use Virtual Reality Modeling Language (VRML) data format as standard for rapid prototyping. VRML was created to put interconnected 3D worlds onto every desktop and it has become the standard language for 3D World Wide Web. VRML is also a rapidly emerging industry standard for exchanging three-dimensional data over Internet, and has the potential for 3D fax and Tele-Manufacture. This paper describes the use VRML as 3D model description for the SFF process planning. The path used from CAD system to SFF part is described.

2. SFF PART DATA EXCHANGE FORMATS

Several intermediate data formats have been developed to transfer the 3D geometry information to the process planning for SFF.

The STL file is the most widely used standard for SFF processes. This format represents a solid object by approximating the object surface with a collection of triangular facets. The STL file format allows for the representation of triangles and their normal vectors. Several limitations of the STL format have been recognized. Those include: redundant data representation, large file size, lack of the topological information between triangles, a non-robust and imprecise geometric representation, lack of tolerance information and extendibility

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(Gilman and Rock, 1995). Rock and Wonzy (1991) proposed a flexible and extensible RPI format, which focuses on facet models with support for additional manufacturing information. The RPI format provides the topological information and eliminates the redundant information found in a comparable STL files. Gilman and Rock (1995) presented the use of STEP (the Standard for the Exchange of Product Model Data) to integrate design and SFF. Cubital introduced CFL (Cubital Facet List) format which uses an approximate n-side polygon representation. This format maintains topological information and does not redundantly represents vertex information which happens in STL format. SLC, introduced by 3D System, represents a 3D model using two and a-half-dimensional contour data. It can be generated from solid or surface modeling software or CT scan data. CLI (Common Layer Interface) originated in the Brite-EuRam Project and is supported by the EARP (European Action on Rapid Prototyping). It is the format for the input of 2D geometric information to layer-wise SFF processes, and would support medical scan data. IGES (International Graphics Exchange Standard) is an international standard used by most CAD vendors. It represents the solid model with CSG primitives and boundary representation support. The size of this format is very large and difficult to handle.

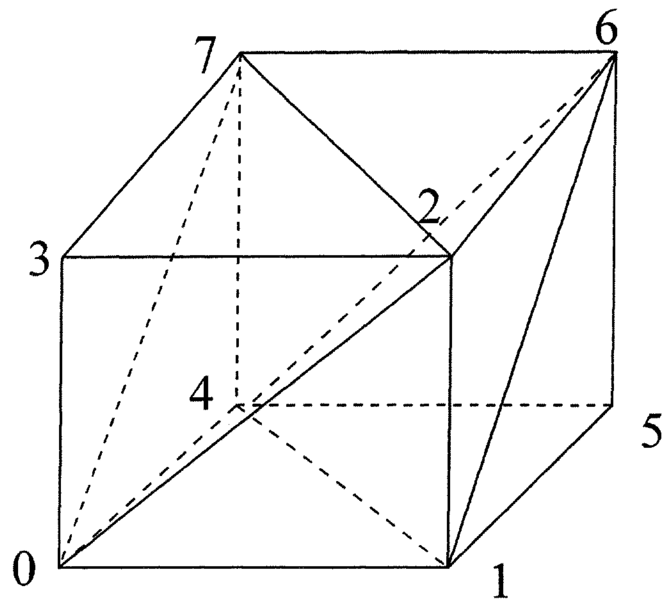
3. VRML

3.1 Overview of VRML

The origin of VRML dates back to the middle of 1994, to a European Web conference in which Tim Berners-Lee talked about for a 3D Web standard. Then the group of people picked up on this idea and joined the VRML mail list and started to produce the VRML specification. VRML is a subset of the Silicon Graphics OpenInventor file format for use in Internet application. It is a platform-independent language for virtual reality scene. This particular format has become the standard Internet Modeling Language format for the 3D World Wide Web. VRML is also a rapidly emerging industry standard for exchanging three-dimensional data over Internet.

The VRML 97 specification (ISO/IEC DIS 14772-1, 1997) states: "*The Virtual Reality Modeling Language (VRML) is a file format for describing interactive 3D objects and worlds. VRML is designed to be used on Internet, intranets, and local client systems. VRML is also intended to be a universal interchange format for integrated 3D graphics and multimedia. VRML may be used in a variety of application areas such as engineering and scientific visualization, multimedia presentation, entertainment and educational titles, web pages, and shared virtual worlds.*". San Diego Supercomputer Center (SDSC) announced the availability of a repository on the World Wide Web for exchanging information, software, and utilities related to the VRML. The repository, located at *http://www.sdsc.edu/vrml/,* provides the Internet community with information about VRML, hyperlinks to VRML documents, and access to VRML-related software.

3.2 An Example of VRML Format




```
#VRML V2.0 utf8
Transform {
    Children [
       Shape {
           appearance Appearance {
                 material Material {
                     diffuse Color 1 0 0
                          }
                      }
           geometry IndexedFaceSet {
                  coord DEF C Coordinate {
                      point [ -1.000000  -1.000000  1.000000,
                               1.000000  -1.000000  1.000000,
                               1.000000   1.000000   1.000000,
                              -1.000000   1.000000   1.000000,
                              -1.000000  -1.000000  -1.000000,
                               1.000000  -1.000000  -1.000000,
                               1.000000   1.000000  -1.000000,
                              -1.000000   1.000000  -1.000000 ]
                                }
                      coordIndex [    0, 1, 2, -1,
                                      0, 2, 3, -1,
                                      1, 6, 2, -1,
                                      1, 5, 6, -1,
                                      2, 7, 3, -1,
                                      2, 6, 7, -1,
                                      4, 6, 5, -1,
```

```
                4, 7, 6, -1,
                0, 7, 4, -1,
                0, 3, 7, -1,
                0, 4, 1, -1,
                1, 4, 5, -1 ]

                  }
              }
          ]
    }
```

Figure 1 An Example of VRML Format

Figure 1 shows an example of VRML format for a cube. In that file, the *Transform* node has a *Children* field that can hold a *Shape* node. Inside the *Shape* node, there is an *Appearance* node that holds the *Material* field. The *diffuse color* is defined in the *Material* field. Following the Material field, the *IndexedFaceSet* is used to describe the geometry of the shape. It contains the *coord DEF C Coordinate* node and the *coordIndex* multiple value field. The *point* field which lists the coordinates of the points is under the *coord DEF C Coordinate* node. The polygon is defined in the *coordIndex* by a list of indices into the *point* list. In the VRML file, polygons are still used to approximate the 3D surfaces.

Unlike STL file, the VRML format does not redundantly represent the vertex information, and reuses the points in the file. The reusability of points can save a lot of space in the file. Also VRML maintains the topological information among polygons.

3.3 Use of VRML for SFF Part Data Exchange

Several researchers have suggested applying VRML as 3D-SFF data exchange format (Bauer and Joppe 1996, Fadel 1996). However, few VRML - SFF implementations exist. Fadel and his student (1996) have done some work from STL to VRML translator. This translator allows you to view STL files on a VRML viewer.

At the University of Connecticut, the SFF process planning and virtual prototyping (using OpenGL) system have been developed directly to read VRML subset "*Material and Geomertry IndexedFaceSet*". The laser path-planning data generated by the process planning are transferred to a virtual prototyping system to check the design and process planning correctness, and then transferred to the close-loop laser scanning and temperature control system for SALD (Selective Area Laser Deposition) and SALDVI (Selective Area Laser Deposition Vapor Infiltration) for physical prototyping. The architecture of this system is shown in Figure 2.

In the system listed in Figure 2, the 3D model is built using specific CAD packages (ex,. I-DEAS , CADKey). Then it can be translated to VRML format. The new versions of CAD package (I-DEAS MS 5 and CADKey 97) contain the VRML translator. Because VRML is the standard for 3D World Wide Web, it is convenient to show 3D shapes in any platform in Netscape. This is beneficial for the remote communication between designer and manufacturer.

4. RESULTS

The production of SFF is directly from a CAD model. An I-DEAS CAD model of a bracket is shown in Figure 3. Using the VRML translator of I-DEAS MS 5, a VRML file is created for the bracket. Figure 4 shows the VRML model of the bracket displayed in Netscape. The VRML file is used as input to the process planning system - Geometric Slicing and Path Planning. Then the path planning data are transferred to the virtual prototyping system. Figure 5 shows the 3D shape of the bracket after the virtual prototyping. The coarse features are due to the scan line which is used for the virtual model building.

There are several advantages of using VRML instead of STL as 3D format for SFF. (1) VRML file has better structure and it is smaller than the comparable STL file. (2) VRML is the 3D extension of World Wide Web. (3) VRML maintains the topological information among polygons. (4) VRML can do everything that STL can do. But VRML still uses the polygons to approximate the 3D surface. So it can not improve the geometry accuracy in SFF.

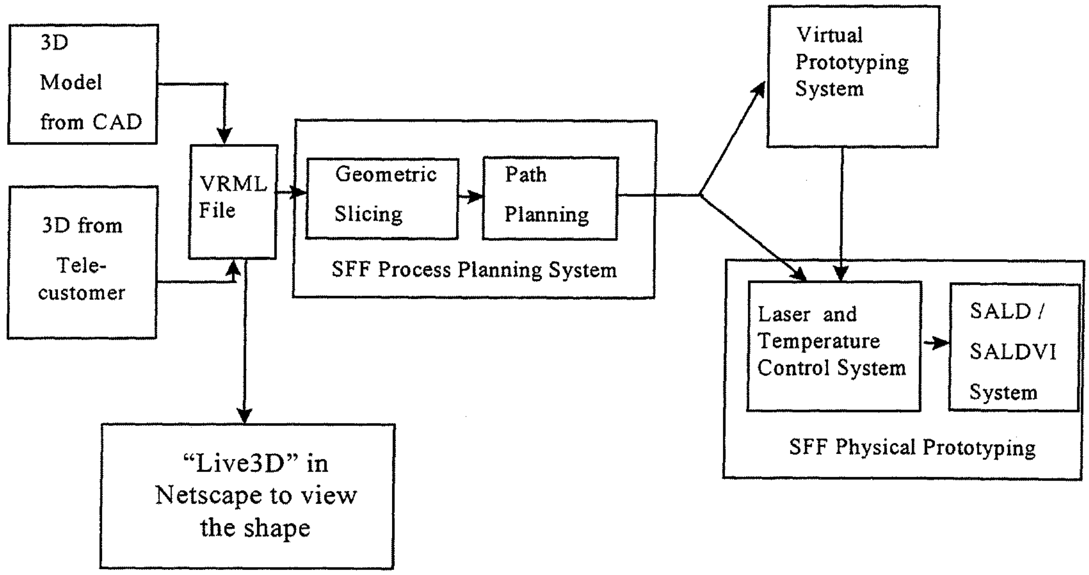


Figure 2 System Architecture

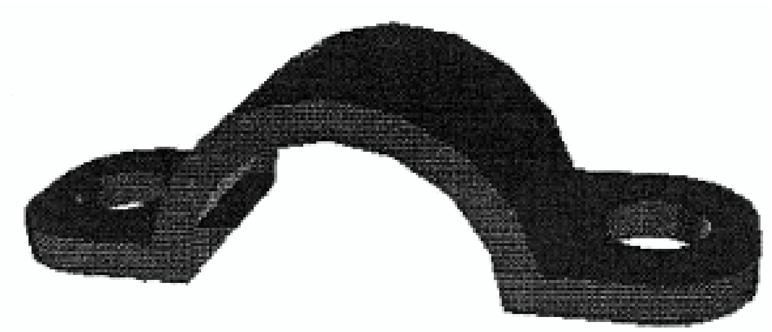


Figure 3 A CAD Model from I-DEAS Package

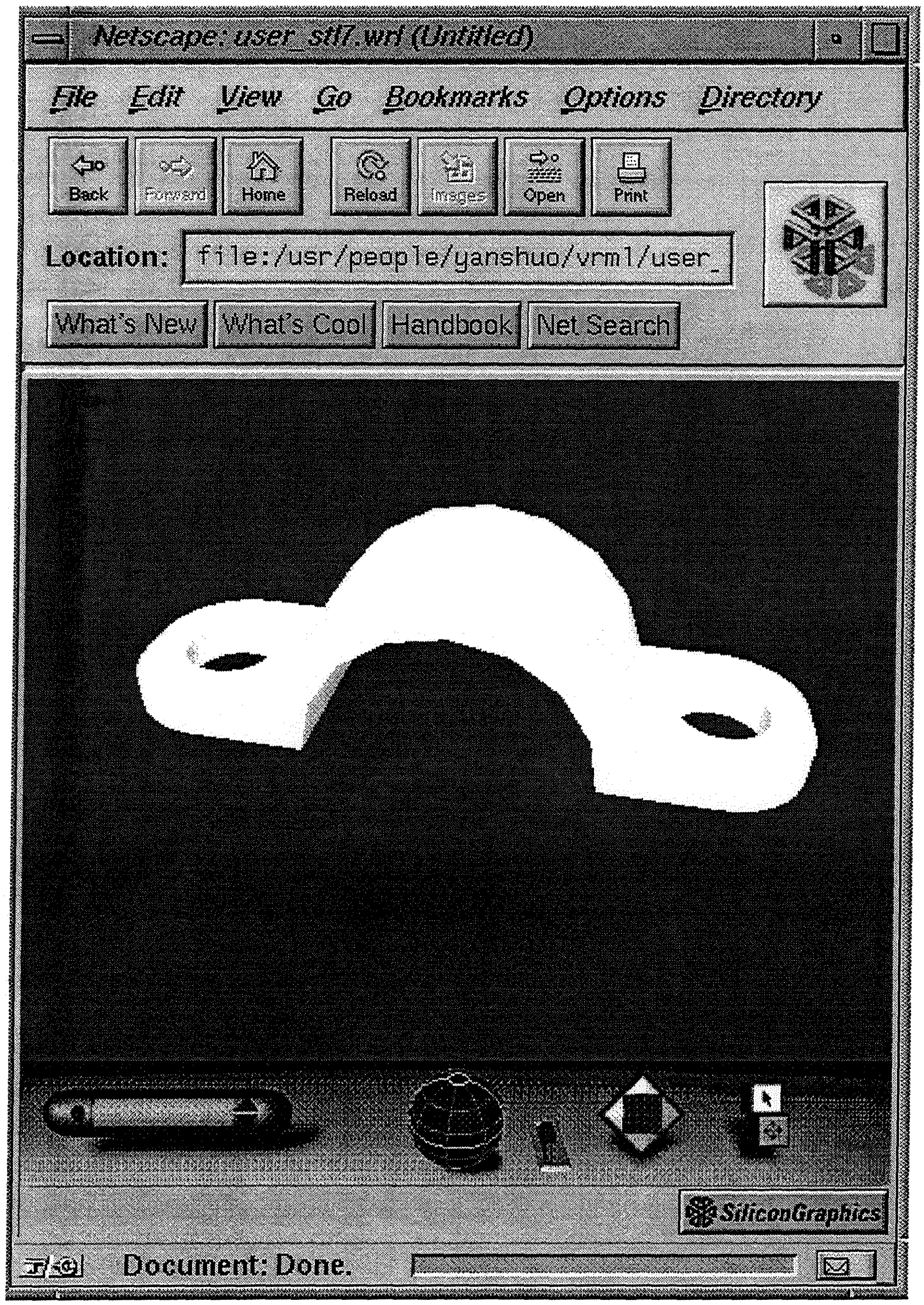


Figure 4 Bracket VRML Model Displayed in Netscape

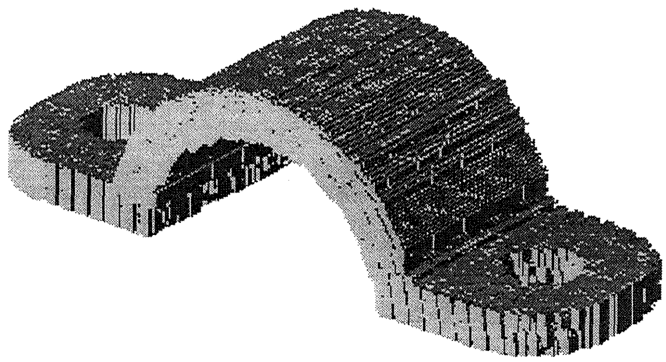


Figure 5 The Virtual Prototyping of the Bracket

5. CONCLUSIONS

VRML is a Standard for the exchange of 3D data in Internet. VRML format can do everything that STL can do. It doesn't redundantly represent vertex information, and contains the topological information among polygons. It is also independent of the platform and has become the standard 3D format for World Wide Web. So using VRML as 3D format for SFF can improve the communication between designer and the manufacturer.

The SFF process planning and virtual prototyping system that described in this paper is an example of VRML as 3D data format for SFF.

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7. REFERENCES

Bailey, M. J., 1995, "Tele-Manufacturing: Rapid Prototyping on the Internet", IEEE Computer Graphics and Applications, November, 1995.

Bailey, M. J., "Tele-Manufacturing: Rapid Prototyping on the Internet with Automatic Consistency-Checking", http://www.sdsc.edu/tmf/Whitepaper/ whitepaper.html, University of California at San Diego and San Diego Supercomputer Center.

Bauer, Jurgen and Joppe, Marcus, 1996, "Use VRML as Standard for Rapid Prototyping". http://www.biba.uni-bremen.de:80/docs/users/bau/s2v.html, BIBA, Germany.

Dolenc, A and Makela, I., 1996, "Rapid Prototyping from a Computer Scientist's Point of View", Rapid Prototyping Journal, Vol. 2, No. 2, 1996, pp. 18-25.

Dong, J., 1996, "The Issues in Computer Modeling and Interfaces to Solid Freeform Fabrication", 1996 ASME Winter Congress and Exposition, Atlanta ,GA.

Dong, J., 1997, " New Challenges in Computer Aided Solid Model Design for Rapid Prototyping of Vehicle Components", International Journal of Vehicle Design, Vol-18, No.5 pp548-557.

Fadel, G. and Krischman, C., 1996, "Accuracy issues in CAD to RP translations", Rapid Prototyping Journal, Volume 2- Number 2, 1996, pp. 4-17.

Graphics 3D Object File Formats, " 3D Object File Formats", http://www.cee.indiana.edu/~brian/graphics/3D.formats.html

Harrison, S., Crocker, J. E., Manzur, T. and Marcus, H. L., 1996, " Solid Freeform Fabrication at the University of Connecticut", Solid Freeform Fabrication Symposium, University of Texas at Austin, Austin, TX, August 1996, pp. 345-348.

ISO/IEC DIS 14772-1, 1997, " The Virtual Reality Modeling Language", http://vrml.sgi.com/moving-worlds/spec.DIS/index.html.

Lehner, V. D. and DeFanti, T. A, 1997, "Distributed Virtual Reality: Supporting Remote Collaboration in Vehicle Design", IEEE Computer Graphics and Applications. March-April, 1997, pp13-16.

Marrin, C. and Campbell, B., 1997, "Teach Yourself VRML 2 in 21 Days", Sams.net Publishing.

Martin, J., 1997, "Part Design Comes Together on the Net", Mechanical Engineering, June 1997. pp76-78.

Rock, S. J. and Gilman, C. R., 1995, "The Use of STEP to Integrate Design and Solid Freeform Fabrication", Solid Freeform Fabrication Symposium, University of Texas at Austin, Austin, TX, August 1995.

Rock, S. J. and Wozny, M. J., 1991, " A Flexible File Format for Solid Freeform Fabrication", Solid Freeform Fabrication Symposium, University of Texas at Austin, Austin, TX, August 1991, pp. 1-12.

SDSC Announces the VRML Repository: "A World Wide Web Resources for the Virtual Reality Modeling Language",http://www.sdsc. edu/vrml_repository/Press/repository_press.html

Whitehouse, K., 1996, "VRML Adds a New Dimension to Web Browsing", IEEE Computer Graphics and Applications, July 1996, pp7-9.