UNIT 4

DATA FORMATS AND SOFTWARE

STL Format

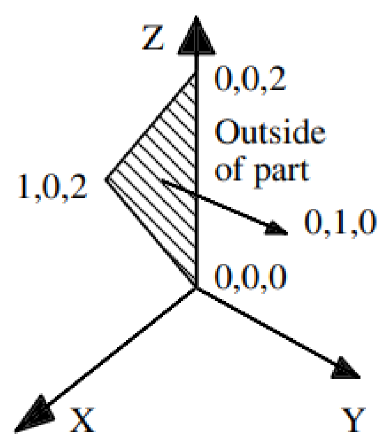
The STL file consists of an unordered list of triangular facets representing the outside skin of an object.

STL file can be specified in two formats.

1. ASCII format and
2. Binary format.

The size of the ASCII STL file is larger than that of the binary format but is human readable. In a STL file, triangular facets are described by a set of X, Y and Z coordinates for each of the three vertices and a unit normal vector with X, Y and Z to indicate which side of the facet is an object. An example is shown in below figure.

```
solid print
  facet normal 0.00000e+00  1.00000e+00  0.00000e+00
    outer loop
      vertex   0.00000e+00  0.00000e+00  2.00000e+01
      vertex   0.00000e+00  0.00000e+00  0.00000e+00
      vertex   1.00000e+01  0.00000e+00  2.00000e+01
    endloop
  endfacet
  facet normal 0.00000e+00  1.00000e+00  0.00000e+00
    outer loop
      vertex   1.00000e+01  0.00000e+00  2.00000e+01
      vertex   0.00000e+00  0.00000e+00  0.00000e+00
      vertex   1.00000e+01  0.00000e+00  0.00000e+00
    endloop
  endfacet
.......
```



Advantages of the STL file

- It provides a simple method of representing 3D CAD data.
- It is already a de facto standard and has been used by most CAD systems and rapid prototyping systems.
- It can provide small and accurate files for data transfer for certain shapes.

Disadvantages

- The STL file is many times larger than the original CAD data file.
- The STL file carries much redundancy information such as duplicate vertices and edges shown in figure.

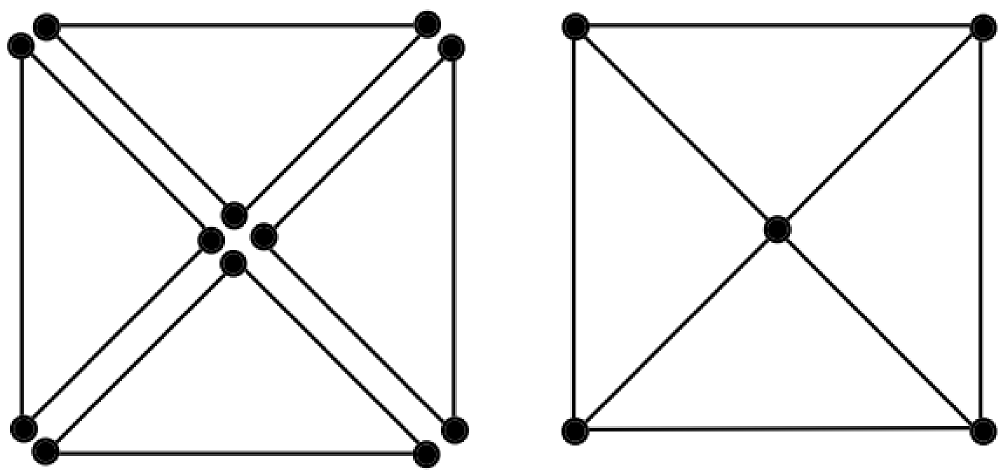


Figure 6.2: Edge and vertex redundancy in STL format

- The geometry flaws exist in the STL file because many commercial tessellation algorithms used by CAD vendor, this gives rise to the need for a repair software which slows down the production cycle time.
- The slicing of large STL files can take many hours. However some RP processes can slice while they are building the previous layer and this will avoid this disadvantage.

STL File Problems

- Several problems exist in STL files as they contain no topological data.

▪ Many commercial tessellation algorithms used by CAD vendors today are not robust and as a result they tend to create polygonal approximation models which exhibit the following types of errors.

1. Gaps (Cracks, holes, punctures) that is, missing facets
2. Degenerate facets (where all its edges are collinear)
3. Overlapping facets.
4. Non manifold topology conditions.

Reasons: Due to the difficulties encountered in tessellating surfaces, surface intersections, and controlling numerical errors. Hence it is necessary to perform model validity checks before the tessellated model is sent to the rapid prototyping equipment for manufacturing. If the tessellated model is invalid, specific problems are to be determined (whether they are due to gaps, degenerate facets or overlapping facets etc.)

Missing facets or gaps

Tessellation of surfaces with large curvature can result in errors at the intersection between such surfaces, leaving gaps or holes along edges of the part model. A surface intersection anomaly which results in a gap is shown in figure.

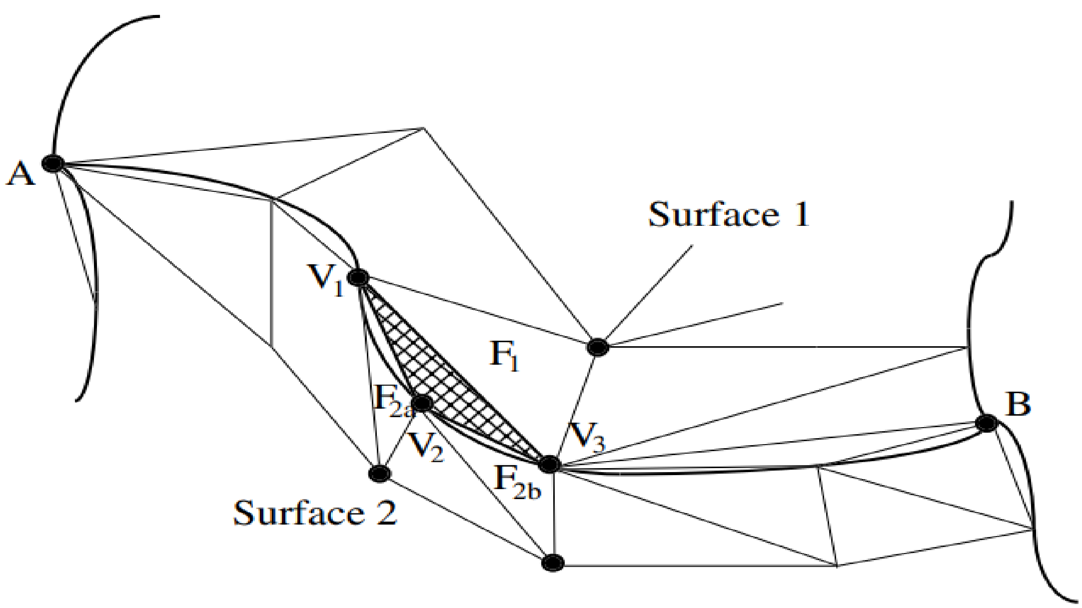


Figure 6.3: Gaps due to missing facets [4]

Degenerate Facets

A geometrical degeneracy of a facet occurs when all of the facets' edges are collinear even though all its vertices are distinct. This might be caused by stitching algorithms that attempt to avoid cell punctures as shown in figure 6.4 a below. The resulting facets generated shown in figure 6.4 b eliminate the cell punctures.

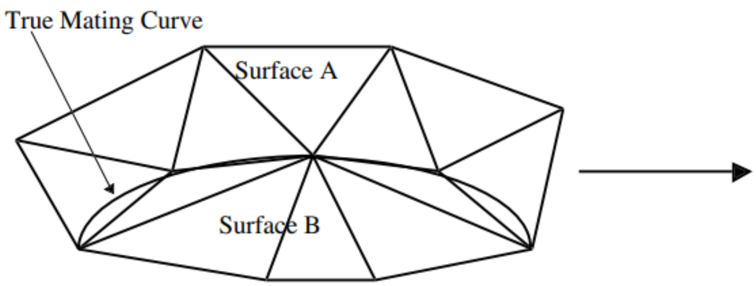


Figure 6.4(a): Shell punctures created by unequal tessellation of two adjacent surface patches along their common mating curve

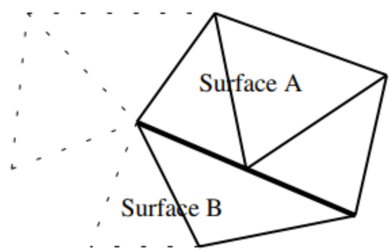


Figure 6.4(b): Shell punctures eliminated at the expense of adding degenerate facet

However this is done at the expense of adding a degenerate facet. While degenerate facets do not contain valid surface normals, they do represent implicit topological information on how two surfaces mated. This important information is consequently stored prior to discarding the degenerate facet.

Overlapping facets

Overlapping facets may be generated due to numerical round-off error occurring during tessellation. The vertices are represented in 3D space as floating point numbers instead of integers. Numerical round-off can cause facets to overlap if tolerances are set too liberally. Example of an overlapping facet is shown in figure 6.5.

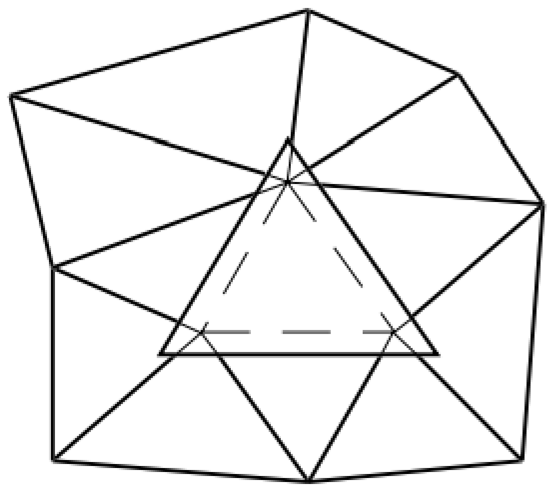


Figure 6.5: Overlapping facets

Non-manifold conditions

There are three types of non manifold conditions.

1. A non-manifold edge
2. A non-manifold point.
3. Non-manifold face.

These may be generated because tessellation of the fine features are susceptible to round-off errors. An illustration of a non-manifold edge is shown in Figure 6.6(a). Here, the non-manifold edge is actually shared by four different facets as shown in Figure 6.6(b). A valid model would be one whose facets have only an adjacent facet each, that is, one edge is shared by two facets only. Hence the non-manifold edges must be resolved such that each facet has only one neighboring facet along each edge, that is, by reconstructing a topologically manifold surface. In Figures 6.6(c) and 6.6(d), two other types of non manifold conditions are shown

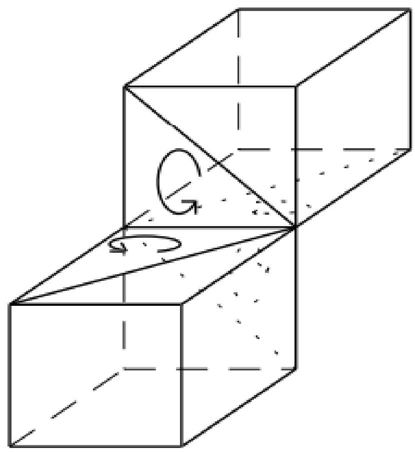


Figure 6.6(a): A non-manifold edge whereby two imaginary minute cubes share a common edge

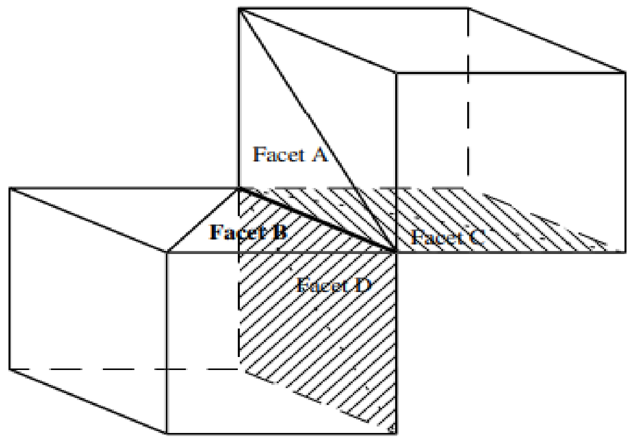


Figure 6.6(b): A non-manifold edge whereby four facets share a common edge after tessellation

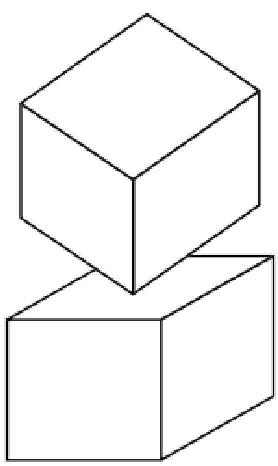


Figure 6.6(c): Non-manifold point

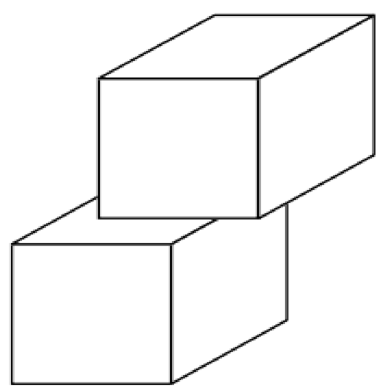


Figure 6.6(d): Non-manifold face

All these problems are difficult to handle by most slicing algorithms. They also cause fabrication problems for RP processes which essentially require valid tessellated solids as input. Thus such problems have become almost inevitable as long as the representation of the solid model is done using the STL format which inherently has these limitations.

Consequences of building a valid and invalid tessellated model.

A Valid Model

A tessellated model is said to be valid if there are no missing facets, degenerate facets, overlapping facets or any other abnormalities. When a valid tessellated model as in figure 6.7 a is used as an input, it will first be sliced into 2D layers as shown in figure 6.7 b.

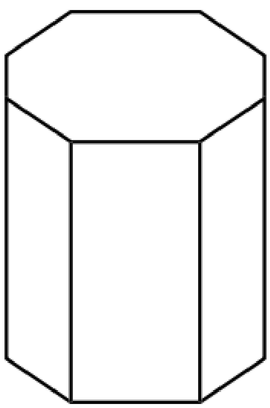


Figure 6.7(a): A valid 3D model

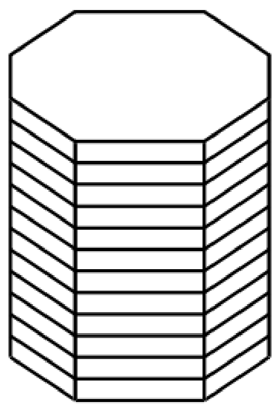


Figure 6.7(b): A 3D model sliced into 2D planar layers

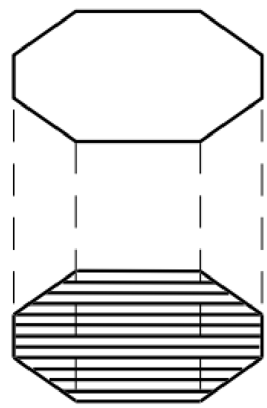


Figure 6.7(c): Conversion of 2D layers into 1D scan lines

Each layer would then be converted into unidirectional or 1D scan lines for the laser or other RP techniques to commence building the model as shown in figure 6.7c. The scan lines would act as on/off points for the laser beam controller so that the part model can be built accordingly without any problems. Each layer would then be converted into unidirectional (or 1D) scan lines to commence building the model using laser or other RP techniques as shown in figure 6.7c. The scan lines would act as on/off points for the laser beam controller so that the part model can be built accordingly without any problems

An invalid model

If the tessellated model is invalid, a situation may develop as shown in figure 6.8. A solid model is tessellated non robustly and results in a gap as shown in figure 6.8 a. If this error is not corrected and the model is subsequently sliced as shown in figure 6.8 b, in preparation for it to be built layer-by-layer, the missing facets in the geometrical model would cause the system to have no predefined stopping boundary on the particular slice, thus the building process would continue right to the physical limit of the RP machine, creating a stray physical solid line and ruining the part being produced as shown in figure 6.8 c.

Therefore it is of paramount importance that the model must be repaired before it is sent for building.

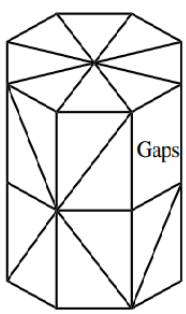


Figure 6.8(a): An invalid tessellated model

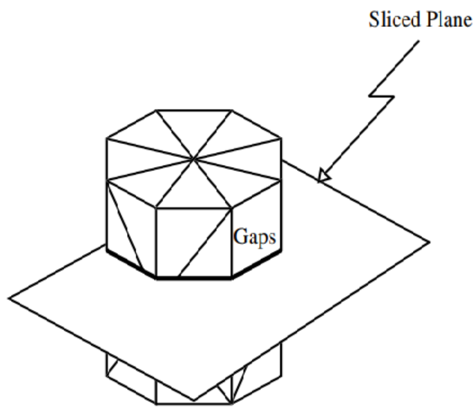


Figure 6.8(b): An invalid model being sliced

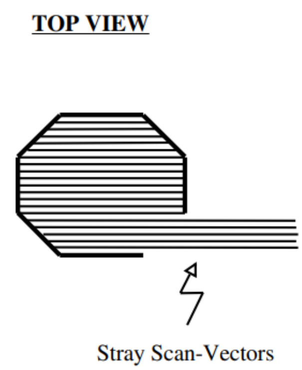


Figure 6.8(c): A layer of an invalid model being scanned

STL File Repair

The STL file repair can be implemented using:

1. A generic solution and

2. Dedicated solutions for special cases.

Generic Solution

In order to ensure that the model is valid and can be robustly tessellated, one solution is to check the validity of all the tessellated triangles in the model. In existing RP systems, when a punctured shell is encountered, the course of action taken only requires a skilled technician to manually repair the shell. This manual cell repair is frequently done without any knowledge of the designer's intent. The work can be very time consuming and tedious, thus negative the advantages of rapid prototyping as the cost would increase and the time taken might be longer than traditional prototyping process is used.

The main problem of repairing the invalid tessellated model would be that of matching the solution to the designer's intent. The generic algorithm aims to match the quality of repair done manually by a skill technician when information of the designer's intent is not available.

The basic approach of the algorithm to solve the missing facets problem would be to detect and identify the boundaries of all the gaps in the model. Once the boundaries of the gaps are identified, suitable facets would then be generated to repair and patch up these gaps.

Thus, this generic algorithm can be said to have the ability to make an inference from the information contained in the STL file so that the following two conditions can be ensured.

1. The orientation of the generated facet is correct and compatible with the rest of the model.
2. Any contoured surface of the model would be followed closely by the generated facets due to the smaller facet generated.

Finally the basis for the working of the algorithm is due to the fact that in a valid tessellated model there must only be two facets sharing every edge. If this condition is not fulfilled then this indicates that there are some missing facets.

Dedicated solutions for special cases Special Algorithms

The generic solution presented only caters to gaps that are isolated from one another. However, should any of the gaps were to meet at a common vertex; the algorithm may not be able to work properly. Special algorithms are used to address the following special cases.

1. Two are more gaps formed from a coincidental vertex.

2. Degenerate facets

3. Overlapping facets

The special cases are classified as such because these errors are not commonly encountered in the tessellated model. When there are still problems in the tessellated model after the generic solution's repair, the expanded algorithm could then be used to detect and solve the special case problems.

Newly Proposed Formats

The STL file ----a collection of co-ordinate values of triangles----- is not ideal and has inherent problems in this format. As a result, researchers have in recent years proposed several new formats and these are discussed below.

SLC File

The SLC (Stereolithography Contour) file format is developed by 3D systems. It addresses a number of problems associated with the STL format. An STL file is a triangular surface presentation of a CAD model.

Since the CAD data must be translated to this faceted representation, the surface of the STL file is only an approximation of the real surface of an object. The facets created by STL translation are sometimes noticeable on rapid prototyping parts.

When the number of STL triangles is increased to produce smoother part surfaces, STL files become very large and the time required for a rapid prototyping system to calculate the slices can increase. SLC attempts to solve these problems by taking two dimensional slices directly from a CAD model instead of using an intermediate tessellated STL model.

According to 3D systems, these slices eliminate the facets associated with STL files because they approximate the contours of the actual geometry.

Problems with SLC:

1. In slicing a CAD model, it is not always necessary more accurate as the control of each slice is still approximations of the geometry.
2. Slicing in this manner requires much more complicated calculations and therefore is very time consuming when compared to the STL file.
3. A feature of a CAD model which falls between two slices but is just under the tolerances set for inclusion on either of the adjacent slicers may simply disappear.

CLI File

The CLI (Common Layer Interface) format is meant as a vendor independent format for layer by layer manufacturing technologies. In this format, a part is built by a succession of layer descriptions. The CLI file can be in binary or ASCII format. The geometry part of the file is organized in layers in the ascending order. Every layer is started by a layer command, giving the height of the layer. The layers consist of series of geometric commands. The CLI format has two kinds of entities.

One is the polyline------ The polylines are closed, which means that they have a unique sense, either clockwise or anti-clockwise. This directional sense is used in the CLI format to state whether a polyline is in the outside of the part or surrounding a hole in the part. Counter-clockwise polylines surround the part, whereas clockwise polylines surround holes. This allows correct directions for beam offset.

The other is the hatching to distinguish between the inside and outside of the part. As this information is already present in the direction of polyline, and hatching takes up considerable file space, hatches have not been included into output files.

Advantages of the CLI format:

- Since the CLI format only supports polyline entitles, it is a simpler format compared to the HP/GL format.
- The slicing step can be avoided in some applications.
- The error in the layer information is much easier to be corrected than that in the 3D information. Automated recovery procedures can be used and if required, editing is also not difficult.

Disadvantages:

- The CLI format only has the capability of producing polylines of the outline of the slice.
- Although the real outline of the part is obtained by reducing the curve to segments of straight lines, the advantage over the STL format is lost.

The CLI format also includes the layer information like the HP/GL format. But, the CLI format only has polyline entities, while HP/GL supports arcs and lines. The CLI format is simpler than the HP/GL format and has been used by several rapid prototyping systems.

RPI File

The RPI (Rapid Prototyping Interface) format is derived from STL format data. It is capable of representing facet solids, but it includes additional information about the facet topology. Topological information is maintained by representing each facet solid entity with indexed lists of vertices, edges, and faces. Instead of explicitly specifying the vertex coordinates for each facet, a facet can refer to them by index numbers. This contributes to the goal of overall redundant information reduction.

The format is developed in ASCII to facilitate cross-platform data exchange and debugging. A RPI format file is composed of the collection of entities, each of which internally defines the data it contains. Each entity is composed of an entity name, a record count, a schema definition, schema termination symbol, and the corresponding data. The data is logically subdivided into records which are made up of fields. Each record corresponds to one variable type in the type definition.

Advantages:

- Topological information is added to the RPI format. As the result, flexibility is achieved. It allows users to balance storage and processing costs.
- Redundancy in the STL is removed and the size of file is compacted.
- Format extensibility is made possible by interleaving the format schema with data.
- Representation of CSG primitives is provided, as capabilities to represent multiple instances of both facet and CSG solids.

Disadvantages:

- An interpreter which processes a format as flexible and extensible as the RPI format is more complex than that for the STL format.
- Surface patches suitable for solid approximation cannot be identified in the RPI format.

The RPI format offers a number of features unavailable in the STL format. The format can represent CSG primitive models as well as facet models. Both can be operated by the Boolean union, intersection, and difference operators. Provisions for solid translation and multiple instancing are also provided.

Process parameters, such as process types, scan methods, materials, and even machine operator instructions, can be included in the file. Facet models are more efficiently represented as redundancy is reduced. The flexible format definition allows storage and processing cost to be balanced.

LEAF File

The LEAF or Layer Exchange AASCII Format is generated by Helsinki University of Technology. To describe this data model, concepts from the object-oriented paradigm are borrowed. At the top level, there is an object called LMT-file that can contain parts which in turn are composed of other parts or by layers. Ultimately, layers are composed of 2D primitive and currently the only ones which are planned for implementation are polylines.

Other Translators

IGES File

IGES (Initial Graphics Exchange Specification) is a standard used to exchange graphics information between commercial CAD systems. It was set up as an American National Standard in 1981. The IGES file can precisely represent CAD models. It includes not only the geometry information, but also topological information.

In IGES, surface modeling, constructive solid geometry and boundary representation are introduced. Especially the ways of representing the regularized operations for union, intersection and difference have also been defined.

Advantages:

- Wide adoption and comprehensive coverage.
- Since IGES was set up as American National Standard, virtually every commercial CAD-CAM system has adopted IGES implementations.
- It provides the entities of points, lines, arcs, splines, NURBS surfaces and solid elements. Therefore it can precisely represent CAD model.

Advantages of using IGES over current approximate methods include:

- Precise geometry representations,
- Few data conversions,
- Smaller data files and
- Simpler control strategies.

Disadvantages

- Because IGES is the standard format to exchange data between CAD systems, it also includes much redundant information that is not needed for rapid prototyping systems.
- The algorithms for slicing an IGES file are more complex than the algorithms slicing a STL file.
- The support structures needed in RP systems such as SLA cannot be created according to the IGES format.
- Lack of transfer standards for a variety of cad systems and system complexities.

HP/GL File

HP/GL (Hewlett Packard Graphics Language) is a standard data format for graphic plotters. Data types are all two-dimensional including lines, circles, splines, texts etc.

Advantages:

- Lot of commercial CAD systems have the interface to output the HP/GL format.
- It is a 2D geometry data format which does not need to be sliced.

Disadvantages:

- Because HP/GL is a 2D data format, the files would not be appended, potentially leaving hundreds of small files needing to be given logical names and then transferred.
- All the support structures required must be generated in the system and sliced in the same way.

CT Data

CT (Computerized Tomography) scan data is a particular approach for medical imaging. This is not a standardized data. Formats are proprietary and somewhat unique from one CT scan machine to another. The scan generates data as a grid of three-dimensional points where each point has a varying shade of grey indicating the density of the body tissue found at that particular point.

Data from CT scans have been used to build skull, femur, knee and other bone models on stereolithography systems. Some of the reproductions were used to generate in-plants which have been successfully installed in patients.

The CT data consists essentially of raster images of the physical objects being imaged. It is used to produce models of human temporal bones. There are 3 approaches of making models from CT scan data.

- Via CAD systems
- STL interfacing
- Direct interfacing.

Advantage of CT data as an interface of rapid prototyping is that it is possible to produce structures of the human body by the rapid prototyping systems.

Disadvantages:

1. Increased difficulty in dealing with image data as compared with STL.

2. Need for a special interpreter to process CT data.

PART-B

Rapid Prototyping Software

Magics Software

Over the past few years, Magics RP software has proven to be an indispensable software tool for achieving the goal. This delivers high quality prototypes with the shortest lead times. At the same time, Magics provides with full documentation of the process.

Magics RP software can import most standard 3D formats - STL, VDA, IGES, STEP, VRML - and native CAD formats like UG/Para solid and CATIA. It can also work with scanned data by offering the import and export of point clouds.

The imported files are converted to a digital CAD structure according to a user-defined accuracy.

The conversion process includes correction of common errors. The resulting STL file is ready to produce prototypes or tools without the need for further conversion.

Features of Magics Software:

Magics software calculates a comprehensive quote in seconds:

Magics software has excellent 3D visualization capabilities, instantly giving a clear picture of a part's intricacies. With Magics build time estimator, the machine capacity and cost can be assessed. Simply input the necessary dependencies, such as volume or surface, and the software will define the parameters for calculating the cost of a part.

Magics software cuts back repair time for STL files:

Since CAD systems don't always export clean STL files, correction may be needed before they can be sent to an RP machine. Magics software is packed with features that interact directly on defective files and correcting errors in a matter of minutes.

Magics software allows process-related design changes:

Magics software includes several critical features specifically developed to optimize the process. Examples:

- Compensate for parts that need to be milled or painted after production by offsetting them.
- Hollow parts to avoid deformation as a result of internal stresses and to save on material.
- Pinpoint the best way to cut large parts to fit on the RP machine, ensuring a strong bond when they're glued together later.

- Put indicators into position to determine the best possible location for a seam, and for simpler assembly.
- Label the parts so that they're easier to identify.
- Other features such as removing holes, Boolean operations, triangle reduction, triangle smoothing and aligning.

Magics software speeds up specialized RP work preparation:

Magics can save time on data pre-processing. Parts can be nested with a single mouse-click. Magics' powerful nesting function quickly arranges the parts on the smallest possible area. Magics slices the STL file into the desired format in just a few seconds. Magics takes care of the final step too, automatically generating the necessary supports before sending the STL to a stereolithography machine.

Magics software provides unmatched quality control:

The Magics Rapid Fit module offers a fast, unique solution for quality control. Create fixtures in three easy steps: position the part on the reference plate, indicate on the part the contact points that need fixtures, and Magics will design the fixtures automatically, based on customized settings. The fixtures can be built on an RP machine simultaneously with the part.

Magics software offers detailed documentation:

Not only does Magics prepare data for RP machines, it also creates documents that can guide the overall product flow, from quotation through production to quality control.

The templates provide the freedom to document a part with the information to be included. Once the template is defined, Magics uses the part information to generate specifications automatically into a document. Use these standardized documents to provide a client with a quote, to guide the finishing on the shop floor, and for quality control.

Mimics Software:

The MIMICS software takes care of medical image processing, and is capable of converting CT and MRI data directly to Rapid Prototyping models. Additional modules are available for medical device design or dental implant preparation.

Mimics interfaces between scanner data (CT, MRI, Technical scanner,) and Rapid prototyping, CAD or Finite Element analysis. The Mimics software is an image processing package with 3D visualization functions that interfaces with all common scanner formats.

2.1 The applications of Mimics:

Although Mimics was originally designed to link medical images to rapid prototyping, there are many applications possible using the 3D model. The applications are:

- Rapid Prototyping (RP)
- Computer Aided Engineering (CAE)
- Computer Aided Design (CAD)
- Surgical Simulation

All these applications require slightly different processing before they can effectively be used.

Mimics Remesher

Mimics Remesher provides 14 of the most common quality inspection parameters.

Easy automatic remeshing:

The Remesher can improve mesh quality automatically. The software searches for all triangles whose quality is below the indicated level and transform them to triangles with a better shape.

Manual remeshing:

In some cases, a few triangles with a shape inferior to the required quality level may remain after automatic remeshing. The Remesher offers a unique toolbox to reshape those triangles manually.

Increased reliability and accuracy of FE analyses:

The Mimics Remesher is a highly automated interface with FEA packages. It significantly increases the reliability and accuracy of FEA results on STL models. Most FE packages don't allow to manipulate or optimize the mesh generated when a part is imported. This might reduce the accuracy of the results. With the Remesher, the file can be optimized and deliver good meshes that will run in the FEA software.

Reduced calculation times:

Calculation times for running a sub-optimal mesh can be very lengthy. The optimized meshes generated by the Remesher usually take a much shorter time.

SolidView Software:

Solid View software allows non-CAD users to easily view, measure and markup CAD data, opening up communication to all who need to be involved in the design process.

SolidView Features:

View – Measure – Markup CAD Data:

SolidView's advanced feature recognition capabilities combined with its extensive measurement options make it possible to measure any design feature or attribute. This means that engineers don't need to spend hours creating complex 2D drawings just in case someone needs a particular dimension. One mouse click will instantly calculate volume, surface area, mass and center of gravity for complex designs and assemblies. Annotation features make it easy to communicate design intent or to highlight changes or errors. Note and text features add detailed design information, and an electronic grease pencil add red-line markups.

Supports Popular CAD Formats:

It supports popular CAD formats such as SolidWorks, Pro/E, CATIA, Unigraphics, IGES, STEP and many others. It is also possible to import geometry from multiple CAD systems into one SolidView file.

CAD Interaction for Non-CAD Users with SolidView:

Unlike complex CAD systems, SolidView is easy to learn, use and re-learn. No formal training is required and online video tutorials are available

Applications of SolidView:

- Design Reviews
- Assembly Instructions
- Design Collaboration
- Manufacturing Quotes
- RP Layout and Repair
- Project Management
- Request for Quote/Proposal
- Shop Floor
- Technical Illustrations
- Communication and Visualization

View Expert Software:

ViewExpert is entry level tool targeted for viewing, verifying, dimensioning and communicating 3D geometry information. View Expert allows to input triangle models, create consistent topology, check errors, repair normal's and output STL data for 3D printing without any cost.

For validating 3D model data:

- View Expert is a software tool for CAD designers to provide perfect solid data to downstream applications.
- Import STL models or optionally surface models into View Expert.
- Locate costly errors and correct them.
- Verify the integrity of the data before sending it to rapid prototyping, CNC or CAE systems.

View, verify and communicate faceted 3D models:

ViewExpert can input and output all relevant faceted 3D file formats for Additive Manufacturing. Automatic model verification, measuring and clipping commands help to easily decide if the model can be printed or not.

- Input various faceted models: STL, VRML, ZPR, OBJ, DXF, PLY, 3DS, Collada, FBX and proprietary 3DE Files.
- Output following faceted models: STL, VRML, ZPR, DXF, PLY and 3DE Files.
- Automatically orient triangle normal direction for correct 3D Printing.
- Viewing with rotate, pan, zoom and clipping commands, real-time slices for internal geometry checking.
- Measuring with distance, radius, angle, wall thickness and 2D Drawings commands.
- Export bounding box, area and volume for build time estimation

ViewExpert offers the following features:

ViewExpert for STL files

- Faster display list generation and texture handling
- Improved topology generation for architectural models
- 64 bit implementation improvements to handle millions of triangles

Communication

- Print and Email Images and 3D Geometry with Annotations and Measures
- Input STL, VRML, ZPR, OBJ, DXF, PLY, 3DS, Collada, FBX and 3DE Files
- Write STL, VRML, ZPR, PLY and 3DE Files

Model Editing

- Cut, Copy and Paste 3D Data
- Help Text window to Aid in the Analysis Process

- Different Error Filtering Levels for Repairing Models for Simulation vs. 3D Printing

3D Viewing, Transformations and Measuring

- Viewing with Colors, Textures and Clipping
- Transformations to Scale, Position, Rotate, Mirror & Platform positioning
- Generate professional 2D Drawings from STL data
- Point value, Distances, Angle, Radius and Wall Thickness Measuring

Rhino Software:

STL is the standard format for rapid prototyping systems. While STL was originally developed for use with stereolithography, many other processes now use it. Since SLA machines usually require the STL file to be a watertight mesh, Rhino provides tools for repairing mesh files to remove gaps.

Using Rhino's Bonus Tools, it is possible to print 3dm, STL, IGES, STEP, DWG, 3DS, and many more file formats directly to a stereolithography printer or file. This allows taking nearly any 3-D model and sending it to a prototyping machine. As with any model going to a printer, the output STL file must be watertight. Rhino has many tools to repair STL files that are not watertight and to create watertight geometry to send to a 3-D printer.

Rhino's Bonus Tools includes commands for analyzing and repairing STL files to make them watertight. There are new tools for advanced display, edge matching, selection, and filling holes. These tools allow to manipulate meshes in ways previously not possible in Rhino. While Bonus Tools mesh covers many new commands, the commands that are used for STL repair can be grouped into a few categories:

• Offset (thicken)

• Display

• Remove unwanted detail

• Display and close gaps

Rhino Software has the following features:

- Display Mesh Wires
- Remove Unwanted Detail
- Display Gaps
- Close Gaps
- Stitch Larger Gaps
- Fill Holes
- Remove Geometry by Feature
- Fill Holes between Objects

3D-DOCTOR

3D-DOCTOR Software is used to extract information from image files to create 3D model. It is developed by Able Software Corp. It is an advanced 3D modeling, image processing and measurement software for MRI, CT, PET, microscopy, scientific, and industrial imaging applications.

3D-DOCTOR's vector-based tools support easy image data handling, measurement, and analysis. 3D CT/MRI images can be re-sliced easily along an arbitrary axis. Multi-modality images can be registered to create image fusions. Misaligned slices can be automatically or semi-automatically aligned using 3D-DOCTOR's image alignment functions. Other image processing functions include template-based film cropping, image re-slicing to correct slices of uneven thickness, volume resizing, and image rotation.

3D-DOCTOR supports a variety of image formats in both 2D and 3D. These formats include DICOM, TIFF, JPEG, BMP, Interfile, GIF, PNG and RAW. Other non-standard image formats are also supported, but only with known dimensions (number of columns, rows and planes), bit depth per pixel, little endian or big endian, and the size of file header.

3D-DOCTOR supports both grayscale and color images stored in DICOM, TIFF, Interfile, GIF, JPEG, PNG, BMP, PGM, RAW or other image file formats. 3D-DOCTOR creates 3D surface models and volume rendering from 2D cross-section images in real time.

Using 3D doctor, it is possible to export the polygonal mesh models to STL, DXF, IGES, 3DS, OBJ, VRML, XYZ and other formats for surgical planning, simulation, quantitative analysis and rapid prototyping applications. Leading hospitals, medical schools and research organizations around the world are currently using 3D-DOCTOR.

Features of 3D Doctor Software

- **Unique vector-based technologies** for better 3D model creation and easy editing.
- **Surface model uses smaller number of triangles** while maintaining all details for high quality rapid prototyping applications.
- **Smart memory management** with no limit for the number of slices to be used. It has been used to process images with over 2000 slices on a PC with only 256MB RAM.
- **Single command** volume calculation and quantitative analysis report
- **Handles DICOM and other image formats**, such as TIFF, JPEG, PNG, GIF, BMP, Interfile and RAW (vendor proprietary formats).
- Works with both grayscale and color images (color classification and separation)
- **Supports CT, MRI, PET,** microscopy, industrial CT, scanned film images, boundary slices, slice data and XYZ points.

- **High End 3D Image Processing Functions:** image registration for multi-modality application, image fusion, image resizing, image reslicing, etc.
- **3D Output Formats:** STL (ASCII and Binary), VRML, DXF, 3D Studio, IGES, Wavefront OBJ and more.
- **Software Reliability:** No known bugs in our products because we fix them right away once they are reported.
- **Reasonably priced.**

FlashPrint

FlashPrint is the printer control and slicing software that you'll use with the Flashforge Finder. The software is easy to use and can hide some of the advanced settings, but when you are ready, you just hit a button and the advanced settings are shown to you.

OBJECT STUDIO

Developed specifically for Objet 3D printing systems, Objet Studio supports STL and SLC files from any 3D CAD application. The software offers simple “click & build” preparation and 3D print tray editing and provides easy, accurate job estimation and full job control, including queue management. The software also features powerful wizards that facilitate and speed up system maintenance.

Key Advantages of Objet Studio software includes:

Automatic support generation

Networking capability supports multiple users

Easy tray build saves setup time

Slice-on-the-fly dramatically reduces pre-print time

Auto-placement of parts ensures accurate and consistent positioning

Intuitive, wizard-guided maintenance provides high up-time

CURA

The preferred software for your Ultimaker is Cura. This software package prepares your 3D model into instructions that your 3D printer requires to produce an object. Cura is developed by Ultimaker to make 3D printing as easy and streamlined as possible. It contains everything you need to prepare a 3D file for printing. It is fully preconfigured to work on every Ultimaker model. Cura comes with a friendly setup program that helps you install the latest firmware as well as to calibrate your printer. While you make decisions on the look and quality of your 3D object, Cura’s slicer engine prepares your model in the background faster than ever. From there It is just seconds away from your printer and ready to become your physical object.

ITK SNAP

ITK-SNAP is a free, open-source software tool for interactive segmentation of 3D image volumes. It is used by thousands of researchers to label structures of interest in different imaging modalities, including MRI, CT, 3D ultrasound, and others. It includes both manual and automatic segmentation functionality, and it designed to be easy to learn and use. Since 2006, ITK-SNAP has has contributed to over 1000 publications, spanning a wide range of biomedical applications and imaging modalities

Materialise 3-Matic

Materialise introduced its 3-matic software, allowing 3D printer users to edit files directly in the STL format. Previously, if design changes were required in the digital model, designers had to make them in the CAD suite of choice before re-converting the entire file to STL again. 3-matic enables design optimization and modification on STL level, using CAD designs, scanned data and topology optimized models as a starting point. It allows 3D printer users to edit files directly in the STL format.

Design with Materialise 3-matic will:

- Modify design at mesh level
- Create textures, patterns and perforations
- Create latticed, conformal or porous structures
- Clean up rough topology optimization results for simulation (FEA) and printing
- Convert mesh back to CAD

Features

- Enjoy freedom of design, create a unique or customized object
- Control density with latticed, conformal and porous structures
- Save material, reduce printing time and decrease costs with lightweight designs
- Change aerodynamic, acoustic and cushioning properties or increase grip
- Avoid labor-intensive finishing steps with smart use of textures
- Gain foresight from the strong link with simulation packages
- Automate your design process or accelerate your iteration cycles, by scripting these flows using the 3-matic Python API

Simplant

Simplant offers you a comprehensive 3D system for accurate and predictable implant treatment – from scanning and planning, to drilling and implant placement, to the ultimate Immediate Smile.

FEATURES OF MESHLAB

- 3D Acquisition- Aligning: MeshLab provides a powerful tool for moving the different meshes into a common reference system, able to manage large set of range-maps. The alignment can be performed on meshes and point clouds coming from several sources, including active scanners and 3D-from-image tools.
- 3D Acquisition- Reconstruction: The process of transforming independent acquisitions, or point clouds, into a single-surface triangulated mesh can be fulfilled with different algorithmic approaches. MeshLab provides several solutions to reconstruct the shape of an object, ranging from volumetric to implicit surfaces.
- 3D Acquisition- Color Mapping and Texturing :Color information may be as important as geometry. MeshLab contains a pipeline for the alignment and projection of color information onto a 3D model. Several automatic and assisted methods are provided to obtain a high quality color encoding.
- Cleaning 3D Models: Removes topological errors, duplicated and unreferenced vertices, small components, degenerated or intersecting faces, and many more geometrical and topological singularities.
- Simplification, Refinement and Remeshing: MeshLab offers different ways to simplify triangulated surfaces to preserve geometrical detail and texture mapping. Remeshing and resampling filters are present to increase geometric complexity of 3D models.
- Measurement, and Analysis: Interactive point-to-point measurement of a 3D model is done in MeshLab. Automatic filters will return various geometric and topological information about 3D model. Different geometric information may be calculated on meshes and 3D models using automatic filters.

Ansys for Additive manufacturing

Ansys Additive Solutions, a comprehensive and scalable software solution, allows you to minimize risk and ensure high quality, certifiable parts. Dive deeper into the properties of your printer parts, ensure traceability of your data, optimize build files and more. Our software lets you create additive manufacturing designs and simulate the metal additive manufacturing process to reduce product development time. An end-to-end manufacturing solution, Additive Solutions spans across multiple Ansys product offerings.