M.Tech
Digital Manufacturing

BITS Pilani
Pilani Campus

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Guest Faculty

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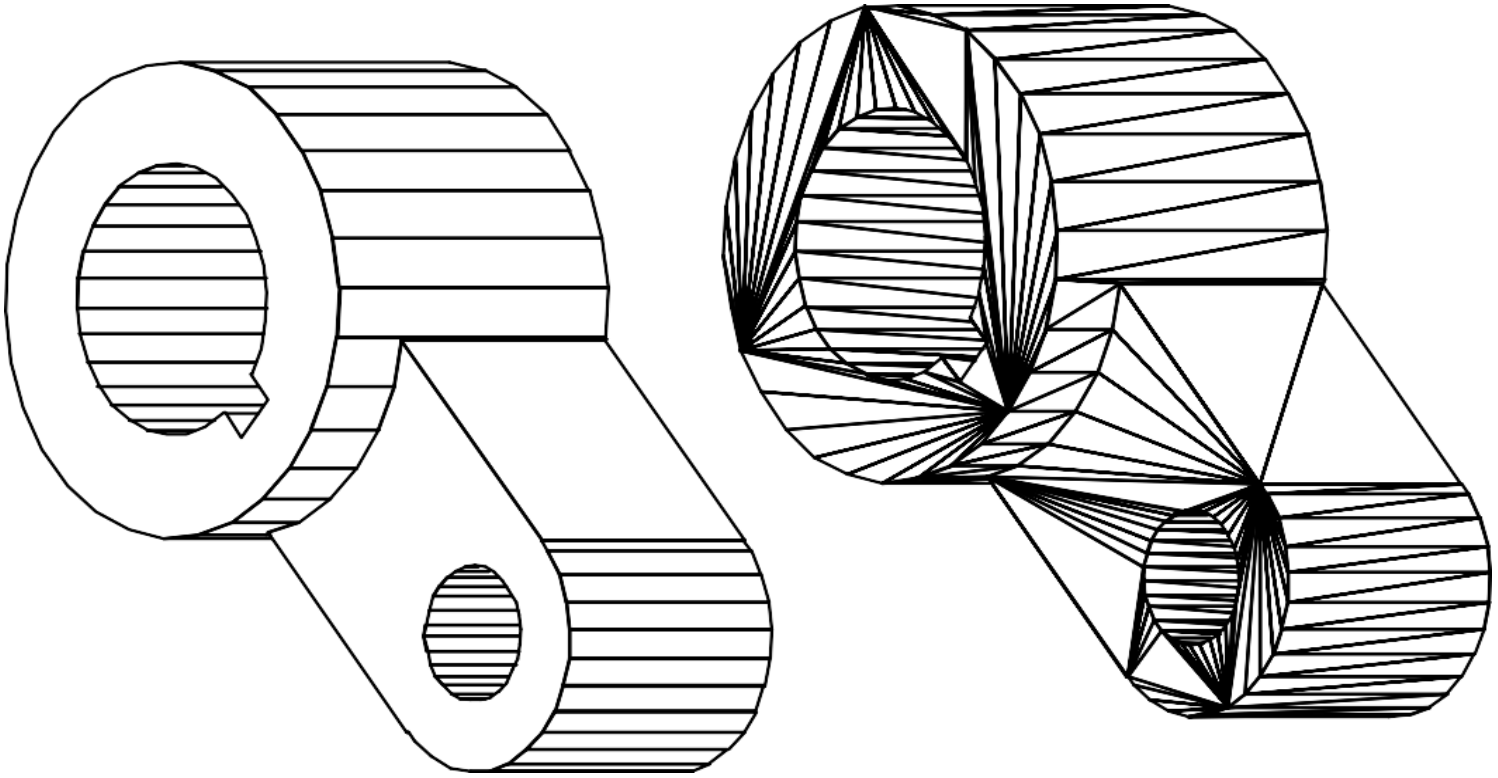
DMZG521- Design for Additive Manufacturing
Session 13 & Lecture 25-26

Stereolithography File

- CAD data can be converted to the Stereolithography (.STL) file format.
- The .STL file is an industry standard interface.
- Developed by the Albert Consulting Group for the 3DSystems, Inc., StereoLithography Apparatus (SLA).
- Consists of triangles that describe the shape of a closed model.
- Faceted surface must be completely bound.
- Many CAD packages export files in the .STL format

3D Models

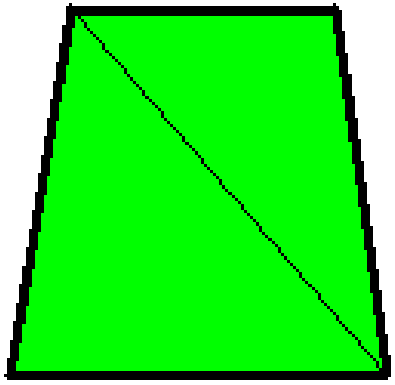
- A solid model is exported as Stereolithography (.STL) file



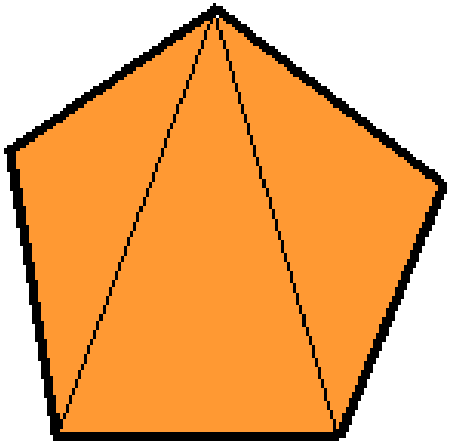
Triangulated Surfaces

- Any 3D form (polyhedral or curved) can be approximated by a triangulated surface.
- Polygons of 4 or more sides can be divided into triangles.
- On a computer these are represented by listing the three corners for each triangle.
- A corner (a vertex) is described by XYZ coordinates

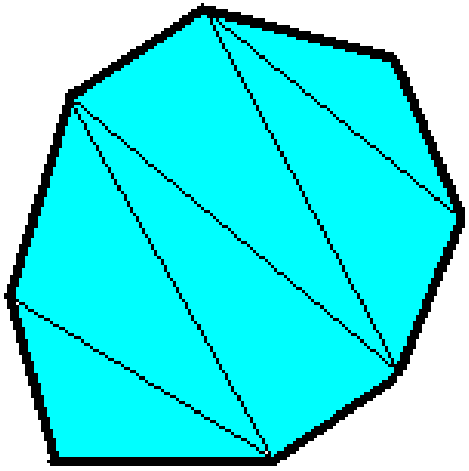
Polygons Divide into Triangles



4 sides → 2



5 sides → 3

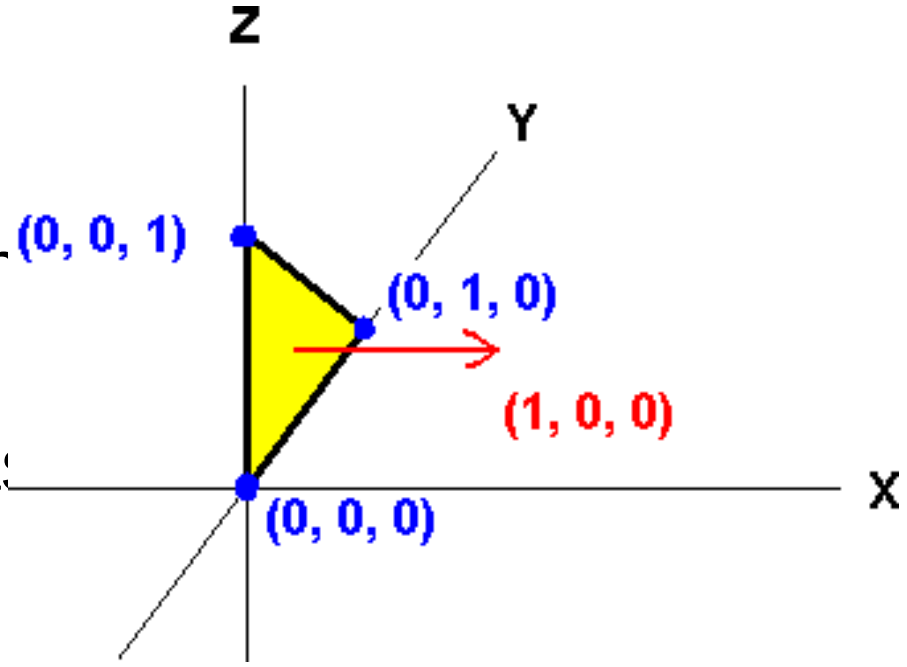


8 sides → 6

An *n*-gon is represented as *n*-2 triangles

Triangles in Space

- Each vertex has (X, Y, Z) coordinates
- List vertices starting with any of the three
- List counter-clockwise as seen from outside
- “Normal vector” points out from object
- Use “Right-handed” XYZ axes

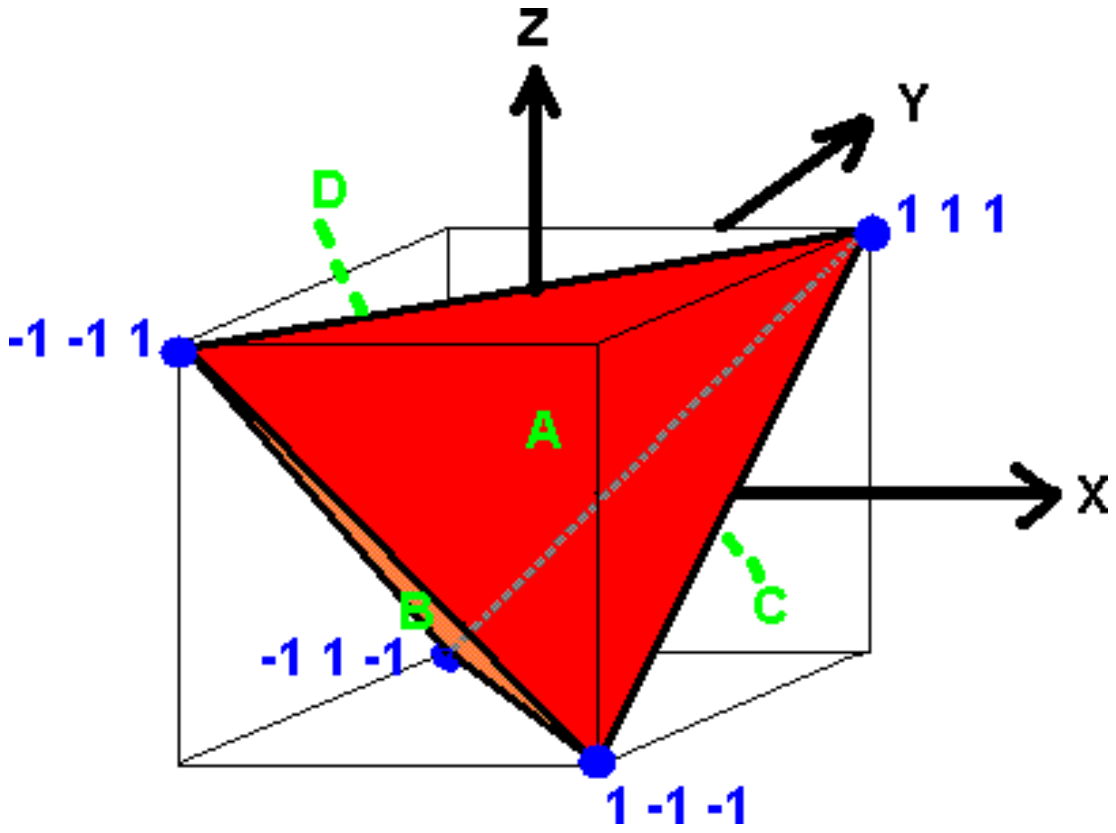


Triangle: (0,0,0) (0,1,0) (0,0,1)

Or: (0,1,0) (0,0,1) (0,0,0)

Or: (0,0,1) (0,0,0) (0,1,0)

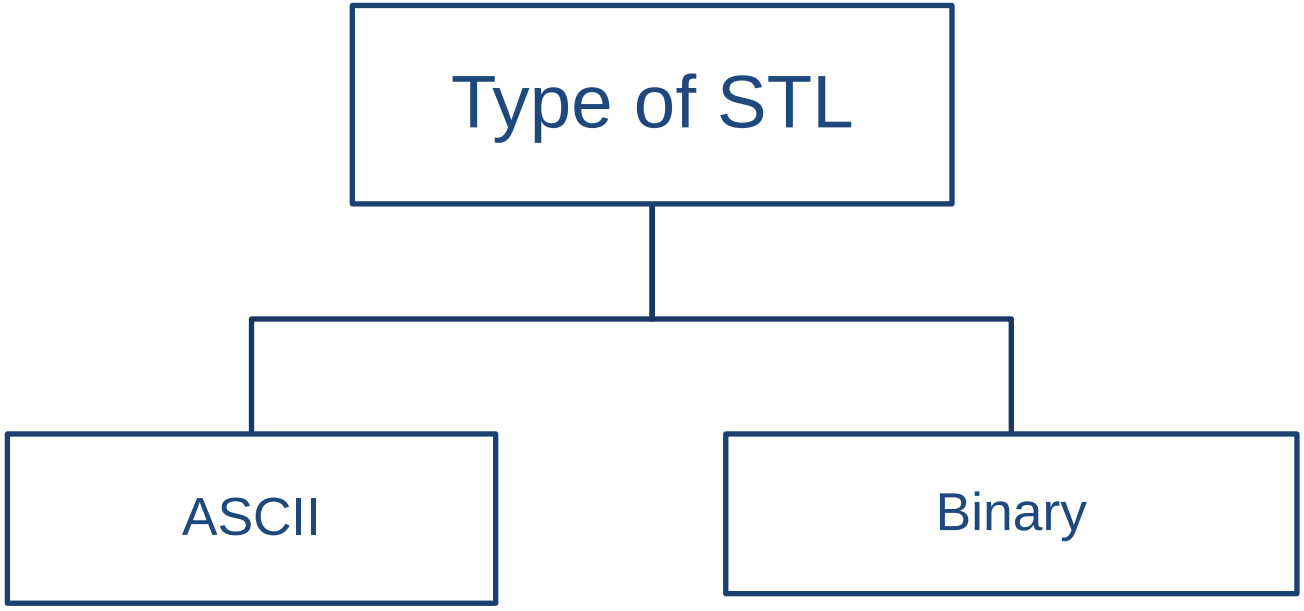
Example Tetrahedron



A: (1 1 1) (-1 -1 1) (1 -1 -1) B: (-1 -1 1) (-1 1 -1) (1 -1 -1)

C: (1 1 1) (1 -1 -1) (-1 1 -1) D: (1 1 1) (-1 1 -1) (-1 -1 1)

STL file formats



ASCII stl File Format

- Triangles can be listed in any order.

solid <name>

<triangle 1 (7 lines)>

<triangle 2 (7 lines)>

<triangle 3 (7 lines)>

…

endsolid <name>

stl File Format

- For each triangle give 7 lines:

facet normal 0 0 0 outer loop vertex X Y Z vertex X Y Z
  vertex X Y Z endloop
endfacet

- Only the X Y Z parts need to change for each triangle
- (Some programs need the “normal”)

Binary STL file

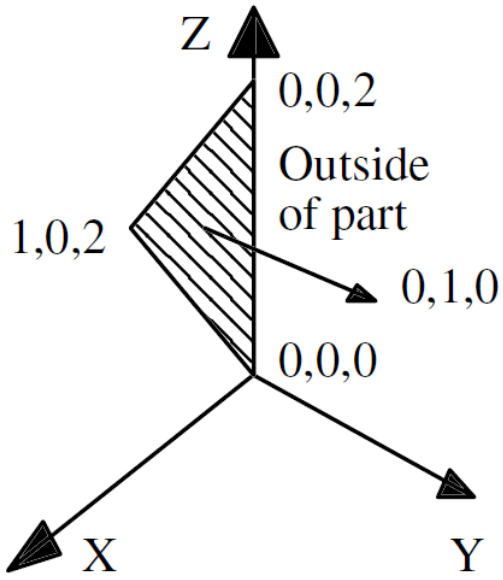
The binary STL file starts with a 80 character header.

```
UINT8[80] – Header
UINT32 – Number of triangles
```

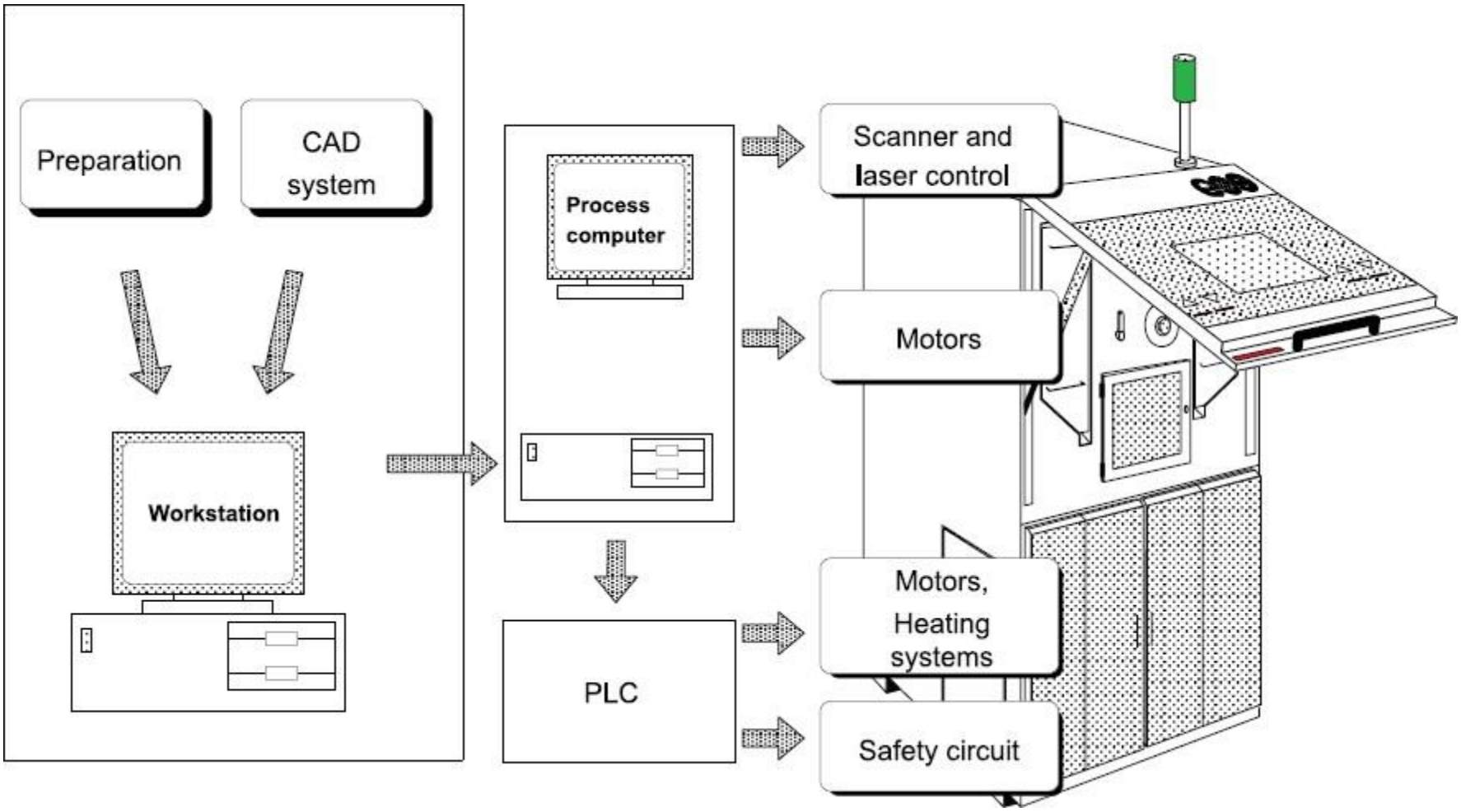
```
foreach triangle
REAL32[3] – Normal vector
REAL32[3] – Vertex 1
REAL32[3] – Vertex 2
REAL32[3] – Vertex 3
UINT16 – Attribute byte count
end
```

sample STL file

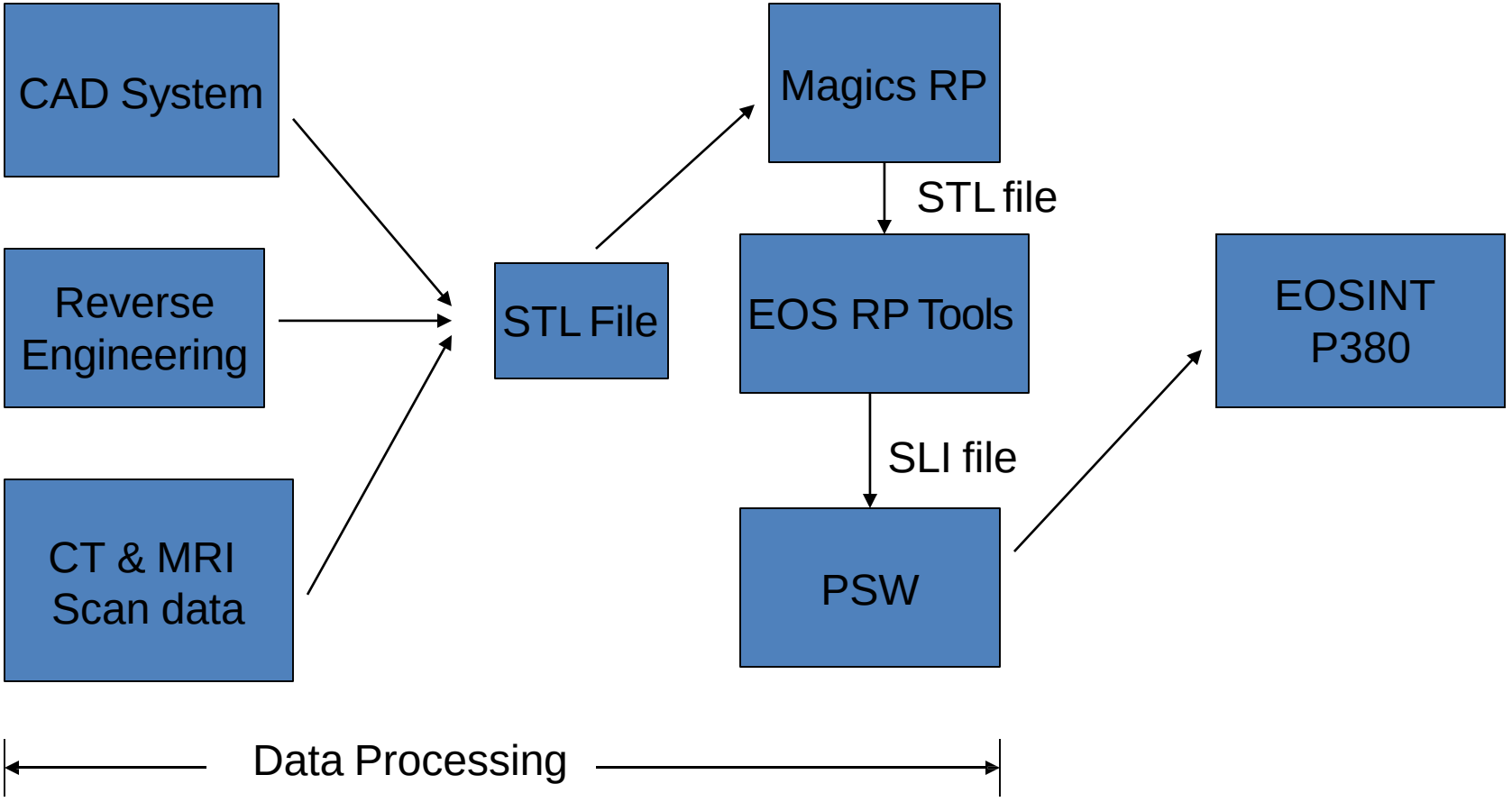
```
solid print
  facet normal 0.00000e+00  1.00000e+00  0.00000e+00
    outer loop
      vertex   0.00000e+00  0.00000e+00  2.00000e+01
      vertex   0.00000e+00  0.00000e+00  0.00000e+00
      vertex   1.00000e+01  0.00000e+00  2.00000e+01
    endloop
  endfacet
  facet normal 0.00000e+00  1.00000e+00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



Information flow

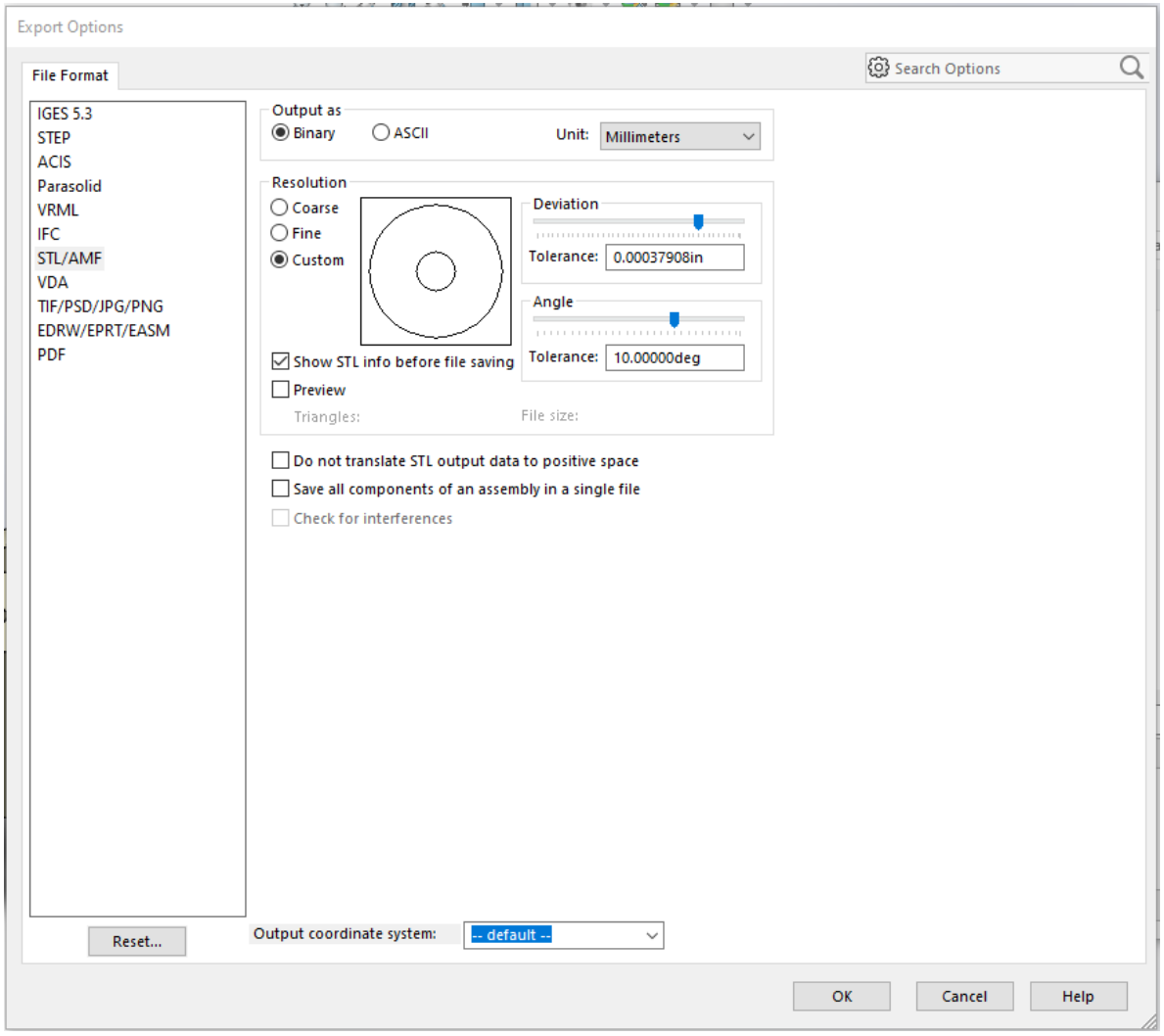


AM process

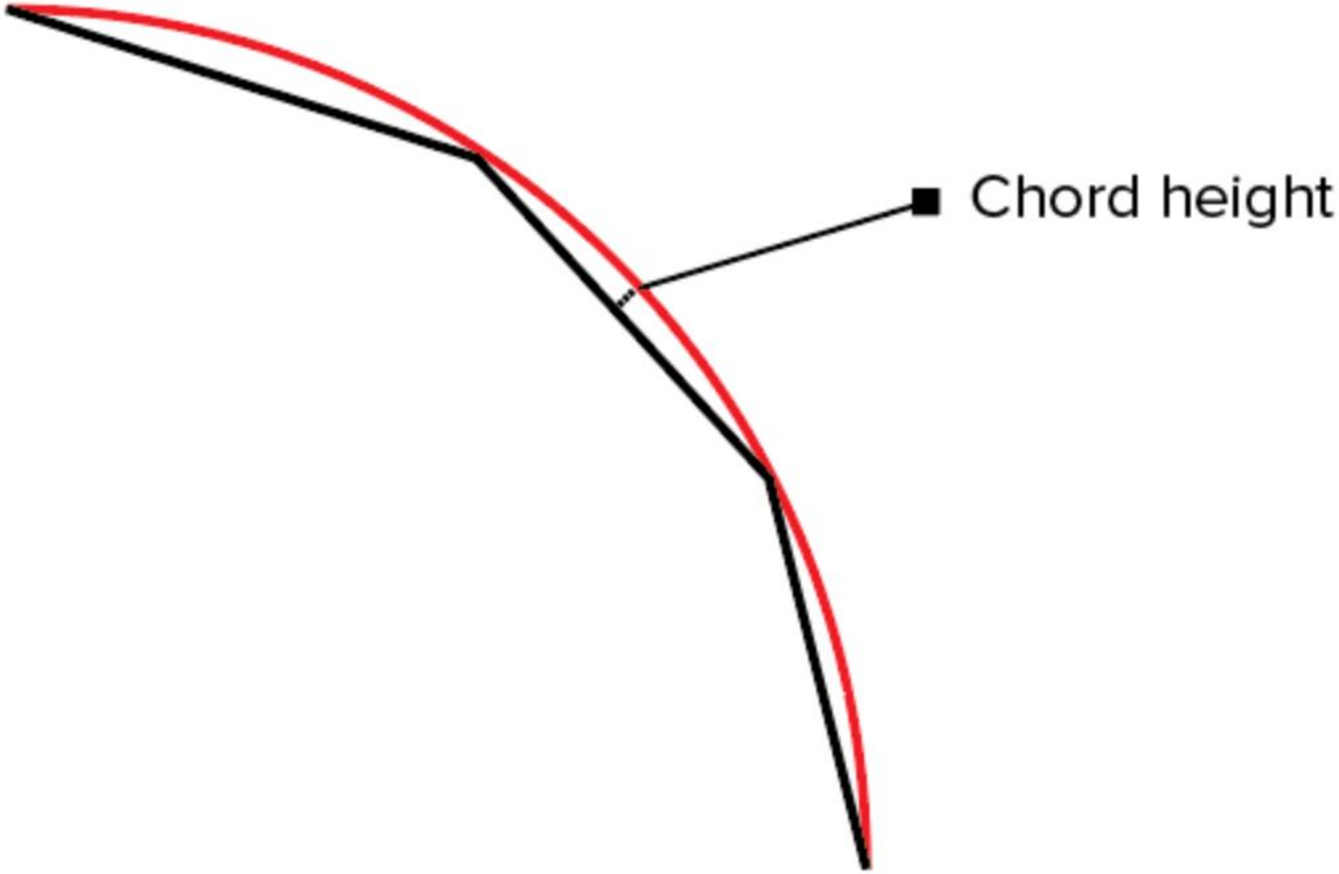

CAD System
Reverse Engineering
CT & MRI Scan data
STL File
Magics RP
STL file
EOS RP Tools
SLI file
PSW
EOSINT P380
Data Processing

Resolution of an STL file

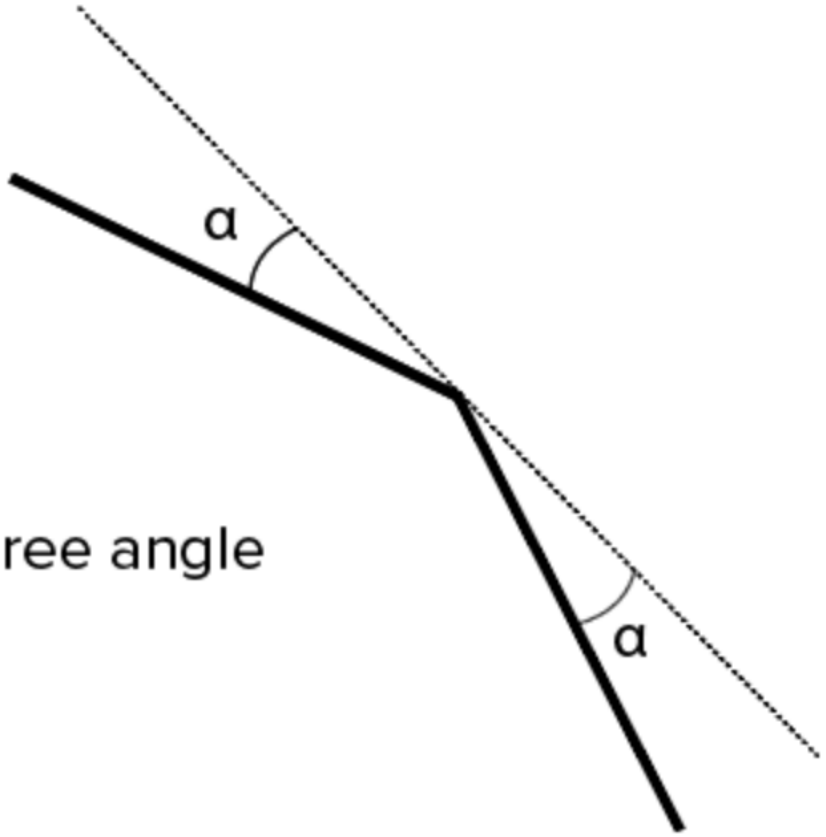
Exporting STL file



Chordal deviation

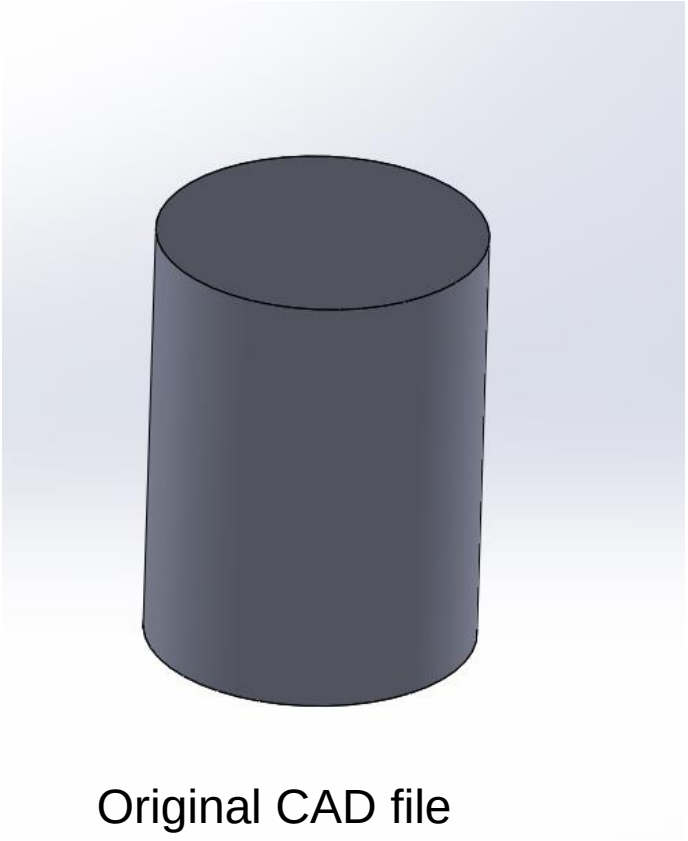


Angle tolerence



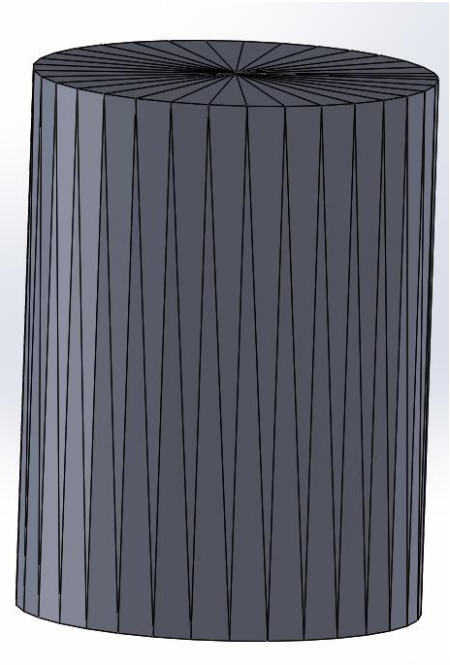
α = 15 degree angle
by default

STL file visualization



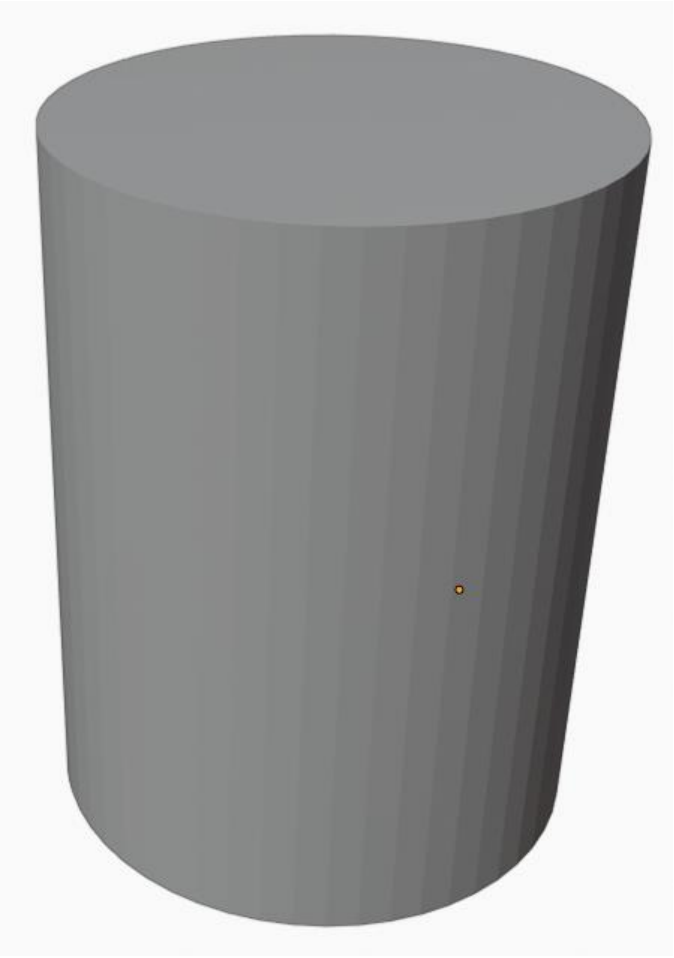
Original CAD file

Fine resolution



Coarse resolution

STL file in very fine ASCII



Rules for STL file

1. Vertex rule
2. Orientation rule
3. Water tight rule

$$\frac{\text{No. of faces}}{\text{No. of edges}} = \frac{3}{2}$$

$$\text{No. of faces} - \text{No. of edges} + \text{No. of vertices} = 2 \times \text{No. of bodies}$$

STL File Problems

(1) Gaps (cracks, holes, punctures) that is, missing facets.

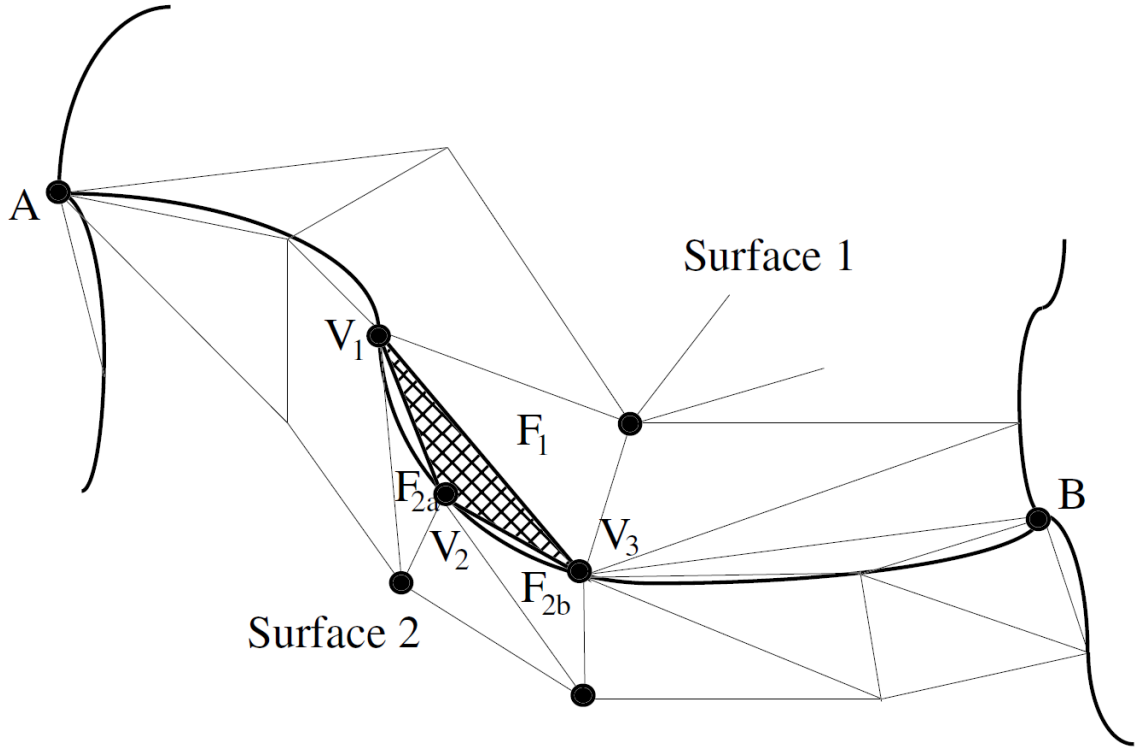
(2) Degenerate facets (where all its edges are collinear).

(3) Overlapping facets.

(4) Non-manifold topology conditions.

Missing Facets or Gaps

- Tessellation of large curvature can result in these type of errors.
- It creates gaps and holes along edges



Degenerate Facets

- Degeneracy of a facet occurs when all of the facets' edges are collinear even though all its vertices are distinct

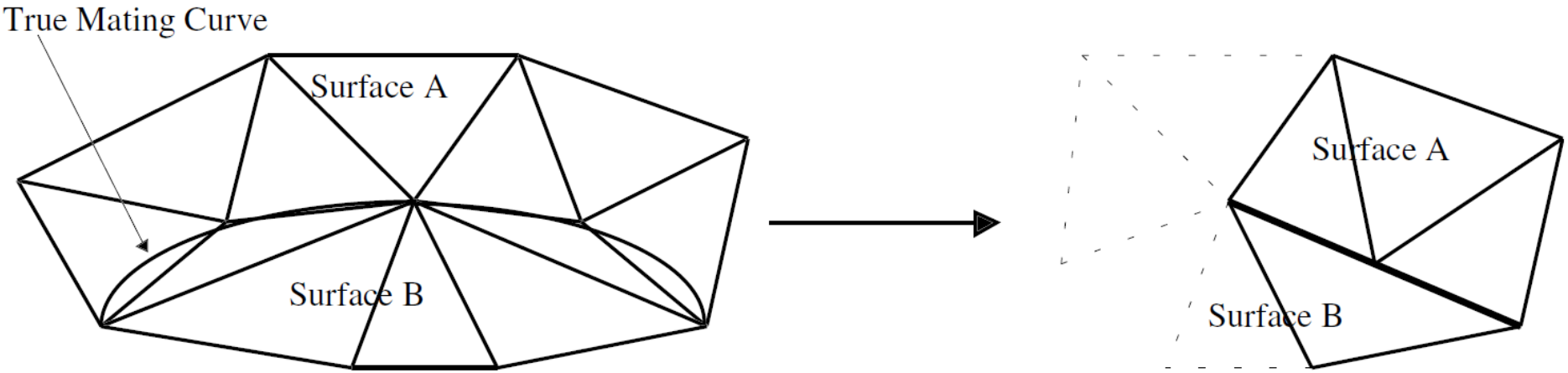
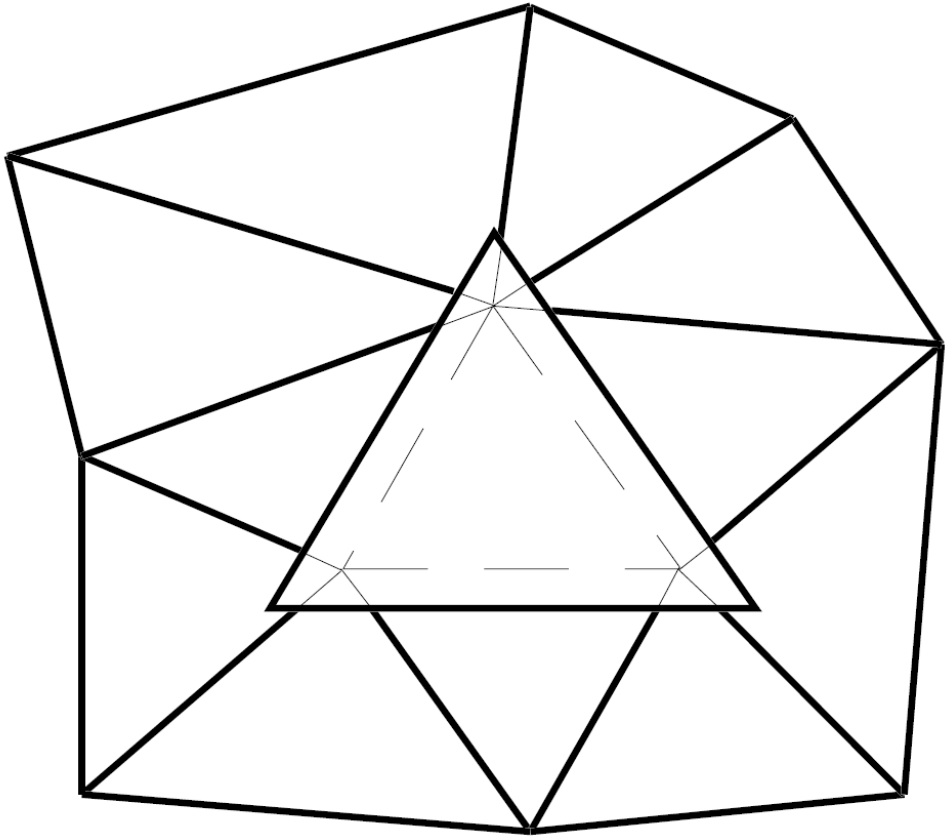


Figure 6.4(a): Shell punctures created by unequal tessellation of two adjacent surface patches along their common mating curve

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

Overlapping Facets

- Overlapping facets may be generated due to numerical round-off errors occurring during tessellation



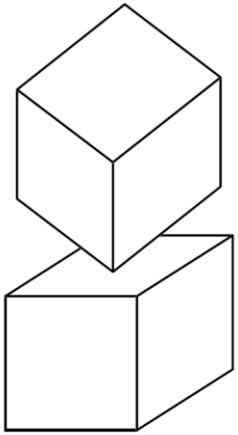
Non-manifold Conditions

Three types of Non-manifold conditions

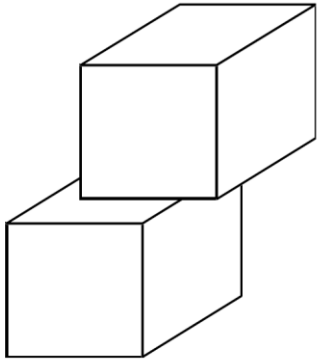
(1) A non-manifold edge.

(2) A non-manifold point.

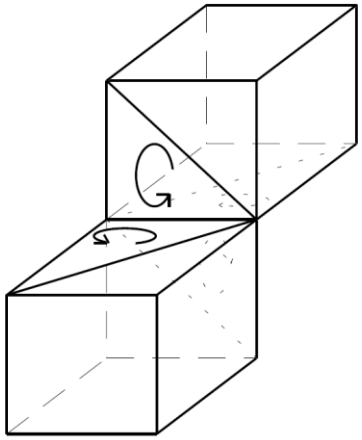
(3) A non-manifold face.

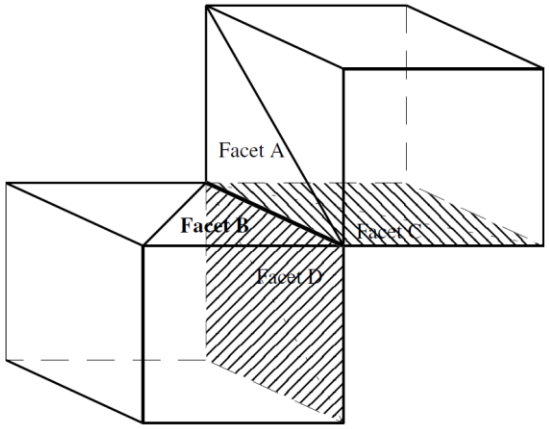


(2)



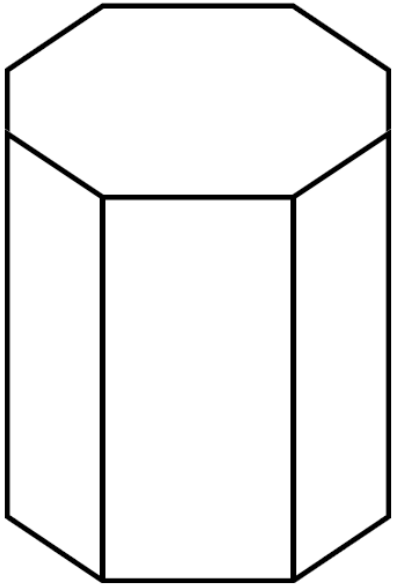
(3)



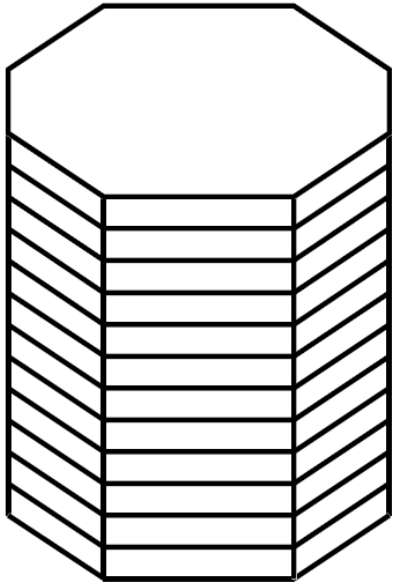


(1)

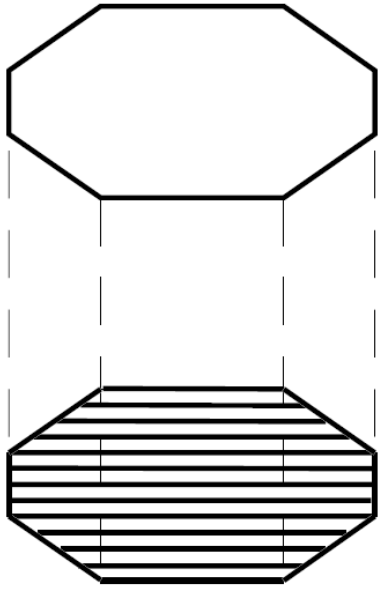
Valid STL file



A valid 3D model

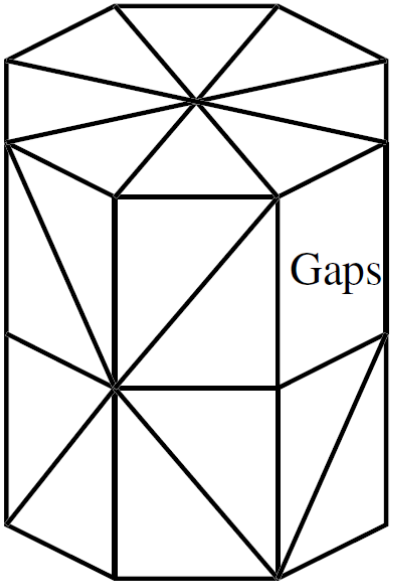


A 3D model sliced into 2D planar layers

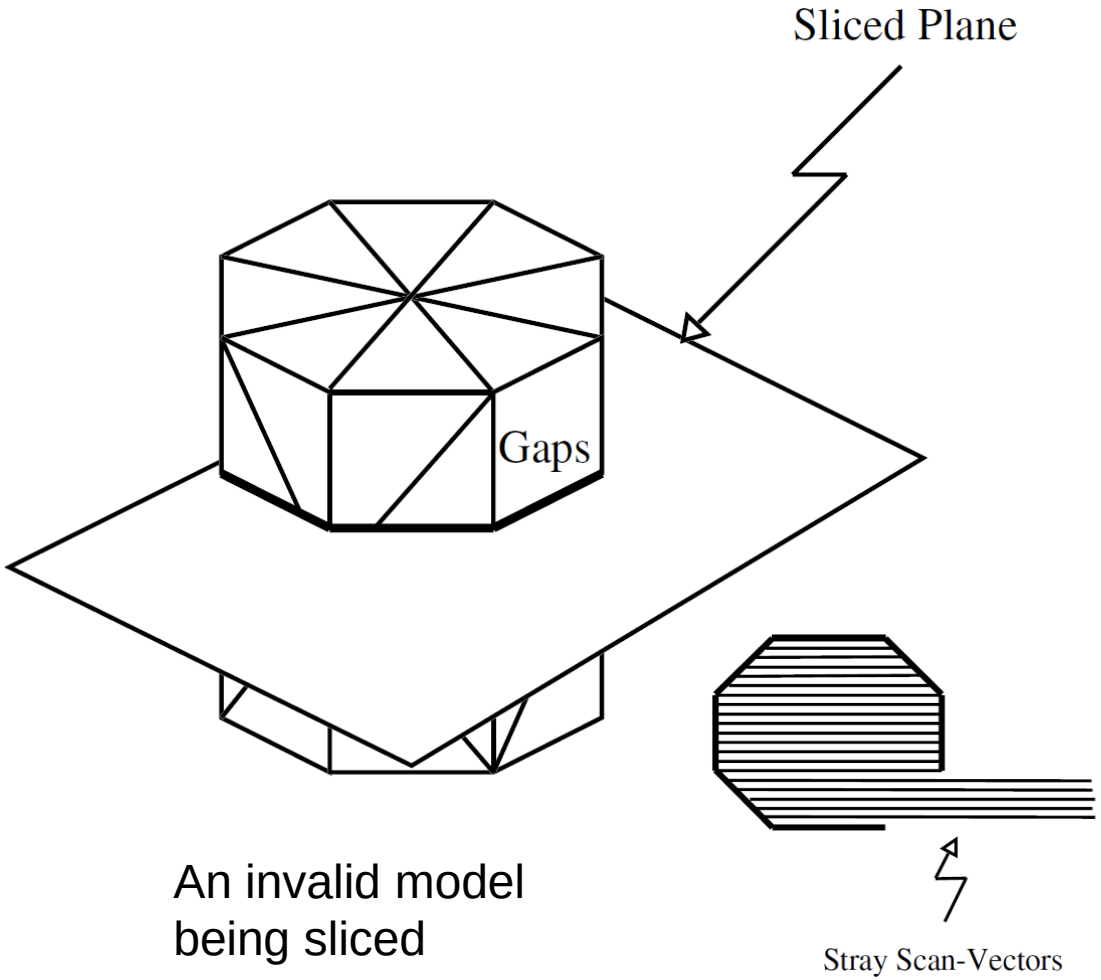


Conversion of 2D layers into 1D scan lines

Invalid STL File



An invalid tessellated model

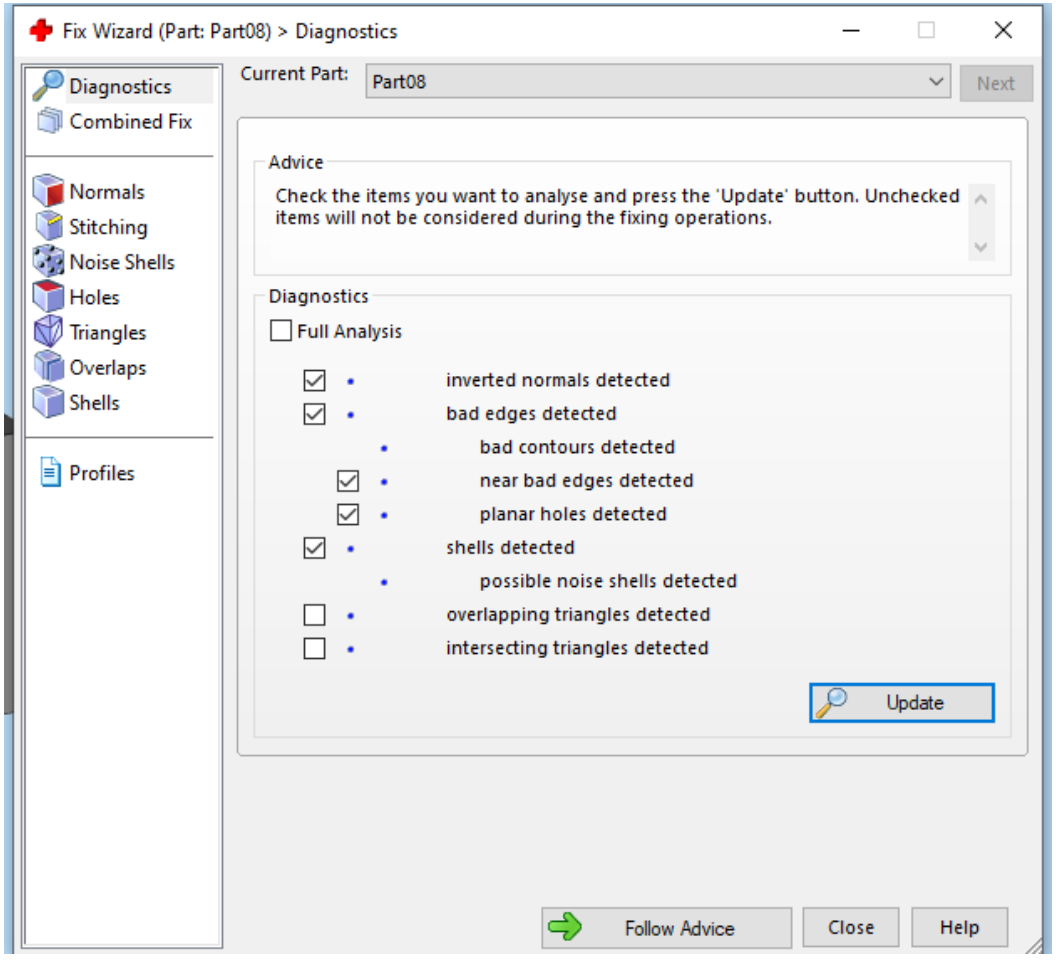


An invalid model being sliced

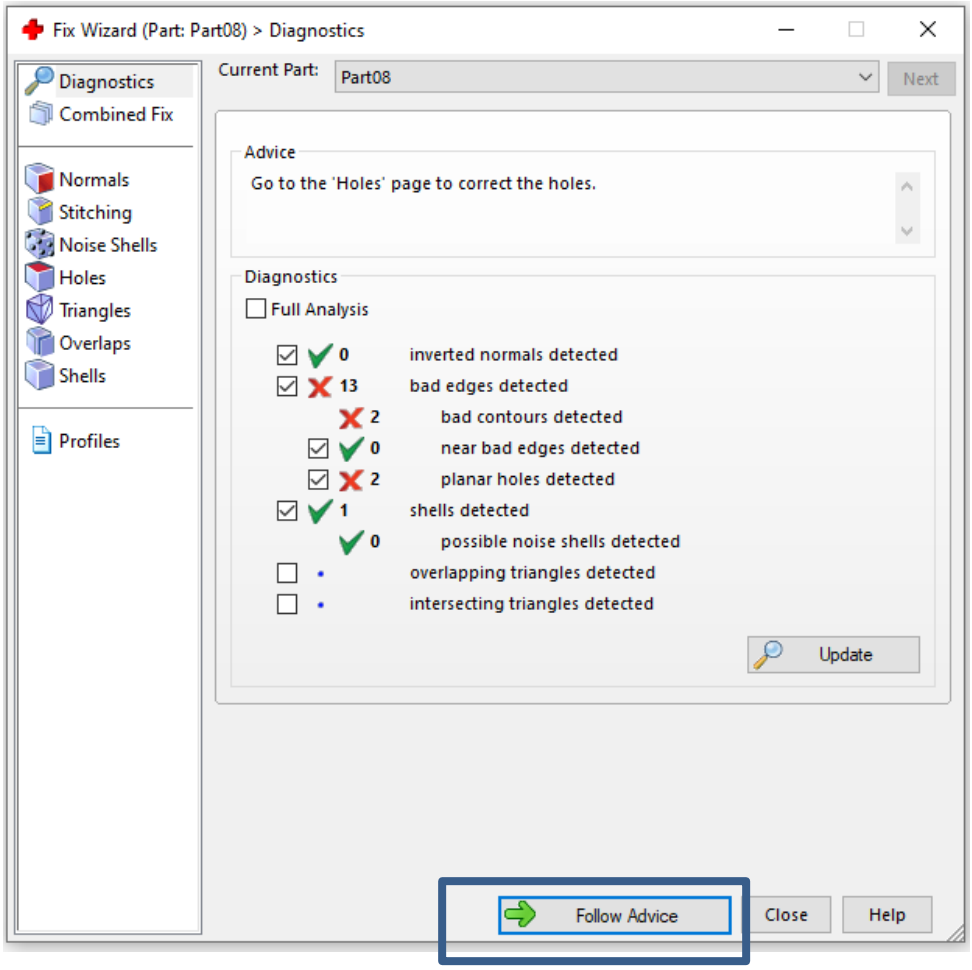
STL file repairing

- Its a time consuming and tedious job
- Design intent has to be kept in mind while repairing the bad STL files
- Repairing software
  - Materialise magics
  - Autodesk netfabb
  - Meshmixer

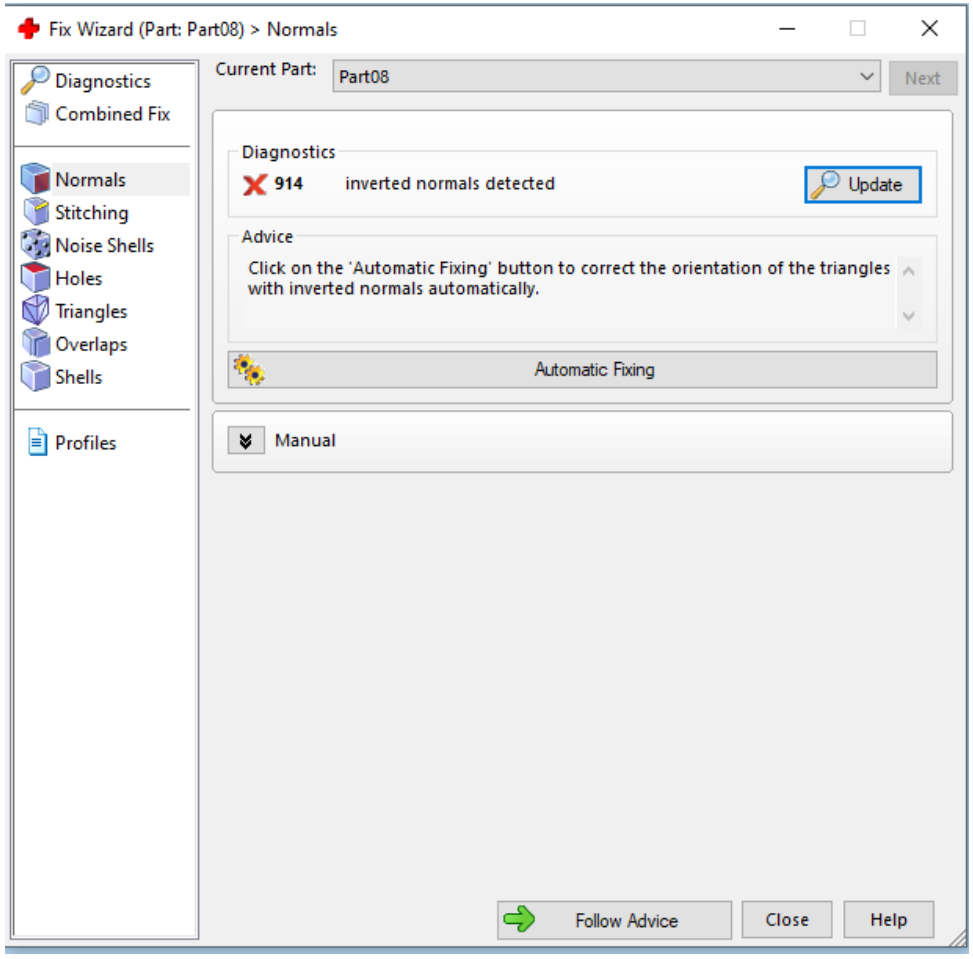
STL file error fixing using Magics



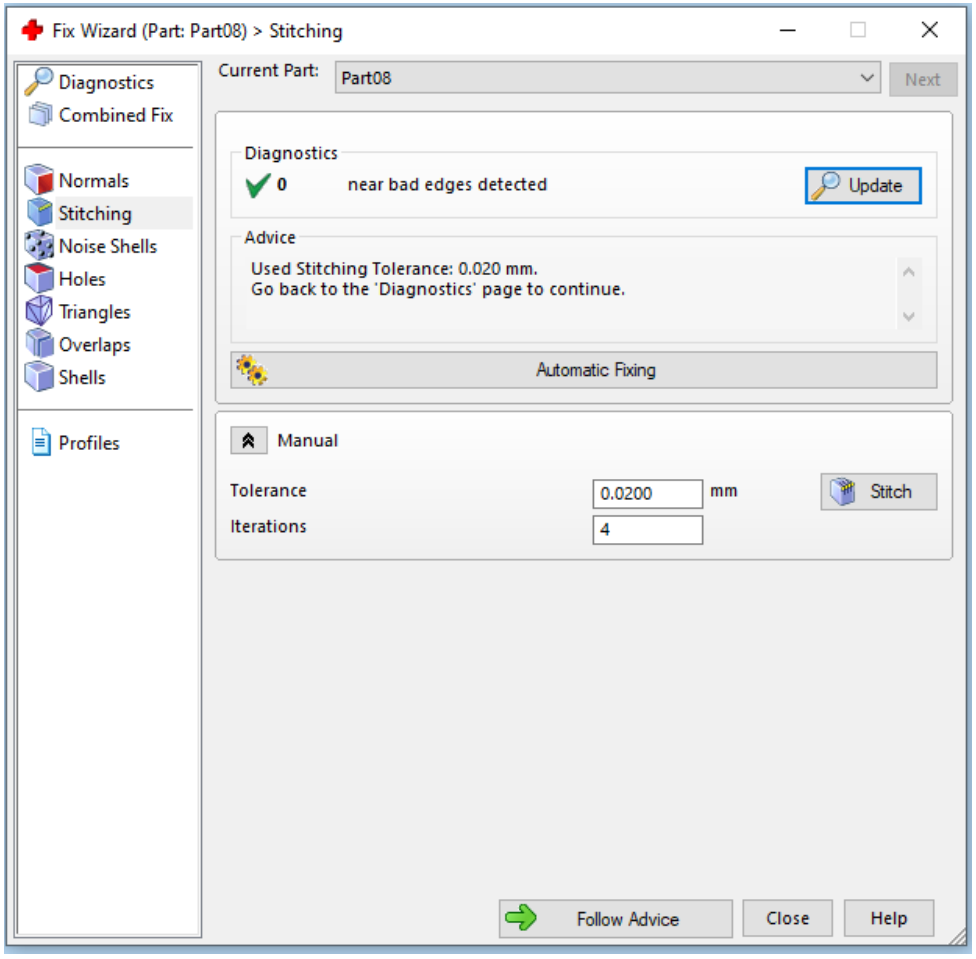
STL file error fixing using Magics



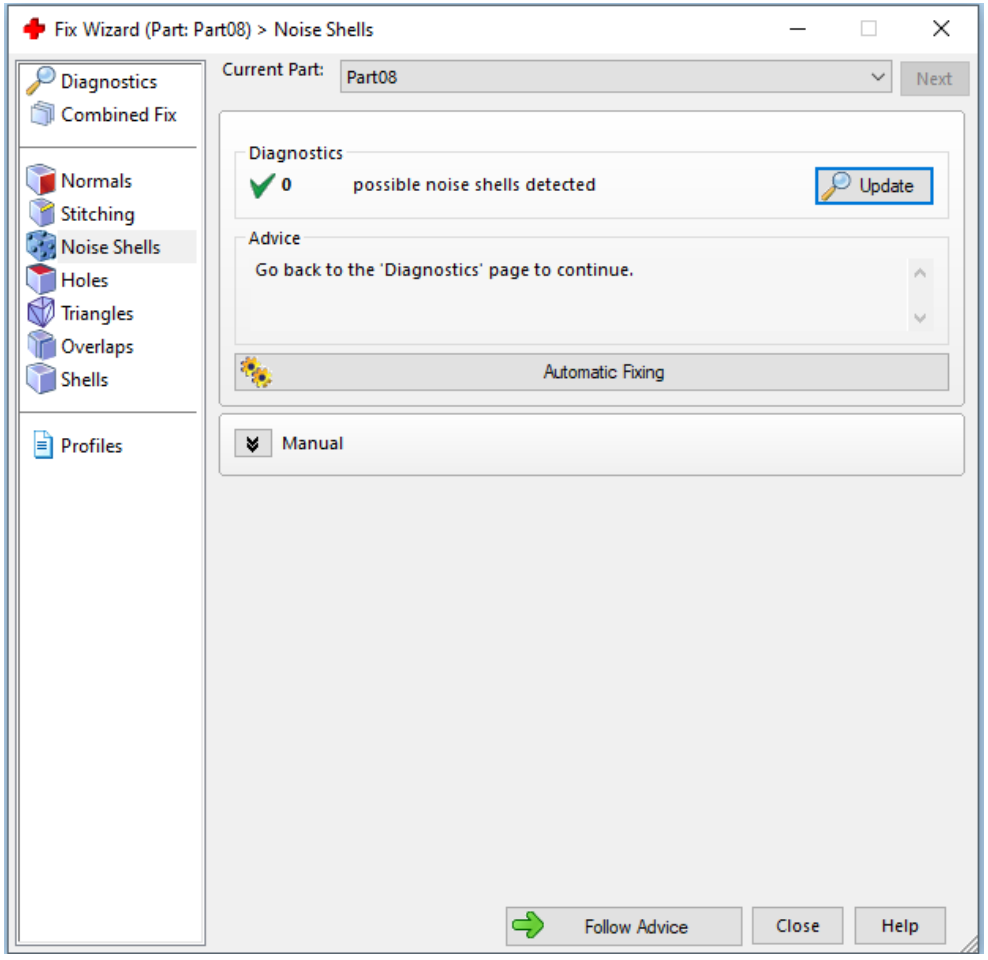
Normal fixing



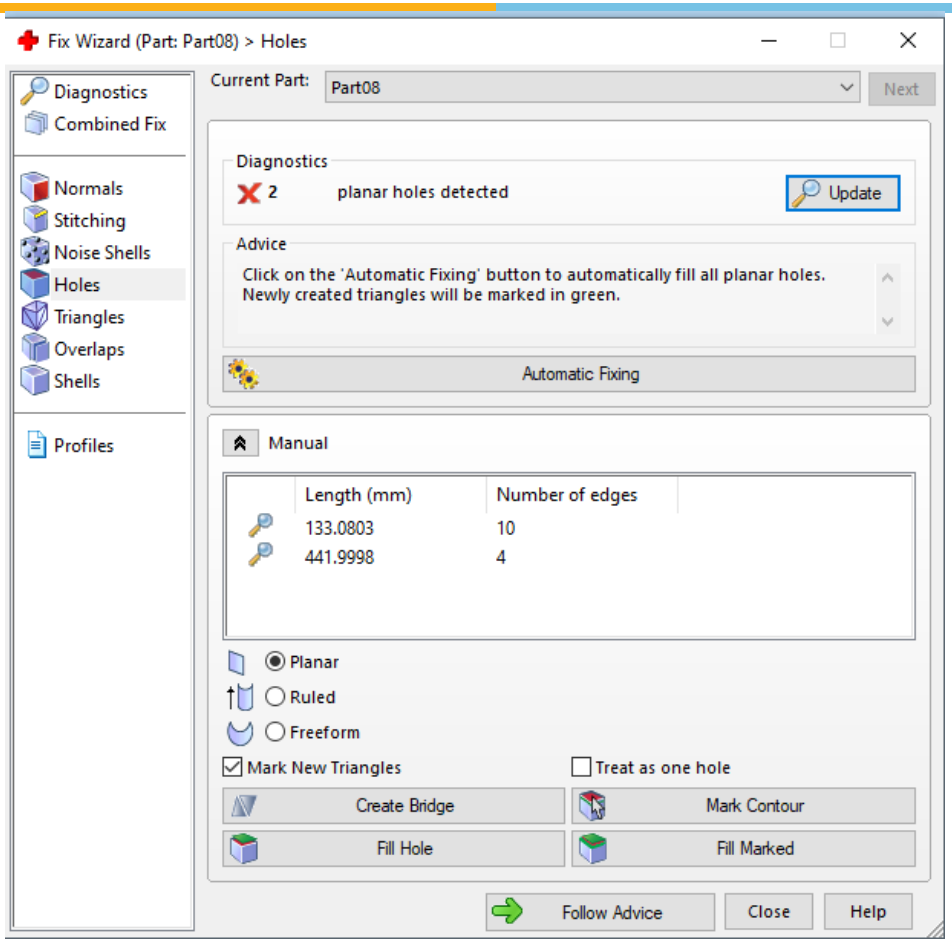
Stitching

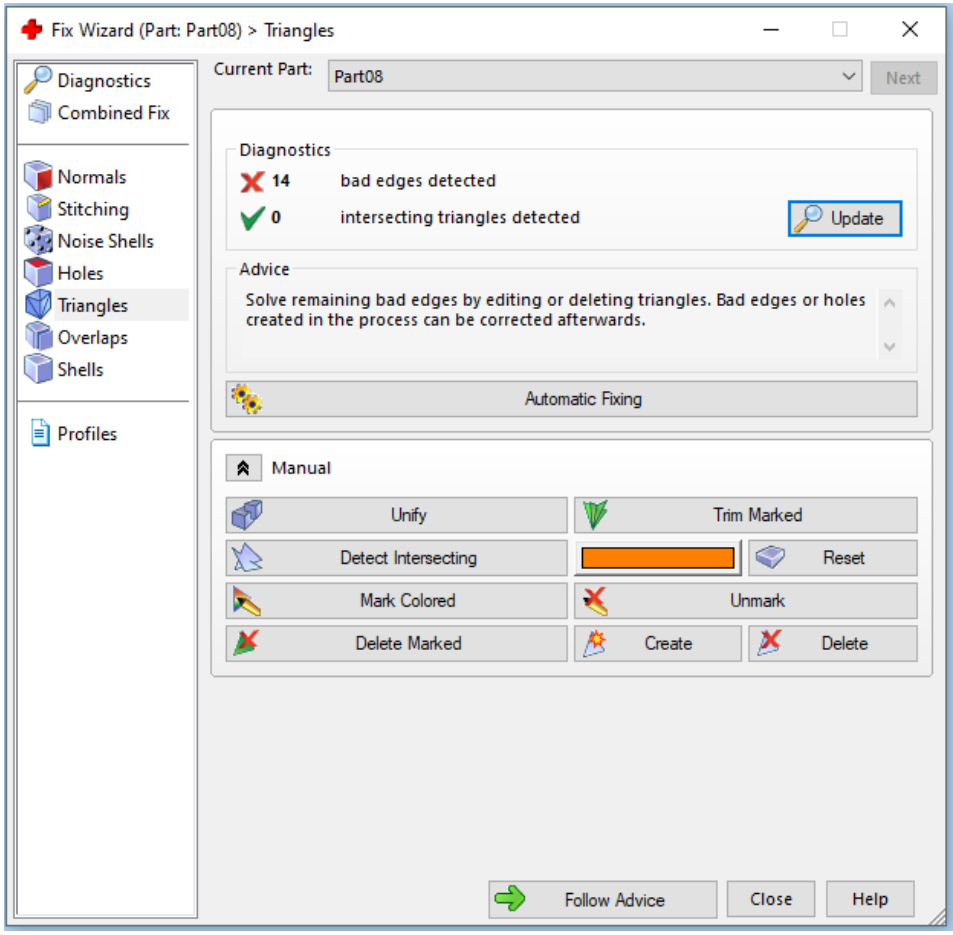

Fix Wizard (Part: Part08) > Stitching
Diagnostics
Combined Fix
Normals
Stitching
Noise Shells
Holes
Triangles
Overlaps
Shells
Profiles
Current Part:
Part08
Next
Diagnostics
0
near bad edges detected
Update
Advice
Used Stitching Tolerance: 0.020 mm.
Go back to the 'Diagnostics' page to continue.
Automatic Fixing
Manual
Tolerance
0.0200
mm
Stitch
Iterations
4
Follow Advice
Close
Help

Noise Shells



Holes and Triangles





STL File fixing using Magics

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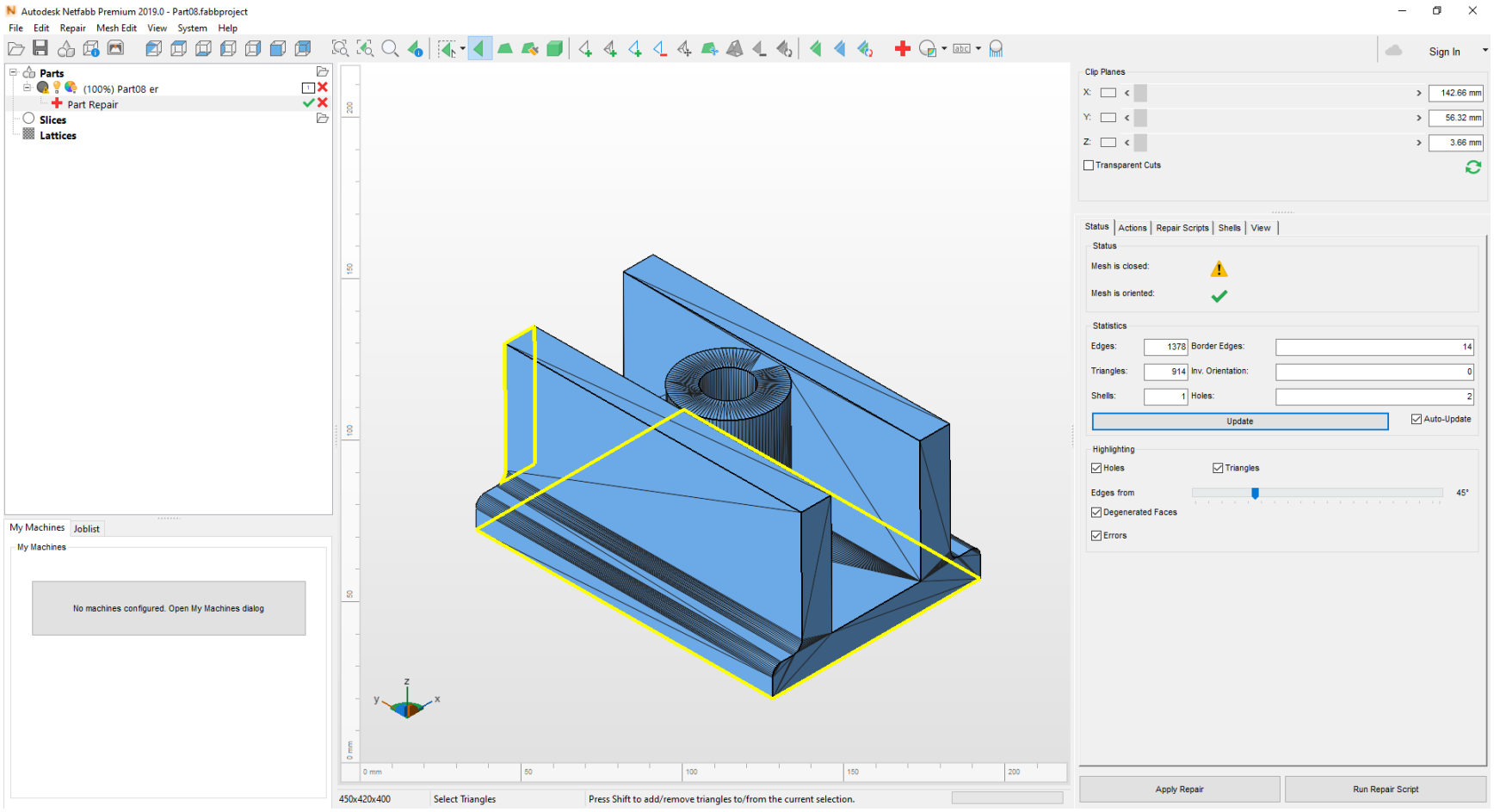
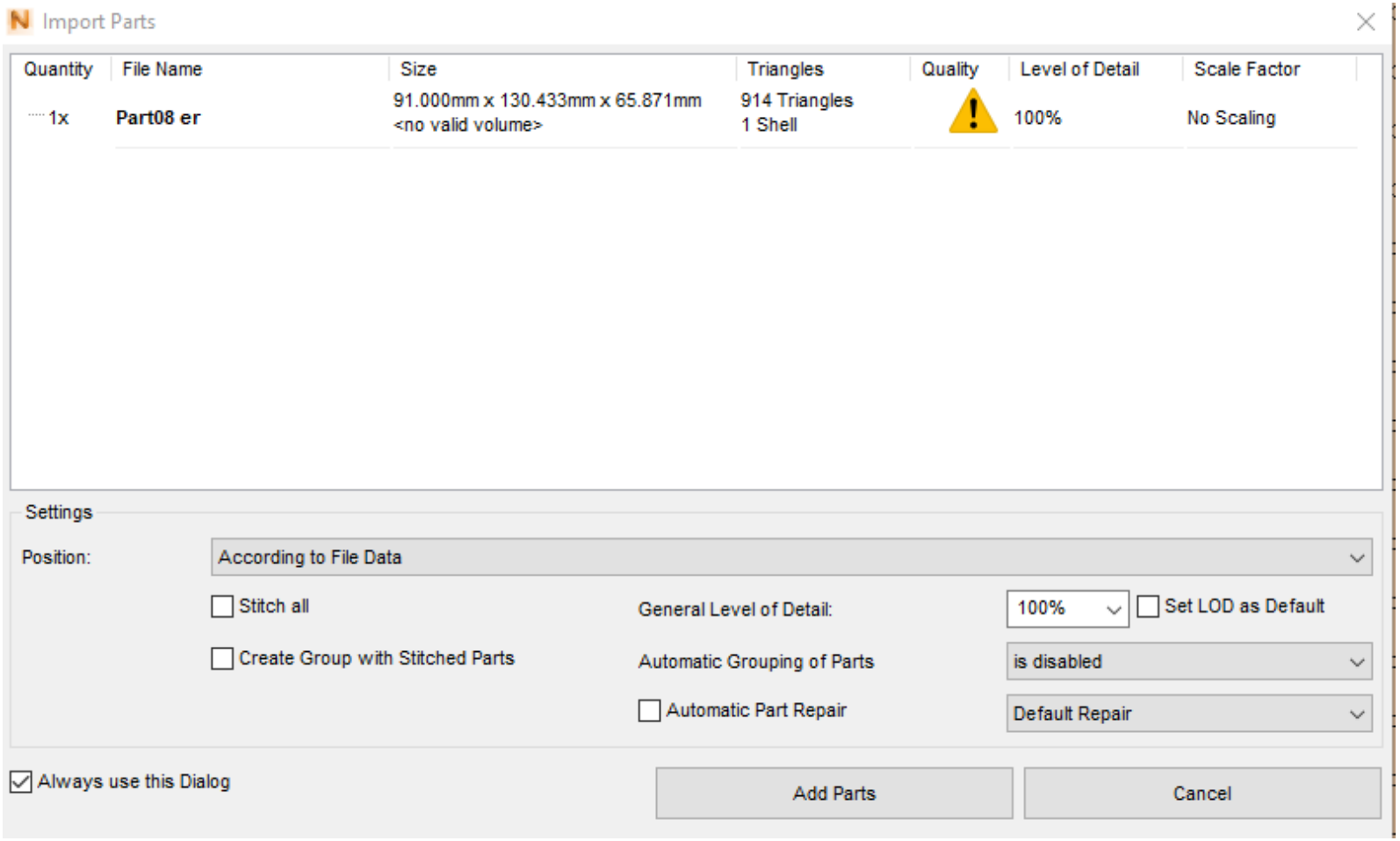
https://www.youtube.com/watch?v=x1mrpvEmmA8

STL file correction using Netfabb



Fixing error while loading



Alternate for STL files

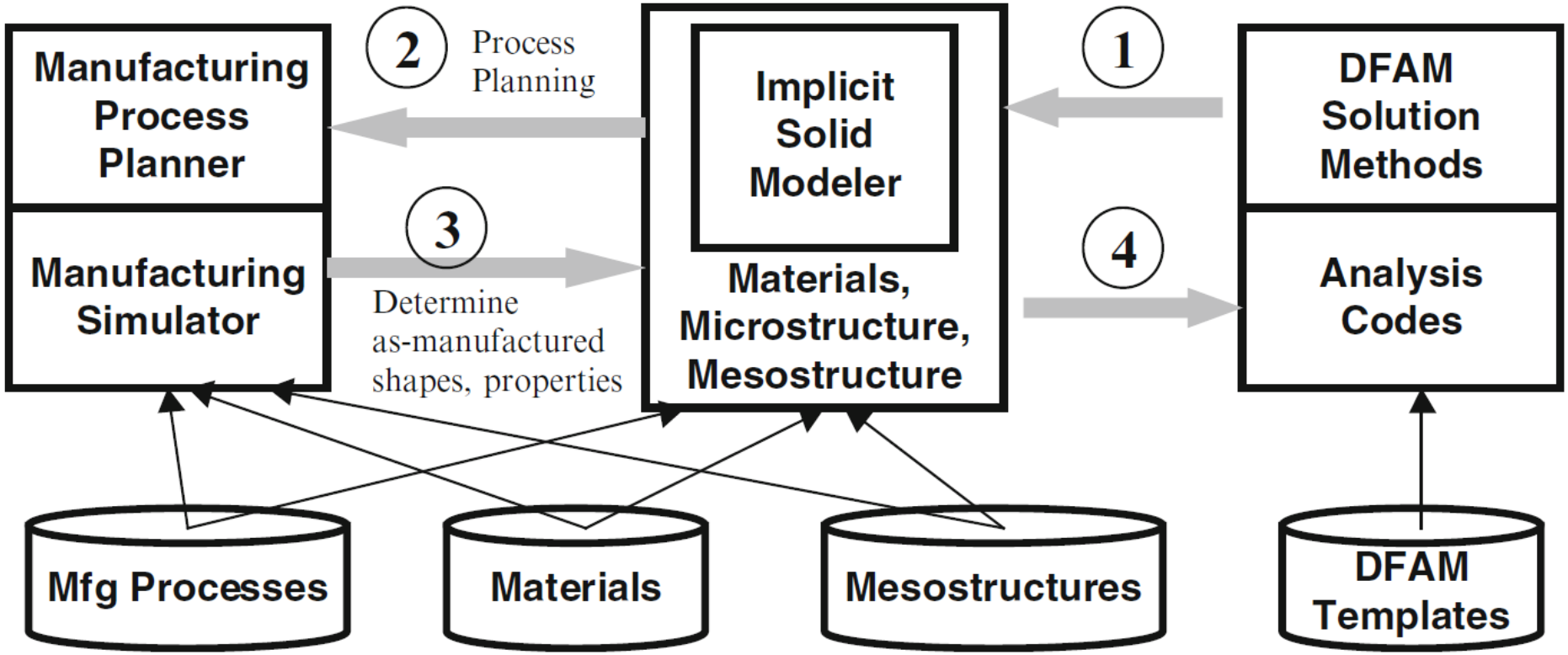
- OBJ- stores colour and texture profiles
- PLY – used for storing 3D scanned objects
- 3MF – new file type launched by 3MF consortium
- VRML
- AMF

Challenges in CAD for AM

- Geometric complexity—need to support models with tens and hundreds of thousands of features.
- Physically based material representations—material compositions and distributions must be represented and must be physically meaningful.
- Physically based property representations—desired distributions of physical and mechanical properties must be represented and tested for their physical basis.

CAD needs

- Process–structure–property relationships for materials must be integrated into geometric representations of CAD models.



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End of Session 13