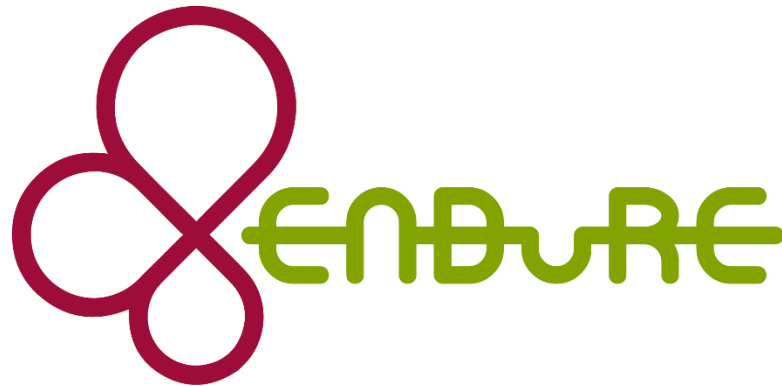




Rapid Prototyping

carmelo.demaria@centropiaggio.unipi.it



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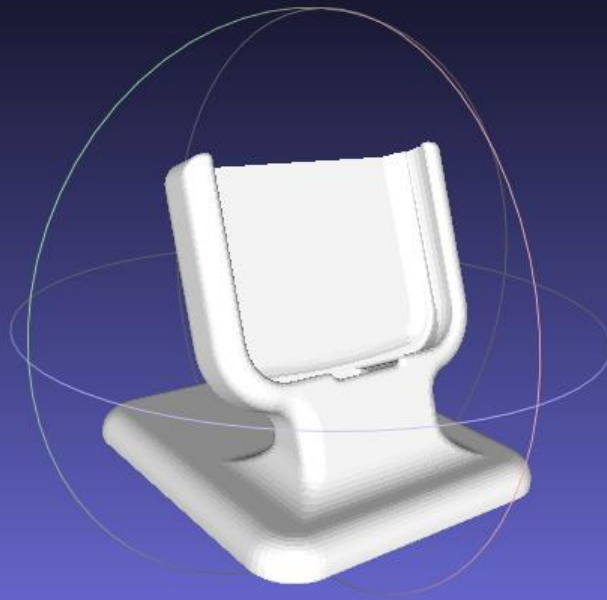
Co-funded by the
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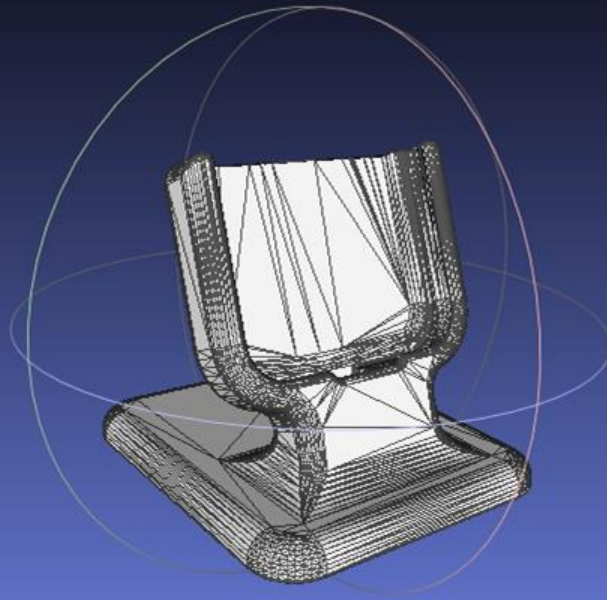
Additive manufacturing Process Flow

- Solid Modelling
- Tessellation/Generation of STL file
- Support Generation
- “Slicing” of the Model
- Model Physical Buildup
- Cleanup and Post Curing
- Surface Finishing

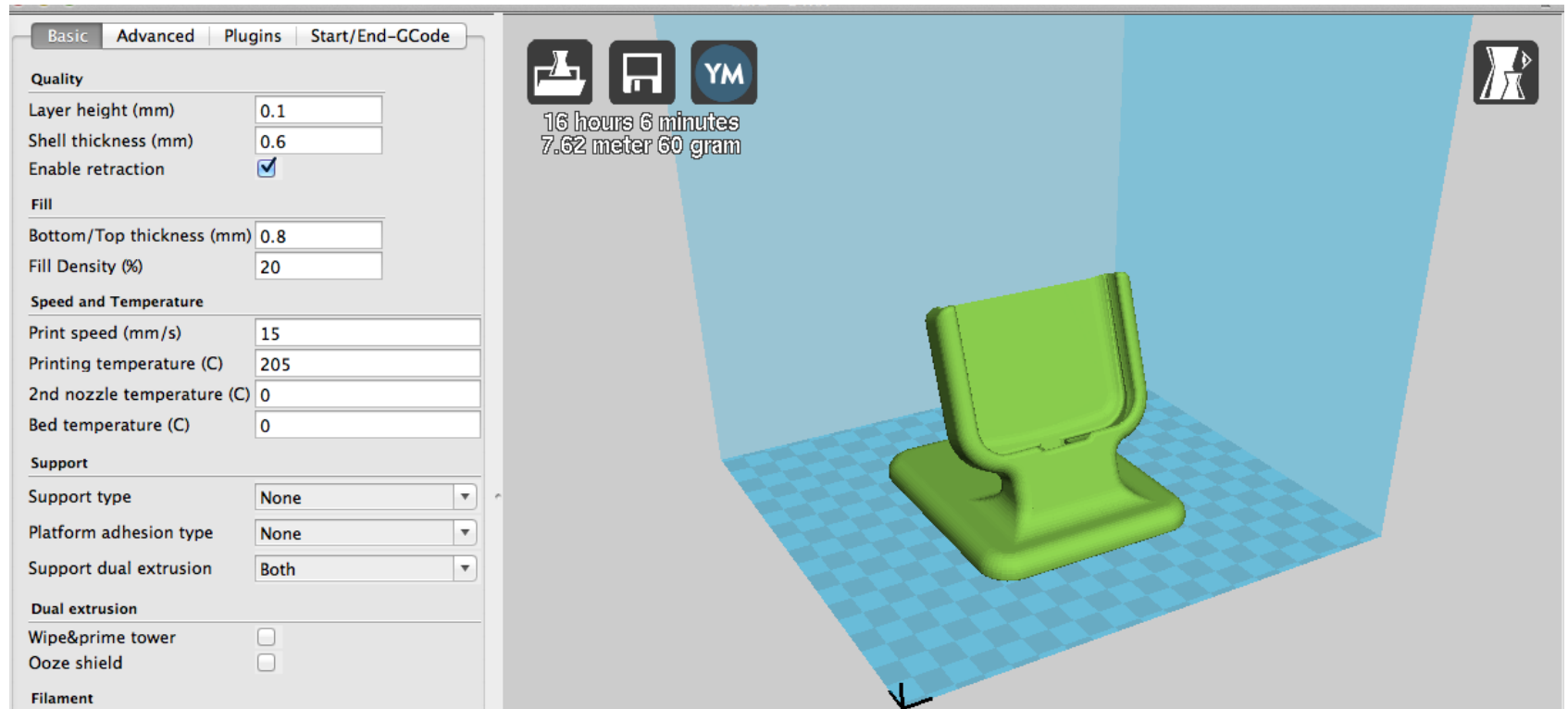
from idea to design



from idea to design



from design to object



from design to object



from design to object



Additive manufacturing Process Flow

File



Description



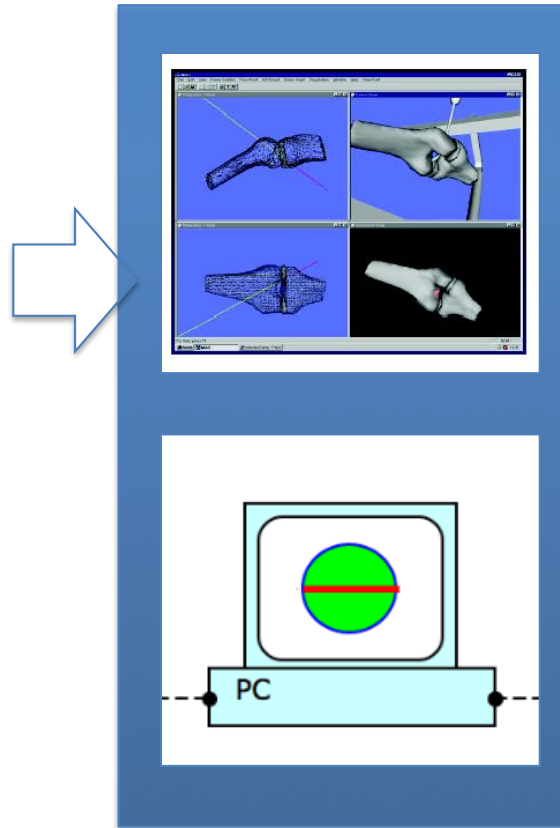
Software



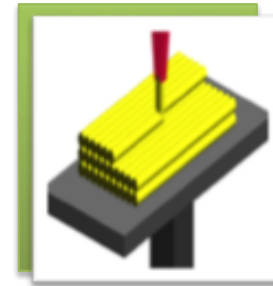
Additive manufacturing Process Flow



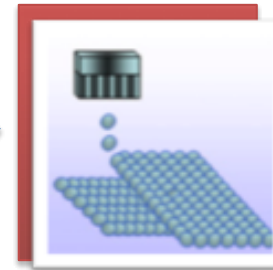
Image Acquisition



CAD/CAM System



Direct writing



Inkjet based





DATA SOURCE

Data source

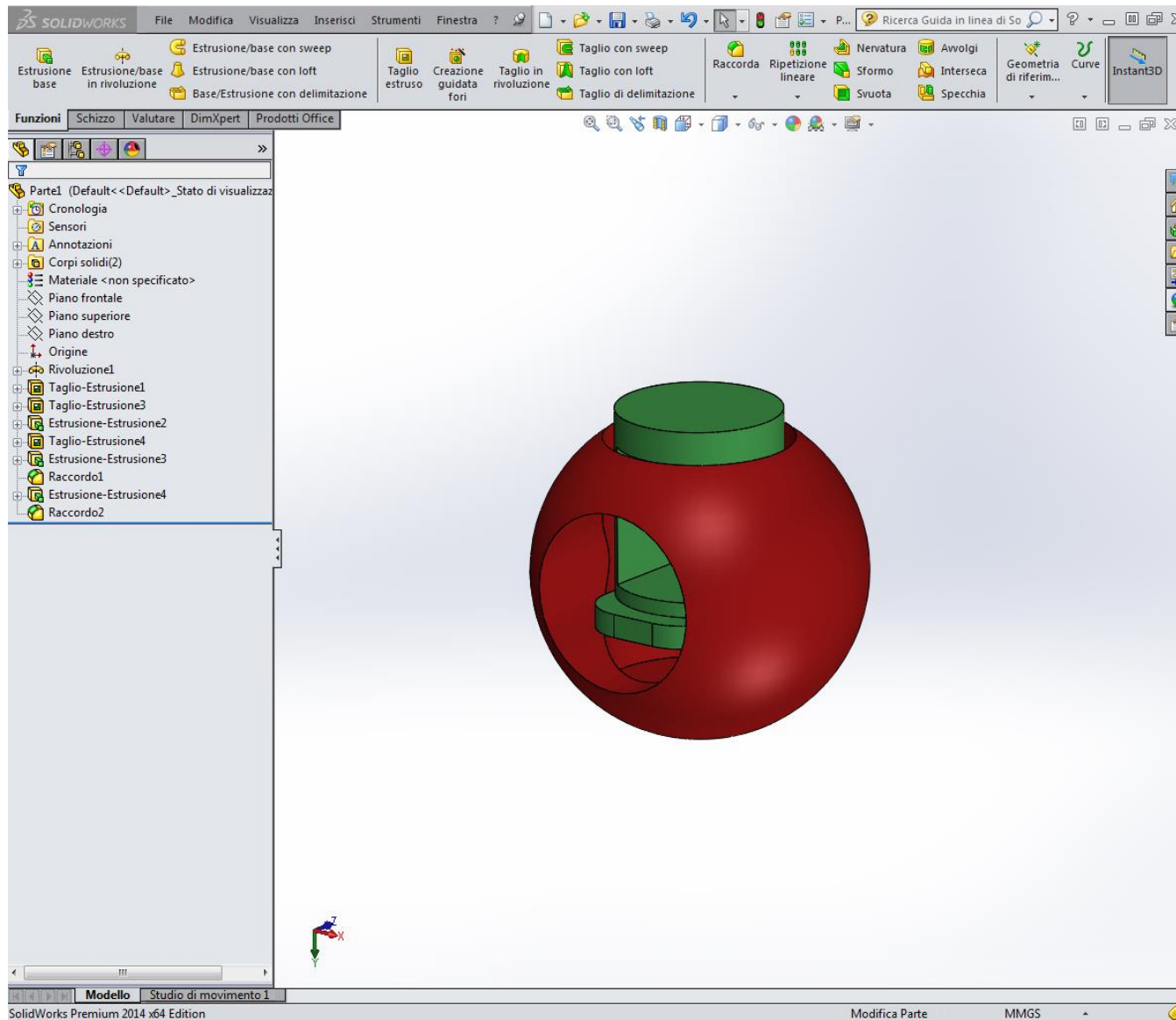
- Representation of a volume
 - CAD model
 - Your specific design
 - Web repository
 - Instruments output
 - Segmentation of medical Images (Tomographic Data: CT scan, RM scan)
 - Surface scanning
 - Laser
 - Optical (also phone camera)

CAD model

Dimensions of CAD Elements	Elements	Type of CAD Model
0D	Point	Corner Model
1D	Line	Edge Model
2D	Surface	Surface Model
3D	Solid/Volume	Solid or Volume Model

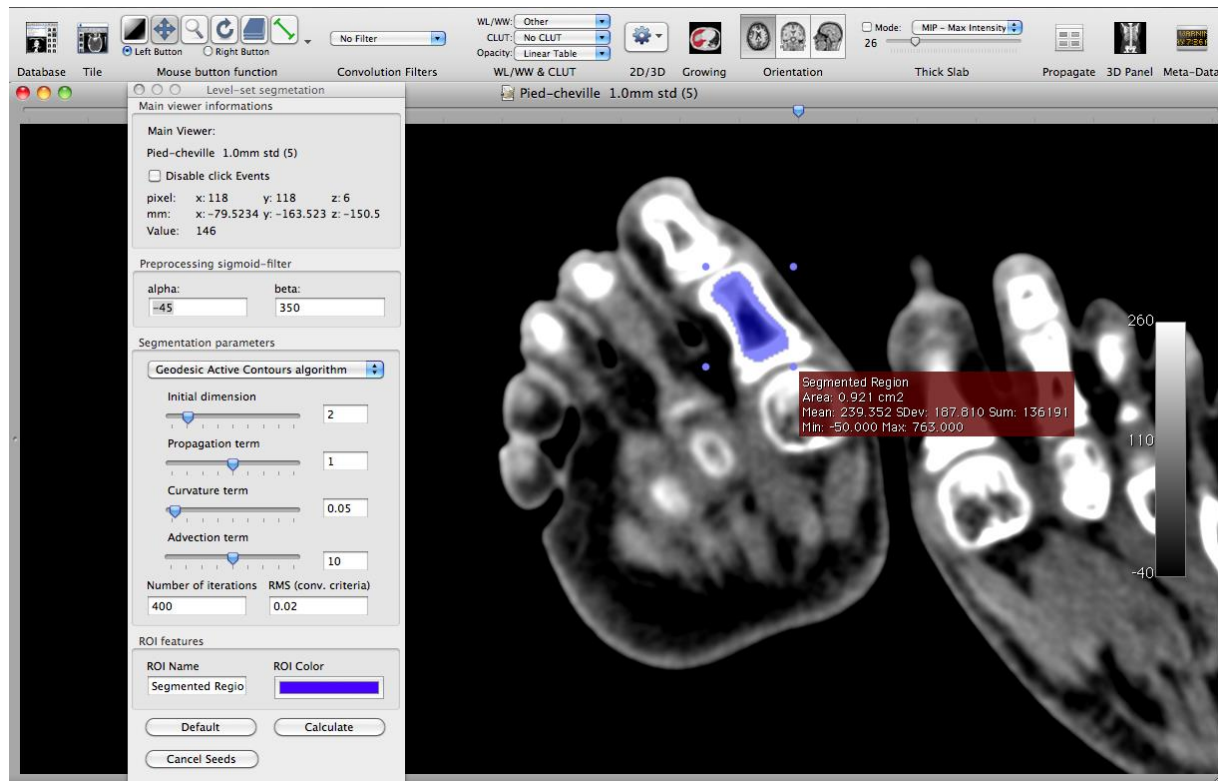
- Most of the CAD software are proprietary with a relatively high cost
- Free or Open Source examples
 - FreeCAD
 - 123D Design
 - Sketch Up

CAD Model



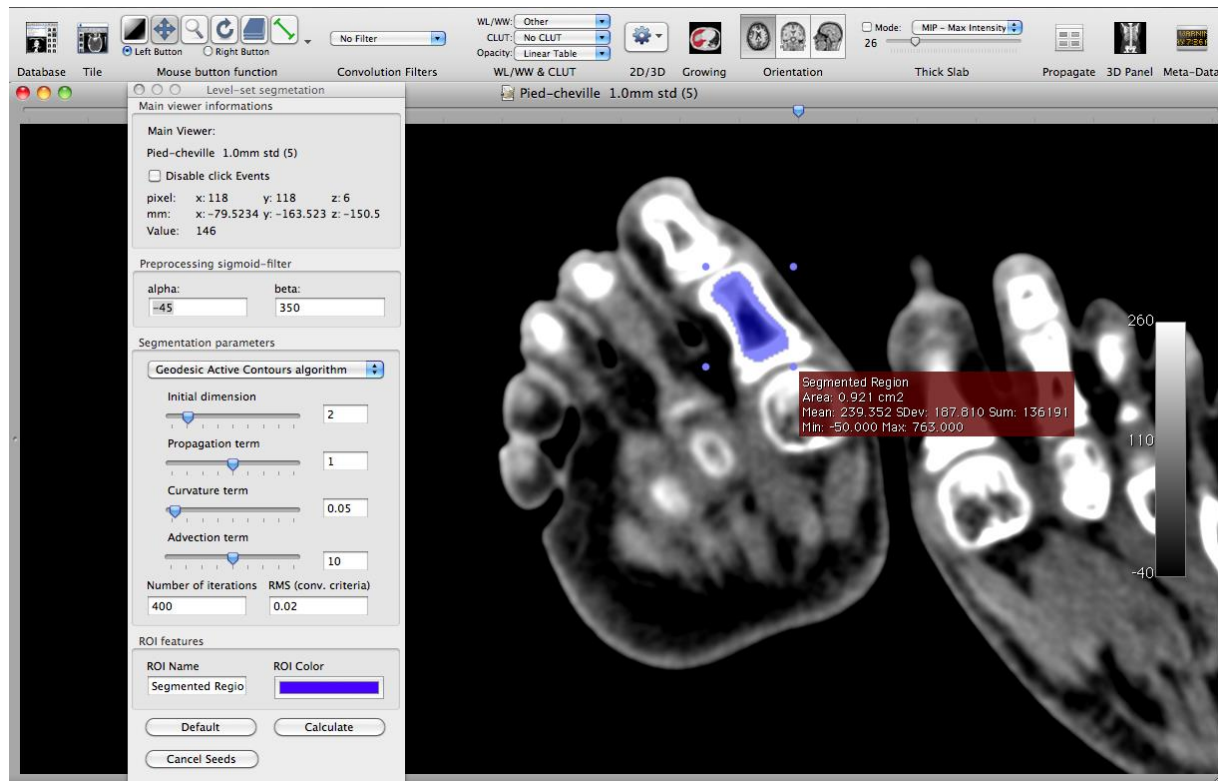
Segmentation

- Segmentation subdivides an image into its constituent regions or objects.
- The level to which the subdivision is carried out depends on the problem being solved



Bioimaging software

- OsiriX (www.osirix-viewer.com)
- 3DSlicer (www.slicer.org)
- ImageJ (rsb.info.nih.gov/ij)
- MIPAV (mipav.cit.nih.gov)
- itk-SNAP (www.itksnap.org)





FROM 3D SCAN TO STL

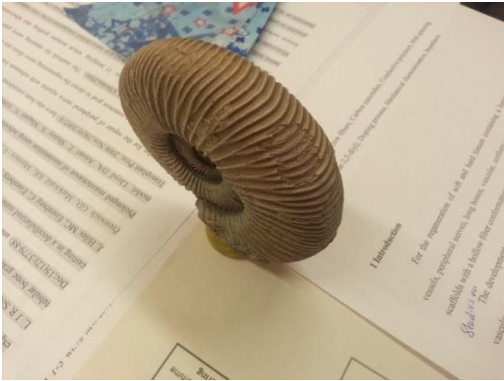
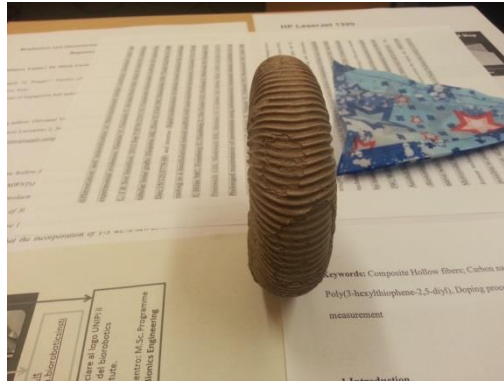
Use of 123DCatch





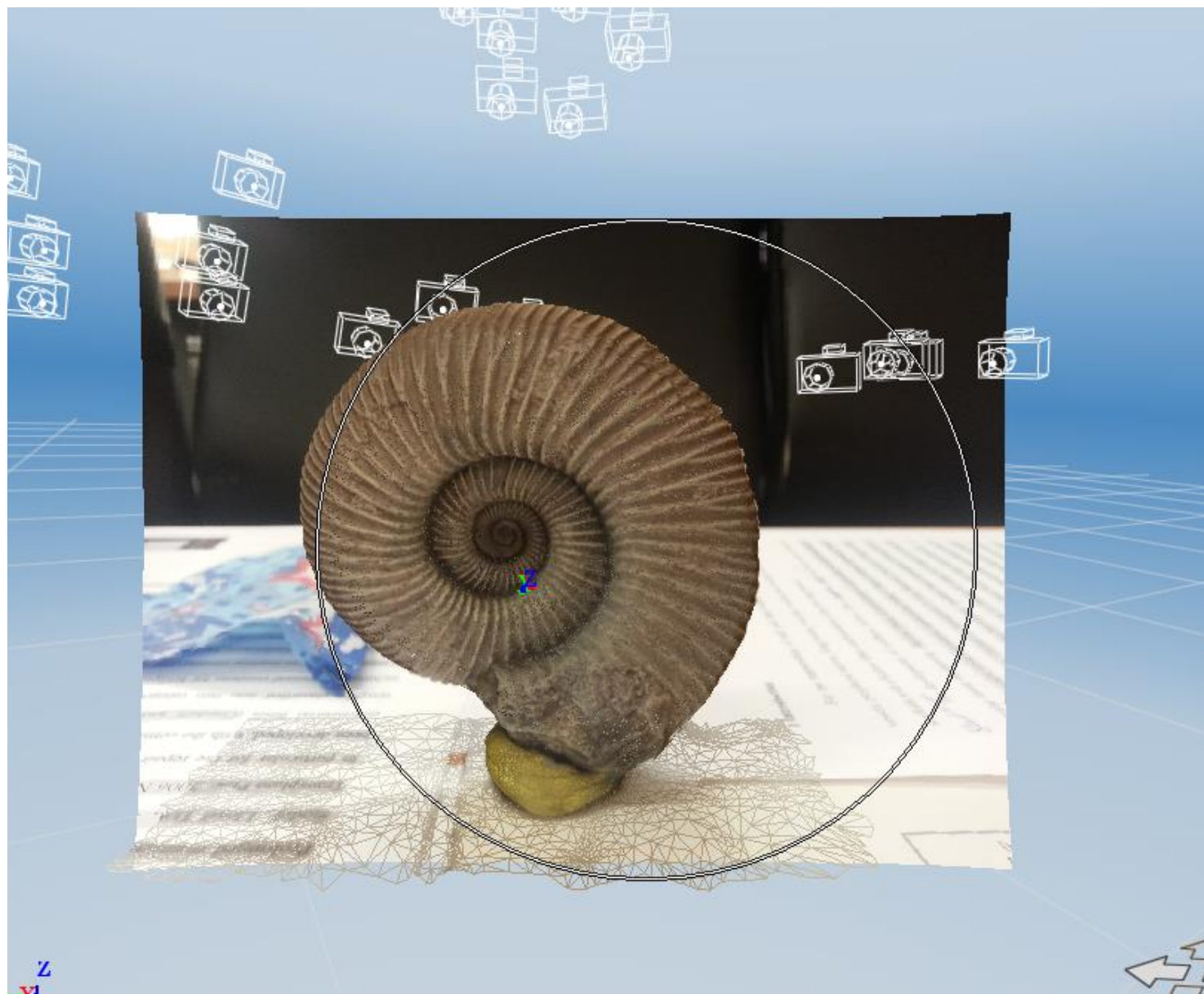


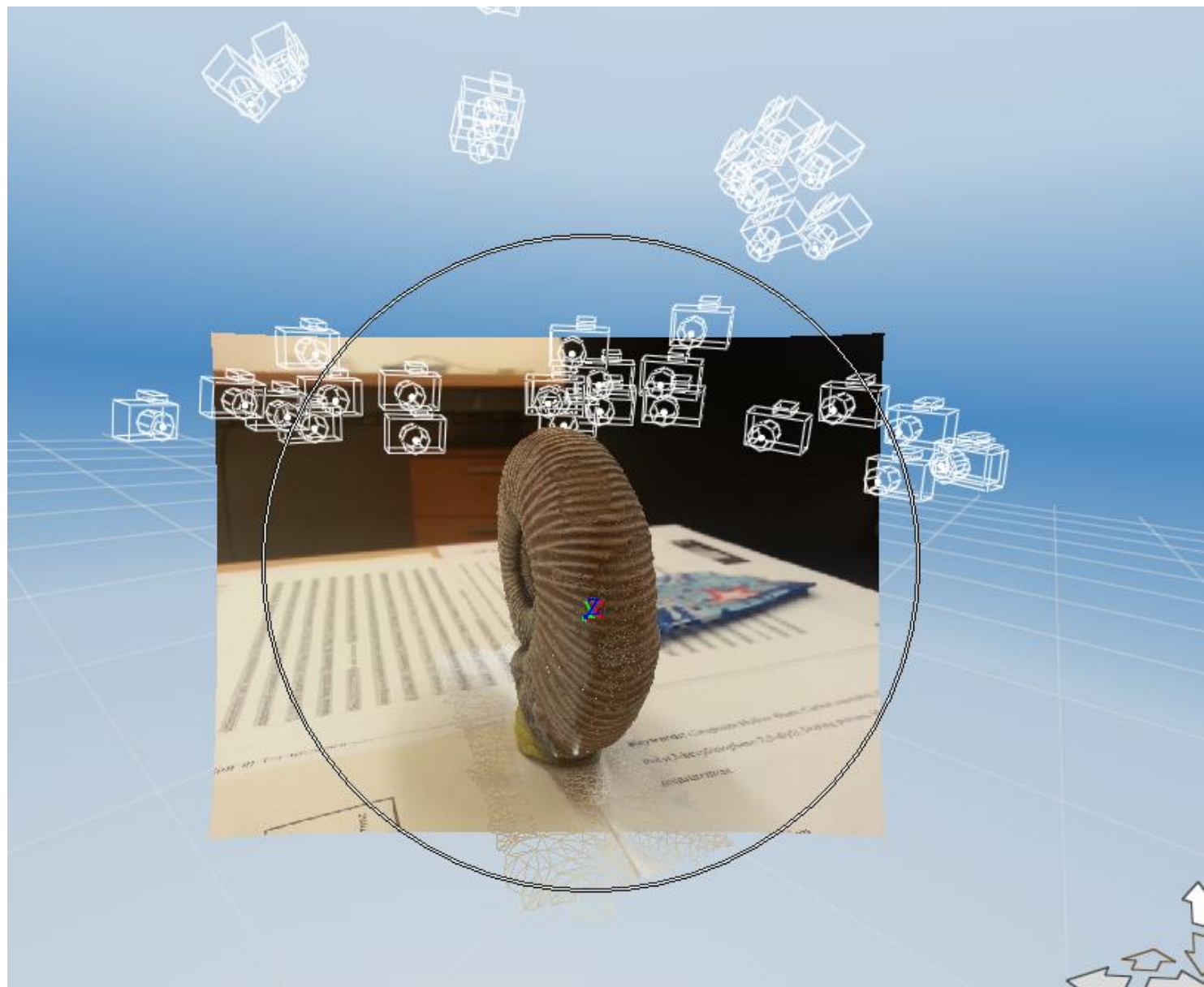






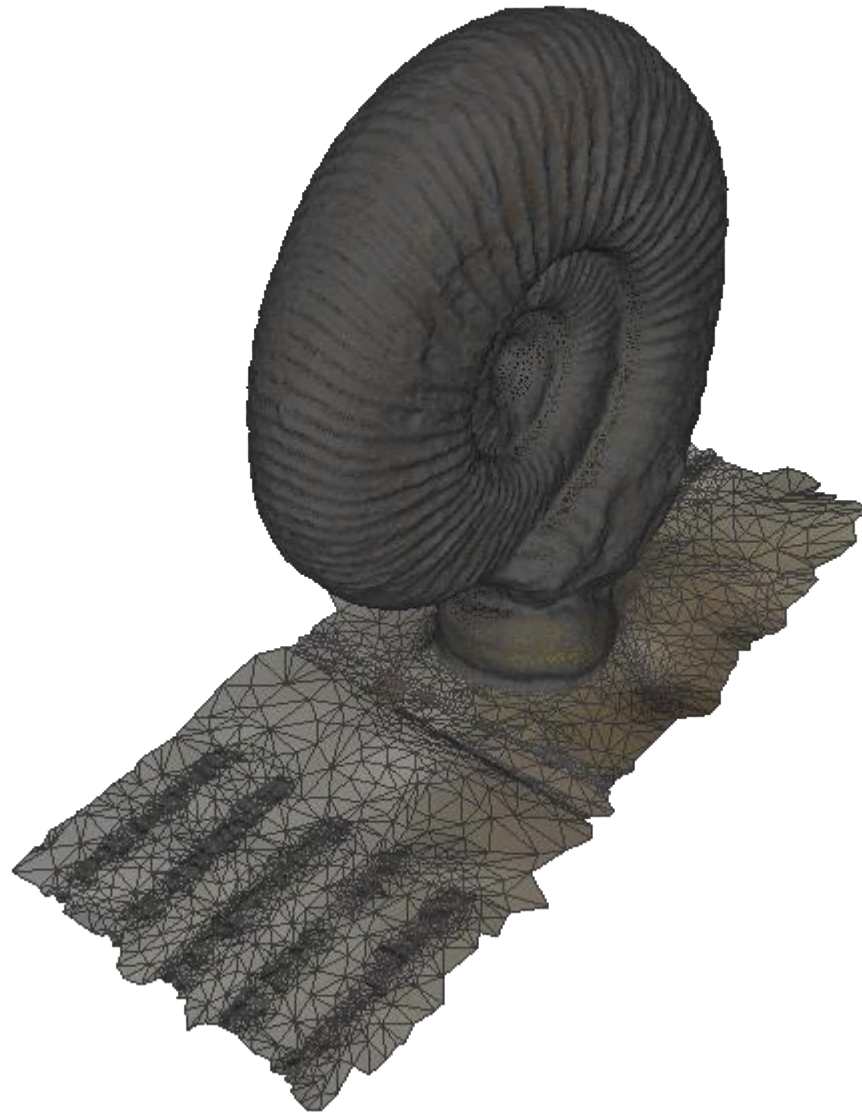


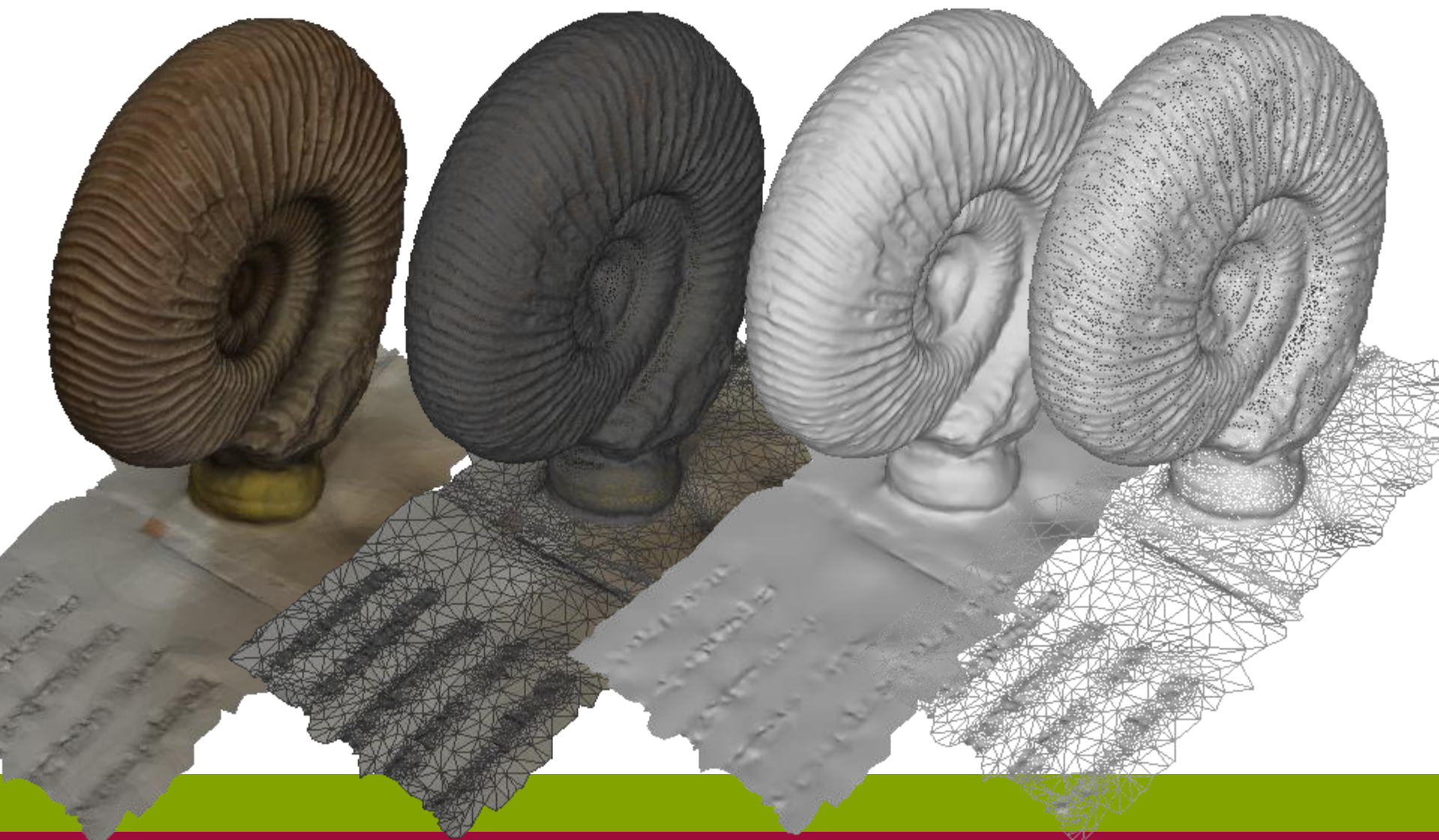


















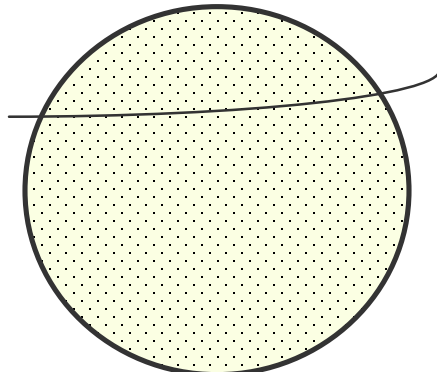
EXCHANGE FORMATS

STL Files (*.stl)

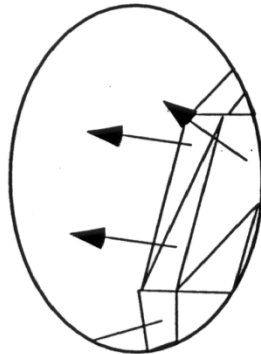
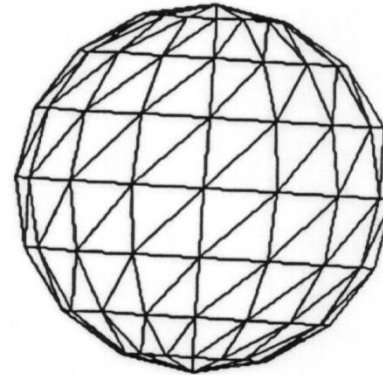
- STL files describe only the surface geometry of a three dimensional object without any representation of color, texture or other common CAD model attributes.
- An STL file describes a raw unstructured triangulated surface by the unit normal and vertices (ordered by the right-hand rule) of the triangles using a three-dimensional Cartesian coordinate system.



Example of *.stl Representation

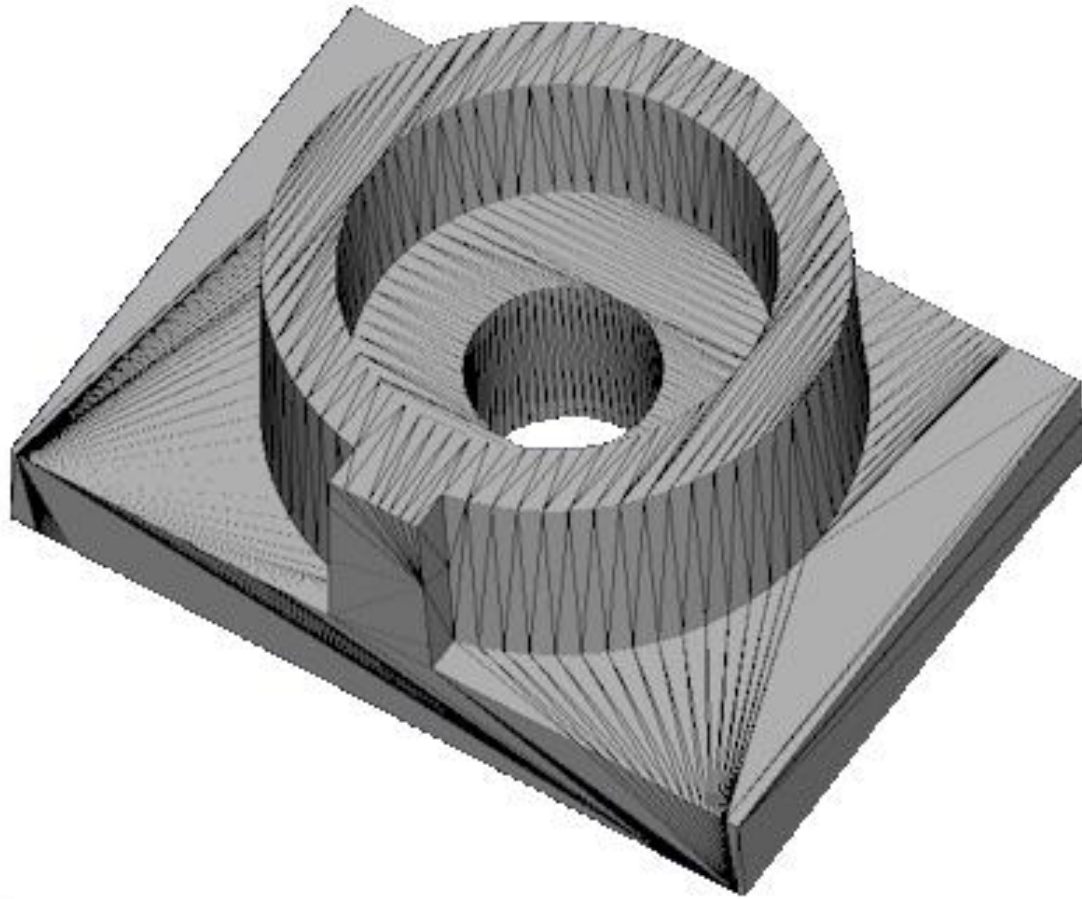


Representing
a sphere



```
solid obj1
facet normal 1.457591e-01 -9.885599e-01 -3.877669e-02
  outer loop
    vertex 9.614203e+00 4.757629e+00 0.000000e+00
    vertex 7.875000e+00 4.501190e+00 0.000000e+00
    vertex 9.483117e+00 4.764183e+00 -6.598330e-01
  endloop
endfacet
facet normal 1.161178e-01 -9.870778e-01 -1.104267e-01
  outer loop
    vertex 9.483117e+00 4.764183e+00 -6.598330e-01
    vertex 7.875000e+00 4.501190e+00 0.000000e+00
    vertex 9.109818e+00 4.782848e+00 -1.219212e+00
  endloop
endfacet
facet normal 6.134766e-02 -9.843393e-01 -1.652652e-01
```

Example of *.stl Representation



Current STL

Advantages	Disadvantages
Simple	Geometry leaks
Sequential memory access*	No specified units
Portable	Unnecessary redundancy
	Incompatible with color, multiple materials, etc
	Poor scalability
*Does not require large amounts of RAM, critical in '80s	Lacks auxiliary information

- There are several other formats
 - 3D PDF, ISO 14649 (STEP-NC), STEP / IGES, SAT, Parasolid, X3D VRML, PLY, 3DS, SLC

AMF: Additive Manufacturing Format

- XML format
 - metadata
- Compressibility
 - Curved mesh
- Encryption and watermark
- Multiple material
 - Graded Material
 - Internal microstructures
- Appearance
 - Color
 - Tolerance
 - Texture



ISO STANDARD



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ISO/ASTM 52915:2013[®]

Standard specification for additive manufacturing file format (AMF) Version 1.1

Abstract

Preview ISO/ASTM 52915:2013

ISO/ASTM 52915:2013 describes a framework for an interchange format to address the current and future needs of additive manufacturing technology. For the last three decades, the STL file format has been the industry standard for transferring information between design programs and additive manufacturing equipment. An STL file contains information only about a surface mesh and has no provisions for representing color, texture, material, substructure, and other properties of the fabricated target object. As additive manufacturing technology is quickly evolving from producing primarily single-material, homogenous shapes to producing multimaterial geometries in full colour with functionally graded materials and microstructures, there is a growing need for a standard interchange file format that can support these features.

General informationRevisionsCorrigenda / Amendments

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Status: ✓ Published	Stage: 90.92 (2014-09-17)
TC/SC: ISO/TC 261	Number of Pages: 15

FORMAT ?

LANGUAGE

✓  PDF

 PAPER

EnglishEnglish

CHF88

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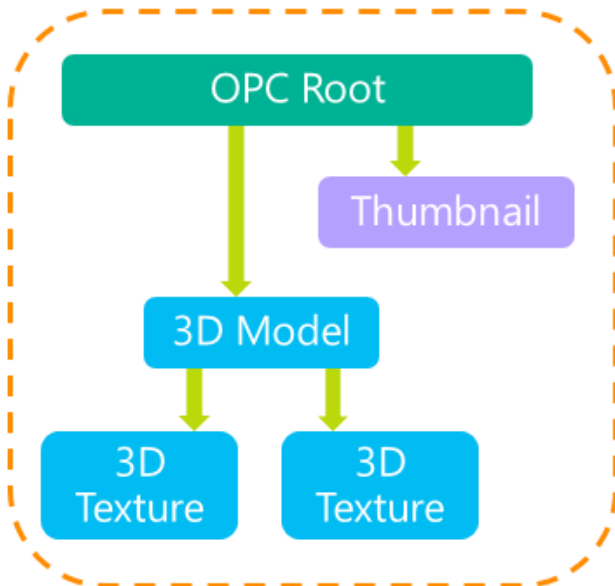
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3MF format

<http://3mf.io/>

3MF design considerations



Complete

- Open Packaging Conventions (OPC)

Compact

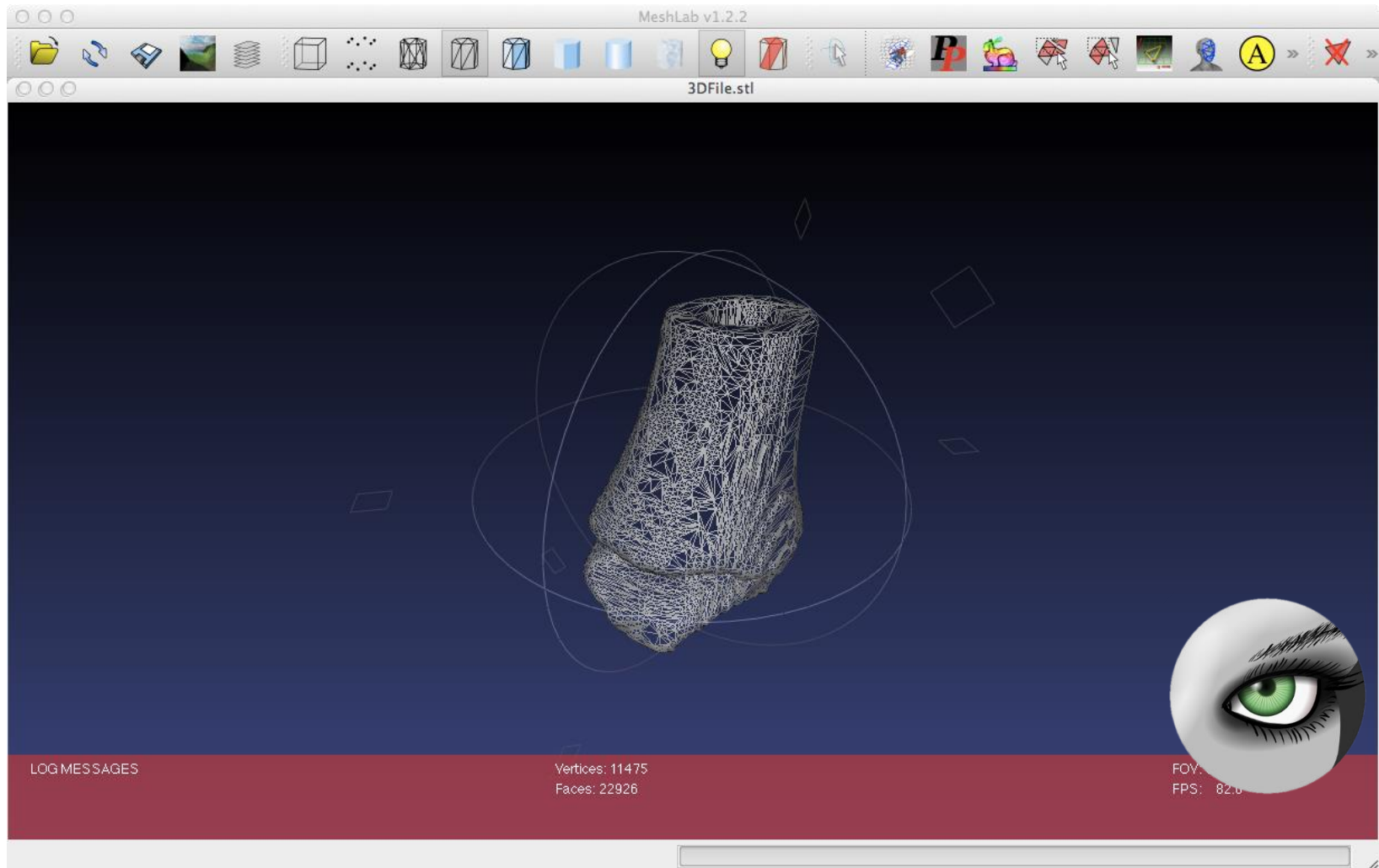
- ZIP package
- References avoid duplication

Human-readable

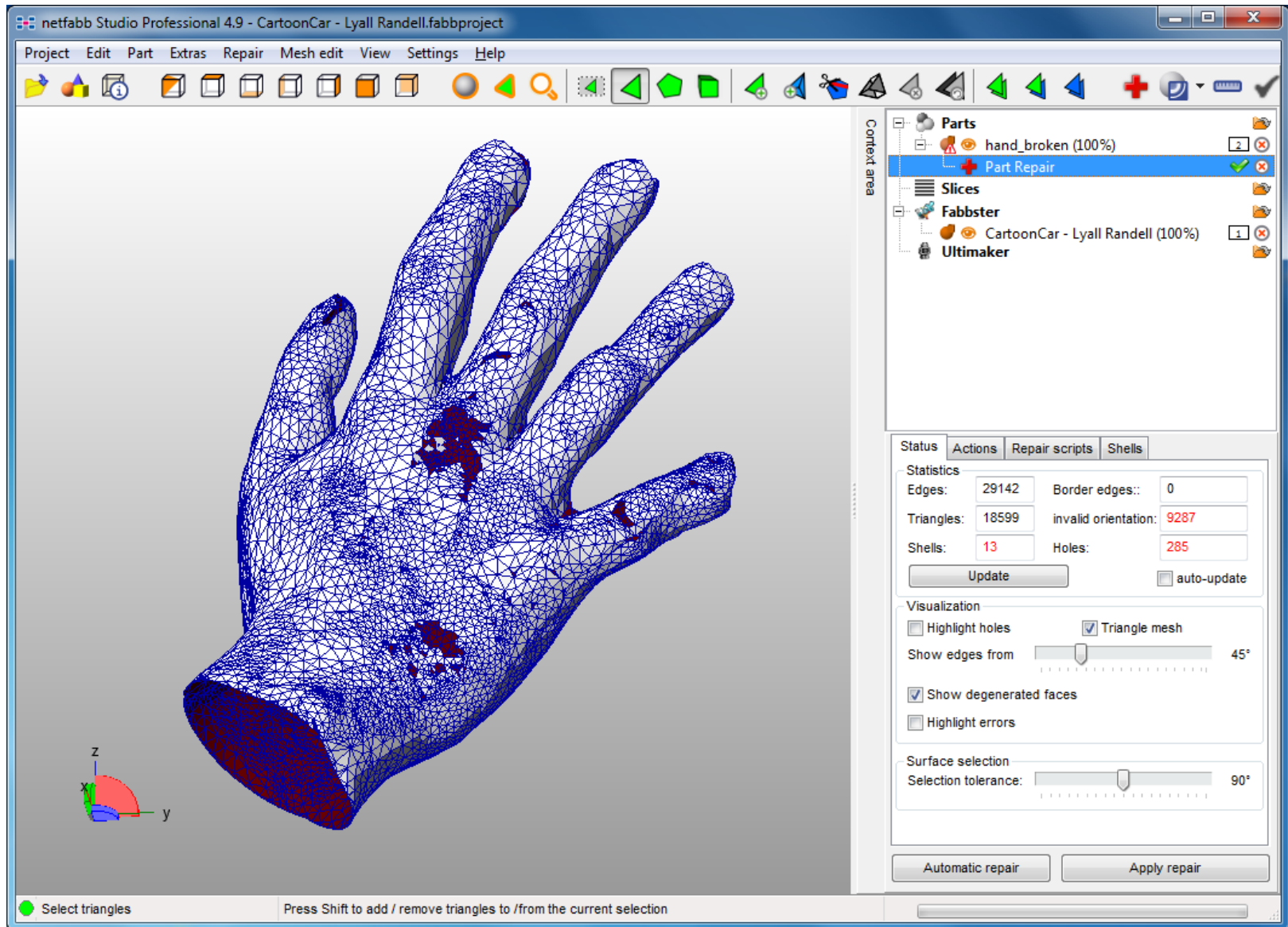
- XML
- Well-known binary formats (e.g. PNG, JPEG)



MeshLab

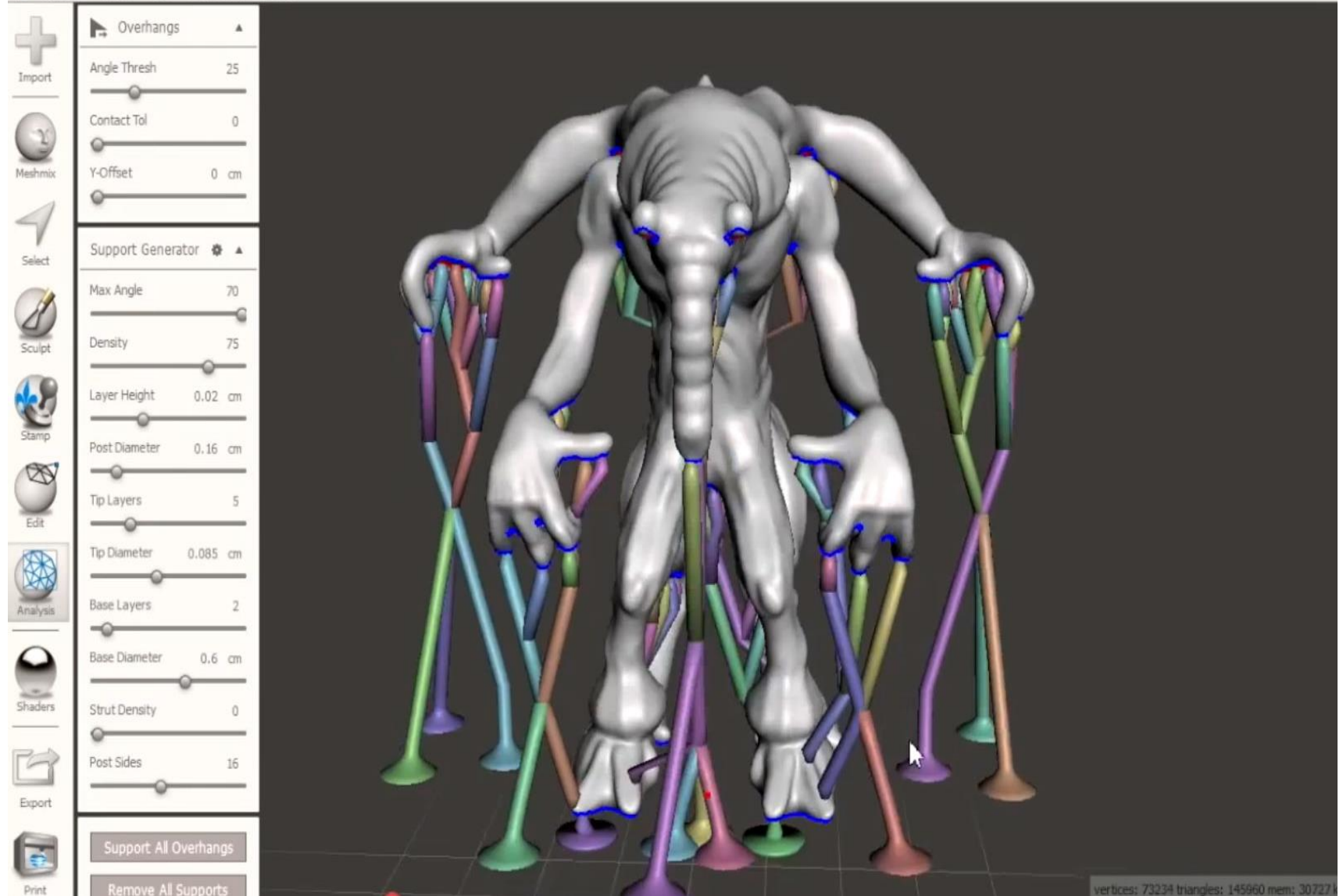


Netfabb

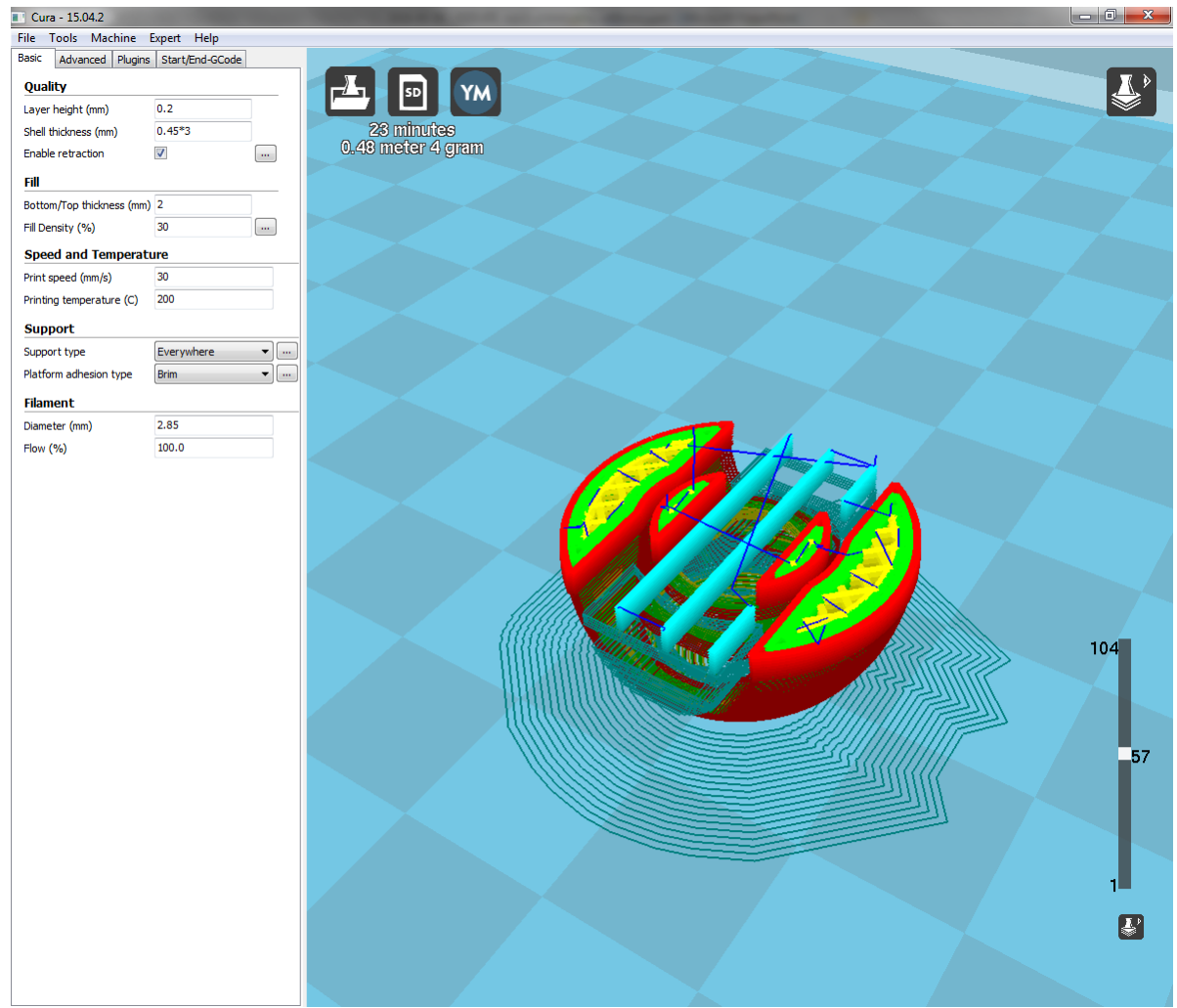


Meshmixer

File Actions View Help Feedback Debug



From CAD to CAM



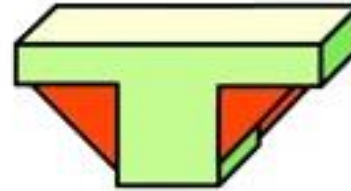
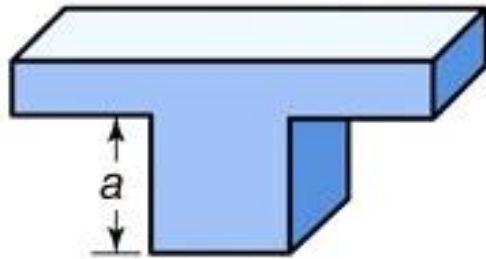
Processing of *.stl Files

- After the CAD system has generated *.stl file, it can be passed to the AM machine
- Machine then processes the *.stl file, slicing it into many thin layers stacked on one another. The resulting files are called slice files.
- The shapes of the slices represent cross sections
- In SFM processes thick solid sections of material are often removed and replaced with cross hatching
- Thus SFM parts are usually hollow, with cross hatching on the inside to add strength/stability

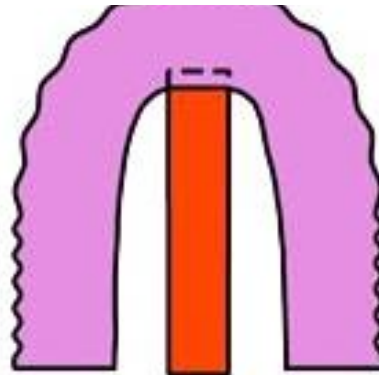
Support material

- Some solid freeform fabrication techniques use two materials in the course of constructing parts.
- The first material is the part material and the second is the support material (to support overhanging features during construction).
- The support material is later removed by heat or dissolved away with a solvent or water.

Support material

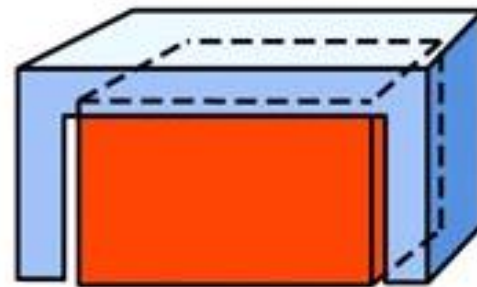


Island



Ceiling within an arch

Gussets

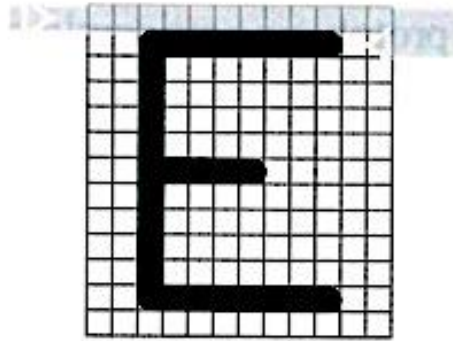


Ceiling

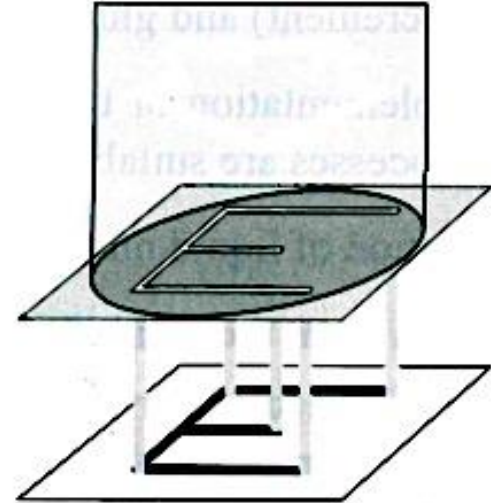
Patterning



Vector



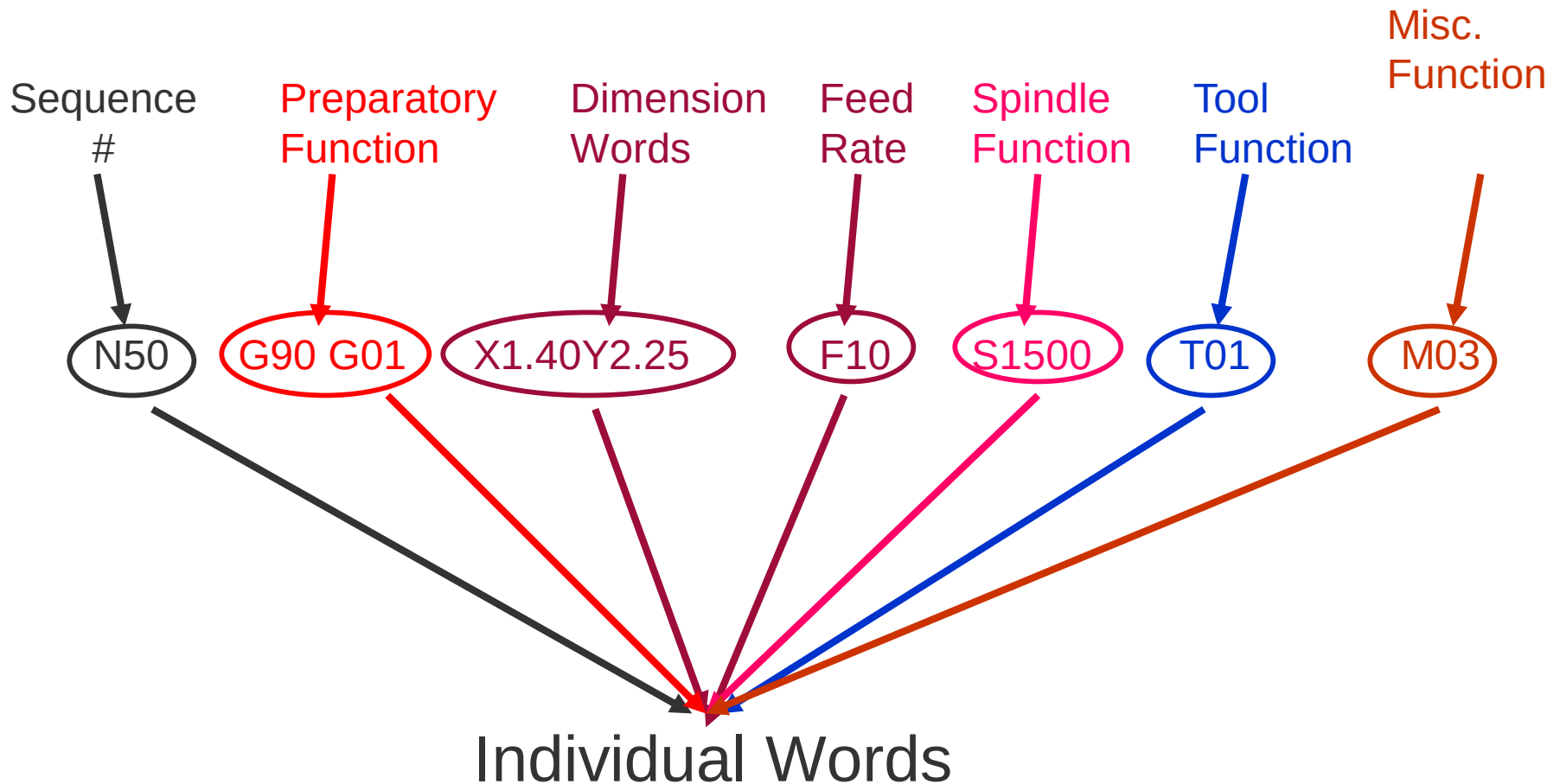
Raster



Projection

G-CODE

- Originally called “Word Address” programming format.
- Processed one line at a time sequentially.



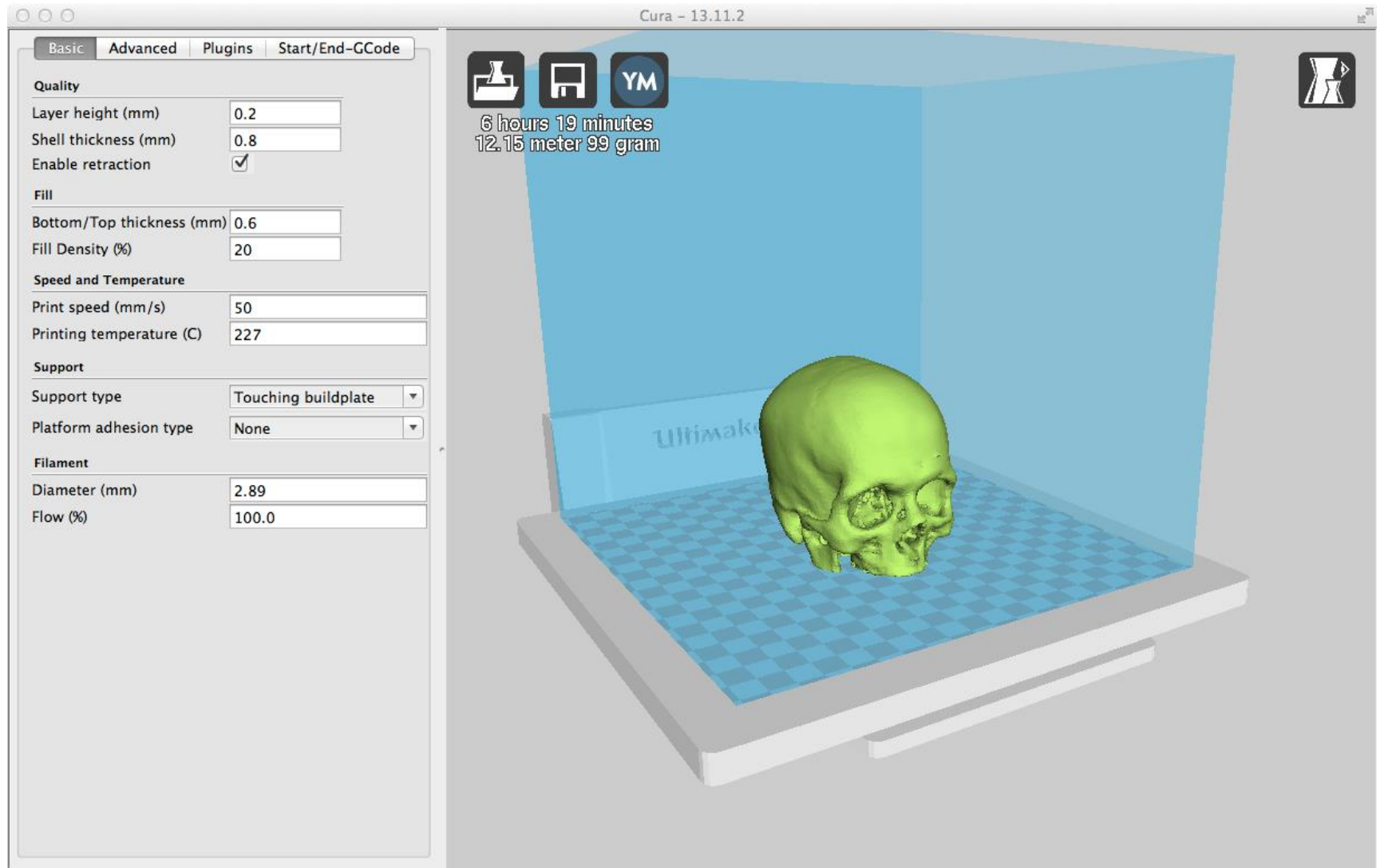
G-Code example

```
;Generated with Cura_SteamEngine 13.11.2
M109 T0 S227.000000
T0
;Sliced ?filename? at: Tue 26-11-2013 17:33:05
;Basic settings: Layer height: 0.2 Walls: 0.8 Fill: 20
;Print time: #P_TIME#
;Filament used: #F_AMNT#m #F_WGHT#g
;Filament cost: #F_COST#
G21      ;metric values
G90      ;absolute positioning
M107     ;start with the fan off
G28 X0 Y0 ;move X/Y to min endstops
G28 Z0   ;move Z to min endstops
G1 Z15.0 F?max_z_speed? ;move the platform down
15mm
G92 E0           ;zero the extruded length
G1 F200 E3       ;extrude 3mm of feed stock
G92 E0           ;zero the extruded length again
G1 F9000
M117 Printing...
```

```
;Layer count: 179
;LAYER:0
M107
G0 F3600 X87.90 Y78.23 Z0.30
;TYPE:SKIRT
G1 F2400 E0.00000
G1 F1200 X88.75 Y77.39 E0.02183
G1 X89.28 Y77.04 E0.03342
G1 X90.12 Y76.69 E0.05004
G1 X90.43 Y76.63 E0.05591
G1 X91.06 Y76.37 E0.06834
...
```



A LOOK INTO SLICING PARAMETERS



Slic3r

