## Comparison of file formats for 3D printing

### **[1],[2] STereoLithography (STL)**

Developed in 1988 by David Hull of 3D Systems, the STereoLithography or .stl file format is the most preferred option for 3D printing purposes over the decades. With extension as .stl, these files are a mesh of triangles in its most basic forms. However, they have problems including:

* Models can have gaps along with overlapping regions
* No information regarding the material, texture or color
* Scaling the model can be difficult
* Holes, non-manifold edges, flipped normal or self-intersecting models may be present
* Doesn’t support multi-material geometries
* Orientation and position of the model is not known
* No data to confirm correct triangulation which can lead to defects such as unconnected triangles, duplicate vertices and edges

Although there are techniques for detection and correction of topological defects along with construction of data structures which are more appropriate using mathematical tools. Meshes can also be smoothed but many people are already migrating towards newer file types including 3D Systems which provided the .stl file format.

### **[3] 3D Manufacturing Format (3MF)**

This is an open-source file format developed by Microsoft. It is supported by a large number of companies including industry giants such as HP, SIEMENS, AutoDesk, Dassault Systemes, NetFabb, Shapeways, Materialise, Stratasys and 3D Systems. This type of files are compact which give them a friendly size for easy storage and transfer.

A 3MF file consists of a 3D payload which carries information relating to the 3D model, its texture and print ticket which has information relating to print settings. This can also be referred to as a complete collection consisting of interdependent parts along with their relationships in a package. A 3MF document may consist of more than one 3D payload but it can have only one primary payload.

Other information such as thumbnails, core document properties and digital signatures are also contained within a 3MF file. However, these are referred to as the OPC package parts. Some benefits of 3MF file format are:

* Data is stored in XML format which is easily readable by humans and contains definitions relating to 3D manufacturing
* Allows for information updates along with additional functionality in future
* Supports multiple materials and colors
* The model can be scaled which makes it printable over different platforms
* It supports files with .stl format

### **[4] Additive Manufacturing File Format (AMF)**

This is quite similar to the .3mf file format and is also based on XML format. The basic .amf file only consists of a list of triangles and vertices while being compatible with STL standards. However, it can always be modified to contain information regarding the color, composition, geometry and materials of the model. AMF models feature backwards compatibility with .stl files along with forward compatibility allowing comfortable addition of features. Some of its benefits are:

* Models in a .amf file can be scaled comfortably even with an increase of complexity in the part
* AMF files are independent of layer thickness and resolution while not consisting any information specific to a single manufacturing technique or process. This allows models to be built by any general machine in the best way it can
* Information is not duplicated making it easy to edit the file with singular changes
* It features support for curved triangles and edges which can help in reducing the number of mesh elements for defining a curved surface
* Restrictions are placed to avoid:
  + Triangle overlap
  + Zero volumes
  + Vertices which are not connected properly or are defined at the same location
* Colors can have a transparent effect along with grading and texture mapping capability

**Comparison with STL format:**

1. Keeping the number of triangles same, an uncompressed AMF file is more than four times the size of an uncompressed STL file. However, on compression, the AMF file is half the size as compared to the STL file
2. Time required for reading, parsing and writing an AMF file is much greater than STL files having the same number of triangles
3. AMF file format has higher accuracy ranging from 15 to 256 times as the number of triangles increases from 20 to 1,310,720.

# References

[1] Szilvsi-Nagy, M. & Mátyási, Gyula. (2003). Analysis of STL files. Mathematical and Computer Modelling. 38. 10.1016/S0895-7177(03)90079-3.

[2] Leong, K.F., Chua, C.K. & Ng, Y.M. A study of stereolithography file errors and repair. Part 1. Generic solution. *Int J Adv Manuf Technol* **12,**407–414 (1996). https://doi.org/10.1007/BF01186929

[3] 3MF Consortium 2015. 3D Manufacturing Format Specification and Reference Guide Version 1.1. 2/24/2016. <http://3mf.io/wp-content/uploads/2017/07/3D-Manufacturing-Format.pdf>

[4] ASTM International. ISO/ASTM52915-16 Standard Specification for Additive Manufacturing File Format (AMF) Version 1.2. West Conshohocken, PA, 2016. Web. 6 Mar 2020. [<https://doi.org/10.1520/ISOASTM52915-16>](https://doi.org/10.1520/ISOASTM52915-16)