ABOUT 3D PRINTING FILE FORMATS

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ABSTRACT: *In this paperwork is presented the situation existing in 2018 regarding the four most common 3D printing file formats, which are STL, OBJ, AMF and 3MF. There are presented also some characteristics of these formats, some limitation and the future perspective of these formats.*

KEY WORDS: *3D printing, STL, OBJ, AMF, 3MF.*

1. INTRODUCTION

In [1] it has been presented the situation existing in 2010 regarding 3D printing using STL file format, as a most common and well known format and therefore supported by most software and hardware for 3D printing.
Also in [1] has been concluded that"In recent years 3D printing and 3D printers have become financially accessible to small and medium sized business, thereby taking prototyping out of the heavy industry and into the office environment. The technology of rapid prototyping also finds use from industrial design to dental and medical industries".
Also was stated that STL files used to transfer data from CAD package to 3D printers have a series of limitations and therefore new formats will replace it soon.
In this paper will be presented the situation existing in the end of 2018, regarding the four most common 3D printing file formats, their features and future perspective.

2. STL File format

STL is a file format native to the stereolithography CAD software created by 3D Systems Inc. It means also *Standard Tessellation Language.*

This file format is supported by many other software packages and it is widely used for rapid prototyping and computer-aided manufacturing. STL native files describe only the surface geometry of a three dimensional object without any representation of color, texture or other common CAD model attributes. The STL format specifies both ASCII and Binary representations. Binary files are more common, since they are more compact.
A 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.

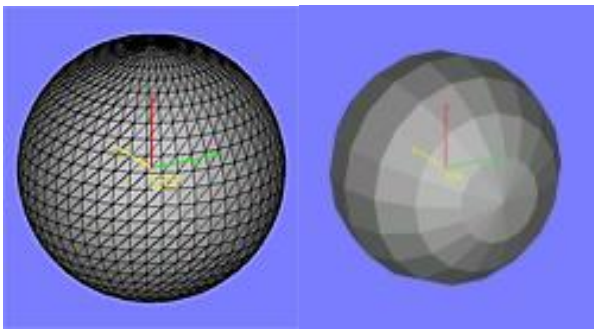

Figure 1. Surfaces are represented by triangles with coarse or fine tolerance

As the file format was used in the first-ever 3D printer (1987), it quickly became a 3D printing standard.
The VisCAM and SolidView software packages use the two 'attribute byte count' bytes at the end of every triangle to store a 15 bit RGB color, trying to remove some limitation of native STL file format [1].
The STL file format has a few inherent problems [2]: file size is excessive, file security is limited, and it can't detect or fix errors (especially unintended holes) in the part to be built. In conclusion STL files used to transfer data from CAD package to 3D printers have a series of limitations and therefore new formats will replace it [3].

3. OBJ File format [4]

Since the native STL 3D printer file format cannot store color information, the OBJ format is the preferred 3D printer file format for multicolor printing.
The OBJ 3D printer file format was originally used by 3D graphics designers as a neutral interchange format for 3D graphics. It was later adopted by the 3D printing community when 3D printers got the capability of printing in multiple colors and materials. The two factors that worked in the favor of the OBJ 3D printer file format are its open source license and simplicity.
The OBJ 3D printer file format is an open source specification. The 3D printer file format supports both ASCII (human readable, larger file size) and binary (smaller file size) encodings (just like STL format).
There are also other two file formats similar to OBJ: the FBX and COLLADA file format. The practice shows it was easier for CAD manufacturers to introduce modules for importing and exporting OBJ files than for its closest competitor FBX (proprietary format) or COLLADA (complicated specification). As a result, the winning candidate for multicolor printing was OBJ file format.
OBJ files can encode a 3D model's geometry along with information about color, materials, and textures.
It uses tessellations with polygons to cover the object surface (just like STL), but if someone wish, can also use more advanced schemes like free-form curves and free-form surfaces, as in figure 2.

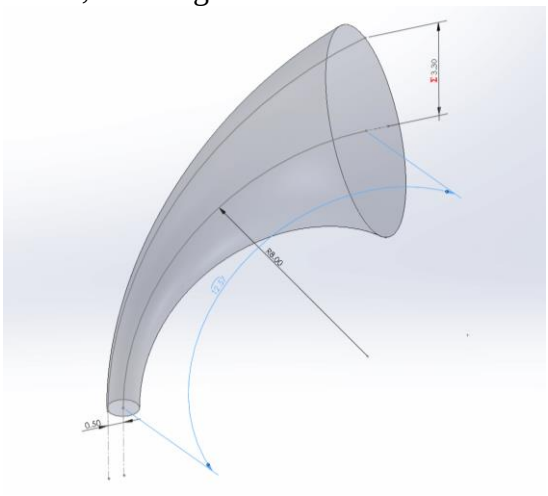

Figure 2. Free-form curve on 3D model

The OBJ 3D printer file format also lets you store color and texture information in a companion file format called the Material Template Library (MTL) format. It has the file extension MTL. The .OBJ file, when paired with the corresponding MTL file, can render a multicolor textured model (figure 3).
MTL files can define material properties like ambient color, diffuse color, specular color, transparency etc.

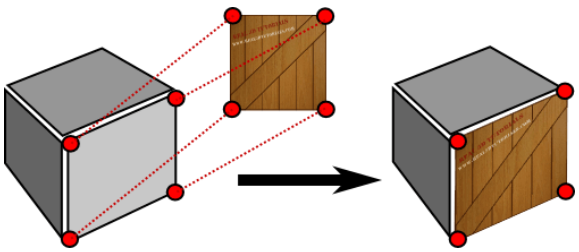

Figure 3. Texture information in MTL [4]

The OBJ 3D printer file format is much more complicated than the STL format, and repairing a broken OBJ file it can be difficult.
Another common fact is that OBJ files come in pairs (an .OBJ file along with a .MTL file). In companies where the progression from design to printing involves hundreds of people, the MTL files often get lost or separated from its parent OBJ file, leading to a lot of confusion.
The OBJ 3D printer file format also isn't supported as much as the STL format. For

example, one might have to use plugins to export OBJ files with Solidworks.

4. AMF file format [5]

In [1] was presented the fact that "The **ASTM (**American Society for Testing and Materials) **Committee on Additive Manufacturing Standards** (F42) had its first meeting in July 2009, and agreed to form a task group to recommend a new file format standard, called STL 2.0".
The AMF (Additive Manufacturing) 3D printer file format was introduced in 2011 as a replacement for the STL file format. At the time it was called "STL 2.0". The aim was to repair many of the shortcomings of the STL 3D printer file formats. As it was already discussed, STL is too big, quite slow, error possible and incapable of storing color, material and texture information.
To fix these issues, the ASTM was tasked to come up with a modern file format native to additive manufacturing. They eventually came up with the AMF 3D printer file format (figure 4). It is an XML based format with native support for geometry, scale, color, materials, lattices, duplicates, and orientation. In all technical aspects, it is superior to the STL file format.

Figure 4. The AMF logo [5]

The 3D printing industry has been rather slow to adopt the AMF format, in spite of its technical superiority. In the meantime, Microsoft came up with the 3MF format, which also aims to be an alternative to the STL 3D printer file format.

AMF resolve the issues in STL by using an XML format (human readable) with a hierarchy of five elements, object, material, texture, constellation, and metadata.
The XML formatting ensures that the file is easy to read, write and process.
It describes object surfaces with triangular meshes, just like STL. But there is one important difference. It allows curved triangles in addition to planar straight triangles – and it makes all the difference. Using curved triangles, you can describe a curved surface without using too many facets (figure 5). This means that AMF can handle curved surfaces while staying low on file size.

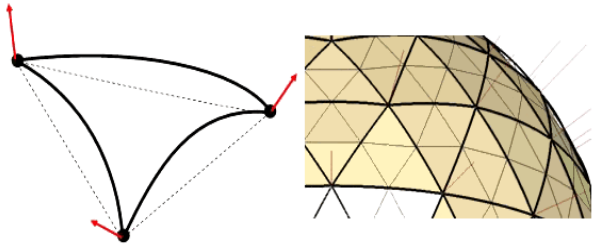

Figure 5. The AMF format uses curved triangles

The AMF file format has support for all the modern requirements of 3D printing, like RGBA colors, graded colors and texture mappings. It can natively handle mixed and graded materials, microstructures, sub-structures, and even porous materials.
With the AMF 3D printer file format, you can specify the scale of the design in different units. The absence of this feature is a source of great frustration for STL users.
Finally, it has extensive metadata fields including name, author, company, description, volume, tolerances, and much more.
AMF became an ISO standard in 2013. The STL 3D printer file format will be replaced eventually, but at this moment isn't clear if AMF or 3MF will be the one to do it.

5. 3MF file format

As was presented, the biggest weakness of the AMF format wasn't technology, because its technology is great and solves most of the

problems people have with STL. The real problem was industry adoption.
ASTM, the developers of the AMF standard, did not consult the key players in the 3D printing industry. Since they were not directly involved, the major brands were very slow in adopting the standard.
Microsoft, which is the creator of the 3MF 3D printer file format, for a few years developed the 3MF (3D Manufacturing Format) 3D printer file format internally (alongside Windows 8 and 10 developments) with the goal of creating a seamless, high-quality experience for 3D printing consumers and manufacturers.
In 2015, Microsoft announced the **3MF Consortium**, an association that will govern further development and progress of the 3MF format. They included all the big names in 3D printing as founding members: Autodesk, Dassault Systems, Stratasys, Ultimaker, Materialize, Shapeways, 3D Systems, Siemens, HP, GE, and many more.
3MF is an XML-based format. The 3MF consortium decided the benefits of human readability for ease of development outweighed the performance gain from going to a binary format.
It features geometry representation similar to STL (triangular meshes), but in a more compact and size-friendly format than AMF 3D printer file format. As an example of its space-saving features, multiple identical objects can be placed referencing the same mesh (figure 6).

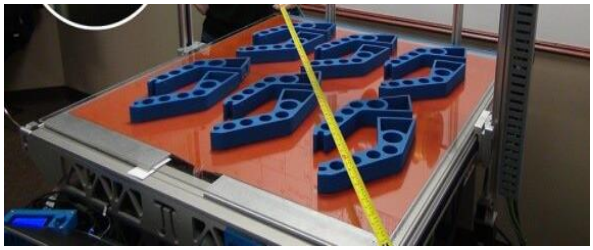

Figure 6. Duplicate objects do not take up any additional space in the 3MF file format

Just like AMF, it can encode information about the model's color, material, and textures.
The biggest concern with the 3MF 3D printer file format is how free and open source it will be. One can also get free access to the 3D Printing SDK and 3MF 3D printer file format specifications anytime by contacting ask3dprint@microsoft.com.
The 3MF want to be a "plug and play 3D printing" tool that will "avoid frustrations related to bad geometry, model repair, and print failures" [4].

6. CONCLUSIONS

At this point in time (end of 2018), STL, OBJ, AMF, and 3MF seem to be the most important 3D printer file formats. They all have their own strengths, weaknesses and have varying levels of compatibility with 3D printing software and hardware. STL is the predominant format, OBJ is preferred for multicolor (or many materials) printing, while formats like AMF and 3MF are trying to provide a more capable STL for modern 3D printing.
As is stated in [6], one can theoretically use any 3D file format for 3D printing. And people do use all kinds of formats, like VRML, X3D, FBX, IGES, STEP, and so on. They have all been used for 3D printing at some point or another. But these file formats are not really made for 3D printing.
For 3D printing consumers and manufacturers, it is imperative to know and understand the key differences between these formats. The choice of format affects the tool chain, production efficiency and the quality of 3D prints.

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