Robotfactory

3DLPrinter
3DLPrinter-HD
3DLPrinter-HD 2.0
3DLPrinter-HD 2.0+

Technical Note 06/14

STL file and support

Rev-4.03 February 2016

3DPrinting and its different applications

Rapid prototyping has existed for over twenty years and is a process in which a single object is achieved by the addition of material, layer by layer, following a three-dimensional digital model.

Rapid prototyping is also called **addictive manufacturing**.

Rapid prototyping technology today is mistakenly called **3D Printing**, a definition that includes affordable 3D Printers, rapid prototyping systems and rapid manufacturing for professional and industrial company.

It is also known that the characteristics of the products created with the various technologies are heterogeneous such as the final result.

In general, **rapid prototyping** can be divided into three technologies which are different one from the other for the raw material:

- **Solid**: the devices for **rapid prototyping** that use starting components in the solid state are divided in models that use technology based on the **bond** (LOM) or extrusion of a thread (FDM), the last can also create objects with a discrete size, but normally with a low-medium resolution.
- **Liquid**: As technologies that use liquid material, there are printers that are based on **photopolymerization** throught **UV lamps (DLP)** or **lasers (Galvo),** which allow you to create small objects, but with a high resolution. In the same technology we find printers that **jet print (Multijet modeling and Drop on demand)** that can also make objects of considerable size and with a good resolution (normally the cost is high).
- **Powder**: In this technology we find printers based on **selective laser sintering (SLS)**, which use both polymers that metals, in addition to printers that used powder and binder. Even with this technology can be make objects with a medium-size and a high-resolution (but in this case the cost is very high).

The use of one technology or another is a choice to be evaluated according to a set of parameters that are very different: speed of realization of the piece, the final cost, the investment required for the printer, the cost of consumables, strength and solidity of the object, the surface quality etc. There is not a technology better than another, for each application must be chosen the most appropriate. It 'so important understand the different technologies available today, their potential and their limits, to choose carefully the most suitable technology based on the characteristics of the object that you want to print.

In our technical note will examine the technology of **Photopolymerization (Stereolithography)** that uses DLP devices, and this is the technology used in our series 3DLPrinter (**3DLPrinter, 3DLPrinter – HD, 3DLPrinter - HD 2.0 and 3DLPrinter - HD 2.0+**).

The **D**igital **L**ight **P**rocessing (**DLP** Acronym) is a technology owned by **Texas Instruments**, applied to devices that display images, as the projectors of the latest generation. It uses an optical semiconductor to manipulate light digitally. The microchip **DMD** (**D**igital **M**icromirror **D**evice) is covered with millions of mirrors that move independently of each other and that are able to better represent each pixel of the image. The result is a quality of vision better than LCD technology with a high contrast ratio.

Rapid Prototyping with technology of photopolimerization (stereolithography)

The technology is based on the use of a photosensitive liquid material (resin) which is placed in a vat and a DLP projector connected to the computer which projects, one after the other, the horizontal sections of the object that you want to print. The light is projected into the resin making it react and become solid layer by layer.

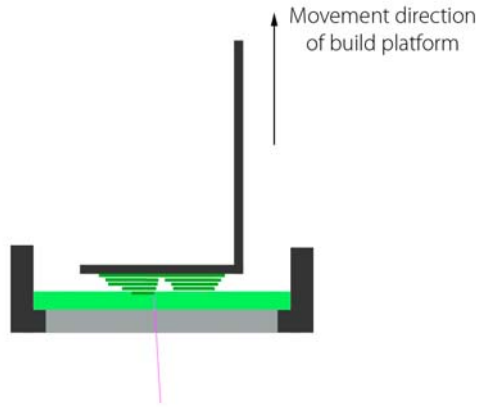

Fig. 1 – Schematic representation of a stereolithographic technology

Each layer is built on top of the previous and constructs the object to additive process. This technique is characterized by very fast printing times that do not depend on the complexity and the number of the objects, but only on the height (unlike the laser technology that depends on the number of objects to be printed and size of them).

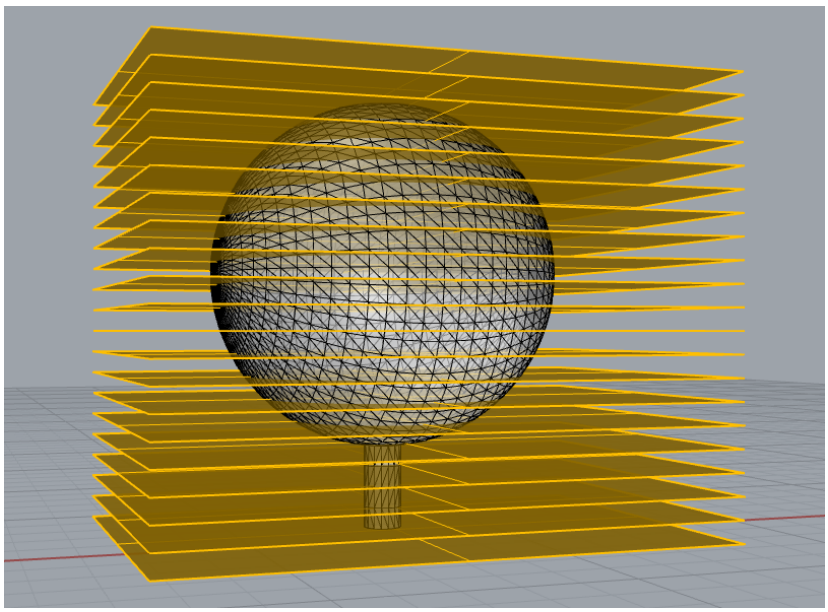

Fig. 2 – Schematic representation of the layers

The importance of a correct STL for a good printing

For our series **3DLPrinter**, we have developed a software **Printer3DLP** which can import models in **STL** format, the most common type of files for rapid prototyping. The STL format can be either **Binary** or **ASCII**.

The **STL** format defines the surface of an object using triangles.

Most **3D CAD** software, can directly export the object in **STL** format or can have tools for his conversion. It's important to note that in the process of saving the file, to not to make it heavier, you should export the object with a **lower-average** number of **triangles**.

In the image below, to the left, you see the parametric surface of a sphere and to the right you see the same sphere represented by triangles, and that's how it is generated in the STL format.

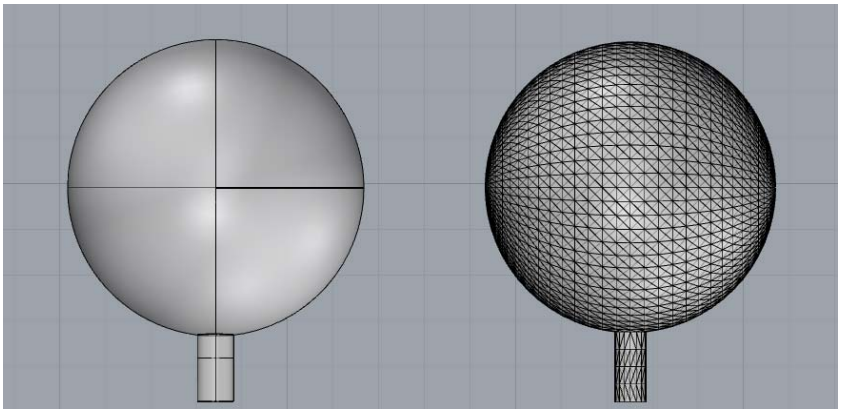

Fig. 3 – STL format

As it happens in the preparation of a piece for an operation with a CNC machine, similarly there are some simple but important considerations that must be made, to prepare a correct model for 3D Printing.

To ensure that the printing process creates a perfect object, it is important to take some precautions before you start printing.

First, the model must be represented by a continuous form. Many times when a 3D model is realized, for easy, is drawn making it up with dozens or hundreds of separate pieces. Unfortunately, this approach makes the most of the time, a model not immediately usable for 3D printing.

Rule number 1 is to create a 3D model designed with a single continuous shape. For simple objects this should not be a big deal, for a complex object this step can take many hours, if the model was not originally thought in order to print it in 3D.
If you have an older model that you absolutely want to print, you will have to arm of patience, trying to merge vertices and edges until you get a set of continuous mesh and without holes.

Another important thing is to make sure that there are no intersections between the parties that make up the model, this could damage the file because during the export some triangles (simple geometries that divide all the 3D models converted to STL format) may cross other triangles, cutting them. The geometry must be combined, creating a single solid.

Rule number 2 is therefore, the elimination of "Intersecting" geometries.

Finally, **Rule Number 3**: It is very important that the 3D model you want to print is given the appropriate supports (external and internal), distributed appropriately to create the structure of the object before printing. This last rule is perhaps the most difficult to understand and apply, but with a bit of experience and with the help of some software, which we will discuss later, everything will be easier.

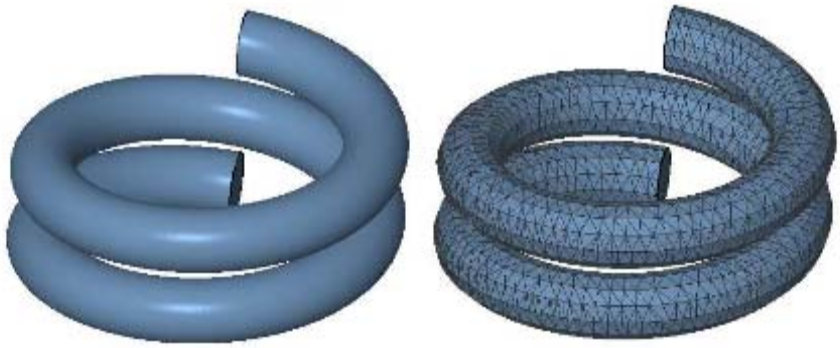

Fig. 4 - Correct STL – Surface and parametric surface represented by triangles

The following pictures show some of the most common problems in STL files.

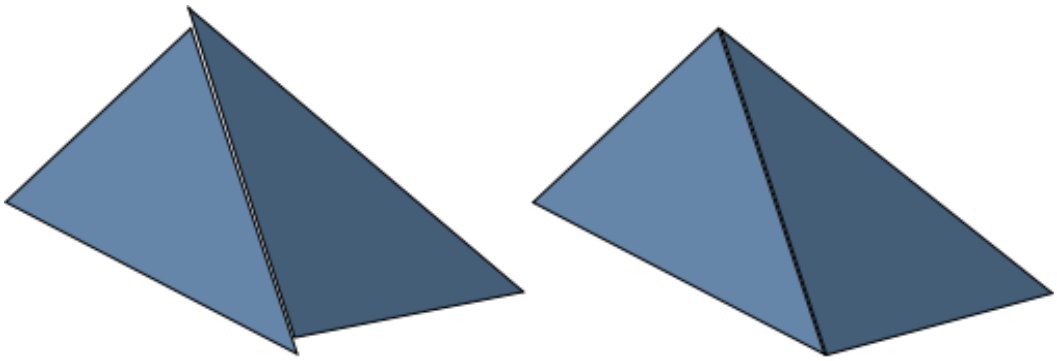

Fig. 5 - Error – Triangles disconnected vs triangles connected

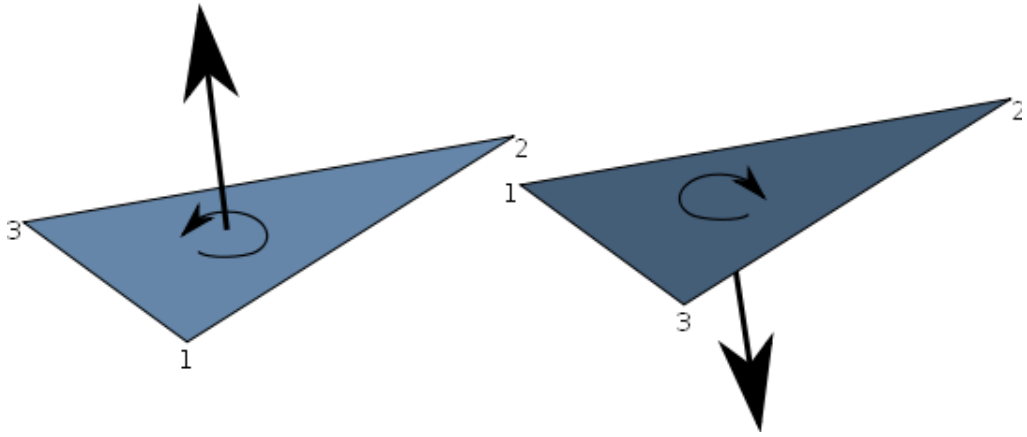

Fig. 6 - Possible error - The vector identifies the orientation of the normal to the surface

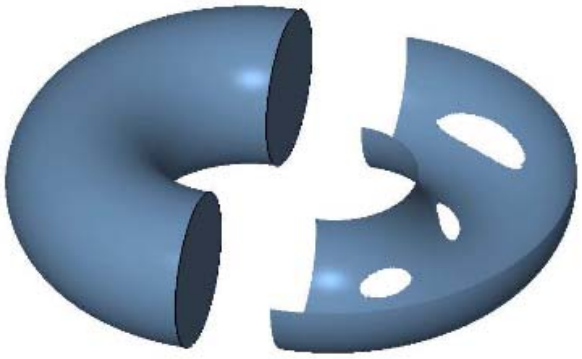

Fig. 7 - Error – close surface vs surface with holes

The last important operation to do before export file in STL format is the **Boolean Union,** in order to obtain a single solid and a single surface without intersections.

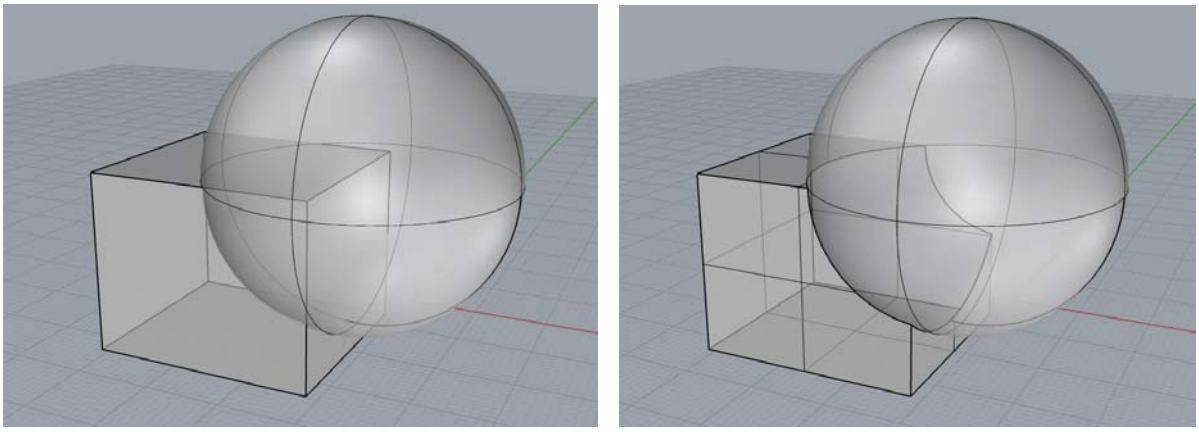

Fig. 8 - Intersection of two solids vs Boolean union of two solids

In summary, the first fundamental operation will be a careful **analysis** of the model to understand the best **orientation** to give the object to be able to print, the choice of the type of support to use and their location. Finally, after all the geometries have been combined with a Boolean Union, you can import the file into the program **Printer3DLP** in STL format, ready for printing.

One last note: a cavity completely closed (such as a hollow sphere) may inevitably trapped inside, small amounts of liquid resin during printing, for that reason it is always better to draw these cavities with a pair of small exhaust holes, one to allow the escape of the resin and one in the opposite position in order not to create depression, so as to facilitate the escape of the liquid from the other hole.

Finally, it is always important to consider the advantages and potential of 3D printer but also its limitations, because if you design an object that has a structure does not conform to the 3D print, for example, with too many overhangs and therefore with too many supports to be included, will risk a loss of time and an excessive consumption of material. **3DLPrinter** series have great **potential**, but also some **limitations** (like all printers that use the same technology) and it is essential to learn to know them if you want to achieve a good end result.

Orientation

After analyzing the 3D model, making sure that the geometry is correct and that all the "mesh" (mesh of triangles representing the surface) are joined together, it is important to understand the optimal orientation to give the object to get a good printing.

To understand how to rotate the 3D model, we must consider two fundamental concepts:

- Use the minimum number of supports as far as possible, for a savings of material and for a quicker and easier removal of supports, after printing
- Decrease the discontinuous parts in the model (islands) and parts at 90 °, which need supports

In the case of a sphere, for example, for 3D Printing is only necessary to support the base. This is because, by cutting the object with a horizontal plane, there are not overhangs and the construction for horizontal layers is performed without interruption.

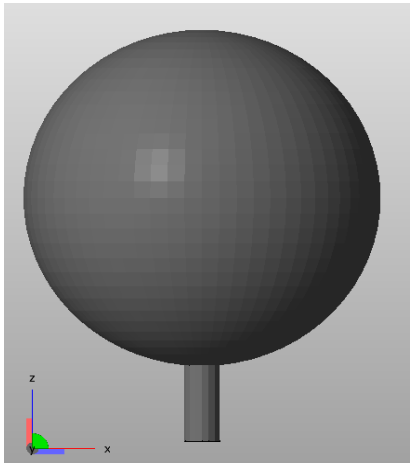

Fig. 9 - In a sphere is necessary only one support

If we should print a cylinder, as in the following picture, probably instinctively we would put a single support, but it' s wrong, because the object in question contains parts of the model at 90 ° needing suitable supports to build properly.

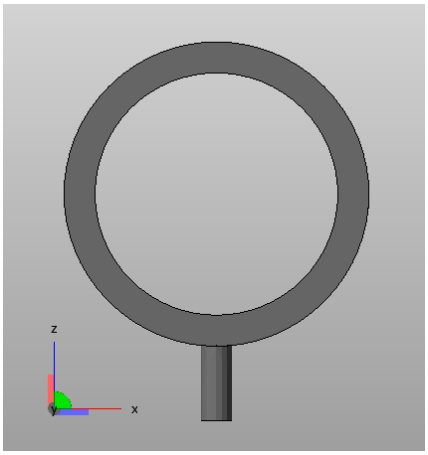

Fig. 10 - Front view of the cylinder

The correct choice involves the design of multiple supports, to ensure the construction of the part of the cylinder placed at 90 °, as in the figure below.

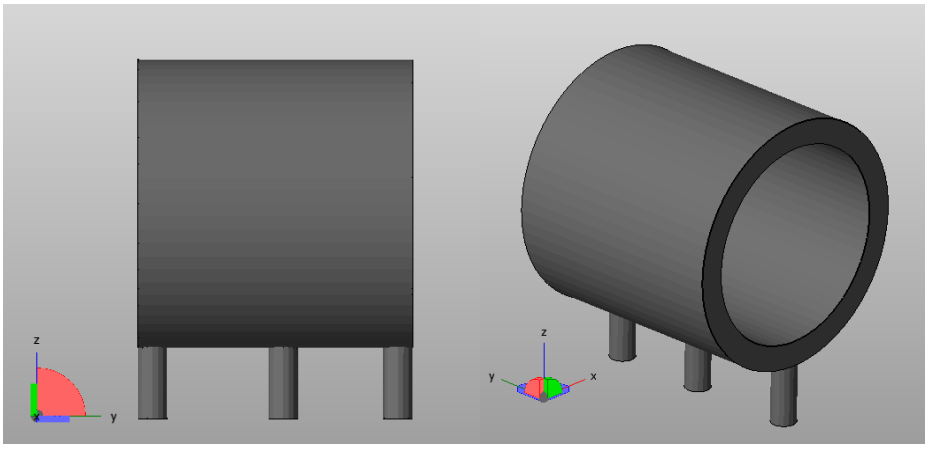

Fig. 11 - Side view of the cylinder and axonometric

In the case of a cube, with a simple rotation of the object, we can decrease the supports up to use only one support. The construction for layer will be without interruption, because it will no longer be present overhangs with angles of 90 °.

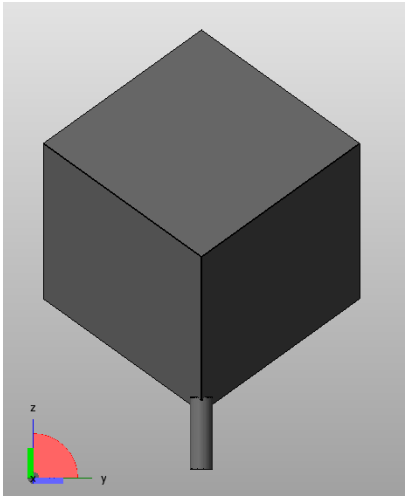

Fig. 12 - Side view of correct cube

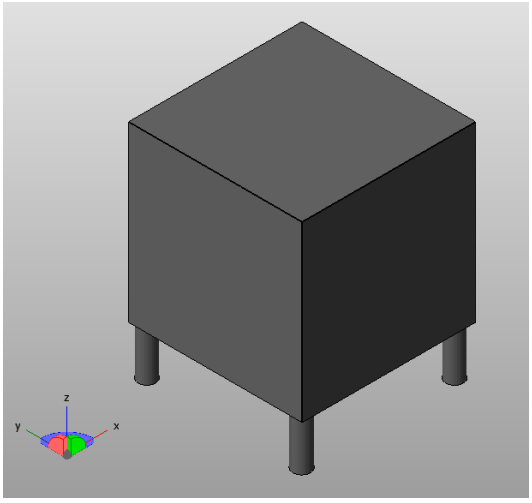

Fig. 13 - Cube with too many supports

Below, we can analyze another case with two different geometries:

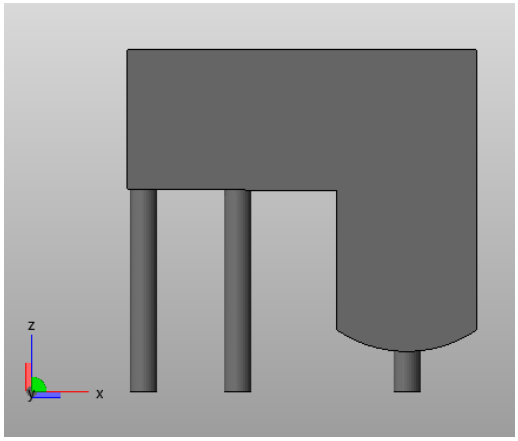

Fig. 14 - Object with parts at 90°

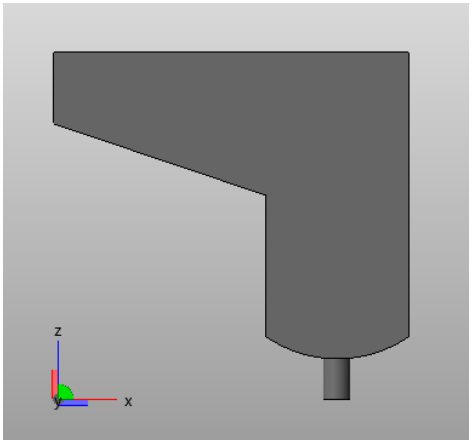

Fig. 15 Object with an inclination mayor than 90°

The object in the figure *Fig. 16* , in the left part, requires supports while the object of *Fig. 17* does not require them (even if, for improved rigidity of construction, it is better to put one support at the end).

We can see in the figure below a better example, as explained above, where there are two types of ring with different characteristics.

In the first case, *Fig. 18* , the ring is composed of too many overhangs with an angle less than 90 ° (islands), this would require a large amount of supports in addition to the fact that the final result of the print would not be good and could create defects.

In the second case, the model of *Fig. 19* contains parts with overhangs greater than 90 ° and absence of islands, it is therefore suitable for printing without too many supports.

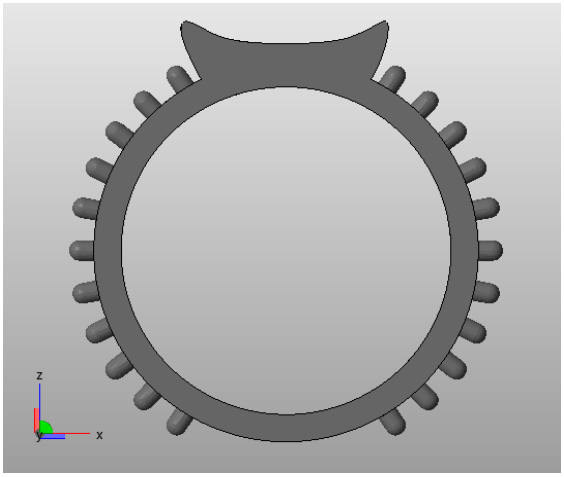

Fig. 20 - Object not suitable for 3D Printing

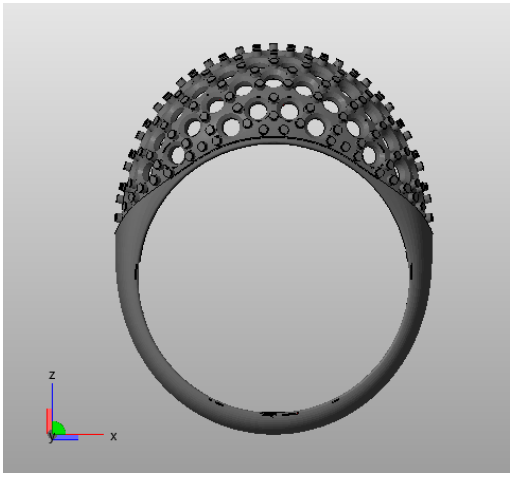

Fig. 21 - Object suitable for 3D Printing

A real example (as explained)

Now let's see a real case with the different steps for optimal orientation and a good 3D printing:

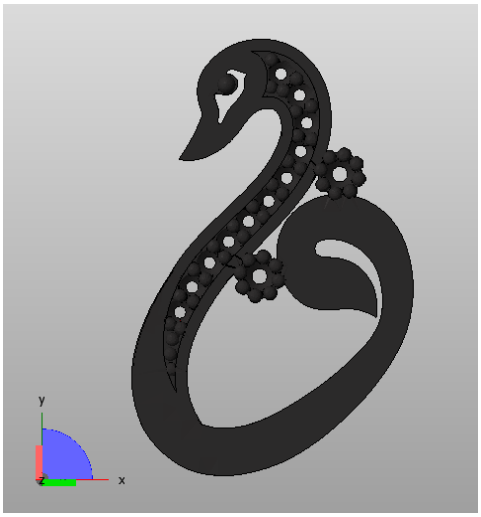

Fig. 22 - Original object

Initially, one might think to orient an object in a horizontal position along the x-axis, but in this way the whole geometry would be placed at 90 ° and would require too many supports for the construction.

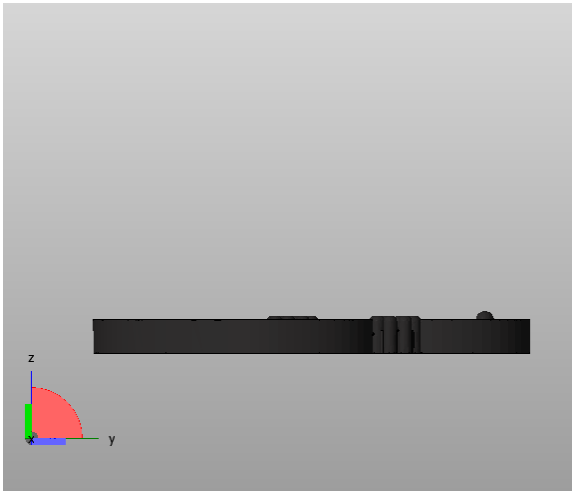

Fig. 23 - Incorrect horizontal orientation

It was decided to place it vertically (Z axis) and along the X axis, because the movement of the vat containing the resin is along this axis.

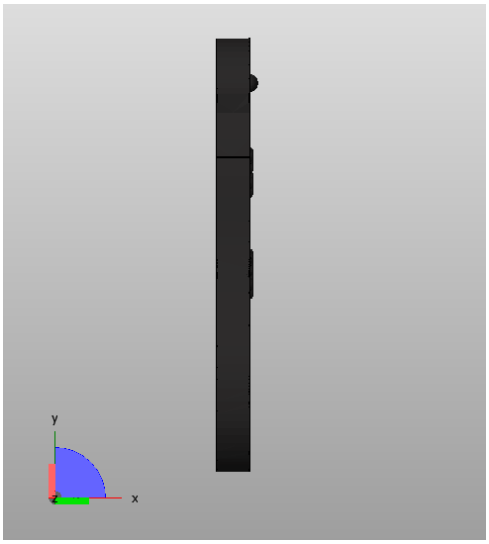

Fig. 24 - Correct vertical orientation

Analyzing the last orientation, we encounter several problems:

- Very small holes that could trap the resin in them.
- Griffe to 90°.
- Parts discontinues (islands) and overhangs which would require supports inside the object.

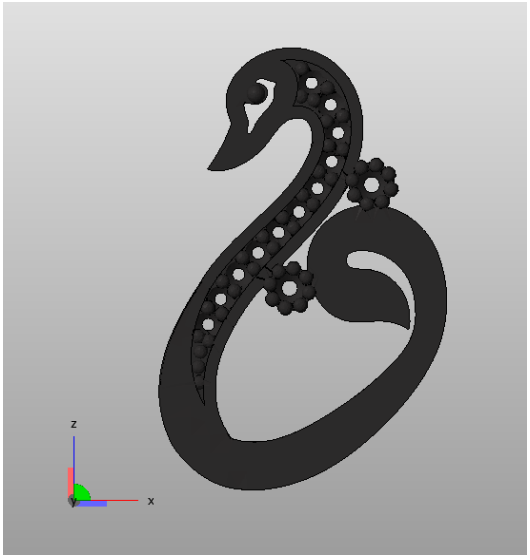

Fig. 25 - Correct orientation

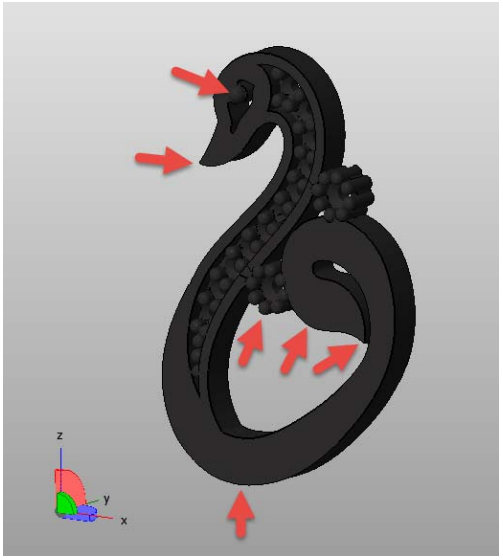

Fig. 26 - Islands in evidence

To solve these three problems it was decided to rotate the object by applying two additional rotations, the first is an inclination along the X-axis to allow the resin to slide without pinching in the holes of the object, besides the fact that the griffe in this way are not more than 90°, this also allows the creation of external support without damaging the object. The second and final rotation along the axis Y, allows the elimination of a further support (relative to the eye of the swan).

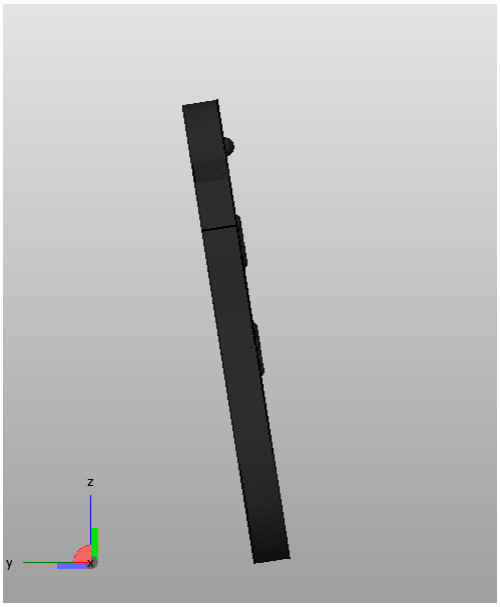

Fig. 27 - Rotation along X axis

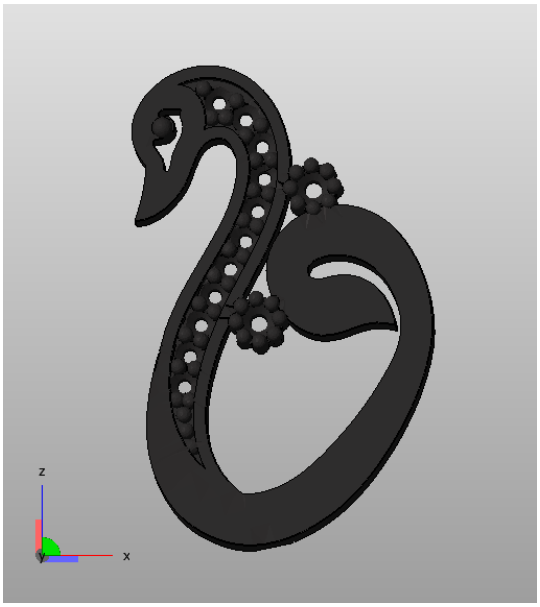

Fig. 28 - Rotation along Y axis

At this point, trying to cut the object with a hypothetical plane along the Z axis, we find the critical points and areas that need supports and we will create them with CAD software that we prefer. In the following pictures, we highlight overhangs (islands) that are visible when cutting the 3D model.

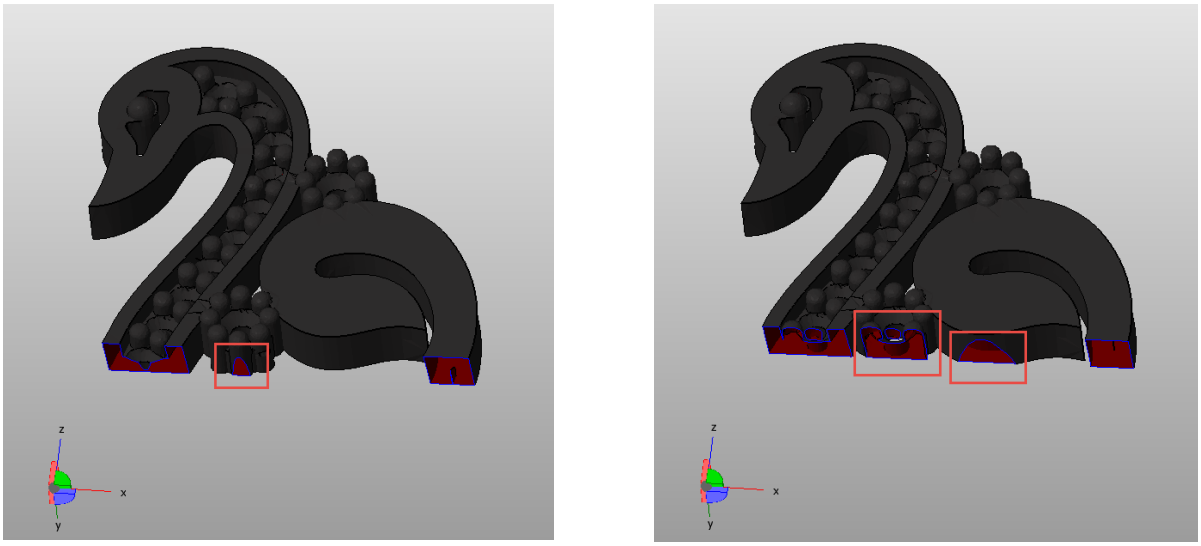

Fig. 29 - Discontinuous areas (islands) are highlighted with a red rectangle

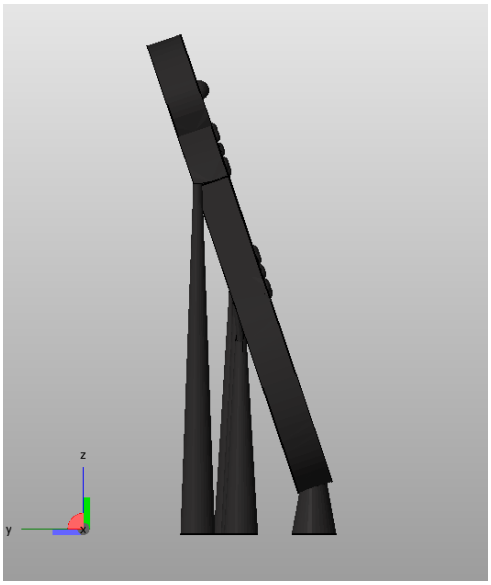

Fig. 30 - supports placed outside the object

In conclusion, the correct orientation of the object has allowed the construction of a few simple supports, which allow to build also critical points, overhangs, which are parts of the object with an angle less than 90° to the plane. These parties would create overhangs that could not be printed without supports.

It's important to remember that, at the end, the intersection of the supports with the object must be combined with the **Boolean union** in only one solid to create a single surface.

Types of support

Supports may change depending on the size and shape of the object, these can be:

- **Cylinder**
- **Cone**, with a cylindrical base and a diameter not less than 1 millimeter
- **Conical cylinder**, with a diameter not less than 1 millimeter
- **Support with a branching angle**
- **Support with more branches**

Below, we can see the different types of supports you can use most of the time:

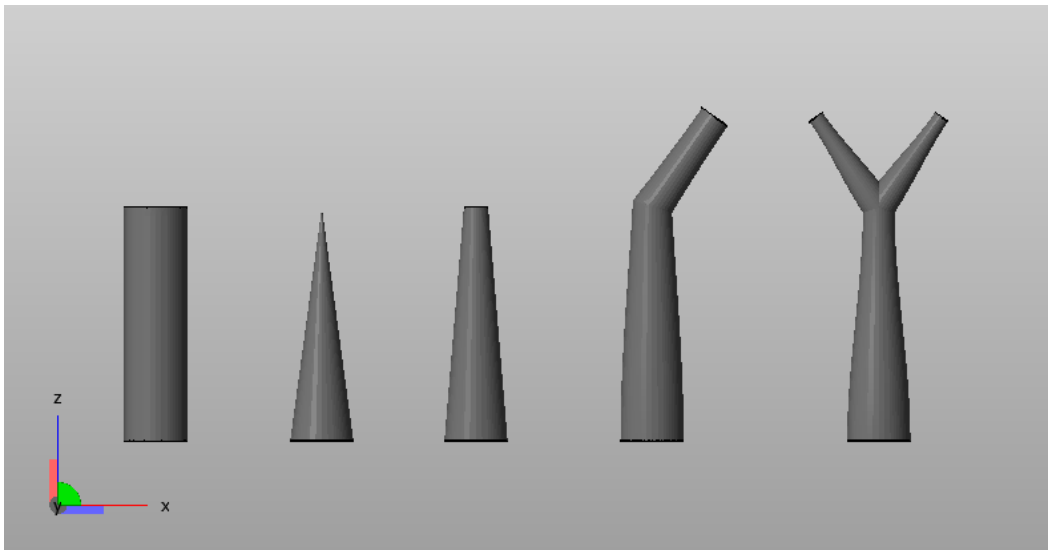

Fig. 31 - different types of supports

Size of the supports

The size of the support is very important, because it has a structural function.

The **diameter** of the support must **never** be below 1 mm and will have to increase in proportion to the height of the object, always for structural reasons.

Usually, if the height exceeds 10 mm, it is better to increase the diameter of the support at least 2mm and beyond.

It's always better to make a **first test print**, you may want to print in the first trial about 20-30 layers, that is the smallest amount necessary to ensure the right choice of supports created.

If the object is built correctly, it means that the supports are able to hold up the structure, if not, it will need to open the STL file and change the diameter and geometry of the supports.

Intersection between support and objects

After the creation of suitable supports, the following operation, essential for a good end result, is the **Boolean Union** of the geometries in a single solid and a single surface.

To understand what happens inside two solid intersected and two solids together with the **Boolean Union**, we cut the object with a horizontal plane along the Z axis.

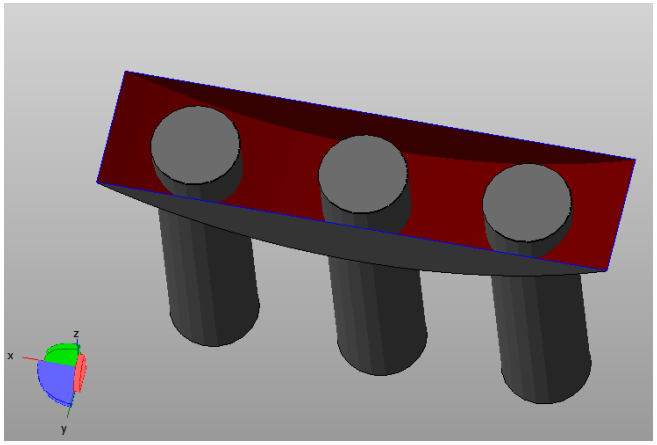

Fig. 32 - Intersection of the supports with the object

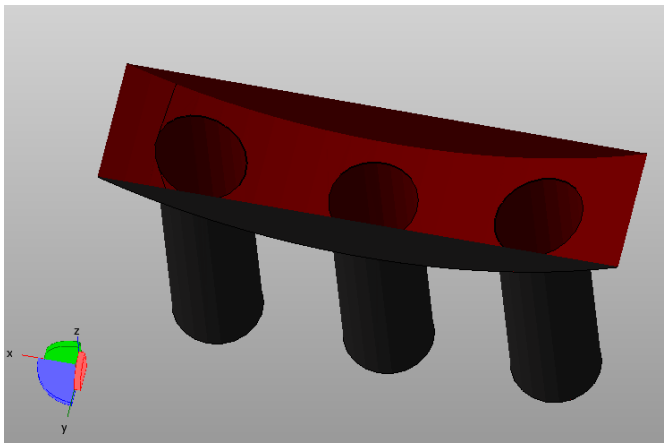

Fig. 33 - Boolean Union of the supports and the object

As can be seen, in the *Fig. 32*, the parts that constitute the drawing are separate, while in the *Fig. 33* the drawing is a solid constituted by a single surface.

Software for editing STL file

Analisys with NetFabb Studio

Often, the 3D model, as previously mentioned, contains errors of different type. It is possible to try to correct the **STL** file using one of the many software available in the market.
In this technical note we will consider one of the most popular software available, **NetFabb Studio**.
The software is available in different versions:

- **NetFabb Studio Basic** – this version is free and it is suitable to rotation of the drawing (and a little more).
- **NetFabb Studio Private** – this version has a not excessive cost and in addition to rotation also allows repair and manipulation of 3D drawings.
- **NetFabb Studio Professional** – this version has a higher price but allows maximum freedom in editing as well as supports creation.

The *free* version can be found inside the DVD in our printers.

We strongly recommend, however, to buy and use the **Private** version that helps to solve most of the problems that can be found in the **STL** file.

In the following figure we analyze a typical example and the steps to follow:

- **Importing** of STL model in **NetFabb Studio Private**: make sure that there are no errors and that the surfaces are closed (if there were errors, would be displayed a red triangle with an exclamation mark).

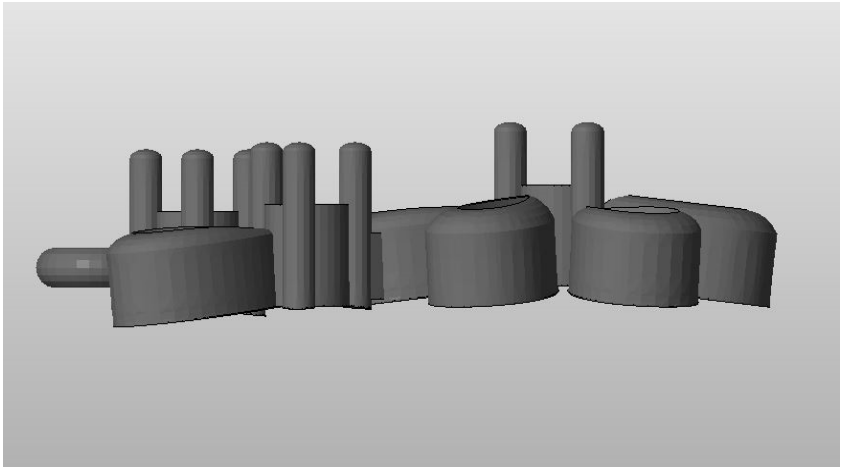

Fig. 34 - Import model and analysis of possible errors

Fig. 35 - Report error

- **Sectioning** STL model: using the tool "***cuts***" the object is cut with a plan. While you move the invisible plan, it must be observed carefully, if there are overhangs without support that can't be printed and starting to find a possible direction of the object to decrease the overhangs and therefore the supports to create. This allows a saving of material and time.

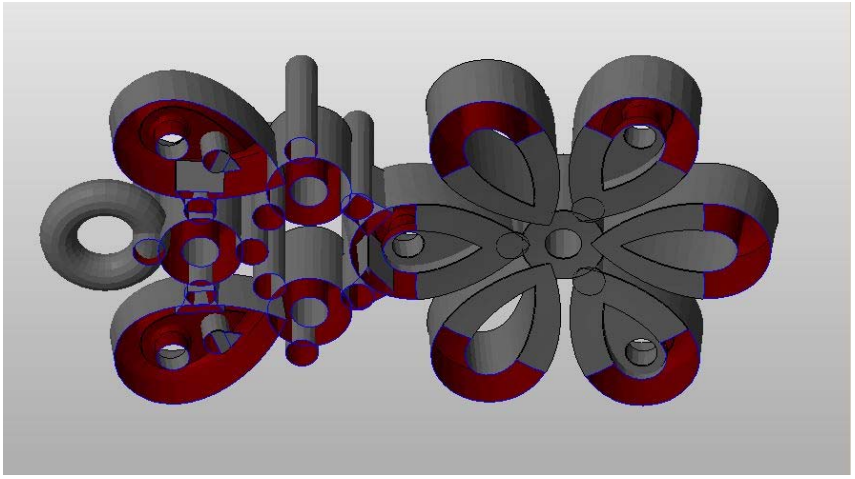

Fig. 36 - Section view (Cuts)

- **Rotation**: hooking the object (Right button mouse) you can see the rotated object along the three axes x-y-z, this allows you to find the correct orientation that decreases the presence of discontinuous parts (islands) and parts that form angles smaller or equal to 90° relative to the plane. This operation can also be made with any 3D CAD software.

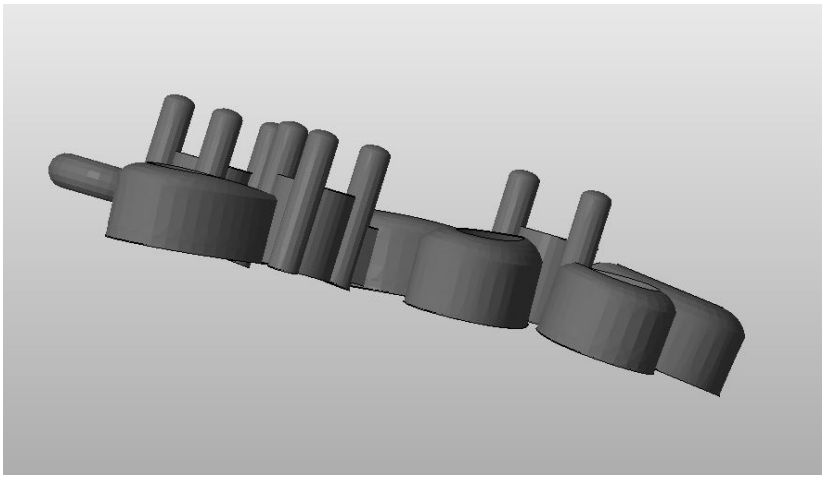

Fig. 37 - Rotation of the object

In this case, trying to rotate the model about 25°, we can see a decrease of the critical areas, in addition to a marked decrease of the supports required for a correct print of the object.

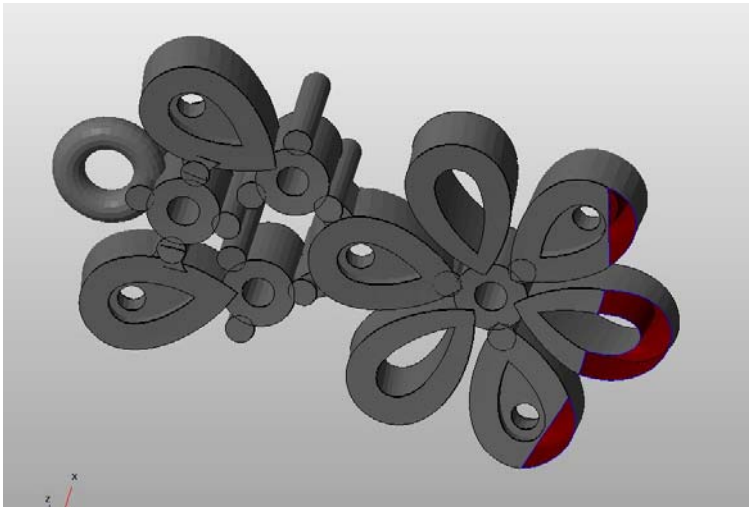

Fig. 38 - Object rotated

Create the support

As well as the **'bases'** are the foundation of a building, the '**supports**' are the pillars of the same building. In general, supports are needed on all overhangs of the 3D model (the parts that are located on a level equal to 90°) and on all those areas of discontinuity, called 'islands', which in the process of "**slicing**" or cutting, are not connected to each other.

There are two ways to create the right support, the automatic generation or 3D modeling. All 3D CAD systems contain functionality that can be used for the creation of the supports.

Among the existing software that can create and manage supports in a 3D drawing, we recommend:

- **Meshmixer** (http://www.meshmixer.com/) contain a “supports generator”
- **Rhinoceros** (http://www.rhino3d.com/) to 3D modeling

Before you print a 3D model with **3DLPrinter** series, you must have available an **STL** file corrected with appropriate supports.

If the 3D print without supports can be attractive, especially for models with a flat surface, remember that the first layers (layers near the base of the construction) are subject to shrinkage and compression and for this reason is better to provide the model with appropriate supports.

Also there may be overhangs in the model that require one of more supports to printing.

It’s important to understand the function of the supports in order to achieve an optimal result, and it is also important to understand that all overhangs inside the object also require the supports (internal supports).

Now let's see how to create supports through the two recommended software.

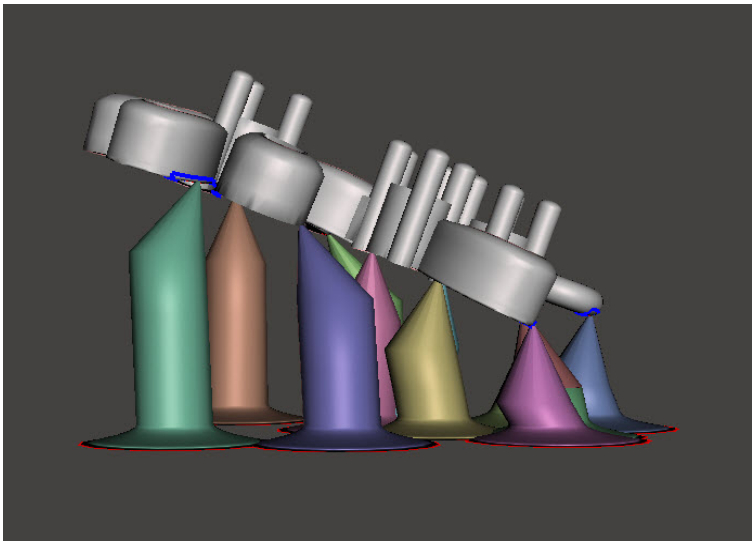

Fig. 39 - Supports created with Meshmixer

For an **automatic** creation of the support you can use **Meshmixer**:

- With the function ***analysis*** at the first, we can choose the best orientation to printing with the function ***orientation****.*
- The function ***overhangs*** analyze the 3D model based on the type of 3d printing (in our case we must choose **DLP** technology**)** and highlight with a red color all the parts that need structural supports.
- The function ***support generator*** create the necessary supports, we can customize them changing the value of several parameters (base diameter, shape, etc..)
- The function **convert to solid** combines the model to the supports created with a **Boolean Union**, final and essential operation for the correct printing of the object, because the different components parts must be combined into a single solid.

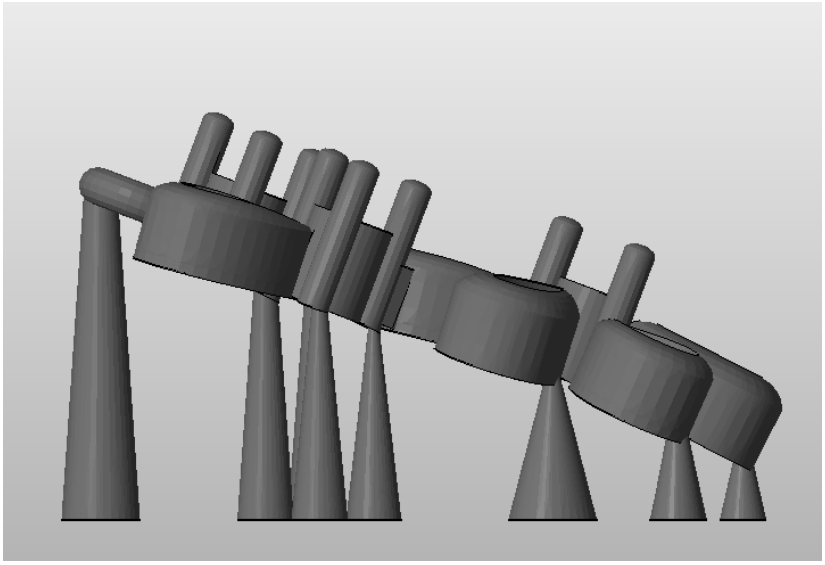

Fig. 40 - Supports created with Rhinoceros

For the **manual** creation of the supports you can use the software **Rhinoceros**:

- Make a preliminary **analysis** of the possible "islands" in the 3D model with the software **Netfabb Studio Personal**, using the function ***Cuts***. In essence, the model is sectioned along the Z axis with a plane so as to be able to see the discontinuous parts that need support. Then you will search for the most suitable orientation to minimize the critical areas.
- **Export** the model in **STL** format and import the same in the software **Rhinoceros** where they created the support, paying close attention to a good intersection with the object and the choice of the type and size of the support.
- **Apply** the **Boolean Union** function in all geometry of the 3D model. This function is essential to print the object in 3D, it is advisable to apply it using software **NetFabb Studio Personal**.

Final check with Printer3DLP software

As final analysis, after following all the instructions given above, load the **STL** file in the software **Printer3DLP**, checking with the function ***Slicer***, that all Layers are present properly.

Moving the cursor, we will see a sequence of photographs that represent the layers of construction, from Layer 0.

Here below, two defects that we can find in the final test:

1) Absence of Layer 0: without the layer 0 the file can't be printed in 3D

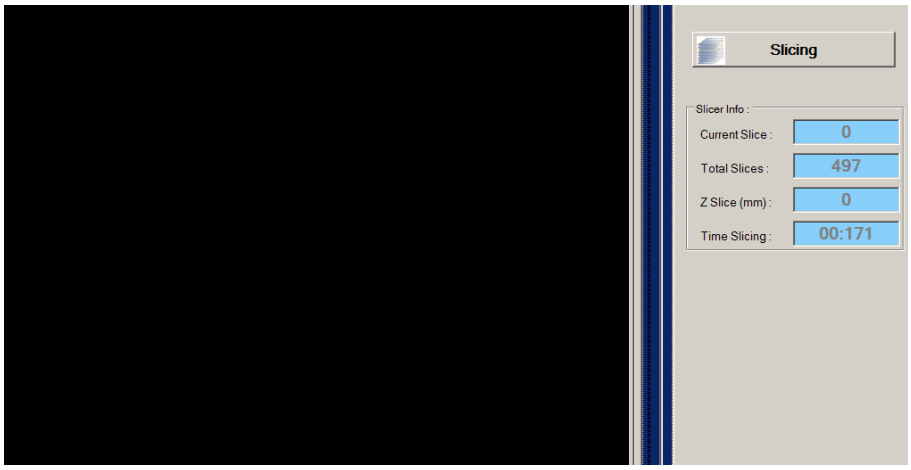

Fig. 41 - Absence of "Layer 0" (you do not see nothing)

In this case, we recommend to cut the supports slightly (there may be triangles with some defects in the layer zero or not all of the supports starting from the same plane); making a cut of the drawing, raising the starting plane of the supports, you normally exceeds the problem.

2) Absence of **Boolean Union** in the 3D model (mesh). In the figure below, you can see that it was not made a **Boolean Union** of the various geometries.

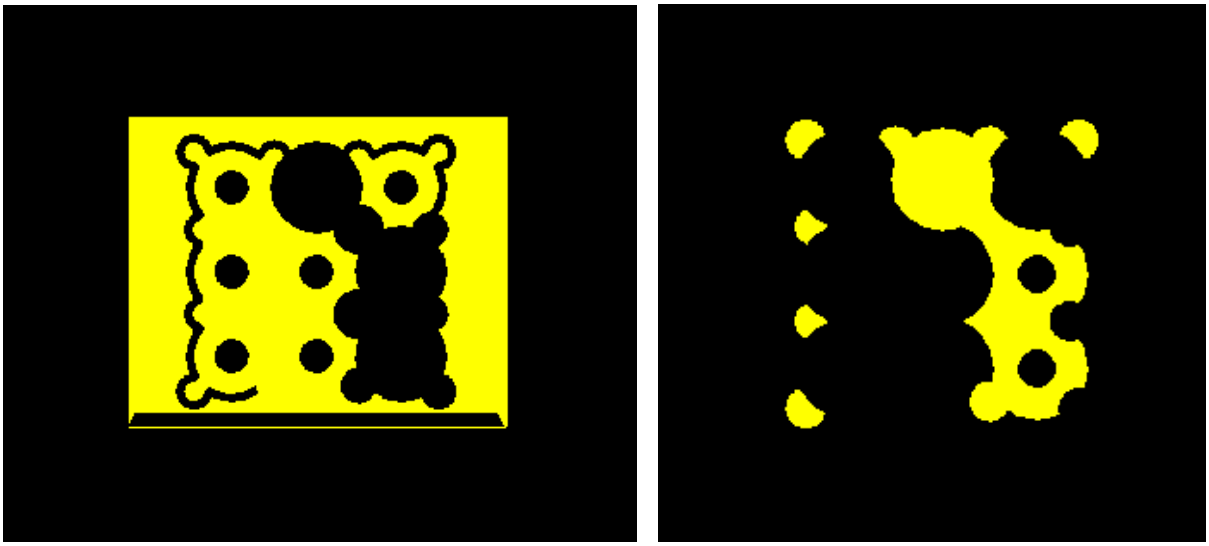

Fig. 42 - Mesh disconnected and holes inside the object

In conclusion, please remember the following note:

Optimal STL drawing = Perfect Piece

In order to improve and grow the product, we ask that you inform us of any possible malfunction or improvements, sending an email to robot@robotfactory.it with the much detail as possible description about the problem when it occurs or the required improvement.

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