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Specific techniques for printing 3D objects

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Abstract. Techniques for implementing 3D objects are synthetized, emphasizing the most useful ones that could save time and expensive materials for creating scientific or home objects, for research or for nowadays use. We present how to project and how to process them, using different types of texture with shapes adapted to our needs. A comparative study of printing 3D objects with two different types of devices is proposed: (i) DaVinci printer device that uses high detail texture, cold printing bed, and extruder with PLA filament at the temperature of 203°C, 90% infill density, and (ii) Prusa printer device with heated bed, 70% infill density, and extruder with PLA type filament at the temperature of 215°C. Following this study, an optimal approach to the design and printing of 3D objects is outlined. Moreover, our study can be used as a didactic material helping students to improve their knowledge and abilities in the field.

1 Introduction

For implementing different ways while doing research or creating industrial devices for laboratory or constructing devices for home appliances, nowadays, the 3D printing process acts a very defining role. Regarding so, for doing such 3D printings we need specific techniques [1-2]. Starting from one of the classic techniques such as Fused Filament Fabrication (FFF) or Fused Deposition Modelling (FDM) and by executing a Polyjet printing which is the one of the most precise and accurate printings, we will point out advantages, but also disadvantages for creating 3D printed objects using different printing accuracy heads (extruders) in different resolution types printers, as well as different types of textures [3].

In the following we will briefly describe the above techniques and their contributions regarding implementing the 3D printing process in our lives whether we talk about industrial, designing or laboratory use.

The most common technology used for 3D printing, more specific for those which are using print heads (extruders) is Fused Filament Fabrication or Fused Deposition Modelling. By using these techniques a filament that represents the printing material is driven into print head (extruder). The process is controlled through printer's stepper controller that is receiving data signal from a computer. This is the most widespread. In this type of techniques a printer device will print by depositing the subsequent layers of fused material and will permit the adjacent layers to cool and merge with the following layer before another layer is deposited. The advantage of this method is that the user may print an exact

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quantity for a desired object and therefore it prevents high losses of used material. The accuracy for which an object is being printed using Fused Deposition Modelling technique has a ranged between 0.15 mm and 0.25 mm. The Fused Filament Fabrication technique is optimal for producing 3D printed objects suitable for fast prototyping projects in which standard tolerance must being kept.

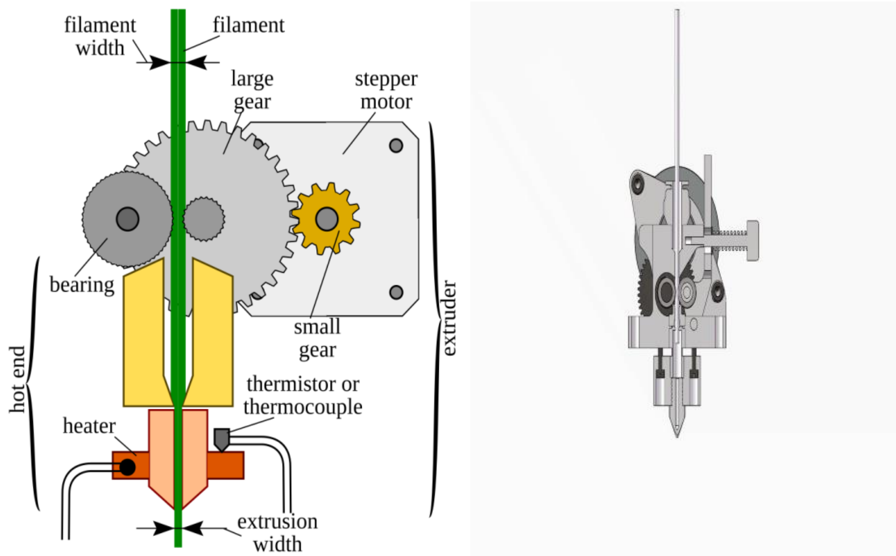

Fig. 1.1 – Illustration of a direct drive extruder

Another improving technology that consists in merging polyamide particles with a high energy laser beam is Selective Laser Sintering (SLS). By starting this technique you must fill a chamber with powered material. The printing process evolves by adding another layer of powder. The advantage of this printing technique is that a widespread of geometric elements with high accuracy may be printed. More over by using this technology, we may print not only large elements up to 600 mm in height, but also series of small elements, guaranteeing only 0.15 tolerance accuracy. These are 2 complementary techniques which are most common for small laboratories or prototyping common size objects. If the 3D object that we want to print is designed to be analysed for high details, another 3D printing technology based on a liquid photopolymer resin may be used. In this case, the 3D modeling procedure consists in scanning the desired part of the resin with an UV laser beam in order to reach the final object geometry. This technique assures an accuracy of about 0.1 mm to 0.2 mm.

As long as we need high detailed object we may base on this technology but if we need more complex printing which lets 3D objects to fuse metals and alloys on a micro-scale, stereo lithography can be used. These parts can be fully functional, heat resistant and they will have strong architecture immediately after the printing process.

One of the most complex technologies that allows the 3d printing process to run even more precise is Polyjet printing. This may allow user to print 3D elements even more precise than SLA technique and the accuracy up to 0.099 mm. [4-5]

In the following we will present two different types of printers that we actually used for the most of our printings in our research laboratories.

2 Explaining 3D printers' extruder technique on DaVinci printer device

Da Vinci Printer XYZ is one of the best printers for education. Not very expensive price and its architecture allows that printer to be very useful for making small parts and accessories not only for home prints, but also for laboratory use.
The printer is represented in the figure below. The object files that will be printed are sent to the printer via USB interface connection between the PC and the printer. The device does not have a built-in files reader to print directly from the printer itself. So actually the device firmware that drives the bed and the extruders follows direct instructions given from PC. In order to start working with the device, the proprietary driver and software interface must be installed on the PC running Windows operating system. [6]

Fig. 2.1 - Da Vinci Mini 3D Wi-Fi Printer

In order to send files to this printer we must use the dedicated software that DaVinci producer provided within the 3D printer. After starting up the printer's interface, a window as figure 2.2 will appear.

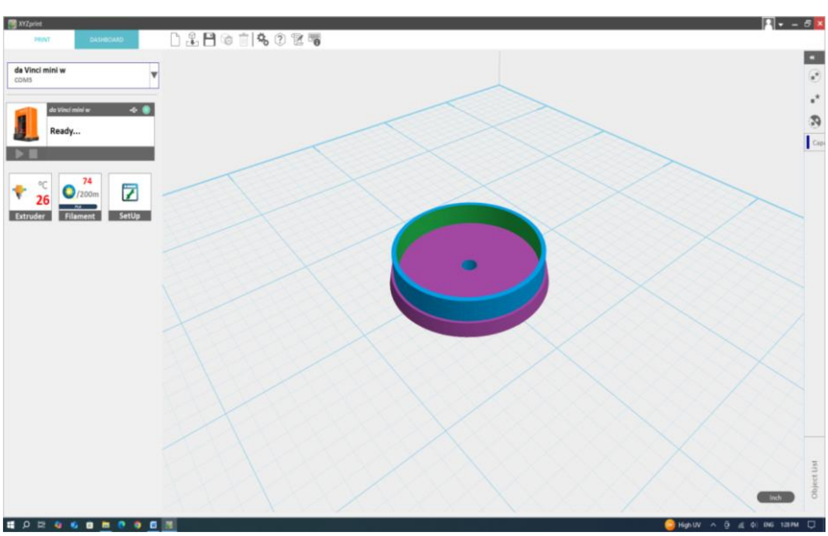

Fig. 2.2 DaVinci printer main interface with 3D object loaded

The software will pop up the tool menu that is in the main line of the window. It detects the device and displays the parameters for the extruder nozzle, filament characteristics and the setup parameters.

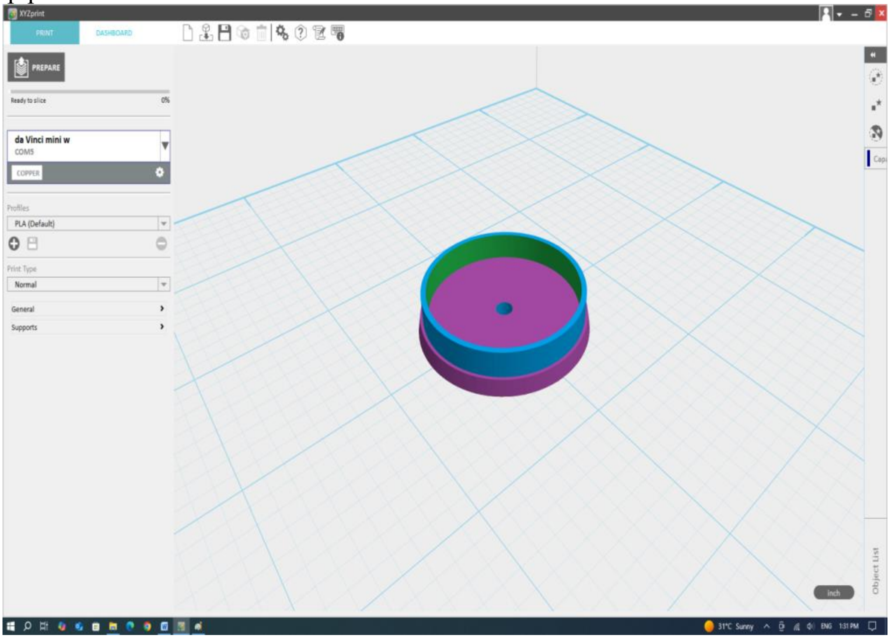

Fig. 2.3 - The printer main interface with the Prepare printing tab displayed

If all the parameters required for the 3D object that is waiting to be sent to the printer are satisfied, user may follow the screen that we can see in figure 2.3 in order to execute the printing process. Here we can also find the preparing printing object menu where we can define several parameters that the physical 3D object will have. This includes: type of filament (material) used for printing, printing type including quality and resolution of printing and other settings that include infill density, infill type, shell, layer height, print speed, temperature and details.

If all this parameters are being set up, the user can use “Prepare” command which will convert the 3D loaded object into data packages information that is required for the printer to actually print physical object. These described details are illustrated in the figures 2.4 and 2.5. This file can also be saved as 3W file format dedicated for this printer device.

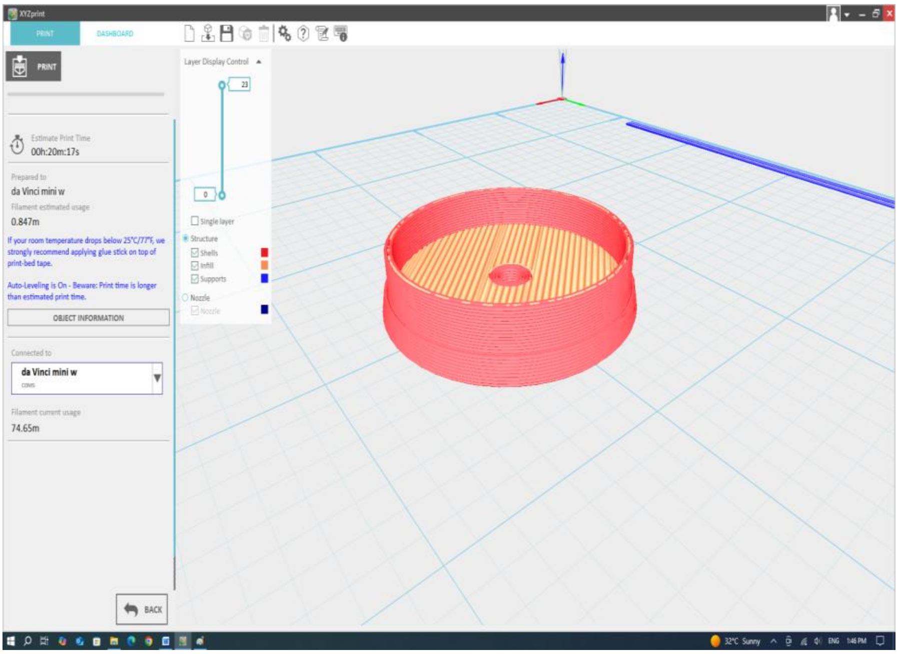

Fig. 2.4 - The prepared 3D objects screen including how much material is being used

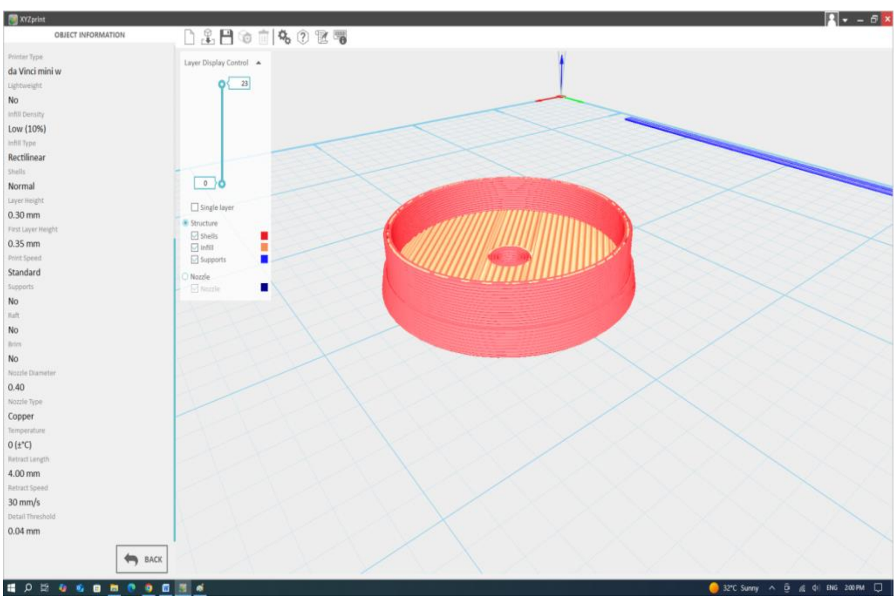

Fig. 2.5 - The parameters of 3D objects are going to be printed

After finalizing the printing process, which regularly lasts between 40 and 80 minutes for small pieces, the object is ready to be used.

3 Explaining 3D printers' extruder technique on Prusa device printer

Another more complex printer that we used in our laboratory is Original Prusa Research I3 MK2 that successfully can be used for various research projects. This printer is shown in the figure 3.1.

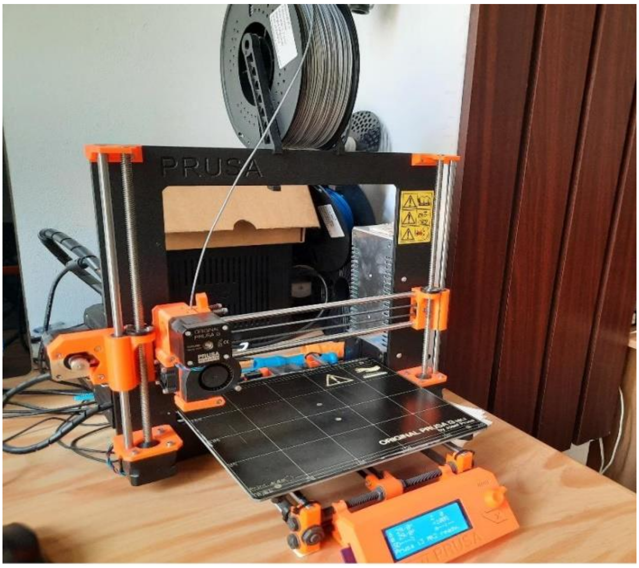

Fig. 3.1 - Original Prusa I3 MK2 photo in our laboratory

The device is similar to the one we presented earlier, but the printer has several noticeable advantages.
First evident advantage that the printer actually has as an improvement compared to DaVinci Printer is that it can print elements bigger than DaVinci Printer. That it makes the device more useful in certain circumstances especially when it comes to laboratory 3D prints. Another useful improvement that it has is the resolution. This printer makes clear objects with very fine and smooth shapes. This feature is very useful especially when it comes to precision geometry, embossing and art design. Of course the device has heated layer bed, which will make the printing more accurate and precise, especially at long lasting printings or when different type of geometry is needed. This improvement is also used to keep the print warm, preventing the unstick issues and warping at the surface.

When it comes to printing, the device can work not only receiving the user project data from the PC but also can easily print 3D projects with a built-in file explorer that the user can access from the dedicated interface that the producer provided within the dedicated firmware for this device.

This can be seen in figure 3.2.[7]

Fig. 3.2 – Prusa 3D printer interface and explorer

In the following we will present the 3D dedicated printing software that the producer provided for the Prusa device.

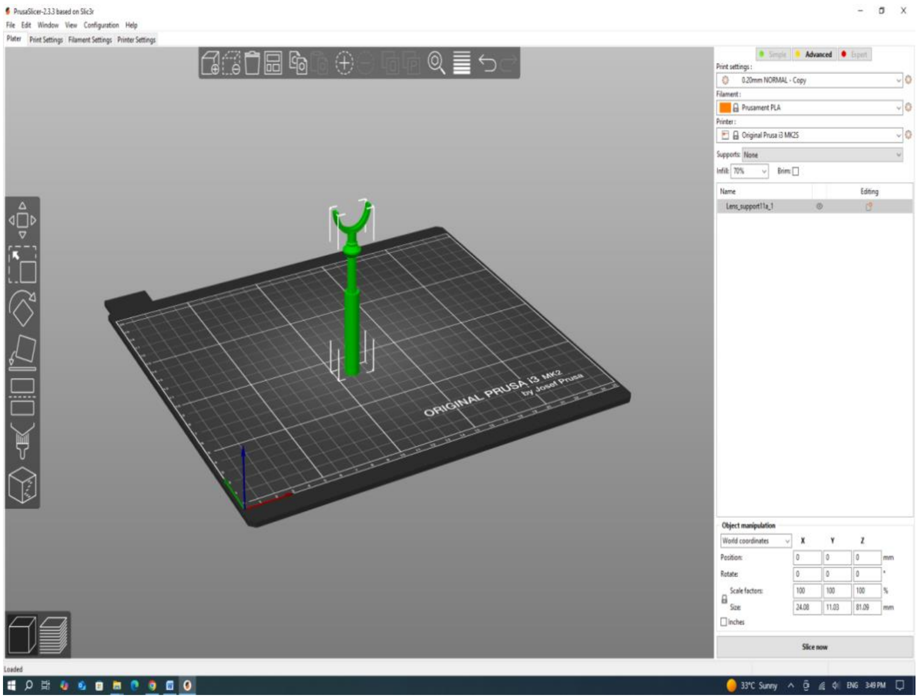

Fig. 3.3 - Mirror or lens support 3D object for optics laboratory loaded in Prusa printer interface

In the figure 3.3 we can see the main interface window for dedicated printing software in which is loaded an original object made in our laboratory for education purposes. In this case we used it for student courses in a Michelson device. The main interface has configuration and parameters that will allow the user to easily handle the whole 3D printing process. Its main menu includes platter, print setting, filaments settings and printer setting. For this printer we mainly use printing extruder nozzle with about 0.20 mm in diameter and PLA filament (polylactic acid filament) with 1.75 mm in diameter at a nozzle temperature of about 215 ºC. The layer bed is heated at 60 ºC. One of the PLA advantages is that this material is one of the most reliable.

In order to analyze some characteristics as durability and strength of the PLA filament we made a small experiment that reveals the quality of PLA. A piece of two filaments bonded together using printer extruder with different colors in a very small spring form is stretched with a small weight of about 0.82 g, gravitationally. We let the small spring already created exposed to normal room light for several months. It is noticeable that the filament stretches faster in the first days. For the non colored filament the stretch is harder, revealing a higher flexibility compared with the green one that its stretch is smaller. Material was PLA at 1.75 mm in diameter heated at 215 ºC with Prusa extruder and the small spring has 0.32 mm. After a couple of months the stretching stops on both filaments and the spring maintains its shape without any noticeable changes

Fig. 3.4 - Small PLA spring using two materials with a small weight for analyzing the deforming parameters and quality of PLA different materials

In order to send the 3D project to the printer after loading the 3D project file we need to prepare it. The Prusa printer interface allows us to preview the object to be printed and to analyze the geometrical architecture of the 3D object that is going to be printed. The app is called “slicer”. This app allows the user to manage the coordinates of 3D file that will be printed and to see real world object coordinates. After the characteristics are being set, using this software interface we can export a GCODE file format dedicated for this printer device. The subsequent file might be used for analysing and editing using for example “Notepad”. These can be seen in the figures 3.5 and 3.6.

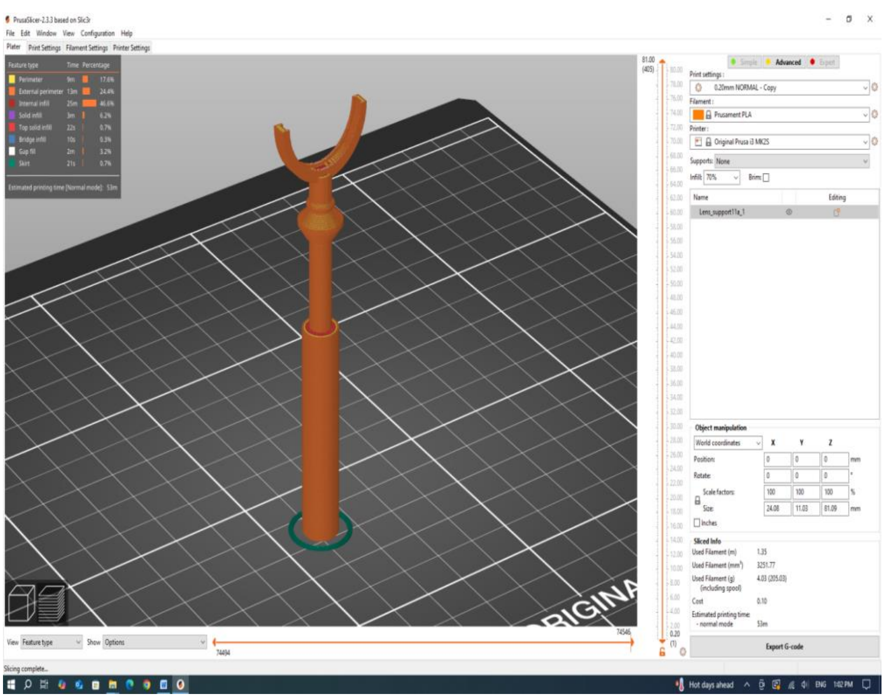

Fig. 3.5 - Preview of 3D object to be printed with layers and geometry architecture

```
; external perimeters extrusion width = 0.45mm
; perimeters extrusion width = 0.45mm
; infill extrusion width = 0.45mm
; solid infill extrusion width = 0.45mm
; top infill extrusion width = 0.40mm
; first layer extrusion width = 0.42mm

M73 P0 R53
M201 X9000 Y9000 Z500 E10000 ; sets maximum accelerations, mm/sec^2
M203 X500 Y500 Z12 E120 ; sets maximum feedrates, mm/sec
M204 P2000 R1500 T2000 ; sets acceleration (P, T) and retract acceleration (R), mm/sec^2
M205 X10.00 Y10.00 Z0.20 E2.50 ; sets the jerk limits, mm/sec
M205 S0 T0 ; sets the minimum extruding and travel feed rate, mm/sec
M107
;TYPE:Custom
M862.3 P "MK2S" ; printer model check
M862.1 P0.4 ; nozzle diameter check
M115 U3.2.3 ; tell printer latest fw version
G90 ; use absolute coordinates
M83 ; extruder relative mode
M204 S2000 T1500 ; MK2 firmware only supports the old M204 format
M104 S215 ; set extruder temp
M140 S60 ; set bed temp
M190 S60 ; wait for bed temp
M109 S215 ; wait for extruder temp
G28 W ; home all without mesh bed level
G80 ; mesh bed leveling
G1 Y-3.0 F1000.0 ; go outside print area
G92 E0.0
G1 X60.0 E9.0  F1000.0 ; intro line
G1 X100.0 E12.5 F1000.0 ; intro line
G92 E0.0
G21 ; set units to millimeters
G90 ; use absolute coordinates
M83 ; use relative distances for extrusion
M900 K0.05 ; Filament gcode LA 1.5
M900 K30 ; Filament gcode LA 1.0
;LAYER_CHANGE
;Z:0.2
;HEIGHT:0.2
;BEFORE_LAYER_CHANGE
G92 E0.0
;0.2


G1 E-0.80000 F2100.000
G1 Z0.400 F10800.000
;AFTER_LAYER_CHANGE
;0.2
G1 X119.603 Y99.604
G1 Z0.200
G1 E0.80000 F2100.000
M204 S1000
;TYPE:Skirt
;WIDTH:0.42
```

Fig. 3.6 – The main characteristics of the 3D object loaded from a GCODE file fomat

4 Designing 3D objects using 3D Builder

The projects that we have proposed for this presentation were designed and edited using 3D Builder, which is provided and licensed by Microsoft Corporation. This can be seen in the figure 4.1. [8]

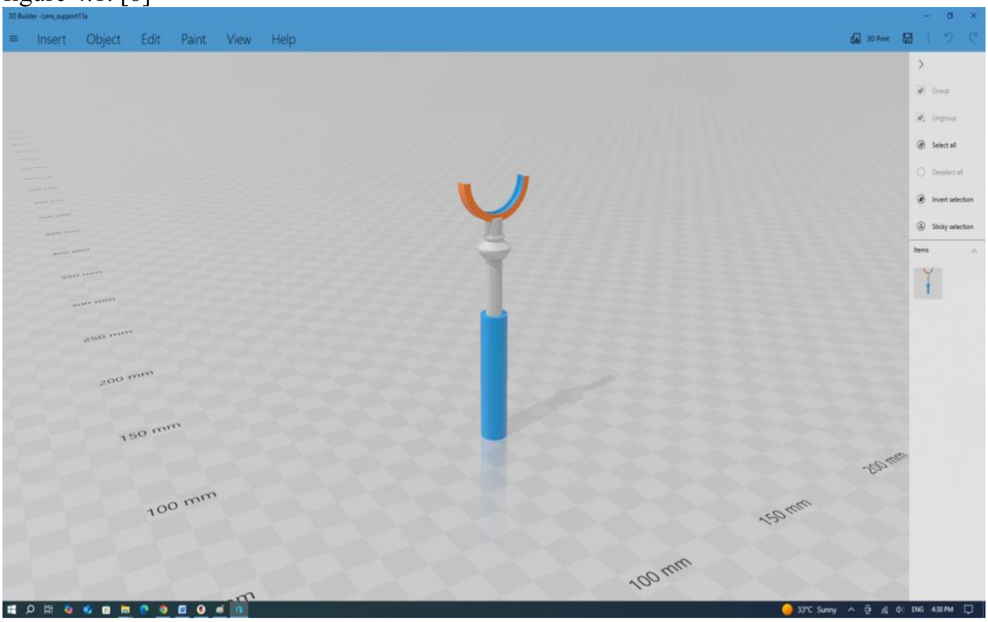

Fig. 4.1 - 3D holder for mirror or lens opened in 3D Builder software

The software offers full-access features and tools that allow the user to handle the task very well in order to design and edit many 3D projects not only for home use but also for laboratory purposes. It can also allow the possibility to animate, feature that is very helpful for designing 3D objects. A window with a project loaded can be seen in the figure 4.1. Using this software we can design and adapt the shapes to many scientific purposes. The software interface allows us to adjust the length, width, holder angle regarding horizontal plane, resizing the object in any desired shape, duplicate and sculpt. We used the object illustrated in the figure 4.1 for Michelson device in optical experiments. The parameters of this device are 111.43 mm on X axis, 88.67 mm on Y axis and 40.55 mm on Z axis. Using software interface we can access features and tools for providing a very good manner to design and edit 3D objects; we can also simplify the object texture saving time and material. This feature that we can find and apply using 3D Builder Interface allows us to reduce the quantity of material that is not really necessary for printing and, of course, reduce the total time that is needed to print the entire project. This is very useful to adapt our existing project to the actual needs of the 3D printing. Doing so, we can obtain a 3D object that is suitable and accurate in shapes that could be very useful in scientific laboratory. For the object presented above, we may reduce the density of material and maintain its shape and strength, for example, if the sustainable element such as mirror or lens is light enough and the stress on the stand leg regarding rotation and height are considerably low.

In order to adjust the desired 3D element in the manner presented we may choose the simplify screen included in the interface of 3D Builder software. This can be seen in the figure 4.2

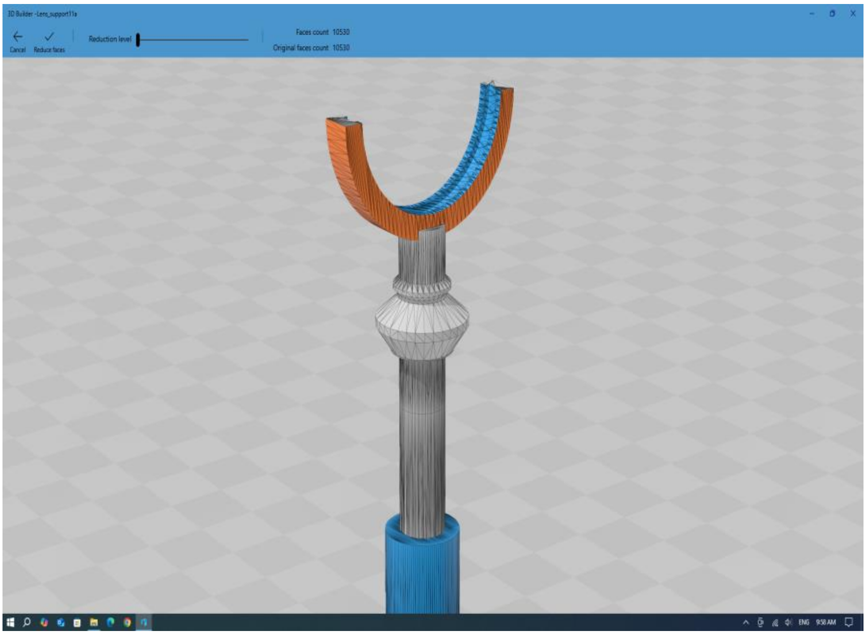

Fig. 4.2 – 3D holder for mirror or lens in the simplifying window

Another useful feature that we may access using 3D builder is soothing object. This feature allows us to sculpt the 3D element the way we need. This is very important because it allows the user to define a shape of the 3D element that will create a very accurate 3D object after the printing process is done. This can be seen in the figure 4.3.

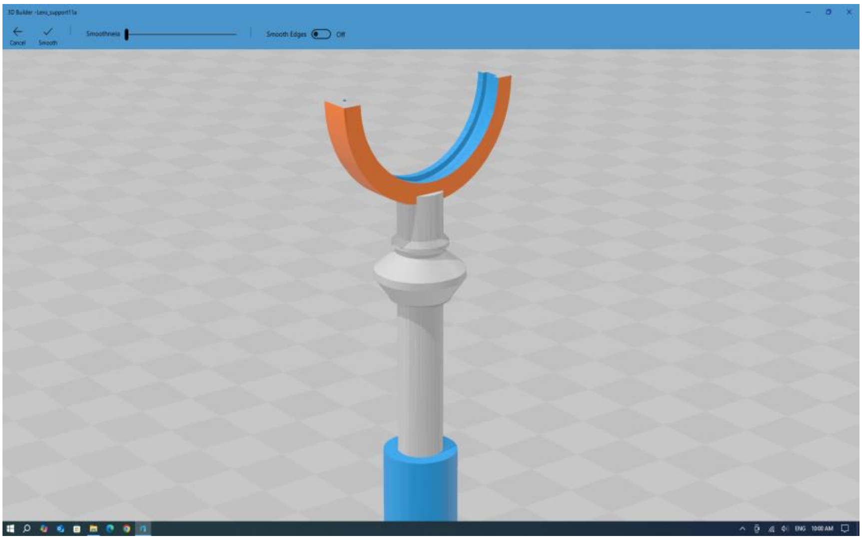

Fig. 4.3 - 3D holder for mirror or lens in the smoothing window

After setting up the 3D object parameters, the project file can be saved either in 3MF file format, which is the standard format for 3D Builder software file, or in STL file format which is a simplified file that could be compatible to many other printer devices. These files can be loaded into the printer interface and the object is ready to be printed.

4.1 Examples of a 3D object class created and used as research equipment in our laboratories

In the following we will present a class of objects that we created in our laboratory for education and research purposes. We may see in the figure 4.4.

Fig. 4.4 - Objects printed using Prusa Printer

The figure above illustrates objects printed using Prusa printer device. What it can be seen is that the object has fine shapes, it allows multiple parts that may work as a mechanism and the details such as embossing can be very useful to define specific object geometries. Another figure below it shows an acoustic experiment, a resonant tube, that can easily reveals 3D acoustic waves. The tube was created in our laboratories using 3D parts such as wave guide and the support that holds the tube. It is shown in the figure 4.5

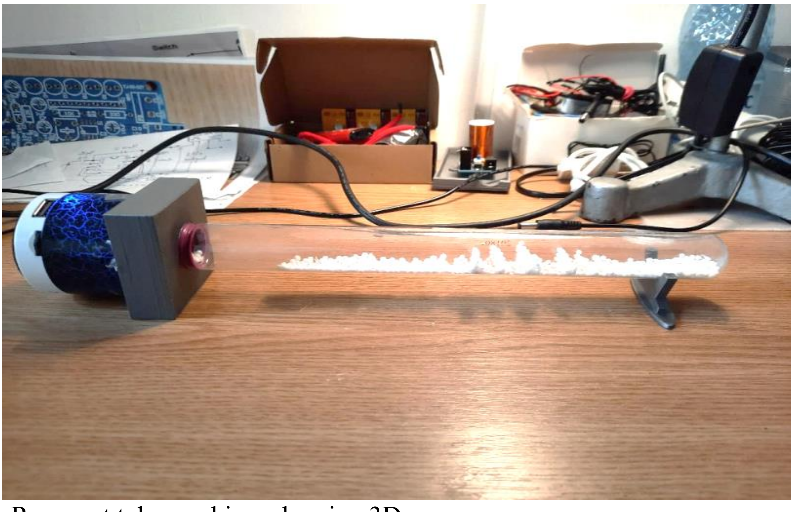

Fig. 4.5 - Resonant tube working, showing 3D waves

Another laboratory experiment in which we included 3D objects is a Tesla module which has base component as a 3D printed element.

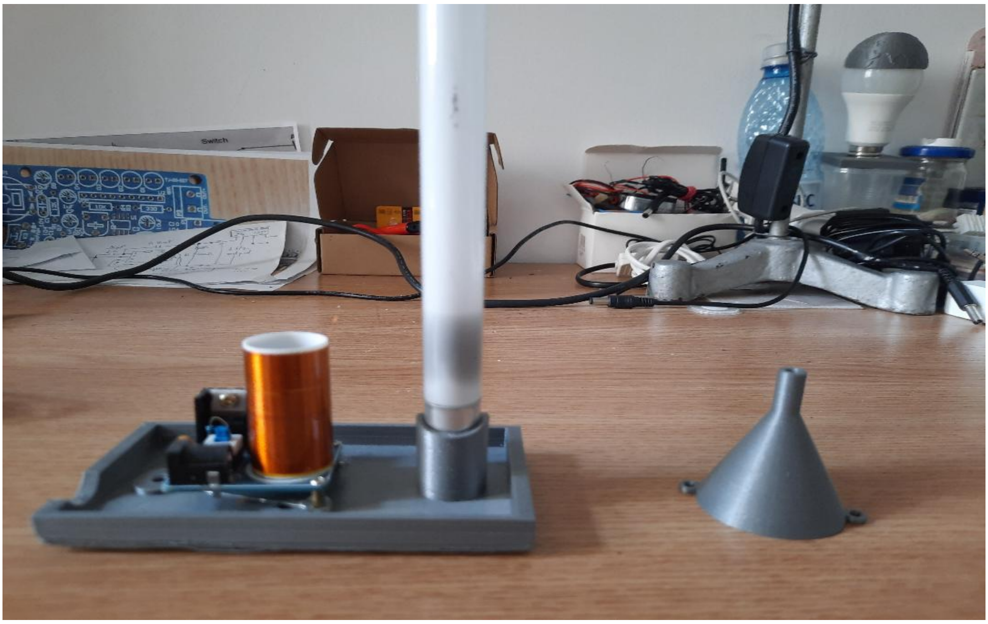

Fig. 4.6 - Tesla experiment at small scale that has 3D printed objects, and close to it a 3D funnel object

In the figure 4.6 we can also see a funnel that can be used not only for working with fluid solutions but also can be used for small particles powders or fine sand.

5 Conclusions

The 3D printing allows a very rapid experience of printing not only with a plastic material but also in a metal format that will give you almost exact replica of what we are trying to build. It can create a very accurate shape of an element that can be a part of a complex. This can be done quite rapidly and with less expensive costs. That is very useful not only for laboratory projects but also for home usage and, of course, we can edit or get a project started from scratch. Moreover we can rebuild a missing element from a complex structure. Nowadays it’s easier to create projects whenever it comes for prototyping, creating unique gifts, or designing art projects and other useful tools with the 3D printing devices.

For our case using 3D Builder software allows us to design almost any 3D project and sculpt the elements with the desired characteristics, while using Prusa 3D printer device allows us to print various 3D objects in order to build devices for scientific research in our laboratories. Doing so, we can manage more easily the scientific research process by building devices that can acquire scientific data. It is also useful for the teaching process, because it helps students to achieve more easily useful knowledge about building and managing a scientific or technical concept. 3D printing process also save a lot of time and expensive costs because by doing it we can avoid expensive costs on equipment parts orders and shipping cost.

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