Module 4

Design and Materials used for Personal 3D Printers

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Introduction

Design using a computer is known as Computer-aided design or CAD, which aids in the creation, modification, analysis, or optimization of a design. Working with CAD increases the productivity of the designer, improves the quality of design, improves communications through documentation, and creates a database for manufacturing. With CAD you can design curves and shapes in 2D space or surfaces and solids in 3D. [1]

One of the biggest advantages after creating 2D or 3D objects is the possibility of making as many changes as needed with less effort than drawing them on paper with a pencil. Also, some software allows the user to change something in the history of the design, and automatically it changes everything done after that point.

For almost every professional sector that uses design, there's CAD software with specialized features and tools for each one, making it widely applicable. For example, architecture is one of the most demanding disciplines when talking about CAD; there are so many elements involved during the design of a project that one almost needs software support. Industrial designers use CAD software not only to visualize an object but also to understand and confirm how it will function. Professional graphic design also makes use of 2D or 3D CAD software to create visualizations, it lets designers add effects, typography, shapes, and backgrounds.
Given the many and diverse engineering fields, the types of CAD programs used by engineers are also many and diverse. Some of the most common targets include infrastructure, buildings, circuits, telecommunications networks, thermodynamics, mechanical parts, medical devices, and manufacturing.

To process the designs produced in CAD and turn them into physical objects, CAM or Computer-Aided Manufacturing is used. It uses numeric control software that encodes automated instructions for a specific machine, processing the data for manufacturing methods such as 3D printing, CNC (Computer Numerical Control) routing, or laser cutting and engraving. CAD and CAM work better when they're integrated because they provide more control over the design and fabrication process.

These days, CAD is in constant evolution, different software is always being updated and new features added. [2]

How to design

As seen in the last chapter, there's a lot of different software available according to one's needs or level of expertise. Some software can really be difficult to use, with a lot of different features and complex interfaces. Even with free CAD software, there are really complex and technical programs so the level of expertise should be the first criterion while choosing the 3D software. [3]

The overview below is based on Autodesk Fusion 360 and will be a simple approach to intermediate-level software, some more options or parameters will not be seen below but may also be important according to each person's needs for the software.
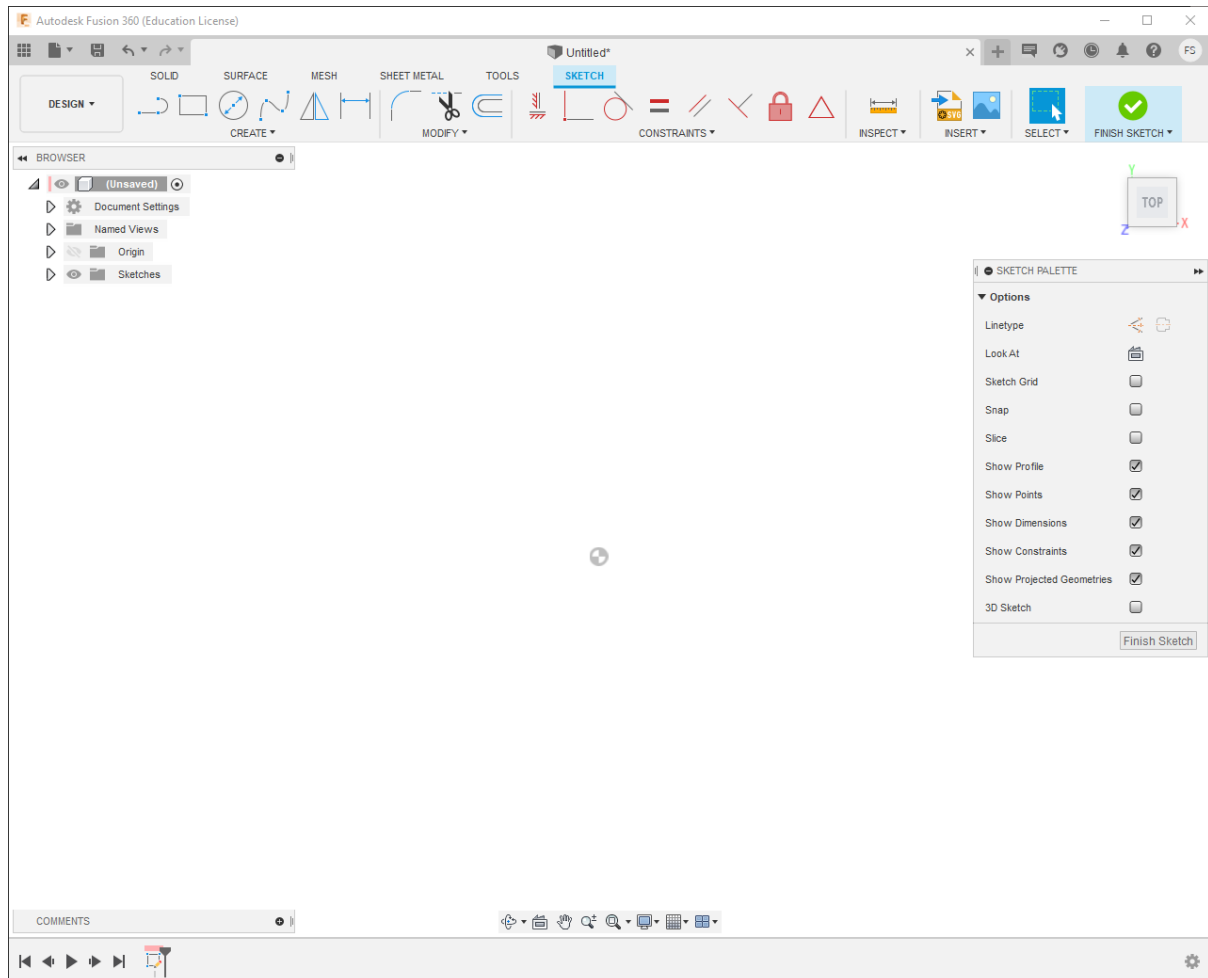
Know the User Interface
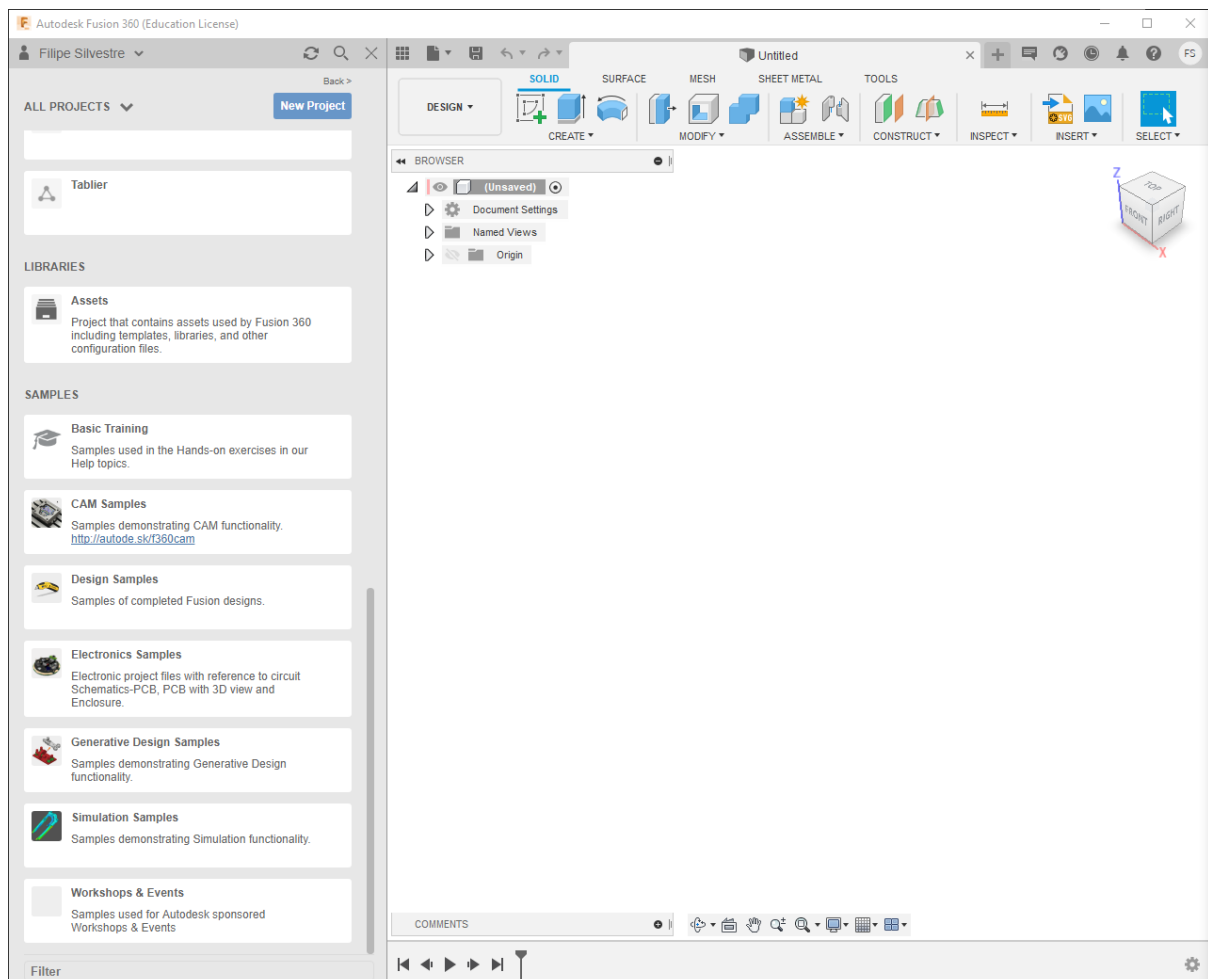
In the image above, the left panel is where the files are listed, all being based so internet connection is required.
- On the bottom of the image there is the Orbit, Look at, Pan, Zoom, and view options.
- On the top right corner is where the view cube and home view are.
- On the top tab, there are the commands with expandable tabs for the options.

2D Sketching

Most designs start by using the basics of 2D sketching that develop into 3D models. So, in the image above, a sketch view with the different commands on top is shown, which are separated into sections (the most used is the create and modify) but there are also the constraints that will help with the sketching process. Some of the more important commands from each section are:
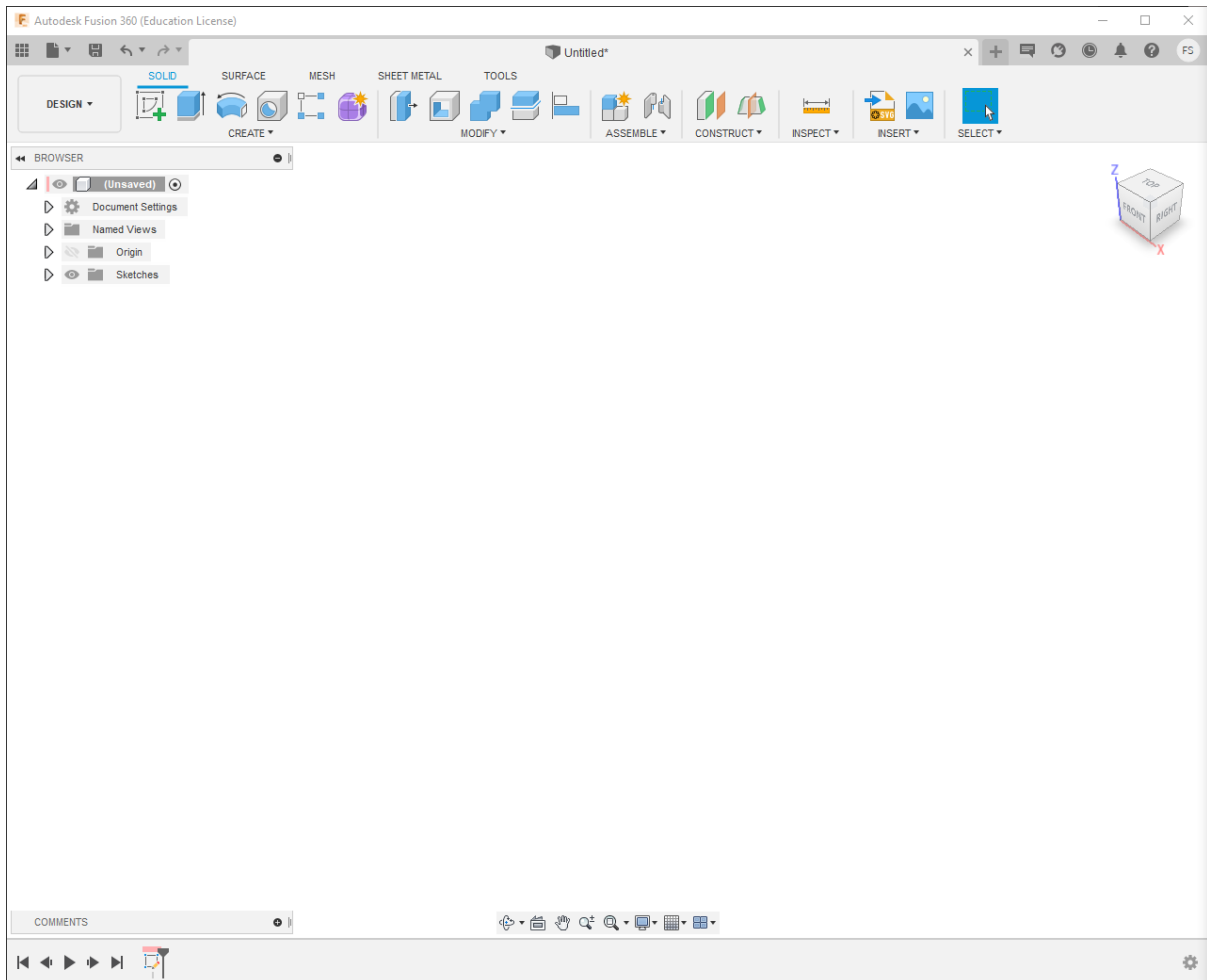
Create

- Line
- Circle
- Mirror
- Adding Dimensions
- Patterns

Modify

- Move/Copy
- Trim
- Offset

- Fillet
- Chamfer
- Change parameters

3D Modeling

The design workspace is where the 3D modeling will be made, either starting from a 2D sketch or just from 3D shapes and modifying them.
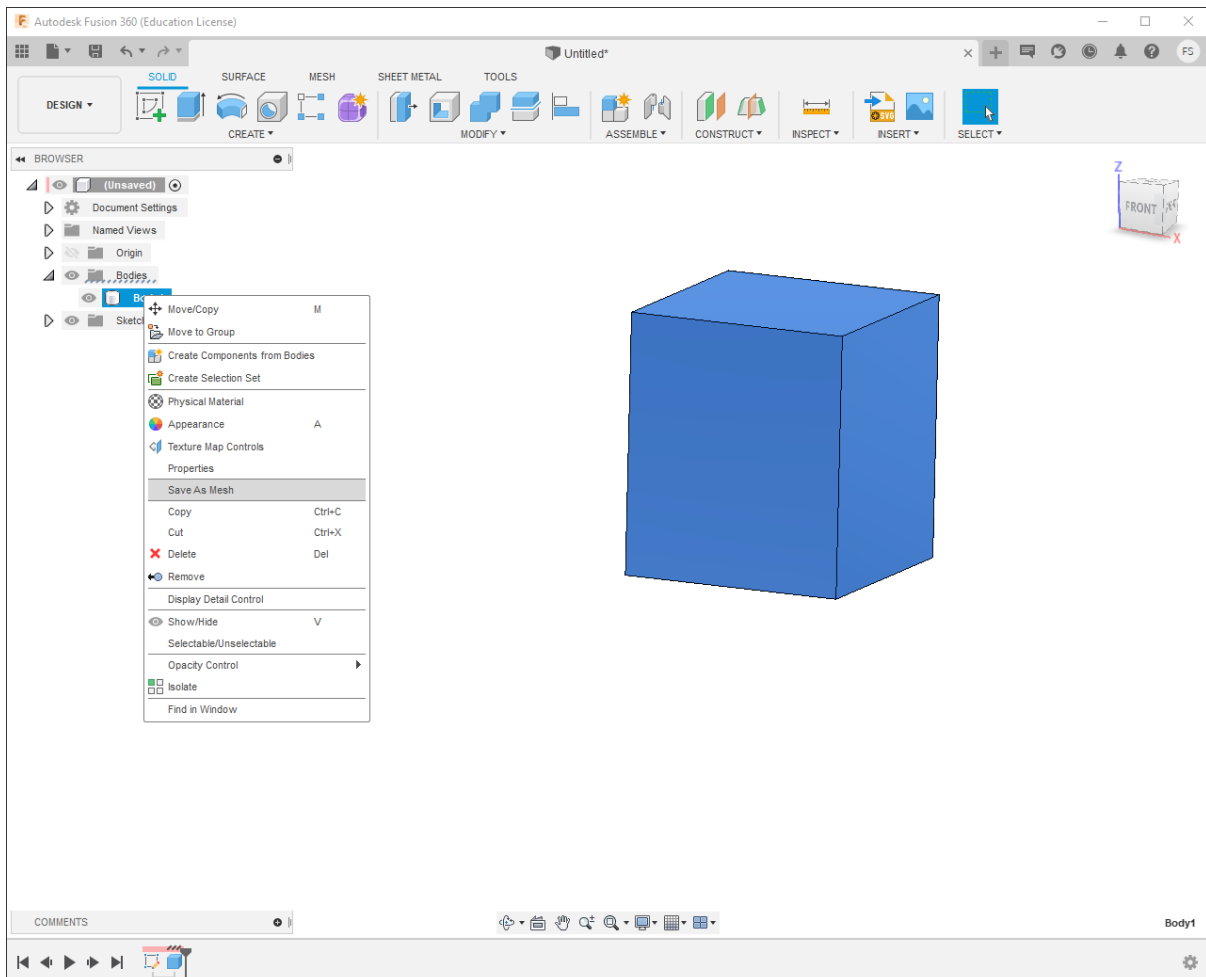
Create

- *From 2D*
  - Extrude
  - Revolve
  - Loft
  - Sweep
  - Others
- *Basic shapes*
  - Box
  - Cylinder

○ Sphere
　　　　　　○ Others
Modify
　　　● Move/Copy
　　　● Press-Pull
　　　● Fillet
　　　● Chamfer
　　　● Combine
　　　● Split body
　　　● Align
　　　● Others

Saving/Exporting

As with most software nowadays, saving the file is not needed as it is being automatically saved on a server. But it can always be backed up on the computer for offline work.

If the objective is to export the file for 3D printing the way to do it, in this case, is to save it as a mesh and save it with the file format desired. [4]

Materials

The scope of this module is the personal 3D printers that one might have at home, therefore this chapter will refer only to FDM and SLA technologies.

FDM (Filament Deposition Modeling)

Introduction

Having the correct type of filament to print a certain object is difficult, as the 3D filaments market sees the regular emergence of radically new materials. The filaments of PLA (Polylactic Acid) and ABS (Acrylonitrile Butadiene Styrene) have been the two main materials used for a long time, but their initial dominance was mostly fortuitous, so there should not be any major roadblocks for other polymers to play a key role in the future of FDM. Nowadays new materials are becoming more popular, both pure polymers and composites. Some examples that exist in the market today are PET (Polyethylene Terephthalate), Nylon, TPU (Thermoplastic Polyurethane) - Flexible, and PC (Polycarbonate). Its characteristics are what will make one prevails over the other according to the purpose they're going to serve, some of which are:

- Ease of printing: Bed adhesion, max printing speed, frequency of failed prints, flow accuracy, ease to feed into the printer, among others.
- Visual quality.
- Max stress: Maximum stress the object can undergo before breaking when slowly pulling on it.
- Impact resistance: Energy needed to break an object with a sudden impact.
- Layer adhesion (isotropy): How good the adhesion between layers of material is. The better the layer adhesion, the more isotropic the object will be.
- Heat resistance: Max temperature the object can sustain before softening and deforming.

PLA

PLA is the easiest polymer to print and provides good visual quality. It is very rigid and actually quite strong, but is very brittle.

ABS

ABS is usually picked over PLA when higher temperature resistance and higher toughness are required.

PET

PET is a slightly softer polymer that is well rounded and possesses interesting additional properties with few major drawbacks.

Nylon

Nylon possesses great mechanical properties, and in particular, the best impact resistance for a non-flexible filament. Layer adhesion can be an issue, however.

TPU

TPU is mostly used for flexible applications, but its high impact resistance can open for other applications.

PC

PC is the strongest material of all and can be an interesting alternative to ABS as the properties are quite similar.

The choice of the right polymer is critical to get the right properties for a 3D printed part, especially if the part has a functional use. This article will help users to find the right material depending on the needed properties. However, material suppliers also often provide blends or add additives to modify the properties of the pure polymer (e.g. adding carbon fiber to make the material stiffer). [5]

SLA (Resin)

Introduction

SLA or stereolithography is the ability to produce plastic parts with high resolution and accuracy resulting in a smooth surface finish. Since there's a big variety of different resins available for SLA 3D printing with many applications in diverse industries such as:

- Standard resins are used for general prototyping
- Engineering resins have specific mechanical & thermal properties
- Dental & medical resins have biocompatibility certifications
- Castable resins have zero ash content after burnout

SLA technology uses a UV (Ultraviolet) laser to cure liquid resin into hardened plastic in a process called photopolymerization. Different combinations of monomers, oligomers, photoinitiators, and various other additives that comprise a resin result in different material properties.

Like every process, there are benefits and limitations that are common to all SLA materials:

Pros:
- Surface finish
- High detail
- High stiffness

Cons:
- Relatively brittle (low elongation at break)
- The material properties may change over time, due to overexposure to UV radiation
- Susceptible to creep

Standard resin

Standard resins 3D prints have higher stiffness and a high resolution with a smooth injection molding-like finish. Usually, this is the cheapest resin making it the top candidate for quick prototyping.

Most of the time, the color of the resin affects its properties. For example, the grey resin is better suited for parts with fine details and white resin for parts that require a very smooth surface.

Clear resin

Clear resin has similar mechanical properties to the standard resin but one main difference, it can be post-processed to achieve better optical transparency.

Tough resin

Tough resin has been developed for applications that require materials that could resist high levels of stress and strain. The prints made with this resin will result in sturdy, shatter-resistant parts and functional prototypes.

Heat resistant resin

Heat resistant resins have a heat deflection temperature between 200-300°C and are adequate for manufacturing heat resistant fixtures, mold prototypes, hot air, and fluid flow equipment, as well as, casting and thermoforming tooling.

Rubber-like resin (flexible)

Flexible resin allows engineers to produce rubber parts that are soft to the touch and have a low tensile modulus and high elongation at break. It is well-suited for objects that will be bent or compressed. The rubber-like resin is great for packaging, stamps, wearable prototyping, handles, and grips.

Ceramic filled resin (Rigid)

Rigid resins are reinforced with glass or other ceramic particles and result in very stiff and rigid parts, with a very smooth surface finish. These resins are also suitable for parts with thin walls and small features (the recommended minimum wall thickness is 100 μm). [6]

Bibliography

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[6] M. Latouche. "SLA 3D printing materials compared," *Hubs*. A Protolabs Company, 2021 https://www.hubs.com/knowledge-base/sla-3d-printing-materials-compared/ (accessed Jul. 19, 2021).