VIBE PROJECT

Virtual Biomedical and STEM/STEAM Education

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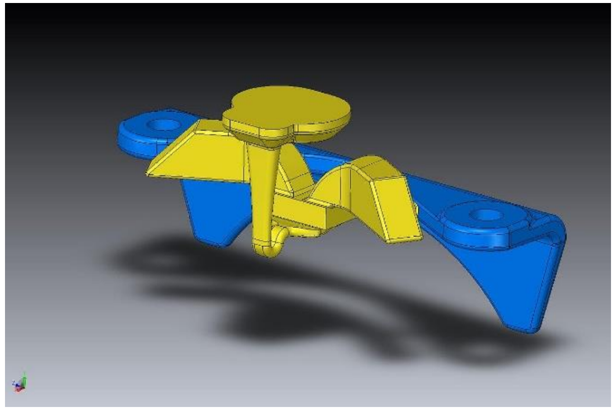
VIBE PROJECT

3D VISUALISATION & PRINTING

PRINCIPLES OF 3D PRINTING, PROCESS-TECHNOLOGIES

Modelling

You can create 3D printable models with a computer-aided design (**CAD**) package with a **3D scanner** or digital camera and a **photogrammetric** software. 3D printed models created using **CAD** results in relatively **fewer errors** than other methods. On the models, **errors** can be identified and **corrected** before printing.



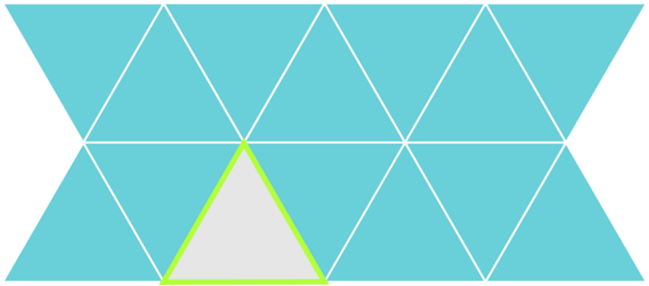
3D scanning is a **process for collecting digital data** for the shape and appearance of a real object, based on which the digital model can be created.

The CAD models can be **saved** in the stereolithographic file format (**STL**), which stores the actual CAD file format of additive production based on the triangulation of the CAD models surface. The **STL** format is just a **transition** between the **CAD** software **and the slicing program**. In 2011, a new CAD file format, the Additive Manufacturing file format (**3MF**) was introduced. The information is stored using curves.

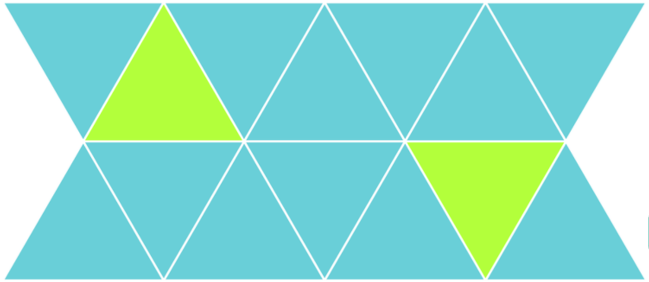
Post processing

Before we print a 3D model from STL file, we must first look at whether there are no erros in it. CAD applications can produce errors in the exported STL files, these are called Non Manifold Object:

1. **Holes**
   The error can be solved by patching.

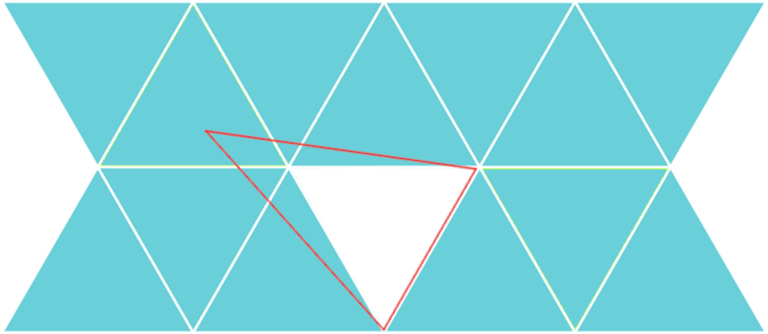


2. **Normals of the polygons turn around (Normals)**
   The error can be solved by flipping the polygons



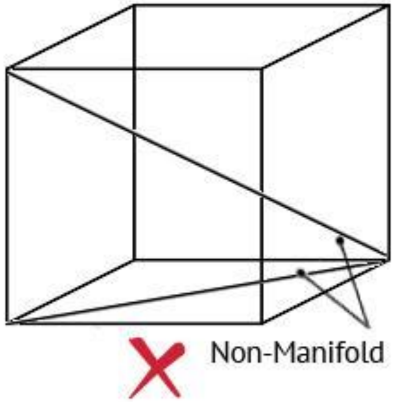
Post processing

3. **Intersecting surfaces**
   The error can be solved by merging the climax.

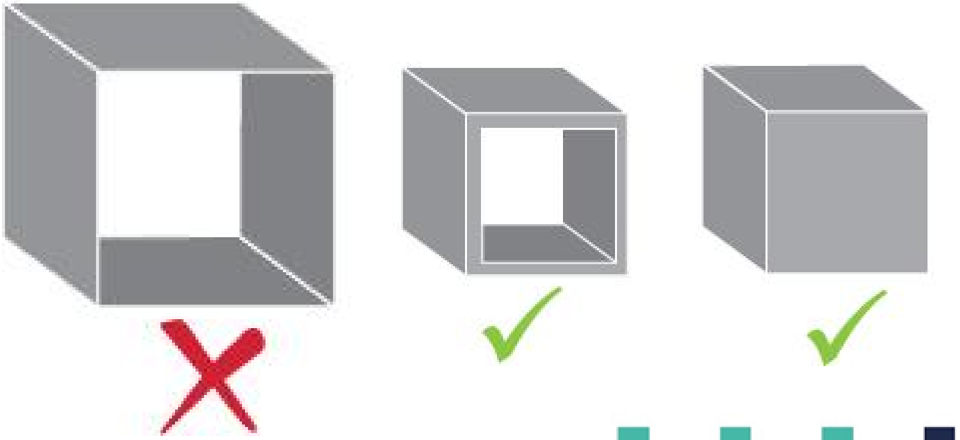


4. **Inner cavities generated from noises (shells)**

The error can be resolved by deleting the inner surface.

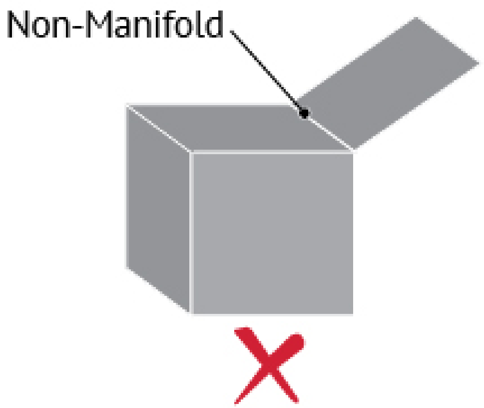


5. **Open geometry**

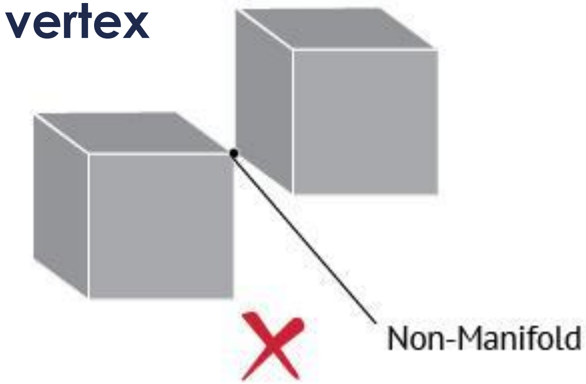


Post processing

6. Multiple connected geometry
The open surface should be terminated either by giving it volume or by deleting the non-manifold surface.



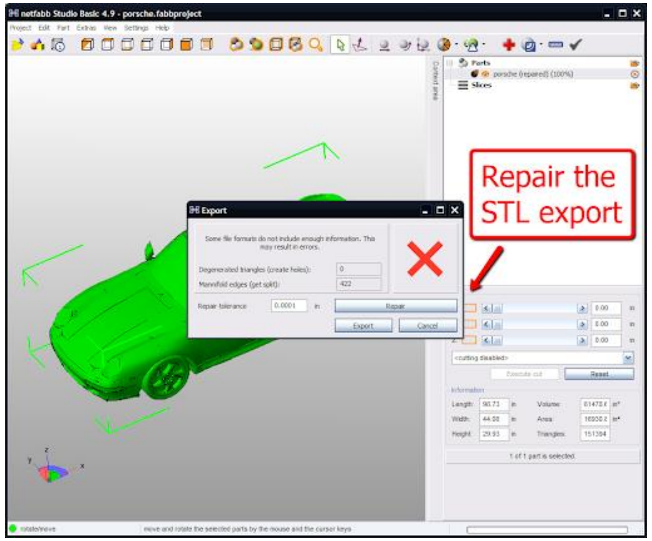
7. Several surfaces are connected to a single vertex
This error can be eliminated by disconnecting cubes or completely deleting one.

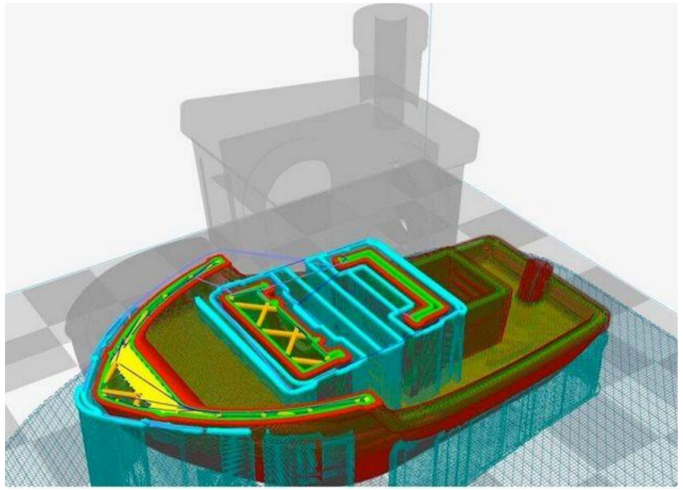


Slicing

The step of STL export "**Repair**" solves **most of** these issues in the original model. In general, STLs produced by **3D scanning** contain **several such errors** as 3D scanning is often carried out by mapping from point to point. This **3D reconstruction** often contains errors.

After being completed, the STL file must be processed with a "**slicer**" software that converts the model into a series of **thin layers** and creates a **G-code** file, which is a **customized instructions** for a particular 3D printer (eg FDM) included. The G code file can then be printed with the 3D printer client software (which is controlled by the G code **controls the printer during the process**).

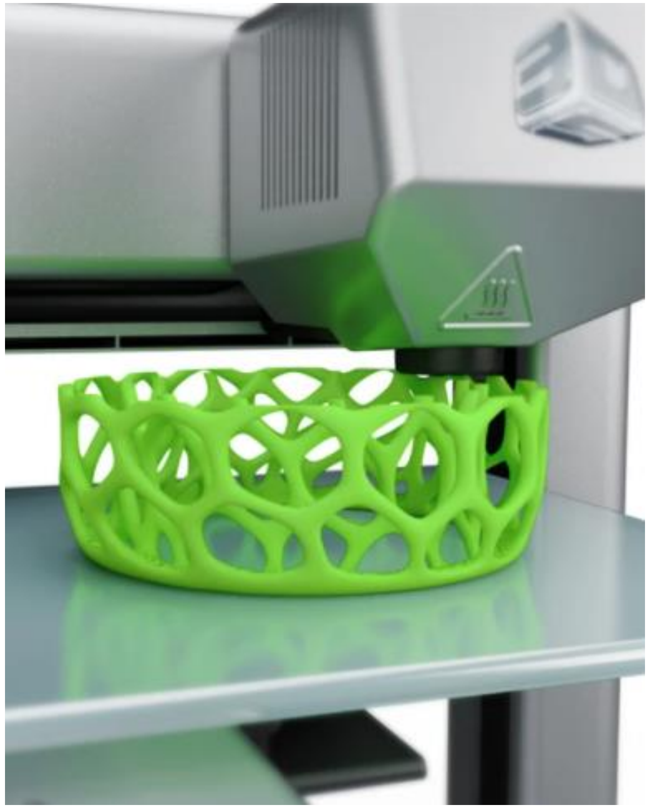




Process of printing - video

Printing

The resolution of the printer describes the **layer thickness** and **x-y resolution** in point / inch (dpi) or **micrometer** (μm). The typical layer thickness is around **100 μm** (250 dpi), although some machines can print 16 μm (1600 dpi) thin layers. The X-Y resolution is similar to laser printers. **Voxels** (3D pixels) have a diameter of about **50-100 μm** (510-250 dpi). For this printer resolution, the output file is optimized for **0.01-0.03 mm** mesh resolution and ≤ 0.016 mm edge length. Specifying a **higher resolution** results only a larger file size, but it will **not enhance** the quality of the print.



Creating the model with current methods may take several hours to several days or even weeks, depending on the method used and the size and complexity of the model. **Printing time** can usually last a few hours up to several days depending on the type of machine used and depending on the size and number of simultaneous models.

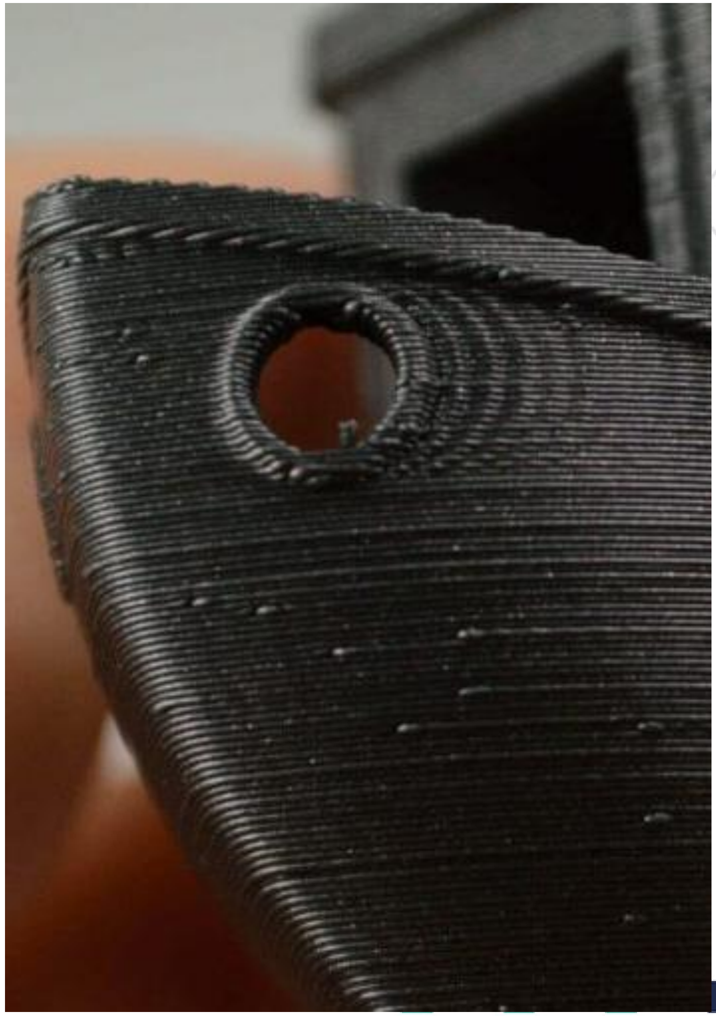
Final product

The **layered structure** of all additive procedures will inevitably result in a **staggered** effect on component surfaces that have been **curved or shoved** compared to the building platform. These effects are largely dependent on the model's orientation that we have defined during slicing.
Some printable polymers, such as ABS, allow the **surface smoothing** and improving **chemical vapor** flow based on **acetone** or similar solvents.

Some additive techniques can use **multiple materials** when manufacturing parts. These techniques can print in **multiple colors** and color combinations simultaneously and do not necessarily require painting.

Some printing techniques require to build internal structures (**support**) for overhanging shapes. These support elements must be **mechanically removed** or dissolved when printing is complete.

Removing supports - video



Materials

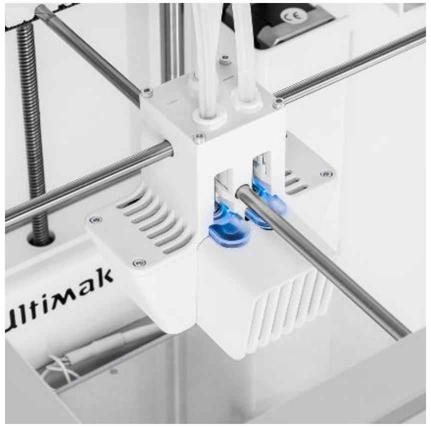
In general, 3D printing focuses on **polymers** due to the simplicity of manufacturing and handling polymeric materials. However, the method is developing rapidly and will not only allows printing different polymers, **metals** and **ceramics** but also, making it a versatile 3D printing opportunity in the industry.

	ABS	Flexible	PLA	HIPS	PETG	Nylon	Carbon Fiber Filled	ASA	Polycarbonate	Polypropylene	Metal Filled	Wood Filled	PVA
	Learn More	Learn More	Learn More	Learn More	Learn More	Learn More	Learn More	Learn More	Learn More	Learn More	Learn More	Learn More	Learn More
Compare Selected													
Ultimate Strength	40 MPa	26 - 43 MPa	65 MPa	32 MPa	53 MPa	40 - 85 MPa	45 - 48 MPa	55 MPa	72 MPa	32 MPa	20 - 30 MPa	46 MPa	78 MPa
Stiffness	5 / 10	1 / 10	7.5 / 10	10 / 10	5 / 10	5 / 10	10 / 10	5 / 10	6 / 10	4 / 10	10 / 10	8 / 10	3 / 10
Durability	8 / 10	9 / 10	4 / 10	7 / 10	8 / 10	10 / 10	3 / 10	10 / 10	10 / 10	9 / 10	4 / 10	3 / 10	7 / 10
Maximum Service Temperature	98 °C	60 - 74 °C	52 °C	100 °C	73 °C	80 - 95 °C	52 °C	95 °C	121 °C	100 °C	52 °C	52 °C	75 °C
Coefficient of Thermal Expansion	90 µm/m-°C	157 µm/m-°C	68 µm/m-°C	80 µm/m-°C	60 µm/m-°C	95 µm/m-°C	57.5 µm/m-°C	98 µm/m-°C	69 µm/m-°C	150 µm/m-°C	33.75 µm/m-°C	30.5 µm/m-°C	85 µm/m-°C
Density	1.04 g/cm³	1.19 - 1.23 g/cm³	1.24 g/cm³	1.03 - 1.04 g/cm³	1.23 g/cm³	1.06 - 1.14 g/cm³	1.3 g/cm³	1.07 g/cm³	1.2 g/cm³	0.9 g/cm³	2 - 4 g/cm³	1.15 - 1.25 g/cm³	1.23 g/cm³
Price (per kg)	$10 - $40	$30 - $70	$10 - $40	$24 - $32	$20 - $60	$25 - $65	$30 - $80	$38 - $40	$40 - $75	$60 - $120	$50 - $120	$25 - $55	$40 - $110
Printability	8 / 10	6 / 10	9 / 10	6 / 10	9 / 10	8 / 10	8 / 10	7 / 10	6 / 10	4 / 10	7 / 10	8 / 10	5 / 10
Extruder Temperature	220 - 250 °C	225 - 245 °C	190 - 220 °C	230 - 245 °C	230 - 250 °C	220 - 270 °C	200 - 230 °C	235 - 255 °C	260 - 310 °C	220 - 250 °C	190 - 220 °C	190 - 220 °C	185 - 200 °C
Bed temperature	95 - 110 °C	45 - 60 °C	45 - 60 °C	100 - 115 °C	75 - 90 °C	70 - 90 °C	45 - 60 °C	90 - 110 °C	80 - 120 °C	85 - 100 °C	45 - 60 °C	45 - 60 °C	45 - 60 °C
Heated Bed	Required	Optional	Optional	Required	Required	Required	Optional	Required	Required	Required	Optional	Optional	Required
Recommended Build Surfaces	Kapton Tape, ABS Slurry	PEI, Painter's Tape	Painter's Tape, Glue Stick, Glass Plate, PEI	Glass Plate, Glue Stick, Kapton Tape	Glue Stick, Painter's Tape	Glue Stick, PEI	Painter's Tape, Glue Stick, Glass Plate, PEI	Glue Stick, PEI	PEI, Commercial Adhesive, Glue Stick	Packing Tape, Polypropylene Sheet	Painter's Tape, Glue Stick, PEI	Painter's Tape, Glue Stick, PEI	PEI, Painter's Tape
Other Hardware Requirements	Heated Bed, Enclosure Recommended	Part Cooling Fan	Part Cooling Fan	Heated Bed, Enclosure Recommended	Heated Bed, Part Cooling Fan	Heated Bed, Enclosure Recommended, May Require All Metal Hotend	Part Cooling Fan	Heated Bed	Heated Bed, Enclosure Recommended, All Metal Hotend	Heated Bed, Enclosure Recommended, Part Cooling Fan	Wear Resistant or Stainless Steel Nozzle, Part Cooling Fan	Part Cooling Fan	Heated Bed, Part Cooling Fan

Printing with multiple material

Many existing 3D printing technology's disadvantage that they allow simultaneous printing with **only one substance**, restricting many possible applications that require integration of different materials in the same object. 3D printing using **multiple materials** solves this problem by enabling complex and heterogeneous objects to be produced **by a single printer**. Here, you must specify a material for each voxel (3D pixels) in the slicer.

Printing - video



4D printing

The use of 3D printing and **multi-material structures** enabled the so-called 4D printing in additive production. **4D printing** is a process in which the printed **object changes its shape** due to **time, temperature** or other stimulation. 4D printing allows you to create **dynamic structures** with **adjustable shapes**, properties or functionality. Intelligent / stimulus reacting with 4D printing **can be activated** for predefined tasks such as **self-assembly, self-repair**, multifunctionality, **reconfiguration** and **shape change**. This allows customized printing of the shaping and shape memory materials.

4D printing can provide **completely new application options** for various materials (plastics, composites, metals, etc.) and create **new alloys** and composites that have not been viable before. The **versatility of** technology and **materials** can lead to progress in several areas of industry, including **space research, trade and medicine**. Repeat, accuracy and substance range of 4D printing **should further improve** to become practical.

4D printing - video

Sources

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- Ultimaker 3