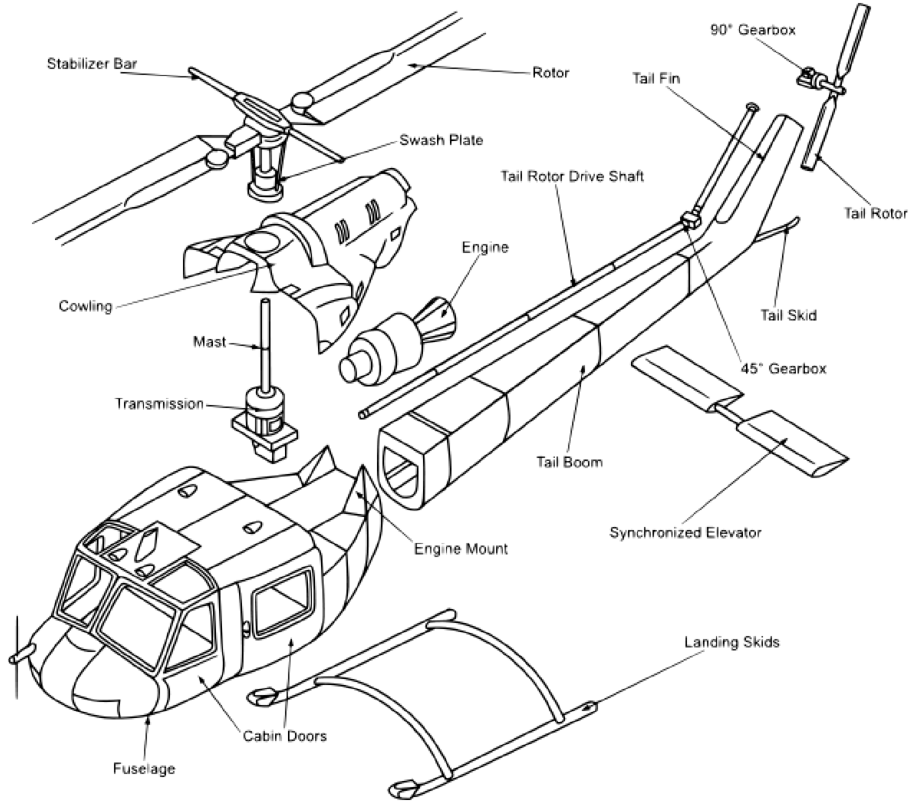
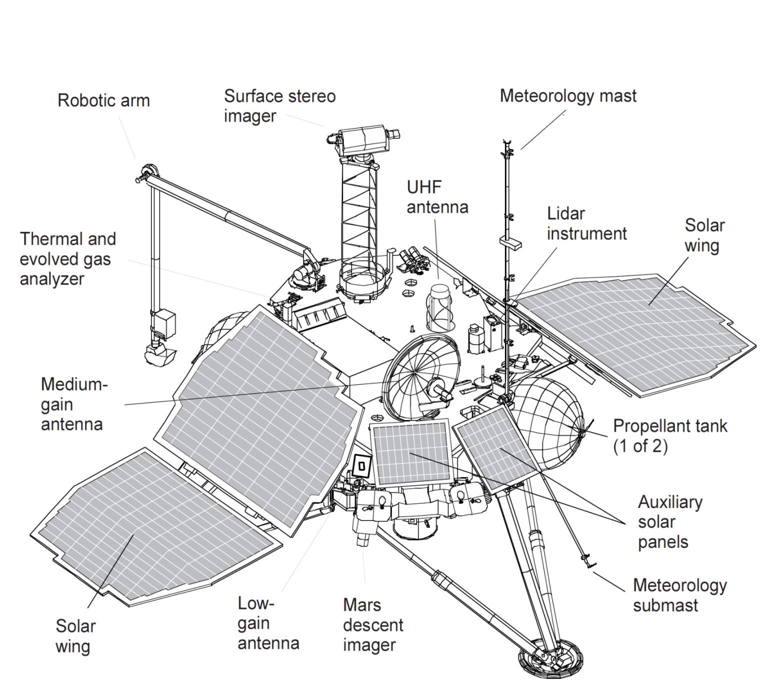
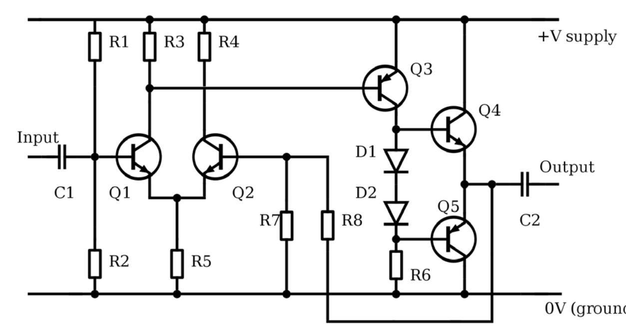




Lecture 2 – 3D printing and Assemblies

Andrés Faíña (anfv@itu.dk)



Overview

- 3D modelling discussion
- Assemblies
- Introduction to 3D printing
- Different 3D printing technologies
  - LOM
  - SLS
  - SLA
  - FDM
- Fused Deposition Modelling (FDM)
  - Printers
  - Restrictions
  - Slicer settings
  - FDM problems

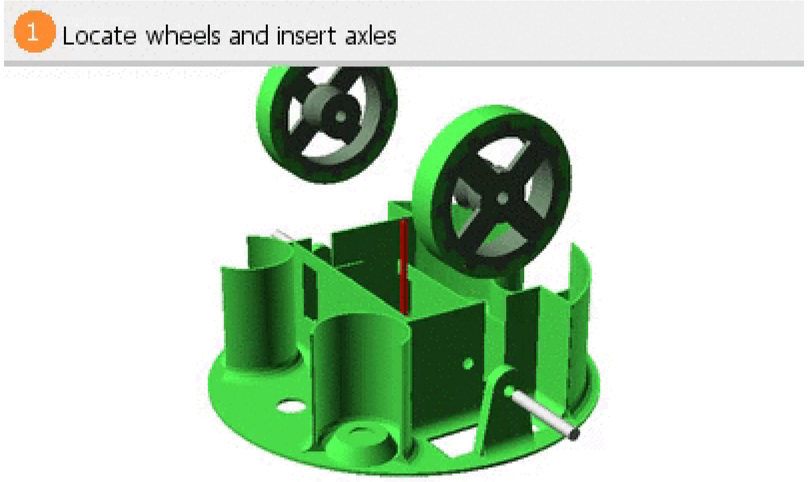
3D modelling discussion

Find a person who is not your partner
Open your 3D models in Fusion 360
Show your models and discuss

- Operations that you used
- Problems that you found
- Did you remember to create a component?
- Have you used the design history?
- Have you used the browser to find components, sketches and bodies?
- Did you use the show/hide feature?

Assemblies

Usually, a machine is built with a lot of different parts: Can we assemble all these parts together in the computer?



Assembly: a file that contains the modelled parts in their final position

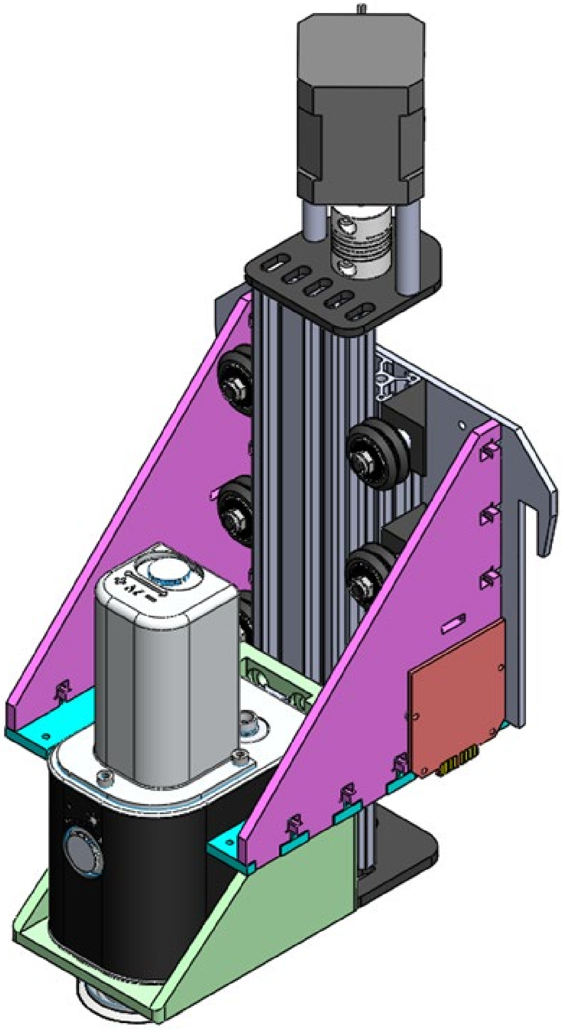
Building the assembly

How to place the positions and orientations of the parts:

- Global/local coordinates and rotation vectors
  - Programs: OpenScad, FreeCAD
- Use mates (SolidWorks):
  - Face to face coincident
  - Point to line/edge/face/plane coincident
  - Concentric
- Use joints or degrees of freedom (Fusion 360)
  - Slider
  - Hinge
  - Planar

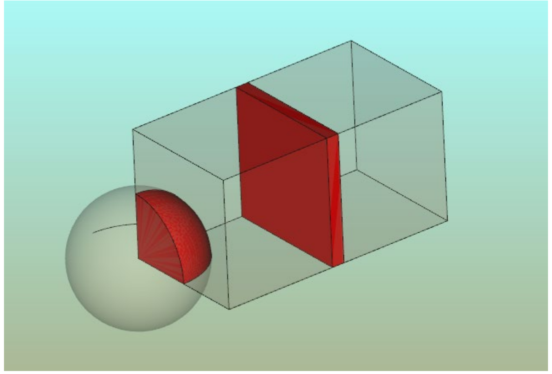
Assemblies – Benefits

Check that the design works as expected

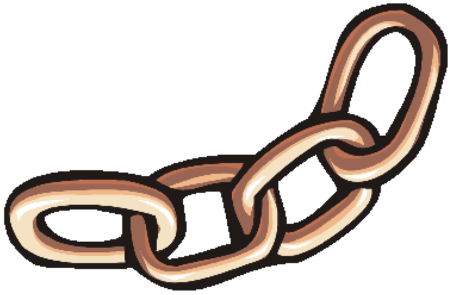


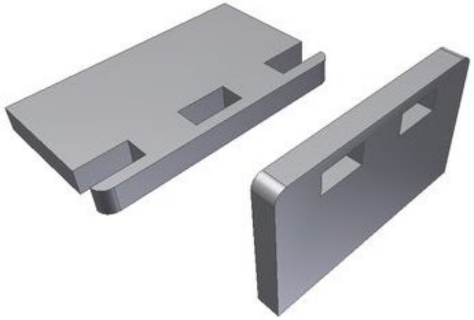
Check that the assembly is feasible

Interferences (overlaps)

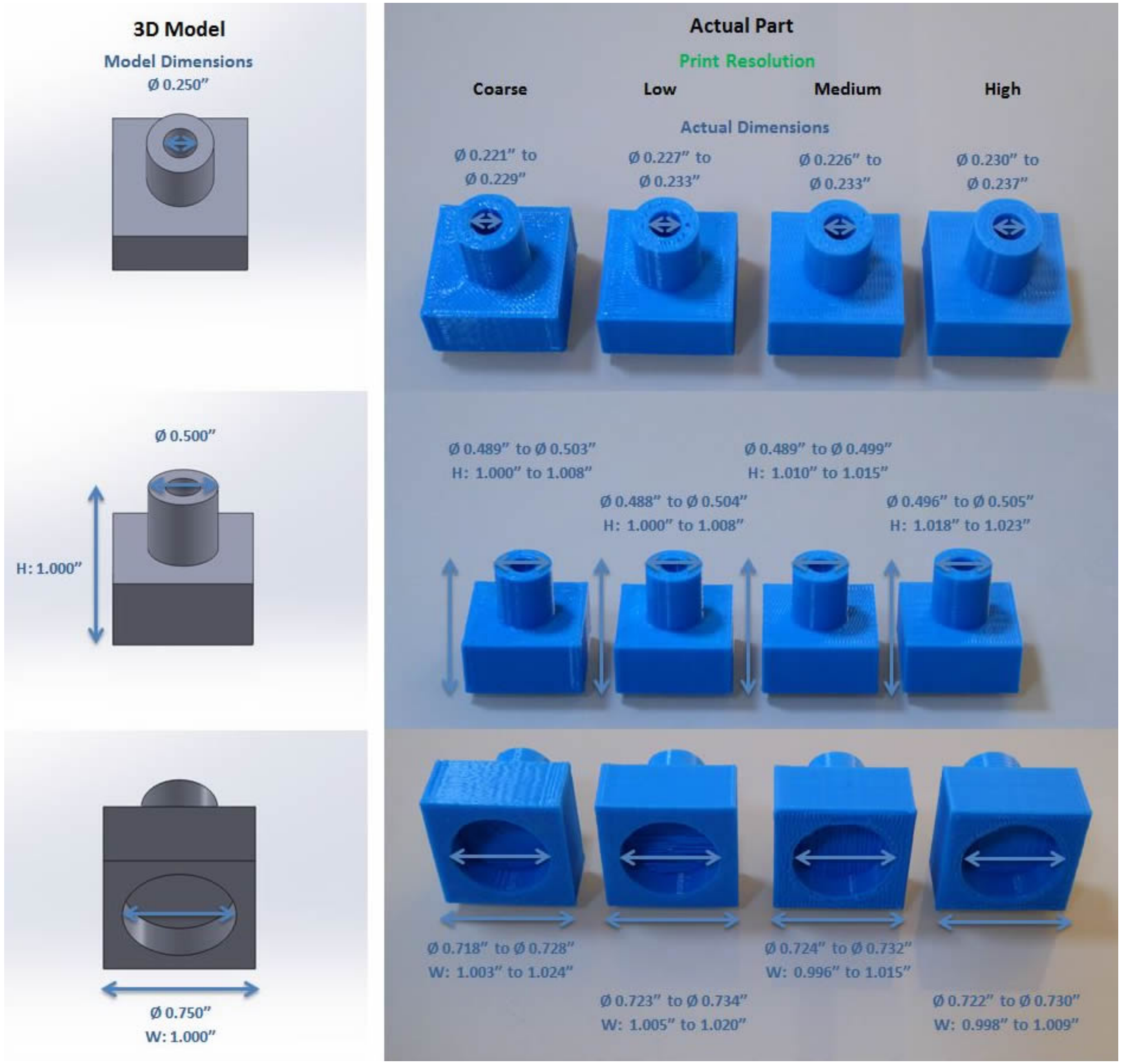


Feasible assemblies

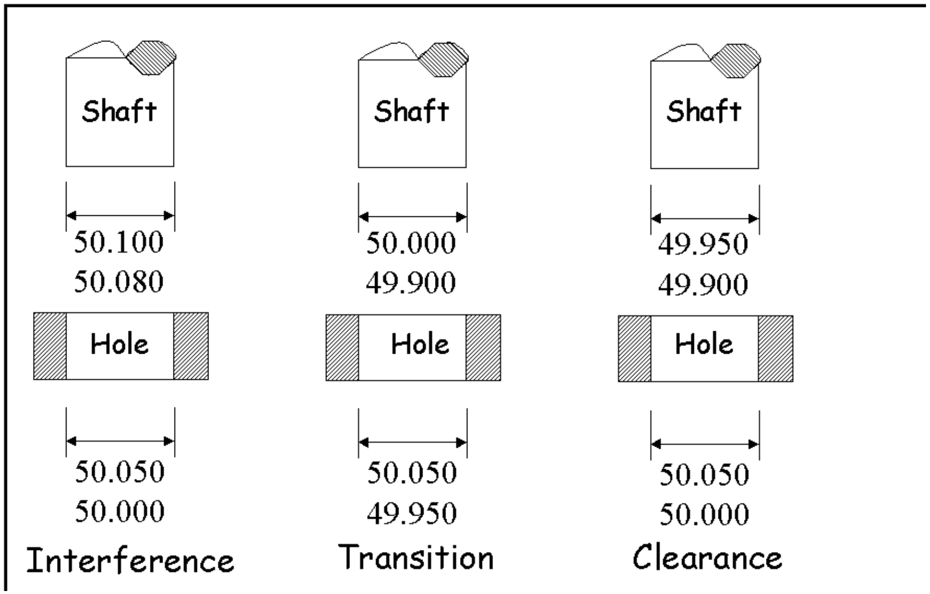




Assemblies - Tolerances



Assemblies - Tolerances



Generating an assembly

Change to Fusion 360!

Tips - Use the inspect tools:

- Measure
- Interference
- Component Colour Cycle Toggling

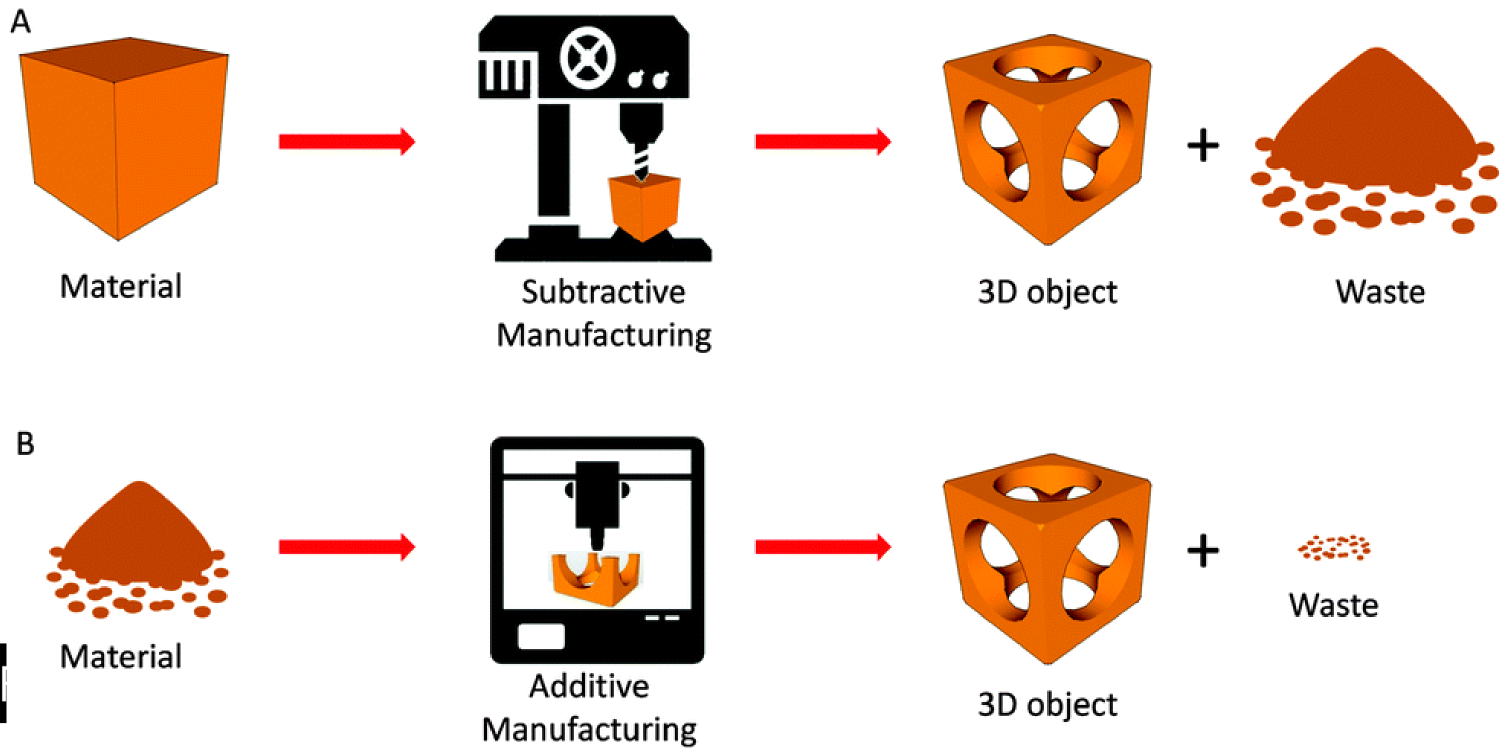
3D printing – History

Subtractive manufacturing (Traditional process):

- Start with a stock material
- Remove material until desired shape is achieved
- Examples: Milling, Turning, Drilling, etc.

3D printing is additive manufacturing:

- Add material until desired shape is achieved



3D printing – Advantages

Almost no waste material
Allows us to produce incredibly complex parts
- Infeasible assemblies
- Hollow parts

Minimal lead times (in very low quantities):
- perfect for prototypes

Customization of parts

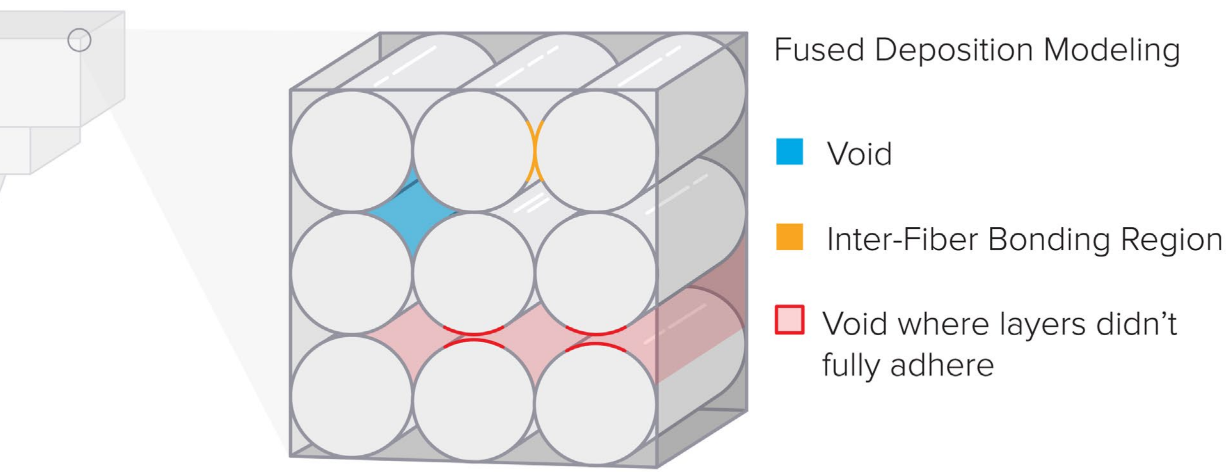
3D printing – Disadvantages

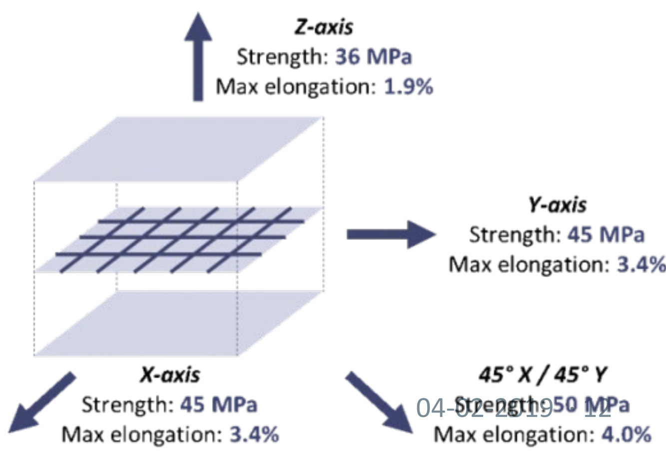
Not suitable for big quantities

- No efficient (time)
- More expensive than subtractive methods

Can exhibit anisotropic behaviour*

Less resistant than raw material (internal voids)





3D Printing Technologies and Processes

LOM(90s):
- Laminated object manufacturing

SLS(90s):
- Selective laser sintering

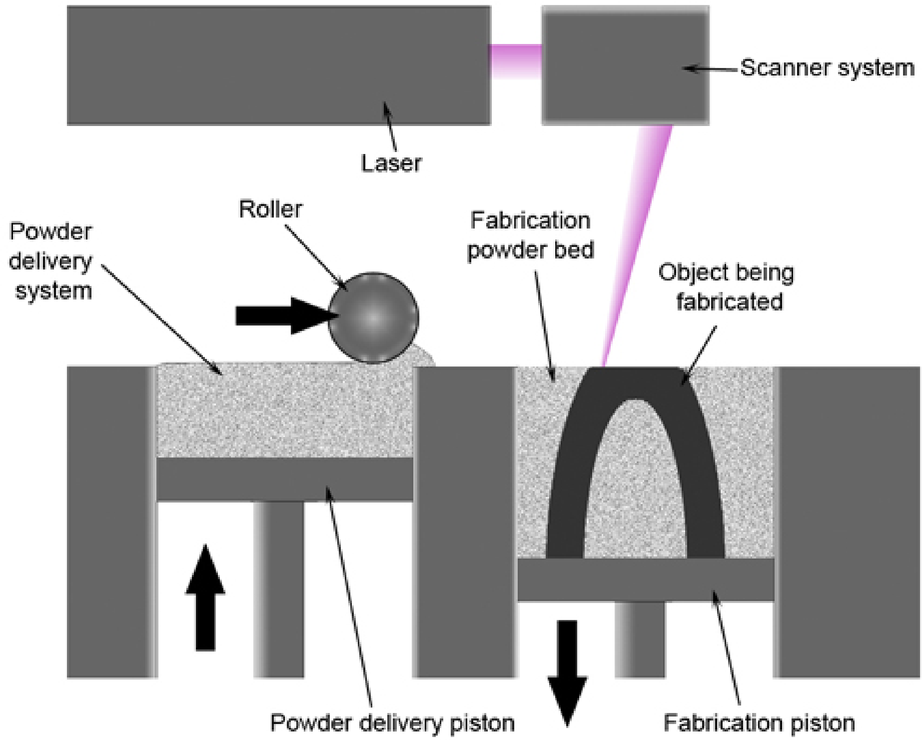
SLA (90s):
- Stereolithography

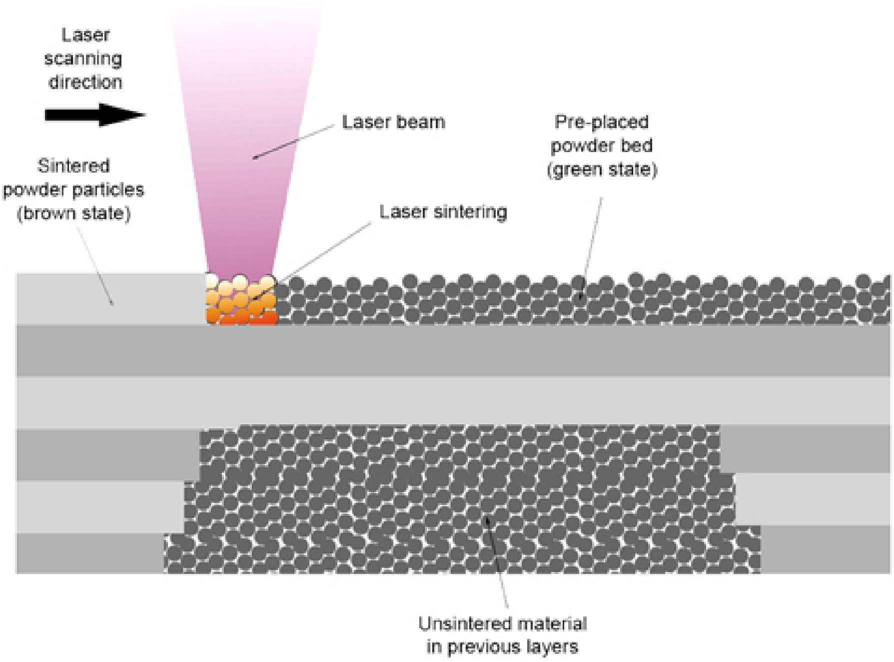
FDM (90s):
- Fused Deposition modelled

LOM or SDL (Selective Deposition Lamination)

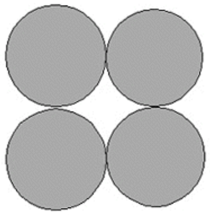
Sheets or laminates are successively glued together and cut to shape with a knife or laser cutter

SLS - Selective laser sintering

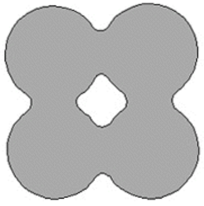




To Sinter: to bring about agglomeration in (metal or plastic particles) by heating.



Representation of the initially unsintered powder particles.



Represention of Sintered Powder Particles

Stereolithography – SLA

Stereolithography – Form2

Very good quality
Very good definition
Different materials:
- High Temperature Resin
- Tough Resin
- Flexible Resin

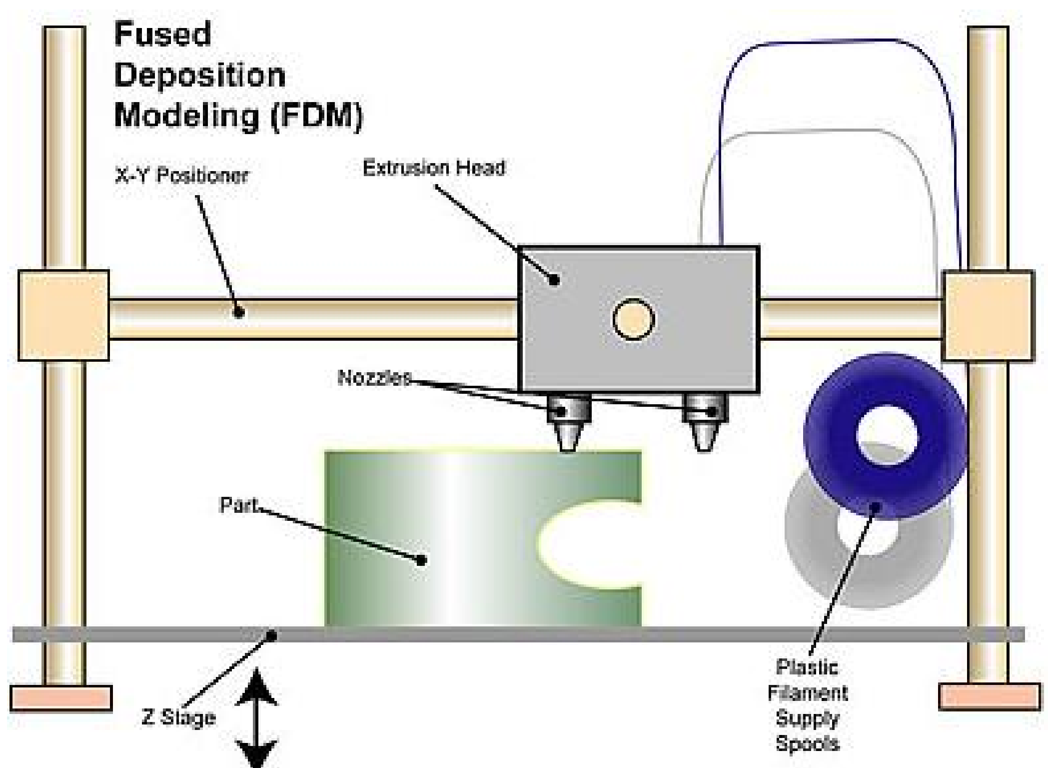
Cons:
- Expensive
- Needs support material
- Parts need to be cured

3D printing – FDM

Cheap
Functional parts

Cons:
- Anisotropy
- Need support

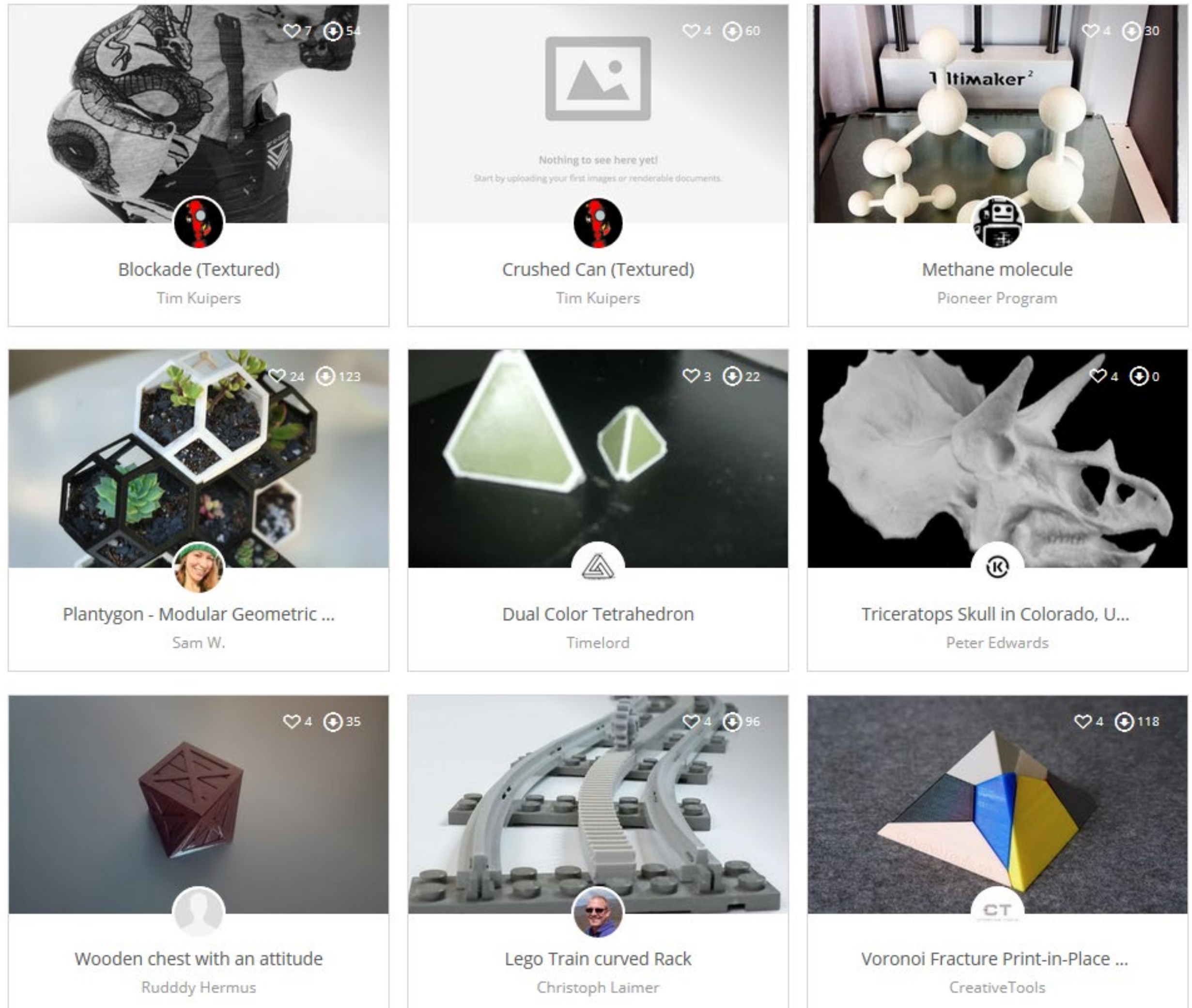
Materials:
- PLA
- ABS
- Flex



FDM in action!

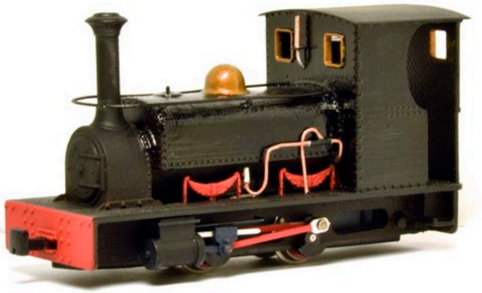
Part repositories

- Thingiverse
- YouMagine
- Instructables
- GrabCad
- MyMiniFactory
- 3dagogo
- 3D Warehouse
- 3dhubs



Using other 3D printing technologies

New materials:
- Metal
- Precious metals
- Plastic
- Ceramic



Online Shops:
- 3D hubs (https://www.3dhubs.com/)
- Shapeways (https://www.shapeways.com/)
- Sculpteo (https://www.sculpteo.com/en/)
- I.Materialise (https://i.materialise.com/)
- All3DP (https://print.all3dp.com/)
- **Upload your designs and sell them!**

Task – 5min

Work in groups of 2 persons

Find a Lego part (or another small part) in Thingiverse

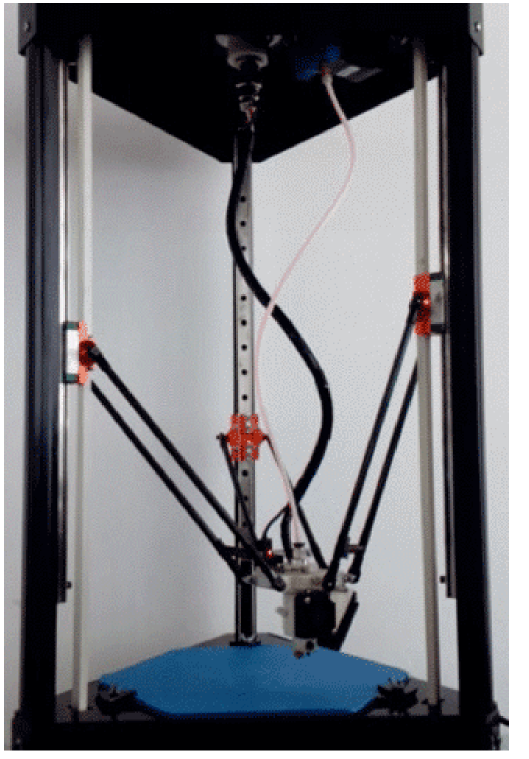
Upload it to an online 3D printing service (www.sculpteo.com/en)

Compare different 3d printing methods

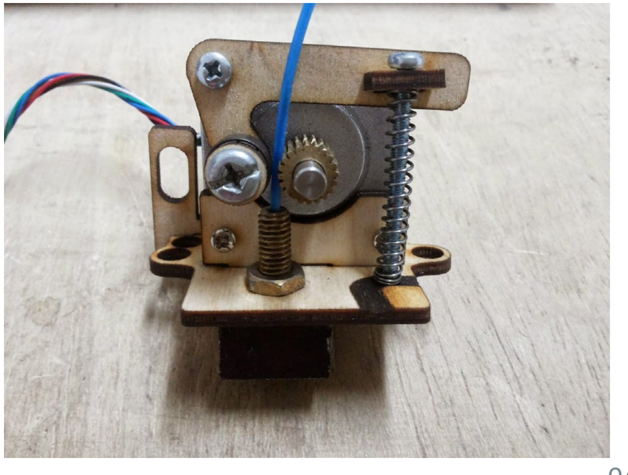
Learn about the properties of each material and technology

FDM – parts of a 3D printer

- XYZ stage:
  - Cartesian
  - Delta
- Extruder (several):
  - Feeder:
    - Direct (head)
    - Bowden (outside)
  - Hot end
- Bed
  - Optional: Heated
- Optional: Fan
- Spool holder



Delta Printer

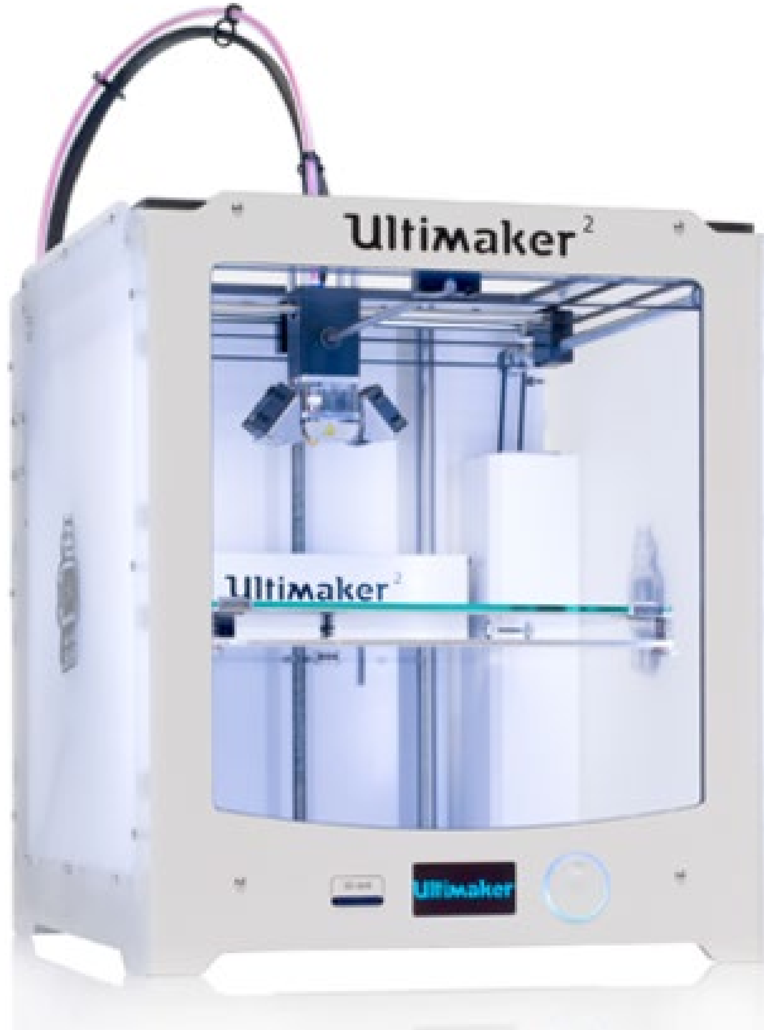


Extruder

Ultimaker 2+

Open Source
Commercially available
UM2+ ~2000 €

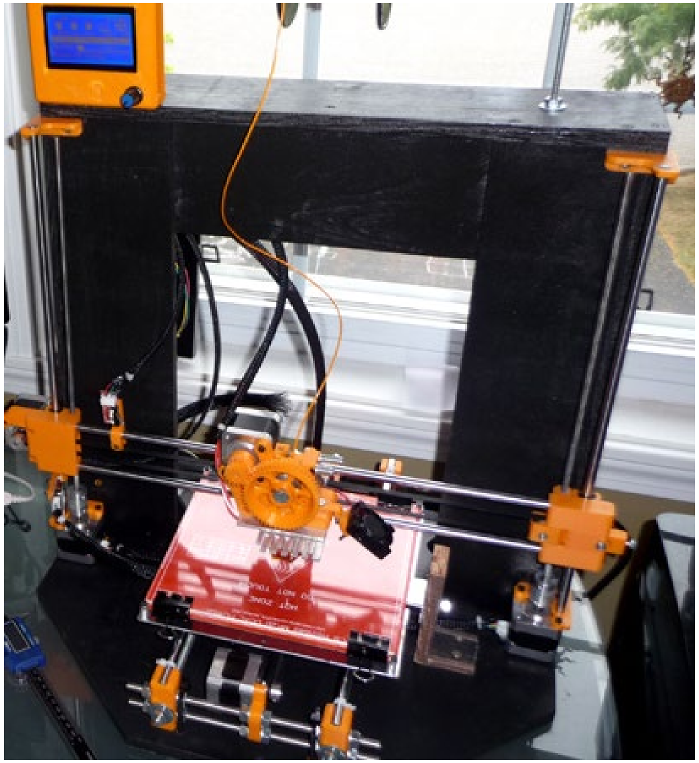
Bowden extruder
Cartesian table



A 3D printer: Prusa i3 (REPRAP)

Gantry style
Direct extruder
Very affordable (300 euros)
A bit tricky to print
Replicable

Read: **Jones et al., 2011, reprap project**, in LearnIT.



FDM – Restrictions

Overhangs

Anisotropy

Printing time

FDM – Overhangs

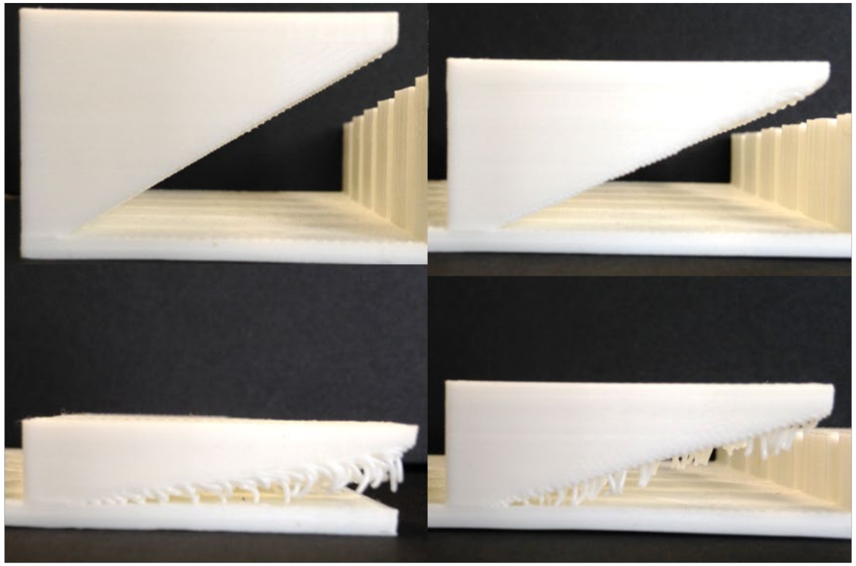
Printing without any support

Only possible for short lengths

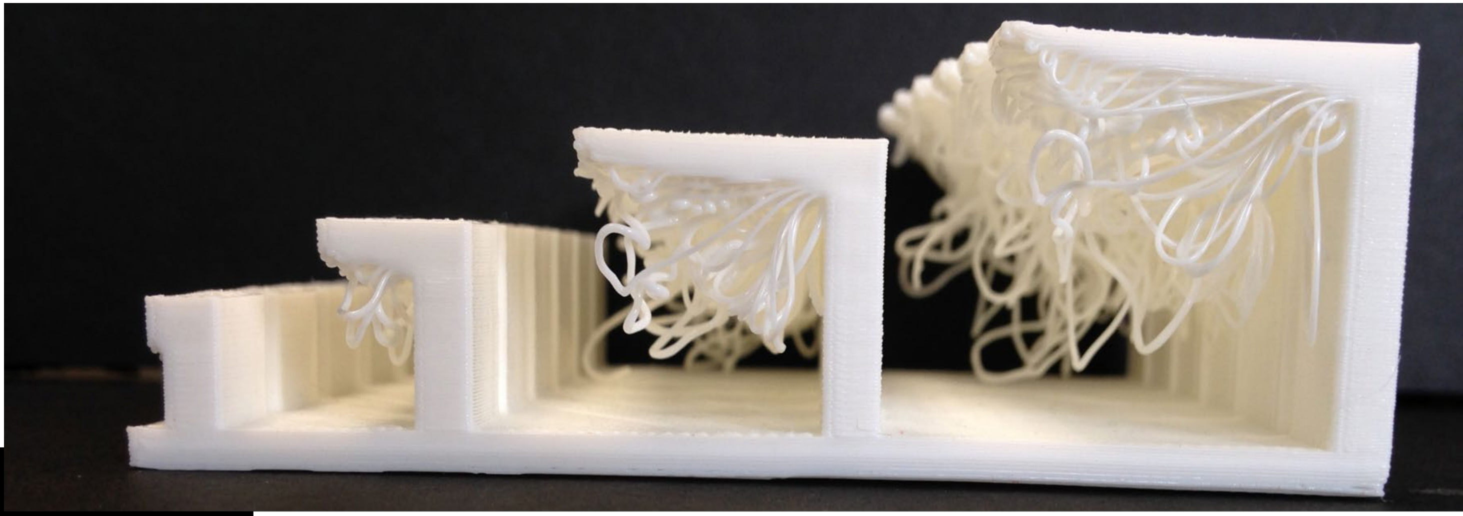
Quality degrades

Solutions:

- Remove overhangs
- Add support material



Clockwise from top left
30°, 22.5°, 15°, and 7.5° angled overhangs



Failed Horizontal Overhangs

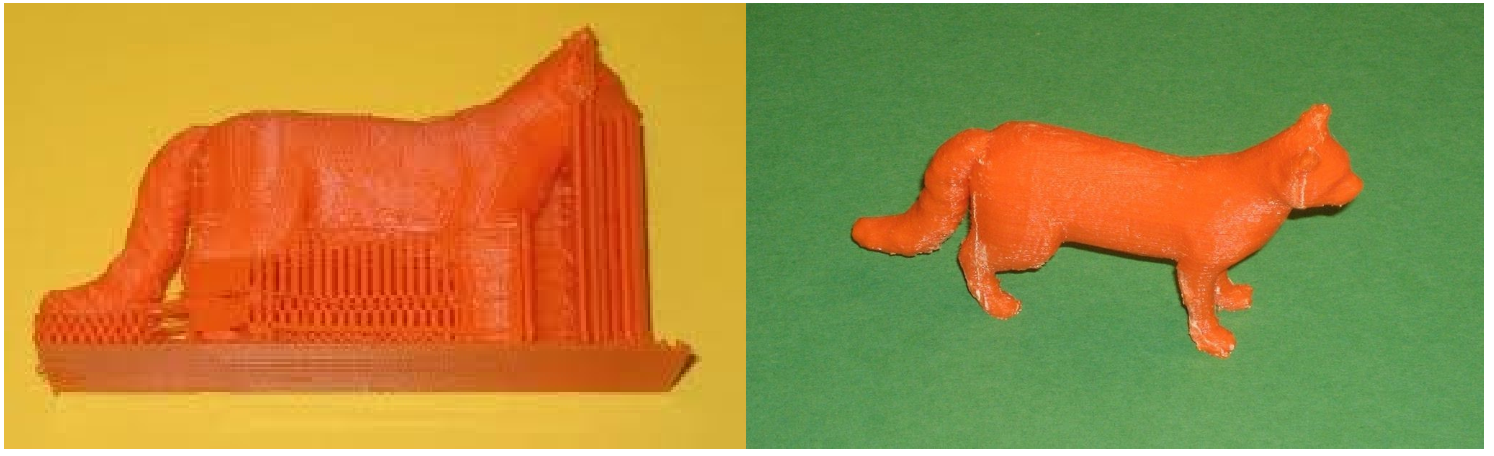
FDM - Support material

Type of material:

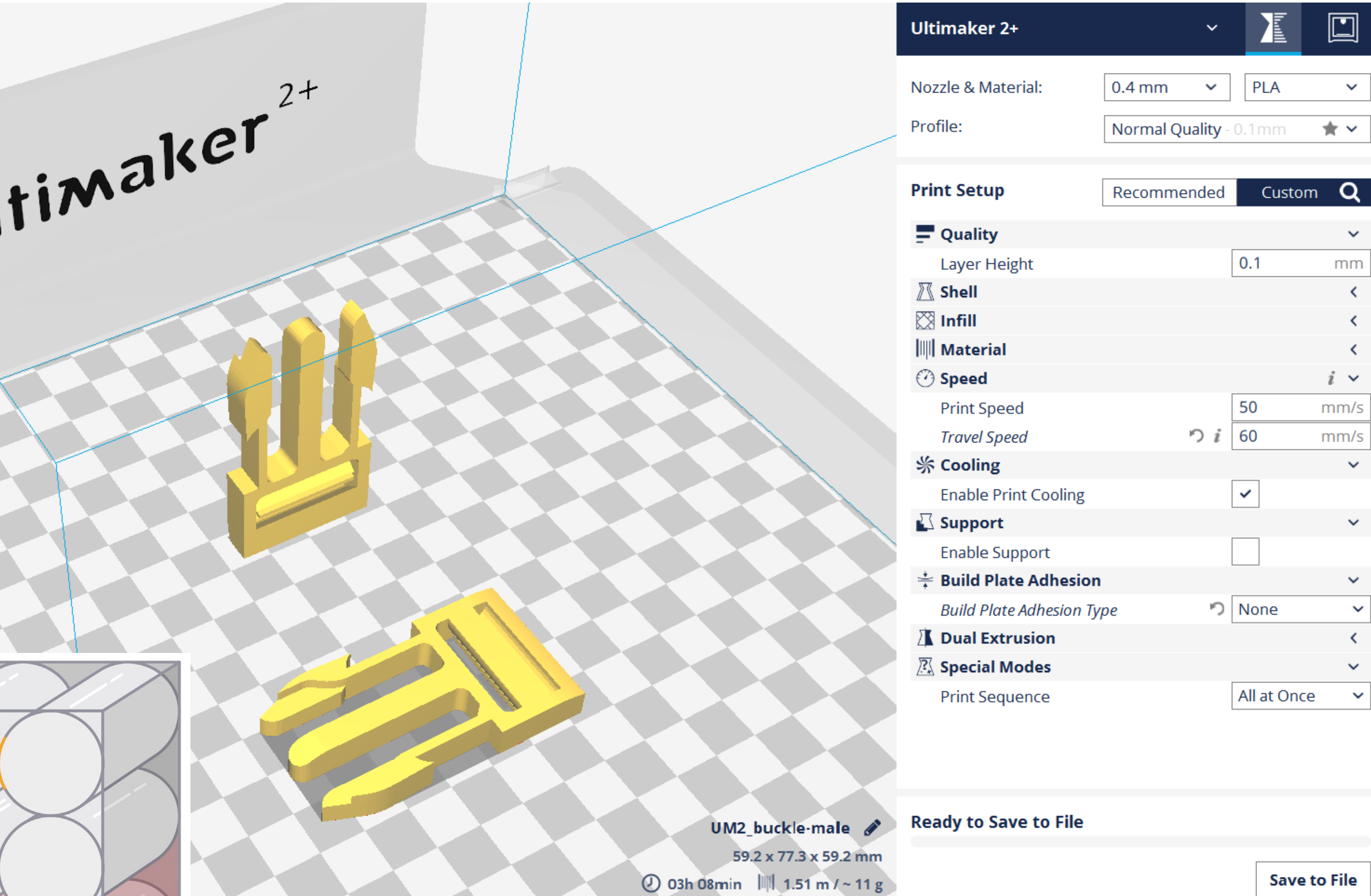
- Same material (difficult to remove)
- Special material (2 nozzle head)

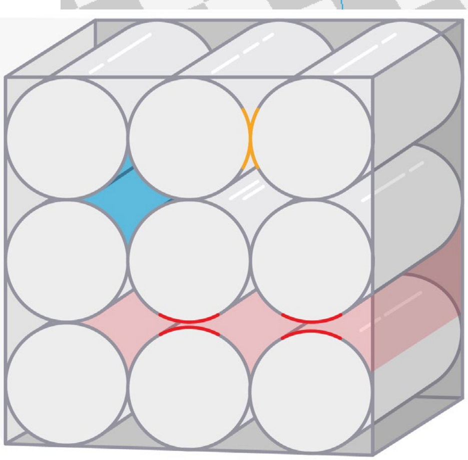
Generated:

- Manually
- Automatically (slicer setting)



FDM – Anisotropy





FDM – printing time

Thermal process

- The plastic should cool down before add next layer

Printing time depends on:

- Nozzle size (printer dependant, fixed)
- Layer height
- Infill
- Number of perimeters
- Printing speed

FDM – Quality of the parts

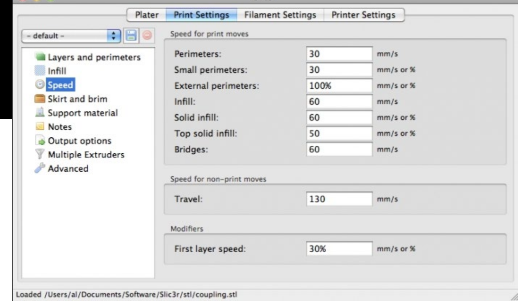
Quality depends on:

- Nozzle size (printer dependant, fixed)
- Layer height
- Printing speed
- Overhanging angle
- Nozzle temperature
- Slicer

Better quality = more printing time

- and it is not a linear function!

How to print a part




```
G1 X111.743 Y77.297 E2.24822
G1 X112.037 Y77.438 E2.26383
G1 X112.120 Y77.495 E2.26866
G1 X112.506 Y77.871 E2.29449
G1 X112.783 Y78.234 E2.31636
G1 X112.913 Y78.493 E2.33021
G1 X113.031 Y78.791 E2.34559
G1 X113.165 Y79.235 E2.36779
G1 X113.400 Y80.378 E2.42365
G1 X113.455 Y81.028 E2.45490
G1 X113.420 Y81.652 E2.48483
G1 X113.334 Y82.097 E2.50656
G1 X113.238 Y82.422 E2.52279
G1 X113.091 Y82.756 E2.54025
G1 X112.877 Y83.124 E2.56065
G1 X112.664 Y83.409 E2.57768
G1 X112.246 Y83.859 E2.60709
G1 X111.631 Y84.417 E2.64685
```

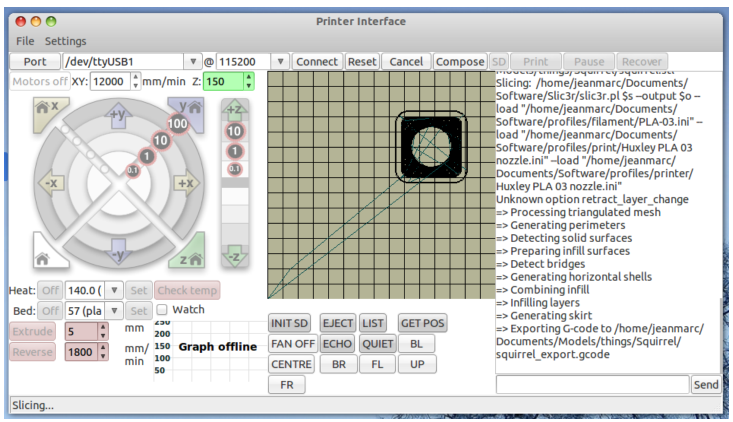
3D model → STL file → Slicer → G code

G code → G code sender (Pronterface)

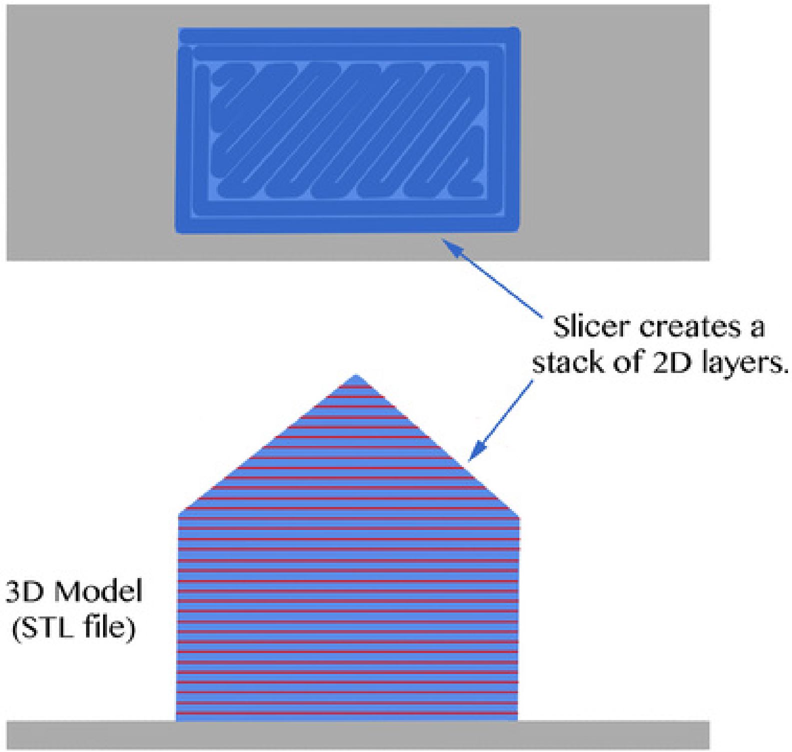
G code → SD Card / USB pen drive

G code sender (Pronterface) → USB → Printer

SD Card / USB pen drive → Printer



Slicers



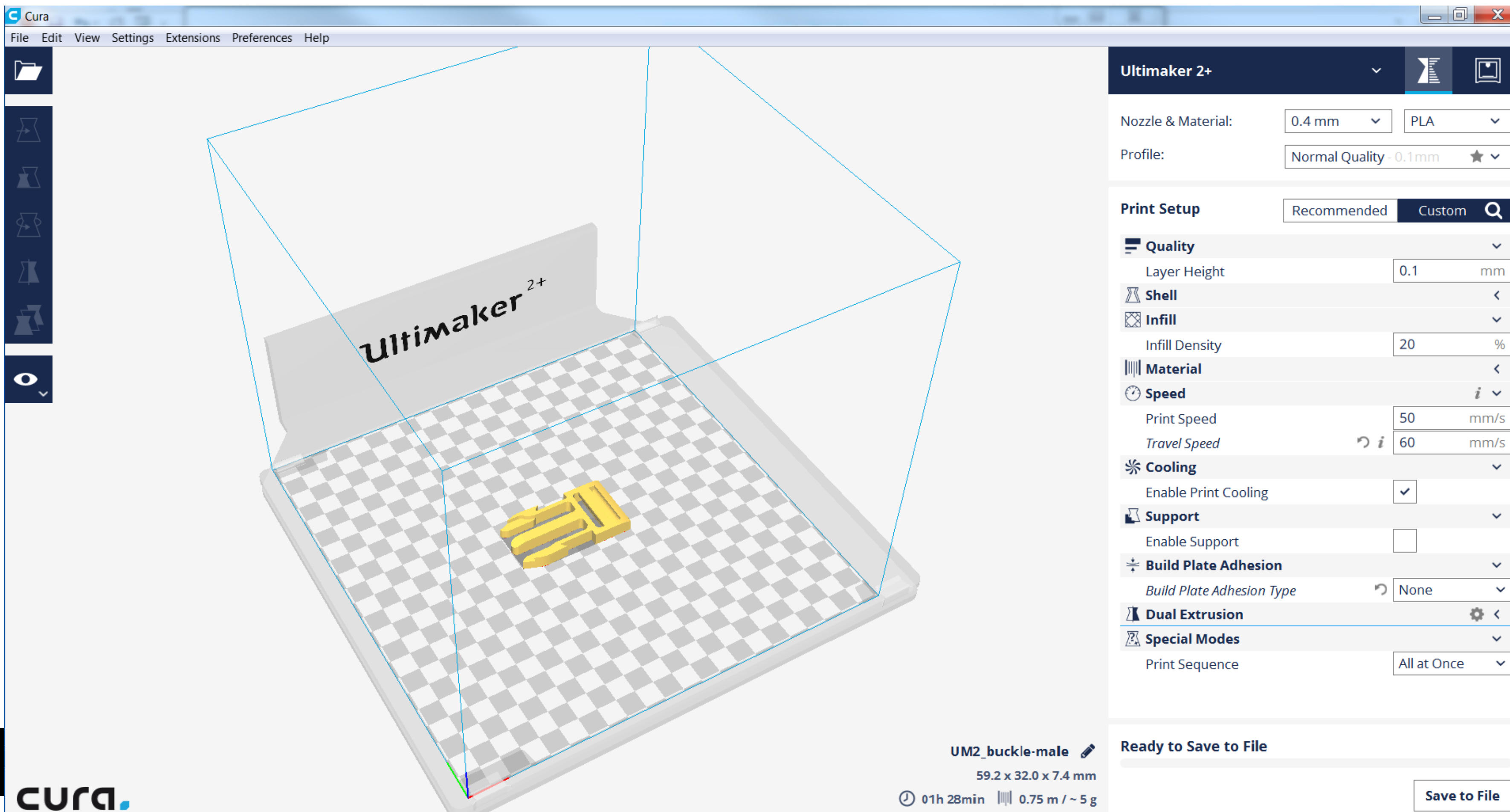
Slicers

Open Source:

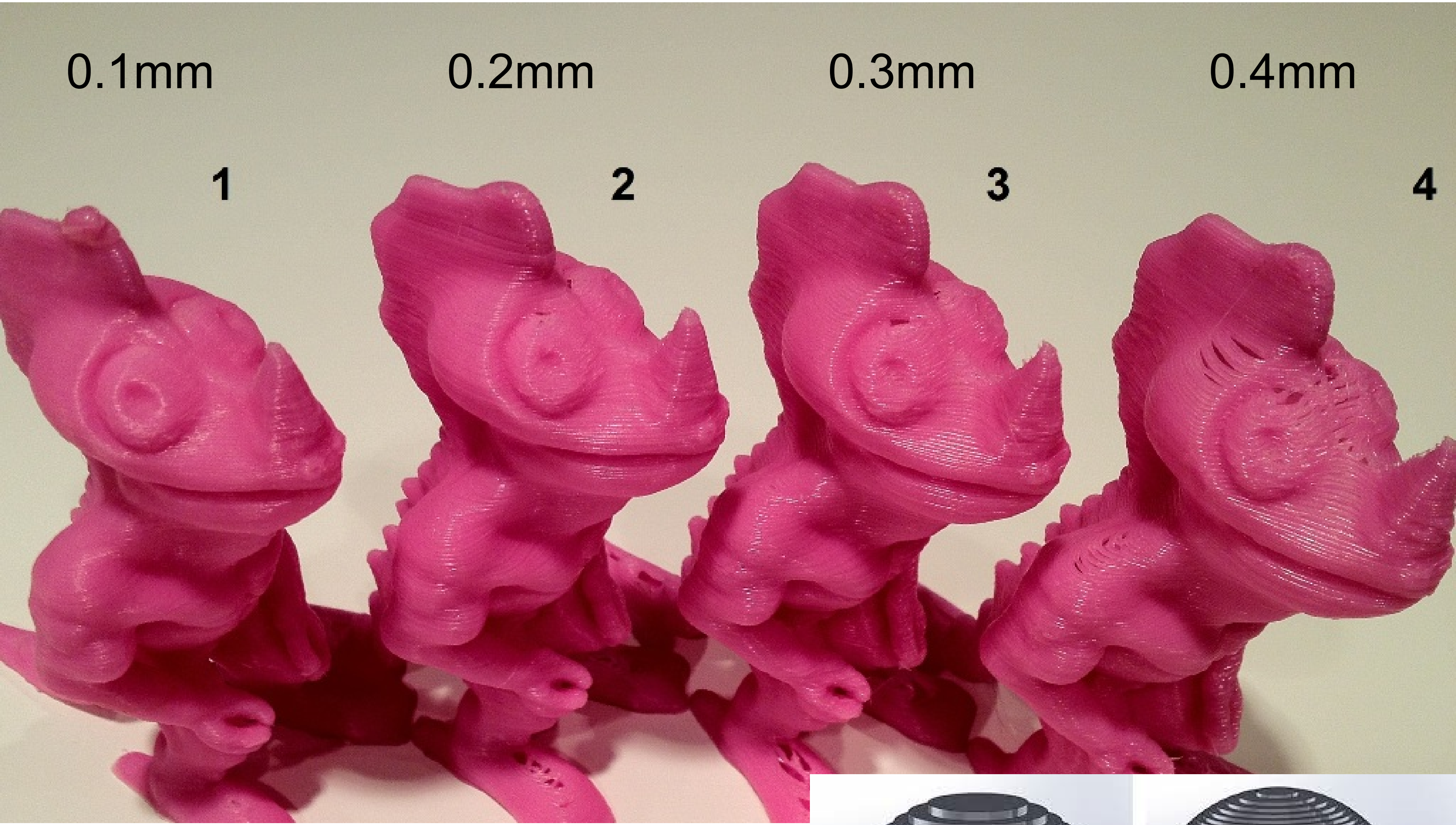
- Cura
- Slic3r
- Repetier

Commercial:

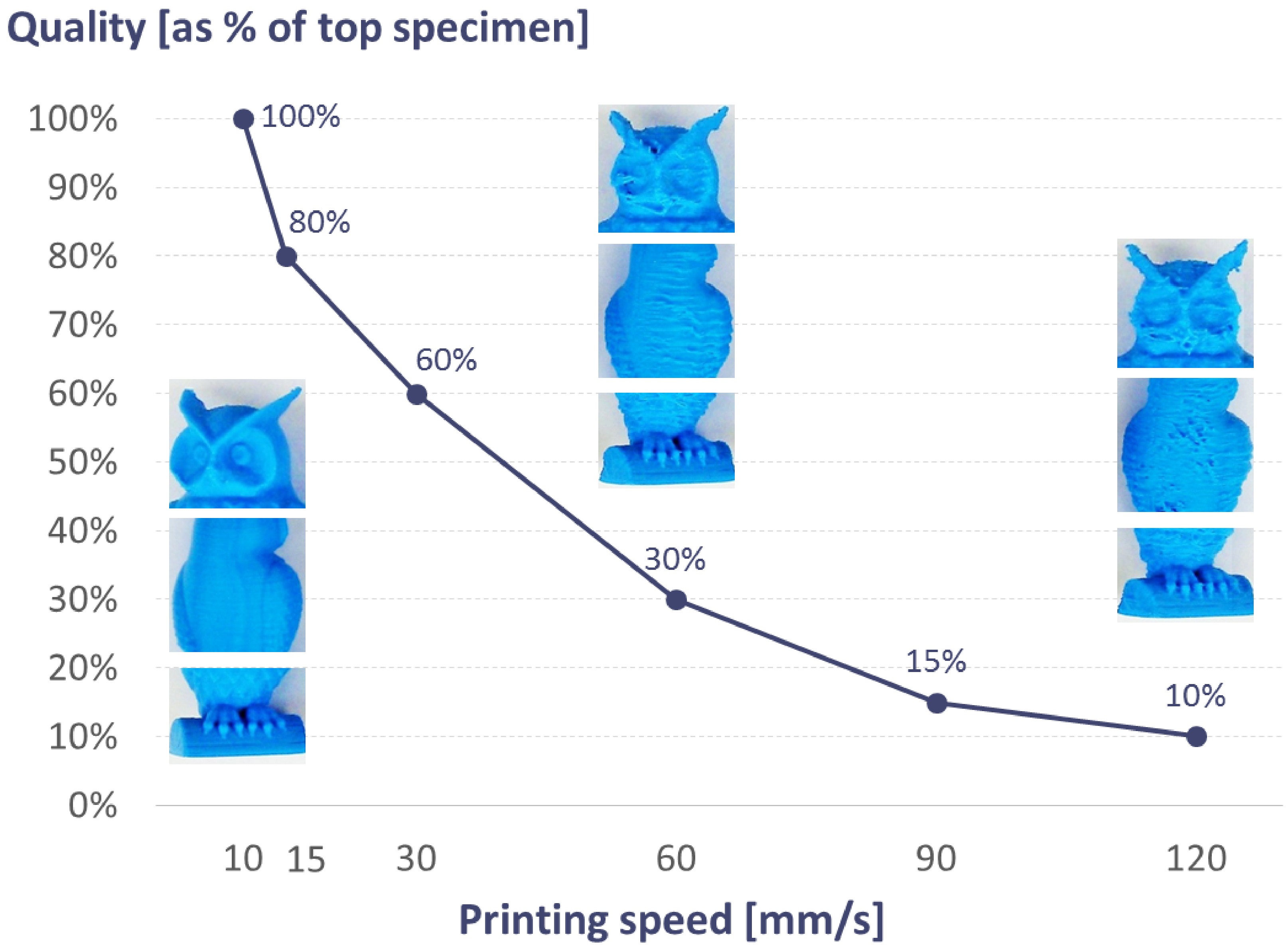
- UPStudio (UP printer)
- CraftWare (CraftBot)
- Simplify3D



Slicer settings - Layer height

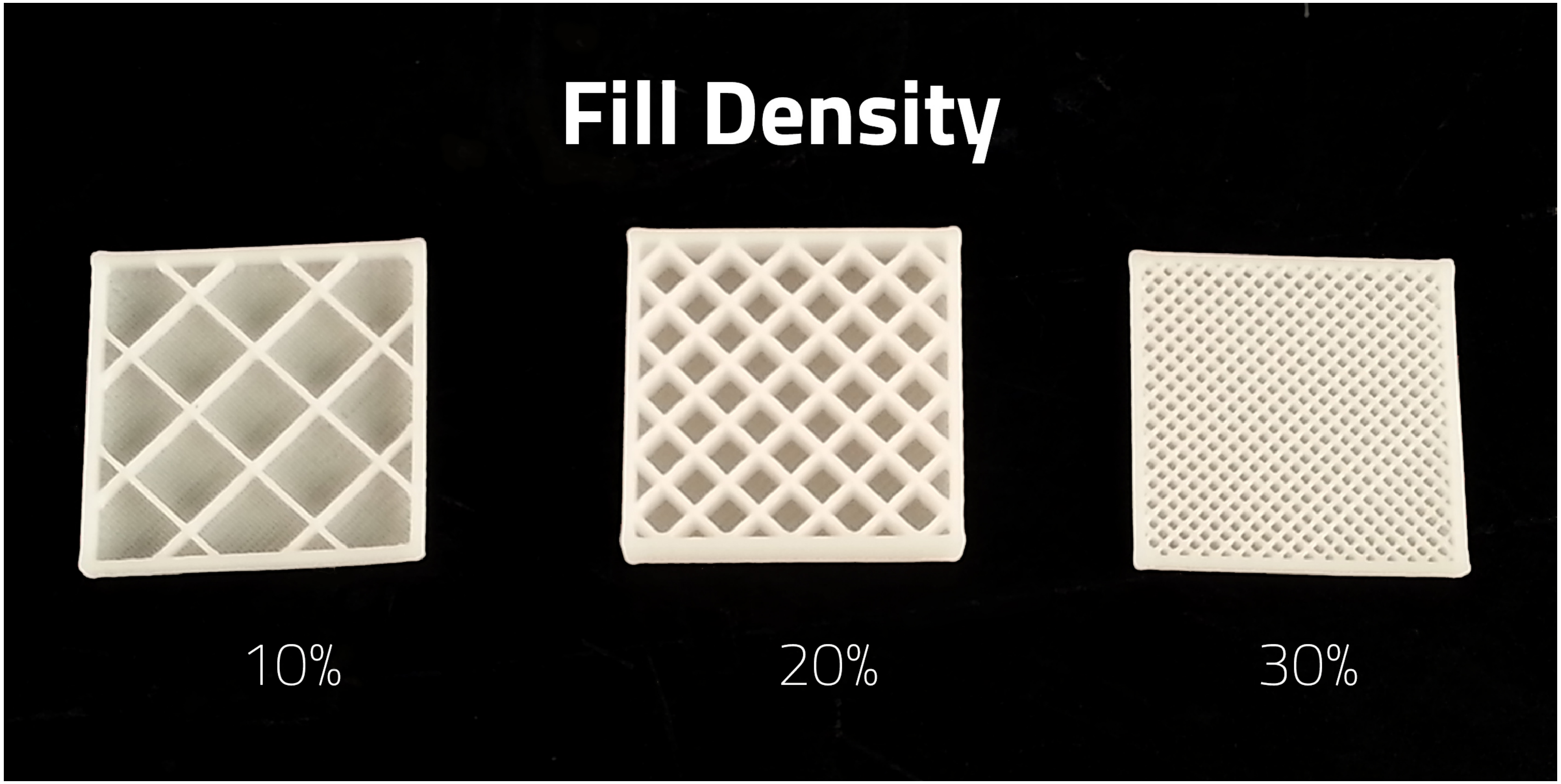


Slicer settings - Speed

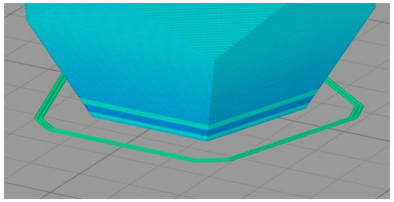


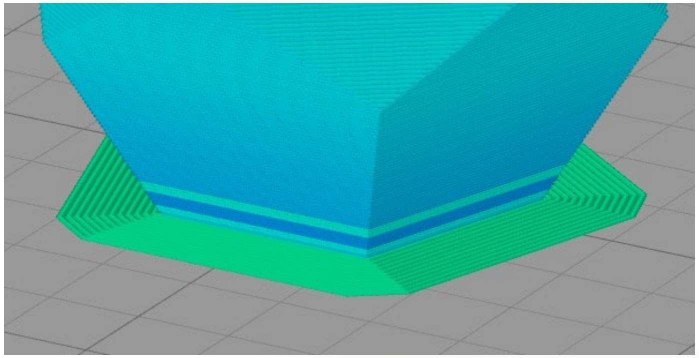
http://my3dmatter.com/what-is-the-influence-of-color-printing-speed-extrusion-temperature-and-ageing-on-my-3d-prints/

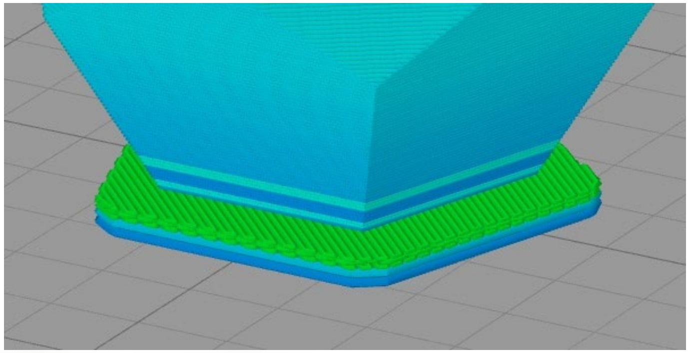
Slicer settings - Infill



Slicer settings - Rafts, Skirts and Brims

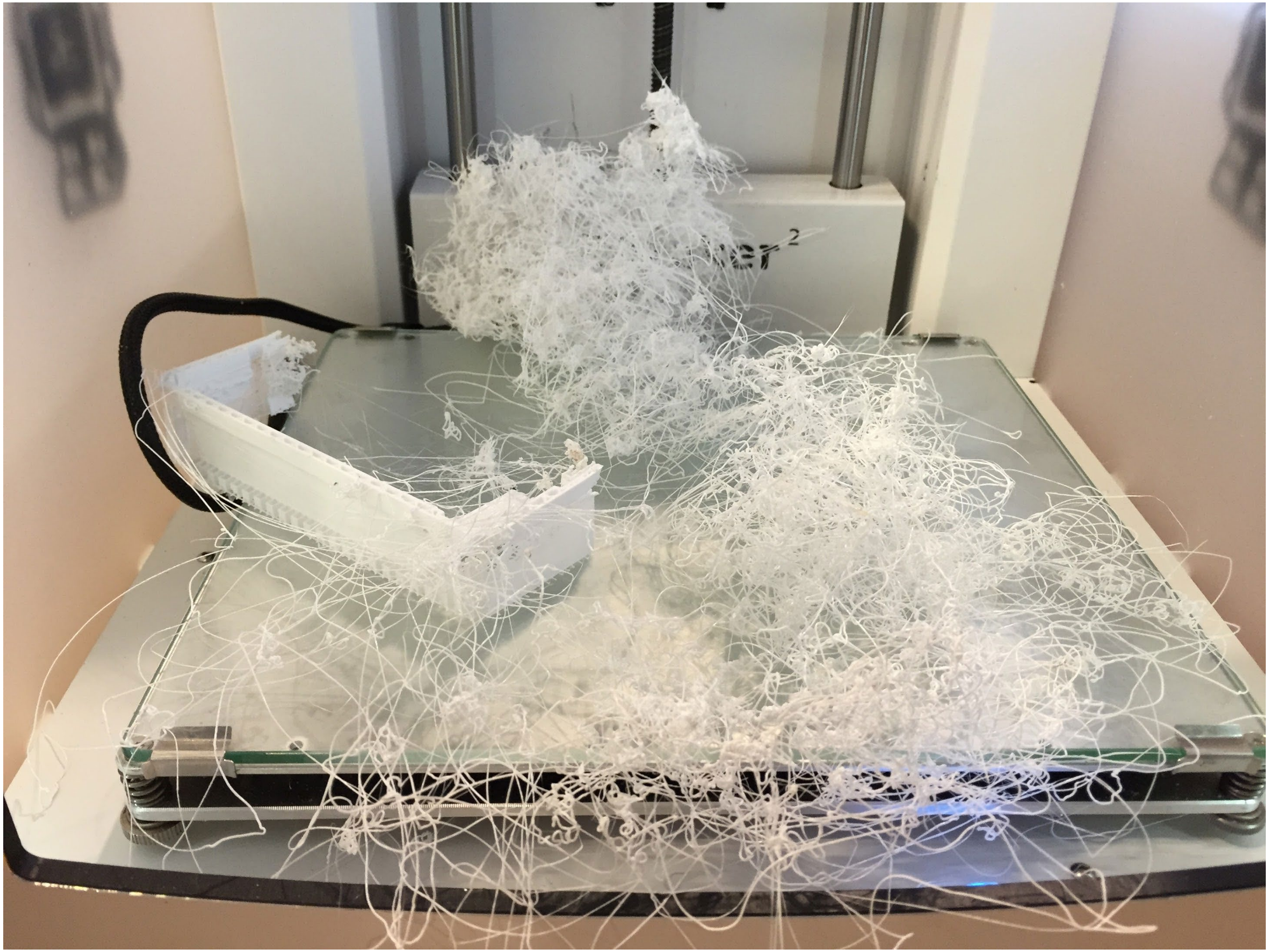




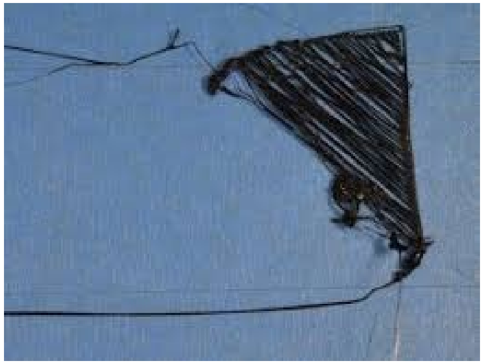


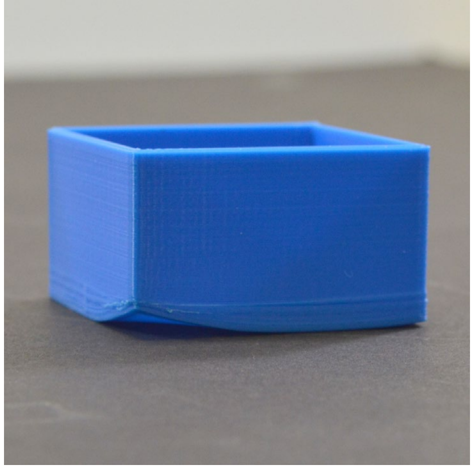
https://www.simplify3d.com/support/articles/rafts-skirts-and-brims/

Sometimes, this happens.



Common problems





Adhesion problems:

- The bed is not levelled
- The bed is not clean

Warping

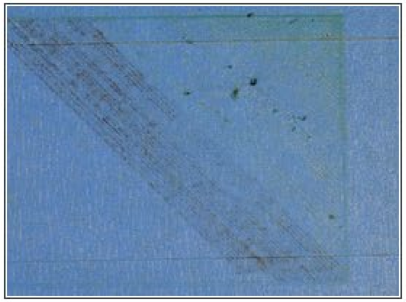
- Use heated bed
- Disable fan cooling
- Use brims and rafts

Troubles?

https://www.simplify3d.com/support/print-quality-troubleshooting/

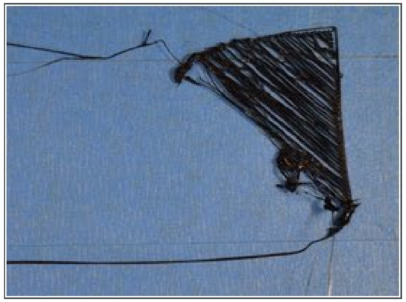
Thumbnail Overview

Use the thumbnails below to identify the picture that most closely represents the quality issue that you are seeing in your own 3D printed parts. You can click on the thumbnail to jump that that portion of the guide for immediate recommendations on how to resolve the issue. If you are not able to locate your issues from the thumbnails, feel free to scroll down and read through each section of the guide in more detail. There are plenty of useful tips to learn that can help improve your 3D printed results!



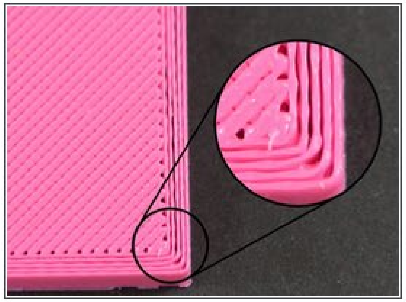
Not Extruding At Start

Printer does not extrude plastic at the beginning of the print



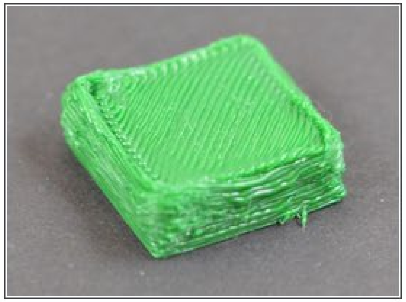
Not Sticking To Bed

The first layer does not stick to the bed and the print quickly fails



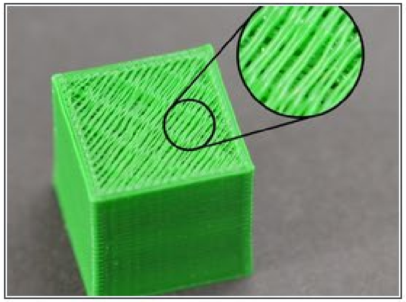
Under-Extrusion

Printer does not extrude enough plastic, gaps between perimeters and infill



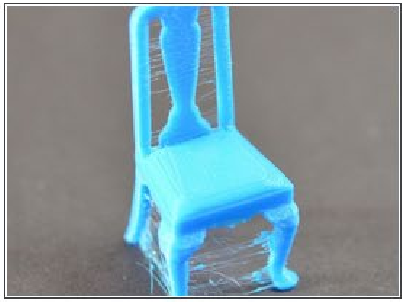
Over-Extrusion

Printer extrudes too much plastic, prints looks very messy



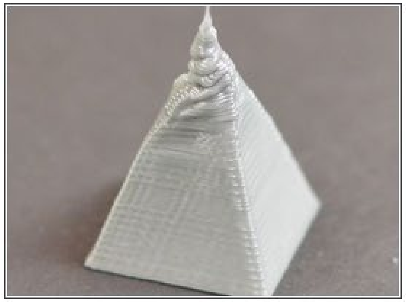
Gaps in Top Layers

Holes or gaps in the top layers of the print



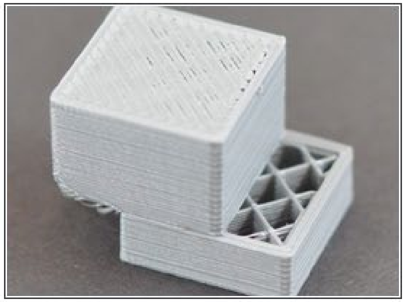
Stringing or Oozing

Lots of strings and hairs left behind when moving between different sections of the



Overheating

Small features become overheated and deformed



Layer Shifting

Layers are misaligned and shift relative to one another

FDM – Safety

3D printed parts:

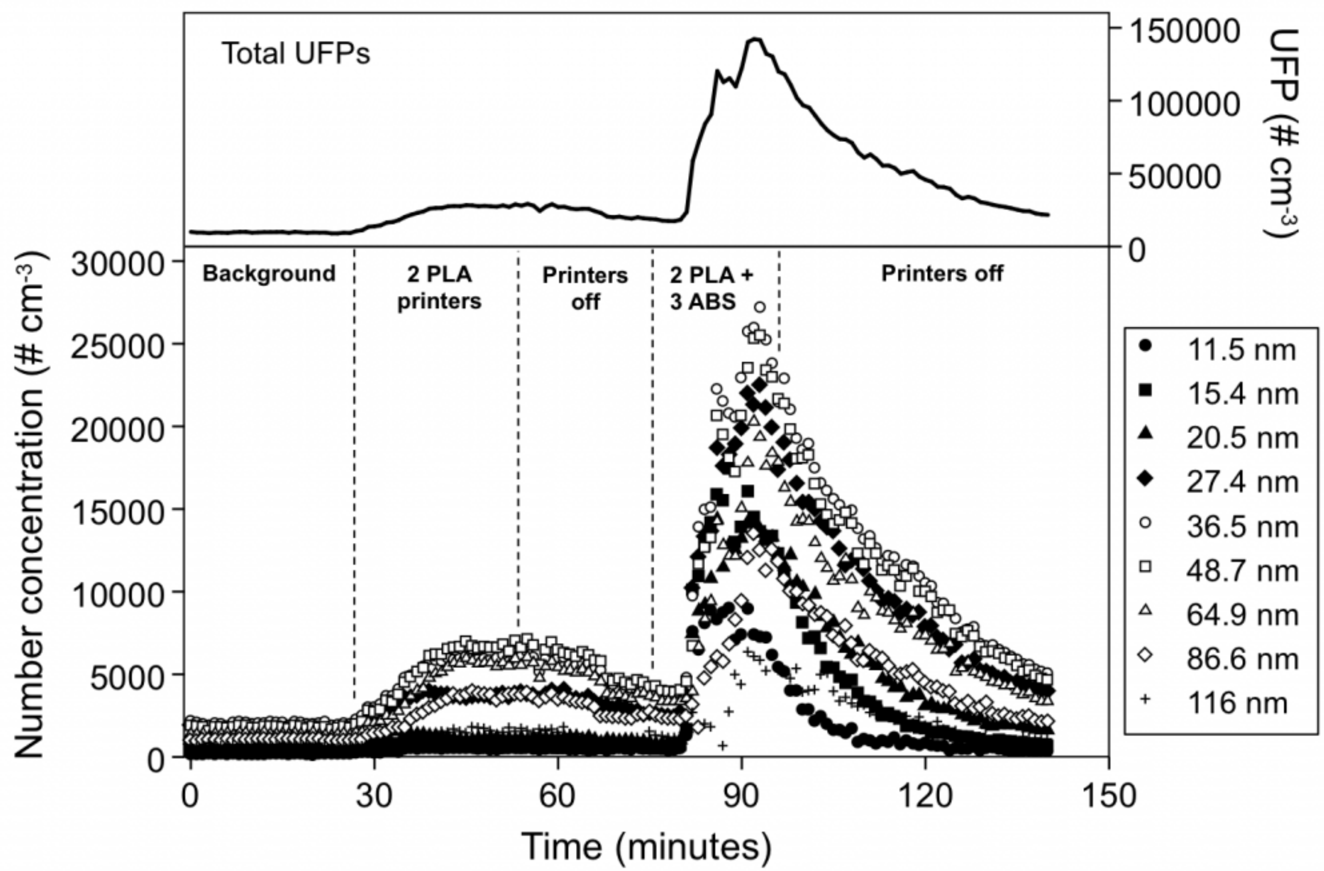
- Not approved for food handling (do not use 3D printed forks!)
- Not use them for critical applications

3D printers:

- The nozzle is hot
  - Do not touch it!
- Risk of entrapment
  - Only reach in the machine when it is turned off
- Emission of Ultrafine Particles (UFP) and Volatile Organic Compounds (VOC)
  - Do not breathe?

Risk: UFP and VOC

Print in ventilated areas or use a filter
Place the printer in a different room (and not stay there)
Avoid using ABS and Flex filaments



Take-home message

Assemblies

- Multiple components (3D models) in their final pos.
- Allow us to:
  - Inspect our prototype virtually
  - Check the feasibility of your design
  - Measure dimensions

3D printing

- Several techniques (available online, 3d print house)
- FDM printers are affordable
- Select orientation, check for overhangs (support?)
- More quality = More printing time

Today´s plan

- Print some Lego blocks
  - Find them in a part repository
  - Install a slicer
  - Generate G-code (**<15min**!)
  - Go to the printers in small groups
- ~~Visit the Stereolithography (SLA) printer~~
- While you wait:
  - Measure some dimensions of the 3D part and compare them with the dimensions of the model
  - Design a chassis to hold the motors and make an assembly (chassis + motors)
  - **Ask your doubts about modelling !**

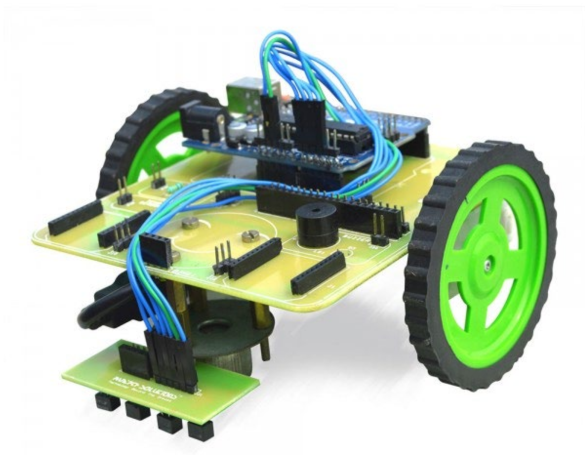
Mandatory activity

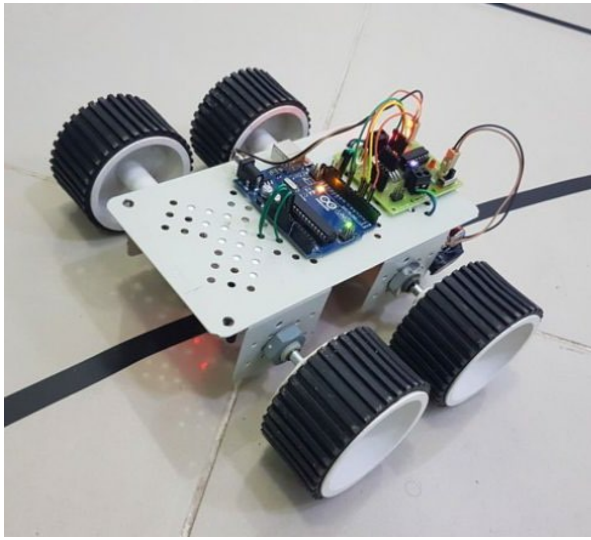
Design two motor holders (or a chassis) to hold the motors of your robot

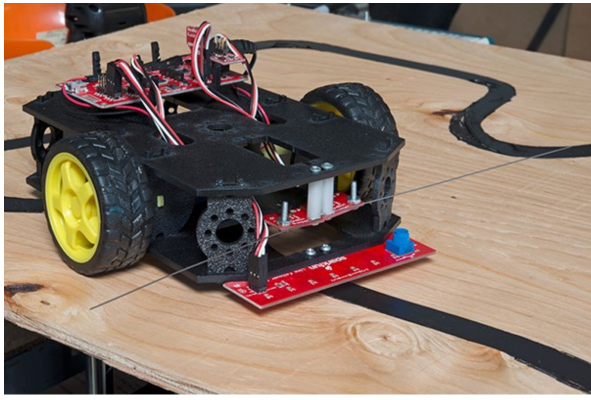
3D print it and come to next lecture with them

Try to use the 3D printers as soon as possible:

- It takes time to 3D print
- There are multiple groups
- Prints can start today at 16:00







REAL – Opening hours

Tuesdays from 12:00 to 14:00 (Martin)
Wednesdays from 9:00 to 10:00 (Martin) and 12:30 to 14:00 (Hugo)
Thursdays from 12:30 to 14:00 (Hugo)

This week ONLY:
14:00 – 17:00 on Thursday (Martin)
13:00 – 15:00 on Friday (Andres)

Rest of the time: Stop by the lab, a lot of times there is someone there

Ready?

Let´s 3D print!

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