

Algorithms for 3D Printing and Other Manufacturing Methodologies

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Ultimaker 3 & Cura

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Outline

- 1 Cura
 - Additive Manufacturing
 - Ultimaker 3
 - Cura



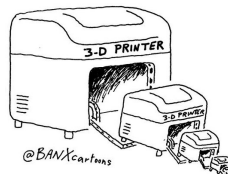
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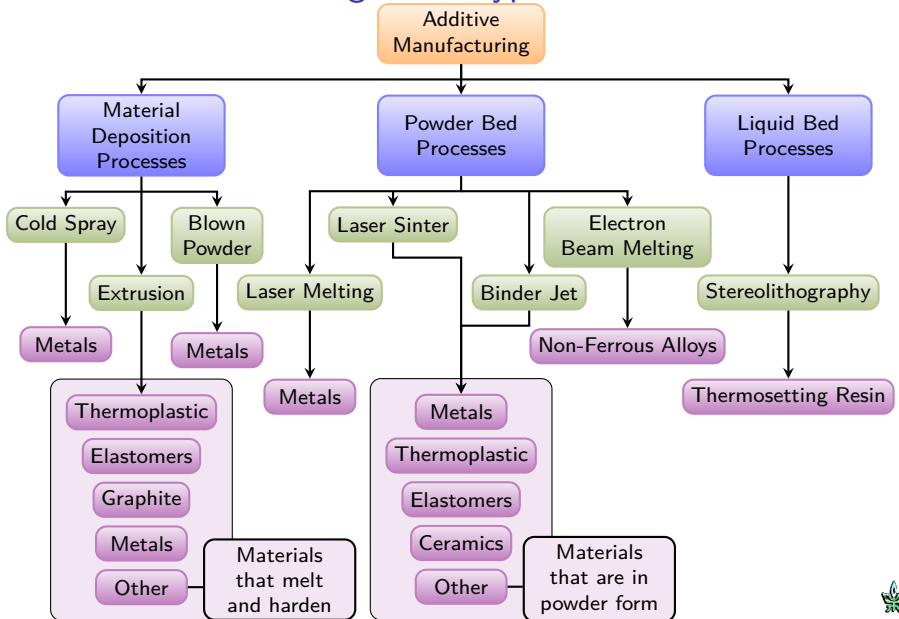


Additive Manufacturing

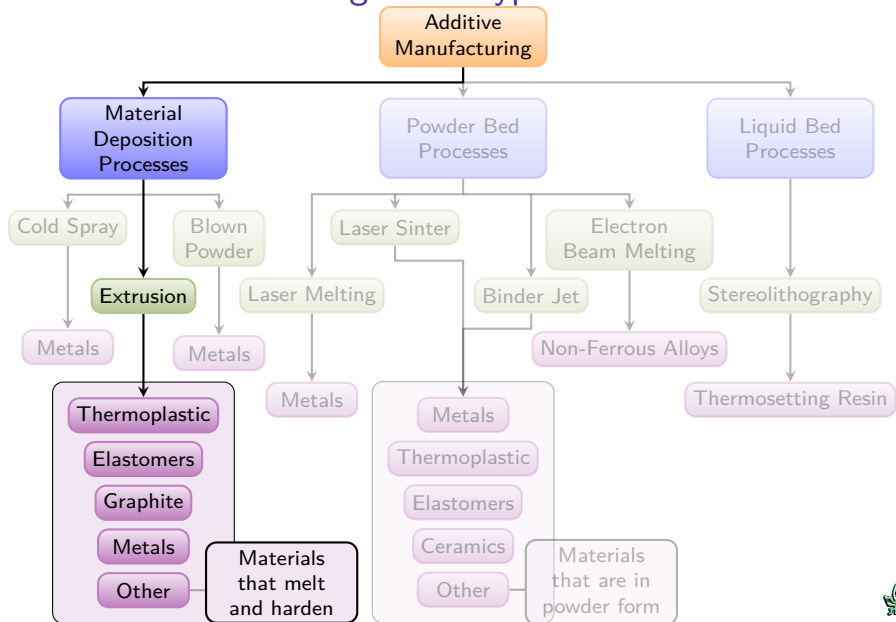
- *Additive Manufacturing* (AM) is the official term for 3D-printing.
- *3D printing* is the fabrication of objects through the deposition of some material under computer control. The deposition forms successive layers using one of several technologies.
- A large number of different AM processes exist.
 - The deposition technique differentiates between the different types.
- 1,000 different 3D printer models are available on the market today.



Additive Manufacturing Main Types

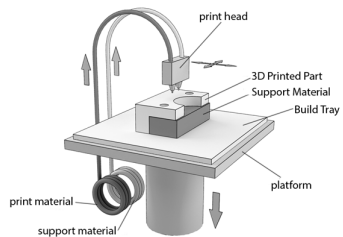


Additive Manufacturing Main Types

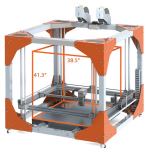


Fused Filament Fabrication (Fused Deposition Modeling)

- Fused Filament Fabrication (FFF) is the most popular additive manufacturing (AM) process by number of machines.
- The term Fused Deposition Modeling™ and its abbreviation FDM™ are trademarks of [Stratasys Ltd.](#)
- FFF is equivalent to FDM and is used by the rest of the world.
- The machine may dispense multiple materials, either
 - multiple colored thermoplastic materials to build the object, or
 - one thermoplastic material and another soluble support material.
- The object is produced by extruding small flattened strings of molten material to form layers.
- The material hardens immediately after it is extruded from the nozzle.



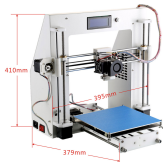
Fused Filament Fabrication Types



BigRep, Large



Baam, Huge



Prusa,
Cartesian XZ-head



Drag,
Cartesian Z-head



Felix,
Cartesian X-head



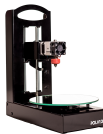
Ultimaker,
Cartesian XY-head
Bowden extruder



Go, Cartesian
XYZ-head, mobile



Kossel,
Delta technique



Polar 3D,
Polar bed

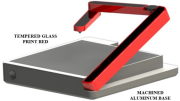



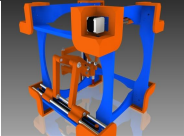




Morgan, Scara¹

¹Selective Compliance Assembly Robotic Arm



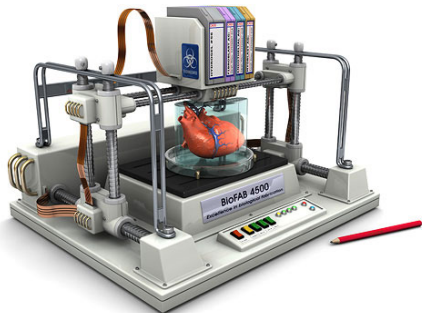
Fused Filament Fabrication Types, more

 <p>TEMPERED GLASS PRINT BED</p> <p>SLAC-BENDER ALUMINUM BASE</p>			 <p>Printing 3-dimensional curves instead of layers by Mataerial.</p>
 <p>Controlling all 6 degrees of freedom of the nozzle, Sextupteron</p>	 <p>A curved house by Contour Crafting, a computerized construction company</p>	 <p>Lunar settlement of space colonies, simulation by Nasa</p>	



Bioprinting

- Artificially construct living tissue, printing layers of living cells.



Search ID: 671037
"Find an economist that supports our position, and if you can't, 3-D print one!"

Bioprinters print replacements of human organs



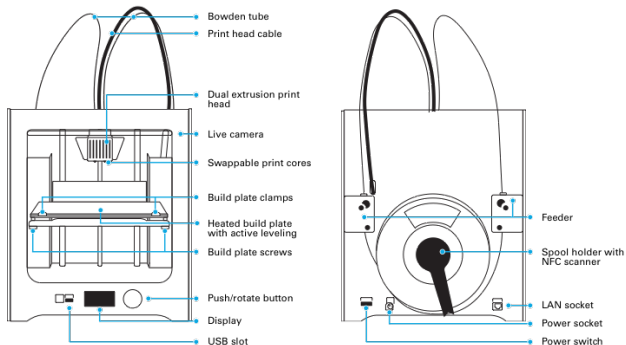
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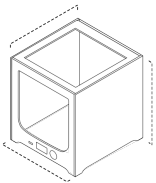
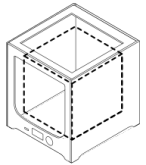


Ultimaker 3

Ultimaker 3 printers are designed and built for FFF.



Ultimaker 3 Specification

Property		Value	
Dimensions	Net	342 x 380 x 389	
	Gross	342 x 505 x 588	
Build Volume	Single extrusion	215 x 215 x 200	
	Dual extrusion	197 x 215 x 200	
Weight		10.6 kg	



Ultimaker 3 Specification, cont.

Layer resolution	20–200 μm	The thickness of a 3D printed layer. Thin layers are used for high detailed prints, thick layers are used to high speed printing.
Build plate temperature	20°–100°	Affects the selection of printing materials.
Build speed	$\leq 16 \text{ mm}^3/\text{secs}$	The filament extrusion speed, which affects the printing speed. ²
Print head travel speed	30–300 mm/sec	The speed of the printer head. ²
XYZ accuracy	12.5, 12.5, 2.5 μm	The accuracy of the stepper motors, which determines the accuracy of the the print.
Nozzle diameter	0.4 mm	Affects the printing speed, ² accuracy, grabbing to the print bed, and sticking to the layer underneath, which affects the support requirements.
Nozzle temperature	180°–280°	Affects the selection of printing materials.
Nozzle heat up time	< 2 min	Affects the overhead time it takes to start printing and melting the material.
Build plate heat up time	< 4 min	Affects the time it takes to start printing.
Operating sound	50 dBA	Suitable for use in quite environments.

²High printing speed decreases the risk that the process will fail at a late stage, wasting material and time.



Ultimaker 3 Head

Dual extrusion: Enables the combination of (i) build and support materials, or (ii) two build materials of different colors.

Swappable print cores: Enables easy and quick replacement of print cores.



The Ultimaker 3 comes with two print cores, namely, AA and BB, with different inner nozzle geometries customized for build material and water-soluble support material, respectively.



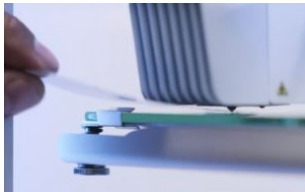
Ultimaker 3 Build Plate

Refined design: The Ultimaker 3 features a light & stiff build plate, which reduces vibrations, and a removable glass plate, which allows easy cleaning.

Heated glass build plate: Increases the range of usable printing material.

Active leveling: Build-plate calibration is done automatically.

- The capacitive sensor in the print head measures distances between the print bed and the nozzles.
- The tilt angle is compensated by adjusting the z-height in the first layers.



Manual calibration



Ultimaker 3 Materials

Various Materials can be used by the Ultimaker 2 printer.

- Nylon** (polyamide) has high strength-to-weight ratio, low-friction and is flexible.
- PLA** (polylactic acid) is reliable, offers good surface quality, and is made from organic, renewable sources.
- ABS** (acrylonitrile butadiene styrene) has good mechanical properties, e.g., it can withstand temperatures of up to 85°.
- CPE** (co-polyester) is chemical and temperature resistant, with dimensional stability.
- PVA** is a water soluble support material.

Material recognition with NFC scanner: Detects and identifies the material on the spool holder and checks the correspondence of a filament and print core type being used.



Ultimaker 3 Additional Features

Optimized Cooling: Ultimaker 3 has a low-noise fan system featuring two radial fans and fan shrouds; it builds up pressure for an improved airflow. This ensures better cooling, high quality bridging, faster print runs and smooth print surfaces.

LED status indicators: Alerts when a user interaction is needed.

EEPROM print core chip: The chip memorizes the size and type of the nozzle, notifies the user in case of misuse.

USB port

Wi-Fi, LAN

Live camera



Ultimaker 3 Software

Ultimaker 3 application: The user of the application can start and monitor the printing process. Together with the integrated camera the user can check the progress and inspect the intermediate print.

Cura Prepares your model for 3D printing.



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- CURA is slicing software for 3D printers.
 - It accepts a digital 3D model, typically in the STL format, as input.
 - It computes the toolpath that the printhead(s) need to take to print the model.
 - It emits the instructions to the printer, in the GCODE format, to a file.

```
G0 F7200 X19.698 Y28.262 Z.36
G1 F1500 E0
G1 F1350 X22.467 Y26.175 E0.15654
G1 X23.338 Y25.568 E0.20447
G1 X24.246 Y25.027 E0.25218
```

- CURA is maintained by [Ultimaker Ltd.](#)
- CURA is well suited for Bowden-extruder machines,
 - e.g., RepRap, Ultimaker and most Delta-bots.



Where Do Models Come From?

- The Internet
 - A matrix of sources of printable models can be found [here](#).
 - [Thingiverse](#)
 - [Youmagine](#)
 - [GrabCAD](#)
- The product of a modeler running 3D-modeling software
 - A list of 3D modeling software can be found [here](#)
 - A collection of useful software can be found [here](#).
 - [Tinkercad](#)—freeware, cloud
 - [Sketchup](#)—freemium
- The output of a 3D-reconstruction process



Cura Software

- CURA is Open Source software released under the AGPLv3 license.
- CURA is made of two parts:
 - The GUI, written in Python, is based on the [Uranium](#) framework.
 - ★ A Python framework for building 3D printing related applications.
 - The slicing engine, namely [CuraEngine](#), is written in C++.
- There are additional optional parts and plugins,
 - e.g., [OrientationPlugin](#)—a wrapper around [Tweaker](#), a Python module that finds the optimal printing orientation of a 3D model.
- CURA is a multiplatform app. for LINUX, MAC, and WINDOWS.
- CURA 2.3.1 is now available.



Cura Features (Version 2.3)

- There are two operational modes:
 - **basic** offers few settings, good for novice users.
 - **advanced** offers all settings, good for experienced users.
- Handles various profiles
 - Maintains a set of predefined profiles
 - Automatically adjusts the settings for each material and print core
- Accepts files in the STL, 3MF, and OBJ file formats
- Supports dual extrusion printing
- Supports various infill types

- Provides time and weight estimation
- Supports wireless printing
- Enables live monitoring



Cura Simple Mode

Ultimaker 3

Print core 1 Print core 2

Print core & Material: AA 0.4 PLA

Profile: Normal Quality - 0.1mm ★

Print Setup Recommended Custom

Infill: Hollow **Light** Dense Solid

Enable Support:

Support Extruder: Print core 2

Build Plate Adhesion:

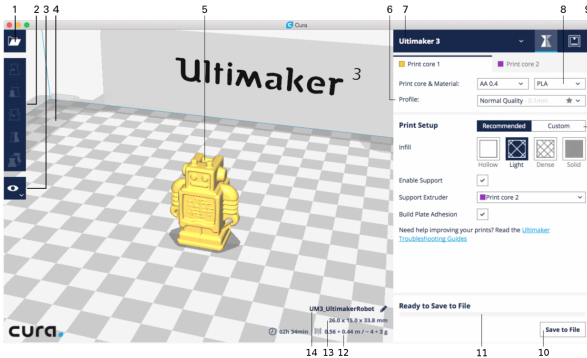
Need help improving your prints? Read the [Ultimaker Troubleshooting Guides](#)

- 1 Profile selection
- 2 Simple mode settings



Cura Interface

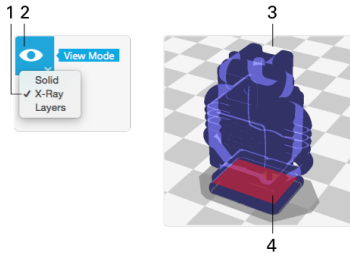
- 1 Open file
- 2 Toolbar: move, scale, rotate, mirror & per-object settings
- 3 View modes: solid, X-ray & layers
- 4 Brim/skirt margin
- 5 3D model
- 6 Profile settings
- 7 Printer selection



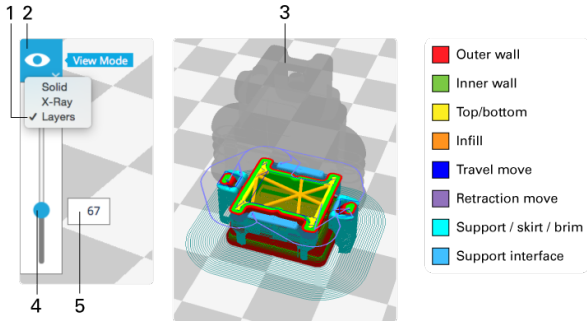
- 8 Print core & material selection
- 9 Simple/advanced mode
- 10 Save GCODE
- 11 Progress bar
- 12 Estimated print time & cost
- 13 3D-model dimensions
- 14 Print-job name



Cura Model Viewing



- 1 X-ray view mode
- 2 View mode
- 3 3D viewer
- 4 Error in model



- 1 Layers view mode
- 2 View mode
- 3 Model preview
- 4 Layer slider
- 5 Layer number



Cura Custom Mode

Machine Machine related settings.

Quality Settings that define the (visual) quality of the print.

Shell Settings related to the outside of the print.

Infill All settings that have to do with the inside of the print.

Material Material related settings.

Speed Speeds at which the print head moves while printing.

Travel How the print head behaves during travel moves.

Cooling Settings that define how the plastic is cooled.

Support Options for printing with support structures.

Platform adhesion Defines the adhesion of your model to the build plate.

Mesh fixes Options for fixing faults in models.

Special modes Features that influence the way of printing.

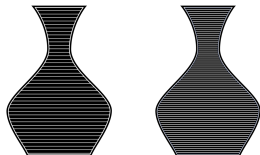
Experimental Experimental new features.



Cura Quality

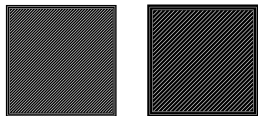
- Layer height

- The thickness of one printed layer.
- Acceptable values must be in $[0.06-0.20\text{mm}]$.
- Thinner layer height increases the quality.
- Thicker layer height decreases printing time.
- Options:
 - ★ First layer height.
 - ★ All other layers.



- Line width

- The width of a single printed line.
- Affects the extrusion rate.
- Options:
 - ★ Wall line width
 - ★ Top/bottom line width
 - ★ Infill line width
 - ★ Skirt line width
 - ★ Support line width
 - ★ Support interface line width
 - ★ Prime tower line width



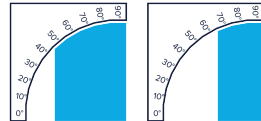
Cura Support

Enable Support

Placement options:

- Touching build plate
- Everywhere

Overhang angle the maximum angle of overhangs for which support material is added.



Support pattern

Concentric



Grid



Lines



Triangle



Zig Zag



Connect zig zags

Support density



Cura Platform Adhesion

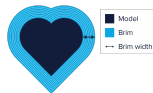
Skirt A line printed around the object on the first layer.

- It is not connected to the model.
- It helps priming the extrusion.



Brim A flat area around the base of the model on the first layer.

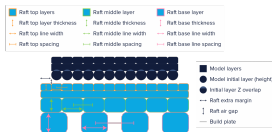
- It is connected to the model.
- It prevents warping.
- It may enlarge the bounding box.



Raft Several sparse layers between the model and the build plate.

- Useful when the bottom surface of a model is not flat, or
- the contact area with the build plate is small.

Visualization of the raft settings



The printed raft

