3D Printing

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Glossary

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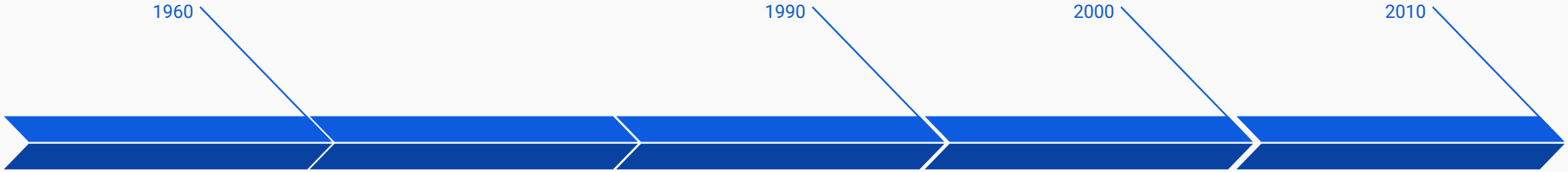
What is 3D printing?

- Additive manufacturing method
- Opposite to Subtracting manufacturing methods (CNC)
- We can produce truly any shape we want
- Can be used for plastic, metal and more materials

History



First sci-fi 3D printing

Raymond F. Jones in “Tools of the Trade” published in Astounding Science Fiction

UV exposure of polymer

Hideo Kodama of Nagoya Municipal Industrial Research Institute where polymer has exposure to UV is controlled by mask pattern

Application of plastic extrusion

S. Scott Crump designed system where melted plastic polymer is applied in specific pattern - FDM

More methods!

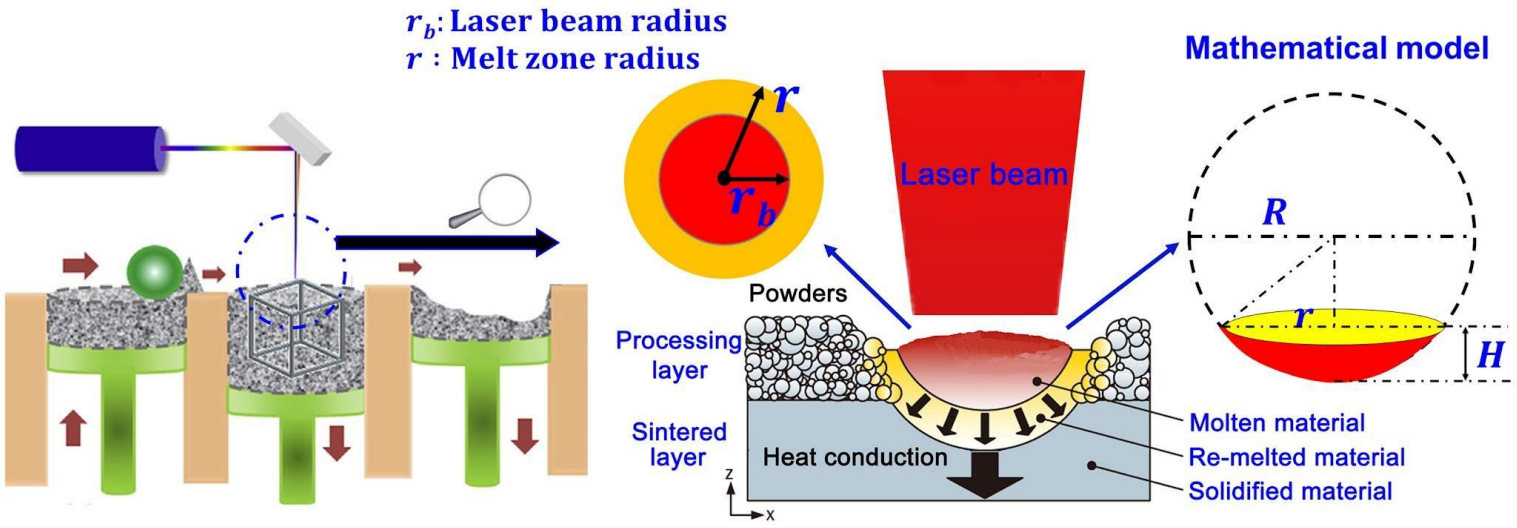
Fraunhofer Society developed SLS printing

Open Source

Project RepRap was created

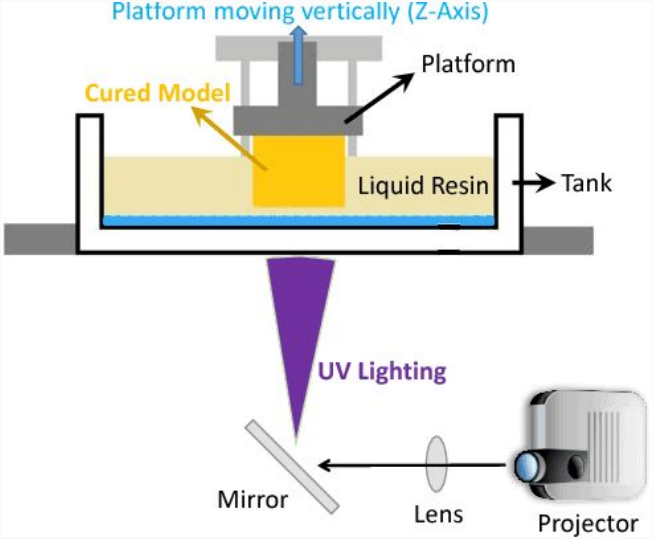
How it works…

SLS printing



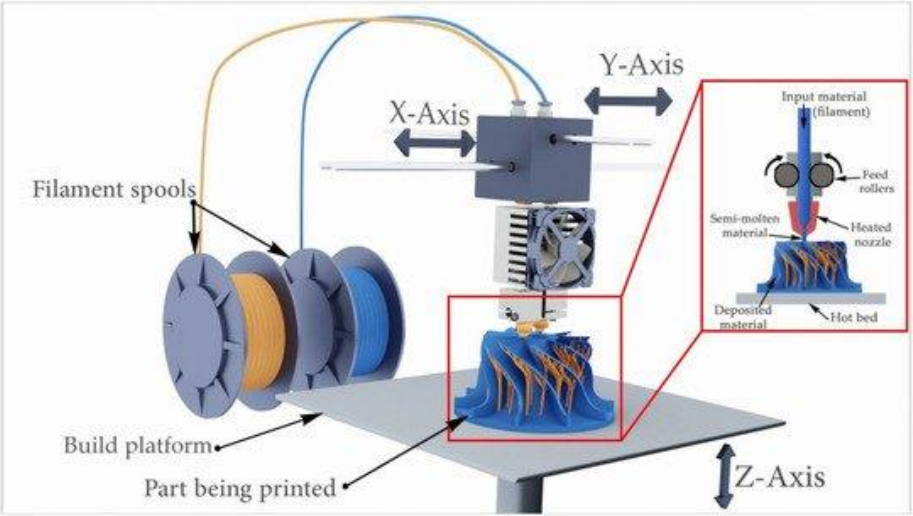
Source: https://www.tandfonline.com/doi/full/10.1080/14686996.2018.1455154#d1e532

SLA Printing



Source: https://xometry.pro/en-eu/articles/3d-printing-sla-overview/

FDM Printing



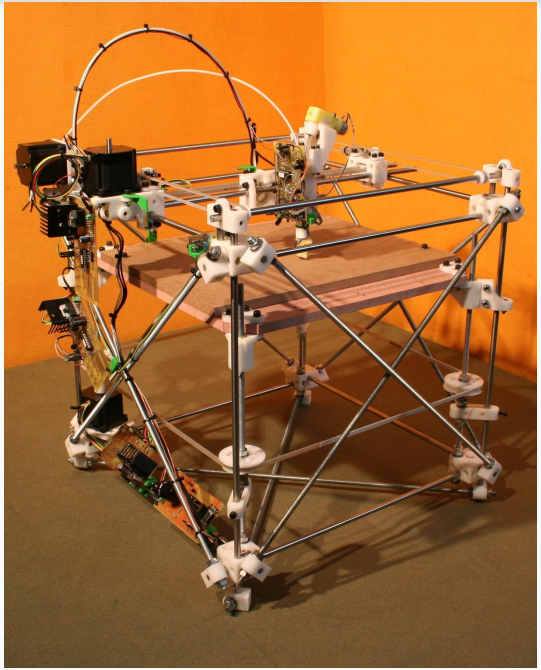
Source: https://3dprint.com/267642/fdm-3d-printing-effects-of-typical-parameters-on-functional-parts/

Open Source and 3D Printing

Rep Rap

- aka The Replicating Rapid Prototyper
- first open source and low-cost 3D printer design
- first “self-replicating” 3D printer

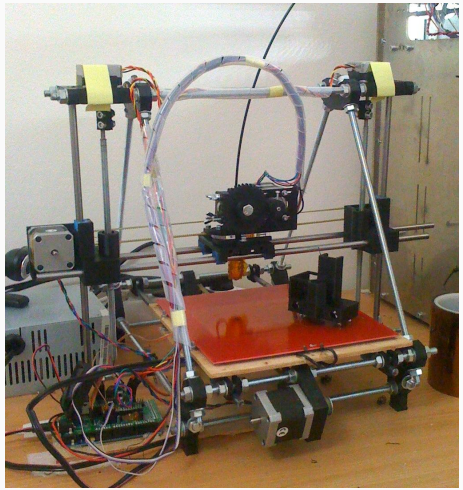
- There is many printer designs now



Source: https://reprap.org/wiki/RepRapOneDarwin

Průša

- Czech manufacturer of 3D printers

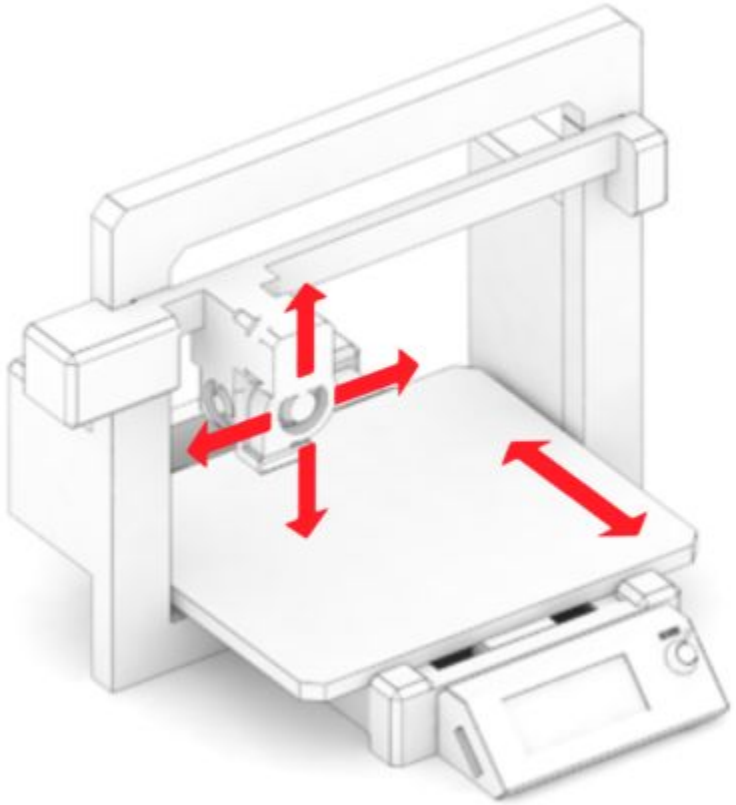


Source: https://reprap.org/wiki/Prusa_Mendel

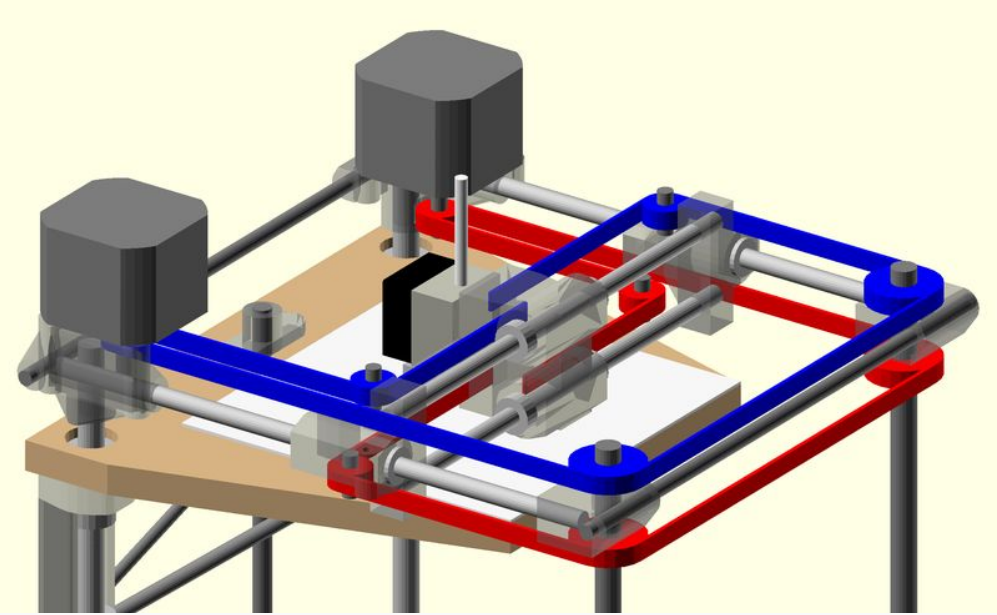
https://www.prusa3d.com/cs/produkt/original-prusa-mk4-2/

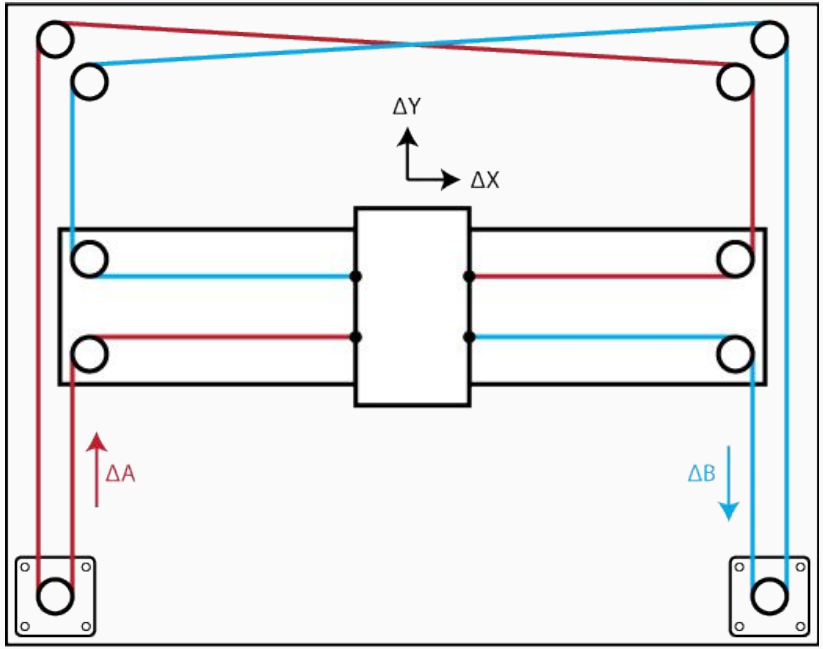
The Fun Part

Printer kinematics



Cartesian (Source: https://help.prusa3d.com/article/types-of-printers-and-their-differences_112464)





Equations of Motion:

$$\Delta X = {}^{1}/_{2}(\Delta A + \Delta B), \quad \Delta Y = {}^{1}/_{2}(\Delta A - \Delta B)$$

$$\Delta A = \Delta X + \Delta Y, \quad \Delta B = \Delta X - \Delta Y$$

CoreXY (Source: https://reprap.org/wiki/CoreXY, https://corexy.com/theory.html)

Delta (Source: https://www.deltaprintr.com/product/delta-go/)

Comparison of technology

Technology	Material Type	Resolution (µm)	Speed (mm/s)	Cost ($ per kg)	Strength (MPa)	Surface Finish
FDM	Thermoplastics (PLA, ABS)	100-300	40-100	20-50	20-60	Moderate
SLA	Photopolymer resin	25-100	10-50	80-200	40-80	Smooth
SLS	Metal & polymer powder	20-100	5-20	100-500	50-150	Rough

When is good to use which technology?

Technology	Best Use Cases	Pros	Cons
FDM	Prototyping, hobbyist models, low-cost functional parts	✅Affordable, easy to use, widely available	❌Lower resolution, visible layer lines
SLA	Dental applications, jewelry, high-detail models	✅High resolution, smooth surfaces	❌Expensive, limited material options
SLS	Aerospace, automotive, medical implants	✅Strong, durable parts with complex geometries	❌High cost, slow print speed
DMLS	Metal parts for aerospace, medical, automotive	✅Extremely strong, complex geometries	❌Very high cost, requires post-processing

Boards

How to choose proper board?

- Number of axes?
- Number of extruders?
- Sensor support?
- 8bit vs 32bit
- Firmware compatibility
- Connectivity?

Board	MCU	Firmware	Extruders	Drivers	Price ($)	Pros & Cons
Arduino + RAMPS 1.4	8-bit	Marlin	1-2	A4988 / DRV8825	20-40	✅ Cheap, Open-source, Customizable ❌ Outdated, Limited performance
SKR 1.4 Turbo	32-bit	Marlin Klipper	2	TMC2209	40-60	✅ Modern, Reliable, Great community support ❌ Needs firmware flashing
BTT Octopus	32-bit	Marlin Klipper	8	TMC5160	80-100	✅ High-end, Multi-extruder support ❌ Expensive for beginners
Creality 4.2.7	32-bit	Marlin	1	TMC2225	30-50	✅ Silent operation, Plug-and-play for Creality printers ❌ Limited to Creality ecosystem
Duet 3	32-bit	RepRap Firmware	3-5	TMC5160	150-200	✅ Powerful, Web interface, Expansion support ❌ High cost, Learning curve

Sensors

Bed Leveling

Sensor Type	How It Works	Pros	Cons	Best For
BLTouch	Deployable probe measures bed height	✅ Highly precise ✅ Works with all bed types	❌ Requires firmware setup ❌ Mechanical part can wear out	Most accurate leveling, general use
Inductive	Detects metal beds via electromagnetic field	✅ No physical contact ✅ Long lifespan	❌ Only works with metal surfaces ❌ Affected by temperature changes	Metal print beds
Capacitive	Measures changes in capacitance near bed	✅ Works on glass & non-metal beds ✅ No physical contact	❌ Can be affected by humidity ❌ Less precise than BLTouch	Glass or non-metal surfaces
TAP Sensor	Uses nozzle contact to detect bed height	✅ No additional probe needed, direct contact	❌ Requires strong nozzle, potential wear	High-precision direct nozzle probing

Filament sensors

Sensor Type	How It Works	Pros	Cons	Best For
Filament Runout	Detects filament presence via switch	✅ Stops print if filament runs out ✅ Simple & effective	❌ Does not detect jams ❌ Requires firmware support	Preventing failed prints due to filament depletion
Filament Jam	Measures filament movement	✅ Detects extrusion failures ✅ Reduces wasted filament	❌ Slightly more complex ❌ Requires additional electronics	Prevent jams

Thermal Sensors

Sensor Type	How It Works	Pros	Cons	Best For
Thermistor	Changes resistance based on temperature	✅ Affordable & widely available ✅ Works well for most printers	❌ Limited accuracy at high temps ❌ Slower response time	General use, standard 3D printers Prints under 350 °C
PT100 / PT1000	Uses platinum resistance for high accuracy	✅ High precision ✅ Works at very high temperatures	❌ More expensive ❌ Requires amplifier board	High-temperature 3D printing Prints above 350 °C

Motion and Endstop Sensors

Sensor Type	How It Works	Pros	Cons	Best For
Mechanical Endstop	Physical switch triggers when axis reaches the limit	✅ Cheap & reliable ✅ Easy to replace	❌ Can wear out over time ❌ Requires contact	Basic home positioning
Optical Endstop	Light beam detects axis position	✅ More precise than mechanical ✅ No mechanical wear	❌ Requires clean environment ❌ Slightly more expensive	High-precision applications
Hall Effect Sensor	Detects magnets near the axis	✅ No mechanical contact ✅ Long lifespan	❌ Needs a magnet installed ❌ Requires proper calibration	Precision movement, high-speed printers
No sensor	Measure input current for motors	✅ No mechanical contact ✅ Cheap & reliable	❌ Requires proper calibration	

Additional Sensors

Sensor Type	How It Works	Pros	Cons	Best For
Vibration (Input Shaping)	Measures resonance to optimize movement	✅ Improves print quality ✅ Reduces ringing artifacts	❌ Requires firmware setup ❌ Not supported by all boards	Klipper-based printers, high-speed printing
Humidity Sensor	Monitors filament moisture levels	✅ Prevents filament degradation ✅ Useful for hygroscopic filaments	❌ Requires integration with storage system	Filament storage monitoring
Smoke/Fire Sensor	Detects smoke or excessive heat	✅ Improves safety ✅ Can trigger emergency stop	❌ Needs external relay for power cut-off	Industrial Printers

Software aka Firmware

Marlin

- Open-source firmware, widely used in hobbyist and professional 3D printers.
- Runs directly on the printer’s control board (no external computer required).
- Supports most 3D printer hardware, including LCDs, stepper drivers, and sensors.
- Slower execution speed due to on-board processing limitations.
- Extensive community support and continuous updates.

Klipper

- Offloads complex calculations to an external computer (e.g., Raspberry Pi), improving processing power.
- Enables higher-speed printing with improved motion planning and input shaping.
- Uses Python-based configuration, making it more flexible and customizable.
- Less beginner-friendly due to additional setup requirements.
- Ideal for advanced users looking for high-speed, high-precision printing.

Questions?