VIN Predavanja – 1. DN (2023/24 Tema: 3D printer; Authors: Ignat Pocevski, Nik Bažato, Stefanija Atanasova; Date: 15.03.2024)

What's 3D printing?

3D printer

3D printing or additive manufacturing is the construction of a three-dimensional object from a CAD model or a digital 3D model. It can be done in a variety of processes in which material is deposited, joined or solidified under computer control, with the material being added together (such as plastics, liquids or powder grains being fused), typically layer by layer.

Development

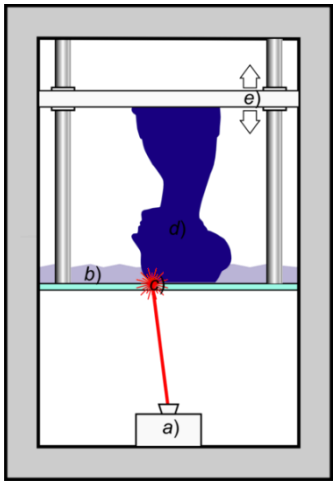
This technology was invented in the early 1980s, with the need for rapid prototyping and manufacturing. In 1984, Charles Hull, an American engineer, invented a technology known as stereolithography (SLA) and founded the company 3D Systems to further develop and commercialize it. Hull's invention utilized a process where a UV laser selectively solidified layers of liquid photopolymer resin to create three-dimensional objects. This marked the beginning of the modern era of 3D printing. [1]

Types of printers

In the realm of 3D printing, various technologies have emerged to accommodate diverse materials, applications, and printing methodologies. Among the prominent types of 3D printers are:

- ***Fused Deposition Modeling (FDM):*** This widely utilized technology involves the extrusion of thermoplastic filaments layer by layer, offering versatility and affordability for both hobbyists and professionals.

- ***Stereolithography (SLA) and Digital Light Processing (DLP):*** These resin-based printing methods employ photopolymerization to solidify liquid resin into precise, high-resolution objects, making them ideal for intricate designs and detailed prototypes.



Schematic representation of Stereolithography

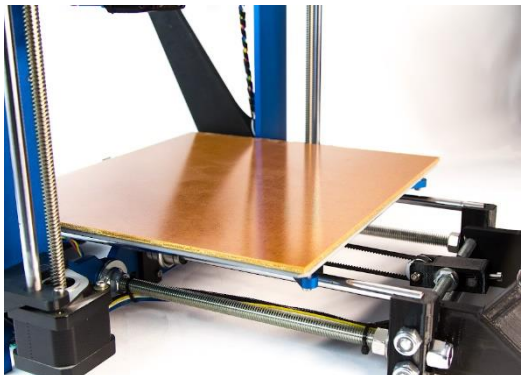
- ***Selective Laser Sintering (SLS):*** Utilizing lasers to fuse powdered materials, such as nylon or metals, SLS enables the fabrication of durable, functional parts with complex geometries, revolutionizing manufacturing in various industries.

- ***Binder Jetting and Material Jetting:*** These additive manufacturing techniques involve depositing binding agents or photopolymers onto powder or liquid substrates, respectively, to build objects layer by layer, offering versatility and speed for prototyping and production applications. [2]

Architecture

Key components of a 3D printer

- ***Print Bed:*** This is the foundation where the object is built. It's typically a flat surface that can move along the X and Y axes. The can be heated or unheated, but it ismost commonly heated. A heated bed helpsprevent warping and improves adhesion ofthe printed object to the build surface. It'sparticularly useful for printing with materials like ABS.



Example of a print bed

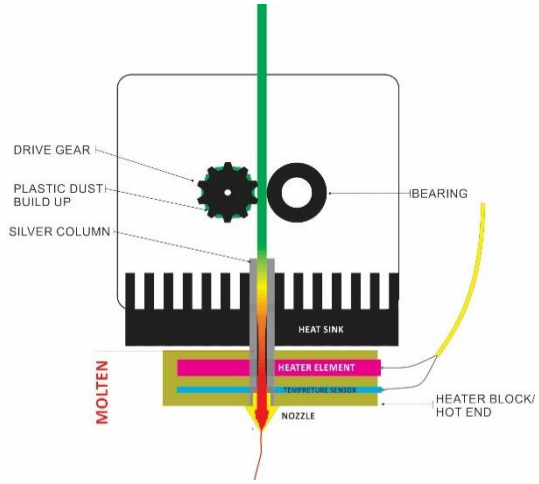
- ***Extruder/Nozzle:*** The extruder is the most complex part of the printer, and thus only the most important parts will be explained:

    - *Extrusion Mechanism:* The extruder comprises several key parts, including a motor-driven gear or pulley system responsible for feeding the filament into the hot end. The filament is typically housed on a spool and guided through a filament tube to reach the extruder.

    - *Hot End:* At the heart of the extruder lies the hot end, where the filament is heated to its melting point. This component consists of a heating

element and a temperature sensor to regulate the temperature accurately. Once heated, the filament softens and becomes malleable for deposition.

- *Nozzle:* The nozzle, a small opening at the end of the hot end, is where the molten filament is extruded onto the print bed. Nozzles come in various diameters, typically ranging from 0.2mm to 1.0mm, influencing the level of detail and speed of printing. Smaller nozzles allow for finer details but longer print times.



Example of the Extruder

- *Cooling System:* To ensure precise deposition and prevent unwanted sagging or deformation, many 3D printers employ a cooling system near the nozzle. This rapidly cools the extruded filament, maintaining its shape and structure. [3]

- ***Filament:*** This is the raw material used in 3D printing. It's usually a thermoplastic material like PLA or ABS, which is fed into the extruder. Filament comes in spools of various colors and types.

- ***Stepper Motors:*** These motors drive the movement of various components of the printer, such as the print head and the build plate. They receive precise instructions from the control board to move with high accuracy.

- ***Endstops and Sensors:*** Endstops are switches that help the printer determine the position of the print head and the build plate. Sensors may also be used to monitor temperature and other parameters.

How 3D printers work

The process of 3D printing begins with the creation or acquisition of a **digital 3D model**, which serves as the blueprint for the physical object to be fabricated. This model can be crafted from scratch using specialized **computer-aided design (CAD) software** or procured from repositories hosting **pre-existing designs**.

Creating a 3D model

Diverse software tools are available for this purpose, each tailored to different skill levels and application requirements. For novices, platforms like **Tinkercad** offer an accessible entry point, boasting an intuitive interface and a repository of community-generated designs. These tools facilitate the creation or modification of 3D models and provide functionalities for exportation in industry-standard file formats such as .STL or .OBJ, ensuring compatibility with 3D printing workflows.

Slicing

Following the acquisition or creation of the 3D model, the next crucial step is slicing – the process of subdividing the digital model into numerous discrete layers. This segmentation is essential for the subsequent layer-by-layer fabrication process inherent to 3D printing technology. Slicing software is employed to accomplish this task, utilizing algorithms to dissect the model into intricate cross-sections. These software applications not only partition the model but also calculate toolpaths, determining the precise trajectory of the print head or equivalent mechanism throughout the fabrication process.

Communication

Upon completion of the slicing process, the resultant digital file is prepared for transmission to the 3D printer. This transfer can be facilitated through various means such as USB, SD card, or Wi-Fi connectivity, depending on the capabilities of the printer. The sliced file, now encoded with instructions for layer-by-layer fabrication, is ready for execution. [4]

G-code

At the heart of 3D printing lies the pivotal role of software in orchestrating the additive manufacturing process. The instructions guiding the 3D printer's operations are conveyed through **G-code** – a specialized programming language that delineates intricate directives governing movements, temperatures, and other vital parameters. Generated from the 3D model via the aforementioned slicing software, G-code translates the abstract geometry of the digital model into a tangible, physical reality. Each line of G-code embodies a specific action, dictating the precise maneuvers of the printing apparatus as it progressively constructs the object layer upon layer. This systematic control imbues users with the flexibility to fine-tune parameters, enabling the realization of diverse designs and facilitating the attainment of desired outcomes with precision and efficiency.

Summary

3D printing encompasses many forms of technologies and materials as 3D printing is being used in almost all industries you could think of. It's important to see it as a cluster of diverse industries with a myriad of different applications.

Companies have used 3D printers in their design pocess to create prototypes since the beginning of 3D printing. Using 3D printers for these purposes is called **rapid prototyping.**

Rapid prototyping is the most common use for 3D printing, as it allows the user to quickly and relatively cheaply transform the idea to a prototype (3D model).

Besides rapid prototyping, 3D printing is also used for **rapid manufacturing**. **Rapid manufacturing** is a new method of manufacturing where businesses use 3D printers for short run / small batch custom manufacturing. [5]

Literature

[1] What's 3D printing, Wikipedia: https://en.wikipedia.org/wiki/3D_printing

[2] Types of 3D printers: https://www.cdwg.com/content/cdwg/en/articles/hardware/how-does-a-3d-printer-work.html

[3] How extruders work: https://3dprintingsystems.freshdesk.com/support/solutions/articles/4000003132-how-does-the-up-3d-printer-s-print-head-extruder-work-

[4] How 3D printers work; [5] Summary: https://3dprinting.com/what-is-3d-printing/