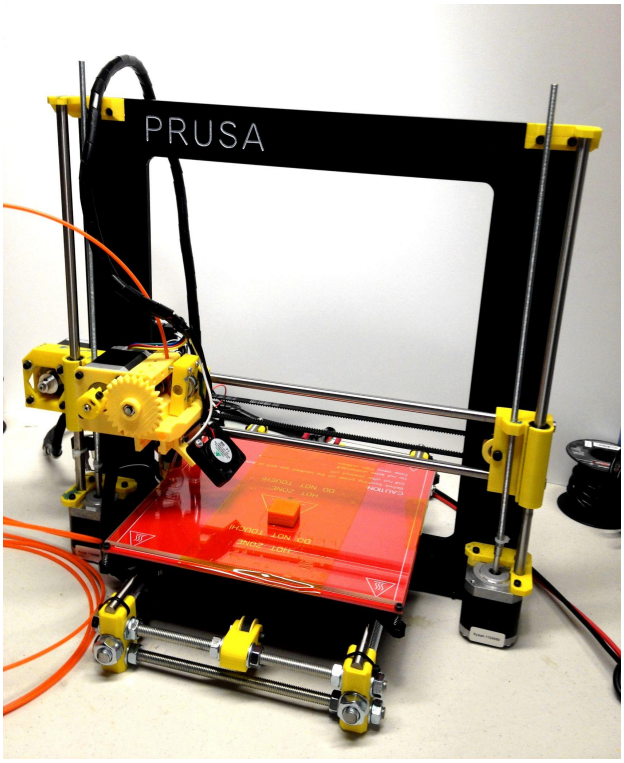
FDM Printing

A Beginner's Introduction to 3D Printing



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June 27, 2021

Overview

3D printing, a method of manufacturing objects from digital designs, has experienced an explosion in consumer interest over the last decade thanks in large part to the process known as fused deposition modeling, or FDM. This document describes in brief how printers using this technology operate, what advantages and limitations they have compared to other printing technologies available to consumers, recommendations for anyone who is new to 3D printing whether this technology is appropriate for their needs and knowledge level.

What is FDM printing?

Fused deposition modeling, sometimes referred to as fused filament fabrication (FFF), is one of the most widely available consumer-level 3D printing technologies. During the process, a thermoplastic filament is melted at a precise temperature and extruded through the printer's nozzle, which moves over a print surface in order to build the desired object in a series of layers.

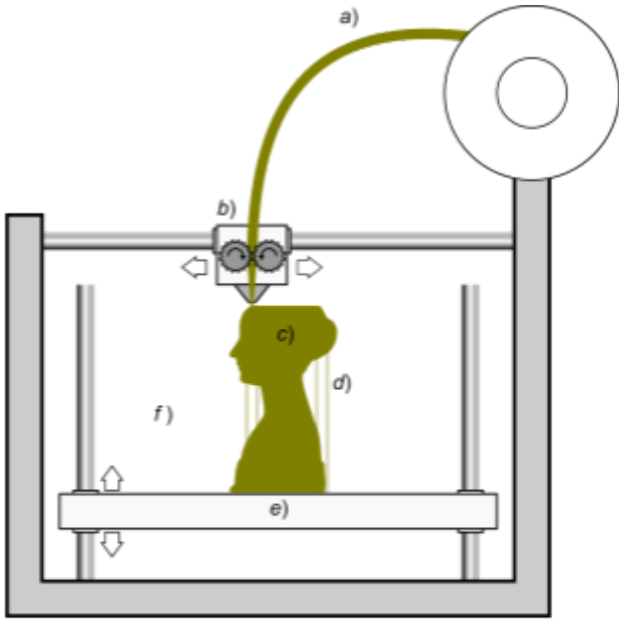

Figure 1. Image from Scopigno R., Cignoni P., Pietroni N., Callieri M., Dellepiane M. (2017). "Digital Fabrication Techniques for Cultural Heritage: A Survey". *Computer Graphics Forum* **36** (1): 6–21. DOI:10.1111/cgf.12781

Process description

An object designed using computer-aided design (CAD) software and exported in the appropriate format (STL) serves as the template for 3D printing, including FDM printing. This file, which represents a detailed list of instructions, can be transferred from computer to printer manually (using a storage medium such as an SD card), via cable, or wirelessly, depending on the printer's design.

Once a file has been loaded into the printer, printing can begin. During this process, illustrated in Figure 1, filament (a) is fed through the print head (b), which melts, extrudes and deposits the material, layer by layer, to create the desired object (c). When the object has overhanging parts, supports (d) must also be printed. In most cases, the print surface (e) moves to accommodate objects of various heights. The size limit of printed objects is dictated by the internal volume (f) of the printer.

Precision stepper motors enable FDM printers to maneuver both the print head and print surface in increments of a fraction of a millimeter, resulting in a degree of resolution in the finished print limited only by the width of aperture of the nozzle.

Objects for printing can be designed using a variety of commercially-available and open-source computer-aided design (CAD) applications, such as Fusion 360 or Blender. For beginners, there are also large repositories of 3D designs available online, both free and for purchase. Because 3D printing is additive—i.e., occurs one layer at a time—complex objects with moving parts can often be produced in situ, eliminating the need for assembly.

Once the desired object has been exported to the proper format (STL), it must be first processed by a slicing app (such as Ultimaker Cura) before it can be printed. This software analyzes the object before "slicing" it into layers according to the object's dimensions and the printer's resolution, calculating the precise set of stepper movements needed to extrude each layer. Most consumer-level printers include such software, and many provide additional features, such as wireless file transfer and print monitoring.

Advantages over similar technologies

The simplicity of the FDM printing process means a wide variety of materials can be used. Many plastics that can be melted and reformed at predictable temperatures are suitable for extrusion. The most economic filament is PLA, a lightweight bioplastic; but with little or no modification to the printer, most off-the-shelf printers can also accommodate ABS, PETG, nylon, carbon fiber, and metal- or wood-infused filaments, providing the user with a range of choices of materials with a variety of aesthetic and physical properties.

Another 3D printing technology available to consumers is so-called SLA (stereolithography) or resin printers, which utilize a high-intensity laser to build objects within a reservoir of liquid resin by curing the resin one layer at a time. Because their inner mechanisms are simpler and lasers very precise, SLA printers are capable of a higher degree of resolution, density, and isotropy than their FDM counterparts. But the printers themselves are, on average, more expensive than their FDM counterparts, and the liquid resins used are light-sensitive and toxic, requiring special care and cleanup.

Limitations

Despite their amazing flexibility, FDM printers share a few limitations that any prospective buyer should take into account. By far the greatest drawback of FDM technology is its need for precise temperature control. Because the thermal properties of filament materials vary widely, it is best for a printer to be kept in a temperature-controlled environment. Even small changes in ambient air temperature or humidity can affect the properties of the extruded plastic, so a dedicated printer enclosure is the best way to ensure optimal printing.

A second limitation is speed: depending on the printer's resolution and the characteristics of the object being printed, print jobs can take hours or days to complete. Because of this, users of printers without any sort of built-in monitoring or "print resume" capability risk costly delays in the event of miscalibration or power failure.

The rapid movement of the print head and the precision required to print to sub-millimeter accuracy mean FDM printers are highly susceptible to errors produced by vibrations. Stepper

motor dampers can be installed to reduce the effects of machine vibration, and taller printers should be fitted with extra supports to prevent swaying that may produce skewed top layers.

Conclusions

Fused deposition modeling is a technology that offers a simple and flexible method of 3D printing objects. The wide availability of different printers and filaments mean a new user will have the capability of printing a variety of object dimensions and materials, and the simplicity of the design compared to SLA printers will reduce the possibility of additional expense or hazard.

Works Consulted

Emmett Grames, “FDM 3D Printing – Simply Explained.” *www.all3dp.com*, https://all3dp.com/2/fused-deposition-modeling-fdm-3d-printing-simply-explained/. Accessed 27 June 2021.

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