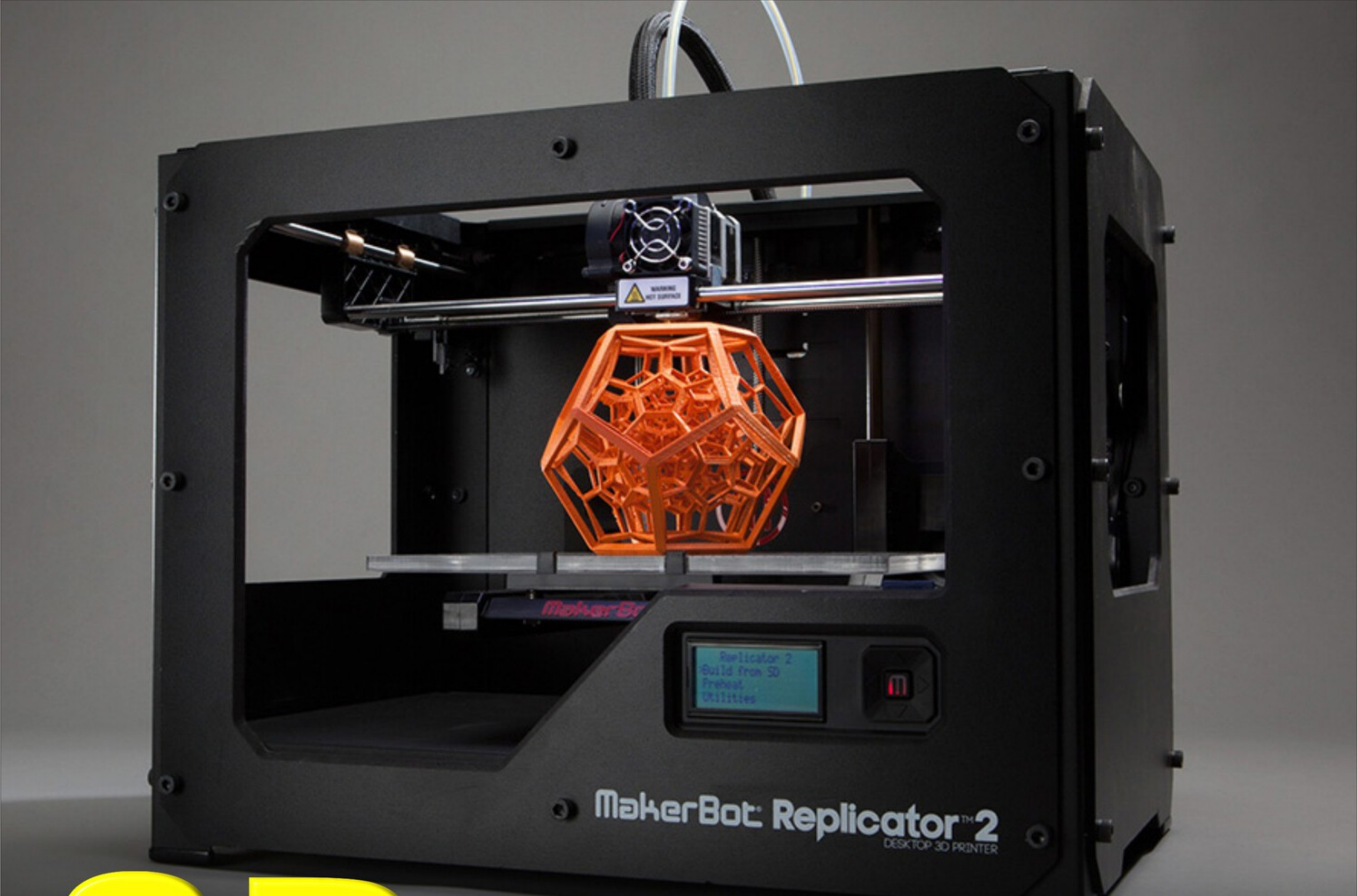
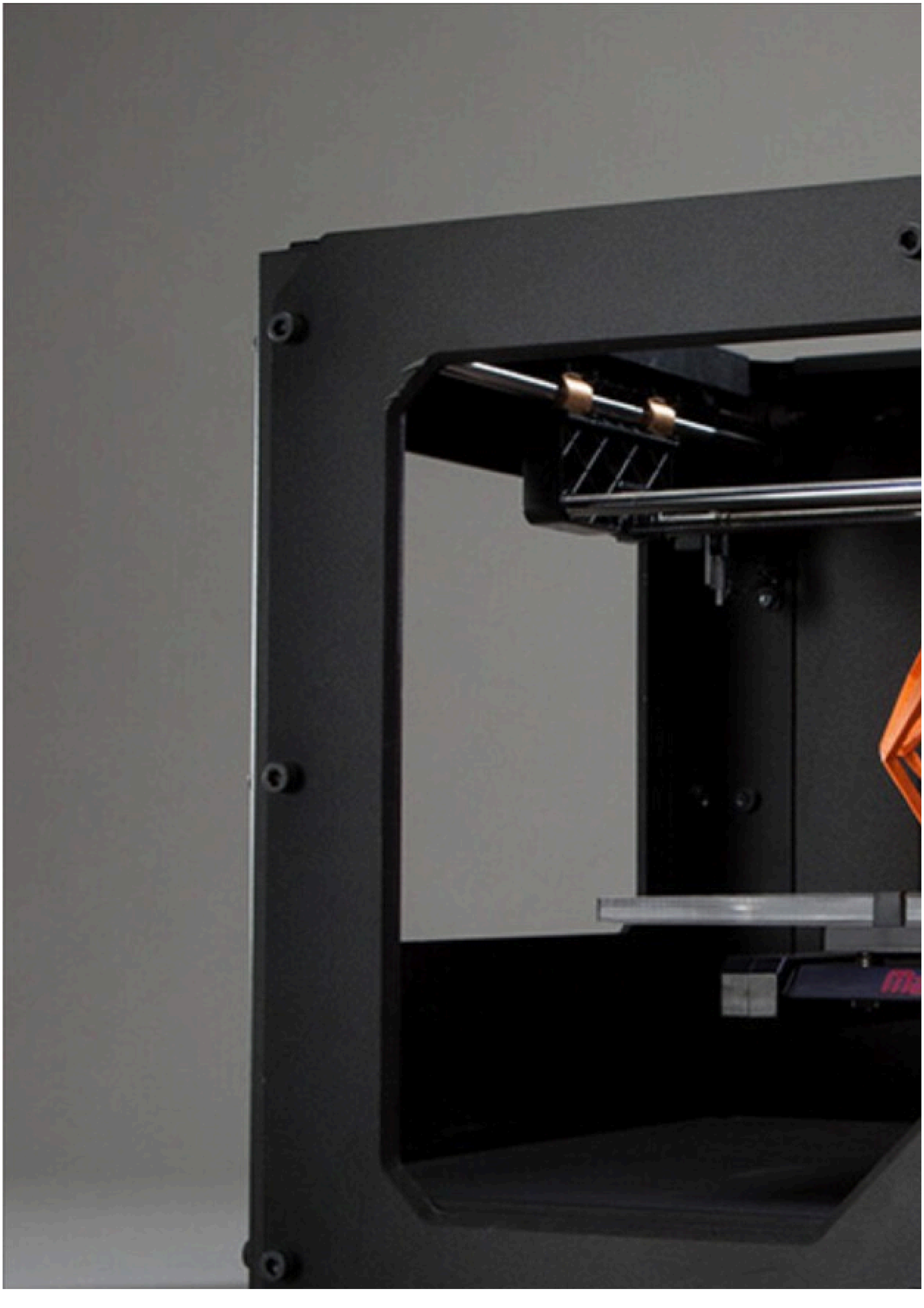


3D PRINTER USERGUIDE

A Complete Step By Step User Manual For Understanding The Fundamentals Of 3D Printing, How To Maintain And Troubleshoot Common Difficulties

Keith J. Prout



3D PRINTER
USER GUIDE

A Complete Step By Step User Manual For Understanding The Fundamentals Of 3D Printing, How To Maintain And Troubleshoot Common Difficulties

Keith J. Prout

Copyright © 2020 Keith J. Prout
All right reserved
Kindly note that this book cannot be reproduced in any way or by any means without obtaining written consent from the author or his representative

Table Of Contents

Introduction

Although it has not been larger than the internet as it was once projected to be, 3D printing has slowly and progressively started to change how manufacturing is done: from the tedious subtractive way of fabrication to a more easier additive manufacturing.

3D printing involves a host of different technological processes that ensure the manufacturing of a range of three-dimensional objects by adding layers upon layers of different build materials. This technology, which has long been enjoyed by early adopters, has been applied in many industries that would be discussed extensively later

Other topical issues, talked about in this book, relating to 3D printing you might want to know are:

- What 3D printing truly is
- The brief and key history of 3D printing
- How 3D printing works and the seven distinctive processes of 3D printing categorized by the American Society for Testing and Materials (ASTM)
- How to choose a 3D printer
- The tools and build materials useful of a good additive manufacturing

This guide also shed some light on the benefits and applications of 3D printing which can only be achieved when a quality print is made. The guide elaborated on how a quality print could be achieved through appropriate slicer settings and proper machine maintenance.

By the time you are done with this book, you would have been able to fully understand what 3D printing is, the difference between traditional and additive manufacturing, what to look out for when buying a 3D printer, what software, how to slice your 3D digital model, and how to maintain your personal 3D printer. You would also be vast in the use of some 3D printing terms.

Chapter 1: Basics Of 3D Printing

What Is 3D Printing?

3D printing, also known as additive manufacturing, is the process of 'printing' or manufacturing three-dimensional objects using 3D printers by stacking up layer-by-layer 3D printing materials.
The manufacturing objects' processes using 3D printers could be more than one, but the methods are the same. The layer, designed with Computer-Aided-Design (CAD) software, is printed in a 3D printer.
The term additive manufacturing for 3D printing comes from the method by which objects are 3D printed. Unlike the traditional subtractive manufacturing method, 3D printers produce three-dimensional objects by adding layer upon layer of production materials.
As earlier stated, this is directly opposite to how objects are made traditionally. The traditional manufacturing process involves subtracting part of a larger block of material for production. Cutting or carving out objects from the material they are made of is the hallmark of traditional manufacturing. For example, woods are cut out of a log of woods to make wooden shapes
But with 3D printing, complex objects are made only by adding layers of materials upon layers to meet the objects' 3D digital models. More 3D beneficial differences to traditional manufacturing would be discussed later.

Key History

Printing in 3D format has been in existence for quite a long time; it all started in 1981 after Dr. Hideo Kodama of Nagoya Municipal Industrial Research Institute filed a patent (JP S56-144478) was published. In 1v980, Kodama invented an additive rapid-prototyping system to produce a model using photopolymers. They were, at the time, called Rapid Prototyping (RP) plan because they were thought to be fast and cost-effective.
Before Hideo Kodama's invention, the idea of 3D printing and its additive manufacturing method was first described by Raymond F. Jones in a 1950 issue of Astounding Science Fiction magazine. He termed the process as 'molecular spray.'

Five years later, in 1986, after Kodama's invention, the first 3D patent was issued to Charles "Chuck" Hull of the 3D Systems Corporation. His patent was filed in 1984 for a stereolithography fabrication system, also known as the stereolithography apparatus (SLA). Hull's stereolithography 3D system uses digital data of a 3D model to create real three-dimensional objects. His patent is considered the first because Kodama did not follow through with his patent request after one year of filing it.

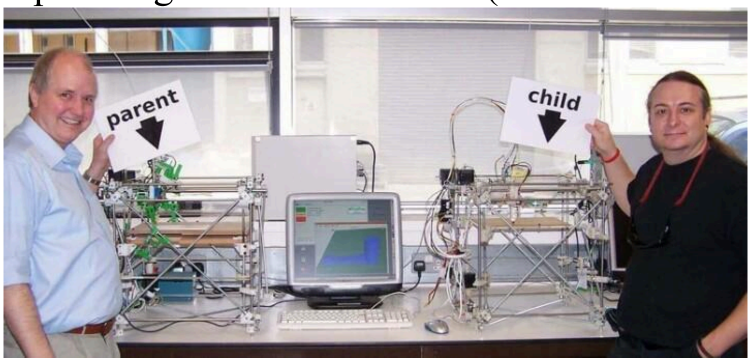
Hull's 3D Systems Corporation went ahead to produce the first commercial 3D printer, the SLA-1, in 1987. The SLA-1 was not sold until 1988, after it had gone through rigorous testing.

Although SLA could be regarded as the first 3D printing technology produced in 1987, another technology, known as the Selective Laser Sintering, was also designed that year. In 1987, Carl Deckard, a student of the University of Texas and working at the university, filed a patent for the SLS RP printing process. Hull's 3D Systems Corporation later acquired the 3D printing process after the SLS patent was issued in 1989.

As research and development continued in the production of RP systems in finding a more suitable manufacturing process, Scott Crump, who co-founded Stratasys Inc., developed the technology widely employed by 3D printers today, the Fusion Deposition Modeling (FDM), in 1988. He filed for a patent for this process in 1989 and sold the first FDM printer in 1992 through Stratasys.

With the entrance of different technologies and makers in the years following the developments of SLA, SLS and FDM printers, the application of 3D printing grew beyond industrial prototyping. Hence, the materials used also grew beyond plastic. Metals and human cell materials were successfully introduced. In 2006, a 3D printer maker, Objet, introduced a 3D printer that could use different types of raw materials to 3D print any objects.

3D printers became affordable at the entrance of an open-source self-replicating printer in 2005. Dr. Adrian Bowyer of Bath University started the RepRap Project to initiate a low-cost 3D printer development. RepRap is an acronym for Replicating Rapid 'prototype.' This remained until 2008 when the RepRap makers produced Darwin, the dream of an absolute self-replicating 3DP (3D Printer) into fruition.



All of the plastic parts for the 3D printer with Vik Olliver on the right were produced by the machine with Dr. Adrian Bowyer of RepRap on the left.

In 2009, a RepRap open-source investor, MakerBot, started selling 'Do-It-Yourself' (DIY) kits that would allow buyers to assemble or make their desktop 3D printers. MakerBot was later, in 2013, acquired by the initiator of the FDM printing process, Stratasys. The years following this saw a sharp rise in this tech's adoption, as the world's first 3D printed plane flew the skies above the University of Southampton.

In 2012, two alternative 3D printing processes were introduced into the RP market. By June that year, B9Creator introduced its printer using Digital Light Processing (DLP). The DLP project was funded through the site Kickstarter.

Although 3D printing has not entirely taken over the world's manufacturing process, it was initially thought of by some that it has gone beyond the initial use for rapid prototyping to direct digital manufacturing (DDM) for high-end industrial manufacturing or desktop manufacturing for low-end manufacturing for hobbyists.

Chapter 2: 3D Printing Technology And Processes

Just like many technological products, there is a general principle that dictates how 3D printing works. There are many processes in printing three-dimensional objects, but all of these processes follow just one direction: additive fabrication.

How it Works

The general principle of additive fabrication is to stack up raw materials layer by layer for an object to be produced. Regardless of the process your machine takes in processing whatever is made; the production stages are the same.
There are four distinct steps in the operation of any 3D printing machine:

A Digital 3D Model Is Required

This is the starting point for any 3D printing. The 3D digital design can be made through softwares made for engineering or photo designs. The standard software programme for 3D digital modelling is CAD. Also, 3D scanners can be used to scan designs off an already made object.

Conversion Of 3D Digital Design To STL File

The second stage is to export the designed model into a .stl file. The STL format derives its name from STereoLithography. The printer cannot understand a 3D model; the model must be saved in a form the machine can understand.

'Slicing' The STL Format Into G-Code

After the digital model has been Converted into an STL format, the model in the .stl file is then 'sliced' into layers for the 3D printer to understand how to go about designing the model. The process of converting the model is Slicing from STL to G-code. G-code is not peculiar to 3D printers alone. It is a set of instructions for the machine describing every movement required to produce an object.

Models are printed according to the G-code: The last step is printing the 3D model in real-time. The printer's movement during the additive fabrication is informed by the instructions it receives from the G-code. Layer upon layer, it prints the designed model.
For any 3D printing to be done, a 3D digital design has to be made first using a design Software, like CAD or 3D scanner. The designed model must then be converted into an STL format, which would be 'sliced' into a readable format (G-code) for the 3D printer to print.
These are the stages involved in the fabrication of three-dimensional and complex objects by any 3D printer irrespective of what such a printer employs a technological process in printing objects.

3D Printing Processes

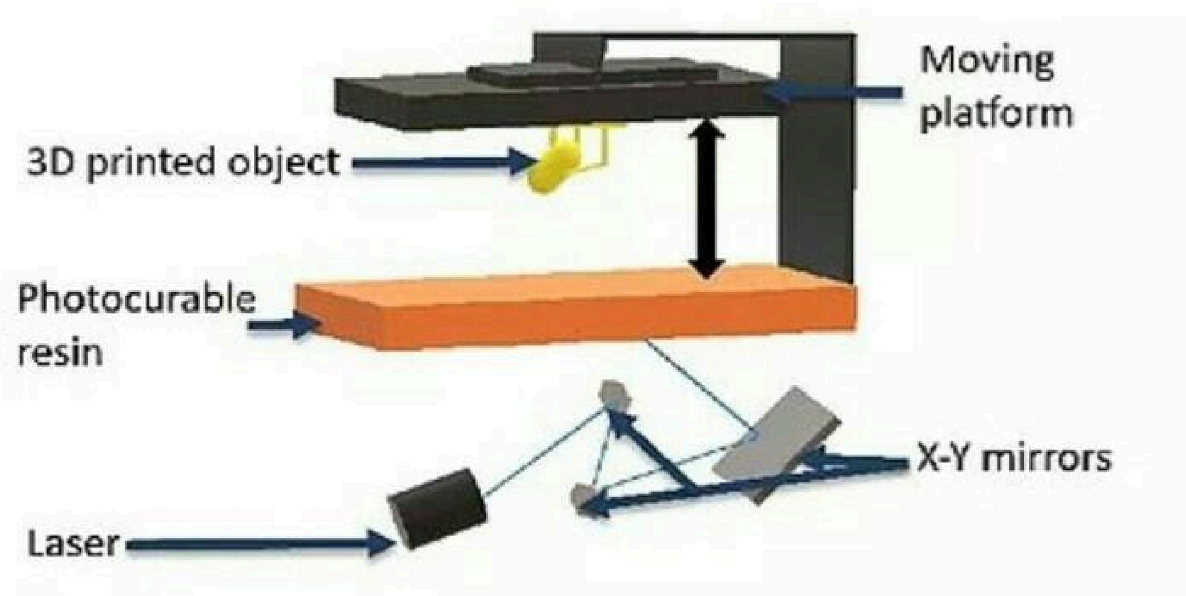
As was mentioned earlier, there are different 3D printing processes employed by different 3D printers in the business of additive manufacturing.
In the course of defining what 3D printing is and its history, SLA, SLS, and FDM have been mentioned. All three of these printing processes and more have diverse technology they utilize in the manufacturing of objects.
The American Society for Testing as well as Materials (ASTM) divides 3D printing processes into 7 classifications:

- Vat Photopolymerisation
- Material Jetting
- Binder Jetting
- Material Extrusion
- Powder Bed Fusion
- Sheet Lamination
- Directed Energy Deposition
- Vat Photopolymerisation

There are three different types of 3D printers that function based on the vat photopolymerisation printing process:

- Stereolithography (SLA)
- Digital Light Processing (DLP)
- Continuous Liquid Interface Production (CLIP)

Of all these three, SLA is the first and the most common. SLA, DLP, and CLIP are developed to use photopolymer resin as their raw material for additive fabrication. The printers are built to have a 'vat' to hold the photopolymer resin. The resin is cured layer by layer on the build platform when exposed to light from a light source.

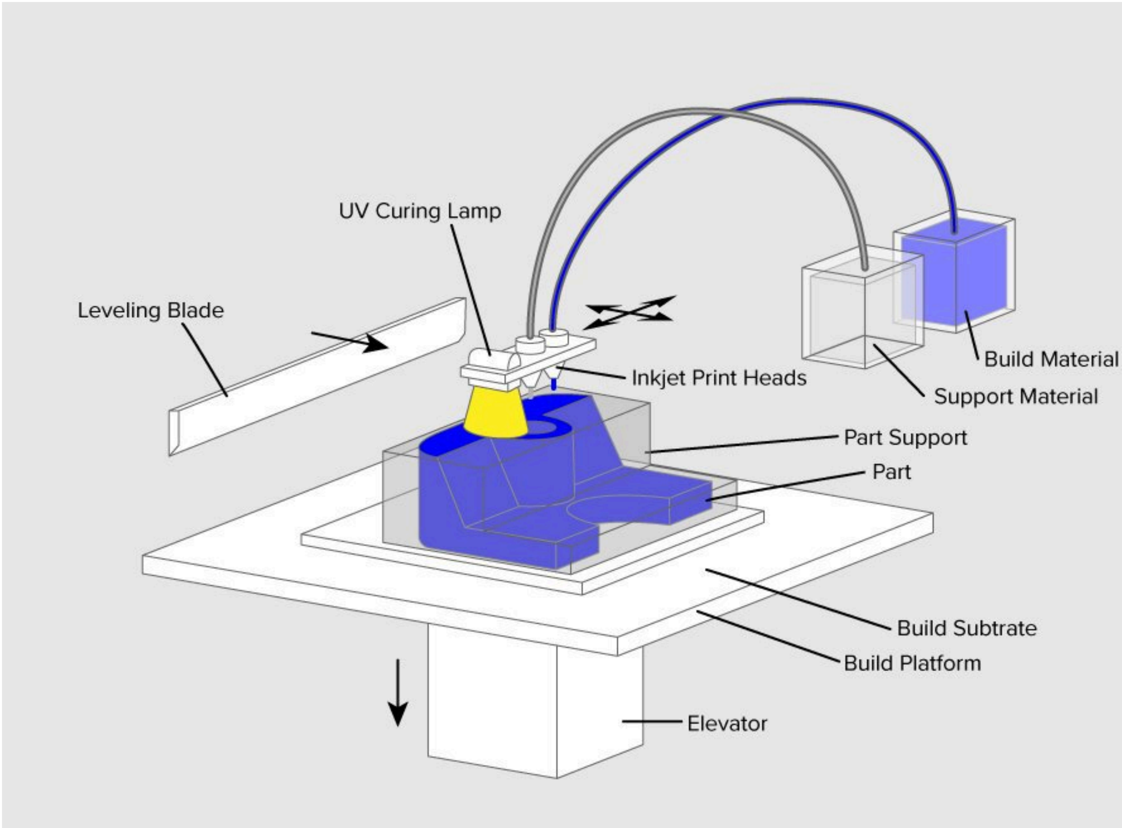


SLA schematics. Image source: fabrx.co.uk

While SLA uses UV laser light to cure and solidify the exposed resin, the DLP utilizes a more conventional light source - more like an arc lamp.

Material Jetting

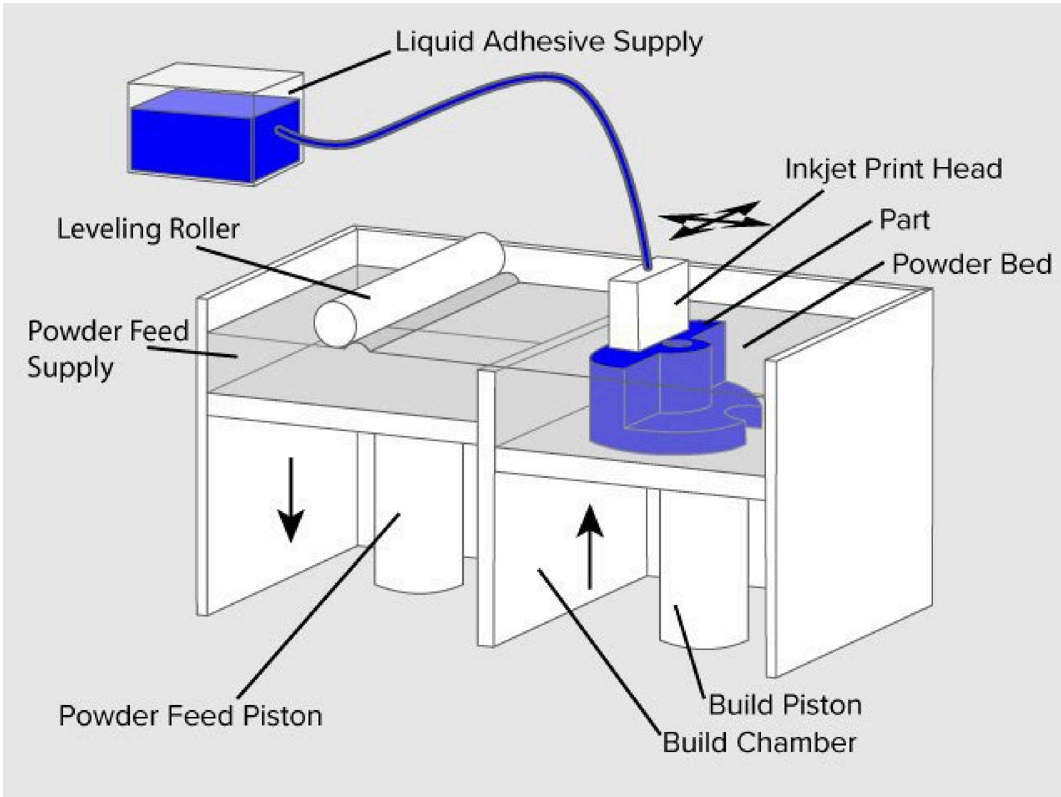
Material jetting works much like a 2D inkjet paper printer, except it is a 3D printing process. The production materials are selectively applied through multiple nozzles to the build platform, cured of ultraviolet light. The build materials, in this case, are usually liquid photopolymers.



Material Jetting schematics

This process could sometimes be called poly jetting, as it allows for the use of multiple materials with support materials also simultaneously jetted out when needed.

Binder Jetting



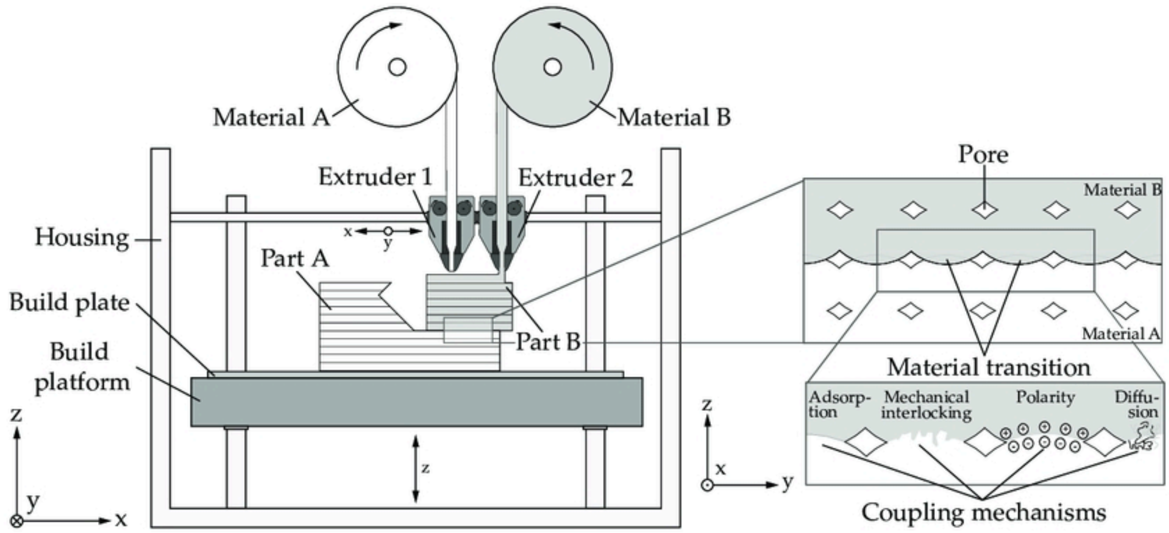
Binder Jetting schematics

The binder jetting technology was developed and used first at the Massachusetts Institute of Technology in 1993. This process utilizes two materials to build a part. One serves as a binder, and the other as the build material - usually in powdered form.
The binder jets out a glue-like substance which fuses each layer of the part material (in powdered form) to the next. This method is reiterated until the part is developed.
As with most processes using powdered materials, binder jetting requires no support during printing the part. This also allows for the use of different powdered materials like food flours and ceramics.

Material Extrusion

There are two types of machine using material extrusion process:

- Fused Deposition Modeling (FDM)
- Fused Filament Fabrication (FFF)



Material Extrusion Schematics

Image Source: Researchgate

Fused Deposition Modeling is the first and most common of these two. It is the most used of all the printing processes. The FDM process was invented and patented in the late '80s by Scott Crump of Stratasys Inc. The method uses plastic filament unwound from a reel into an extruder: it is a chamber where the plastic filaments are melted. The melted plastic is then extruded out to the build platform through the small-diameter extrusion nozzle. The deposited melted filament is stacked up layer by layer as the nozzle moves in the X-axis and Y-axis, while the build platform moves in the Z-axis.

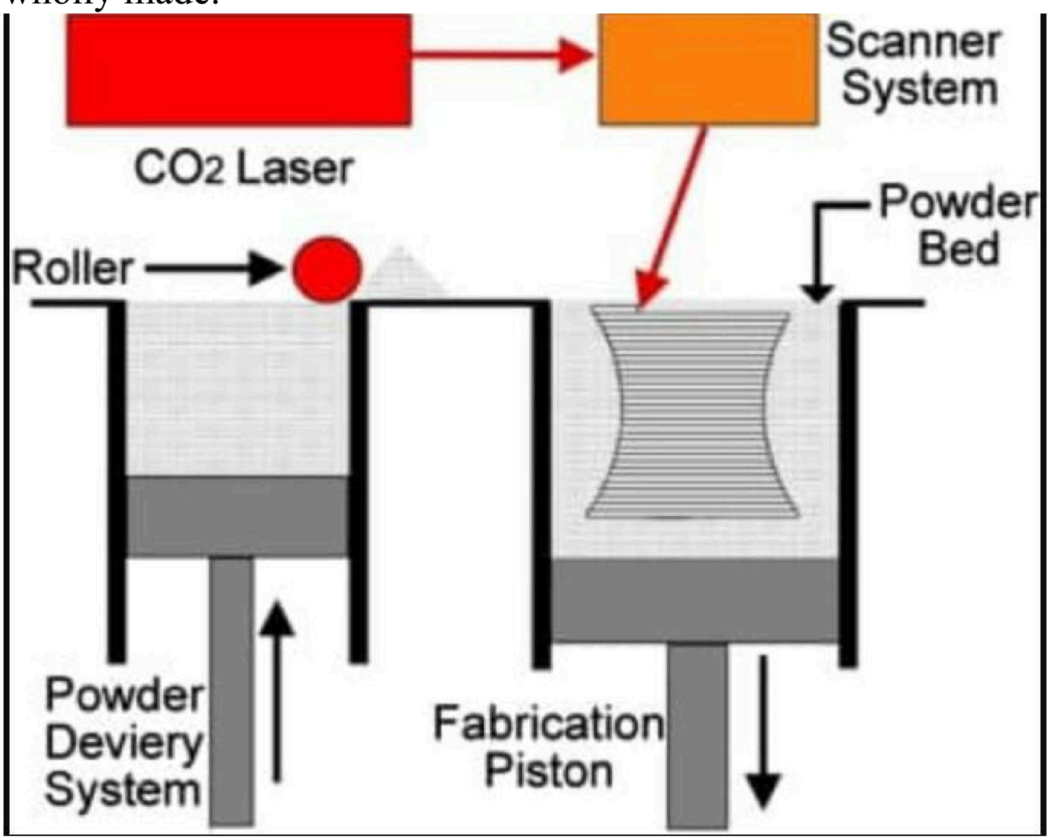
The FFF works the same way as the FDM, except that this process is unrestricted to be used by anyone. The acronym FFF could also mean FreeForm Fabrication. The RepRap movement coined this concept.

Powder Bed Fusion

Just like the name implies, the build material employed in this process is in powdered form. This powder is fused, melted or sintered together using different techniques to mold a 3D object.
The various techniques are;

- Selective Laser Sintering (SLS)
- Direct Metal Laser Sintering (DMLS)
- Multi-Jet Fusion (MJF)

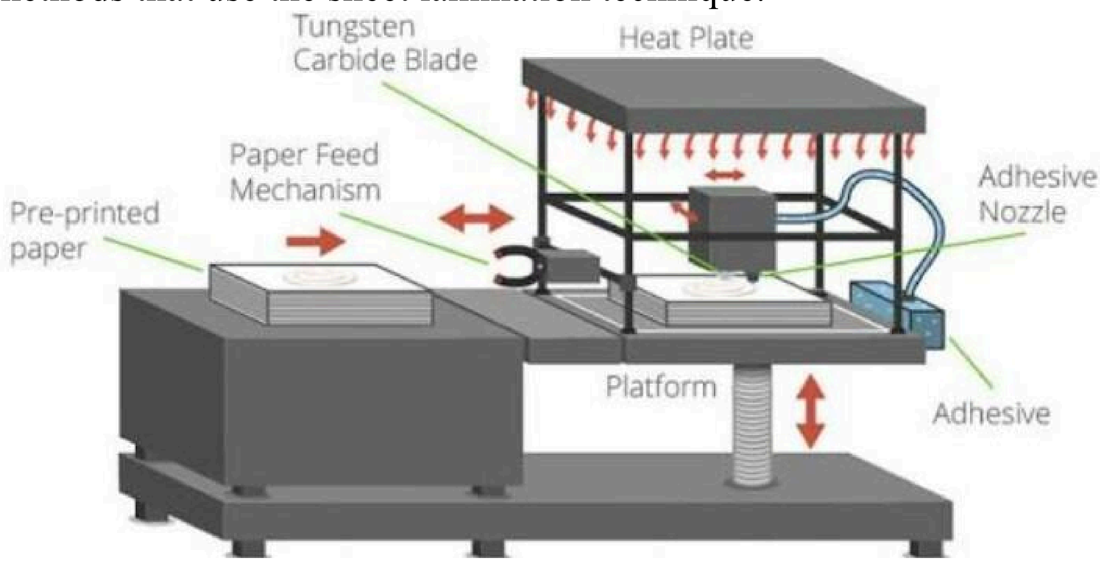
SLS is the oldest of them all. This technology developed in the late '80s by Carl Deckard works by using a high power laser to sinter (mould together) particles of powder into a solid 3D shaped object. The process is selective, in that the sintering laser light scans the layers of the 3D digital item on the powder bed. The powder bed moves a step lower at the size of the thickness of each layer scanned. This allows the formation of a new scanned layer on top of the previous layer. These processes are repeated until the 3D object is wholly made.



SLS schematics. Image source: microworkshops.co.uk
DMLS works in the same vein as the SLS. The only exception to DMLS is that it uses metal powder only. Just as it is with SLS, DMLS unused power is packed to be re-use for another additive fabrication.
Instead of sintering using high power laser light, Multi-Jet Fusion (MJF) uses dozens of glue-like substances to fuse the powder particles. Layer by layer, an arm of the machine deposits powder particles and the other arm, with a series of nozzles, injects selective binders (a glue-like substance) to bind each layer to the next. Because objects built using this technique are not always rigid, SLS is preferred. Hewlett Packard developed this process.

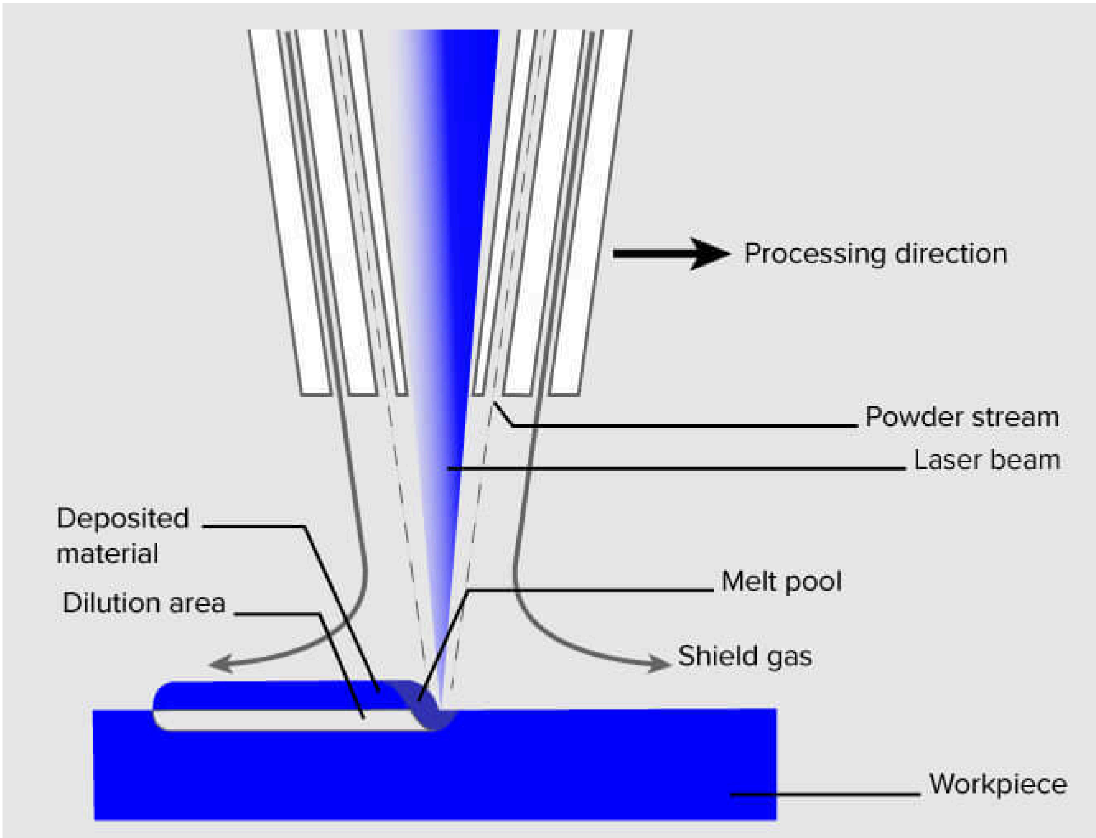
Sheet Lamination

This is additive manufacturing, whereby sheets in layers are bonded together to mould a single 3D object. Laminated Object Manufacturing (LOM) and Ultrasonic Consolidation (UC) are the two 3D fabrication methods that use the sheet lamination technique.



Sheet Lamination schematics. Image source: 3DPtinting.Lighting
Build sheets used in this process include metal, paper, or polymer. The bonding method for each of these materials is different. Ultrasonic welding are used together to weld metal sheet, while paper and polymer sheets are bound by adhesive glue.

Directed Energy Deposition



DED schematics

DED printers are not the sort of 3D printer found amongst hobbyists. They are mostly found in large steel milling firms. This process involves the deposition of layer upon layer of melted build materials - usually metals - by thermal energy use.

Summary

3D printing technology is additive manufacturing. A 3D model created with a CAD or scanned is 'sliced' into a readable format for a 3D printer to 'print' 3D objects by adding a layer to existing layer(s).

This tech comes in different processing styles. Some build three-dimensional parts from liquid resin, powder, plastic filaments, or sheets. The differences in the raw materials needed for 3D printing informed the use of different processes: material deposition (extrusion), material jetting, binder jetting, powder bed fusion, sheet lamination, directed energy deposition, and more. A common thing to all is the method of manufacturing. If it is not additive manufacturing, it is not 3D printing.

Chapter 3: Choosing a 3D Printer

The previous chapter discussed how 3D printing works and extensively discussed the different processes involved in 3D print parts. But in this chapter, the discussion will center on choosing a 3D printer.
The first question you might want to ask yourself is, "Do I need a 3D printer?" Yes and no, depending on so many factors. You might be running on a lean budget, and you might not want to add a 3D printer and its expenses to that. So, if you can't afford one, not to worry; there are many online sites that provide 3D printing services to the public and deliver your prints.
Below are a few places to get your 3D projects done and delivered to you:

Craftcloud

Craftcloud delivery service is worldwide. This means you can be in Saudi Arabia; choose and print your 3D object on their site, and get it delivered to you. The build materials they offer include PLA, ABS, nylon, resin, and many more. Check online for Craftcloud.

- 3DExperience Marketplace
- Shapeways
- Sculpteo
- 3D Hubs

All of these provide worldwide delivery services. They also offer a wide range of build materials that you can imagine.
If you decide to get a 3D printer, however, you should know what you are getting. It would be disastrous if you choose to pick a particular type of 3D printer without knowing the load of problems that come with it.

What Printing Process You Should Choose

It is essential to know which printing process would be suitable for your project. Out of all the methods mentioned above, only three 3D printing processes suit a beginner. This is because these three processes are quite

common: FDM of material extrusion, SLA of vat photopolymerization, and SLS of powder bed fusion.
All of these processes have been well discussed. But let's take a look at their strong and weak points so that we can decide on which one to go for.

FDM Printers

This process involves extruding melted filament layer upon layer on a heated bed to create an object. Much of this has been earlier discussed.

Advantages

3D printers that adopt this manufacturing process are the cheapest because they are common; they are the most recognizable 3DP process. You can readily get an FDM desktop printer for as low as $500.

- It is also very easy to operate.
- Maintenance is the cheapest of all 3D printers using other processes.
- The material (filament) employed by this printer is also very common.
- The online support is great for beginners.
- It provides accurate and reliable 3D print of an object.

Disadvantages

Materials are mostly limited to ABS and PLA plastic filaments at the entry-level. This is changing, however.
The layers of 3D printed objects are usually visible.
The FDM printing process sometimes requires a support structure for complex designs. This means a second material that could dissolve in water might be needed.
As fast as the printing of FDM could be, it can be prolonged for some geometry.
If the right measure of material is not used, the printer could stop working due to clogging.

Stereolithography Printers

Although SLA printers are not as common as the FDM printers, they are, however, the oldest 3D printers to be commercialized. SLA printers adopt the SLA printing process.

Advantages

- It is the most accurate of all 3D printers. So anyone needing great detail in his or her final product should go for SLA.
- You can easily get help online.
- Final product is smoother than FDM

Disadvantages

Using liquid resin and other limited materials can be quite expensive.
It also requires a support structure for some three-dimensional objects. This structure needs to be sometimes manually removed.
Sometimes, the final product needs to be subjected to much heating to harden it.
They are not as common as FDM.

SLS Printers

The SLS printers follow the principle of powder bed fusion in how it operates. They are likely the third most common printers after FDM and SLA.

Advantages

Complex shapes that cannot be 'printed' using any other processes or printers can be done with the SLS printers.
Materials are not as limited as FDM and SLA. SLS printers can process both metal and plastic materials
No support structure is needed for production.
Objects produced this way are miles stronger than most created using other 3D printers.
They are better in accuracy than the FDM.

Disadvantages

There are no known desktop models for now. So, they are only industrial models available, which makes them very expensive.
It requires a very high temperature for laser sintering of powder particles.
It takes quite some effort to clean up excess powders around the produced object.
By understanding the advantages, as well as disadvantages of these three standard printers, can help you make a healthy choice.
As a beginner, FDM/FFF would be the recommended choice; and this book would focus on that. Why? FDM/FFF printers are very common and materials, though limited, are easy to come by. They are also easier to operate than the rest.
Before opting for any FDM/FFF printers, there are some questions you should ask yourself: What type of package to go for? And, what is the need for the printer?

What Package Type To Go For

At the point of buying a 3D printer, you will be faced with the option of either purchasing a printer kit or a completely assembled printer.
If you love the challenge and are up for it, you can buy a 3D printer kit. These kits come with guides as to how to assemble your machine. You also need to have a little bit of some technical abilities. RepRap machines are a place to start when buying 3D printer kits.
Buying 3D printer kits comes with some of its risks. Don't go for the wrong kits because they seem cheaper than assembled machines. Poorly constructed machines by you can lead to fire; this is not very common, though.
Although some benefits are attached to buying kits and assembling your machine, buying an already completed machine is recommended. If you would be getting a desktop 3D printer, the chances you will get an already assembled one by the producer are very high. However, the assembled ones are a little expensive.

What Is The Need For The Printer?

What do you need this 3D printer for? There are a lot of reasons to buy or own a 3D printer.

You can decide to hop on the new trend of additive manufacturing as a hobby. You desire to try the latest tech involved in manufacturing objects. With this mindset, you can produce anything you think about around your home or office. You can create toys, vases, a broken dial of a washing machine, board game pieces, and even models of things or people you love. The list of what you can create with a 3D printer, as a hobbyist, is vast.
You can also have prototypes of what you want to produce created with your simple desktop 3D printer; as a business owner into construction, having a model of what you desire to construct before the actual construction is helpful. Printing your model with a 3D printer could cut costs and help convince your clients.

Things to Look for Before Choosing a 3D Printer

When choosing a model or brand of a machine that suits your need, there are things to consider before you make a purchase:

- Price
- Reviews
- Reliability
- Customer support/support community
- Material
- Price

You have to consider how expensive a 3D printer is before you spend on it. You have to consider what the 3D printings you will be doing to know the machine's price range that fits your needs. You have to know what features you will be getting vis-a-vis the money you will pay for the machine.
As a hobbyist, how much are you willing to part for your hobby?

Reviews

You need to review what people are saying about a brand or model of the machine you want to get. It is essential to know the strong and weak points of a machine before you flash the cash. By doing this, you are prepared for anything that comes your way.
You can ask friends or family members who have experience with the 3D printer you intend to acquire. There are also online places that provide such

reviews.
Sites like 3dprinterreviewsite.com and toptenreviews.com can pretty much help you get reviews of any machine you wish to get. There are other online forums to ask questions about whatever machines before you buy.

Reliability

Reliability might mean different things to different people. To some, it is the machine's accuracy; to some, it is the quality of a machine's final product. The speed in completing a task could also mean reliability. Whichever you go for, both the quality of what is produced and the machine's accuracy to details are essential.
The quality of what is produced might partly depend on the material used. It is not always dependent on the machine. It could also depend on your understanding of how to make necessary adjustments to the printer.
Concerning the speed of operation, some 3D printers complete tasks very fast at the expense of quality. Some would give you a good quality product longer than you desire. Not all machines would give you both.

Customer Support/Community

The next thing to take into consideration is the community support for any model of a 3D printer. There are lots of massive online communities for most models of 3D printers. There are common problems that you can solve on your own when you visit these online communities. You meet people who have had such issues and could put you through on what to do.
Also, there should be customer support from the makers of your machine. If there are none, buying such a machine is not a good idea.

Materials

Some 3D printer makers design their machines so that the building materials for production can only be bought from these makers. That wouldn't be a problem if you get such materials easily and at a low price, but it would be if that is not feasible. You want a machine that is flexible with available materials.
There are many other factors to consider when choosing a 3D printer, like the cost of running it and maintenance cost. But when the factors mentioned

above have been thoroughly considered, be rest assured you will get the best machine that suits your 'printing' needs.

Chapter 4: Tools And Build Materials

Our discussions before now have centred on 3D printing, its history, and the printers and the processes employed in 3D printing. But in this chapter, our focus would be on the essential software and materials that help make 3D printing possible.

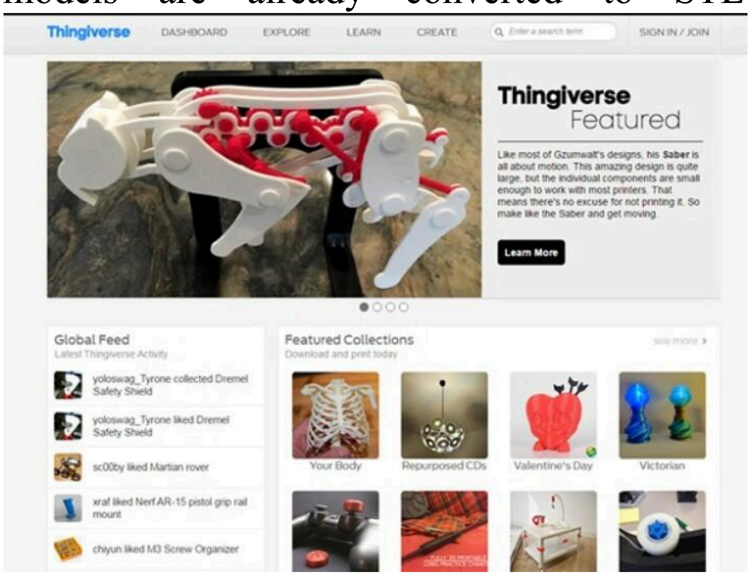
Essential Steps and Tools Required

In the discussion relating to how 3D printing works, it was mentioned that 3D printing starts from the data of a 3D digital model. This digital model is then interpreted to what the machine could understand in the printing of this model.

By now, you must have got your 3D printer and are feeling so ready to make your first 3D print, but that is just the beginning. Regardless of how your 3D printer is set-up, the steps mentioned above to fabrication have to be followed; and there are tools needed to complete each step in this process.

The first step is designing the model: 3D digital models are mostly designed using CAD. There are instances where non-CAD applications are used in designing 3D models. This includes the use of 3D scanners.

If you are bad at creating designs, you can always get an already designed blueprint of what you intend to create online. Sites like Thingiverse and Pinshape offer you lots of free 3D printing models that you can use. Their models are already converted to STL format for your slicer.



The homepage of Thingiverse
But if you are feeling adventurous and very good at designing, then, there are loads of free CAD software you can use:

TinkerCAD

This is recommended for beginners, as it is browser based software.

SketchUp

This is also browser-based.

FreeCAD

This is really not for beginners but still easy to work on. Available on Windows, Mac, and Linux.
Fusion360

Google Sketchup

There other advanced and professional CAD software, like AutoDesk Inventor, you can buy for a full design experience.
Alternatively, you can use 3D scanners. This technology is rare; it also requires lots of work. So, it is not ideal for a beginner.
The second step is to convert 3D designs into an STL file: for any 3D digital model that can be sliced, it must be exported into a .stl file. If you use Google Sketchup, you would have to get Cadspan as a plug-in before converting your models in STL format.
If you use other non-CAD software like Photoshop, you will need to subject your designs to a series of processes to convert them into STL.
The third step is slicing the model: Slicing the model involves converting the saved model in the STL file into an instructional code (G-code) the 3D printer would understand.
Slicers are computer software, just like CAD software used in the digital modelling of your design. There are many slicers to choose from. They pretty much work the same way. However, your machine manufacturer may recommend one for you. Most modern slicers have inbuilt control software in them.

Below are five common slicers to choose from:

- Cura
- Repetier
- Slic3r
- KISSlicer
- Skeinforge

A Slicer helps control the required temperature, speed, and material flow for an excellent layer-on-layer fabrication. More on how to set your slicer for perfect 3D printing would be explained better in the next chapter.

The final step is printing. The G-code from the slicer could be exported to the machine through a USB cord/drive, SD card, or through the WiFi for professionals. Once the machine gets the instruction, printing would begin.

Build Materials

Having gone through the diverse processes and technologies involved in the fabrication of a three-dimensional part, you would have got some ideas of the materials involved in additive manufacturing. These materials range from plastic, powder (metals, food, ceramics, and more) resin, to living human tissue. With the advancement in science and tech, the build materials would likely be limitless.

Our focus on this subtopic would be on plastic filaments, as the discussion is centred on FDM/FFF Printers.

There are two plastic filaments common to FDM/FFF printers: ABS and PLA.

ABS (Acrylonitrile Butadiene Styrene)

ABS is a plastic which is gotten from fossil fuels. It is the plastic used for the production of Lego blocks because they are reliable. ABS plastics are not biodegradable, which puts off lots of environmentalists. They smell like burning plastic when melted in the extruder.

PLA (Polylactic Acid)

This is an environmentally friendly plastic. It is derived from corn, sugar starch or sugarcane. It is biodegradable and gives off sweet smells when melted. Although it is very easy to print with, it is prone to clogging. Another disadvantage it has is that it is brittle. This is why ABS is preferred by engineers: It is very strong and flexible.


Multiple plastic filament reels

How to Store PLA and ABS

When you buy any PLA or ABS to keep for a while, they must be sealed against contact with moisture. Contact with water will reduce the quality of your final product.
If exposed to moisture, both PLA and ABS tend to bubble and gush from the extruder during the printing process. If any of the plastics was in contact with moisture before use, you could dry them up using moderate heat from a food dehydrator.

Before Buying a Filament

Before you buy any of these filaments, it is better you know the design of your machine. Different machines are designed to specific filament thickness because both ABS and PLA come in different thicknesses. ABS and PLA filaments have 1.75mm and 3mm diameters, respectively.

Summary

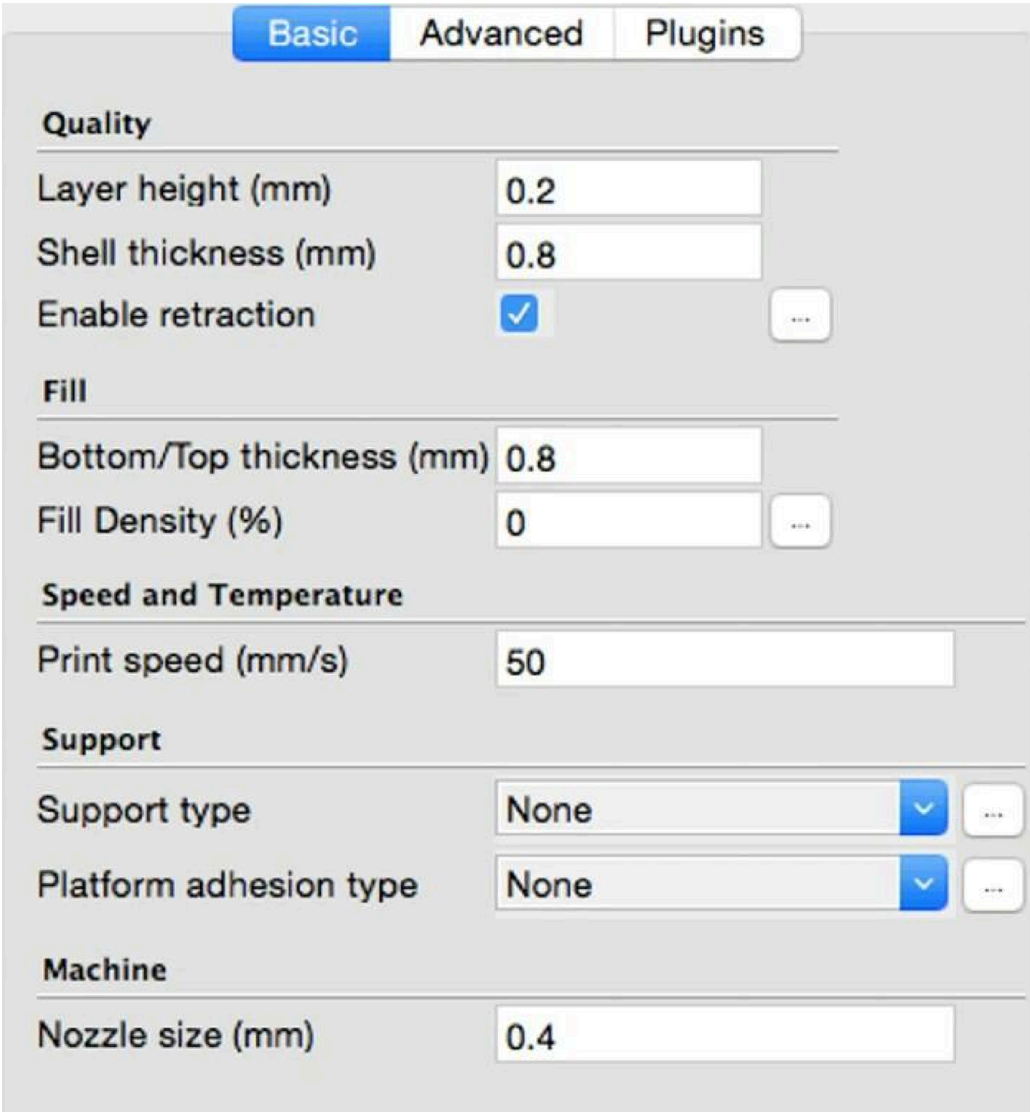
Printing in 3D format is not just about the printer only; the process involves using software to develop a 3D model, slicing the model into G-Code understandable by the machine, and the actual printing. The type of material used for printing depends on what to be fabricated. Materials include plastic filaments, living tissue, powders, and woods. The spectrum of build materials is increasing with the advancement in tech.

Chapter 5: 3D Slicer Settings

By now, we already have a glimpse of what a slicer can do. But to do one better, a slicer is not just a type of software converting your models into G-code; it dishes out printing instructions on how your machine should go about converting your model into a real object.

The slicer does 'slice' your 3D digital model into horizontal layers and determines how much time and material would be needed to complete each layer. After all of this has been done, the information is sent as G-code to the machine. So, whatever error is made during the slicing process could affect the final 3D printed object.

The slicer could be the difference between a lousy print and a significant print. This chapter would focus on helping beginners - or professionals - make basic slicer settings.



The settings on slicer software

There are nine (9) slicer settings to look at for smooth printing:

- Layer Height
- Shell Thickness
- Retraction
- Bottom/Top Thickness
- Fill Density
- Print Speed
- Support Type
- Platform Adhesion Type
- Nozzle Size
- Layer Height

The layer height shows the toughness of every layer during additive manufacturing. The thickness chosen here determines the smoothness of your print. The thicker the layers, the coarser the print would be, and the thinner the layers are, the smoother the final product's surface.
Imputing a lower number would raise the quality of the printed 3D object, of course, this at the expense of speed. The printing will take a longer time to complete if the thickness is set to be thin. This is, however, different with higher numbers.
An average of 0.15 to 0.2mm would give a fine print and quality. A lower quality would be achieved at 0.6mm with a much-improved speed than 0.2mm.
Some slicers like Cura recommend 0.1mm for a quality printing that requires much detail and 0.2mm for prints requiring fewer details.
You can work on this setting to understand how it works on your 3D printed object.

Shell Thickness

This setting affects the thickness of the outer wall - or sidewalls. This setting determines the strength of the fabricated object.
3D printers traced the outer walls before getting to the inner hollow part of the design. The default measurement for almost all 3DP is set at 0.8mm. If, however, you want a thicker wall, you can raise this number. The lowest we recommend you go should be 0.4. If you are a little confused about this, stay at the default number of your slicer.

Retraction

Retraction is mostly enabled on many slicers. This is a good thing because it occasionally pulls back into the nozzle the melted filament in the extruder to skip places on your 3D design with gaps.
Although this is good, it can be very messy: The melted filament clogs the extruder if retraction takes longer than expected. You can always disable this setting if it does not affect your project.

Bottom/Top Thickness

A 3D object is not always strong on the inside. This setting is directed towards the thickness of the top and bottom layers of the object. This helps reduce wastage of build materials. It is recommended that you set it to between 0.6 and 0.8mm.

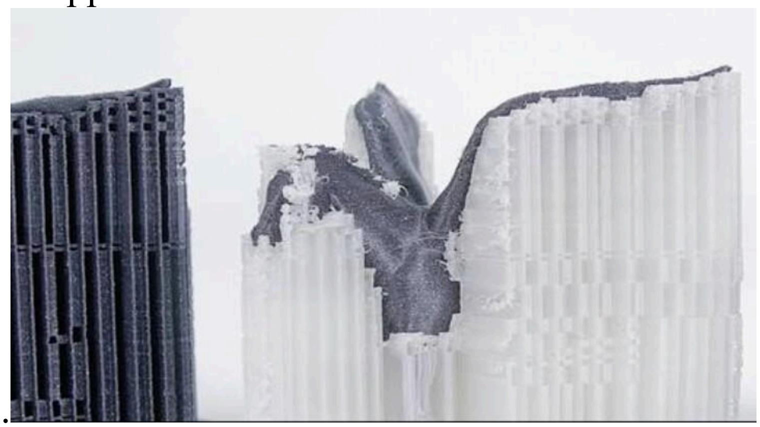
Fill Density

This is used to determine the density of the space inside the outer wall of the 3D object. This is measured in percentages (%) as opposed to mm.
A completely solid object has an infill of 100%. This means such an object would be weighty. The lower the fill density, the less heavy the object would be.
It will be a waste of material if 3D is always printed with a density of 100%. The recommended thickness for most objects should be between 15 - 25%. You can go as high as 45% if you desire a solid object.

Print Speed

This refers to the travelling distance covered by the extruder in laying the filament per time. The print speed can also affect print quality. The faster the extruder's print speed, the higher the chance of getting a deficient quality print. But this shouldn't be an excuse to lower the print speed. It might take forever to complete a print; yes, the quality is assured.
The advice would be to stick to the recommendation given by the maker of your slicer. The best speed range should be between 50mm/s to 70mm/s.

Support Type

One of the few disadvantages of FDM printing is the inability to fabricate complex objects without a support structure. This is because fabrication always starts from the base.
A dragon is printed on a support structure.

Support in 3D printing is like the scaffolding used in regular construction sites. Say you intend to fabricate an object with overhangs with angles of 45 degrees; there is always a need for support. To break this down, objects with "H," "T," and "Y" shapes need support.

In the drop-down menu of the support type, there are two support types to choose from:

Touching Build Plate

Sometimes, not all the printing parts of a design need support. This is the type of support to choose where the intended object's section needs support to build.

Everywhere: Just as its name implies, this is used for part of an intricate design that needs support all through. When a design has overhangs everywhere, you choose this.

Platform Adhesion Type

Warping is sometimes common to 3D prints on platforms with either uneven surfaces or surfaces that wouldn't hold the print nicely. There are two types to this:

Raft: This is the right choice for an uneven platform. A small horizontal raft or grid is laid or printed before the actual 3D object is printed when this is chosen. You can do this for objects with a shallow or thin base.

Brim

This helps reduce warping by printing outer layers around the bottom of the object, which keep the corners of the object glued to the platform.

Nozzle Size

Nozzle Size could be 0.4mm or 0.3mm; it could be whatever you want. But know this, the smaller your nozzle's size, the better the quality of your object. This would also affect your machine's printing speed: The smaller the nozzle, the slower the 3D printing process and vice versa. If you are unsure, you can leave this on default on your slicer; google the size right for your machine.
Other settings that you may find on some slicers are;

- Printing Temperature
- Bed Temperature
- Filament Diameter
- Flow Percentage

Both printing and bed temperatures can be left to the default settings of the slicer you are using. Flow percentage can also be set to default, which is mostly 100%. It is used to adjust the rate of flow of melted filaments from the extruder. You can either reduce or increase this to suit your needs.
As mentioned earlier, there are only two filament diameters - 1.75mm and 3.0mm - depending on whether you go for ABS or PLA. Set your slice to meet the filament you use.
When all of these settings have been completed, the slicer converts them to G-code for the machine. The converted code could be sent to the machine in three ways:
Through the use of a USB
Through the use of SD Card, or
WiFi

Chapter 6: Benefits and Applications of 3D Printing

When we began this course, we mentioned that 3D printing technology had changed three-dimensional objects' fabrication process.
Until the start of the industrial revolution, manufacturing has been subtractive, but 3D printing tech has introduced a different manufacturing object, known as additive manufacturing. So, is there any benefit to this? Yep, there are many! But a few would be discussed.

Speed

Printing in 3D format is often referred to as rapid prototyping because, unlike subtractive manufacturing, it requires lots of processes before an object is made; it is fast. Even changes in the design can only take a few minutes to a few hours for an improved fabricated object. This also helps in complex structures that could otherwise take months of planning to produce. Within hours, such complex designs would have been made with 3D printing tech.

Flexibility and Customization

In traditional manufacturing, customization means new casting tools would be needed for a slight change in the original design. This is different from 3DP tech. Changes in the design can be done with the same machine, in the same build chamber without additional tools. If a change in the support is needed, this can be done in the slicer settings. So, with this tech, customization is possible without additional time or tools.

Cost-Effectiveness

3DP tech eliminates the astronomically high cost involved in the production of objects. The money expended on labour and machinery for the fabrication of different objects is immensely cut with 3D printing fabrication. Wastage of raw or build materials during chiselling and other traditional fabrication processes are not in 3D printing processes. About

80% of materials used in traditional manufacturing are waste; such waste is eliminated using 3DP. All unused materials are reused.

Localizing Production

Goods that may need to be imported into a place where required could be 3D printed in such a place, cutting the time, cost, and stress involved in importing such goods. With 3DP, accessibility is a certainty.

Environmentally Friendly

3D printing tech has brought a perfect way to cut the carbon footprints in the economy's manufacturing sector. Since most of its materials can be recycled to cut wastage, there wouldn't be many non-biodegradable materials to be disposed of.

Applications

Based on the massive benefits that come with the use of 3DP in the manufacturing of products and complex three-dimensional objects, 3DP tech has been overwhelmingly adopted and used across all industries of the world economy. From health care to food production, this technology is no less a force to reckon with.

Health

3D printing tech has been well received in the health care sector. The technology has been utilized to fabricate some medical items like hip and knee implants, hearing aids, personalized prosthetics and implants for patients suffering from diseases such as osteoarthritis, osteoporosis and cancer.

It has been widely used in the dental industry. Crowns and dentures have massively been 3D printed. 3D printed surgical guides for dental and other medical operations have also aided dentists and surgeons in different medical fields.

Automotive

The automotive industry is one of the early adopters of 3DP tech. Ford, for example, chunks out about 20,000 3D printed parts yearly. Many other automotive companies are also looking to produce spare parts using this tech. Hobbyists, who are eager to show off their 3DP abilities, now try to restore old cars using 3D printed parts.

Aviation

The aviation industry has keyed in well into the use of this tech. It is on record that GE Aviation, a subsidiary of General Electric, has used additive manufacturing to produce more than 30,000 Cobalt-chrome fuel nozzles for its LEAP aircraft engines. This innovation by GE Aviation has also been used on Boeing 787 Dreamliner.
Other high-profile users of this tech, besides GE Aviation and Boeing, in the aviation industry are Rolls-Royce, Airbus, and BAE Systems.

Construction

Hundreds of houses have been 3D printed already. So, there is no question as to whether this is possible or not. From 3D printed architectural models to actual home construction, 3DP tech has been relatively active in this industry. It is estimated that homes additively constructed using this tech can last 50 to 60 years.

Rapid Manufacturing (RM)

This tech has evolved from the rapid prototyping used for rapid manufacturing by a host of manufacturing industries. Because it provides a cheap and fast way to the whole production process, 3DP has broadly been adopted in this industry to produce both prototypes and actual objects.

Food

Although this technology was adopted very late in the food industry, it has become a very active food processing tool. 3D printing has been used very actively to process foods with chocolate and sugar as raw materials. Mélisse in Santa Monica; La Enoteca in Barcelona; La Boscana, also in Spain; and Food Ink in the UK are all famous restaurants printing food with tech use.

Food Ink serves you 3D printed foods and cutlery while you eat on a 3D printed table and sit on a 3D printed chair. Almost everything you use in the restaurant is 3D printed.

Consumer Products

Jewelry, fashion, footwear, eyewear, and many other end-use products have been produced using additive manufacturing.
Although this has not been fully commercialized, companies into end-user products have extensively employed this tech in manufacturing. Adidas has successfully manufactured hundreds of thousands of 4D range midsoles since 2018 using 3D printing.

Education

3D printing is not new to those in the line of education. SLS was first developed between the four walls of an educational institution. Courses like architecture, engineering and those relating constructions have been using 3D CAD applications for a very long time.
There are Universities now offering diploma courses in 3D printing. Besides that, universities utilize 3DP tech for research purposes. 3D prints help students with the visualization of complex topics.
Others
3DP tech is applicable in industries like defence, entertainment, art, and many others not covered in this guide. For example, pieces of board games can and have been produced using additive manufacturing of 3D printing. In defence, light-weight surveillance equipment has been manufactured.

Chapter 7: Basic Maintenance of 3D Printer

To continuously enjoy the many benefits discussed in the last chapter of this guide, it is essential to care for and maintain your 3D printer.

A machine not cared for would only break down within a short time; if not, it would not give you quality print or work to its full capacity. You don't want this for a machine you spend so much to acquire, so below are a few of the maintenance tips to help keep your machine in shape.

Lubricate the X, Y, and Z rods

As your machine is mostly built of metal, it is vital to lubricate any moving parts, especially the X, Y, and Z rods. These rods ensure the movement of the extruder in these axes. If these parts lack lubrication, friction sets in and movements are restricted. It is vital to lubricate once a month after cleaning. Also, make sure that the oil applied should not be too much, as it could attract dust.

When selecting a lubricant, be sure to know the recommendations of the manufacturer of your 3D printer. If no specific recommendation is given, there are common lubricants for 3D printers to choose from. This includes white lithium greases and dry lubricants like silicone and Teflon.

Periodic Inspection and Cleaning

It is vital to inspect your machine once in a while. This can help you assess minor problems on your machine and detect potential ones. While on this, you can also clean up your machine. After lubrication, your machine may have packed some dust. This is why your machine should be cleaned; this includes the machine's build plate and other components.

Tighten Loosen Screws

The continuous motion of your machine may cause some nuts and bolts to become less tightened. The pulley screws around the X and Y axes are mostly affected by these continuous vibrations. Loosened pulley screws will affect your print quality; therefore, it is recommended that you tighten all the loosened nuts and bolts on your machine whenever you do your periodical inspections or when you notice unusual movements or vibration of the machine.

Adjust Belt Tension

Timing belts are common to most FDM/FFF 3D printers to transfer motion around the X and Y axes, so they need to have the right tension for quality printing.

If the belts are too loose, they become slack and respond sluggishly to any change in command; if too tight, the machine becomes stressed and breaks down. To prevent this, install a belt-tensioner mechanism that would aid you in adjusting these belts accurately. You can also consult your printer's guide book.

Nozzle Cleaning

Use a wire brush to clean the nozzle of your machine. This is important to avoid clogging of the nozzle due to melted plastics that have accumulated around the nozzle. You can also use some filaments designed for cleaning.

Besides clogging issues, you can also have extrusion issues if you fail to clean up your machine's nozzle periodically.

Replace Worn-Out Or Old Parts

After years of using your machine, there would come a time you have to replace expired parts. These parts may look to still be giving you some measure of quality work at the moment. But when you notice you are not getting the level of quality you are used to, then do not hesitate to change these old parts. This should not be a problem for those using 3D printers like the RepRap.

Calibration

One good step of maintenance to always consider is calibrating your machine. It's an excellent way to check the surface quality and bed Adhesion and solve most of the issues that have been discussed above. Low-quality prints, under-extrusion, over-extrusion and overheating are other issues calibration will help eliminate.

Firmware Update

Just as you update your computer's software for optimal functionality, so you should do with your 3D printer. The manufacturers of 3D printers usually provide firmware updates. Never hesitate to update your machine's firmware when available.

Conclusion

Decades after it was first used, 3D printing has moved from RP to RM. It has grown beyond the gigantic machine restricted to industrial complexes to a self-replicating desktop machine that could be found in people's homes. Also, It has become widely accepted in every industry you could think of. These might not be unconnected to the rapid advancement in technology and the different technological processes employed by other 3D printing machines.

3D printers that function based on processes like vat photopolymerization, material jetting, binder jetting, material extrusion, powder bed fusion, sheet lamination, and directed energy deposition have made possible the production of anything across all industries using build materials like plastic, powders, sheets, ceramics, resins, and human tissues.

As the range of build materials utilized for manufacturing by this technology grew, industries like healthcare, automotive, aviation, construction, food processing, and education have thrived using this tech.

Parts of the benefits these industries have derived from adopting 3D additive manufacturing are the speed of production, the accuracy of producing complex designs, flexibility, cost-effectiveness, a waste reduction that characterizes traditional manufacturing, and bringing production close where it is needed the most.

Nevertheless, all of these benefits would not be accrued to either people willing to use the 3DP tech in these industries or hobbyists if maintenance is neglected. It is crucial to make routine checks on a frequently used 3D printer. A critical step in maintenance is a constant calibration of the machine for quality object printing.

With most FFF or RepRap 3D desktop printers costing as low as $300, you can now do some fun manufacturing at home. Boardgame pieces, a broken machine dial, or damaged car parts can all be manufactured by you. Just follow the guidelines in this book, become very good at 3D printing your stuff, and spend nothing on something you can fabricate.

Glossary

- 3DP: 3D Printing
- RP: Rapid Prototyping
- CAD: Computer Aided-Design
- SLA: Stereolithography Apparatus
- FDM: Fusion Deposition Modeling
- SLS: Selective Laser Sintering
- RepRap: Replicating Rapid Prototyper
- DLP: Digital Light Processing
- DDM: Direct Digital Manufacturing
- STL/.stl: STereoLithography
- FFF: Fused Filament Fabrication/FreeForm Fabrication
- CLIP: Continuous Liquid Interface Production
- DMLS: Direct Metal Laser Sintering
- MJF: Multi-Jet Fusion
- DED: Direct Energy Deposition
- PLA: Polylactic Acid
- ABS: Acrylonitrile Butadiene Styrene
- RM: Rapid Manufacturing

Sales Pitch

What if I tell you that it is possible to make your food, in your kitchen, without paying the chef across the street a dime for it?
Will you believe me?
Oh, the best part, you don't have to know how to cook to make your food!
Will you also believe me if I also tell you that you can produce the broken piece of your board game and other broken things in your home or office without paying for them?
Ahhh, who am I that you should believe? You don't have to believe me, but you can google about these and see how 3D printing is changing the world.
It is estimated that over the last decade, more than 100,000 hip replacements have been 3D printed by GE Additive.
It is forecasted that by 2029 the total market of 3D printed footwear would reach $5.9 billion. More of the same is also predicted for 3D printed eyewear.
Even restaurants are not shying away from benefiting from this tech. Mélisse in Santa Monica; La Enoteca in Barcelona; La Boscana, also in Spain; and Food Ink in the UK are all famous restaurants using 3D printers to make foods for their customers.
So why won't you key in as the rest of the world and enjoy the benefits that come with this tech?
Maybe you think you need about $1000 or need to know about engineering design to get started. Well, I tell you, you might be wrong.
You don't need to have your 3D printer; neither do you need to have any engineering design knowledge to enjoy the benefits of 3D printing. All you need is to buy this book and find out how to go about that.
If, however, you've got yourself an excellent 3D printer or you want to buy a friendly cheap 3D printer to fully benefit from this trend of additive manufacturing, this guide is also for you.
This guide is going to teach you about 3D printing:

- What it is
- The history of 3D printing
- How it works
- How it is better than traditional manufacturing

- The different technological processes of 3D printing
- Why you need a 3D printer
- How to choose a machine (If you haven't got one)
- 3D printing software tools and build materials
- Benefits and applications of 3D printing
- Slicer settings to ensure smooth printing, and
- How to maintain your machine.

You can't get it all in one place like it is done in this book. Order for a copy, read, practice and don't be left behind by technology.
P.S.: All you have to do to make your own food is a 3D digital design of the food, a food material - flour maybe - and a good 3D printer. When you buy this book you get the full gist on how to make that happen.

About The Author

Keith J. Prout is a professional programmer with over 15 years' experience in the tech industry.

He has worked for some of the largest tech firms in the United States and has acquired a deep understanding of software development. Keith and his partner, Stephanie, founded their own development company in 2009 to be able to pursue more demanding and innovative projects. They're serving high-quality customers from all around the world now.

Keith loves spreading his experience through his series of books, creating revolutionary tech applications for his customers, as well as watching old science-fiction movies in his spare time.

Table of Contents