**3d Printing Basics**

The version of 3d printing that I have taken a deep dive in to is called Fused Deposition Modelling (FDM) that term was invented in 1989. It has evolved to the point that there's been for the last few years at least, some semi reliable and affordable home/hobbyist 3d printers so it isn't just the domain of industry & government anymore.

There's kind of 3 levels of FDM printers at the moment, top is the ones that cost more than a car, that industry use, that are reliable, repeatable and solid. There's a rapidly evolving middle ground that used to be dominated by Prusa, but now Bambu Labs, Creality and others have entered this realm and taken a few steps forward. These printers are a bit pricier, but still in reach of the home user. This middle ground is the closest to a usable appliance like printer, that should just work most of the time with minimal user input required. At the bottom there is the ultimate cheapest possible printers where everyone else resides, the Creality Enders, the Anycubics, Artillery, etc. This lowest tier, are all basically a different spin on the Prusa i3 clone built as cheaply as possible, with minimal quality control and cheap components. There is also a weird other tier that spans the bottom two, and that is fully open source build it yourself designs that exist both as bills of materials (BOMs) and instructions online, and more recently third party kits of these printers, these are Voron, Rat Rig, VZbot, and a few others. These build your own printers give you total control over everything and can be made as no compromises basically industrial quality & repeatability machines, or cheaper if you can source or already have the components.

The best way to think of an FDM 3d printer is not as a tool or an appliance yet, they're still a very in development collection of a frame and motors, like a simple robot, that moves a carriage and maybe a platform in 3 axes in a variety of different ways, with a hot melty bit, and a filament feeder bit that moves around as it is told, to melt and deposit plastics in a pre determined path that most of the time, hopefully results in some sort of usable plastic object. Industry has sensors to get better feedback, home users have the cheaper versions, and more recently even lidar has been added to help them self calibrate down to home level thanks to Bambu labs. If you're following, then you may be starting to realise that a nerdy user can integrate additional electronics in to existing designs to modify things to do extra features, and plenty of people are doing this online.

These "dumb" sometimes expensive machines really only do what they are told, they heat up bits, and they move around, and they squirt melted plastic like a mr whippy ice cream, they don't yet have the inbuilt ability to detect anything much other than maybe hitting an endstop, or that a heater isn't heating right, they will continue to move and spit plastic as they've been told regardless. The next part of the equation is that there's a combination of firmware & software needed to tell the machine what to make. Before I get to that though, one critical component in a home FDM 3d printer's ability to be useful is the user. The machine always does what it is told, so most problems in reality are user error, the sooner you get your head around that the better. Most home machines require calibration, levelling the bed, how far each motor or axis moves, how much plastic is being extruded are just the start, then you get in to finer tuning.

**Budget**

Voron Trident kit ~ $1700 - $2100 totally DIY, rock solid once calibrated.

Bambu Lab X1 Carbon $1849 New kid on the block, closed source, has a lidar to calibrate, just works.

Bambu Lab P1P $1069 Cut down version of the above, not enclosed, missing some features, but works.

Prusa mk4 ~ $1400 The established top dog of home printing from Prague. Works, ageing, a bit pricey.

Prusa mini ~ $800 The budget from the top dog, little cantilever, works, pricey for the size.

Creality Ender 3 ~ $250 Crapshoot, massive community, huge modding potential, good starter if you're handy.

Indicative prices at 24 May 2023

As you can see, you can get in to basic printing with a reasonable volume at only $250. You could be making things trouble free for a year on that machine, it may not work out of the box, or you could be anywhere in between. If I got that basic printer, I have enough spare parts and know how that I could get it working regardless, but if you don't have stepper motors, belts, soldering and crimping gear, spare mainboards etc lying around in your garage like some kind of weirdo, then you might be thinking you just wasted your money.  Plenty of 3d printing journeys end here, search FB marketplace for examples.

So in some ways, the more you spend initially can pay off in terms of functionality and longevity.  You really need to weigh up what your priorities are.  If you're starting a business or hobby that just needs to be able to spit out things that work with minimal messing around, then you are going to have to shell out.  If you're a hobbyist who wants to be working on the printer itself as much as making things, then you have a lot more options available.

**Volume required**

Most printers have a cubic volume, a small printer is around the 180mm$^3$, mid range is around 200ish mm$^3$, and the big ones start around 300ish mm$^3$ and above.  Bigger than 300mm in any one axis then starts to require a much higher strength and precision frame, it can be done of course, but again, it will take magic beans and some know how.

It is surprising how much you can achieve with a smaller printer, the smallest Voron core XY is built around 120mm$^3$ build volume.  Prusa mini is 180mm$^3$ and can satisfy nearly every build, including helmets in multi parts.  300mm$^3$ is where you start to be able to print a helmet in one main piece, so if that is your main aim then that's where you need to start.  I initially intended to make a suit of Mandalorian armour, so started with an Anycubic Mega X at that size, and have since modified it to make a really solid and awesome cartesian printer.

**Materials you want to create with**

Every printer will print PLA.  It prints in the open air, and doesn't need a heated print bed.  It is very easy to make a decent looking print with, and does fine detail well.  It has a glass transition temperature at around 60 c though, and under stress will deform over time more than some other plastics.  There are versions of PLA that include wood fibres, or are glow in the dark etc that require you to change the stock nozzle from a brass one to a hardened steel one, as the filament will abrade the nozzle otherwise.

PETG is becoming more common, it likes a heated bed, but will print in the open, needs a bit of a better hotend, but you can upgrade a printer's hotend easily.  It can be complicated to print with, stringy and takes a lot more calibration, but it has a bit more elasticity than PLA, and a glass transition temp of around 80, so can tolerate heat more, and can be stressed a bit more than PLA and retain its integrity, like for a desk clamp etc.

As the materials get stronger, they require more heat to melt, a hotter print bed, and often an enclosed printer to prevent warping which can crack a part or cause the print to fail.  We're talking ABS, ASA Polycarbonate, Nylon etc.  Many also produce fumes, meaning your printer will need to be put out of any living areas, and/or mitigated with carbon recirculating air filters or extraction systems, which you can build yourself from open source plans.  You can also integrate these in to your printers electronics using custom firmware and macros to control these fans manually, or automatically.  It sounds complicated, but once you are getting to this level, you either have an industrial printer that takes care of it, or you've learned to setup your custom firmware, crimp wires and connectors etc and you're used to finding the info you need on github.

**Kinematics**

The most commonly used kinematics are below, there are many more, google tripteron if you are interested.  Hopefully home printers will have beds that rotate as well as twist soon, there are prototypes out there, but the sliced files need to be manually edited for them to work at the moment, you may have seen metal propellors being 3d welded/printed in this manner, it isn't at home yet, but give it time.

Cartesian:  The standard home FDM printer is based on the Prusa i3.  It is a cartesian style printer, where the bed moves forward and back on the Y axis, the frame moves the print head up and down on the Z axis, and the print carriage goes side to side on the X axis. These are relatively cheap and simple as each axis is its own entity usually driven by one motor, although some more solid ones might have two motors on the Z axis. Cartesians include some cube printers as well as some cantilever designs like the Prusa mini. These can be good all round, keep the price, calibration and maintenance simple, and can do anything with modifications, just not at super speeds.

Delta: These are some of the most hypnotic to watch as there are 3 vertical axes all driving movement of the print head in all axes all the time. They are notable for being able to be built to be fast as long as print head weight is kept minimal. They can be large and built to print taller objects, for example if you wanted to 3d print rockets, a delta could be your best bet.

Core XY: These are the beastiest in terms of kinematics and speed. Two or four motors drive the XY movement with two belts simultaneously, and one to four motors drive the z axis via belts or screws. Being cubey, these enclose easier than the others, and electronics are easier to keep external to the enclosed print volume. When built well and tuned with an accelerometer, core XY machines can achieve extremely high print and acceleration speeds making them several times faster than a well built and tuned cartesian.

**Print bed & surface**

Cheaper printers still come with a glass or coated glass bed. These are OK for starters, but they can be heavy, and at some stage the coating will wear out or be damaged and it will need replacing, not all plastics will want to stick, or get unstuck easily either. Spring steel beds powdercoated with PEI are a great all round bed for every use case. Many printers are now coming with PEI beds that magnetically attach to the build plate, some have a smooth and a rough side offering more material versatility.

**Direct drive vs Bowden**

Direct drive is where the motor and gears that push the filament to the melty bit are right next to it. Bowden or remote is where the motor is somewhere else on the frame, and it pushes the filament through a Bowden tube to the melty bit. The longer the path of travel, the more it creates issues and the less likely you'll be able to print with flexible filaments. So if you want to be making your own rubber feet, or bumpers or things like that, its probably better to choose a direct drive straight up. Any printer can be modified from one to the other once you know what you're doing though.

**Slicers**

The slicer is a piece of software, don't worry they're free, that turns a 3D object file in to g code that your FDM printer can understand. They have a range of settings that change the results of the printed item. The slicer basically slices your object in to layers, then breaks those layers up in to a series of movements and extrusions for the machine to carry out, which hopefully result in a successful object being created.

Slicers will need a profile put in to them for your printer, and most printers will have a standard profile somewhere online if not in the slicer already. You can easily pick a printer that has similar enough characteristics though, and change the relevant parameters.

The two main slicer options seem to be Prusaslicer & Cura. I have tried Cura, but ended up switching to Prusaslicer. You probably should try both and maybe others if they appeal to you, to get a feel for the UI, and also what all the settings are and how they change the result.

**Design**

Tinkercad & Microsoft 3d builder are both useful tools for starting, but both retain their place even when you've levelled up to a proper industrial style CAD software. Both can be used for making simple objects and/or merging and splitting larger objects to fit them in your printer.

Fusion 360, Freecad, Onshape and others have free versions with limitations, it really depends on you which one you want to run with.

Fusion 360 limits you to 10 open projects for the free version, but it runs on your PC which can be handy. Onshape doesn't limit you at all, but is browser based, and all your creations are publicly available for anyone else to copy and work on. Teaching Tech on youtube has a great intro to onshape, and they have their own online tutorial too that gives you a certificate. Every CAD has tonnes of youtube tutorials though, so play around and see what you click with.

Designing for printing & slicing considerations

As objects are laid down a layer at a time, the weakest part is often layer adhesion. So when designing and slicing it is something to be mindful of. However different materials vary, and it is possible to print small objects in PETG for example, then test them and tune settings to the point where the structure will fail elsewhere, rather than the layers splitting.

**Printing an object**

The process for making printer spit out plastic thingemy is as follows. You take your 3d file, usually a .stl file and open it in your slicer. You change any settings to suit the object, hit slice, enjoy the preview of the gcode, maybe look through the layers to see if there is anything that looks off, then you save the file. You take that saved sliced g code file and via USB drive/sd card/browser interface if you have one to your printer. You load your filament or already have some loaded in your printer, you tell your printer to print the file and if you're lucky, some time later the object will be ready.

Simple hey.

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