3D Printing: Everything You Should Know

What is it? How does it work? What can it do? How can you get your hands on one?

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3D printing—many of us are aware of its existence, but how much do we really know? The media often shows pictures of parts that have been 3D printed, maybe you've even seen videos of a 3D printer working. This is without a doubt an incredible technology. But since few people have ever been able to get their hands on it, the technology tends to fall into the realm of scientific research for most people—technology that sounds cool but is still far out of most people's grasp. Many don't fully understand it, others see it as magic, and still others don't see the potential in it. However, 3D printing is not a concept technology—it is in use right now. Many of the products that you use every day were designed with the help of 3D printing. Even more exciting is 3D printing is starting to become available to consumers. Low-end models can be purchased cheaply, or even built by avid DIYers, and high-end machines can be accessed through websites like ShapeWays, which allow consumers to 3D print their own self-designed parts in a variety of materials. This is not to say 3D printing is perfect, because it's not. Current technologies have their limitations, and just like any tool out there, there is a right and a wrong time to use it. It is important to understand the current limitations of the technology, but equally important to realize where the technology is headed. 3D printing is not going away, and those that want to truly understand it need to get on board now, at the ground floor. Like all technologies, 3D printing is only going to get more complex, and it will be easier to keep up with if you understand the basics.

To date most types of manufacturing fall into subtractive manufacturing. This is where a large chunk of material is machined down to a smaller size. A great example of this is woodworking. You start with sheets of material and dimensional lumber, and that stock is then cut, and drilled, and sanded, and ultimately what is left is assembled into a final product. 3D printing falls into an alternate category—additive manufacturing. This is where a material is continually added to create a product from the ground up. 3D printers vary in how they do this, but all fall into additive manufacturing. They only use the material they need to create the product, in other words, there is no waste. It seems that 3D printing technologies are constantly being invented, but as of right now it is pretty easy to break the technologies into 5 major groups: extrusion based, granular, powder and ink, laminated, and light polymerized. Each has its strengths and each has its weaknesses, but most importantly, each is constantly being improved. As of right now, there is no clear winner as to which technology shows the most promise, it's like a constant race between the five—with an ever-changing leader.

Extrusion based printing is the cheapest technology of the five, possibly because it is one of the oldest. Most home 3d-printing systems are extrusion based. Extrusion based 3D printers can be more or less thought of as a computer-controlled hot glue gun. A computer controls the print head in 3 planes (x, y, and z), while the

print head melts a steady stream of plastic which is pushed out of the print head (just like a glue gun melts and pushes glue through its nozzle). Two of the major downfalls to extrusion based printing is that it can pretty much only print in plastic, and it takes a long time. Since the plastic being laid down is roughly a 0.5mm wide x 0.2mm tall strip, the printer has to make repeated passes over many layers to create a solid object. Furthermore, the technology is unlikely to ever get extremely fast. Precise heating is crucial to successful prints, and an increase in speed makes it significantly harder to precisely control the nozzle heater. Additionally, plastic needs to be given time to cool before successive layers are added, and rapid changes in motion cause extreme wear on the mechanical parts of the printer. Nonetheless extrusion based 3D printing may be one of the most important additive manufacturing technologies in bringing 3D printing to the general public, as we will see later.

Granular 3D printing technology is a fairly promising area, as the technology is capable of printing with a pretty wide variety of materials including metals, however, most printers are designed to print with only a single material (either metal, plastic, etc.). A fine powder of the material is laid on the build platform, and a highly focused energy source (such as a laser) is used to heat a small area of the powder, fusing the grains together. As the laser moves over the powder, a very thin part is created. By adding successive layers of powder over the first and repeating the technique, a 3D part can be created. This technology is still very expensive, and is only seen in high end commercial prototyping equipment, however it is faster than most other technologies, can create better surface finishes, more accurate parts, and since light has no mass, the only thing limiting the speed of granular printing is the properties of the printing material itself. Additionally some companies, such as 3D systems have added color capabilities to their granular printers. This means that it is now possible to create a 3D printed plastic object with detailed colors. For example, a model of a shampoo bottle or shoe could be printed to bring to a sales pitch. Although the part would be fully plastic, and at least in the case of the shoe, pretty unusable, the item could play a crucial part in highlighting design intent and winning over investors.

Light polymerized printers are also beginning to be more utilized. A thin layer of polymer resin is laid onto the platform followed by an ultraviolet light source. The resin is UV curable, so it is hardened by the light. This is done continually for many layers, ultimately building a 3D part. One of the major advantages to this technology is that unlike most other 3D printing technologies, it is relatively fast (for current 3D printing at least). Additionally several materials can be utilized in a single print. Materials are currently all plastic variations, although some mimic the properties of other materials. A 3D printer company, Stratasys, allows some of their printers to combine resins on the fly, creating hundreds of “digital materials” which can be utilized in a single print.

Powder and ink was the first 3D printing technology, and the reason that additive manufacturing is now known primarily as 3D printing. The technology uses a resin powder and an inkjet printer head. As the printer head moves over the powder, it deposits a hardening agent and color. This technology is useful in creating visual prototypes, however parts are generally pretty weak and shouldn’t be used as functional prototypes. This technology was one of the first to implement full color printing, however it is slowly beginning to disappear, as demand for functional prototypes increases.

Like powder and ink technologies, laminated printing technologies are also beginning to be replaced. Laminated printing essentially uses multiple layers of paper or foil and glues them together to create an object. It

could be argued that laminated printing isn't truly an additive manufacturing technology, as paper and foil scraps are produced, however most still consider it to fall into the category, and machines are still marketed as being 3D printers. It is fairly easy to add color to prints using an inkjet printer head, however like powder and ink printers, laminated printed parts are much more visual than they are usable.

So why are people so concerned with 3D printing? Is it really as powerful as people say? And are there even that many uses for it? Well, yes and no. 3D printing is extremely powerful, and there are already hundreds of companies utilizing it, however as you probably gathered from above, it still falls short in many areas. Furthermore, the consumer 3D printing market is just beginning to take off. The primary use of commercial 3D printing is currently in rapid prototyping. Rapid prototyping allows companies to design their products virtually, but test fit and form in the real world. As most companies would tell you, this is tremendously advantageous. Having done some engineering work myself, I can tell you first hand that engineering is an iterative process. The first design never works; changes are made, the second doesn't work; changes are made, and so on. With traditional manufacturing the turnaround time for a single batch of parts could be months, with 3D printing it is as little as several hours—this can equate to a product being on the market years ahead of when it could have been several years ago. This alone has been enough to drive research and development in 3D printing for almost 30 years, however, as technologies have improved and become more user friendly, additive manufacturing has piqued the interest of a number of industries. Most recently, this has been the medical industry. Joint replacement parts are basically a one-size-fits-all type product. This means that it is up to the surgeon to determine the right size replacement part and the correct configuration of parts to make the joint work correctly. Every patient and situation is unique, and until recently surgeons have had to rely solely on x-rays and CT scans to plan out the surgery. However, it is now possible to use these x-rays and CT scans to create a 3D printed model. Not only does this allow the surgeon to better visualize and plan the surgery, but it also allows the surgeon to test the fit of the parts, and essentially practice the procedure before the patient ever arrives in the OR. This can drastically cut procedure times and costs.

But, medical uses for 3D printing hardly end there, millions of dollars are currently being invested in researching tissue printing. This technology fuses together living cells as opposed to plastic or sintering metals, and would allow replacement body parts to be printed, making transplant waiting lists a thing of the past. To 3D print tissues, a biopsy is performed on a patient, and tissue cells are removed from his/her body. These living cells are then mixed with something called a biopolymer. This cell infused compound is used to 3D print shapes in the same fashion as an extrusion-based 3D printer. After the print is completed, the cell population will continue to grow. As this happens, the biopolymer is actually broken down by the cells themselves, however the tissue structure remains in the shape that the compound was initially extruded into. This technology has already been used to create simple facial geometries like ears and noses. However, more complex geometries, such as internal organs, and their complex makeup of various cell types, currently limits this technology. Nonetheless, it is likely we will see major breakthroughs in this field within our lifetime.

Furthermore, 3D printing is already taking over dental work—and replacing uncomfortable dental molding techniques. Other industries are starting to take interest in 3D printing as well, including NASA, fashion companies, entertainment and effects houses, and architectural firms to name a few.

So with all of this buzz about 3D printing, how does one get their hands on a 3D printer? While it is true that 3D printing is really beginning to take off, we are hardly to the point where they are a desktop necessity. In 2005, a university research project known as RepRap went public and gained a tremendous amount of global support. The RepRap project is an initiative to develop a low cost 3D printer which is capable of printing most of its own parts. One thing that makes this project unique is that it is not a commercial enterprise, it is simply a collaboration of creative engineers, makers, and tinkerers who enjoy pushing the boundaries of at home 3D printing. RepRap 3D printers are open source, meaning that all of the parts and plans are available to anyone, and non-proprietary. Individuals can modify and even sell components and machines, as long as everything is released under the same open source conditions. Prior to the RepRap project almost all 3D printing was focused solely on large companies and commercial printers. 3D printers started at around $50,000. The first RepRap machine was able to be assembled from almost 80% 3D printed parts with the majority of remaining parts being available at a local hardware store. Even more astonishing was that it could be built for around $600. This almost immediately opened the flood gates to desktop 3D printing. Since then, dozens of RepRap printers have been designed, all of which feature free plans on the internet. However, the RepRap project has done even more than provide cheap DIY printers, it has sparked the fire that has led to many consumer 3D printing companies like MakerBot and Ultimaker. In fact, even some of the big commercial 3D printing companies like Stratasys and 3D systems are starting to produce consumer models. With this new push to produce the simplest and most user-friendly consumer printer, it is probably only a matter of time before we start to see consumer printers available in libraries and schools, perhaps even at local office supplies stores. For those who just can't wait, there are many consumer models available now, many of which can produce high quality parts, just be warned that these are in no way plug and print—there is a fair number of programs, settings, and tweaking that will need to be played around with. For those that want to print their parts on a commercial printer, there are many websites such as ShapeWays.com which allow users to upload their parts and have them fully printed and delivered within a few weeks.

If previous technologies such as computers, the internet, and smartphones have taught us one thing, it is that it doesn't take long for our society to adopt promising technologies—and 3D printing is no exception. Over the next several years we will see 3D printing become more and more popular as machines continue to improve and the price-of-entry continues to drop. While you probably won't be 3D printing groceries off the internet any time soon, personal 3D printers will certainly become a more viable option for creative professionals, and many will see reason enough to buy one.

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