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Three-Dimensional Printing: Background and Usage

Printing, which refers to the process of reproducing text and images by using a template, has been around for almost 2000 years. Stemming from its roots in China, where woodblock printing was practiced, the process grew rapidly in the next hundreds of years where its evolution eventually changed how printing would be performed and for what applications. Most notably, after the introduction of the printing press in the 1400s, printing became mechanized and production done en mass. Advancements in technology following the Industrial Revolution and during the twentieth century allowed for more complex and sophisticated machines such as printers and scanners (compact and non-compact) to become widely used. Furthermore, new printing processes were developed, from inkjet printing to laser printing which are still in use today after being introduced decades ago. One process in particular, 3D printing, has gained significant use since its introduction and is becoming more accessible as printers are now supporting them at present time. There are many reasons for why this is so; 3D printing is used in many applications and as with anything, there are constant updates to software that can improve on its use to make it more user friendly and by extension, cheaper.

What is 3D printing one may or may not ask? The answer should be self-explanatory: it is a printing technique that allows for an object printed to be rendered as a solid shape. This is true as 3D printing, also known as additive manufacturing, is the process of using additives

to form 3D objects of virtually any shape from a digital model. This is achieved by using specifically formulated additives (i.e. plastics) that are formed into successive or continuous layers of material usually laid down on a platform into various shapes. The end result of 3D printing isn't too different from what is accomplished in sculpting. However, sculpting in 3D notably contrasts from the 3D printing process in that the former relies on removing layers from a whole object (subtractive manufacturing) to produce a 3D object while the latter relies on adding distinct layers to make a whole object "come to life" (a process of adding parts to a whole). ("The History of 3D Printing")

3D printing is used for many applications, both in professional use and even at home. Although 3D printers hold much of their relevance today as a result of this and due to several startups including MakerBot producing printers capable of turning digital models on a computer to real-world objects on paper, they were certainly not the first printers to be made accessible in the market ("The History of 3D Printing"). 3D Printers can be thought of being conceived as far back as 1976 when the inkjet printer was first invented. In 1984, the inkjet concept used for developing those printers was morphed with the technology at the time from printing with ink to printing with materials, thus setting the stage for a printing process called stereolithography. Stereolithography, which was invented by Charles Hull (later a co-founder of 3D Systems), allowed for a tangible 3D object to be created from digital data where the data would be then turned into a 3D model. In addition, the technology permitted users to test a design before investing in a larger manufacturing program which was and still is important today in order to satisfy a client's needs and specifications before printing. (Maxey, "A Brief History of 3D Printing)

Throughout the 1990s, 3D printing would start to evolve (both in execution and use) following new advancements in technology. In 1992, the first stereolithographic apparatus (SLA) machine was produced by 3D Systems. The SLA involved a UV laser solidifying photopolymer that created 3D parts layer by layer of an object, making complex drawings simple to manufacture. In 1999, the idea of engineering organs on computer and printing them in 3D came about when the first lab-grown organs were implanted in humans undergoing urinary bladder augmentation. Patients obtaining the implants would use a 3D synthetic scaffold coated in their own cells which simply means that they are getting tissue repair or replacement with little to no rejection in using the same cells. A few years later, in 2002, scientists at the Wake Forest Institute for Regenerative Medicine were able to engineer a mini functional kidney that was capable of filtering blood and produce diluted urine in an animal. The institute was then aiming to use their findings to print 3D organs and tissues to be used in the scientific community to further regenerative science. (Maxey, "A Brief History of 3D Printing)

During the mid-to-late 2000s, 3D Printing not only became more advanced following the development of newer technology but also played an important role in more applications. In 2006, the first selective laser sintering machine (SLS) was introduced. The SLS utilized a laser that could fuse materials into 3D products. This breakthrough made it possible for mass customization and on-demand manufacturing of industrial parts. During that same year, Objet, a 3D printing system and materials provider, created a machine capable of printing in multiple materials, allowing for even more options for users to consider when creating 3D prints. Perhaps one notable project regarding the evolution of 3D printing at the time was envisioned by Dr. Adrian Bowyer from the University of Bath, England. In 2005, Dr. Bowyer

established RepRap, an open-source initiative to build a 3D printer that could print most of its own parts. Bowyer's goal was to "democratize manufacturing by cheaply distributing RepRap units to individuals everywhere," enabling buyers to create everyday products of their own. This vision was soon realized when Darwin, the first self-replicating printer was released in 2008, enabling those who own one to make more printers! MakerBot industries would soon follow suit with a similar idea. In 2009, the company began selling do-it-yourself (DIY) kits that would allow buyers to make their own 3D printers and products utilizing the functions of said 3D printer. (Maxey, "A Brief History of 3D Printing)

Within the last five to six years, the 3D printing process began to break the boundaries of how its technology could be utilized even further than before to create complex ideas and designs. To start off, between 2008 and 2009, more breakthroughs were made in the field of physiological science via 3D printing. Certainly, the largest of them was the creation of the world's first 3D printed prosthetic leg—with all parts (knee, foot, socket, etc.) without any assembly! Even more, a medical laboratory by the name of Organovo led the way for bioprinting when they became the first to print a blood vessel after adopting the technology used to originally make cells (blood is made up of cells and a vessel is made up of blood). New ideas continued to flourish into this decade, starting with the world's first 3D printed robotic aircraft as well as the world's first 3D printed car, both developed in 2011. Regarding the former, engineers from the University of Southampton took seven days at a budget of 5,000 pounds to print the plane in its entirety. The use in 3D printing not only reduced the time to manufacture the plane but also made it easier to implement special elliptical wings—a design normally expensive by conventional means—which improves aerodynamic efficiency and reduces drag. Regarding the latter, "Urbee," the world's first printed car, was unveiled to

be fuel-efficient and inexpensive, both as a direct result of being made on spot with selective materials (i.e. environmentally friendly ones). (Maxey, “A Brief History of 3D Printing)

At present time, there is no doubt that 3D printing is shaping how products—both simple and complex—are being created. As far as applications go, as already discussed, they run the gamut. Since 3D printing has become more mainstream, its use has worked its way into a number of markets In those markets, 3D printing has helped manufacture applications within the fields of including but not limited to architecture, construction, industrial design and automotive design, aerospace, military and engineering (“The History of 3D Printing”). The process also has become popular with dental and medical technology, fashion, footwear, eyewear and more. Interestingly, 3D printing has even been practiced with jewelry. A service by the name of i.materialise has recently offered 14K gold and sterling silver as components to be used for printing, a first for materials usually used in the process. The service could potentially function as a unique and cheaper manufacturing option for jewelry designers worldwide (Maxey, “A Brief History of 3D Printing”).

When looking at the future of 3D printing, there are certainly a few expectations that are likely to be fulfilled given the trends with how the process has been utilized in the past up to the present day. One of these trends is the rise of manufacturing objects and items via 3D printing instead of traditionally assembling them in a factory. This has become a notable practice to engage in due to the drop in both time and cost it takes to print something, at times almost effortlessly depending on the simplicity or complexity of an object. Coupled with the price of 3D printers dropping in the world (from 2010 to 2013, the cost of the machines fell from $20,000 to less than $1,000 in a 3 year period alone!), it is safe to say that the future will see an increased use of 3D printing for many goods in the mass market (“The History of

3D Printing"). The automotive industry, for example, would be drastically changed when 3D printers start to print whole cars, layer by layer as opposed to individually building each part of a car in large factories and then assembling them en mass today. Even food has the potential to be printed in virtually the same manner; ingredients including sugars, carbohydrates and proteins can be used in tandem with a printer to produce layers of flavors of which the sum of its parts forms a specific meal (D'Aveni, "3D Printing Will Change the World").

A future with 3D printing can and most definitely will change the economic landscape of producing goods. As one would only have to pay for obtaining raw materials to use in 3D printers to print their desired items and/or food, everyday goods would be effectively manufactured at or close to their point of purchase or consumption. This would also usher in an era of do-it-yourself production on a household level which contrasts strikingly from today where many goods are relied on the scale efficiencies of large, centralized plants. With the advent of producing goods locally, let alone privately (even if the per-unit production cost is higher), the overall cost that would have been from shipping and buffer inventories could be eliminated. Furthermore, the need for supply chain management would be no more when considering how parts can be made for a car, for example, at a repair shop or dealership in practically any major metropolitan area in the world, thereby making assembly plants defunct (D'Aveni, "3D Printing Will Change the World").

In conclusion, 3D printing is a highly complex yet very innovative method of production that already has and eventually will change the way people implement creations, once done by hand to the simple use of a machine doing all the work and more. 3D printing has shown to handle producing objects in a manner once practiced in an assembly line but

has since evolved to a point where scientists are using the process to create artificial organs. 3D printing has even permitted users to customize their creations where different materials can be used to properly or uniquely design them. Perhaps, most importantly, 3D printing has broken the barrier and will continue to do so in bringing about the mass production of everyday and not-so everyday items at a level not seen before that does beckon favorably toward the future given our perceptions of it. This is truly remarkable in how much of an evolution 3D printing was from regular 2D printing, the latter simply being the foundation for inventing and developing a means of rendering designs as fully shaped entities. As the possibilities seem endless for what 3D printing can accomplish, we will have to wait for what is next achieved via this spectacular process.

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