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3D Printing: An Introdution

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ABSTRACT

3D Printing is basically a process for making a physical object from a three-dimensional computer-aided design (CAD) file via a layering approach. It encompasses many forms of technologies and materials as 3D printing is being used in almost all industries. 3D printers are a new generation of machines that can make pretty much anything from ceramic cups to plastic toys. They have become affordable enough to hit the mainstream. 3D printer can be purchased online or in stores, which gives people the ability to print items from anywhere in the world. Technology is always updating and evolving, and 3D printing is no expectation. This paper provides an overview of 3D printing and its applications.

KEYWORDS: *3D printing, 3DP, traditional manufacturing, additive manufacturing, modeling*

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INTRODUCTION

We live in a world surrounded by technologies and materials. These technological apparatuses have reached such an evolution that it is possible nowadays to print actual material. The third industrial revolution is all about personal fabrication and it is happening now. Powered by information age advancements, it is poised to unlock the potential in every person to create, innovate, and fabricate. 3D printing is starting a new industrial revolution. It developed as a modification of an old inject printer.

Traditionally, a printer is used at home or in the office to print out text and images on paper. This conventional printer print in a flat two-dimensional (2D) space using the dimensions length and width. A three-dimensional (3D) printer uses length and width but also adds depth to the print. A 3D printer has more manufacturing capacity than a traditional manufacturing machine. It is regarded as a disruptive technology that will change manufacturing [1].

Three-dimensional printing is becoming the chosen method of manufacturing for lots of companies. This new and versatile method of producing goods is becoming the best choice for companies in the 21st-century marketplace. For those organizations used to traditional production processes, 3D printers can save a tremendous amount of time. Industries like automotive, aerospace, defense, consumer goods, healthcare, apparel and fashion, and construction will stand to benefit from 3D printing with reduced costs and improved lead time.

WHAT IS 3D PRINTING?

3D printing (also known as additive manufacturing (AM) or rapid prototyping (RP)) was invented in the early 1980s by Charles Hull, who is regarded as the father of 3D printing. Since then it has been used in manufacturing, automotive, electronics, aviation, aerospace, aeronautics, engineering, architecture, pharmaceutics, consumer products, education, entertainment, medicine, space missions, military, chemical industry, maritime industry, food industry and jewelry industry. All the parts created using a 3D printer need to be designed using some kind of CAD software [2].

The process of 3D printing has three basic components: computer assisted (i.e. digital) design, machine equipment, and an added material. Different materials can be used to build 3D-printed objects, from plastic, metal and rubber to human cells. A 3D printer works in similar ways as a regular printer. 3D Printing essentially describes a assortment of technologies that digitally formulate three dimensional objects on a layer-by-layer basis. It has been adopted by students, entrepreneurs, hobbyists, and various industries. As shown in Figure 1, 3D printing involves three steps [3]. A typical 3D printer is shown in Figure 2 [4]. The business uses of 3D printing are growing year by year.

In essence, 3D printing is a manufacturing process in which material is laid down, layer by layer, to form a three-dimensional object. 3D printing can create physical objects from a geometrical representation by successive addition of material. 3D printing is an umbrella concept for a set of processes and technologies that offer a wide range of the production of parts and products in different materials. Varieties of 3D printing technologies have been developed with the different function. One thing common in all these processes is the manner in which production is carried out – layer by layer in an additive process. Not all 3D printers use the same technology.

BRIEF HISTORY

The 3D printing technology has affected recent human history probably more than any other field. There were several individuals who contributed to the development of 3D printing. The earliest 3D printing technologies first appeared in the late 1980's. At that time, they were called rapid prototyping technologies. The first patent for 3D printing technology was issued in 1986 to Charles Hull for stereo lithography apparatus (SLA). 3D printing had its start when Chuck Hull designed and printed a small cup. In the 1980s, 3D printing techniques were considered suitable only for the production of functional or aesthetic prototypes,

3D printing technology was first commercialized in the 1990s. Throughout the 1990's and early 2000's a host of new technologies continued to be introduced. A flurry of patents followed in the early 1990s for various power-based systems. Fused deposition modeling (FDM) is the most common 3D printing process in use as of 2020. By 2020, 3D printers have reached the level of quality and price that allows most people to enter the world of 3D printing. Using 3D printing and multi-material structures in additive manufacturing has allowed for the design and creation of what is called 4D printing [5].

TYPES OF 3D PRINTING

There are generally three types of additive manufacturing: selective binding, selective solidification, and selective deposition. Typically, people refer to these technologies as Selective Laser Sintering (SLS), Stereo lithographic (SLA), and Fused Deposition Modeling (FDM), which are discussed as follows [6,7].

- *Stereo lithography* (SLA): This was the world's first 3D printing technology, invented in the 1980s. It is an additive manufacturing process which employs a vat of liquid ultraviolet curable photopolymer "resin" and an ultraviolet laser to build parts' layers one at a time. For each layer, the laser beam traces a cross-section of the part pattern on the surface of the liquid resin. SLA parts have the highest resolution and accuracy and the smoothest surface finish of all plastic 3D printing technologies. Although stereo lithography can produce a wide variety of shapes, it has often been expensive.
- *Selective laser sintering* (SLS): This is an additive manufacturing technique that uses a high power laser (for example, a carbon dioxide laser) to fuse small particles of plastic, metal (ceramic, or glass powders into a mass that has a three-dimensional shape. The SLS machine preheats the bulk powder material in the powder bed somewhat below its melting point. SLS is trusted by engineers and manufacturers across different industries for its ability to produce strong, functional parts. Low cost per part, high productivity, and established materials make the technology ideal for a custom manufacturing. The material selection for SLS is limited compared to FDM and SLA.
- *Fused Deposition Modeling* (FDM): This is the most widely used form of 3D printing at the consumer level, fueled by the interest of hobbyists of 3D printers. This technique is suited for basic proof-of-concept models, as well as quick and low-cost prototyping of simple parts. FDM is regarded as a very clean technology, usually simple and office-friendly. It uses a continuous filament of a thermoplastic material. The technology can produce complex geometries and cavities that would otherwise be quite problematic. Since 2004, FDM technology has been used in a particular sector to produce load-bearing scaffold. Home printer based on FDM typically work with plastic filament.
- Which technology makes the most sense for you to use depends on your budget, the model's complexity, and the finest detail that is necessary.

APPLICATIONS

3DP applications are booming. 3D printing has a variety of uses in numerous disciplines such as healthcare, aerospace, engineering, printing, manufacturing, entertainment, education, chemistry, mathematics, biology, history, and architecture. 3D printing technology is used in several industry such as jewelry business, printing industry, fashion industry, food industry, medical industry, machine industry, and education industry. We consider the following applications of 3D printing.

- *Manufacturing:* Manufacturing plays an essential role in the lives of many entrepreneurs and small business owners. 3D printing is becoming popular with manufacturers. It presents several advantages over the more traditional manufacturing methods of subtractive manufacturing and injection molding. Automotive industries are utilizing 3Dprinting to fabricate spare parts, tools, jigs, fixtures, and end-use parts. Jaguar, the famous car manufacturer, is using 3D printing to create spare parts for its old vehicles. Items can be produced in plastic, glass or ceramic, so the possibilities are unlimited.. High technology companies such as aerospace and automobile manufacturers have been using 3D printing as a prototyping tool for some time. The number of 3D-printed parts on board satellites is growing [18].
- *Healthcare:* One of the most exciting areas where business owners are innovating and creating new products with 3D printers is in the medical field. Medical technology is rapidly changing due to emerging technologies such as the 3D printing. It offers a range of precision healthcare solutions, including tissue and organ fabrication, creation of customized prosthetics, implants, and anatomical models, drug delivery, and testing, as well as in clinical practice. The applications of 3DP in healthcare are already in the mainstream. These include medical device manufacturing, tissue engineering, pharmacology, surgery, anatomy, dentistry, orthopedics, prosthodontics, periodontics, personalized care, research and development, education and training, and medical imaging [9].
- *Dentistry:* This is one of the fields leading the adoption of 3D printing in medicine. Dental implants were one of the first medically approved uses of 3D technology. Surgical guides, splints, temporary and permanent restorations, and dentures can all be directly 3D printed. In the dental industry, crowns and dentures are already directly 3D printed. Permanent crowns manufactured using a ceramic-filled resin material is shown in Figure 3 [10].
- *Education:* Education is now be identified as a key target market within the 3D printing industry because 3D printing engages students more profoundly to learn lessons. It is currently in the process of revolutionizing the manufacturing industry worldwide. The concept of 3D printing is simple, tried, and tested education tool for teachers. Educators and students have been using 3D printers in the classroom. Today the importance of including 3D printing in professional degrees and in schools is a fact. 3D printing should be added to the curriculum in all academic institutions because it prepares the youths for the future. It presents opportunities to learn and use the same cutting-edge tools as professionals in the industry [11].
- *Business:* A 3D printing business can produce several products for various businesses. It is a business where there is still plenty of space to compete.
- 3D printing technology is used in several industry such as jewelry business, printing industry, fashion industry, the medical industry, the machine industry, and education industry. One of the benefits of this type of 3D printing business is that the inventory is small and lightweight. This new and versatile method of producing goods is becoming the best choice for companies in the 21st-century marketplace. 3D printing for small businesses is becoming mainstream [12].
- *Construction:* 3D printing opens new design possibilities, reduces costs, and produces sustainable construction projects with low environmental impact. 3D printing in the construction industry also means significantly reduced production time. Using 3D printing in the construction industry brings innovative solutions. Producing buildings layer by layer allows for a considerable cost reduction. The construction industry has been adopting a futuristic printing method for printing out entire homes. The first 3D printed house was produced in Nantes, France, and is called the Yhnova project. It took only 54 hours to print the house, and the overall cost was about 20% cheaper than building a traditional home. There are many benefits to using 3D printing in the construction industry and the companies using it already are very successful. Figure43 shows a construction using 3D printing [13].

- *Fashion Industry*: 3D printing has entered the fashion industry, with fashion designers experimenting with 3D-printed bikinis, shoes, and dresses. In commercial production Nike is using 3D printing to prototype and manufacture football shoe for players of American football. On-demand customization of glasses is possible with rapid prototyping. 3D printing will have a significant value for fashion companies down the road, especially if it transforms into a print-it-yourself tool for shoppers. Printing anything that drapes or feels good to touch remains prohibitively expensive. That makes cloth a no-go [14]

BENEFITS

For most people, 3D printing sounds less like a manufacturing technique than magic. 3D printing has several benefits over traditional manufacturing techniques. One chief benefit of 3D printing is that it does not require the cumbersome and costly equipment needed in traditional manufacturing. The emergence of 3D printing technologies is introducing industrial skills to 21st century learners. 3D printing allows industrialists in the mainstream to create customized products and affordable prices. With economies of scale, the costs of 3D printers are becoming less prohibitive. 3D printers are also fully automated, which eliminates human error.

Other benefits include the following [15]:

- *Speed:* This is the most obvious advantage because no special tooling is required and parts can be built in a matter of hours.
- *Flexibility*: 3D printing technology has emerged as a flexible and powerful technique in advance manufacturing industry. 3DP allows for much greater flexibility and creativity in the design process. It gives us new design freedom allowing for the production of new shapes and solutions to our needs. Parts can be completely re-designed so that they are stronger in the areas that they need to be and lighter overall.
- *Zero Skill Manufacturing*: Traditional manufacturing machines still demand a skilled expert to adjust and calibrate them. 3D printer requires less operator skill than does a traditional subtractive machine.
- *Compact, Portable Manufacturing:* A high production capacity per square foot makes 3D printers ideal for home use or office use since they offer a small physical footprint.
- *Less Waste:* The rapid adoption of 3D printing could have a large impact on the environment. Additive manufacturing creates products layer-by-layer and prints only relevant parts, wasting much less material than do traditional manufacturing techniques.

CHALLENGES

As an emerging technology, 3D printing has a lot of challenges. These challenges can be classified technological limitation, material limitation, and design limitation. Other challenges include the following [15]:

- *Loss of Jobs:* As with all newly emerging technologies, manufacturing jobs will decrease due to 3DP.
- *Limited Materials:* An 3D printer can use only a specific material, so printing different products requires different printers or modifications on a single printer.
- *High Cost:* The cost of 3D printer per item you produce is higher, so the economics of 3D printing do not stack-up against traditional mass production yet.
- *Copyright:* With 3D printing, the printing of copyrighted products to create counterfeit items will increase and nearly impossible to prevent.
- *Dangerous Items:* With 3D printers, it is easy to create knives, guns, explosives, and any other dangerous items. Criminals and terrorists can, therefore, make such weapons without traces.
- *Harmful Emissions:* 3D printer is often used in enclosed places such as homes. This can generate potentially toxic emissions and carcinogenic particles.
- *Size:* Currently, 3D printers are limited with the size of the products that they can create. To print larger more complicated objects one requires larger printers.
- *Energy Consumption:* 3D printers use a lot of power for machines that only make one object at a time. The energy required to operate a 3D printer is still high compared with other household appliances,

4D PRINIING

This paper would not be complete without mentioning 4D printing, which is based on 3D printing. 4D printing may be regarded as the process through which a 3D printed object transforms itself into another structure under the influence of external stimuli such as humidity and temperature. 4D printing promotes the use of 3D printers for creating final products instead of prototypes. It adds the fourth dimension of time to 3D printing. It is basically the combination of 3D printing technology and smart

materials. The rapid advances in shape memory materials (or smart materials) and additive manufacturing have fueled the development of 4D printing. Two main technologies are responsible for 4D printing: 3D printing and smart materials (SMs); i.e. 4D printing = 3D printing + SMs. Special materials are necessary to enable 4D printing. Smart materials are those materials which sense some stimulus from the external environment and create a useful response. They exhibit certain characteristics which can be exploited in products that in turn exhibit "intelligent" behavior. Smart materials have the ability to change their shape or properties shape or property (rigidity, color, texture, transparency, volume) under the influence of external stimuli. The technology is still in research and development stage [16].

CONCLUSION

To some people, 3D printing still feels like a futuristic dream. In reality, the technology is actively used in many industries. Today, the 3D printing industry is a burgeoning technology field that has scaled down from expensive machines to desktop models available to many consumers. There are several do-it-yourself kits available competing with commercialized all-in-one products. The future of 3D printing in industries lies with creating working parts directly from a 3D printer for use in the final product, not just for testing purposes. For more information about 3D printing, one should consult the books in [4,17-21] and a related journal: *3D Printing in Medicine*

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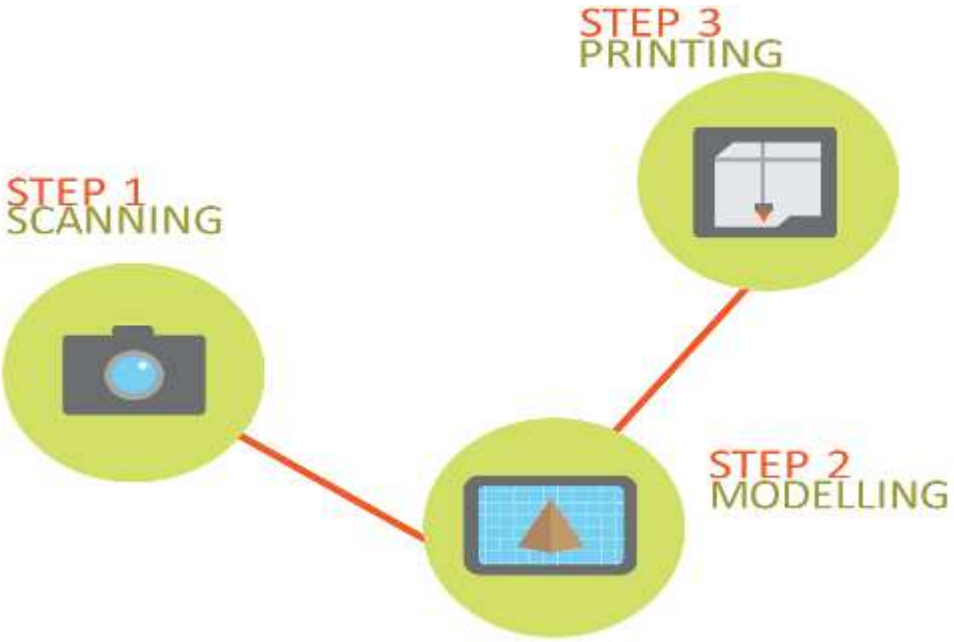

Figure 1 3D printing involves three steps [3].

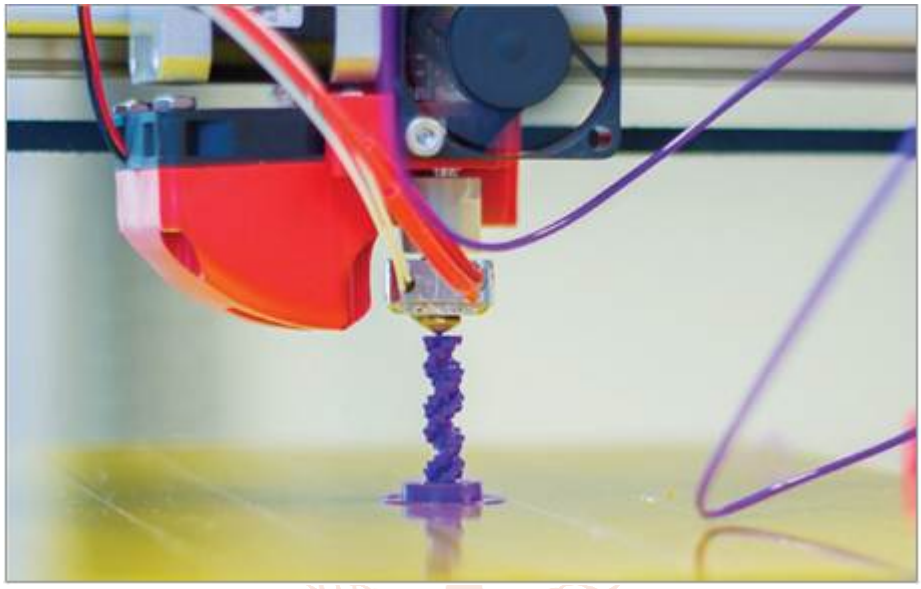

Figure 2 A typical 3D printer [4].

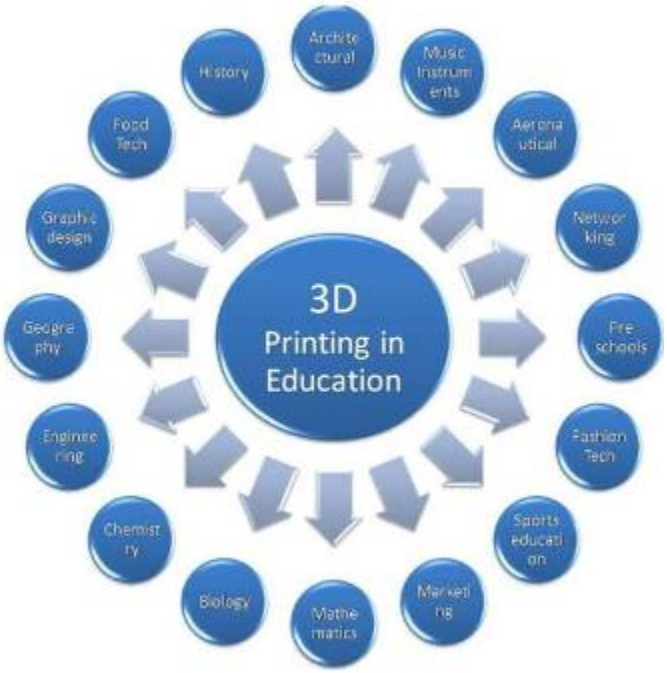

Figure 2 A typical 3D printer [5].

Figure 3 Permanent crowns manufactured using 3DP [10].

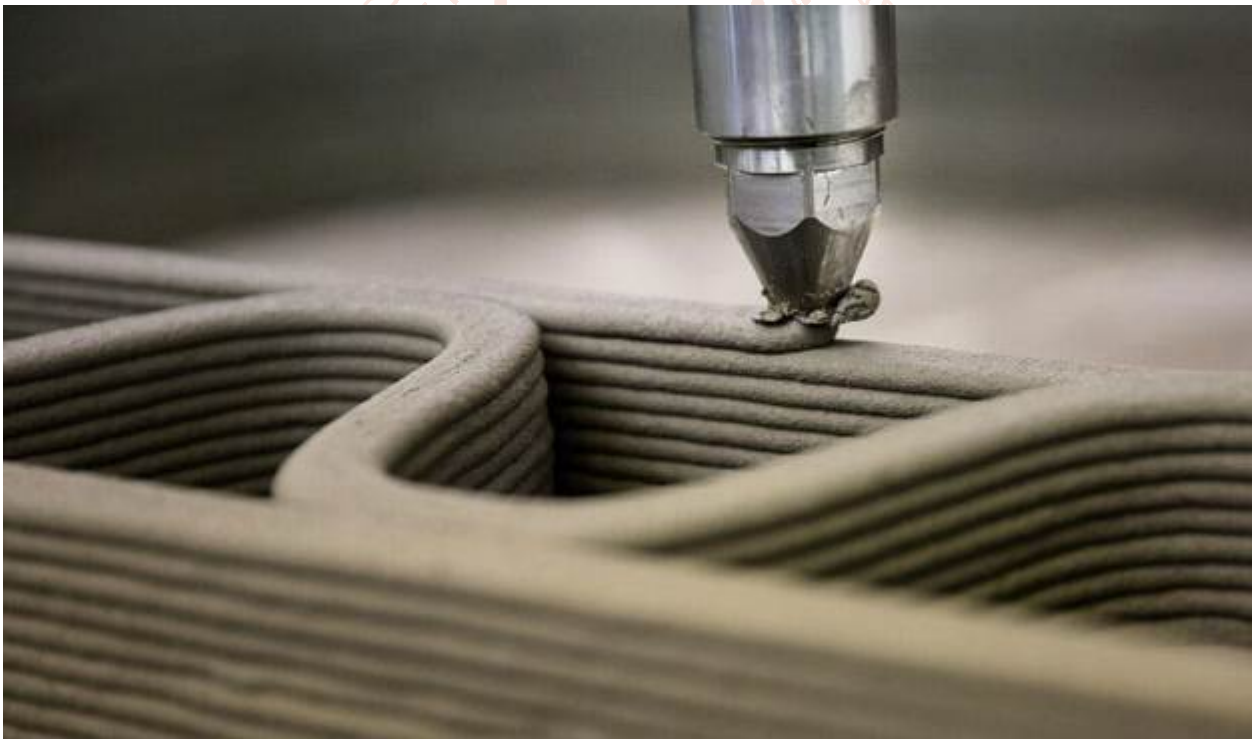

Figure 4 3D printing in construction [13].