The Trends and Challenges of 3D Printing

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INTRODUCTION

3D printing is the new wave of technology advancement in the world of architecture, design and manufacturing. Also known as rapid prototyping, 3D printing is a type of additive manufacturing technology where a 3D object is created by laying down subsequent layers of material at the mm scale. 3D printers print objects by reading a CAD design file or by scanning an object (Sachs et al., 1992). Today, 3D printing is applied in various industries such as footwear, jewelry, architecture, engineering and construction, aerospace, dental and medical industries, education, consumer products, automotive and industrial design. Some claim that 3D printing will put an end to traditional manufacturing primarily since 3D printing imposes a tool-less process. Product parts can be specifically designed to avoid assembly lines, as well as ensuring maximum utilization of raw materials. In this article, the authors discuss the state-of-the-art of 3D printing its future direction.

BACKGROUND

In May 1980, Dr Kodama from Japan filed the very first patent application for Rapid Prototyping technology. Unfortunately, he did not file the subsequent full patent specification before the one year deadline after the application. Hence, in 1986, Charles (Chuck) Hull filed the first patent for stereolithography apparatus (SLA). He was the first to invent the SLA machine in 1983. After obtaining the patent, he went on to co-found 3D Systems Corporation, which is one of the largest organizations operating in the 3D printing world today. During the mid-nineties, the 3D printing sector started to diverge into two specific areas. First, there was the high end of 3D printing, which saw the production of complex parts. These applications include the medical, aerospace, jewelry and automotive sectors. Then there was the lower end of the market, which saw a price war among many 3D printer manufacturers, highlighting improvements in speed, accuracy and materials.

In 2007, 3D Systems came up with the first 3D printer which was priced under $10,000. The first commercial 3D printer was offered for sale in January, 2009. It was based on the RepRap concept, and came in a kit form. Makerbot Industries also developed commercial printers in April of the same year. 2013 saw Stratasys acquiring Makerbot. It was a year of significant growth and consolidation for 3D printing.

Materials for 3D printing were very limited during the early days of the technology. Today, there is an array of different types of materials available for choice.

The first step in 3D printing is to design the 3D digital model using a CAD program or scan the object with a 3D scanner. The model will then be 'sliced' into layers and converted into a printer-readable file. The printing material will be added one layer at a time.

Different materials are suited for different 3D printing technologies. Some 3D printers process powdered materials which utilize a light source to fuse layers of the powder together to make the desired shape. Others process polymer resin

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materials and utilize a laser to solidify the resin in ultra thin layers. Another method is the jetting of fine droplets using materials and a binder to fix the layers. One of the most commonly used 3D printing technology is the stereolithography (SLA) technology. This technology utilizes photocuring resins as raw material. New resins that are being developed will combine transparency, heat resistance and toughness.

The second commonly used technology is called 'Fused Deposition Modeling', as invented by Scott Crump, a co-founder of Stratasys Inc. The FDM technology uses thermoplastic resins as raw materials. It is the simplest 3D additive manufacturing technology, in which the thermoplastic resin softens when heat is applied. The third type of technology is called 'Selective Laser Sintering (SLS)'. This builds objects by using a laser to fuse together layers of a mixture of different powdered raw materials. The fourth type of technology is called 'Multi-jet modeling (MJM)'. Objects are built up from the layering of powder through an inkjet-like print head that also sprays a binder solution to glue the required granules together. The raw materials associated with this type of technology are sand mold or nylon resins.

THE TECHNICAL ISSUES OF 3D PRINTING

3D printing has revolutionized our society from providing medical advances; to scalable production of everything from product parts to buildings. There are, however, many issues that accompany this technology. Two main issues of 3D printing are the technical problems and the controversies. This section will be divided into two parts. Part one presents the technical problems of 3D printing, while part two presents the controversies of 3D printing.

As 3D printing is getting more widespread, the issue of its quality is always being questioned. In 3D printing, the quality of the printed object is linked to the printing speed; and the printing speed is linked to the raw materials' thermoplastic properties. Different raw materials are supposed to be printed at different speeds. To ensure a beautifully printed object, the speed of printing has to be just right – not too slow and not too fast either.

Some of the common printing problems are warping, stringing, gaps in the top layers, under-extrusion, over-extrusion, pillowing, layer-misalignment, elephant foot, etc. Furthermore, the raw materials that can be used for 3D printers are still rather limited. Presently, most of the commercial 3D printed products consist of one single material. The idea of printing electronic goods such as smart phones is already being researched but not yet foreseeable. The tough challenge here is to add different types of materials that fulfill their functionality to make up various parts of an electronic component.

Last but not least, 3D printing requires post-processing. An additive manufacturing (AM) machine cannot add finishing touches to the printed object. It requires a manually intensive process. The printed objects will still have to undergo post-printing processes such as friction-weld, paint, sand, rivet and so on.

The Controversies of 3D Printing

The controversies surrounding 3D printing include infringement of intellectual property laws, fabrication of weapons and drugs for crime purposes, compliance with FDA safety standards and ethical considerations.

Intellectual Property Laws

Online platforms such as GrabCad and Thingiverse provide users with the CAD design files needed for 3D printing. Registered users can download, upload, design and modify a 3D model on these online platforms. Infringement of copyright laws happens through the way users obtain the CAD design files. They either: (1) create an object design file; (2) modify an existing design; (3) scan the object (Mendis & Secchi, 2015). The main ques-

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