



3D Printing; Hardware and Software for the Consumer Market

Paul S. Heath

East Carolina University / Vidant Health
psheath@vidanthhealth.com

Article History: Received on 15th July 2015, Revised on 07th September 2015, Published on 05th November 2015

Abstract—3D printing is an older technology that is just making its way into the consumer market. The story of its emergence into the consumer market is brought about through the efforts of inventors who viewed this technology as a hobby. Since the introduction of desktop 3D printers, the market has exploded with newer and better models created each year. There are many stories of what it can do, but little reason for consumers to adapt to the technology. This paper discusses the emergence of consumer 3D printers into the market. It reviews the history, technology and movements that made its existence possible. It also looks at the technology involved, uses for the technology and how it is being introduced to consumers.

Keywords: 3D printing, Engineering, Maker Movement, DIY, Manufacturing, Hackerspaces

I. INTRODUCTION

If one has been keeping up with trends in computing technology or shopping on a big box electronic retailing site then one might notice what looks like some kind of fancy microwave or microscope. This is no ordinary contraption. This is a 3D printer. Since desktop printers started being produced for the consumer market, they are beginning to show up in retail spaces around the globe. In fact, shipments of 3D printers are estimated to double every year from 2015 to 2018. The rise in sales stems from advances in the technology, cheaper prices and availability of the product, (Gartner.com, 2014).

The beauty of these machines is they allow one to create customized objects or prototypes for future products. Consumers are slow to adapt to this technology but as prices have dropped and 3D printers are showing up at schools, printer stores and libraries, consumers have had more opportunity to interact with the medium. All it requires for use is for the individual to create an electronic design or secure a file online and send it to the printer. There are even companies like Shapeways that will let customers upload their designs in order to print and ship the completed item to them. Customers can also take advantage of the Shapeways online market and sell their products and designs on the company website (Shapeways, 2015). Companies like UPS are even jumping into the 3D market and offering printing services in some of their retail stores (Theupsstore.com, 2015).

The technology for 3D printing has been around since the eighties (3D Printing Industry, 2014a). It was originally designed for manufacturing and given the name "additive manufacturing" (EOS e-Manufacturing Solutions, nd). It was labeled additive technology because it uses a printer to create 3D solid objects by layering successive strands of raw material (3E Printing.com, 2015). The raw materials used with a 3D printer include nylon, epoxy resins and powder materials (Larsson, 2013). 3D printing, a disruptive technology, is

revolutionizing the way products are produced by manufacturers. With 3D printing, producing one item can be as cheap as thousands, which is a game changer for manufacturing (Petrick & Simpson, 2013). The technology is cheaper to use, easy to customize and prototyping can be fast tracked, cutting months off the time line while drastically reducing cost all at the same time. The time efficiency also allows for more modifications and testing. With traditional methods, modifications and testing can be very time consuming and costly. The drawbacks of 3D printing in manufacturing is the speeds of the devices and their inability to keep up with production lines, but as the technology continues to advance, 3D printers will likely be able to outpace the current production line. They will increase in speed all while eliminating some steps or changing workflows in production, warehousing and distribution of products (Chausovsky, 2014).

3D printing is already being credited for bringing about the third industrial revolution. ("The third industrial revolution," 2012). Employers are starting to demand that engineers have 3D printing skills. Numbers released by Wanted Analytics "finds that the number of job ads requiring workers with 3D printing skills increased 1,834 percent in four years, and 103 percent from August 2013 to August 2014" ("Changing technologies, inc.," 2014). The use of additive technology could lead to reduces in human labor as a means of production, but the job market will gain in employees that can support and innovate additive technology products. (Pirjan & Petrosanu, 2013).

3D printers made their way into the consumer market through efforts of the Maker Movement and their sponsored hackerspaces (Laskow, 2014). The maker movement consists of a number of like-minded DIY (Do it yourself) and DIT (Do it together) enthusiasts that have an interest in science, engineering and/or technology. They work together to solve problems and create or innovate products that are already in existence or yet to be in existence. They use open source hardware to invent or innovate products. They are like a research and development team for a company. The beauty of open source hardware is that technology is released to everyone so that anyone can make improvements or solve problems associated with the product. Often these inventors will get together in spaces or labs called hackerspaces or hackerlabs to pool their efforts together to work on a project (P2P Foundation, 2015). When one couples this with their ability to raise money through crowdfunding campaigns on websites like Kickstarter, they have the technology and the capital to bring products to market. Such was the case with the first 3D desktop printers. Their whole story was documented in the movie *Print the Legend* (Toutwine, Lopez, & Tweel, 2014). It spotlights two startup companies, Makerbot and Formlabs as they make their entry into the market of 3D printers. They were the two small companies competing with two giant



companies to bring 3D printing technology to the consumer market. Makerbot changed their management style from open source to propriety and was eventually purchased by the giant in industrial 3D printer manufacturing, Stratasys. (Toutwine, Lopez & Tweel, 2014). Formlabs was the other firm that was documented in the film. It was started with crowdsource funding by some young former MIT students in Cambridge, Massachusetts (Toutwine, Lopez & Tweel, 2014). It is still in production and operating independently to get its product in the hands of consumers (Formlabs, 2015).

II. TYPES 3D PRINTING TECHNOLOGIES

A variety of technologies are used in 3D printing processes:

A. Stereolithography (SLA)

Stereolithography (SLA) is one of the most popular means of 3D printing. It was discovered and patented by Charles W. Hull in 1986 (Uvp, Inc., 1986). It uses liquid photopolymer and a laser to harden and print the object. The process involves a stage for the object to rest on and a perforated pad for the liquid polymer to extrude. The laser traces the first cross section of the design causing it to harden and then another layer is traced and hardened until you have the solid object (Barnatt, 2014).

B. Digital Light Processing (DLP)

Digital Light Processing (DLP), which is also referred to as Vat Polymerization. In DLP processing, a vat of liquid is exposed to the light of a DLP projector replicating the image of the solid object to be produced. The object is then hardened by the DLP projector and the rest of the liquid is drained away to reveal the object. The process is faster and has good resolution (Walker, 2014).

C. Material Jetting Printing or Polyjet Matrix

Material Jetting Printing or Polyjet Matrix, This technology uses a multi-nozzle print head to distribute a liquid polymer on to a surface. The surface is sprayed hard by the UV light before loading another layer and solidifying that layer. The process continues until the solid object is formed. The benefit of this technology is that it can produce hard objects with rubber-like parts. This is accommodated by the jets being able to distribute multiple types of materials at the same time (Barnatt, 2014).

D. Fused Deposition Modeling (FDM).

This technology uses a print head to drop beads of liquid to produce the design. The process starts with a thermoplastic that is heated to a semi liquid form and distributed on to a plate ("FDM Technology", 2015). This technology is often referred to by other names including thermoplastic extrusion, plastic jet printing, fused filament method or fused filament fabrication. FDM offers a lot of flexibility in allowing the user to print various items. The range is based on materials and can be anything from food related delicacies like cheese and chocolate to building materials like concrete (Barnatt, 2014). The majority of desktop 3D printers use FDM technology (Krassensein, 2014).

E. Selective Laser Sintering (SLS)

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Another technology which is pretty expensive but coming down and worth mentioning is Selective Laser Sintering (SLS). Selective Laser Sintering allows the use of various powder substances which is melted down and fused together. This can be anything from wax to metal (Barnatt, 2014).

F. Selective Laser Melting (SLM)

Similar to SLS with the difference between SLS technology and SLM technology being that instead of fusing powders together, it fully melts the substance and produces a solid piece out of the raw material (Barnatt, 2014).

The price of 3D printers continues to come down. One can get a novice printer for about 600 dollars, but one gets what one pays for (Baguley, 2015). Some of the best 3D printers range in price from 1500 to 3000 dollars, depending on what guide one reads (10 TopTen Reviews, 2015).

To get started with a 3D printer a design and an appropriate file format for 3D printing is needed. The system takes numerous file formats, but the standard is the STL file. A new file format recently released by Microsoft called 3MF was announced this year. This file format will be available with new operating systems. The file is designed specifically for additive manufacturing and will be able to carry more information (Krassensein, 2015).

Designs can be created using many software packages that range in price from free to thousands of dollars. This software falls into one of three categories: CAD Tools, Freeform Modeling Tools and Sculpting tools (3D Printing for Beginners, 2015). CAD tools are most often used by engineers and architects and are based on geometric shapes (3D Printing for Beginners, 2015). CAD tools can be difficult to use for some consumers (Makethingsnow, 2015).

FreeForm modeling tools have the most flexibility and allow a user to freeform shapes. ("3D Modeling For Beginners", 2015). With freeform modeling tools one can get a more realistic, organic model (Geomagic Freeform Plus, 2015). It is ideal for customizing and adding surface detail or freeform curves to the object (Yares, 2012).

Sculpting tools are a way for users to create designs by using pinch and pull clicks to design objects ("Modeling for Beginners", 2015). It is easier to use than CAD software and allows more automation in a design than freeform modeling does. Sculpting tools are much like sculpting with clay. You start with an object and pinch and pull it to make a design (Yares, 2012).

There are other options for getting files for 3D printers without having to create them oneself. One can subscribe and take advantage of the many open source and free websites that allow designers to upload their designs to be shared with others. Thingiverse is one of these sites. It started as part of the maker movement and includes 3D designs (MakerBot Thingiverse, 2015). There are also repositories online that allow one to purchase or sell original designs. Cubify is one such website and app that allows designers to sell designs and others to purchase designs. One can even upload a picture of oneself and make a figurine (Geek: Figurines & Collectibles, 2015).

III. ADOPTION

According to the Gartner Hype Cycle consumer 3D printing is still some five to ten years away from being adapted in the consumer market (Lean, 2015). More specifically consumer



printing has reached the cycle's peak of inflated expectations and is descending into its trough of disillusionment. This is typically the point where consumers begin to realize the differences between fact and fiction as far as all the tales that have been spun about 3D printing (Lean, 2015). Gartner predicts shipments of 3D printers will exceed 200, 000 in 2015 (Gartner, 2014).

A study of 3D printing trends examined how individuals were using 3D printers. The study grouped these users based on their uses and backgrounds (3D Hubs, 2015). Professionals were composed of product designers or engineers and were 57% of consumer 3D printing. They divided their uses for 3D printing as prototyping (85%), research (32%) and product production (18%). The second largest groups were described as makers and were comprised of people that produce their own designs. They made up 34.9% of people using 3D printers. Following this group were pioneers which were using the technology while using mostly external sources for designs. This group made up 21.7% of the group studied. The remainder of the people 3D printing was students and researches which made up 8.5% of the group and mostly used 3D printing for their course work or personal projects (3D Hubs, 2015).

These numbers will continue to shift as people discover 3D printing and what can be done with it. Many companies are jumping on board to push out the technology to consumers where they can learn about and become more comfortable with it. MakerBot has been an innovator in marketing 3D printers. They began with a partnership with Sam's Club. They originally started with a deal to put the MakerBot Replicator Mini Compact 3D in 300 of Sam's Club locations but after only three short months amended the agreement to extend distribution of MakerBot Replicator to all 600 stores. Many of these locations will offer in-store displays where customers can test out the technology (Renfrow, 2015).

They have also gone the extra mile to work with the public to put a 3D printer in every school. Through crowdsource funding, they hope to make this a reality (Makerbot Academy, 2015). In addition to school efforts, Makerbot is targeting older students as well by putting resources into their Innovation Centers which they have established at several universities (Gilpin, 2015).

In getting the technology in the hands of schools they are not only expanding the market of 3D printers, they are also performing a public service. In a February State of the Union Address the President of the United States was quoted as saying, "3D printing has the potential to revolutionize the way we make almost everything. We must ensure that the next industrial revolution in manufacturing will happen in America. We can get that done" (Graber, 2013).

IV. OUTLOOK

The outlook for consumer 3D printing is very positive. As the technology gets rolled out and accepted in society there are more retail chains hoping to capitalize on the consumer market by investing in making it available to the public. Lowe's Home Improvement will start having 3D printing and scanning available to help

customers personalize items for their homes (Gustafson, 2015). Even the US Postal Service is banking on 3D printing to increase their amount of deliveries to the tune of 485 million dollars annually. They estimate the need for 3D printing supplies and increases due to the printing and shipment of items being a perfect match for their vast distribution channels (U.S. Postal Service Office of Inspector General, 2014).

The list of companies capitalizing on 3D technology continues to grow as 3D printers and services are being made available and incorporated into the consumer market. Further product innovation will also play a part in expanding the market for 3D printers. The next generation will have features that make it more consumers friendly. Some will sport such features as plug and play, Ethernet and Wifi, cameras, as well as smartphone and tablet compatibility (Kickstarter, 2013). Some models will also have dual heads and print multiple materials and colors. This generation of 3D printers will also be faster, easier to use and cheaper to purchase (Baya and Earls, 2014). Consumers will be able to print anything from food to wearables (Kepczyk, 2015). Developers are already creating software that is more user friendly for the consumer market (Gilpin, 2015). There are even tools like 3D mobile apps that will allow the user to make 3D models of people, works of art or loved ones. The files can then be saved, edited or sent to a 3D printer for printing. ("ETH zurich; your smartphone as a 3D scanner," 2013). Image a world where one can have a replica of an admired piece of art or the bust of a loved one.

V. CONCLUSION

3D printing is the way of the future. It is capable of creating customized items with less tools and less waste (3D Printing Industry, 2014b). It has made its way into the manufacturing market and now it is trickling down to the consumer market. There is much discussion and communication about how it will be incorporated into society, but it is has been embrace by hardware manufacturers, software developers and the President of the United States of America. Crowdfunding sites are saturated with 3D fundraising campaigns and the media is flooded with stories of 3D innovation. As the software becomes easier to use, the printers become faster and the technology becomes cheaper we should see more rapid adaption of 3D printing in the consumer market. There is a great deal of hype about how it will be used, but mostly what has been written about is very positive. Everyone can participate in the next revolution whether investing in the companies that produce the technology, setting up a small business or learning new skills. 3D printing is for everyone.

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