International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

The Impact and Application of 3D Printing Technology

Thabiso Peter Mpofu[1], Cephas Mawere[2], Macdonald Mukosera[3]

[1, 3]M. Tech. Students, Department of Computer Science, School of IT,
Jawaharlal Nehru Technological University Hyderabad, India

[2]M. Tech. Student, Department of Bioinformatics, School of IT,
Jawaharlal Nehru Technological University Hyderabad, India

Abstract: ***3D printing also known as Additive manufacturing technology has been dubbed the next big thing and be as equally wide spread as cellular telephone industry. 3D printers print objects from a digital template to a physical 3-dimensional physical object. The printing is done layer by layer (Additive manufacturing) using plastic, metal, nylon, and over a hundred other materials. 3D printing has been found to be useful in sectors such as manufacturing, industrial design, jewellery, footwear, architecture, engineering and construction, automotive, aerospace, dental and medical industries, education, geographic information systems, civil engineering, and many others. It has been found to be a fast and cost effective solution in whichever field of use. The applications of 3D printing are ever increasing and it's proving to be a very exciting technology to look out for. In this paper we seek to explore how it works and the current and future applications of 3D printing.***

Keywords: 3D printing, additive manufacturing, printing layers, applications, technology, cost effective

1. Introduction

3D printing or additive manufacturing is a process of making a three-dimensional solid object of virtually any shape from a digital model. Successive layers of material are laid down in different shapes. Traditional machining techniques rely on the removal of material by methods such as cutting or drilling whereas 3D printing layers are added successively [1] [6] [7]. Thus it uses a layering technique where an object is constructed layer by layer until the complete object is manufactured. In this way 3D printing moves us away from the mass production line to a one-off customizable production [17]. You can literally make any object from a house to a bar of chocolate, so to say.

The initial 3D printers were used in the 1980s where a pattern submerged in a liquid polymer would be traced by a computer. The traced pattern hardened into a layer, thanks to the laser, and that was how you built an object out of plastic [9]. Since then tremendous progress has been made in additive manufacturing such that material extrusion is now used. By this method, an object is built out of matter that is pushed from a mechanical head like the way an inkjet printers extrudes ink onto paper [9].

Interestingly, the cost of acquiring 3D printers has been decreasing with the advancement of technology. Domestic usage of 3D printers has been on the rise with the average cost ranging from a few hundreds of dollars going up. However, one major drawback is that it requires expertise to print 3D objects [10]. In fact, it requires a competent person to make both the digital file and the final printing. Commercial usage of 3D printers has been on the increase too [16] in sectors such as the automotive industry and aero-space engineering. Spare parts, for example, are being made in the automotive and aero-space industry leading to improved economies of scale. 3D printing is changing how the production line in industries works which made some analysts to dub the emergence of 3D printers as the second Industrial revolution.

3D printing has also had a tremendous usage in the field of medicine; from the field of Bionics, to Prosthetics to Digital Dentistry. Inevitably, this is positively affecting and changing every aspect of medicine [2]. Most of the work is still in its exploratory phase but pundits predict medicine of tomorrow is going to be revolutionized by the integration of 3D printing as a tool.

2. How it works

As shown in figure 1, 3D printing starts by making a virtual design of the object you want to create. The virtual design is used as a template of the physical object to be created. This virtual design can be made using a 3D modelling program such as CAD (Computer Aided Design) to create a design from scratch. Alternatively a 3D scanner can be used for an existing object. This scanner makes a 3D digital copy of an object and puts it into a 3D modelling program.

Figure 1: 3D objects and digital model

The model is then sliced into hundreds or thousands of horizontal layers in preparation for printing. This prepared file is thus uploaded in the 3D printer, which will see the printer creating the object layer by layer as shown in figure 2 below.

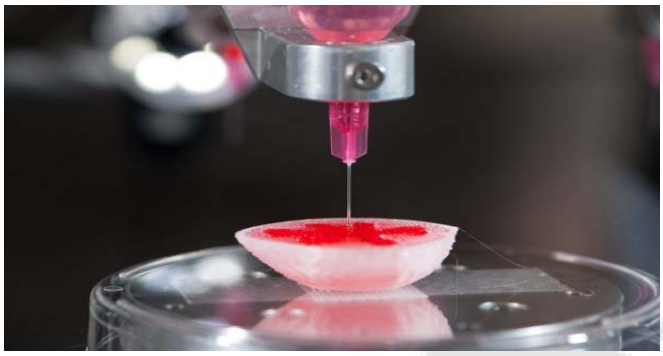

Figure 2: 3D printing layer by layer

Here, every slice (2D image) is read by the printer [5] and proceeds to create the object layer by layer and the resulting object has no sign of layering visible, but a 3 dimensional structure [6].

3. Applications of 3D printing

3D printing technology has been applied in various and varied sectors. Figure 3 shows the various kinds of usages of 3D printing which include research, artistic items, visual aids, presentation models, device covers, custom parts, functional models, and patterns as well as series production.

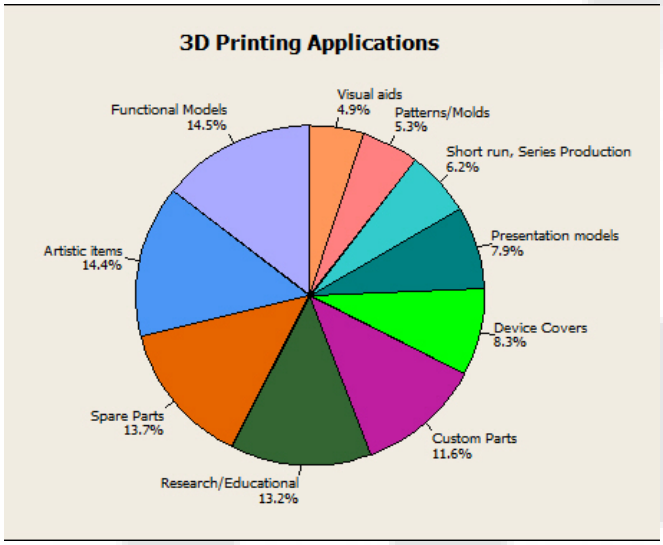

Figure 3: 3D printing applications

3.1 Construction

In China they were able to build 10 one-story houses in a day [18], a procedure which normally takes weeks to months to complete. 3D printing thus provides a cheaper, faster and safer alternative relative to more traditional construction. Four giant 3D printers were used by WinSun Decoration Design Engineering to build houses in Shanghai; by using a mix of cement and construction waste to construct the walls layer by layer. Each of these houses is 10 meters wide and 6.6 meters high [18].

Figure 3: 3D construction

With each house costing less than $5000, it has proved to be both cost and time effective.

3.2 Medicine

3.2.1 Hearing aids

Hearing aids have been made using 3D printing technology.

3.2.2 Bio printers

Organ printing or body part printing is being printed [1] and some parts being used as implants of actual body parts. Body parts such as titanium pelvic, plastic tracheal splint, titanium jaws to mention but a few have been printed.

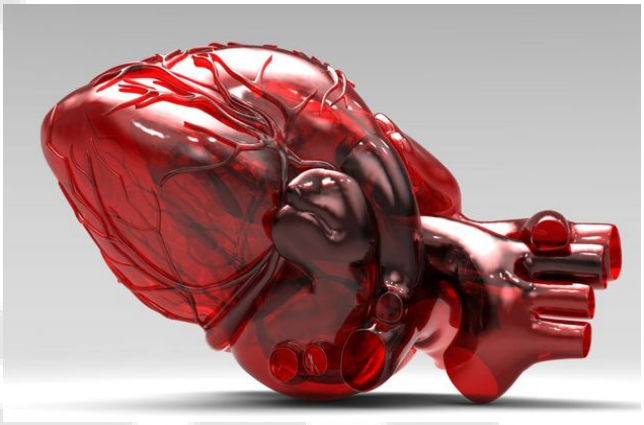

Figure 4: 3D printed heart

Figure 4 shows a 3D printed human heart. New bio printers actually print human tissue for both pharmaceutical testing and eventually entire organs and bones [12].

Tissue engineering has made tremendous strides as they have been able to print 3D blood vessels [13]. This was achieved by combining advances in 3D bio-printing technology and biomaterials through vascularisation of hydrogel constructs.

3.2.3 Digital Dentistry

People are getting 3D printed teeth customised for the individual [10]. Dental Implants are being made on a commercial level and making the whole process faster and more efficient. Before fake teeth used to be a one- size- fits -

all depending with age. Now, people of the same age can have different sized teeth resulting in people getting discomfort with ill-fitting fake teeth. Thus, customised implants have really brought a sigh of relief to the consumers as they are now able to receive teeth suited for them.

3.2.4 Prosthetics

A multitude of people are in need of surrogate body parts from people born without limbs to accident victims. The cost of getting surrogate body parts used to be extremely expensive but thanks to 3D printing; the cost has been significantly reduced.
Prosthetics has really done wonders to disabled people with the likes of Paralympics champion Oscar Pistorious being a world famous example. Oscar Pistorious had his legs cut off as a child, but that did not stop him from running, let alone in the Olympics [10] [2].

3.2.5 Bionics

Researchers from Princeton and John Hopkins were able to make a 3D printed bionic ear [10]. The hearing is done through electronics. This development could help deaf people to hear.

3.2.6 Artificial Organs

Additive manufacturing of stem cells has also led to various possibilities in printing artificial organs, although most of the work is still in the experimental stage. For instance, through 3D printing Heriot-Watt University scientists were able to produce clusters of embryonic stem cells. An endless world of possibilities awaits this world with the prospects of printing actual functioning artificial organs [10] [4].

3.3 Manufacturing

3D printing has introduced an era of rapid manufacturing. The prototyping phase is now able to be skipped and go straight to the end product [8]. Car and aeroplane parts are being printed using 3D printing technology. The printing of parts is being done in a fast and efficient manner thus contributing immensely to the value chain [8].

Customised products are able to be manufactured as customers can edit the digital design file and send to the manufacturer for productions. Nokia Company has taken the lead in manufacturing in this area [20] by releasing 3D design files of its case to its end users so they can customise it to their specifications and get the case 3D printed.

3.4 Domestic Usage

3D printers can be used in the home to make small objects such as ornamental objects such as necklaces and rings. Small plastic toys can also be printed in a domestic setting. In the future, people will be able to print their own products at home instead of buying from shops [8] [15].

3.5 Clothing

The fashion industry has also not been spared. 3D printed clothing is being made. Fashion designers are experimenting with 3D-printed bikinis, shoes, and dresses. Nike made the 2012 Vapor Laser Talon football shoe [19] and New Balance custom-fit shoes for athletes using a 3D prototype [17]. The production was done on a commercial scale.

3.6 Academia

3D printing is now being integrated in the learning curriculum. With applications from printed molecule models to plastic gears [14]. Students are now able to print their prototype models in 3D and it helps in the learning process of the students. Students are better able to understand concepts as it can be practically shown to them.

4. Benefits

3-D Printing has proven to have the following advantages**:**

1) **Lower Cost**
   In China they were able to construct 10 one storey houses at less than $5000 per house [18]. Construction of a similar house costs way more than the stipulated price.
2) **Time**
   Printing of the 3D object can be done directly, differing from the traditional manufacturing where you had to join different components to form the final product. Three-dimensional printing allows businesses to construct working models in just hours instead of days or weeks [17] [19].
3) **Efficiency**
   Generating prototypes with 3D printers is much easier and faster with 3D printing technology.
4) **Flexible**
   Different materials can be used in the 3 D models. This makes it very easy to create construction models or prototypes for a wide variety of projects within many industries.
5) **Durable products produced**
   The objects do not absorb moisture or warp over time making them last for longer.
6) **Quality**
   Products with an excellent surface finish are produced.
7) **Functional Models**
   Real live functional models can be produced as opposed to working with paper of digital models. More realistic products are produced.

5. Future Work

The Future looks bright in the field of 3D printing with the following areas to look out for:

5.1 Manufacturing

The 3D printing industry is set to see unprecedented growth with market analysts predicting a year on year 18 percent growth. As shown in figure 5, it is predicted that the 3D printed part market will grow to an 8.4 billion dollar industry by 2025 [11]. Automobile parts and aerospace will lead in the parts sales forecast.

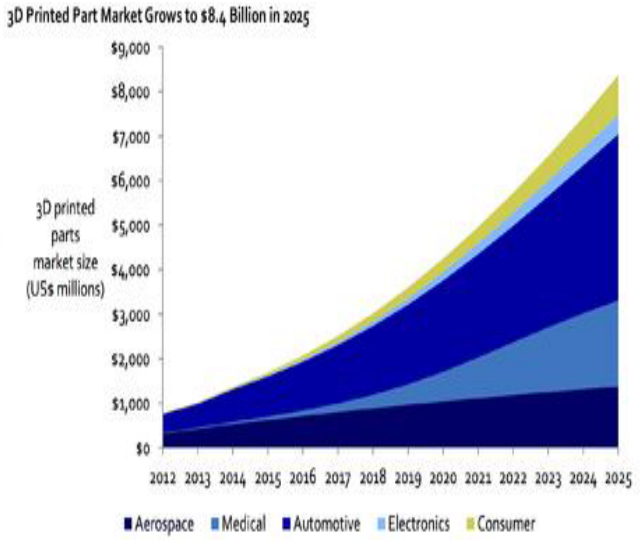

Figure 5: 3D printing growth prospects

5.2 Medicine

5.21 3D printed organs

The combination of Stem cell research and 3D printing will result in transplantable body parts in the future. Real functional body parts will be able to be 3D printed [10] [3].

5.2.2 Skin grafting

In skin grafting healthy skin from a part of the body is used to cover a damaged part of the body. The procedure is very well known to be a painful procedure. University of Toronto researchers have developed a method of skin grafting by loading skin cells and various polymers into 3D printer to artificially create layers of skin. Institute of Regenerative Medicine scientists at Wake Forest University in Winston-Salem, North Carolina, inspired by war victims aim to print skin directly onto burn wounds. They observed that most of the casualties of war were burn victims which had to go the gruesome operation of skin grafting. Hopefully in the near future all this research will turn into reality.

5.3 Commerce

Amazon set up a 3D printer store. They envision selling digital 3D design files and the customer then prints the product on their own [8]. This is going to revolutionise the supply side of products as consumers will be able to print whatever products they want.

6. Conclusion and Recommendations

The 3D printing industry is set on a growth trajectory as evidenced by the growth forecasts [11]. The applications of 3D printing are increasing as more and more research is carried out. 3D printing will change the way people acquire products as evidenced by the Amazon proposed model. The field is definitely a game changer with lots of prospects to look out for.

References

[1] Athanasios Anastasiou, Charalambos Tsirmpas, Alexandros Rompas, Kostas Giokas, Dimitris Koutsouris, “3D Printing: Basic concepts Mathematics and Technologies,” IEEE, pp 1-4, 2013

[2] Emilio Soto, Oscar Baez , Sergio Sosa, “Modeling, Design and Construction of Articulated Hand for use in prosthetics, with adaptive control in Neural Networks based on mathematical model for finger.” In Proceedings of the Ninth Mexican International Conference on Artificial Intelligence, pp 107-112

[3] Akio Doi, Hiroki Takahashi, Bunei Shuto, Masaaki Katayama, Hiroyuki Nagashima, Masahiro Okumura, “Design and application of tailor-made plates for treating fractures in small animals,” IEEE, pp1-5, 2012

[4] Rivo Öpik, Andres Hunt, Asko Ristolainen, Patrick M. Aubin, “Development of High Fidelity Liver and Kidney Phantom Organs for Use with Robotic Surgical Systems,” IEEE, pp 425-430, 2012

[5] Lana Madraevi, Stjepan Šogori, “3D Modeling From 2D Images,” In Proceedings of MIPRO, Opatija, Croatia,pp 1351-1356, May 24-28 2010

[6] 3dprinting “What is 3D printing?” 3dprinting.com [Online]. Available: http://3dprinting.com/what-is-3d-printing/. [Accessed: June. 18, 2014].

[7] Wikipedia, “3D printing” wikipedia.org, 18 June 2014, [Online].Available: http://en.wikipedia.org/wiki/3D_printing. [Accessed: June. 18, 2014].

[8] Dominic Basulto “How 3D printing could transform Amazon and online shopping” washingtonpost.com, March 132014,[Online].Available: http://www.washingtonpost.com/blogs/innovations/wp/2014/03/13/how-3d-printing-could-transform-amazon-and-online-shopping/. [Accessed: June. 18, 2014].

[9] General Electric “7 Things You Didn't Know About 3D Printing,” mashable.com, Dec 3, 2013 [Online]. Available: http://mashable.com/2013/12/03/3d-printing-brandspeak/. [Accessed: June. 18, 2014].

[10] “3D Printing in Medicine: How Technology Will Save Your Life,”August 13, 2013, [Online]. Available: http://www.cgtrader.com/blog/3d-printing-in-medicine-how-technology-will-save-your-life/. [Accessed: June. 18, 2014].

[11] Ann R Thryft, “Report: 3D Printing Will (Eventually) Transform Manufacturing,” designnews.com, 18 August 2013[Online].Available: http://www.designnews.com/author.asp?doc_id=262205&dfpPParams=ind_183,industry_auto,industry_aero,industry_consumer,industry_machinery,industry_medical,bid_27,aid_262205&dfpLayout=blog. [Accessed: June. 18, 2014].

[12] The Daily Telegraph, “3D printing of human organs ,”timeslive.co.za, 2 September, 2013 [Online]. Available: http://www.timeslive.co.za/thetimes/2013/09/02/3d-printing-of-human-organs. [Accessed: June. 18, 2014].

[13] Shannon Stapleton “‘Critical challenge’: Doctors can now 3D-print blood vessels,” rt.com, June 01, 2014 [Online]. Available: http://rt.com/news/162848-3d-print-blood-vessels/. [Accessed: June. 18, 2014].

[14] Jason Hidalgo "The future of higher education: reshaping universities through 3D printing," engadget.com, October 19, 2012 [Online]. Available: http://www.engadget.com/2012/10/19/reshaping-universities-through-3d-printing/. [Accessed: June. 18, 2014].
[15] Marcia Goodrich "MTU Study: 3D Printing Will Reach The Home Soon,"detroit.cbslocal.com, *July 29, 2013* [Online].Available: http://detroit.cbslocal.com/2013/07/29/mtu-study-3d-printing-will-reach-the-home-soon. [Accessed: June. 18, 2014].
[16] David Nicholson, "3D Printing - Approaching Critical Mass In An $8 Billion Industry," forbes.com, May 30 2014, [Online].Available: http://www.forbes.com/sites/davidnicholson/2014/05/30/3d-printing-approaching-critical-mass-in-an-8-billion-industry/. [Accessed: June. 18, 2014].
[17] Mark Fleming "What is 3D Printing? An Overview," *3dprinter.net*,[Online].Available: http://www.3dprinter.net/reference/what-is-3d-printing. [Accessed: June. 18, 2014].
[18] Mellisa Goldin "Chinese Company Builds Houses Quickly With 3D Printing,"mashable.com, April 29 2014, [Online]. Available: http://mashable.com/2014/04/28/3d-printing-houses-china/. [Accessed: June. 18, 2014].
[19] Nike Inc "Nike Debuts First-Ever Football Cleat Built Using 3D Printing Technology", nike.com, February 24 2013, [Online]. Available: http://nikeinc.com/news/nike-debuts-first-ever-football-cleat-built-using-3d-printing-technology. [Accessed: June 18, 2014].
[20] Nokia Developer "3D print a shell for your Nokia Phone", nokia.com, January 18 2013, [Online}. Available: http://developer.nokia.com/community/wiki/3D_print_a_shell_for_your_Nokia_Phone. [Accessed: June 18, 2014].

Author Profile

Thabiso Peter Mpofu received B. Tech degree in Computer Science at Harare Institute of Technology (HIT), Zimbabwe in 2010. He is currently pursuing M. Tech Computer Science at JNTUH, India. He is a HIT staff development research fellow. His research interests are in the area of Data Mining, Network Security and Mobile Computing.

Cephas Mawere received B. Tech degree in Biotechnology from Chinhoyi University of Technology, Zimbabwe in 2010. He is currently pursuing M. Tech Bioinformatics degree at JNTUH, India. He is also a Harare Institute of Technology staff development research fellow. His research interests are in the area of Information Security, High Performance Computing and Computer- Aided Drug Design.

Macdonald Mukosera received the B.Tech Hons degree in Computer Science from Harare Institute of Technology in 2010. During 2011-2012, he worked as a Teaching assistant at Harare Institute of Technology in the Software Engineering Department. He is now studying M Tech Computer Science at JNTUH SIT India. His research interests are in the area of Data Mining, Network Security and Web Services.