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THE DEVELOPMENT, APPLICATION AND BENEFITS OF 3-D PRINTING TECHNOLOGY

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Abstract— **The 3-D printing technology allows the low-cost creation of structures based on user-defined configuration parameters. Unlike other plastic formation technologies, there is no tooling cost related to the creation of a mold. Because of this, highly-customized structures can be created with a minimum production quantity of one. This paper considers the maximum possibilities enabled by the use of 3-D printing for medical, commercial, domestic and industrial applications. These mission types include low-cost student-centric projects, atmospheric, scientific and engineering development missions. In this paper we seek to explore the construction, working and future applications of 3-D printing Technology.**

***Index Terms*—3-D printing, fused deposition modelling, additive manufacturing, heat bed, extruder, thermistor**

I. INTRODUCTION

3-D printing or additive manufacturing based on fused deposition modelling 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 3-D printing layers are added successively [1] [4]. Thus it uses a layering technique where an object is constructed layer by layer until the complete object is manufactured. In this way 3-D printing moves us away from the mass production line to a one-off customizable production. You can literally make any object from a house to a bar of chocolate, so to say. The initial 3-D 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 [6]. 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 ink jet printers extrudes ink onto paper [6]. Interestingly, the cost of acquiring 3-D printers has been decreasing with the advancement of technology. Domestic usage of 3-D 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 3-D objects. In fact, it requires a competent person to make both the digital file and the final printing. Commercial usage of 3-D printers has been on the increase too in sectors such as the automotive industry and aerospace engineering. Spare parts, for example, are being made in the automotive and aero-space industry leading to improved economies of scale. 3-D printing is changing how the production line in industries works which made some analysts to dub the emergence of 3-D printers as the second Industrial revolution. 3-D 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. 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 3-D printing as a tool.

II. CONSTRUCTION

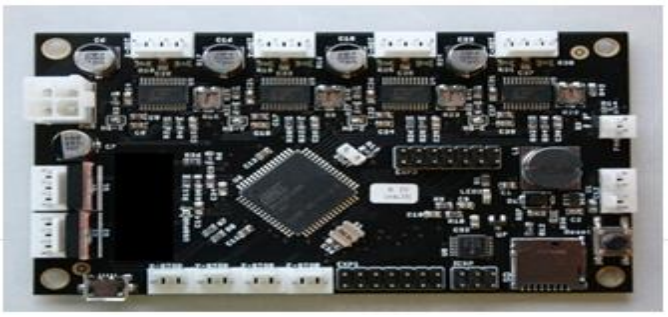


Fig. 1 Printer board Rev F4

Wherever Times is specified, Times Roman or Times New Roman may be used. If neither is available on your word processor, please use the font closest in appearance to Times. Avoid using bit-mapped fonts. True Type 1 or Open Type fonts are required. Please embed all fonts, in particular symbol fonts, as well, for math, etc.

A. Features of Printer board Rev F4

Atmel AT90USB1286 Microcontroller (128kb Flash), Four integrated Allegro A4982 Stepper Drivers, On-board 4-channel DAC to control stepper set current. Thermistor Connectivity: 2, Two N-MOSFETs for Extruder and Heat bed control, One N-MOSFET for low power Fan or motor.

B. Components

1) Stepper Motors: Connect the X, Y, Z axis, and extruder motors to the matching headers at the top of the Printer board (X-MOT, Y-MOT, Z-MOT, E-MOT)

2) Endstops: Connect the 3-pin Molex headers X-stop, Y-stop, Z-stop at the bottom of board.

3) Heaters: Connect the heating element of the hot end (resistor or nichrome wire) to the 4-pin extruder header, positioned next to MOSFET Q1. Connect the heat bed to the Hotbed header, next to MOSFET Q2.

4) Thermistors: Thermistor headers are 2-pin Molex headers at the right side of the board. Connect the heat bed thermistor to the header directly above the reset button. The hot end thermistor connects above the heat bed header.

5) Low Power Fan: A 2-pin Molex header labelled fan is located on the right side of the board, above the thermistor headers. This optional header can be used to power a fan or other small motor.

6) Board Power: Connect the Power Input directly to any +12V DC power supply of sufficient amperage capability to run the intended devices. The two Ground terminals are closest to the edge of the board (left), and the two +12V DC terminals are away from the edge (at the right).

7) USB: Connect a micro-USB cable to the USB jack at the bottom of the PCB.

III. WORKING

As shown in figure 2, 3-D 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 3-D modelling program such as CAD (Computer Aided Design) to create a design from scratch. Alternatively a 3-D scanner can be used for an existing object. This scanner makes a 3-D digital copy of an object and puts it into a 3-D modelling program.

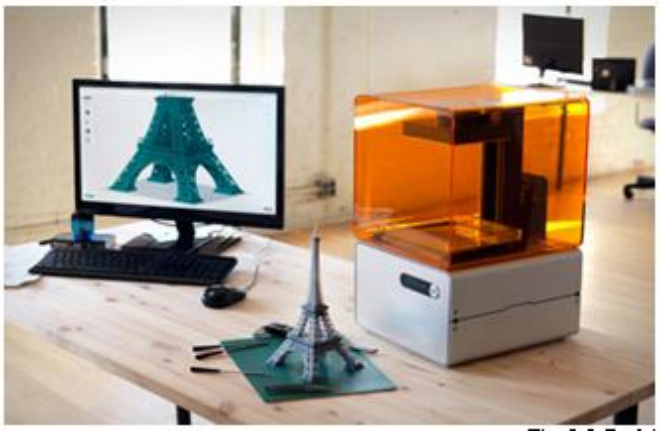


Fig. 2 3-D objects and digital model

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

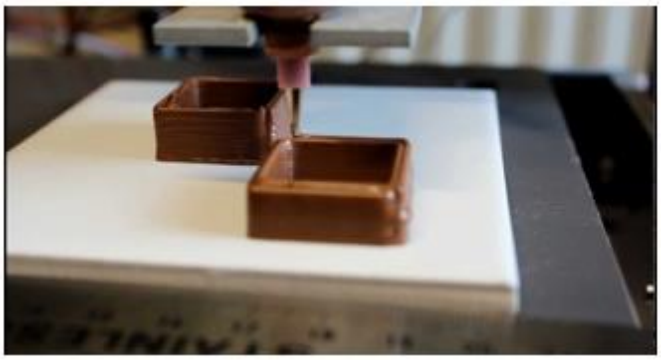


Fig. 3 3-D printing layer by layer

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

IV. APPLICATIONS

3-D printing technology has been applied in various and varied sectors. Figure 4 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.

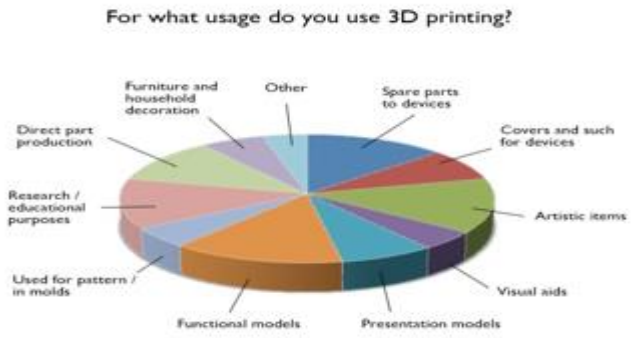


Fig. 4 Applications of 3D printing

A. Construction

In China, Engineers were able to build 10 one-story houses in a day [10], a procedure which normally takes months to complete. 3-D printing thus provides a cheaper, faster and safer alternative relative to more traditional construction.

Four giant 3-D printers were used by Win Sun 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 [10].

B. Medicine

1) Hearing aids: Hearing aids have been made using 3-D printing technology.

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.

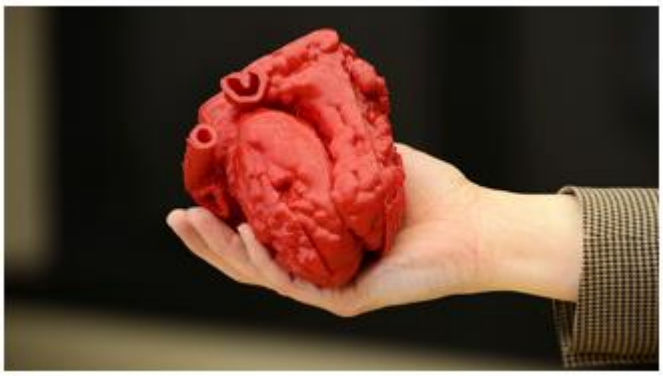


Fig. 5 3-D printed heart

Figure 5 shows a 3-D printed human heart. New bio printers actually print human tissue for both pharmaceutical testing and eventually entire organs and bones [7]. Tissue engineering has made tremendous strides as they have been able to print 3D blood vessels.

3) Digital Dentistry: People are getting 3D printed teeth customized for the individual. Dental Implants are being made on a commercial level and making the whole process faster and more efficient. Thus, customized implants have really brought a sigh of relief to the consumers as they are now able to receive teeth suited for them.

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 because to 3-D printing; the cost has been significantly reduced.

5) Bionics: Researchers from Princeton and John Hopkins were able to make a 3-D printed bionic ear. The hearing is done through electronics. This development could help deaf people to hear.

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 [5].

C. Manufacturing

3-D printing has introduced an era of rapid manufacturing. The prototyping phase is now able to be skipped and go straight to the end product [4]. Car and plane parts are being printed using 3-D printing technology. The printing of parts is being done in a fast and efficient manner thus contributing immensely to the value chain [3].

Customized products are able to be manufactured as customers can edit the digital design file and send to the manufacturer for productions.

D. Domestic Usage

3-D 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 [4] [9].

E. Clothing

3-D printing has garnered attention in the fashion industry as well. 3-D printed clothing is being made. Nike made the 2012 Vapor Laser Talon football shoe and New Balance custom-fit shoes for athletes using a 3-D prototype. The production was done on a commercial scale.

F. Academia

3-D printing is now being integrated in the learning curriculum. With applications from printed molecule models to plastic gears [4]. Students are now able to print their prototype models in 3-D 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.

V. BENEFITS

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

A. Lower Cost

In China, Engineers were able to construct 10 one story houses at less than $5000 per house [10]. Construction of a similar house costs way more than the stipulated price.

B. Time

Printing of the 3-D 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.

C. Efficiency

Generating prototypes with 3-D printers is much easier and faster with 3-D printing technology.

D. Flexible

Different materials can be used in the 3D models. This makes it very easy to create construction models or prototypes for a wide variety of projects within many industries.

E. Durable products produced

The objects do not absorb moisture or warp over time making them last for longer.

F. Quality

Products with an excellent surface finish are produced.

G. Functional Models

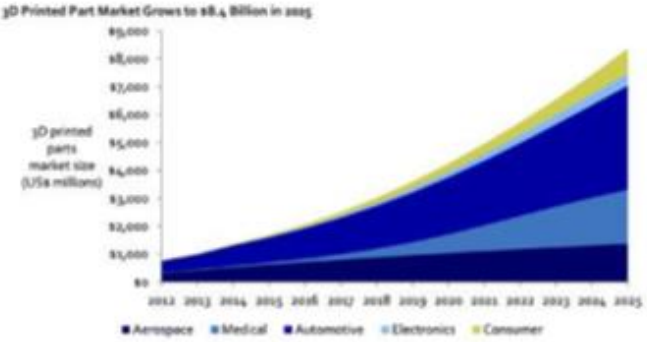
Real live functional models can be produced as opposed to working with paper of digital models. More realistic products are produced.

VI. FUTURE WORK

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

A. Manufacturing

The 3-D printing industry is set to see unprecedented growth with market analysts predicting a year on year 18 percent growth. As shown in figure 6, it is predicted that the 3D printed part market will grow to an 8.4 billion dollar industry by 2025 [8]. Automobile parts and aerospace will lead in the parts sales forecast.



B. Medicine

1) 3-D printed organs

The combination of Stem cell research and 3-D printing will result in transplantable body parts in the future. Real functional body parts will be able to be 3-D printed [2] [5].

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. At University of Toronto researchers have developed a method of skin grafting by loading skin cells and various polymers into 3-D 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.

3) Commerce

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

VII. CONCLUSION AND RECOMMENDATIONS

The 3-D printing industry is set on a growth trajectory as evidenced by the growth forecasts [8] [9]. The applications of 3-D printing are increasing as more and more research is carried out. 3-D 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.

VIII. ACKNOWLEDGMENT

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