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Digital Application of 3D Printing Technology in Architecture

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Abstract—*3d printers have established themselves as very successful and important in various fields- Medical, Dental, Architecture, Engineering, Chemistry, Art and Sculpture*
Now 3D printing can be defined l as a process used to make three dimensional solid object of virtually any shape from a digital model. It is a process in which digital design 3d data is used to build a component in layers by depositing materials. Successive layers of material are laid down under computer control. The first working 3d printer was created in 1984 by chuck hull of 3d systems corp. Since the start of the 21st century there has been a large growth in the sales of these machines.
The worldwide 3D printing industry is expected to grow from $3.07B in revenue in 2013 to $12.8B by 2018, and exceed $21B in worldwide revenue by 2020. As it evolves, 3D printing technology is destined to transform almost every major industry and change the way we live, work, and play in the future.[1].
The use of 3D printing in architecture is although is at very beginning stage, but a new proof of concept has just been unveiled. The improvements on accuracy, speed and quality of materials in 3D printing technology have opened new doors for it.

1. INTRODUCTION

The technology used for printing physical 3d objects from digital out is called 3d printing. It is a process used to make three dimensional solid object of virtually any shape from a digital model. It is a process in which digital design 3d data is used to build a component in layers by depositing materials. Successive layers of material are laid down under computer control.

It is the computer-controlled sequential layering of materials to create 3d shapes.

It is particularly very useful for prototyping and for the manufacture of geometrically complex components.

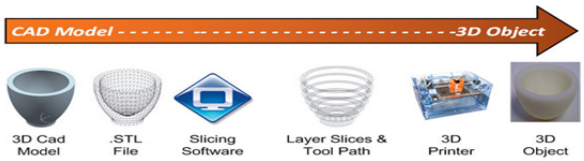

Fig. 1: Process of 3D Printing

[1] *Source: Wohlers Report 2015*

2. HISTORY

It was first developed by Charls Haul in 1984, but only since 2000 that it has become relatively straight forward and affordable and so has become viable for a wide range of uses.

In 1993, Massachusetts Institute of Technology (MIT) patented another technology, named "3 Dimensional Printing techniques", which is similar to the inkjet technology used in 2D Printers.

3. 3D PRINTING AND CONSTRUCTION INDUSTRY

The construction industry is ready to take advantage of 3D printing and its benefits. This type of printing can be used for the creation of complex components or even for the construction of whole buildings. One of the main advantages the construction industry has over others is that it is already experienced in computer aided manufacturing

3D printers have established themselves as very successful and important in various fields-

- Product Design
- Component and tool manufacture
- Aerospace engineering
- Medical Applications
- Architecture

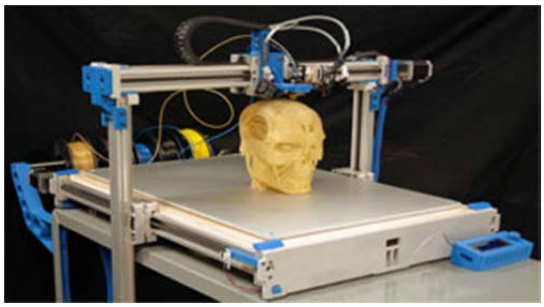

Fig. 2: A 3D Printer in working stage

4. TYPES OF 3D PRINTING

4.1 Stereolithography

Stereolithography was the first type of 3D Printing created. Charles W. Hull has invented it in 1986.

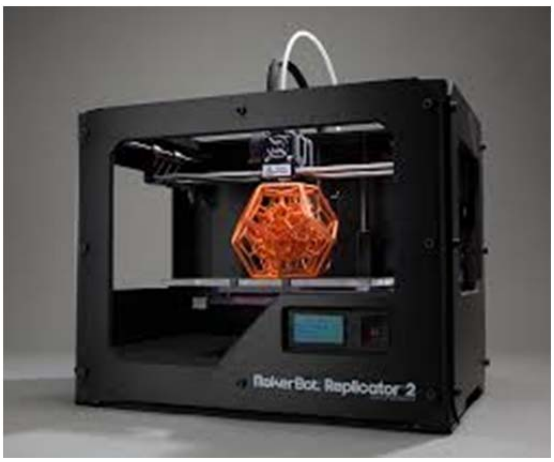

Fig. 3: Stereolithography 3D PRINTER

To create a 3D object, the printer focuses UV light in a pattern on the resin on the vat. This pattern is created by the horizontal movements on the X and Y axis with the UV light. When the pattern is finished, a tiny layer of resin is solidified. The vat moves down vertically on the Z axis, and another layer is solidified. When all layers are completely solidified together, the model is done.

4.2 Selective Laser Sintering

Selective Laser Sintering is what prints the other materials, like glass, nylon, or even metal. Selective Laser Sintering is much like Stereolithography, but instead of liquid resin, you'll find powdered materials, like powdered glass, nylon, or metal. Additionally, instead of a UV light, you'll find a laser.

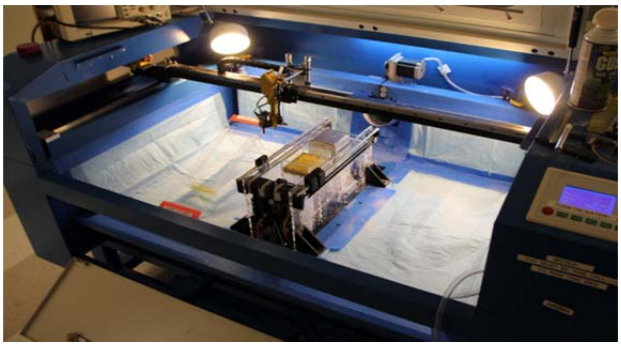

Fig. 4: Selective Laser Sintering Machine

When a 3D model is printed, the laser draws a pattern on a thin layer of the powdered material. When the laser hits the material, particles of the material is fused, or *sintered*, together, creating a solid layer. When one layer is finished, another thin layer of powder is spread, and layer after layer is produced.

After the model is printed, the object is removed and dusted. The rest of the remaining powder is reused

4.3 Fused Deposition Modeling

Fused Deposition Modeling is what is mainly used in consumer-level 3D Printers, and is one of the less expensive 3D printing methods.

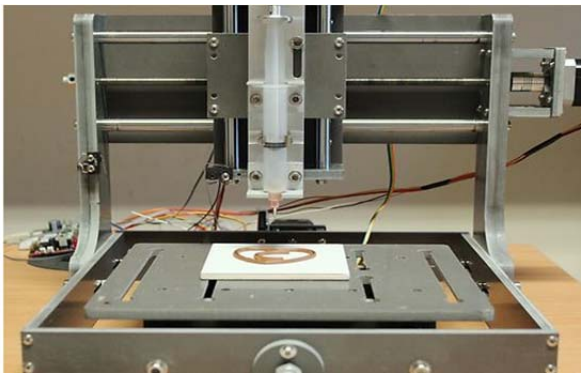

Fig. 5: FDM Printer

To print an object, a thread of plastic is fed through the *extruder* and the extruder moves in a horizontal pattern to place down a small layer of plastic. After one layer is finished, the extruder moves up on the Z axis, and another layer is fabricated. Each layer fuses onto each other before the plastic hardens. When all the layers are complete, the model is finished.

4.4 Laminated Object Manufacturing (LOM)

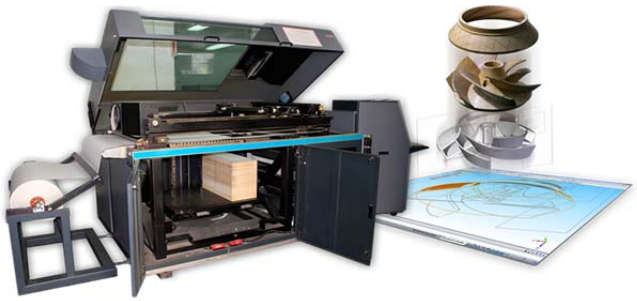

Fig. 6: LOM Printer

It is a rapid prototyping system developed by Helisys Inc. In it, layers of adhesive-coated paper, plastic, or metal laminates are successively glued together and cut to shape with a knife or laser cutter. Objects printed with this technique may be additionally modified by machining or drilling after printing. Typical layer resolution for this process is defined by the

material feedstock and usually ranges in thickness from one to a few sheets of copy paper.

5. MERITS AND DEMERITS OF 3D PRINTING

Some of the **advantages** of using 3D printing in the construction industry are:

- **Faster and accurate construction** – A 3D printer transfers the digital model into a physical one; errors that arise can only be due to faults in the digital model or the materials used
- **Reduced labour cost** – A 3D printer does most of the work with minimal human effort
- **Reduced waste generation** – Components can be printed to order during the construction phase; those that are not used can be recycled
- **Reduced health and safety risks** – By replacing dangerous jobs on site with printing processes
- **Environmentally friendly** – recycled products can be used to produce the construction materials used in 3D printers.

However, there are also a number of **disadvantages** that are associated with 3D printing, including:

- **Reduced Employment** - Reduced employee numbers in the industry, since the 3D printer does most of the work
- **Material Limitation** -A limited number of materials can be used, since the same printer might not be able to print the required multiple materials
- **Transportation** – getting the printers for large in situ components to and from the site
- Storage of the printer on site
- **Higher risks** – any errors in the digital model can result in problematic issues on site during the printing/construction phase
- Conventional product manufacturing companies and plant renting companies could suffer as their products are no longer required
- Additional time may be required on site if the components are created in situ.

The pros and cons mentioned above are just a small number associated with 3D printing. For this type of technology to be successfully adapted by the construction industry, much further research has to be done to produce and refine 3D printers capable of working on both small and large scale projects.

The various types of materials used and the combination of materials in hybrid construction should be also recognized.

6. CASE STUDIES

6.1 Villa by Zhuoda Group, China

A Chinese company Zhuoda Group produced a villa comprising of 6 modules. 90% of the work was done in factory and it took only 3hours to assemble the villa on site, in Xían.

The modules were stacked using a crane, with a bedroom, kitchen, and bathroom assembled on the ground floor and a terrace, bedroom, and utility room stacked on top to create the first floor.

Each module weighs more than 100 kg and the cost of the materials ranged from $605 to $847 a sq.m.

The engineer claims the building can withstand earthquakes because each module bears its own weight. Also the villa is considered to be fireproof.

Fig. 7: Process of construction of the villa

6.2 Canal House, Amsterdam

A Dutch company is making a 3d printed, 13-room canal house made from separate but interlocking components.

The rooms will be structural entities on their own and will be placed on top of each other to make a house. The Canal House is printed with the Kamer Maker, a large portable 3D printer developed by DUS architects that can print entire interiors and measures 2 x 2 x 3.5 meter.

The primary material being used is bio plastic. The interior and exterior walls of the house are printed at the same time with spaces left in between for electric wiring and pipes. These spaces are then filled in with concrete for insulation and reinforcement.

However, this can be considered as a demerit as correcting faults or altering wire between walls would be problematic. The house is expected to be constructed by 2016, while the final cost of the project is unknown.

Fig. 8: Photograph of canal House, Amsterdam

7. MATERIALS

Any material cannot be fed into the printer. It has limitations. Also, different companies are experimenting with different materials. Few most commonly used materials are:-

- Concrete

Fig. 9: Concrete

- Glass Fiber

Fig. 10: Glass Fiber

- Bio Plastic

Fig. 11: Bio Plastic

- Construction Waste

Fig. 12: Construction Waste

- Metal

Fig. 13: Metal Scraps

8. 3D PRINTING AND ARCHITECTURE

The big difference between 3D printing and manufacturing on site is that you're almost entirely skipping the fabrication part," says Retsin. There are huge potential time, labour and transportation savings to be made, compared to traditional construction methods – however, the cost of 3D-printed materials is still far higher than regular bricks and blocks

Fig. 14: Ready to Assemble Castle

"The 3D-printing technology has been developing at a very rapid pace," says Mediated Matter founder Neri Oxman, "but there are still many limitations," such as the range of materials you can use, the maximum size you can print at and the speed of the process.

Figure 15: Ornamentation & furniture product of 3D printer

9. CONCLUSION

3D printing has only been **used on small scale projects** in the construction industry and there are a lot of challenges that need to be dealt with prior to considering adopting it as one of the main construction technologies.

The **price of 3D** printing is also problematic for large volumes. There are still **limitations in terms of materials** that can be used and the speed of the overall process.

3D printing is more than anything an approach for organizing material. Today's material limitations can be overcome by printing with responsive materials.

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