Open Source 3D Printer: A Case Study

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Abstract

Everyday, engineers are impressing us with innovative technologies that have brought into reality what was recently considered as science fiction or inconceivable futuristic, making our lives much more comfortable and more enjoyable. Recently, 3D printing helps in a far-reaching analog-to-digital shift that will completely transform the global manufacturing industry. It will change almost everything, the way we design, manufacture, distribute and consume.3D printers print objects from computer models to real 3D physical objects. The printing is done layer by layer using different materials. As different materials used for printing there are various techniques used for 3D printing, as well as the construction of the printer itself. In this study, we discuss the advantages and disadvantages of installing and analyzing the output of an open-source 3D printer.

Keywords
3D printing, digitization, Open source, FDM, SLS, Repetier, DLP

1. Introduction

Nowadays, 3d printing has become a robust field that is overgrowing to revolute the manufacturing processes. Many disciplines like mechanical, electrical, biomedical, and aerospace industries, use 3d printing to improve the design manufacturing and to minimize the lead time as well as the tooling cost for new objects produced. 3d printing differs from traditional machining such as turning, milling and drilling which helped people many decades ago to build products. However, recently, they are no longer used as much as before because they have some limitations and constraints, such as the expensive cost of the production processes. In this regard, the concept of 3d printing has introduced. It is also known as additive manufacturing, which is part of rapid prototyping in which it is possible to form 3-dimensional objects from a digital file. Additive manufacturing meant to be the deposition of a specific material layer by layer until the desired object is created as per the given design. Those layers that combined one on top of the other is nothing more than a horizontal cross-section of the product itself. The quality of the printed parts using a 3d printer relies on many factors, like the composition of the material used, the manufacturing process, the printing feeding rate, filament flow rate, the type of 3D printer used, and eventually the dimensions of the printed part of the used printer. In general, 3D printing technology has a significant contribution to the world in many directions because of the remarkable advantages to the industrial sector and has a substantial impact on the other fields [Ahmed and Al-Douri (2020), Ahmed and Al-Douri (2018)]. The development has also been applied to other fields, such as prototyping, modeling and failure mechanisms [Aldarmaki, A. N. et al. (2019), Al-Shamsi et al. (2019)], Whereas the aerospace industry is one of the exciting industries due to the wide range of applications that 3D printing technology could be used Alahbabi et al. (2019)]. However, the 3D printing technology started being embraced in schools [Ahmed and Alhamad (2018)] for the learning purposes [Alhamad et al. (2019)], as well as implemented in different university levels [Alhamad et al. (2019)].

1.1 3D printing Technologies

There are numerous technologies that 3D printers use to print the products. In some techniques, the material from which the layers of the object are formed needs to be liquefied or softened. While in other cases high powered UV laser is used to cure photo-reactive resin and print the object.

Figure 1. 3D printing process: from design to printing [Bill (2020)]

As illustrated in Figure 1, the first step in any 3d printing process is always designing a model of the object that is needed to be printed on CAD software [Chua et al. (2003)]. In that model, all the geometrical features of the product should appear clearly. The CAD model later needs to be converted into an STL file format in which the external closed surfaces of that model will be defined. Subsequently, the STL file sent to the 3d printer to be printed. After printing the part, post-processing takes place to make the component ready to be used in a real application.

Some of the most commonly deployed 3D printing techniques these days are:

a) Stereolithography (SLA)
b) Fused deposition modeling (FDM)
c) Selective Laser Sintering (SLS)
d) Laminated object manufacturing (LOM)
e) Digital Light Processing (DLP)

1.1.1 Stereolithography

Stereolithography (SLA) is defined as a 3D printing technology that is mainly used for creating models, patterns, and prototypes. It is said to be a laser-based process because ultraviolet laser and a vat of resin are essentials to make a part using this strategy. The laser beam shows the pattern on the liquid polymer's back. Ultraviolet laser penetration allows the atom chains in the polymer gum to bind [Ba´rtolo and Gibson (2011)]. After that, the photopolymer resins response to the laser to make a solid object in a particular form. Stereolithography is considered to be the best prototyping method, while it is less time-consuming and somehow cheaper than the other methods [Stereolithography (2020)]. Post processes in this technology involve a chemical bath to clean the part plus laying the piece in an oven-like machine to entirely harden the resin.

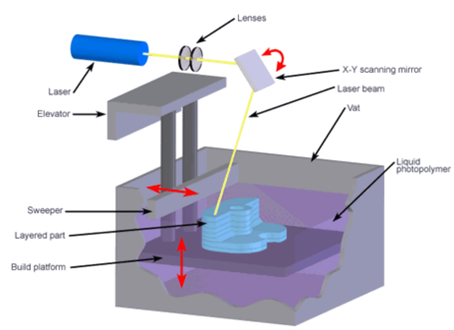

Figure 2. Stereolithography Process
[Stereolithography (2020)]

1.1.2 Fused Deposition Modelling

Fused Deposition Modeling (FDM) is a 3D printing technique using a continuous heated thermoplastic filament to create structures and prototypes layer by layer [Novakova-Marcincinova and Kuric (2012)]. Similar to SLA, post-processes are needed for the parts printed in FDM. By comparison with SLA, FDM is cheaper but less accurate. Furthermore, the material in FDM is limited to thermos plastic.

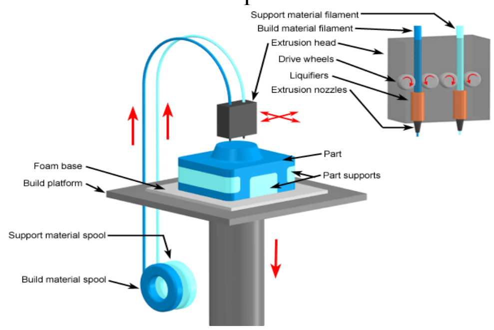

Figure 3. Fused Deposition Modelling
Process [Fused Deposition Modeling (2020)]

1.1.3 Selective Laser Sintering

Selective Laser Sintering (SLS) is another form of additive manufacturing technology, where a small particle of different materials such as plastic, ceramics or glass are bonded together by the use of heat from a high-powered laser beam to build a solid.

In fact, the object printed using SLS lies on a layer of powdered material, which makes the use of structure supports not essential. This matter is suitable even for saving consumable material as well as reducing the production cost. Moreover, this technique doesn't require the need for post-processing [Campanelli, et al. (2010)].

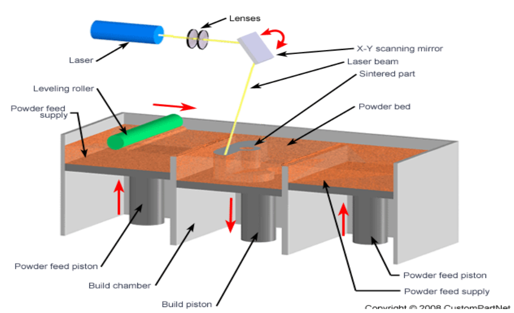

Figure 4. Selective Laser Sintering Process [Selective Laser Sintering (2020)]

1.1.4 Laminated Object Manufacturing

In the Laminated Object Manufacturing (LOM) technique, high pressure and temperature are needed to fuse sheets of plastic to get shaped later on using a computer-controlled laser or blade [Pang (2001)].

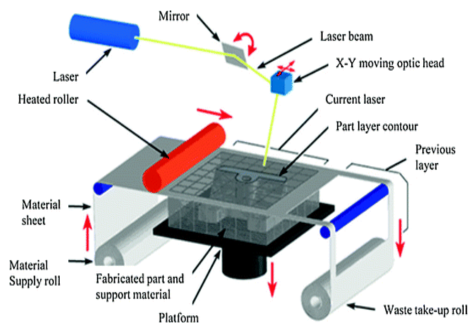

Figure 5. Laminated Object Manufacturing Process
[Laminated Object Manufacturing (2020)]

1.1.5 Digital Light Processing

In the method of Digital Light Processing (DLP), Photopolymers are also used, and the process followed is similar to that in Stereolithography. The light source is the only distinction between them. SLA uses a laser while DLP uses traditional light sources to treat polymer resin that is photosensitive.

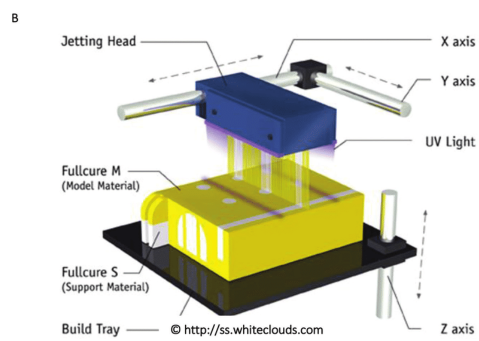

Figure 6. Digital Light Processing [Mouzakis (2018)]

2. Difference between Delta and Cartesian printer

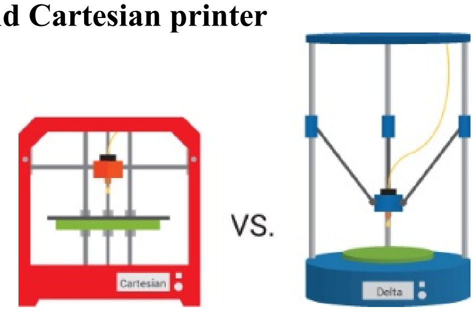

Figure 7. Delta vs Cartesian 3D Printer [3D Printers Explained (2006)]

Cartesian and Delta 3D printers are the most common 3D printers currently available. What are the differences? Printers like FDM printers take a filament of material (most of the time plastic) and dismiss through the printer's head (called print-nozzle). The material rejected is then positioned on the platform of the printer, creating sequential thin layers, built from the bottom up, forming a 3D object.

The difference between them is how does the print nozzle get the material in the right spot? they have various ways of handling the print head in 3D space. Here Is the difference between the cartesian printer method and the Delta printer method [Jason (2020)].

2.1 Cartesian Printers

It's based on the Cartesian plane method of mapping out three dimensions. These Cartesian planes allow you to use X, Y and Z coordinates to map a point in 3D space. So, it can move the print head back and forth, up and down, right and left. And in some of them, the build plate can move up and down, front and back, or may shift in multiple directions.

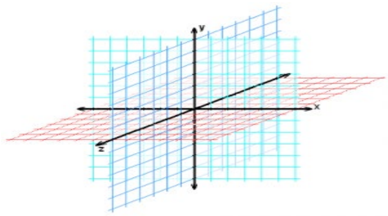

Figure 8. Cartesian axis's (X, Y, and Z axis's) [Jason (2020)]

The construction of the printers that work with the cartesian system primarily has three rails, and each rail corresponds to one of the cartesian plane axes. Each rail consists of sliding joints or screws that locate the nozzle anywhere within the workspace, as specified by your 3D model file [Jason (2020)].

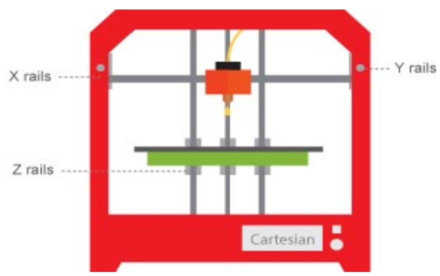

Figure 9. The X, Y, and Z axis's in a Cartesian printer [Jason (2020)]

2.1.1 Advantages

3D extrusion printing technology covers a variety of printers, the cartesian printers are the most common for many reasons. The system is broadly supported with replacement parts almost always easy to find. Also, they are easy to repair or find repairs for, owing to their large market share. In comparison, Cartesian printers often produce better finishes, with fewer errors in contrast to Delta prints. These printers cannot deny that the reason for their excellent prints is their more rigid axes, which reduce print errors within the 3D space [Jason (2020)].

2.1.2 Disadvantages

The use of a Cartesian printer does not have many drawbacks. Anything build by it is a result of the manufacturer.

2.2 Delta Printers

The Delta printer adopts a very different approach in guiding the print-nozzle to where it needs to be. On long vertical rails, there are three runners, each connected with an arm to the print-nozzle. These arms move independently up and down to the print nozzle, keeping it precise throughout the printing process. [Spadaro, J. (2019)].

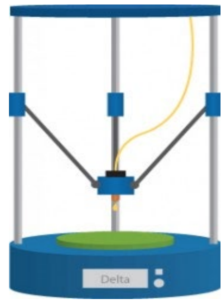

Figure 10. Diagram of Delta 3D Printer [3D Printers Explained (2020)]

An alternative for using simple Cartesian geometry to calculate where the print-nozzle should go, delta printers measure the head position using trigonometric functions. They use three arms, in a parallelogram configuration rather than linear.
In both printers, the print head moves within x, y, and z point to another, in cartesian printers, the print heads move linearly. On the other hand, delta print changes the angle of the parallelograms.

The moving parts that make up the printing process are lighter than a typical cartesian design and move in a larger space.

2.2.1 Advantages

One of the main benefits of Delta printers is that they are sporting circular printing beds, making the printing space probably more efficient. This is particularly noticeable in the creation of circular prints.
Due to their lighter components, their high speed is a definite advantage for Delta printers. This gives their layout a comfortable printing advantage, with quicker flying lightweight print heads.
Also in such designs, print beds are often non-moving, which helps streamline individual prints. Plus, as we said earlier, their more significant storage space allows printing items that are bigger than a Cartesian printer could otherwise. [Jason (2019)]

2.2.2 Disadvantages

Due to their speed, Delta printers are attractive options, but this design approach has its snags. The first on our list is the printer's accuracy. If rate is slightly increased, in their filament implementation, printers are less likely to be accurate. It results in less clarity and a rougher surface finish. The Bowden-style extrusion device has another drawback. Stepping motors were removed and placed in the printer's upper body, and fed to the heads for weight reduction. This is fair, but it limits the number of filaments that can be used and helps to connect the tubing. Developments have been made in this regard, but none have yet been accepted as the norm [Jason (2019)].

3. 3D Printing Safety

Since 3D printers have become available to everyone, taking into account the dangers associated with it is important. New users couldn't don't realize that 3D printers, materials used, hot internal parts, dust and volatile compounds can cause injuries and very serious health problems. There are therefore a number of ways to reduce exposure to these hazards. Printer manual and operating instructions are the first things that must be done before running the printer. Learn to use the printer safely and efficiently. Make sure that the printer is cleaned from waste and dust. Because ABS is more dangerous as well. Use products that are approved by the manufacturer for reduced emissions, such as PLA rather than ABS. Room, where printing is implemented, must have an adequate air supply and exhaust to eliminate emissions. Make sure that the printer has an interlocking system that prevents the computer from operating through access to moving parts. Printers with laser or UV must be adequately shielded to prevent eye exposure [Chua et al. (2017), EH&S (2020)].

4. Open Source Design Software for 3D Printing

Building a 3D model is a crucial step to start printing, there is plenty of software that used to build 3D models. All these tools at the end should provide a file in a format of STL (Standard Tessellation Language). For instance, Tinkercad: is online free software that is helpful for beginners to create 3D printable models from a set of basic shapes. Blender: this software is intended for skilled users; it is rich in features, and includes tools for sculpting, animation, simulation, motion tracking, and video editing. BRL-CAD: an advanced users' software, used to support ballistic and electromagnetic analyses, includes ray tracing and geometric analysis tools. It offers a large number of simple and complex shapes that users can use to build their models. Repeater: an open-source program that can accommodate at the same time up to 16 extruders with different types of filaments. It is targeted at more advanced users [Sun and Parsons (2014)]

5. Open Source 3D Printer

5.1 Specifications

5.1.1 Physical parameters

The delta printer He3D K280 (He3D (2020) stands for 1120mm height, 430mm width and 430mm length, it weighs about 10kg including the packaging. The frame is made of improved steel and aluminum.

5.1.2 Printing parameters

The technique used in printing is fused deposition molding in which it involves the manufacturing a part by depositing the material layer by layer. Materials used for the filament are PLA, wood, nylon and ABS. The printer is capable of printing a part up to 600mm height and 380mm wide and a thickness of 0.05mm to 4mm. It has a high-speed extrusion machine where the speed can reach to 100-300 mm/s. The nozzle diameter can be 0.2, 0.3, 0.4, 0.5mm.

5.1.3 Software requirements

Different software packages are used to create 3D models to provide by the end a file in format of STL, the most common are repetier and pronterface. It requires a DC motor of 400Watt and 24Volt. The software is equipped with LCD screen. Different operating systems can be used to run the software such as: Windows, Linux and Mac.

6. Assembly Process

Figure 11. Assembly process

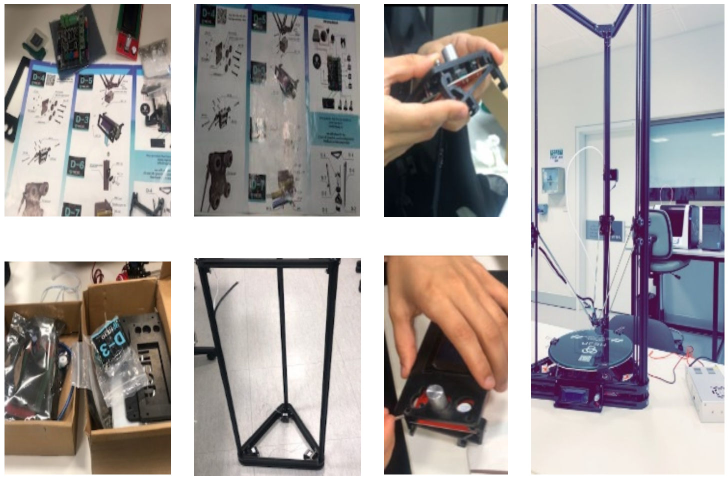

Figure 12. Assembly process of the 3D Printer in the workshop.

7. Observations

During the assembly process, several challenges have been faced, with the help of our instructor and the lab engineer we overcame them. Regarding the home positioning of the printer, there was an issue with the micro switch, it couldn't compress to the end, so as a solution, double-sided foam tape was used on the three trolleys, so it touches the microswitch and lead it to full compression. Moreover, the belts aren't tightly installed in the grooves, they are too thin to fit in the slot, so a cover was designed to keep the belt in the groove and prevent any movement. Regarding the filament spool holder, it wasn't able to hold a high weight, it also permits some movements of the filament spool, so, a new design used to hold the spool from the two sides to hold it tightly.

(a) (b) ©

Figure 13. Challenges faced during assembly: a) Micro switch clearance, b) Spool holder, c) Belts mounting.

8. Conclusion

The main aim of this study is to introduce the students to the process of assembling an open source 3d printer and to enhance their knowledge deeply in assembling parts. Building a 3D printer from scratch gave students a chance to learn more about different types of bolts, nuts and many various tools. Many challenges faced during the assembly and especially the electrical part which was done by the assistance of a mechatronics engineer. In terms of printer performance, students got familiar with the software Repetier, they became able to print 3D models for different purposes

9. Acknowledgment

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