NATIONAL INSTITUTE OF BUSINESS MANAGEMENT

HIGHER DIPLOMA IN SOFTWARE ENGINEERING 23.1

ROBOTIC APPLICATION DEVELOPMENT

MAKING A 3D PRINTED ROBOT

SUBMITTED BY

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Summary

The project lays out how to build a 3D printer with a Bowden extruder and fused deposition modeling (FDM). For stability and adhesion, the design included a heated print bed and a wooden and metallic frame. Printing could be done more quickly because of a Bowden extruder configuration that was directly attached to the hotend and lowered the weight on the print head. The project displayed little stringing, exact details, and outstanding print quality. This project demonstrates the 3D printing possibilities of FDM with a Bowden extruder, with applications in production, education, and prototyping.

Declaration

We certify that everything we have written for this report is completely unique and our own work. All facts, concepts, and material collected from other sources have been properly referenced and mentioned according to our institution's academic standards and rules.

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Project Name: Robotic Application Development (Making a 3D printer)

Abstract

The primary objective of the project is to apply Fused Deposition Modelling (FDM) to design and build an affordable 3D printer for small-scale production and quick prototyping. Because of its cost and ability to adapt, FDM[1] technology has become more well-known in the additive manufacturing industry. This project describes the entire process of making an FDM 3D printer, from choosing the right parts and supplies to assembling and calibrating the machine.

The 3D printer is an ideal choice for educators, creators, and small enterprises on a tight budget because of its design, which prioritizes simplicity, accessibility, and adaptability The project encourages knowledge sharing and collaboration across the maker and 3D printing communities by utilizing open-source hardware and software.

With the designed FDM 3D printer, users can produce prototypes, practical parts, and creative layouts in addition to high-quality prints using a variety of thermoplastic materials. The goal of this project is to democratize 3D printing technology by encouraging innovative thinking and creativity in a variety of fields while maintaining affordability and ease of use.

Acknowledgement

Our sincere gratitude goes out to everyone who helped make the 3D printer idea a reality. Our great thanks go out to NIBM for providing the required resources and support, our supervisor(s) for their priceless advice, and our committed team members for their diligence and inventiveness. We express our gratitude to our family and friends for their consistent support and faith in this project. Without the cooperation and assistance of all parties involved—individuals and organizations—this project would not have been achieved. We appreciate you making our goal of a 3D printer achievable.

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CHAPTER 01

INTRODUCTION

Additive manufacturing, or 3D printing, produces three-dimensional parts and things by layering multiple materials together. You can also call it fast prototyping. It's an automated procedure where a machine that's connected to a computer that contains the blueprints for any object is used to quickly generate 3D objects in the required size.

Fused Deposition Modelling (FDM), stereolithography (SL), laser sintering (LS), high-speed sintering (HSS), Multi jet fusion(MJF), Poly Jet, Digital Light Process(DLP), Electron Beam Melting and other additive manufacturing techniques are examples. Desktop fabrication is another term for 3D printing. It's a quick prototyping method that turns a 3D concept into a tangible product. Additive manufacturing, or 3D printing, is a technique that will usher in a new era of customized, one-off manufacturing and move us away from the huge production lines. A CAD model [2]is used by 3D printing equipment for quick prototyping.

In 3D printing, one technique is fused deposition modelling, or FDM. Researchers and industry are finding it increasingly popular to explore and develop this approach, which falls under the category of the process of additive manufacturing engineering.

The basic concept behind FDM manufacturing is to just melt the raw material and mold it into new shapes. A driver’s wheel pulls the filament, which is subsequently inserted into a roll and heated to a semi-liquid state in a temperature-controlled nozzle head. Layer-by-layer structural elements are produced by the nozzle's precision extrusion and material guidance in ultrathin layer after layer. This traces the contours of the layer that the program—typically CAD—specifies and inserts into the FDM work system.

3D PRINTER

Adding layers of material to create 3D objects and parts is known as additive manufacturing, and it is done with a 3D printer. Another name for it is rapid prototyping. Using a machine that is connected to a computer that holds the blueprints for any object, 3D objects can be quickly created according to the necessary size using this automated process. The subtractive method, which involves drilling or molding material out of a block, may not be the same as the additive method. The primary benefits of using a 3D printer are increased material utilization (90%) and lighter, stronger, longer-lasting products. Many industries, including aerospace, automotive, medical, construction, and the manufacture of numerous consumer items, effectively employ 3D printing. 3D Printer is a CNC[3] type machine.

1.1 PRICIPLE OF 3D PRINTING

A 3D part is created using the additive process of 3D printing, which builds up layers of material. Subtractive manufacturing methods, on the other hand, cut a final design from a larger block of material. Consequently, there is minimal material waste with 3D printing.

1.1.1 Prototyping

Fused Deposition Modelling (FDM) is a 3D printing process that uses filaments of the final material to create strong, durable, and dimensionally stable components. It is the same as fused deposition modeling (3D printing technology).

1.1.2 Modelling

Fused Deposition Modelling (FDM) Modelling An essential stage in the process of turning an idea into a physical product is 3D printing. A well-defined conceptual design, either created by hand or digitally, is the first step in this procedure. 3D modelling software is used to create an accurate digital depiction of the intended thing as the design takes shape. But during this design stage, FDM-specific factors like overhangs, support structures, and the best layer orientation must be considered. The object's geometry is contained in file formats such as STL[4], which are used to store 3D models. Slicing the 3D model into layers and producing G-code [5]instructions—a language that FDM 3D printers can understand—is the next critical step. Users can adjust print speed, infill density, layer height, and support structures with slicing software. The choice of material is essential since different filaments have varied strengths and levels of flexibility. The printer is set up, the model, slicing parameters, and material are selected, and the object is built layer by layer. Surface polishing and support removal are examples of post-processing procedures. The final product is refined through iteration and quality control, guaranteeing that the 3D-printed item complies with the original design and functional specifications.

1.2 PROBLEM STATEMENT

- Although solving difficult problems is an obstacle to development, 3D printing should be utilized as a tool for innovation.
- Consumer demand for final products is so great that the rapid prototyping sector needs to move more quickly to produce technologies that are both affordable and easily accessible to customers.
- Often, the most expensive and time-consuming phase of the product development process is prototyping. Therefore, it is essential for people and organizations to shorten the time needed to develop a product.
- Printing support requires more time and resources to print during the process.

1.3 OBJECTIVES

1. Administrative concerns, qualification requirements, and risk analysis definitions and establishments.
2. To research newer and developing technologies.
3. To accomplish the ongoing development of 3D printing.
4. To comprehend the operation of a 3D printer.
5. To learn more about models and definitions and create tools specifically for that.

CHAPTER 02

MATERIALS AND METHODS

2.1 Working Principle of FDM 3D Printer.

Using FDM 3D printing, an extrusion nozzle travels across a build platform in a horizontal and vertical fashion. To build a 3D item layer by layer, thermoplastic material that has reached melting point and been forced out is used. The search layer can clearly see the design as a horizontal cross section as it takes shape. Afterwards the printer's nozzle is lowered after the last step of one layer so that the subsequent layer of plastic is to be included in the layout When printing starts on the FDM printer, the raw material is tiny filament that is forced through the hot nozzle. It settles to the bottom. Where it solidifies, that of the printer platform.

Building the object layer by layer from the bottom up, the subsequently extruded layer fuses with the layer below. The majority of FDM printers print the outside edges first, then the interior edges, and finally the interior of the layer as a fill-in matrix or a solid layer. Certain items or models have sensitive "overhangs" that, if not supported, will drop. These support structures, also referred to as struts, are created along the item in FDM printers. After the build is finished, they are later deleted. Usually, the struts are made of the same material as the item.

In order to prevent the extensions from drooping, certain printers incorporate a second extruder dedicated to depositing soluble thermoplastic struts. It is possible that the composition of these struts differs from the thermoplastic utilized in the 3D model. A suitable solvent is then used to dissolve them later on.

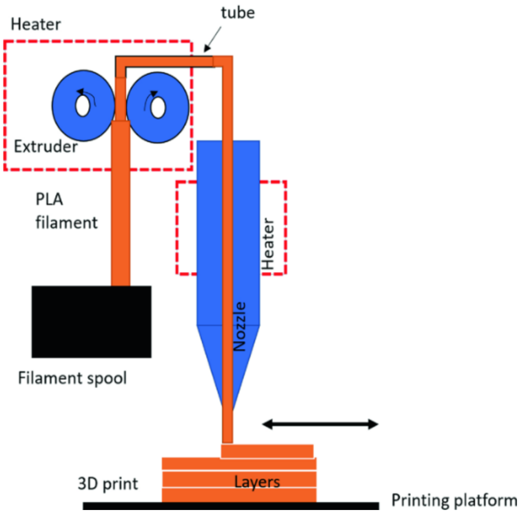

Figure 1 | FDM Methodology

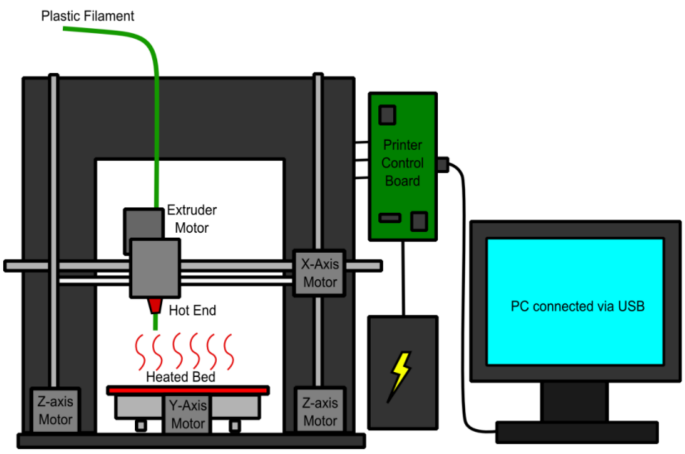

Figure 2 | Experimental Setup

2.2 Flow chart of the3D printing technology (Fused Filament Fabrication)

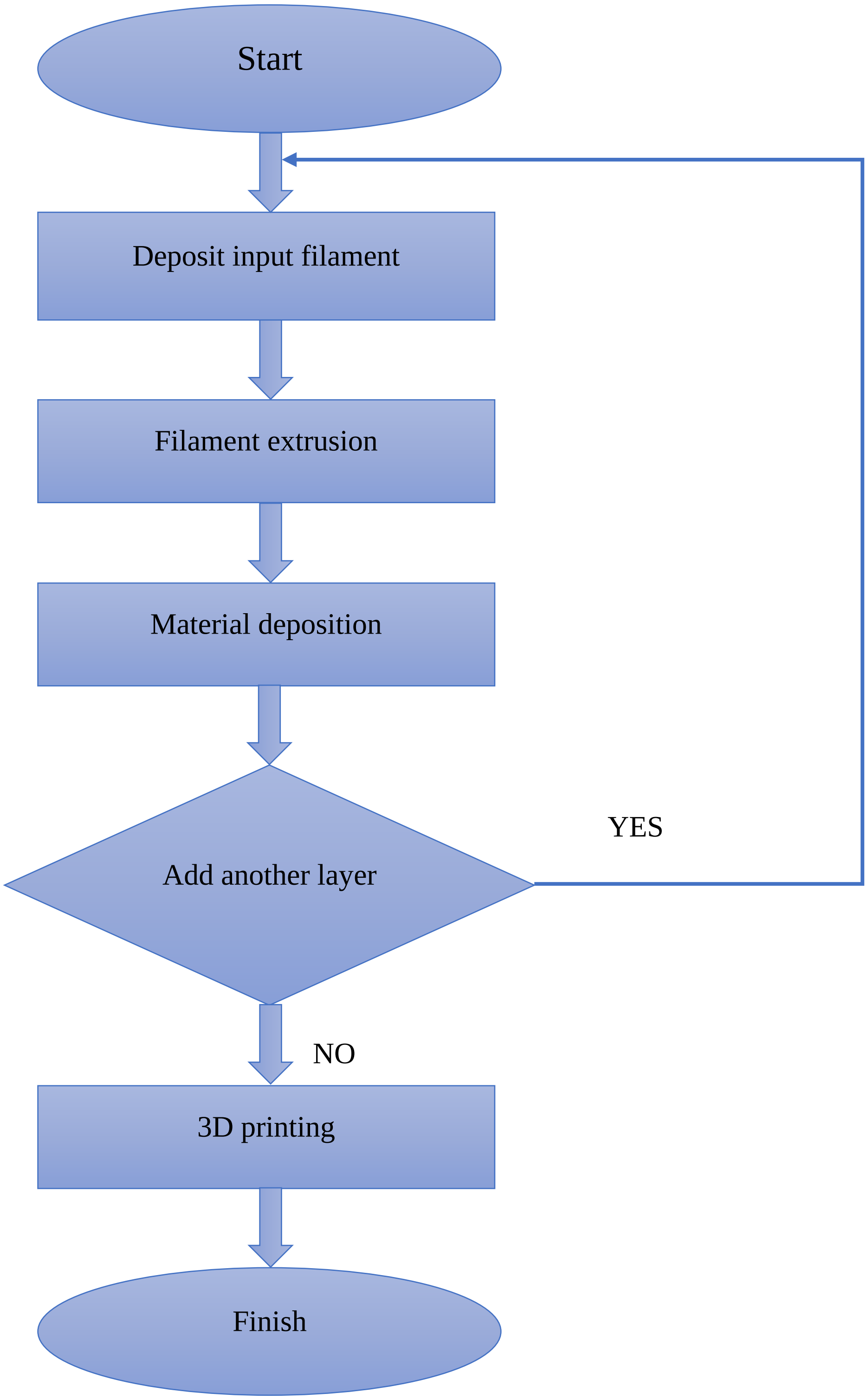

Figure 3 | 3D printing process

2.3 Components and Materials

Ramp Shield 1.4

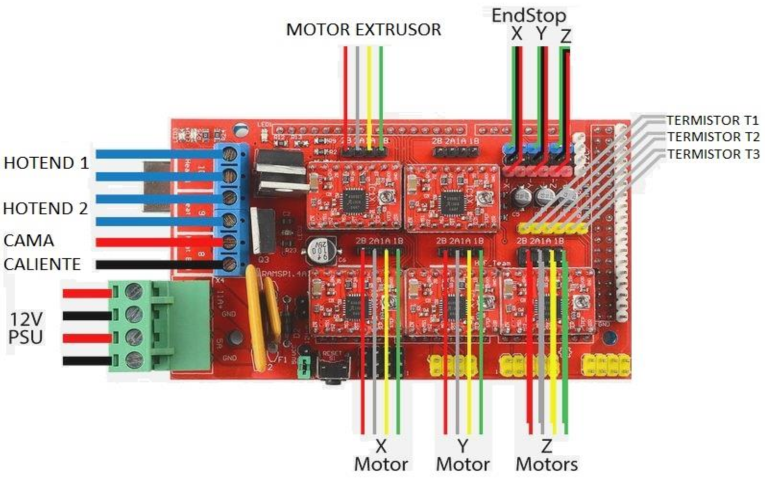

Figure 4 | RAMPS

A key part of 3D printing is the RepRap Arduino Mega Pololu Shield, or RAMPS 1.4. It interfaces with the Arduino Mega and various parts like stepper motors, heaters, and sensors to function as the printer's control board. In order to accurately control the 3D printing process and provide precise and high-quality prints, it controls and organizes their functions.

Stepper Motor

NEMA 17 motors are commonly used in 3D printing to power the movement of several parts, including the build platform and the extruder of the printer. These motors (for X,Y,Z axis) enable the layer-by-layer deposition of material, an important phase in 3D printing, providing the force and accuracy required to move these components properly.

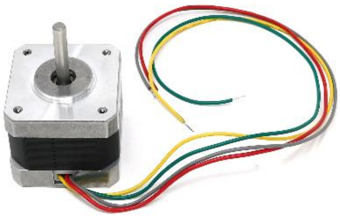

Figure 5 | NEMA 17 Motor

Stepper Motor Driver A4988 Module

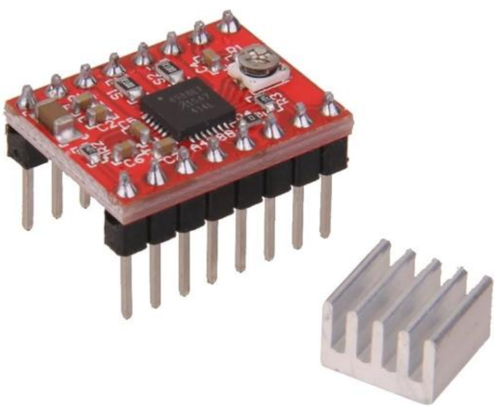

Figure 6 | Stepper Motor Driver A4988 Module

In order to accurately move the NEMA stepper motors during 3D printing, control signals from the printer's mainboard must be translated by the A4988 Stepper Motor Driver Module. In order to produce accurate and high-quality 3D prints, it controls the motors' current and direction. This allows for exact positioning of the print head and build platform.

Extruder and Hotend

The process of extrusion is used to create things with a fixed horizontal shape. A material with the required cross-sectional profile is forced or forced through a machine called a die. The "Cold End" presses the raw material into the hot end in order to extrude molten plastic filament. After passing through the extruder's "Hot End" with the heater, the feeding filament exits the nozzle at an appropriate speed. As the part is being built, the extruded material falls layer by layer onto the fabricate stage.

Figure 7.1 | Bowden Extruder

Figure 7.2 | J -head Extruder Hot end with Cooling Fan

Power Supply

In order to confirm the correct operation of several components, such as motors, heaters, and controllers, while printing, 3D printing needs a 12V 10A power supply.

Figure 8 | Power Supply 12V 10A

Nozzle

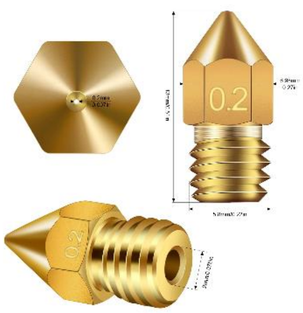

Figure 9 | Nozzle 0.2mm

Nozzle is an important part of the extruder that is used in the extrusion of the melted thermoplastic material onto the printing bed from the heating block.

Figure 9.1 | Extruder Assembly

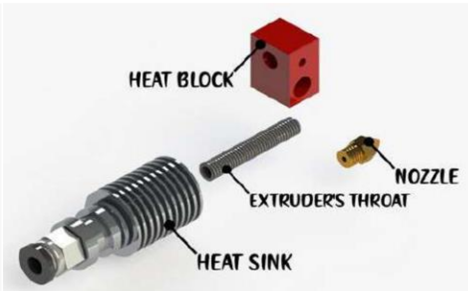

Figure 9.2 | Exploded View of Extruder

Endstop

Endstop set print head and bed places to improve safety provide auto leveling and identify movement problems in 3D printers.

Figure 10 | Endstop

Shaft Coupler(D20 L25 5x8x25mm)

Figure 11 | Shaft Coupler

Shaft couplers help 3D printers to transfer force and provide accurate motion by joining motor shafts to smooth rods or lead screws.

Filament

Figure 12 | Filament

Arduino Board(mega)

Figure 13 | Arduino (Mega)

2.4 Filament

The raw material mostly used in FDM 3D printing is filament. The printed object is made up of layers created by heating and extruding it. It is then sprayed along a precise and accurate shape and thickness in a very controlled way. There are many types of filaments available in FDM 3D printing.

Ex:

- **P**oly**l**actic **A**cid (PLA)
- **A**crylonitrile **B**utadiene **S**tyrene (ABS)
- **P**oly**e**thylene **T**erephthalate **G**lycol (PETG)
- **H**igh **I**mpact **P**oly**s**tyrene (HIPS)

Figure 2.4.1 | Filament

Polylactic Acid (PLA)

This is the filament type that we used in our FDM 3D Printer. The most popular material for 3D printing is PLA filament. because it is simple to use and removable due to its composition of renewable elements. With a 3D printer, printing is simple and always efficient. The written Parts made with PLA have highly accurate angles and an exceptional surface gloss.

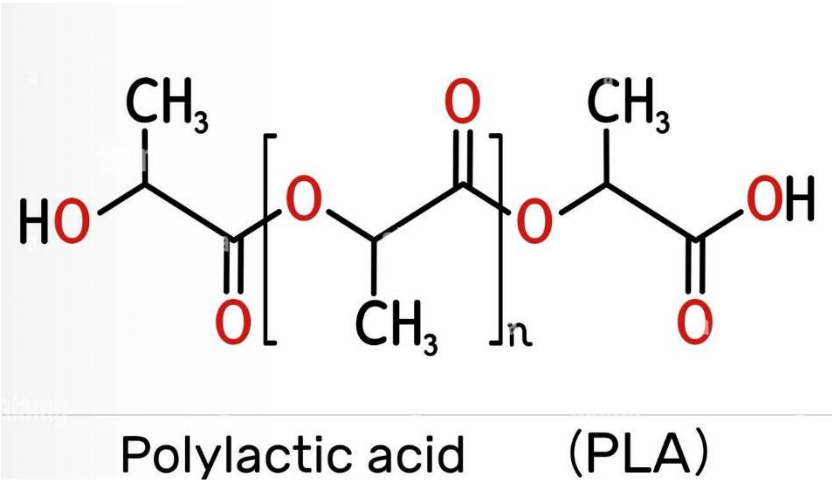

Figure 2.4.2 | Chemical Structure of PLA

- The chemical formula for PLA is $(C_3H_4O_2)_n$
- The extruder temperature for PLA is 205±15°C and bed temperature is 40±15°C.

2.5 How does FDM 3D printer work?

FDM uses a digital design that is delivered to the 3D printer, similar to other types of 3D printing. Numerous polymers, including ABS, PETG, PLA, and PEEK,[6] are utilized. These are like plastic threads that are fed using a nozzle and out of a loop. The nozzle and base of the device, which are both computer-controlled, are called a build platform or table, onto which the melted filaments are fed. The nozzle and base may track the object by using the computer's ability to translate its dimensions into coordinates.

The plastic cools and solidifies as the nozzle passes across the base, creating a strong link with the layer that came before it. In order to lay the next layer of plastic, the printhead lifts at this point. As usual, 3D printing is effective and quick, but the size of the object will affect how long it takes to make it. Several cubic inches and smaller things can be produced rapidly, while larger, more complicated items will require more time.

2.6 Assembly of FDM 3D Printer

The frame is the load-bearing component that is assembled at first, and then different components may be installed on it. Frames can be put together with M5 socket head cap screws and acrylic or aluminum profile frames. Fixing the carriage in the guide rails comes next after the frame is put together. The build surface and extruder assembly are to be installed over those carriages. The most important part of FDM 3D printers is the extruder. Extruders can be divided into two categories: direct extruders and Bowden extruders. This design utilizes the use of a Bowden extruder. The filament keeps using a roller mechanism located inside the extruder.

The filament is tightly held in place by one grove-equipped roller before being pushed into the heating block, where it melts and falls using the nozzle onto the build surface. Just above the heater block is a cooling fan with a radiator attached to keep the heat contained within. In order to cool the produced object, an air blower is additionally coupled with the extruder-nozzle assembly. The extruder's whole assembly is positioned above a carriage to allow for linear movement along an axis. The area that is covered with material is called the build surface. This surface needs to be hot in order to generate better part quality, which is why a hotbed is utilized to create the build surface. The build surface assembly is made with a hotbed and additional mechanical parts. In order to have motion along an axis, this assembly is then installed over one of the tracks.

2.7 Process of 3D Printing

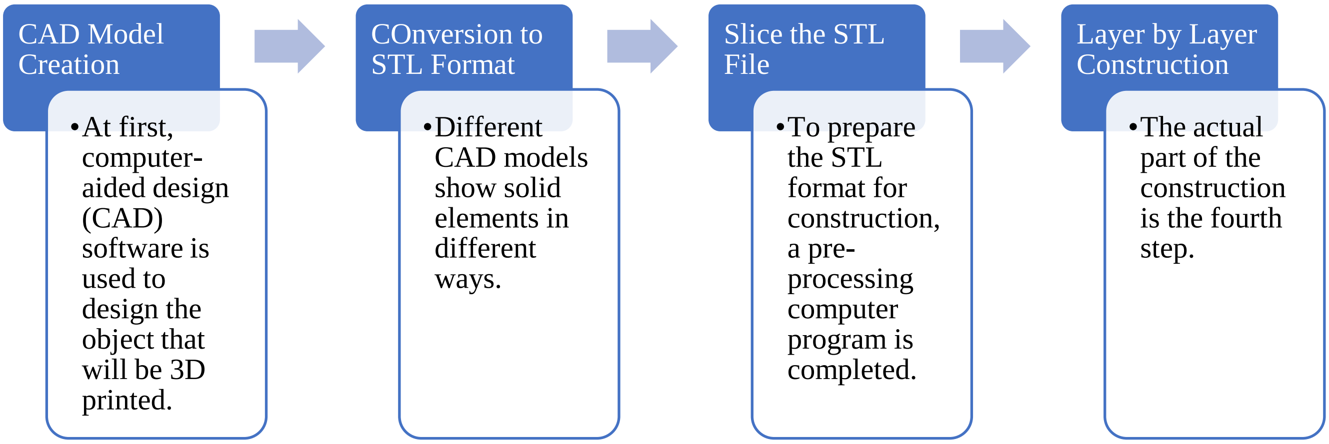

Figure 14 | Process of 3D Printing

CHAPTER 03

RESULTS AND TROUBLESHOOTING

The glass transition temperature of the PLA is 60°C. The PLA requires a heated bed with the temperature range of (50 -60)°C), this is required due to the high glass transition temperature of PLA (60°C) . The thermal properties of ABS are presented in tabular form below.

Table 1 | Material Properties

Property	**Value**
Heat Deflection Temperature (HDT)	52℃
Density	1.24 gcm^{-3}
Tensile Strength	50 MPa
Weight	1 kg
Flexural Strength	80 MPa
Shrink Rate	0.37-0.41% (0.0037-0.0041 in/in)
Glass Transition Temperature	50℃ -60℃
Extruder Temperature	190℃ - 230℃
Bed Temperature	50℃ - 70℃
Printing Speed	40-60 mms^{-1}

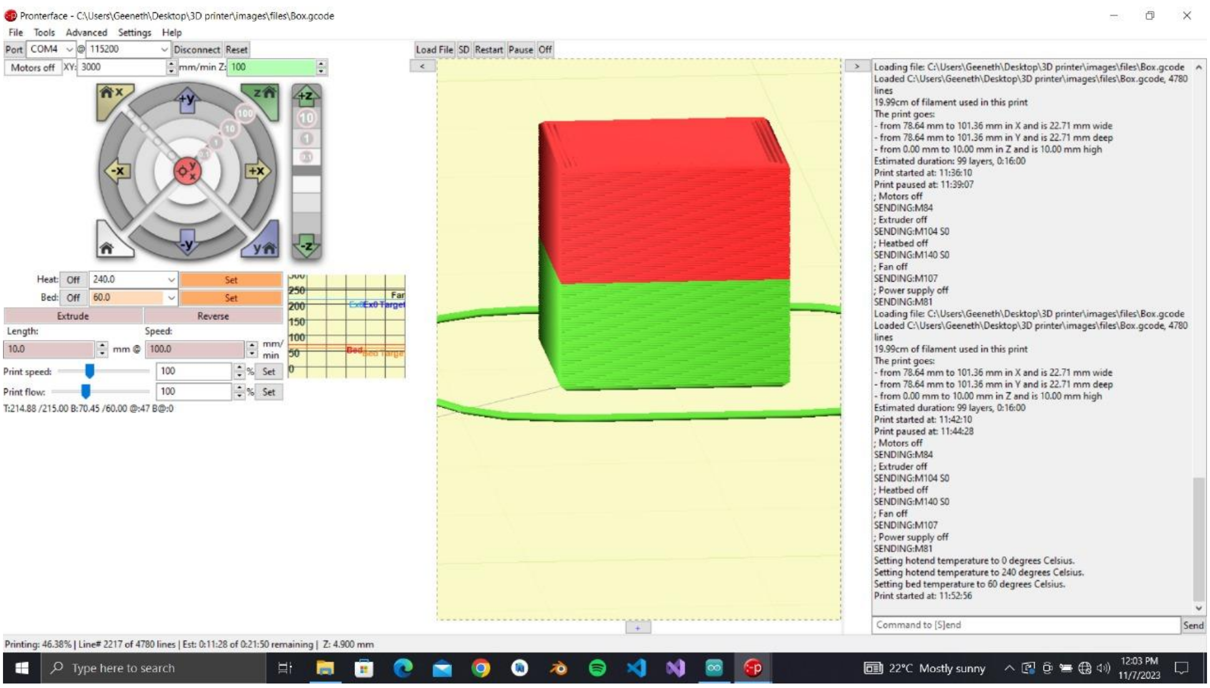

Figure 3.1 | Printing Object Process

Figure 3.2 | Temperature Graph

Above Graph showing Extruder temperature and Bed temperature about printing object. Both Bed and Extruder temperatures are passing the targeted temperature.

Figure 3.3 | Printed Objects

Measures of Printed Objects.

- Filament Used length : 120cm
- The print goes:

  From 78.64 mm to 101.36 mm in X and is 22.71 mm wide

  From 78.64 mm to 101.36 mm in Y and is 22.71 mm deep

  From 00.00 mm to 10.00 mm in Z and is 10.00 mm high

- Number of layers : 99
- Number of lines : 4780
- Time : 00:21:50 (around 22 mins)

Troubleshooting

Problem : Prints aren't sticking to the platform

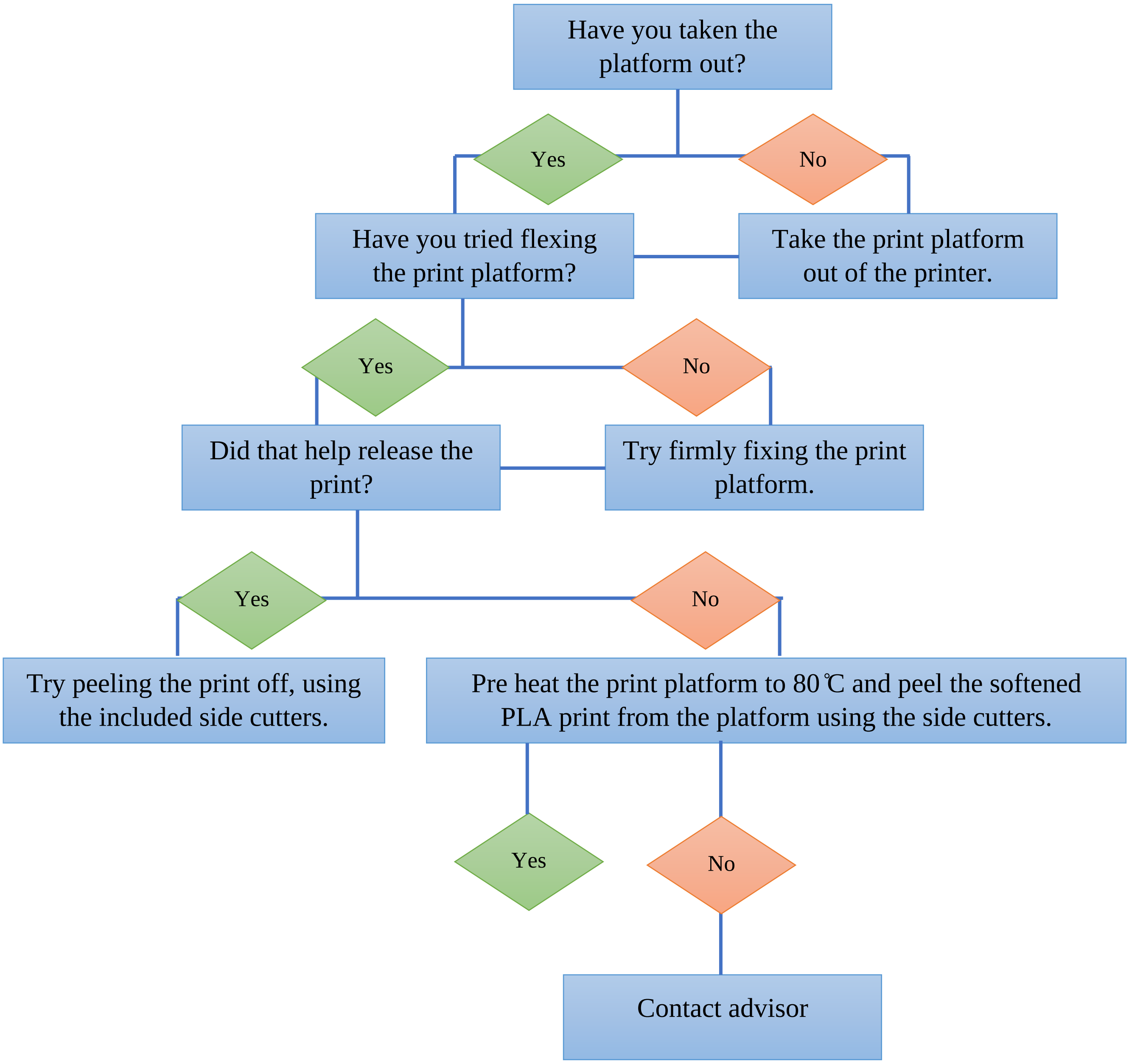

Figure 3.4 | Troubleshooting Algorithm

CHAPTER 04

DISCUSSIONS

Advantages of using FDM method

- **Easy to handle.** - It improves the production process and makes it possible for producers to test, modify, and finally produce a finished good in a quicker period of time than using standard methods.
- **Cost efficient.** - An efficient option that is designed to keep manufacturing costs down is offered by FDM 3D printing.
- **Flexibility in material choice.** - A wide range of materials are available for FDM or FFF 3D printing, and they are all affordable and easily accessible. Additionally, a variety of materials can be used together to assist in building complicated objects, and an enormous range of colors can be printed to offer flexibility and variety.
- **Less post-processing. -** One method that reduces costs and optimizes production times is FDM 3D printing. It only produces a product that is ready to use; there is no need to consider how to use costly liquids used in other procedures because there is less post-processing needed.

Advantages of using 'Bowden' Type extruder

- Reduces stringing and works well with PLA filament.
- When using a Bowden extruder, the printhead's smooth movement helps reduce problems with 3D printing like blurring and ringing.
- Makes it simpler to maintain printhead parts, including cleaning or changing the hotend.

Disadvantages of using 'Bowden' extruder

- When it comes to flexible or fiber-filled hard filaments, Bowden extruders are not the best option.
- **The Bowden extruder needs additional power** from the stepper motor in order to feed the filament because of the distance between the driving gears and the nozzle.
- Bowden extruders are less responsive due to friction within the Bowden tube.
- Slow printing(Speed limitation).

Advantages of using PLA Filament

- **Low printing temperature:** Compared to other filaments, PLA prints at a rather low temperature (for example, the ideal printing temperature for PLA is around 180°C, but the ideal temperature for ABS is around 250°C).
- **Ease to use.**
- **Variety of colors and blending options:** PLA is available in a wide range of colors and mixes and is easily pigmentable. Variety of colors and blending options: PLA is available in a wide range of colors and mixes and is easily pigmentable.
- **Easy post-processing:** PLA prints are simply painted, polished, and sanded, making it possible to get a better surface finish with a minimal amount of work.

Limitations of using PLA Filament

- **PLA cannot be used in high-temperature applications due to its limited heat resistance.** PLA can distort quickly in hot conditions, especially if it is stressed.
- **PLA filament has the ability to leak when heated**, so when the printer moves between print segments, a lot of plastic may come out of the extruder. As a result, your part will have strings connecting its various sections, which could lead to a poor print. For this reason, a cooling fan is necessary to avoid this problem.

Conclusion

A Bowden extruder can be used to create an FDM 3D printer, which has numerous benefits. The object damage is reduced and print quality is enhanced by the lightweight extruder design, which minimizes moving mass on the print head. Due to the extruder's ability to be placed apart from the hotend, it also allows a more flexible and compact printer design. However, because the filament use is longer, there are challenges like filament pull and obstacles. Finally, proper calibration can produce high-quality prints from a Bowden extruder based FDM 3D printer. For best results, however, pulling back settings and filament management must be considered too.

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User Manual

NOTE

1. Do not use the Printer in any way other than described herein to avoid personal injury or property damage.

2. Do not place the Printer near flammables, explosives, or heat sources. It is best to place it in a well-ventilated, low-dust environment.

3. Do not expose the Printer to violent vibration or any unstable environment. This will cause poor print quality.

4. The filaments recommended by the manufacturer are preferred to avoid clogging in the hot end and/or Printer damage.

5. Do not use any other power cable than the one supplied. Use a grounded three-prong power outlet.

6. Do not touch the nozzle or hotbed during printing. Keep your hands away from the machine while in use to avoid burns or personal injury.

7. Do not wear gloves or loose clothing when operating the Printer. These loose particles can become caught in moving parts and cause personal injury or Printer damage.

8. Clean off filament from the nozzle tip with the provided pliers before the nozzle cools. Do not touch the nozzle directly. This can cause personal injury.

9. Clean the Printer frequently. With the machine powered off, clean the printer body with a dry cloth to remove dust, adhered printing materials, and foreign objects on guide rails. Use glass cleaner or isopropyl alcohol to clean the print surface before every print for consistent results.

10. Children under 10 years of age should not use the Printer without supervision.

Parts of 3D Printer

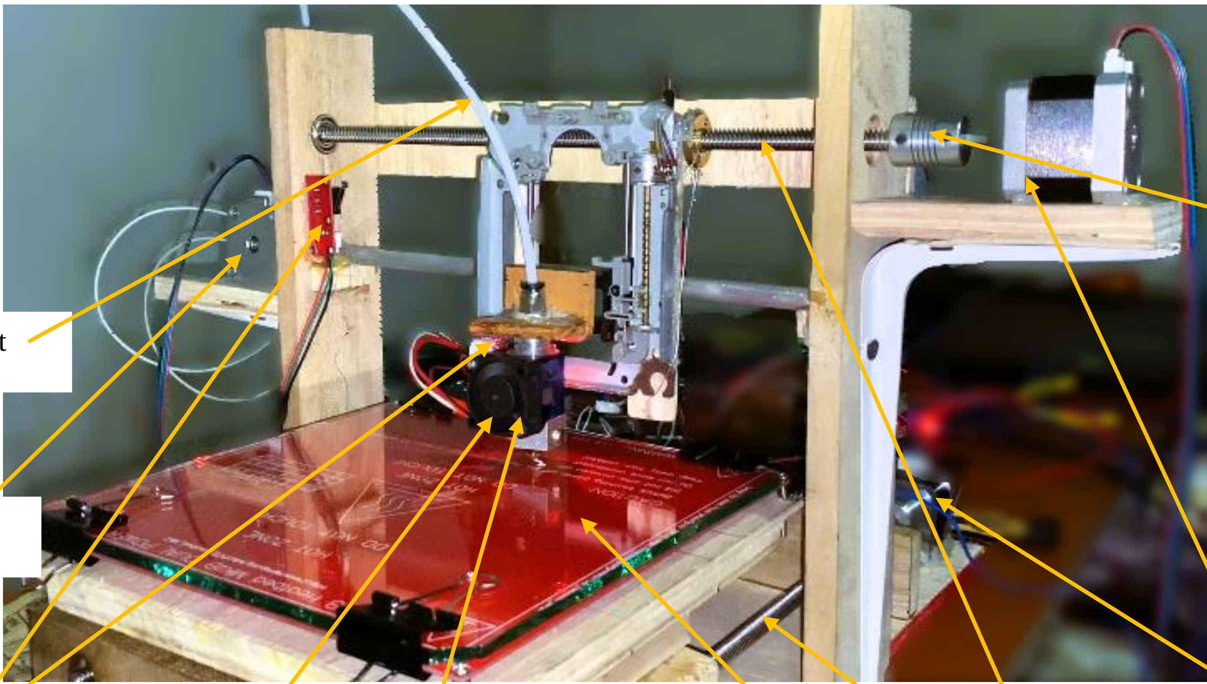

Figure 15.1 | Parts of 3D Printer

- Before using this product, please read this manual completely, paying close attention to the safety instructions and warnings. Kindly store the manual in a safe place for future use.

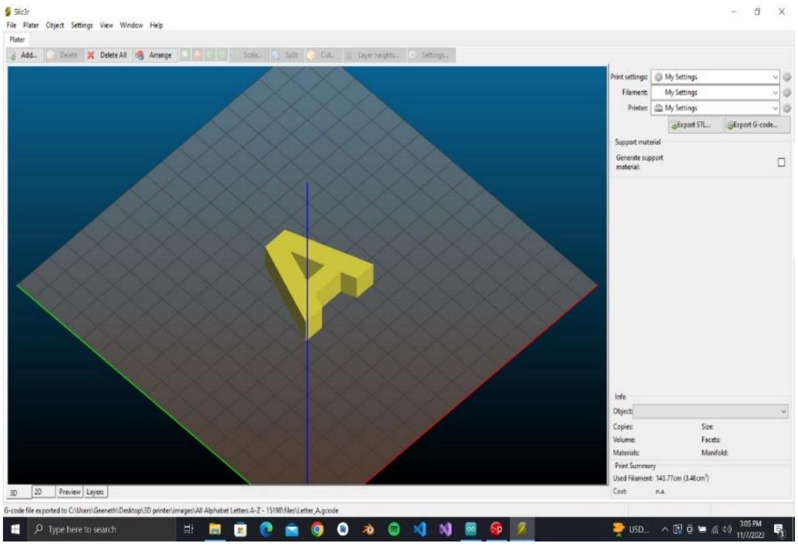

Figure 15.2 | Creating 3D Model

- Create 3D model and save it as STL file.

Software Control Menu

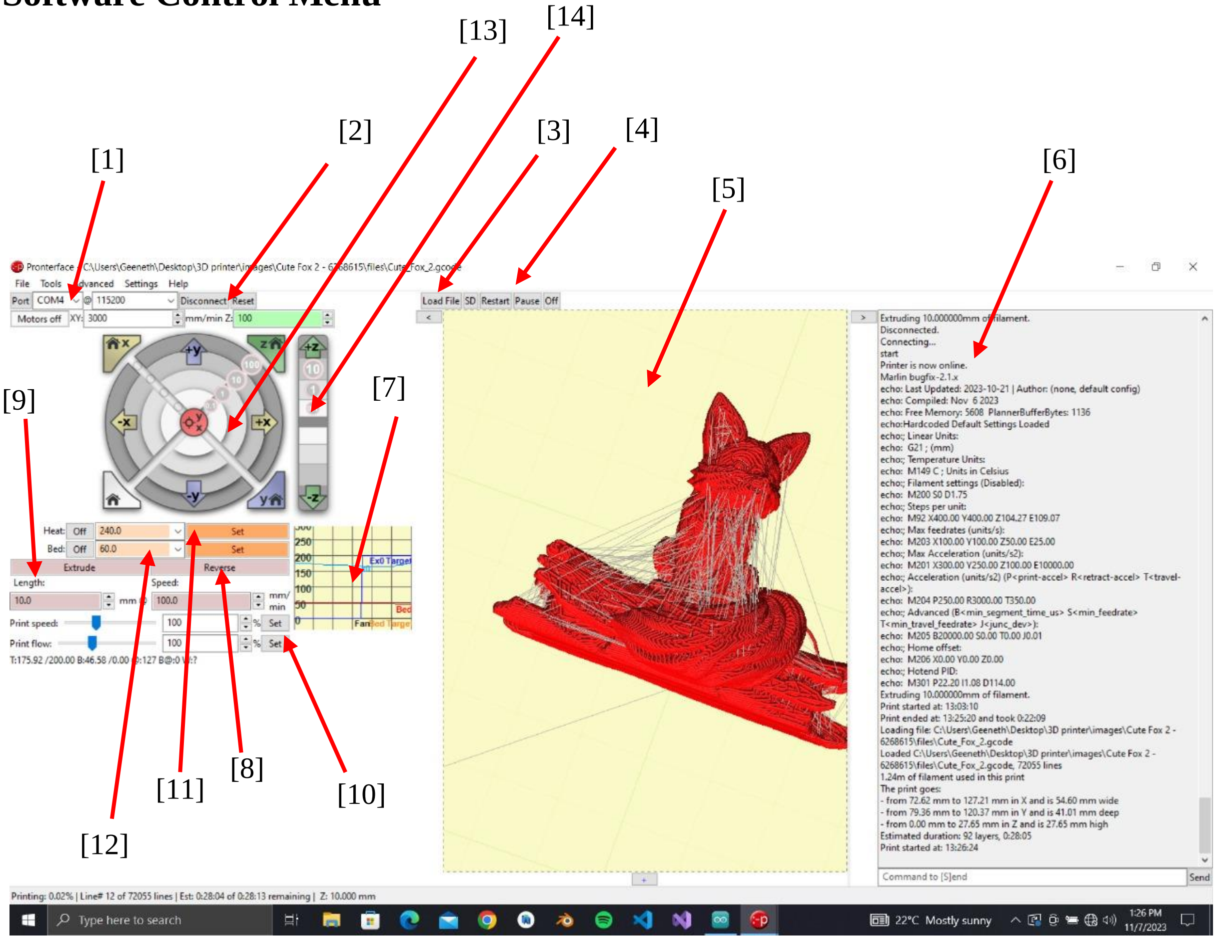

Figure 16 | Software Control Menu

1. Arduino Connected Port
2. Arduino Connect, Disconnect & Reset buttons
3. STL File input button
4. Process Start and Pause buttons
5. Printing object’s STL file image view display
6. Serial Monitor
7. Heat levels viewing display (Printing bed and Extruder’s)
8. Filament ejection button(Reverse)
9. Extrusion process starting button(inputting filament)
10. Printing speed control buttons
11. Extruder’s(Filament) heat control button
12. Printing bed’s heat control button
13. Printing bed(hotbed) movement buttons(x and y axis)
14. Printing bed(hotbed) movement buttons(z axis)

Filament Placement

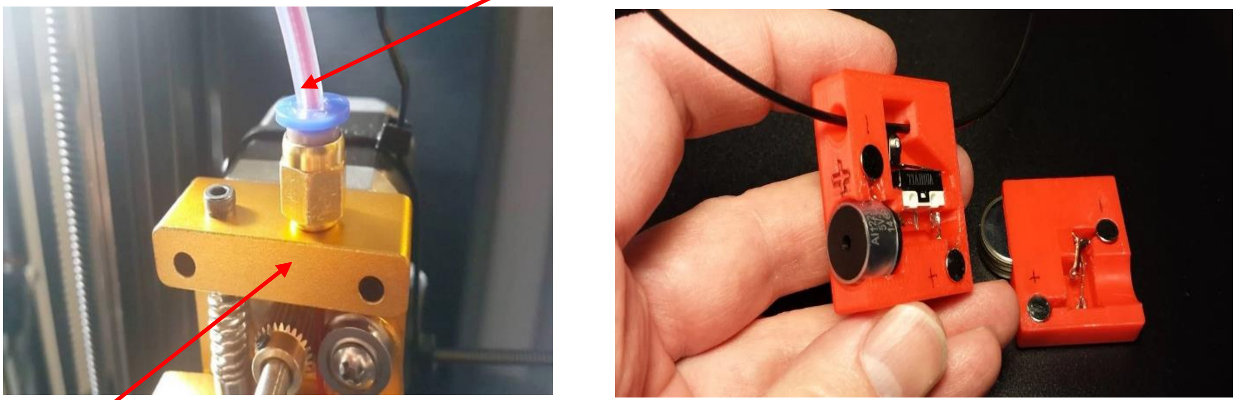

Figure 17 | Filament Placement

Loading Filament

1. Cut off about an inch of the filament's end with a pair of scissors or side cutters, then carefully level the end. On the Extruder, hold the lever, enter the filament into the bottom until resistance is felt, and then release the lever.
2. In order to begin loading the filament, press the button ‘Extrude.’ To stop the filament from extruding from the nozzle once it begins, press the button ‘pause.’ After cleaning the extruded filament, choose the Continue option by turning the ‘Restart’ button.

Unloading Filament

- Press ‘Reverse’ button. The Nozzle will heat to the target temperature. Once the target temperature is reached, the Extruder motor will retract the existing filament.

Inserting STL File

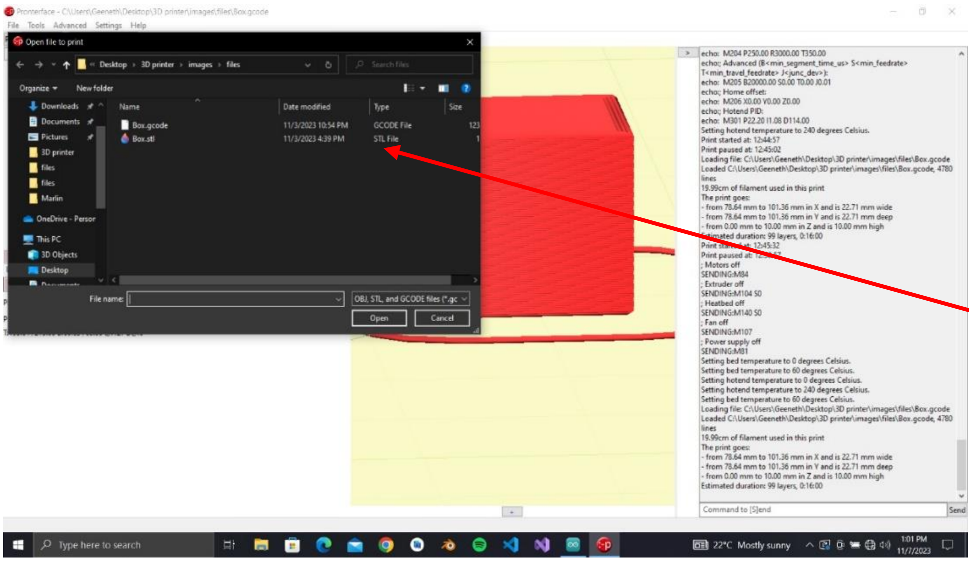

Figure 18 | Inserting STL File

Bed Leveling

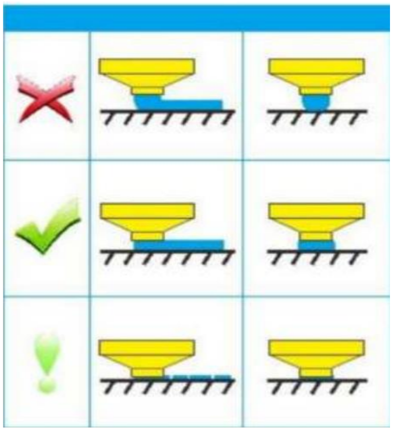

Figure 19 | Bed levelling steps correctly

1. Wait for the nozzle to move to the left/front of the platform.
2. Turn off steppers (remove the stepper drive release mechanism).
3. Turn the knob below to change the platform height and move the nozzle's front/left leveling screw. To help with the adjustment, use a piece of A4 paper, or regular printer paper. Make sure the nozzle only slightly scratches the paper.
4. Complete the adjustments of all four corners.
5. Repeat the above steps 1-2 times if necessary.

APPENDIX - 1

Explanations

[1] FDM - Fused Deposition Model. (Fused Deposition Modeling (FDM) is a 3D printing method that creates objects by depositing layers of melted thermoplastic material.)

[2] CAD - Computer Aided Design (A computer-aided design, or CAD, model is a digital representation of a three-dimensional(3D) item that serves as a blueprint for the 3D printer to follow when producing the final item.)

[3] CNC – Computer Numerical Control (Using preprogrammed computer software that has been embedded into the tools, computer numerical control (CNC) is a manufacturing technique that automates the movement, control, and precision of machine tools. In manufacturing, CNC is frequently used to machine plastic and metal components).

[4] STL File - In order to make easier the printing of 3D objects, the STL (Stereolithography) file format is a standard for demonstrating the surface structure of 3D objects.

[5] G-Code - The language known as G-code in 3D printing tells the printer how to move and extrude material to build an item layer by layer.

[6] ABS, PETG, PLA, and PEEK – Various types of filaments.