3D Printing using Fused Filament Fabrication

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Abstract

Fused Filament Fabrication (FFF) 3D Printing is a technique to directly obtain a real object, designed using CAD, by fusing the thermoplastic material at high temperature and movement of stepper motors as directed by the controller. 3D Printing prototypers and manufacturers face many problems while printing objects. They face the problem of not having 3D Printer repairing service (especially in less developed areas) and thus 3D printers become useless. Another major problem 3D Printing firms face is the transference of object file among many of 3D Printers. Moreover, last one its post-processing, especially re-colouring of the product in different colours and connectivity with a remote location. Thus, this study is carried out to overcome the majors' problems in the 3D printing manufacturing. This study project utilized an open source Marlin Firmware to design and make 3D Printer controller, ESP8266 to provide Wireless connectivity, and dual Extruder setup tailored to make dual colours to make 3D Printer a colourful. The study shows that the accuracy comparison of proposed printed Cube with respect to CAD Cube is about 96.66%.

Keyword: Thermoplastic material, CAD, Arduino Mega, Multi Colour, Wi-Fi ESP8266

1 Introduction

Additive manufacturing, colloquially known as 3D printing, is an umbrella term for technologies that allow the production of physical goods from the ground up. In the case of the usual creation of equipment - machines, saws, drills and rotary motors - taking a piece of raw material and cutting it into a frame shape (manufacture by subtraction), the 3D printer is the opposite. As the terminology suggests, a 3D printer will include raw materials in a small layer at any time, creating the entire project. Unlike plastic infusion molding, 3D printers do not require excessively tall shapes, but only high-level structural records containing ideal project data [1]. The first additions to materials and material-making materials were made in the 1980s. In 1981, Hideo Kodama, of the Nagoya Industrial Research Institute, considered two additive technologies for the manufacture of three-dimensional plastic models with polymers Photo-curable thermosets. The innovations that have been used so far in most 3D printers - especially professional and buyer-designed models - demonstrate the extraordinary use of plastic profiles created by S. Scott Crump in 1988 and promoted by his Stratasys organization. Promote its first FDM machine in 1992 [2].

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The remainder of this paper is organized as follows: Section 2 presents the Conventional 3D Printers. Section 3 explains the types of FFF 3D Printers. Proposed Methodology is presented in Section 4. Section 5 covers the results and discussion. Conclusion of the work is presented in Section 6.

2 Conventional 3D Printers

Recently referenced 3D printing is a generic term that includes unique advances. As part of more than a dozen 3D printing technologies, it can be divided into three main categories, each with its own advantages and disadvantages. The advancement of the main category depends on the liquid or semi-fluid material extruded through the nozzle of the print head into the desired shape. This classification is called material extrusion and most buyer-level gadgets are available. Although any material that can be ejected through a syringe and retains its shape later can be printed along these 3D lines, most material extrusion printers use thermoplastics as fibers. Some of the 3D printers in this category have print heads that can use a variety of materials in one location.

In the second category, called photo polymerization, 3D printers use lasers or other light sources to define or solidify a fluid called a photopolymer. In some procedures, the light source follows the ideal shape in a photopolymer tar box, although it is suitable for the violin because the entire layer must be on the ground and glued without delay. In some applications, the photopolymer is splashed and released directly into the desired shape. Some buyer-level 3D printers use photo aggregation, but such 3D printers are typically used by experts.

Finally, there is a combination of granular materials. Here, the 3D printer uses a laser or blanket to join the fine powders to make an article. Printers in this category usually have a large amount of powder contiguous to the actual printing platform. The roller applies a thin layer of powder to the printing platform and then follows the desired shape with a laser or a fastener. When the main layer is completed, the platform lowers and re-joins the next layer of powder. Printers in this category may use plastic, metal, pottery or even glass as printing material. Currently, no customer-level 3D printer uses binding of granular material [3]. The study project is based on innovative manufacture of fused filaments to create 3D objects layer by layer. The FFF process is described in detail below.

A Fused Filament Fabrication

FFF is a solid-based additive manufacturing (AM) technology. The FFF system builds parts layer-by-layer by depositing semisolid molten polymeric materials in the shape of the thin filament (or road/bead) via a computer-controlled robotic extruder. Figure 1 shows the process of fusion and extrusion of the filament. Heater block provides enough temperature to melt the filament, and the motor is used to push the filament downwards, thereby filament is continuously melted and re-solidifies on the build surface. FFF 3D Printers make motions using stepper motors. Four stepper motors are used basically for the motion, motion along the x-axis, the y-axis, the z-axis and for providing extrusion force. Table I compares characteristics of FDM, SLA and SLS 3D Printing technology.

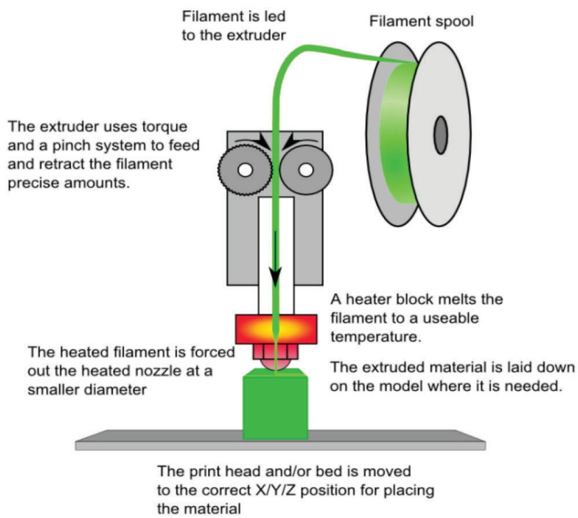

Figure 1: Illustration of Fused Filament Fabrication process

Table 1: Context of our Search Queries

	Fused Filament Fabrication (FFF)	Stereo Lithography (SLA)	Selective Laser Sintering (SLS)
Resolution	★★☆☆☆	★★★★★	★★★★☆
Accuracy	★★★★☆	★★★★★	★★★★★
Surface Finish	★★☆☆☆	★★★★★	★★★★☆
Complex Designs	★★★☆☆	★★★★☆	★★★★★
Ease of Use	★★★★★	★★★★★	★★★★☆
Pros	Fast Low-cost consumer machines and materials	Great value High accuracy Smooth surface finish Range of functional applications	Strong functional parts Design freedom No need for support structures
Cons	Low accuracy Low details Limited design compatibility	Average build volume Sensitive to long exposure to UV light	Rough surface finish Limited material options
Applications	Low-cost rapid prototyping Basic proof-of-concept models	Functional prototyping Dental applications Jewelry prototyping and casting Model making	Functional prototyping Short-run, bridge, or custom manufacturing
Print Volume	Up to ~200 x 200 x 300 mm (desktop 3D printers) printers)	Up to 145 x 145 x 175 mm (desktop 3D printers)	Up to 165 x 165 x 320 mm (bench top 3D printers)

3 Types of Fused Filament Fabrication (FFF) 3D Printers

There are variants of FFF type 3D Printer. They differ by their working mechanism, mathematics and machine parts. There are four basic types of FFF 3D Printers:

A) Cartesian FDM 3D Printers.

B) Delta FDM Printers

C) Polar 3D FDM Printers.

D) FDM 3D Printing with Robotic arms.

A Cartesian FDM 3D Printers

The Descartes 3D printer is currently the best known 3D FDM printer. Given the Cartesian arrangement of arithmetic, the innovation uses three axes: X, Y, and Z to determine the correct position and alignment of the print head. With this type of printer, the print tray generally moves only on the Z axis and the print head operates in both dimensions on the X-Y plane [5].

B Delta FDM Printers

These printers are gaining increasing attention in the FDM 3D printing industry and two research institutes in Switzerland are developing, including six-axis 3D printers based on Delta's innovation. These machines use the Cartesian direction. This includes a circular plate that is attached to the extruder and the extruder is attached to three triangular focal points. Each of the three points on this point goes up and down, which determines the position and orientation of the print head. Delta printers are designed to speed up the printing process. In any case, many people think that this printer is not as accurate as a traditional Cartesian printer. The Descartes and Delta 3D printers are not very unique. It is important that each component can be moved on a print bed. In a Cartesian 3D printer, each component can move in one direction, while in a Delta 3D printer, the print head can move in any path, but the print board does not move [6]. The difference between Cartesian 3D printing mechanisms and Delta FFF is illustrated in Figure 2.

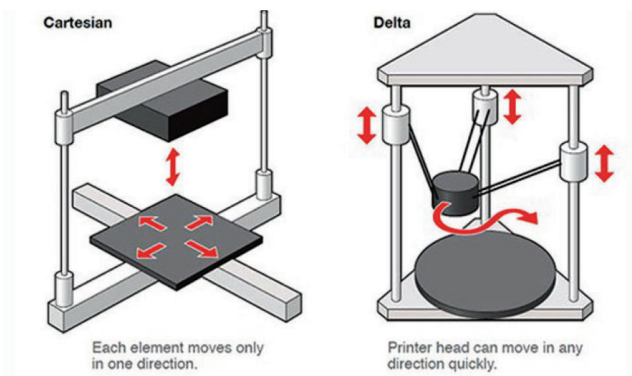

Figure 2: Cartesian vs. Delta printers

C Polar 3D FDM Printers

The positioning of the polar 3D printer is not determined by the organization X, Y, and Z, but by the angle and the length. This means that during this time, when the extruder goes up and down, the plate turns and moves. The main advantage of Polar FDM 3D printers is that they only have two motors, whereas Cartesian printers require three. In the long term, Polar printers have more vitality and can make larger documents while taking up less space [7].

D FDM 3D Printing with Robotic Arms

Robotic arms are often known to accumulate parts on industrial lines, especially in large automobile factories. Although 3D printing has begun to add robotic arms to their build process, it is particularly important in 3D printing of houses and structures, and this innovation is being improved [8]. Although the printing process is not often used, this FDM printing technology begins to see the expansion used. Indeed, the program does not work with the plates to make them more portable. In addition, due to the adaptability when positioning the 3D FDM print head, the requirements for the manufacture of complex structures are low. It should be noted, however, that the final print quality is comparable to that of traditional Cartesian printers.

4 Types of Fused Filament Fabrication (FFF) 3D Printers

With advancement in 3D Printer technologies engineers are working on the Multicolour printed object since there is a need for designers, entrepreneurs and for teaching aids too. There are many techniques to print a multi-colored object, which varies with complexity, ease of use cost and time, with each, is associated is many advantages and disadvantages. With the simplest and cost efficient is printing objects separately. The following section discusses the many possible ways to do it. The functional block diagram of the proposed 3D Printer working is shown in Figure 3.

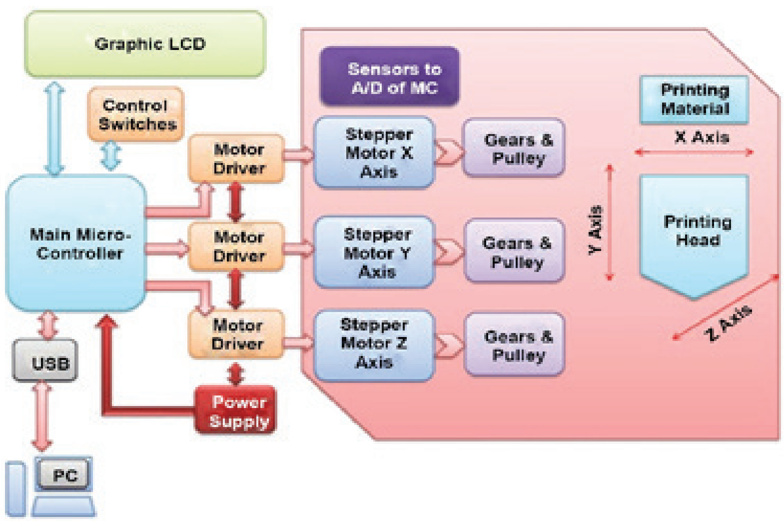

Figure 3: Functional block diagram of the proposed 3D printer

A Printing each Colour Objects Separately

In this technique, objects are first pre-processed using CAD software which will be breakdown the 3D model into different colour models. With 3D models require great labour to break the model into colours. There are many advantages and disadvantages to it. The biggest advantage is that it is cost efficient, that anyone having 3D Printer with single extruder can do it without any further hardware advancements. The disadvantage with these techniques is that it requires pre- and post-processing which is a delicate task [9].

B Pausing Mid-Print

In this technique, the printing is paused at some interval and filament is changed, and then resumed, thus the multicolour object is obtained. It is suitable where layered colour 3D model is printed, and is not suitable where colours are mixed at different Z-axis points. It is advantageous than the previous technique discussed in that it requires lesser pre-processing and object is obtained as a single [10].

C Multi-Extruder

Multi-Extruder comes Multiple Extruders with each extruding different colour, and there is no limit to the number of colours except space which is required for the extruder. The G-code is responsible for each colour change. Multi-Extruder has advantages over the other two discussed so far, that in it there is no need of worry to change the filament and then resume, but just begin and the end product will be ready soon. However, it has many disadvantages too. It reduces the size of Print bed that when, suppose a two-extruder head is used, the Extruder at right will not reach at left corner unless the left extruder is moved outside the print bed, thus the size of bed equivalent to the width of the extruder must be reduced and vice versa for the right corner, reducing the width of the print two times the width of extruder head. It is also unsuitable to create gradient colours [11].

D Multi-Spool Single-Extruder

In this technique, multiple spools are used and each spool holds a filament. Attached with each spool is an extruder motor that pushes the filament to the single nozzle when detected by the software. Advantages of both multiple extruder techniques and of the classic are achieved through it, with no space shrinkage and using a single nozzle to print multiple filaments. But like others it has some disadvantages too it wastes filament when changing the filament colour, thus there is more waste in it, thus it increases prototyping cost [12].

E Wi-Fi Connectivity

Using Wi-Fi Connectivity 3D Model may be transmitted wirelessly instead of using SD card and USB cable reducing space. Many a company produces 3D printed product, it works 24/7 nonstop, which requires many USB ports which a single PC cannot handle. The solution is to implement Wi-Fi connectivity. The Wi-Fi may be implemented using Wi-Fi modules such as ESP8266.

ESP8266 is a Wi-Fi microchip with full TCP/IP stack and microcontroller capability module as shown in Figure 4. This small module allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections.

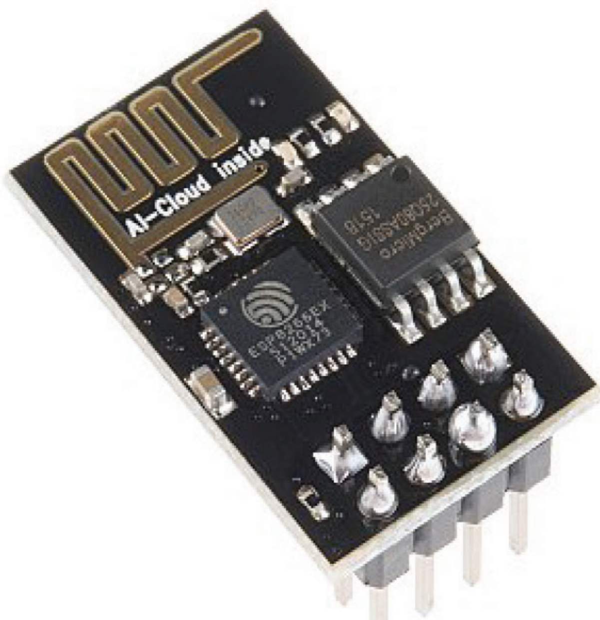

Figure 4: ESP8266 a Wi-Fi Module

F *Schematics of wiring ESP8266 with RAMPS*

Figure 5 and 6 shows pin-out of RAMPS and ESP8266. The ESP8266 TX pin is to be connected to TX pin of RAMPS and RX pin to be connected to RX pin of RAMPS.

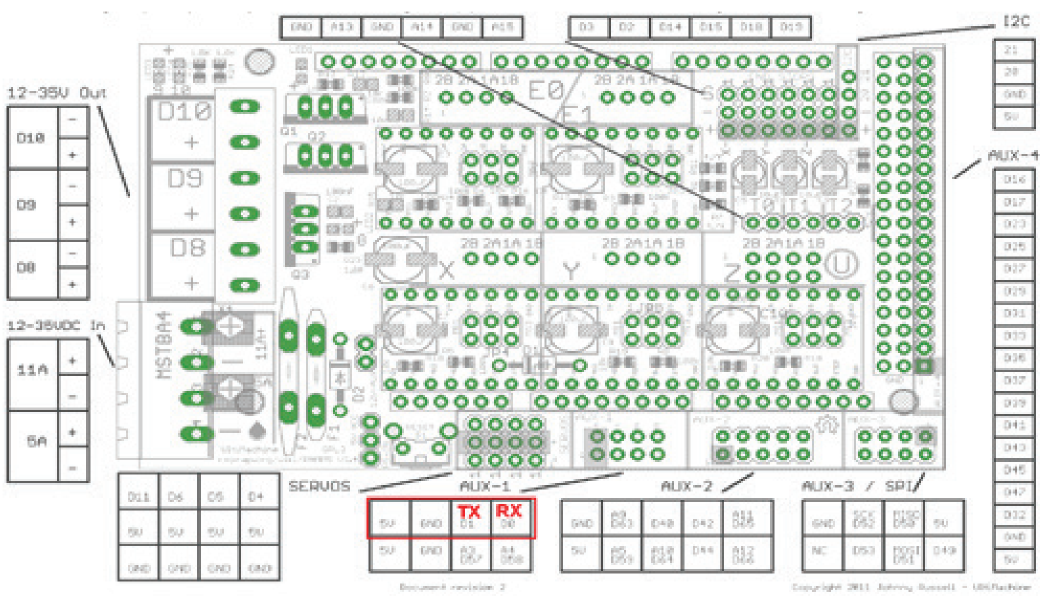

Figure 5: Pin assignment of RAMPS board for Wi-Fi

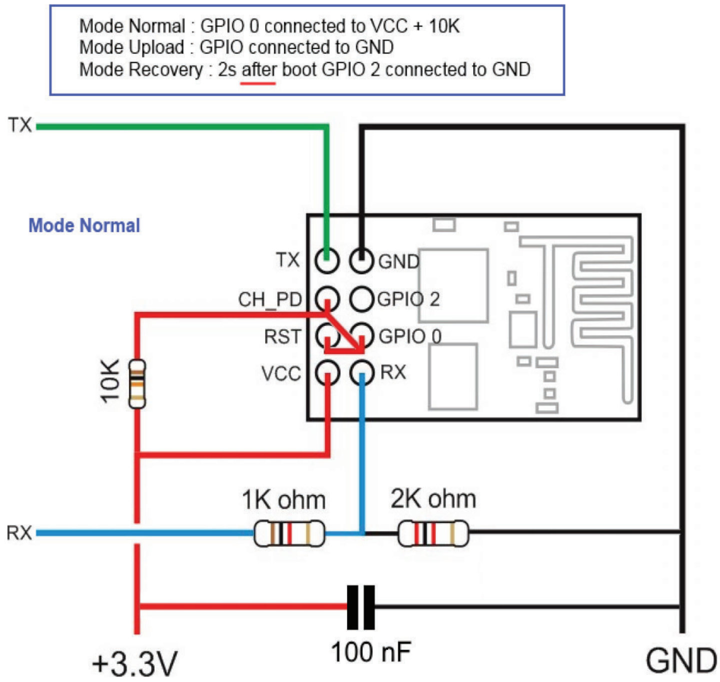

Figure 6: ESP8266 connections with RAMPS board

5 Results and Discussion

This section discusses the three major parameters of 3D printed object, which are as follows:

A Printing at different Infill ratios

Printing with different Infill ratios increases the weight of the object, increasing the time to print. 3D Prints with lesser infill ratios prints faster than higher infill ratio. Usually, 20-25% is sufficient for the object to be of good Quality. 100% infill completely fills the object using much filament to produce. Figure 7 shows the print with different print ratios.

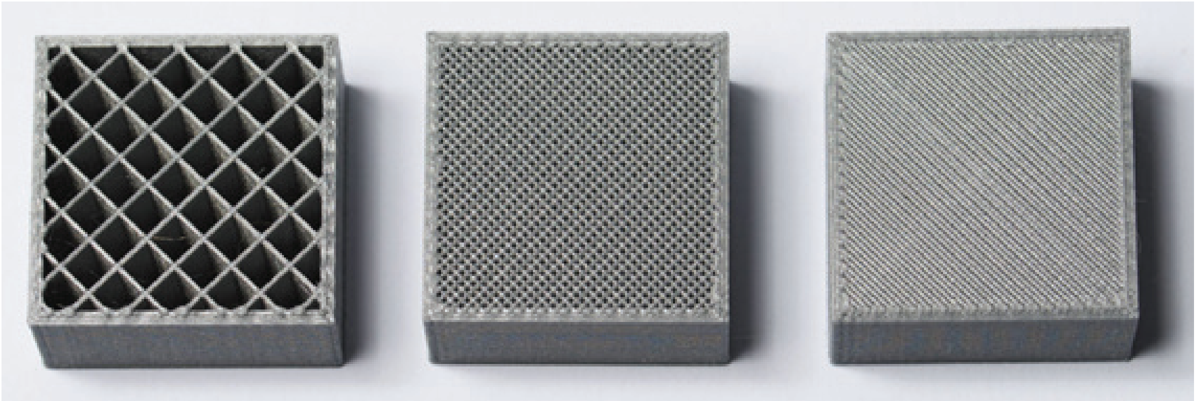

Figure 7: 3D Printing Cube with different Infill ratios

B Printing Time

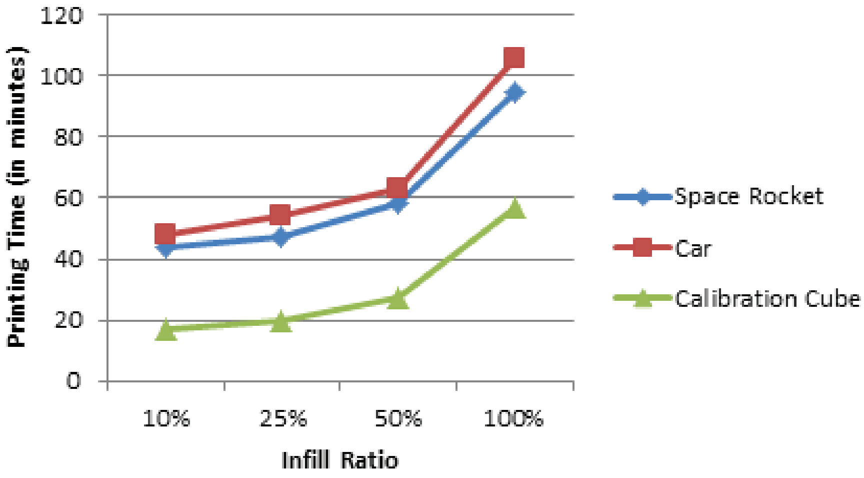

Figure 8: Printing Time vs. Infill ratio

Figure 8 shows the different printing time against infill ratio for three different 3D Printed models i.e. Space Rocket, Car and Calibration Cube. The graph shows the higher infill ratio tends to increase printing time and weight of the printing object. The actual 3D printed objects can be seen in Figure 9.

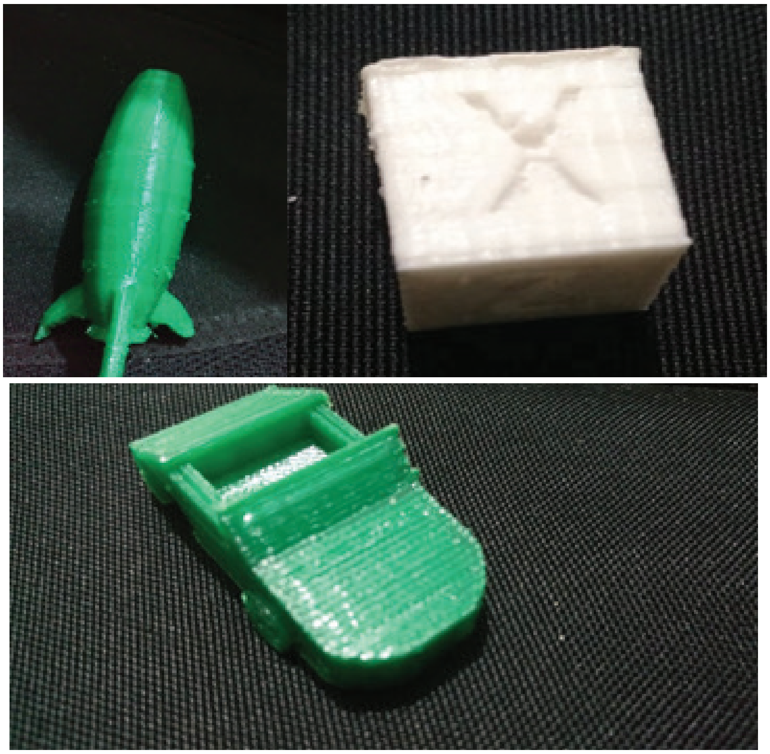

Figure 9: Calibration Cube, Space Rocket, Car (Top-left to bottom).

C Accuracy

A 20x20x20 mm cube is printed with the parameters given below for quality analysis.

Extruder Temperature: 190 C

Flow: 100%

Print speed: 50 mm/s

Infill speed: 60 mm/s

Travel speed: 100 mm/s

Wall thickness: 0.8 mm

Top/bottom thickness: 0.8 mm

Layer height: 0.1 mm

Infill Density: 20%

Build plate adhesion type: Brim

Table II displays the accuracy of the printed Cube against 3D CAD Cube model. The comparison in three different axis shows that the average accuracy of the proposed method is about 96.66% for 3D Cube printing.

Table 2: Accuracy comparison of printed Cube to CAD Cube model

FFT	X-measurement	Y-measurement	Z-measurement
Input Test Cube	20 mm	20 mm	20 mm
Output Test Cube	19 mm	19.5 mm	19.5 mm

6 Conclusion

In this paper, the design of general 3D Printer main-board using RAMPS board and Arduino mega discussed. The design and analysis suggest that a higher infill ratio tends to increase printing time and weight of the printing object. The accuracy comparison of printed Cube with respect to CAD Cube is about 96.66%. Moreover, the addition of Wi-Fi to the RAMPS and methodology of printing with multicolour/multi-material capability has enhanced the performance of this study project. In future work, the quality of 3D printing can be further improved.

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