

3D Printing: A Custom-Built 3D Printer with Wireless Connectivity

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Abstract

The objective of this project is to build a 3D printer with wireless connectivity. We made a 3D printer that can be controlled remotely via the Repetier Server. The custom-built 3D printer has a PiCam camera, LCD screen, SD card reader, and cloud management server to monitor and print remotely. The resulting printer can be accessed through any device with internet connectivity.

Keywords — 3D Printing, Arduino Mega, Raspberry Pi, G-code

I. INTRODUCTION

In the past two decades, there have been many advances in 3D printing. Many of these advances have improved technology and lowered its cost. Many high precision machines have price points within reach of enthusiasts, small businesses, and independent maker shops. Along with the advances in the hardware, the software tools that enable the process, that is, the Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) packages, have also seen their share of advances. In today's world, it is possible for students, researchers, and even Do It Yourself (DIY) technologists to assemble the hardware and software needed to create a compelling and affordable 3D printing system.

Typically, an object that is destined to be created using a 3D printer is designed using CAD software. This software either has the CAM software integrated into it, or its output is exported to CAM specific software. Either way, the CAD/CAM system's final output is a file of instructions that controls the 3D printer. Usually, CAD software produces a Stereolithography (STL) file that describes the object. The STL file is used by CAD software to produce G code, which controls the manufacturing machine.

The STL file format was developed in 1986 by Chuck Hull of 3D Systems. STL files are typically employed as the CAD system's output and describe 3D objects in mathematical terms. For 3D printing, the STL file needs to be sliced into G-code layers. G-code files tell a 3D printer how to print a 3D object. G-code typically describes printer parameters, such as speed and temperature, and the geometry of the 3D object.

Recently, 3D printing technology is increasing in popularity due to some of its distinct advantages.

- It is easy to use, even without any prior manufacturing knowledge.
- The user can create designs that cannot be found in stores or from other products.
- It is an excellent and affordable alternative to a low number of precision parts manufacturing.

However, there are few remote monitoring systems suitable for 3D printing devices in the market. This project provides a simplified and efficient way to monitor 3D printers remotely. The user can start a print from wherever the user is and can monitor that print while away. In the following sections, we review the related works on 3D printing projects. This paper describes the design, implementation, and functionality of the custom-built 3D printer. Finally, this paper shows the results of what this project has achieved and provides ideas for future research areas.

II. RELATED WORK

This project is based on an open-source 3D printer. The Prusa I3 MK3 3D printer has been developed since 2008 with RepRap's Darwin, a self-replicating rapid prototyping machine [1]. Many applications allow us to manage and interact with printers. Once the design is finalized and CAD systems output the STL file, the slicer can convert STL files to G-code [2]. The most notable slicers are Cura, Slic3r, and Simplify 3D. Once the G-code is generated, it is sent to the printer to build the 3D object.

The 3D printer built for this research is based on cloud printing and remote control. Research teams also worked specifically on developing cloud printing and remote-control capability for 3D printers [3] [4]. This work is similar in that a remote monitoring system is used in implementing this project for cloud-based printing. This project used the Repetier Server to store printing objects. It also provides the functionality of communication with all Prusa-like printers. The added benefit is that a computer doesn't have to be attached to the printer since this custom-built 3D printer has wireless connectivity.



III. IMPLEMENTATION

A. Hardware approach and equipment

The hardware for this 3D printer can be divided into a few sections.

- The first element is the frame of the printer.
- The second element is the components that move the extruder to certain points.
- The third element is the operation of the extruder itself.
- Lastly, the logic components to power and control the 3D printer are described.

This printer's frame is built out of 2020 aluminum beams with slots that allow screws to be secured and for wire management. The beams are held together with L-shaped brackets. The frame's base is a square and holds the structure that allows motors and other accessories to be mounted.

The second element is the movement of the extruder. There are three ways to move the extruder: X-axis, Y-axis, and Z-axis coordinate systems [5]. The printer uses one stepper with a belt to move the X-axis and Y-axis, two stepper motors to move the Z-axis, and one stepper to control the extruder. The movement of the Y-axis in terms of 3D printing refers to the movement of the heating bed. The assembly to move the extruder along the X-axis is located on the Z-axis carriage. The Z-axis is a little more complicated than other axes since it uses two stepper motors. Instead of using a belt, it uses two threaded rods that the X-axis carriage is attached to.

The third element of the hardware is the extruder of the 3D printer. The extruder is located directly on the X-axis. The extruder generally has four essential parts: transport of the material, heating, filtration, and exit [6]. The components that make up the extruder are the stepper motor, quick release, heating element, heat sink, and fan shown in Fig. 1.

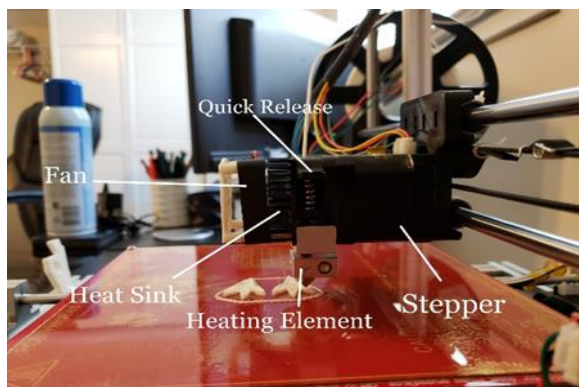


Fig. 1. Labeled Extruder: Stepper, Quick Release, Heating Element, Heat Sink, and Fan

There are several different methods of 3D printing. This Fused Deposition Modelling (FDM) printer uses a thermoplastic filament, which is heated to its melting point and then extruded, layer by layer, to create a three-dimensional object. In the FDM

method, a printer deposits melted filament of a certain material into thin layers, which are cooled very fast. Thus the next layer can be added to the previous layer. The FDM method is a suitable compromise between accuracy and the speed of modeling and transformation of final products and assembly nodes [7] [8]. The extruder feeds the filament into the heating element. Polylactic Acid (PLA) filament is used in this 3D printer project [9]. The heating element heats the filament and then attaches the melted filament to the printing area.

The logic components are used to power and control the parts on the 3D printer. This printer uses a Reprap Arduino Mega Pololu Shield (RAMPS) board shown in Fig. 2 to force the components. Stepper motors, thermistors, and heating elements are plugged into the RAMPS board. This printer uses an Arduino Mega microcontroller shown in Fig. 3 to send control signals to specific parts. We encountered an issue with the Arduino Mega power supply. The RAMPS board has a 24V power supply and would cause the Arduino's 5V regulator to blow because the Arduino's max voltage can handle 12V. Therefore, the Arduino gets its power from a Raspberry Pi with a 5V power supply.

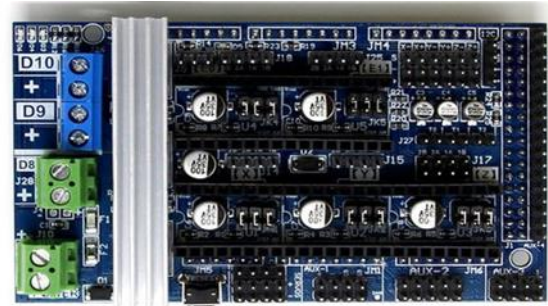


Fig. 2. RAMPS 1.6 Board for Arduino Mega



Fig. 3. Arduino Mega Microcontroller

The Raspberry Pi shown in Fig. 4 is plugged into the Ethernet network to allow internet access [10] [11]. The Arduino Mega gets power from the Raspberry Pi to send G-code files for printing 3D objects [12]. The PiCam shown in Fig. 5 is directly connected to the Raspberry Pi through the Camera Serial Interface (CSI). The PiCam webcam provides a live video feed of the printer, allowing users to start, monitor, and stop their printer wherever there is the internet.

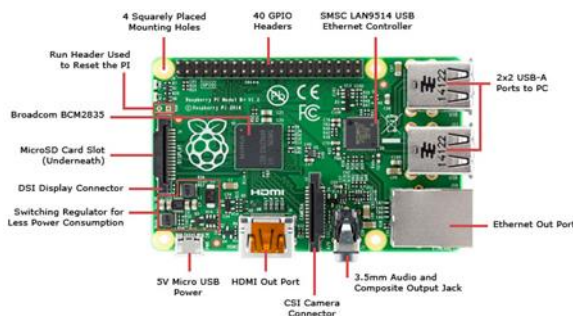


Fig. 4. Raspberry Pi

To print 3D objects, users load the G-code file onto the SD card, plug the SD card into the reader, and then use the potentiometer, button, and LCD screen to navigate the menu to print from the SD card. The SD card reader is attached to the RAMPS board. The LCD screen shown in Fig. 6 is also attached to the RAMPS board. This LCD screen displays information about the printer like the extruder and heating bed's temperature and the coordinates of the extruder on an X, Y, and Z coordinate plane. There are a potentiometer and button to navigate an onboard menu. This menu includes many ways to control the printer.



Fig. 5. PiCam for Raspberry Pi



Fig. 6. LCD Screen with Potentiometer

B. Software Approach

The Arduino needs to receive files in a G-code format for printing a 3D object. G-code is essentially the language that the Arduino's firmware reads (This needs to be rewritten). The Arduino has a library that can translate the G-code to control the 3D printer stepper motors and other actuators. G-code tells a 3D printer how to print a 3D object. As stated earlier, G-code typically describes printer parameters, such as

speed and temperature, and the geometry of the 3D object shown in Fig. 7. Each G-code file comprises multiple G-code commands depending on the size of the object being printed. Each command is read by the Arduino's firmware and then translated into the motors' movements or other necessary tasks.

The firmware that is loaded onto the Arduino is called Marlin. It is popular with many 3D printers and is compatible with Arduino Mega. The firmware is customizable to accommodate many different types of components for custom-built printers.

To create G-code files that Marlin firmware can read, users need to "slice" the object into G-code. The slicer converts STL files into a series of thin layers and produces a G-code file. Furthermore, it divides the object into a stack of flat layers and describes these layers as linear movements of the 3D printer extruder, fixation laser, or equivalent.

There are many different slicing applications available. The Slic3r is an open-source 3D printing slicer software that is used in this experiment. The GUI interfacing photograph of Slic3r is shown in Fig. 8. In the slicer software, the user can configure many settings to acquire a more quality printed object. There are settings for the printer, the filament, and the specific print. Some of these settings include nozzle size, heating bed temperature, location to build the structured material, and more. All these settings are also saved in the G-code file sent to the Arduino.

```
M190 S60 ; set bed temperature and wait for it to be reached
M104 S200 ; set temperature
G28 ; home all axes
G1 Z5 F5000 ; lift nozzle

; Filament gcode

M109 S200 ; set temperature and wait for it to be reached
G21 ; set units to millimeters
G90 ; use absolute coordinates
M82 ; use absolute distances for extrusion
G92 E0
M106 S255
G1 E-1.00000 F1800.00000
G92 E0
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Fig. 7. Example of G-code

The Repetier Server image for Raspberry Pi is installed in this project. This Repetier Server image serves as a web interface to control the printer anywhere with an internet connection. The Repetier Server is available if the device is on the same LAN. To forward the port for the Repetier Server of the Raspberry Pi, the router's settings are set up on the default Repetier Server port number, such as 3344. After the port forwarding, the user can access this server by using the LAN IP address followed by the port number.

A domain name is set up to mask the LAN IP address to provide a more user-friendly service. Instead of typing in the IP address followed by the port number, the user only needs to type in the domain name. The Domain Name System (DNS) servers dispatch the client requests among the web servers through the domain name to an IP address

mapping and load balancing algorithm [13]. This method is used because Domain names are generally easier to remember than a sequence of random numbers.

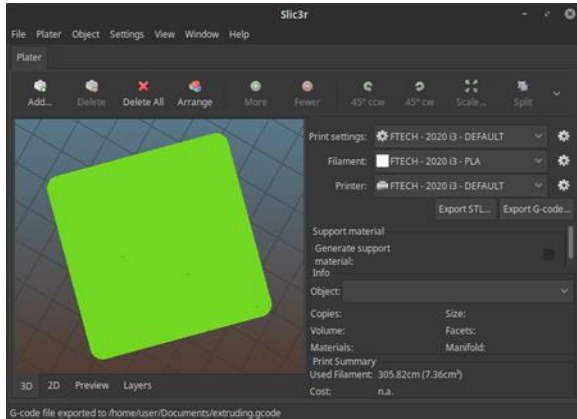


Fig. 8. The Slicing Software Used to Convert to G-code

The No-IP.com service is used to set up a free domain to associate with the Repetier Server. This service allows users to create a free domain name, usually followed by a set of characters, for example, domainname.ddns.net. The No-IP.com also provides a service that functions with a dynamic IP address. Since this Repetier server can run on a home network, it is usually given a dynamic IP address. The dynamic IP address is constantly changing to provide protection. After the service of No-IP.com is installed on the same network as the server, it constantly provides the updated IP address to attach to the domain name. The No-IP.com service provides a solution to the constantly changing IP address.

The Repetier Server is the professional all-in-one solution to control and manage the 3D printers. There is no limit to the number of users one could add, and each user can have different access levels. It provides security and organization within a large group of individuals using the same printer or server. For example, only one user can be able to print. Repetier Server can also add and manage many printers. There is a section on the dashboard of the site that shows all of the printers connected to the server and each printers' information. There is also a toggle switch to see the printers' live camera feed if accessible.

There is also storage for 3D objects on the Repetier Server, as shown in Fig. 9. The user can upload the G-code files to this cloud server and then print 3D objects. A user can even manually send G-code commands to the printer if needed.

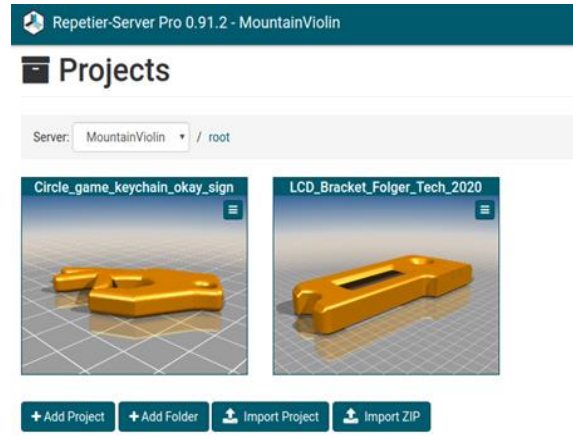


Fig. 9. The Cloud Server to Store Printing Objects

The layout of the 3D printer is shown in Fig. 10. For this project, the system's functionality, the Arduino Mega, Raspberry Pi, LCD screen, and PiCam camera for the custom-built 3D printer have been successfully tested.

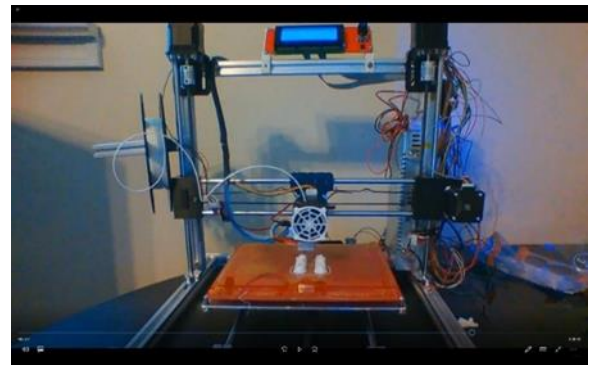


Fig. 10. 3D Printer Layout

IV. CONCLUSION

Additive manufacturing or 3D printing technology is a rapidly advancing technology noticed by many researchers, manufacturers, and maker communities. In this project, a complete 3D printing system was created and tested with internet connectivity, allowing it to be used, controlled, and monitored remotely. Future work includes enabling the Alexa interface to enhance the user experience and simplify interactions with the system.

REFERENCES

- [1] L. Celorrio-Barragué, S. Calvo-Simón, M. Gaspar, M. Vidal-Cortés, and P. Martín-Ramos, "3D Printed Models-Based Lab Activities to Enhance Learning-Teaching Processes in Structural Engineering Courses," Proceedings of the Seventh International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM '19), pp. 80–86, October 2019.
- [2] M. S. Akter and M. H. Kabir, "Temperature Optimization of RepRap (Replicating Rapid-prototyper) 3D Printer," 2018 International Conference on Computer, Communication, Chemical, Material and Electronic Engineering (IC4ME2), Rajshahi, Bangladesh, pp. 1–4, February 2018.

- [3] C. Liu, P. Jiang, and W. Jiang, "Embedded-Web-Based Remote Control for RepRap-Based Open-Source 3D Printers," Proceedings of the 43rd Annual Conference of the IEEE Industrial Electronics Society (IECON 2017), Beijing, China, pp. 3384-3389, November 2017.
- [4] G. Yiming, Z. Rong, Z. Zhisheng, and C. Zhen, "Design of Remote Monitoring System for 3D printing Based on Cloud Platform," 2017 24th International Conference on Mechatronics and Machine Vision in Practice (M2VIP), Auckland, New Zealand, pp. 1-5, November 2017.
- [5] C. Jia, L. Xie, and Z. Li., "A 3D Printer Using Column Coordinate System and Slice Algorithm," Proceedings of the 2018 International Conference on Mechatronic Systems and RobotsMay (ICMSR '18), pp. 95-99, May 2018.
- [6] V. Romero-Alva, W. Alvarado-Diaz, and A. Roman-Gonzalez, "Design of a 3D Printer and Integrated Supply System," 2018 IEEE XXV International Conference on Electronics, Electrical Engineering and Computing (INTERCON), Lima, Peru, pp. 1-4, August 2018.
- [7] Z. Pilch, J. Domin, and A. Szałpa, "The Impact of Vibration of the 3D Printer Table on the Quality of Print," 2015 Selected Problems of Electrical Engineering and Electronics (WZEE), Kielce, Poland, pp. 1-6, September 2015.
- [8] M. Teliskova, J. Torek, T. Cmorej, M. Kocisko, and J. Petrus, "Adjustments of RepRap Type Printer Workbench," 2017 4th International Conference on Industrial Engineering and Applications (ICIEA), Nagoya, Japan, pp. 15-19, April 2017.
- [9] P. Rajamanickam and R. Y. Mulla, "Cloud-Based 3D Printer," 2017 International Conference on Information, Communication, Instrumentation and Control (ICICIC), Indore, India, pp. 1-4, August 2017.
- [10] K. P. Yang, A. Burningham, K. Champagne, D. Dahal, and J. Hernandez, "A Venture to Build a CNC Machine," International Journal of Computer & Organization Trends (IJCOT), ISSN 2249-2593, 9(5): 5-9, October 2019.
- [11] K. P. Yang, N. Moran, I. Bendana, S. Champagne, and T. Becker, "LOPEZ: A Bilingual Robotic Car," International Journal of Research in Advent Technology (IJRAT), E-ISSN 2321-9637, 4(12): 51-55, December 2016.
- [12] K. P. Yang, A. Jee, D. Leblanc, J. Weaver, and Z. Armand, "Experimenting with Hotword Detection: The Pao-Pal," European Journal of Electrical Engineering and Computer Science (EJECE), ISSN 2506-9853, 4(5): 1-5, September 2020.
- [13] C. Wang, W. Li, F. Liu, and Z. Lei, "Research of Domain Name Mapped IP-Address Distribution on the Internet," Proceedings of the 3rd IEEE International Conference on Network Infrastructure and Digital Content, Beijing, China, pp. 284-288, September 2012.
- [14] A.B. Primawan "Performance Analysis of Data Transmission Device In Wireless Sensor Network" International Journal of Engineering Trends and Technology 68.3(2020):1-5.
- [15] Sweta Tripathi, Aprajita Jha, Rishabh Mishra, Prof. N.K. Shinde, "I-Voting – Raspberry Pi Based Anywhere Voting System" SSRG International Journal of Electronics and Communication Engineering 7.4 (2020): 21-23.