A

Project Report

on

"OctoPrint-Based Wi-Fi 3D Printer with Live Video Feed"

Submitted in partial fulfilment for the award of the degree of

Bachelor of Technology

in

Robotics and Artificial Intelligence

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YMCA, FARIDABAD

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DECLARATION

I hereby declare that the work, being presented in the project report entitled "OctoPrint-Based Wi-Fi 3D Printer with Live Video Feed" in partial fulfillment of the requirement for the award of the Degree in Bachelor of Technology in Robotics and Artificial Engineering and submitted to the Department of Mechanical Engineering of J.C. Bose University of Science and Technology, YMCA, Faridabad is an authentic record of our team work carried out during a period from JULY 2024 to DEC 2024 under the supervision of Dr Om Prakash Mishra (Assistant Professor), Department of Mechnical Engineering. No part of the matter embodied in the project has been submitted to any other University / Institute for the award of any Degree or Diploma.

Signature of Student(s)

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CERTIFICATE

This is to certify that the project entitled, "OctoPrint-Based Wi-Fi 3D Printer with Live Video Feed" submitted in partial fulfillment of the requirements for the degree in Bachelors of Technology in Robotics and Artificial Intelligence is an authentic work carried out under my supervision and guidance.

Dr Om Prakash Mishra

Assistant Professor

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ACKNOWLEDGEMENT

This opportunity was taken to express our deep sense of gratitude and respect towards our supervisor Dr Om Prakash Mishra , Assistant Professor, Department of Mechanical Engineering, J.C. Bose University of Science & Technology, YMCA, Faridabad.

We are very much indebted to him for their generosity, expertise and guidance. Without his support and timely guidance, the completion of this report would have seemed a farfetched dream. In this respect, we find ourselves lucky to have him as our supervisor. He has supervised us not only with the subject matter but also taught us the proper style and technique of working and presentation. It is a great pleasure for us to express our gratitude towards those who are involved in the completion of my project report.

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We express our sincere thanks to all our friends, our well-wishers and classmates for their support and help during the project.

ABSTRACT

The aim of this project was to assemble a 3D printer and enhance its functionality by implementing a remote-controlled monitoring system. Utilizing a Raspberry Pi Zero 2 W integrated with OctoPrint and a Raspberry Pi Camera, the system enabled real-time monitoring, remote operation, and control via Wi-Fi and mobile applications such as OctoApp. The objective was to improve the usability and accessibility of 3D printing processes through advanced features.

The methodology involved selecting and integrating hardware components, including a Raspberry Pi Zero 2 W, a 3D-printed gimbal mount for the camera, and OctoPrint software. A custom gimbal mount was designed and printed to attach the Raspberry Pi Camera to the printer's left gantry for optimized monitoring. Remote access was facilitated using plugins like OctoEverywhere, allowing users to give print commands, pause or stop prints, preheat the print bed and nozzle, adjust temperatures, and monitor print progress using a live video feed, all from their mobile devices.

The project successfully demonstrated a functional remote monitoring and control system for 3D printing. Users could operate the printer through an intuitive graphical interface, monitor prints in real-time, and receive alerts for print progress or errors. These features enhanced convenience, minimized downtime, and reduced material waste through timely interventions.

The integration of OctoPrint with mobile applications and additional features such as the OctoEverywhere plugin provided seamless access and control over printing tasks, enabling an efficient and user-friendly experience. Future improvements may include incorporating advanced analytics, further optimizing the user interface, and exploring additional automation capabilities to broaden the system's applications and impact.

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LIST OF ABBREVIATIONS

Gcode	Geometric Code
WiFi	Wireless Fidelity
USB	Universal Serial Bus
IP	Internet Protocol
HTTP	HyperText Transfer Protocol
SD	Secure Digital
CAD	Computer-Aided Design
GPIO	General Purpose Input/Output
RAM	Random Access Memory
CPU	Central Processing Unit
FTP	File Transfer Protocol
LAN	Local Area Network
SSH	Secure Shell
VNC	Virtual Network Computing
MQTT	Message Queuing Telemetry Transport
API	Application Programming Interface
JSON	JavaScript Object Notation
3D	Three-Dimensional

Chapter 1

INTRODUCTION

Over the years, 3D printing technology has brought transformative changes to manufacturing, prototyping, and education. Despite these advancements, traditional 3D printers face challenges such as the need for constant supervision, limited accessibility, and the inability to monitor operations remotely. These limitations can hinder efficiency, especially for users requiring flexibility in managing print jobs.

Recognizing these shortcomings, this project explores the integration of modern IoT solutions into 3D printing to create a smarter and more user-friendly system. By leveraging technologies like the Raspberry Pi Zero 2 W, OctoPrint, and a Raspberry Pi Camera, this system offers features such as remote monitoring, real-time control, and live video feed capabilities. The project not only addresses the issue of accessibility but also enhances productivity by enabling users to monitor and manage prints from any location.

The motivation for this project stems from the growing demand for connected and automated systems in both industrial and educational contexts. Traditional setups, which require physical presence, can be time-consuming and inefficient, particularly for users managing multiple tasks. Incorporating remote access through Wi-Fi connectivity and mobile applications provides a seamless, intuitive interface that empowers users to control and optimize their printing workflows.

This project demonstrates the potential of integrating IoT technology with 3D printing to improve functionality and user experience. By combining these technologies, the system paves the way for more accessible and efficient solutions, catering to the increasing need for smart, connected devices in a variety of applications.

Chapter 2

LITERATURE REVIEW

The literature surrounding 3D printing technology and IoT-based solutions highlights the significant benefits of integrating remote monitoring and control into 3D printing systems. A vast number of hobbyists and professionals have successfully implemented remote monitoring on their 3D printers using OctoPrint and Raspberry Pi, resulting in improved management of the printing process. This integration has proven particularly useful in reducing print failures, material wastage, and the time spent physically attending to the printer, offering users more flexibility and efficiency.

OctoPrint, when paired with a Raspberry Pi, has become a widely adopted solution for remote 3D printing, especially in educational and industrial settings. It allows users to control and monitor their 3D printers remotely, making it easier to manage print jobs without the need for constant physical presence. This remote control capability has streamlined the printing process, improving accessibility and reducing the time spent overseeing prints.

The OctoEverywhere plugin has further enhanced the functionality of OctoPrint by enabling users to access their printers over the internet. This plugin extends remote control capabilities beyond local Wi-Fi, allowing users to monitor and manage prints from anywhere in the world. This global access provides users with greater convenience, as they can intervene or make adjustments to prints from remote locations.

The integration of mobile applications has also contributed to the usability of 3D printing systems, enabling users to receive notifications, monitor print progress, and make adjustments through Wi-Fi or the OctoEverywhere plugin's internet connectivity. These features improve the overall user experience, making 3D printing more efficient, accessible, and flexible.

Chapter 3

OBJECTIVES OF PROJECT

The primary goal of this project is to create a remote-controlled 3D printing system that enhances user experience and efficiency by enabling remote monitoring and control. Using a Raspberry Pi Zero 2W, OctoPrint software, and a Raspberry Pi Camera, the system will allow for real-time data transmission and remote management of the printing process, improving accessibility and reducing manual intervention.

Objectives of the Project:

1. Assemble a 3D printer with the following features:
    a. **Open Source Design**: Allows modifications and improvements.
    b. **Cost-Effective**: More affordable than commercial alternatives.
    c. **Easy Availability of Spare Parts**: Readily available and affordable components.
    d. **Auto Bed Leveling**: Ensures consistent print quality.
    e. **Resume Function**: Automatically resumes printing after power interruptions.
    f. **Stable Dual Z-Axis**: Enhances stability and precision.
    g. **Direct Extrusion**: Improves print quality, especially for flexible filaments.
2. Configure the Raspberry Pi with OctoPrint to manage printer operations such as remote start, pause, stop, and real-time notifications.
3. Enable Wi-Fi connectivity for seamless remote access to the printer via OctoPrint's interface.
4. Integrate the **OctoEverywhere** plugin to extend remote control functionality over the internet, allowing users to manage their 3D printer from anywhere in the world.
5. Implement real-time visual monitoring using the Raspberry Pi Camera to keep track of the printing progress.

Chapter 4

COMPONENTS USED

The following components are used in this project:

1. **3D Printer Assembled Using Creality Ender 3 V3 SE Kit**
2. **Raspberry Pi Zero 2W**
3. **Raspberry Pi Camera v1.3**
4. **OctoPrint Software**
5. **Remote Access Tool (i.e. SimplyPrint, ngrok, or OctoEverywhere)**
6. **OctoApp Mobile Application**

Flow of Connection:

The **3D printer** is assembled using the **Creality Ender 3 V3 SE kit** and connected to the **Raspberry Pi Zero 2W** via USB. Once assembled, **OctoPrint Software** is installed on the **Raspberry Pi**, enabling remote control of the printer. To extend control beyond local Wi-Fi, the **OctoEverywhere Plugin** is added, allowing remote monitoring and control over the internet from anywhere in the world.

The **Raspberry Pi Camera** is mounted on the printer to capture live footage of the printing process, which is then streamed to the **Raspberry Pi**. This video feed, combined with the control functions of **OctoPrint**, provides a comprehensive view of the print in progress.

Finally, the system is integrated with a OctoApp mobile application, allowing users to manage and monitor the printer directly from their smartphones. This setup ensures seamless remote printing, providing users with complete control and real-time monitoring, no matter their location.

Chapter 5

COMPONENT DESCRIPTION

1. 3D Printer Assembled Using Creality Ender 3 V3 SE Kit

The 3D printer, assembled from the Creality Ender 3 V3 SE Kit, is the core platform for 3D printing in our project. It offers fast print speeds, stable dual Z-axis motion, and precise material extrusion. Features like auto bed leveling, filament loading/unloading, and the Sprite extruder ensure high-quality, reliable prints.

Technical Specifications:

- **Nozzle Size**: 0.4 mm (default), but it supports a range from 0.2 mm to 1.0 mm.
- **Bed Size**: 220 x 220 x 250 mm.
- **Extruder Type**: Sprite direct drive extruder.
- **CR Touch Feature**: Integrated with auto bed leveling for precise leveling and consistent first-layer adhesion.
- **Auto Z-Offset**: Automated nozzle height adjustment to ensure accurate and optimal print results.
- **Auto Bed Leveling**: Features CR Touch probe for accurate bed leveling, ensuring better print quality.
- **Dual Z-Axis**: Stabilized with dual Z-axis motors to reduce wobble and improve print consistency.
- **Auto Filament Loading/Unloading**: Automatic filament management system that detects and loads filament when needed.
- **Sprite Extruder**: A direct extruder known for its high reliability, supporting various filament types like PLA, PETG, and TPU.

Assembling the printer from the Creality Ender 3 V3 SE Kit deepened our understanding of 3D printing, enhancing our ability to troubleshoot, maintain, and customize the system for optimal performance. This approach allowed us to calibrate the printer to ensure smooth operation of the extruder, bed leveling, and stepper motors. It also improved our skills in managing the printer’s integration with Raspberry Pi and OctoPrint.

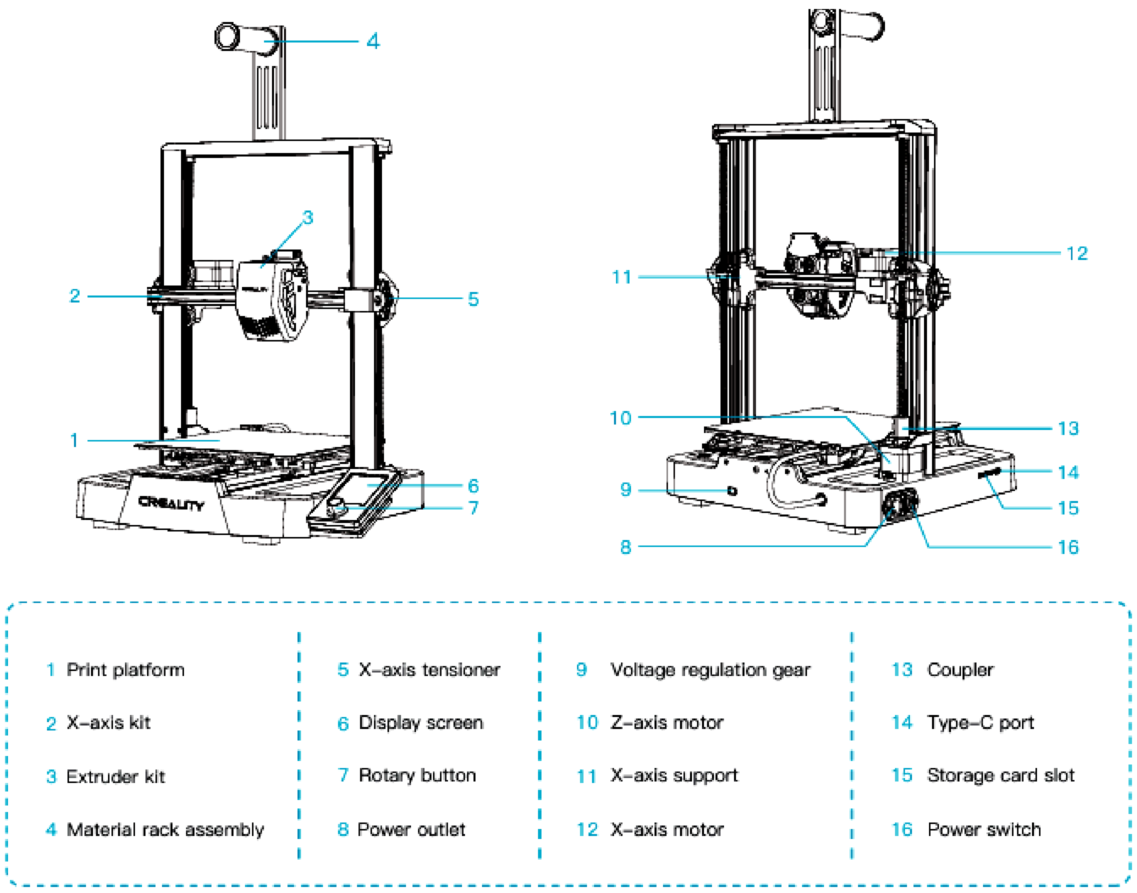

Figure 1: Labeled Schematic Diagram Ender 3 V3 SE

The printer's primary role is to produce 3D printed objects from digital models, remotely controlled via Raspberry Pi and OctoPrint for seamless print job management from any location.

2. Raspberry Pi Zero 2W

The Raspberry Pi Zero 2W is a small yet powerful microcomputer that drives the remote control and monitoring of the 3D printer. It runs OctoPrint software, which communicates with the 3D printer to send commands and receive status updates. The Raspberry Pi Zero 2W connects to the printer via USB and manages the interface between the user and the printer through OctoPrint's web interface.

Features:

- **CPU**: Broadcom BCM2710A1 quad-core Cortex-A53 (ARMv8) 64-bit processor running at 1 GHz.
- **RAM**: 512MB LPDDR2 SDRAM.
- **Connectivity**:
  - **Wi-Fi**: 802.11b/g/n wireless LAN (2.4 GHz).
  - **Bluetooth**: Bluetooth 4.2 (Bluetooth Low Energy).
- **Ports**:
  - **USB**: One USB 2.0 port.
  - **GPIO**: 40-pin header with support for various peripheral devices.
- **Storage**: microSD card slot for storage and operating system.
- **Display & Camera:**
  - **Mini HDMI:** Up to 1080p60 video output.
  - **CSI:** Camera Serial Interface for camera modules.
- **Power:**
  - **Power Supply:** 5V via micro-USB power port (2.5A recommended).
- **Additional Features:**
  - **Form Factor:** Compact and lightweight, ideal for space-constrained projects.
  - **Power Consumption:** Lower power consumption compared to full-size Raspberry Pi models.

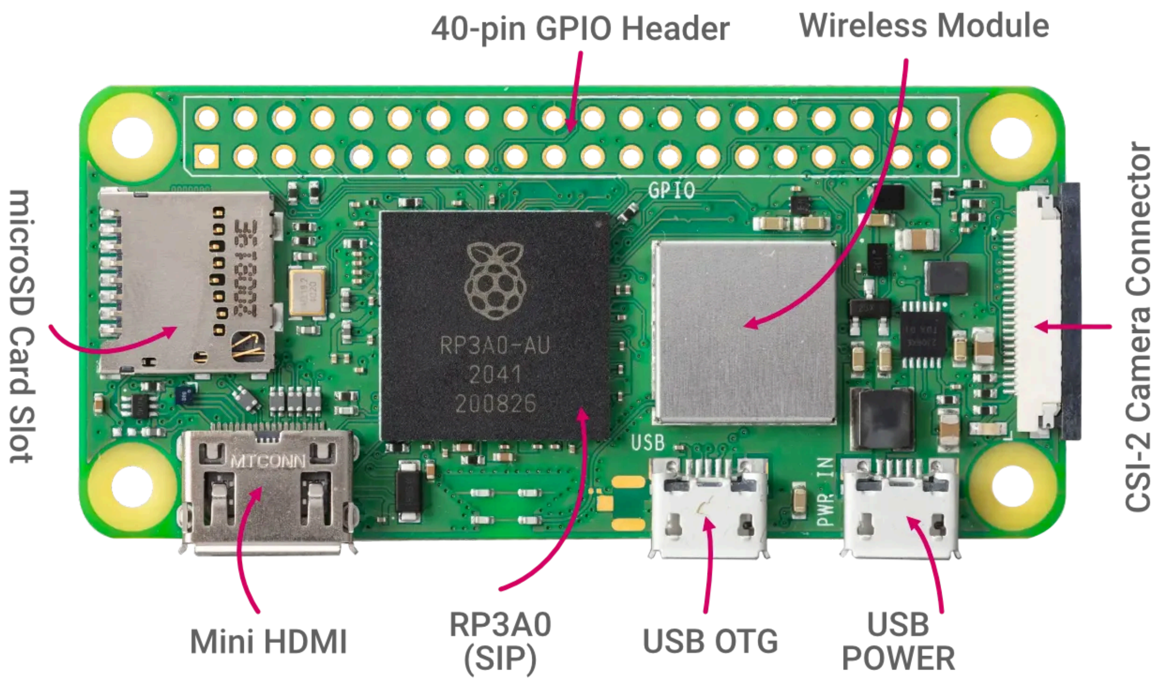

Figure 2: Labelled Schematic Diagram of Raspberry Pi Zero 2W

Its primary use is to provide the processing power and connectivity needed for remote control and monitoring. By integrating OctoPrint and the OctoEverywhere plugin, the Raspberry Pi Zero 2W allows users to access the 3D printer via the internet, enabling seamless remote operation and control over the printing process, regardless of location.

3. Raspberry Pi Camera v1.3

The Raspberry Pi Camera is used to capture real-time video of the 3D printing process. Mounted on the 3D printer, it streams live footage directly to the Raspberry Pi, allowing users to monitor print progress remotely. The camera is integrated with OctoPrint, which allows users to view the live feed through the OctoPrint web interface or mobile app.

Technical Specifications:

- **Resolution**: 2592 x 1944 pixels
- **Video Capability**: Up to 1080p30, 720p60, 640x480p90
- **Lens**: Fixed-focus
- **Interface**: CSI (Camera Serial Interface)
- **Power**: 5V through the CSI interface
- **Size**: 25mm x 24mm x 9mm (standard camera module dimensions)

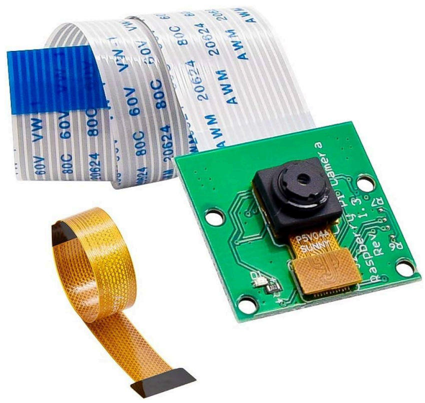

Figure 1: Labeled Schematic Diagram of Raspberry Pi Zero 2W

Its primary use is to provide users with visual feedback of the printing process. The camera's live video stream enhances the remote printing experience by allowing users to monitor the print's quality and progress, ensuring that any issues can be addressed promptly, even when they are away from the physical location of the printer.

4. OctoPrint Software

OctoPrint is an open-source 3D printer management software that provides a user-friendly web interface for controlling and monitoring 3D printers. It is installed on the Raspberry Pi Zero 2W and acts as the intermediary between the user and the 3D printer. Through OctoPrint, users can upload print files, start and stop prints, and receive real-time updates on print status.

Features of OctoPrint:

- **Remote Control & Monitoring:** Control and monitor 3D prints from any device with an internet connection, allowing users to manage prints from anywhere.
- **Print Job Management:** Upload, start, pause, and cancel prints directly from the OctoPrint interface, giving you full control over the print job at any stage.
- **Real-time Video Feed:** View live video streams of the printing process through a connected camera, offering greater insight and control.
- **Plugins:** Extend functionality with a variety of community and official plugins to add custom features or integrate with other tools.
- **G-code Visualization:** Preview G-code files to check settings before printing, ensuring accuracy and efficiency in print setup.
- **Timelapse Creation:** Automatically generate time-lapse videos of the printing process, enabling you to document and share prints.
- **Temperature Monitoring:** Keep track of the hotend, heated bed, and other temperatures in real-time, ensuring safe and consistent printing conditions.
- **Scheduler:** Schedule print jobs to start at specific times for better printer management and efficient use of time.

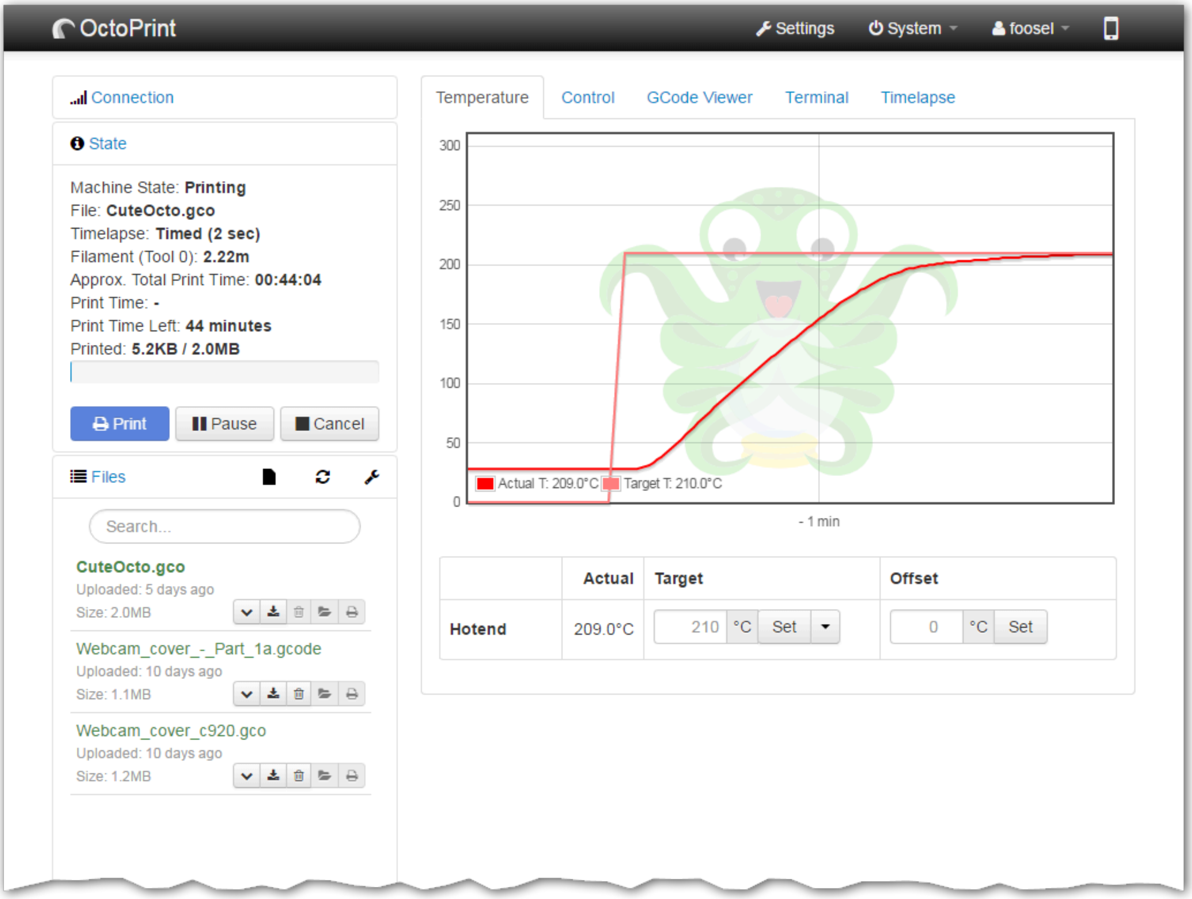

Figure 3: Octoprint Web-Interface Preview

Its primary use is to facilitate remote control and management of the 3D printer. By allowing users to interact with the printer through a web browser or mobile app, OctoPrint simplifies the printing process and offers the flexibility to control prints from anywhere. It ensures that users have complete control over their printing operations, even when they are not physically present at the printer.

5. Remote Access Tool (i.e. SimplyPrint, ngrok, or OctoEverywhere)

This component allows remote management and monitoring of your 3D printer from anywhere in the world, leveraging secure internet-based solutions. By using tools like SimplyPrint, ngrok, or OctoEverywhere, users can control their 3D printer, monitor print jobs, and make adjustments—all without being physically present at the printer.

Features:

- **Remote Access Anywhere:** Access your 3D printer from any device with an internet connection, regardless of your location. No need to be on the same Wi-Fi network.
- **Real-time Monitoring:** Track print progress through live video feeds and receive notifications on job completion or errors.
- **Secure Connections:** With SSL encryption or other secure tunneling solutions, all data transmissions are protected, ensuring privacy and security.
- **Multiple Printer Management:** Manage and control multiple printers remotely from a single account or interface.
- **Easy Setup:** Quick installation and minimal configuration needed to connect the printer to remote services.
- **Web and Mobile App Integration:** Monitor and control your prints via web browsers or mobile apps (iOS/Android), offering flexibility and ease of access.
- **G-code Visualization:** Preview G-code and check print settings before starting the job to avoid issues.

The remote access feature is a crucial part of this 3D printing setup, providing flexibility for users to operate the 3D printer from virtually anywhere. Whether you're working in the office, on the go, or simply away from your printer, this feature ensures that you can still manage your prints seamlessly. The ability to control and monitor the printing process remotely saves time and ensures the smooth execution of print jobs, reducing the need for constant on-site supervision.

6. OctoApp Mobile App

The OctoApp mobile app is designed to work in conjunction with OctoPrint and the OctoEverywhere plugin, providing users with a mobile interface to control and monitor their 3D printer remotely. By connecting to the OctoPrint instance via the internet, the app allows users to interact with their printer through a smartphone or tablet, providing easy access to print status and control features.

Key features of the OctoApp mobile app:

- **Remote Printer Management**: Monitor and control 3D printers remotely from your mobile device, providing complete oversight of print jobs and progress.
- **Real-time Status Updates**: Get real-time notifications about the printer's status, including job completion or errors, directly to your phone.
- **Live Video Streaming**: Watch live video feeds from your 3D printer using integrated camera support for an up-close view of the printing process.
- **Job Control**: Start, pause, or stop print jobs from your mobile device, giving you full control over the printing process on the go.
- **G-code Viewer**: Access and view G-code files directly from your mobile device to track print movements.
- **Multiple Printer Support**: Manage and monitor multiple 3D printers at once, ideal for users with more than one machine.
- **Ease of Use**: Simple, user-friendly interface designed for intuitive navigation and printer management.

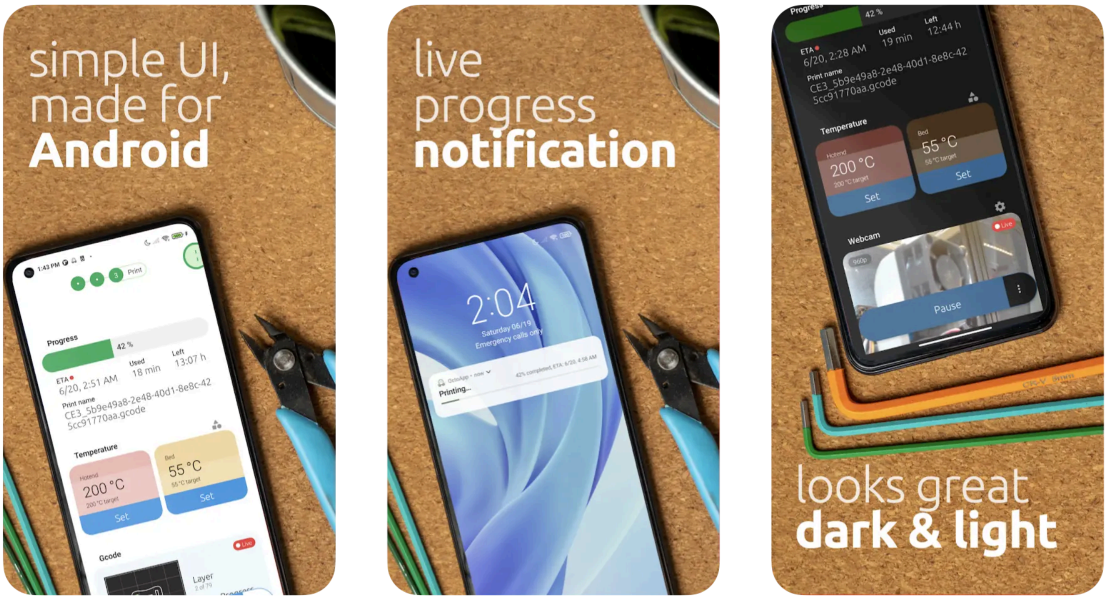

Figure 4: OctoApp Preview

Its primary use is to enable users to manage their 3D printer on the go. With the OctoApp, users can check the progress of their prints, start or pause prints, and even make adjustments to settings directly from their mobile device. This enhances the user experience by offering full control and visibility over the printing process, no matter where the user is located.

Chapter 6

PROCEDURE

The process of building a budget-friendly, remotely controlled 3D printing system using Raspberry Pi, OctoPrint, and mobile application integration can be divided in the following steps:

1. Research and Planning

Assemble a 3D printer kit with advanced features like remote access and power failure resume, keeping the total cost under INR 20,000.

- **Printer Kit Selection**:
  After extensive research, we selected the **Creality Ender 3 V3 SE kit** for its excellent features and affordability. Key features include:
  - **Sprite Extruder Setup**
  - **Auto Bed Leveling (CR Touch)**: Helps solve the recurring problem of manual bed leveling, ideal for a college environment.
  - **Power Failure Resume**: Ensures printing resumes from where it left off in case of power cuts.

  The Ender 3 V3 SE was priced at INR 14,000, making it a suitable choice within the project's budget.

- **Remote Access Setup**:
  To enable Wi-Fi functionality, we opted for a budget-friendly **OctoPrint setup**. High costs of Raspberry Pi models led us to choose the **Raspberry Pi Zero 2 W** (recommended by the OctoPrint community), costing INR 2,000 along with its official power supply.
- **Camera Selection**: A basic Raspberry Camera module was purchased for live video monitoring.

This planning stage helped ensure that all necessary components were selected based on the desired features, keeping the project within the budget and providing a clear path for further setup.

2. Assembling the Printer Kit

Assembling the **Creality Ender 3 V3 SE** 3D printer kit carefully and ensuring all components are functioning properly for subsequent testing and calibration.

- **Frame Assembly**: The frame was assembled first, ensuring all screws were tightened properly for structural integrity.
- **Extruder and Hotend Installation**: The **Sprite extruder setup** was mounted along with the hotend assembly. Care was taken to ensure the wiring was neatly arranged and securely connected.
- **Dual Z-Axis Assembly**: The dual Z-axis was installed to improve bed stability. This part required extra care to align both sides of the bed to ensure proper height and movement.
- **CR Touch Auto Bed Leveling Setup**: The **CR Touch auto bed leveling system** was installed and calibrated for automatic bed leveling. This feature would help minimize manual leveling issues, ensuring smoother and more accurate prints.

Figure 5: Printer Photos after Assembly

3. Material Testing and Cura Profile Setup

Optimizing printing settings for the selected filament by configuring the Cura slicing profile and running test prints to achieve the best quality output.

- **Material Testing**: The printer was tested with the chosen filament, running test prints to adjust settings for the best results. Key parameters tested included **flow rate**, **print speed**, and **temperature** to find optimal values for the filament.
- **Cura Profile Setup**:
    - A custom **Cura profile** was created to adjust the settings specifically for the selected filament. The profile was set up with optimal values for temperature, print speed, retraction, and bed adhesion.
    - The **Autotower** plugin in Cura was used to fine-tune **temperature settings**, **retraction settings** and **flow rate.**
- **Fine-Tuning Settings**: After testing, settings such as print speed, retraction, and layer height were further adjusted to optimize the quality of the prints. These changes ensured reliable and high-quality outputs tailored to the filament being used.

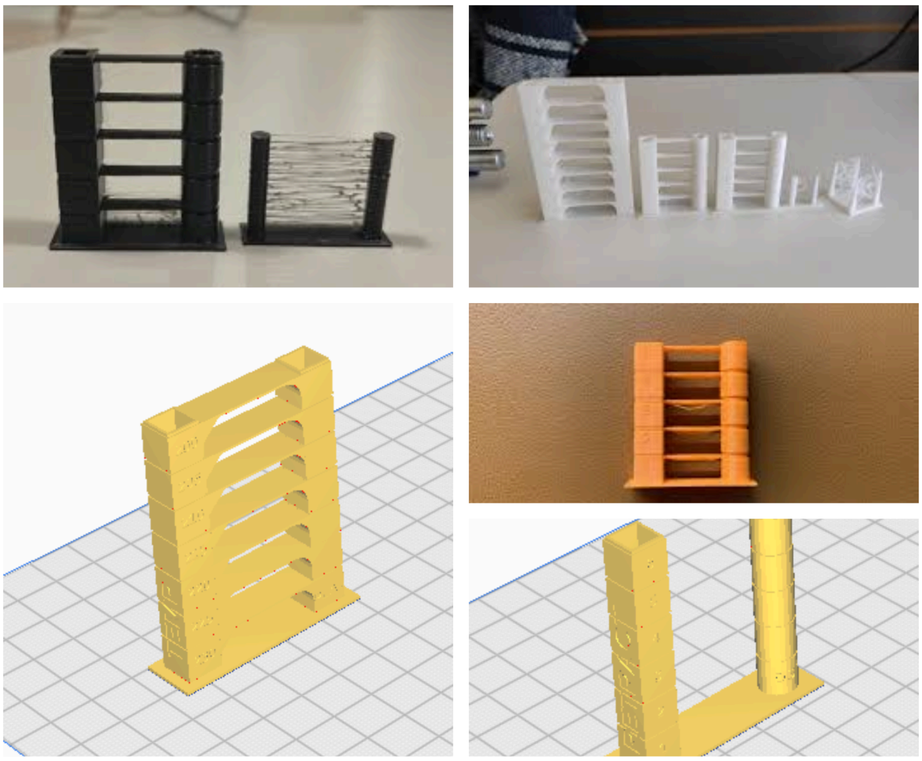

Figure 6: Auto Towers Preview

4. Printer Troubleshooting and Learning

During the setup, various issues were encountered, including layer adhesion and print calibration. The printer was calibrated for optimal performance, focusing on Z-leveling, axis alignment, and bed leveling.

A firmware update was applied to enhance the power failure resume functionality, which was critical for uninterrupted prints. Several test prints helped to fine-tune settings like temperature, flow rate, and retraction. After addressing these issues, the printer was ready for consistent and reliable operation.

5. Hardware Setup for Remote Printing

This phase focused on the physical installation of components that enabled remote printing and live monitoring, for that we created a custom Ender 3 V3 SE Left Side Raspberry & Camera Gimbal Mount:

- **CAD Design**: Merged elements from several designs, including a gimbal assembly, left gantry mount, and Raspberry Pi cover. This design was tailored to fit the specific needs of the Ender 3 V3 SE.
- **Prototype Testing**: Printed and tested prototypes to verify the design fit. Adjustments were made to correct minor dimension mismatches and ensure the camera was securely positioned for optimal viewing angles. The final design has been published on Printables for others to use:

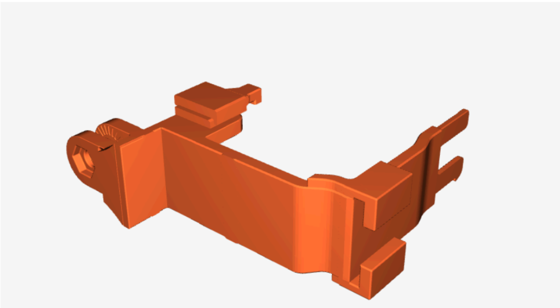

Figure 7: Raspberry & Camera Gimbal Mount Preview

- **Installation**: The Raspberry Pi Zero 2 W was connected to the printer and camera module, completing the setup for remote access and live video streaming via OctoPrint.

This setup enabled seamless attachment of all components to the left gantry of the printer, allowing the camera to move along the Z-axis as the print head lifts up.

Figure 8: Raspberry & Camera Gimbal Mount Photos

6. Remote Printing Software Setup and Configuration

To enable remote printing and power failure recovery, several software configurations were carried out:

1. **OctoPrint Installation Using Raspberry Pi Imager:**
   - Loaded the **OctoPrint image** onto a microSD card using **Raspberry Pi Imager**.
   - During setup, configured the Raspberry Pi to connect to the college Wi-Fi network using the Imager's configuration options.
2. **Accessing OctoPrint Web Interface:**
   - Inserted the SD card into the Raspberry Pi Zero 2 W, powered it on, and connected the device to the network.
   - Located the **Raspberry Pi IP address** via the router's admin interface.
   - Accessed the **OctoPrint web interface** by entering the IP address into a browser and completing the initial setup through the OctoPrint configuration page.
3. **Remote Printing and Camera Testing:**
   - Tested remote printing by sending several test prints from the OctoPrint interface.
   - Ensured the **Raspberry Pi camera** was working by checking the live video feed on the OctoPrint web interface and the OctoApp mobile app.
   - After successful testing, the setup was considered complete, and the system was ready for continuous use.
4. **Power Failure Resume Setup:**
   - Encountered issues with the **power failure resume** functionality when printing from OctoPrint.
   - Installed and configured the **Power Loss Recovery plugin** within OctoPrint to address this issue.
   - Tested the setup by simulating a **fake power cut** scenario, during which the print job resumed seamlessly after power was restored.

The system was now fully functional, with **remote printing**, **live video monitoring**, and **power loss recovery** working reliably.

7. Internet Access from Anywhere

To extend the functionality of the 3D printer, remote access was configured for printing and monitoring from anywhere over the internet. Various remote access services like **ngrok**, **Obico**, **OctoEverywhere**, and **SimplyPrint** were explored for secure, reliable connections. After testing and comparison, the most suitable service was selected based on ease of setup and security features.

1. **Service Selection and Setup**: The chosen remote access service was installed and configured to allow secure connection to the printer. This enabled internet-based printing, providing access regardless of location.
2. **Mobile Control with OctoApp**: The **OctoApp** mobile application was installed on a smartphone to facilitate enhanced control and real-time monitoring of the 3D printer. This setup allowed the user to start, pause, and monitor print jobs from anywhere with internet connectivity.

These steps ensured seamless remote printing capabilities, improving convenience and efficiency in managing print jobs from any location.

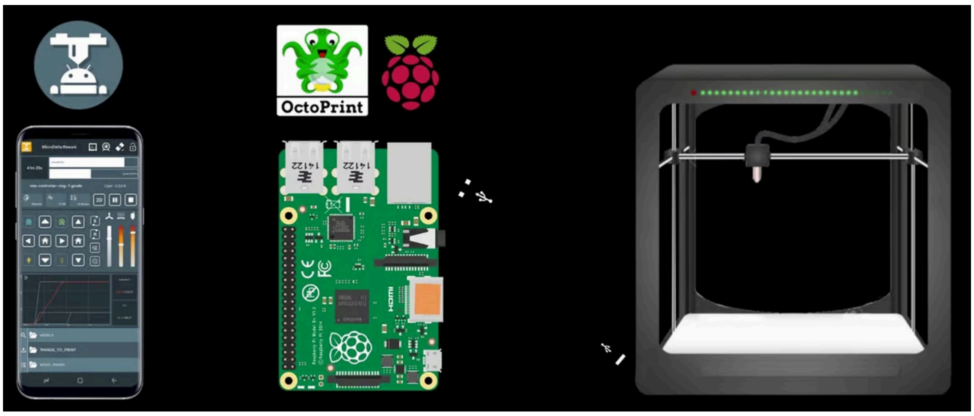

Figure 9: Remote Printing Illustration

8: Final Testing and Documentation

After completing the hardware setup and software configuration, extensive testing was carried out to ensure the functionality and reliability of the remote printing system. The following tests were conducted:

1. **Remote Monitoring and Camera Feed**: The Raspberry Pi camera was tested for real-time video streaming, ensuring smooth monitoring of prints from anywhere.
2. **Power Failure Resumption**: The power loss plugin was tested under simulated power cut conditions to verify that the printer could resume prints correctly after a power failure.

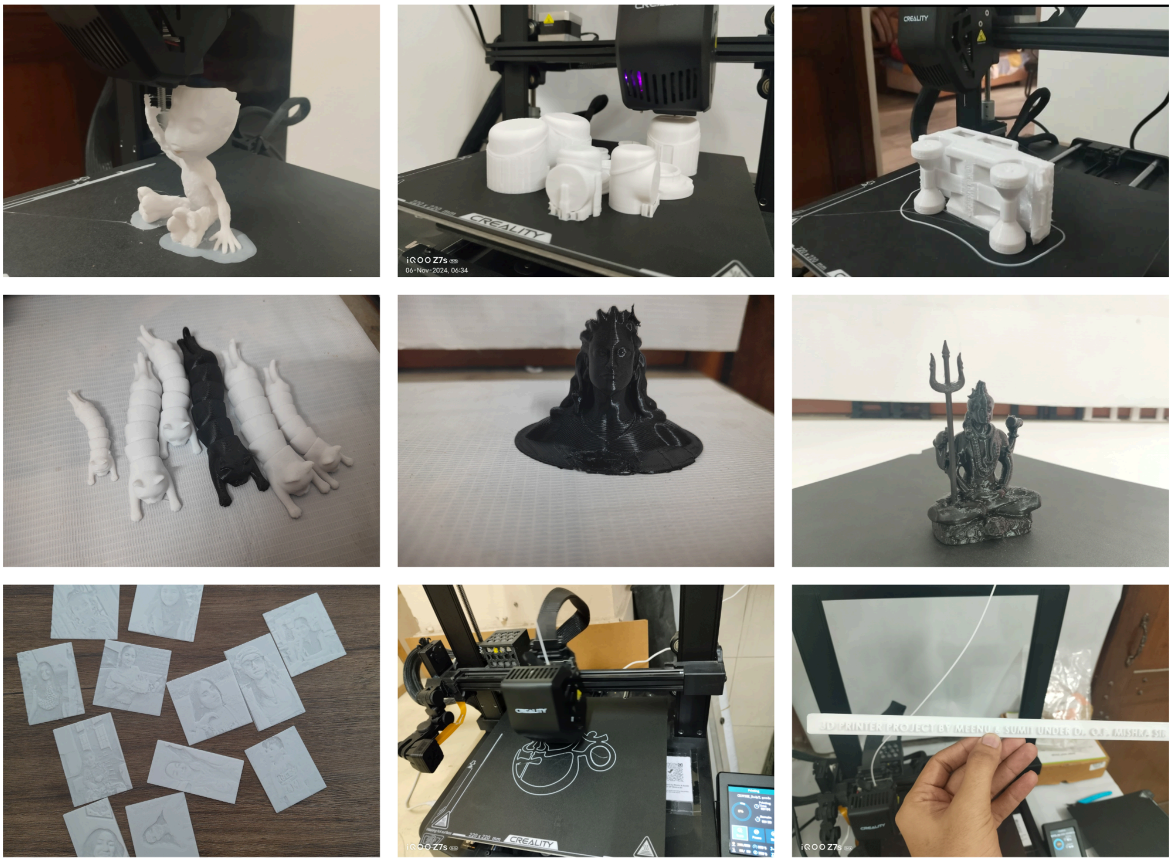

Figure 10: Photos of Test Prints

Through this experience, we discovered the importance of calibrating both the printer and materials to achieve optimal print quality and performance. The following calibration steps were taken:

Printer Calibration:

- **Z-Leveling**: Ensured the nozzle height was accurately set relative to the bed.
- **X, Y, Z-Axis Calibration**: Verified the accuracy of all axis movements.
- **Bed Leveling**: Kept the bed level to ensure proper print adhesion.
- **Z Offset Calibration**: Fine-tuned the nozzle height for the first layer of prints.
- **Temperature Calibration**: Ensured accurate heating of both the bed and the nozzle.

Material Calibration:

- **Temperature Calibration**: Used Cura's Autotower plugin to print a Temperature Tower and identify the optimal material temperature.
- **Flow Rate Calibration**: Printed a Flow Tower to determine the best flow rate for the filament.
- **Retraction Distance and Speed Calibration**: Used Retraction Towers to adjust retraction settings and prevent stringing during prints.

Print Calibration:

- **Layer Height, Speed, and Adhesion Settings**: Fine-tuned these parameters to ensure consistent and high-quality results.

To help others facing similar challenges, this project was documented as a comprehensive guide on **GitHub**. The tutorial, which includes detailed instructions and insights, is available here.

Chapter 7
OPERATION

The remote printing system is built around a seamless communication flow between the 3D printer, Raspberry Pi Zero 2 W, and the user interface via the OctoPrint platform. Here's how the system operates, emphasizing the internal functioning:

1. **Printer and Raspberry Pi Integration**:
   - The **3D printer** (Ender 3 V3 SE) is connected to the **Raspberry Pi Zero 2 W** via USB. The Raspberry Pi serves as the controller for sending commands to the printer's mainboard.
   - **OctoPrint**, an open-source 3D printer management software, runs on the Raspberry Pi. It receives commands from the user (via the web interface or OctoApp) and converts these into **G-code** instructions, which are then transmitted to the printer's mainboard for execution.
2. **Wi-Fi Connectivity**:
   - The Raspberry Pi connects to the local Wi-Fi network, enabling the user to access the printer remotely from anywhere. Once connected, OctoPrint is accessible through a web interface or mobile app (OctoApp), which acts as the user's control panel for managing prints and monitoring the printer's status.
   - The user can send G-code files directly to the printer, or initiate print jobs from the OctoApp, which communicates with OctoPrint over the internet via Wi-Fi.
3. **Live Monitoring via Camera**:
   - A **Raspberry Pi camera** is mounted on the printer to provide real-time video feed, which is streamed to the OctoPrint interface. This feed is accessible through both the web interface and the OctoApp, enabling users to monitor print progress remotely.
   - The camera's live feed is integrated into the OctoPrint web interface, allowing the user to view the print while controlling the process.

4. **Print Initiation and Control**: Once a print is initiated, the Raspberry Pi sends the corresponding **G-code** to the printer's mainboard. The mainboard interprets the G-code and controls the motion of the printer's axes, the extruder, and the hotend according to the instructions provided.
5. **Final Print Monitoring**: Throughout the print, users can monitor the process and adjust settings remotely. If necessary, the user can access real-time data such as print time, temperature, and filament usage.

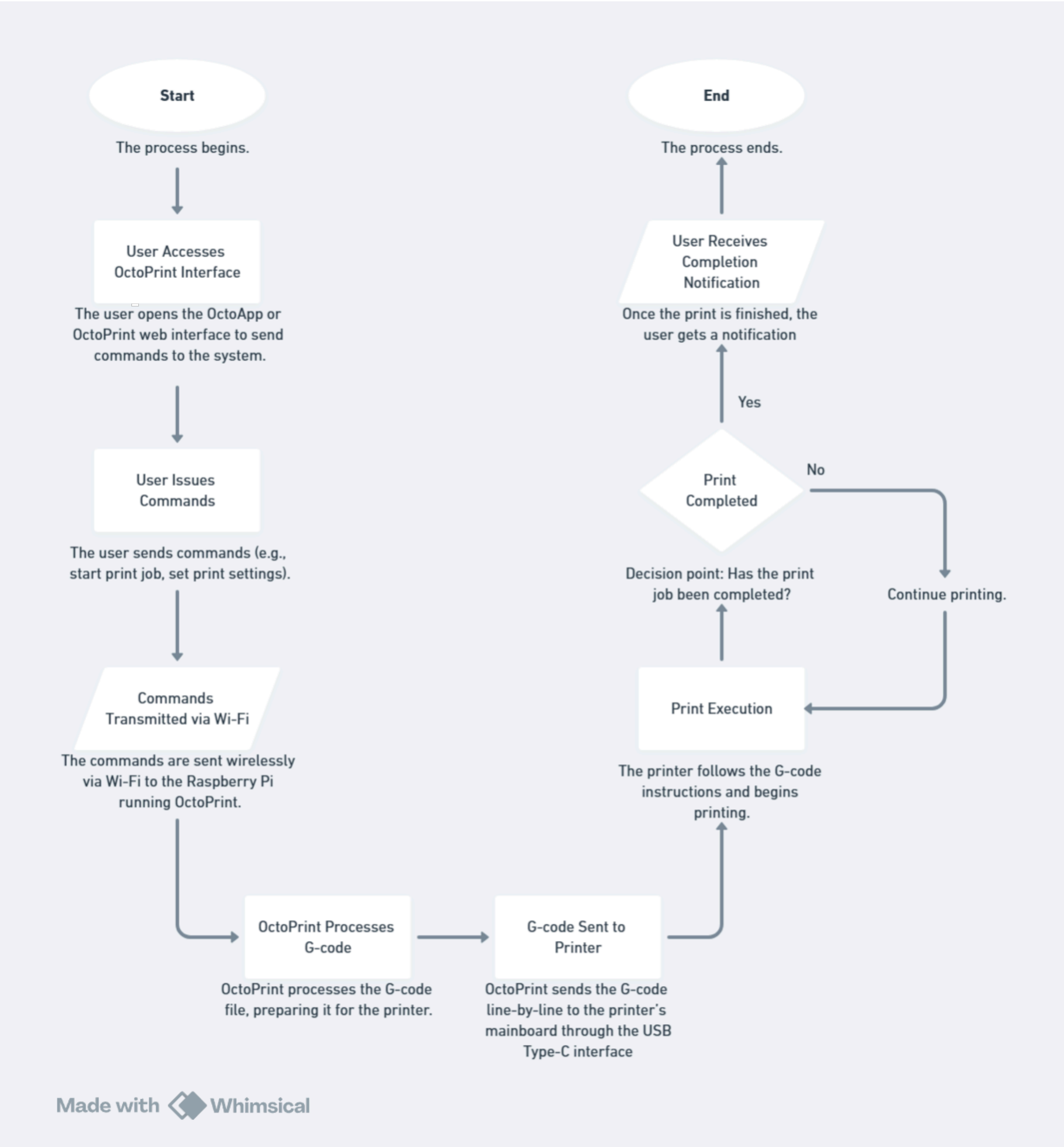

Figure 11: Flowchart of Remote Printing System

Chapter 8

RESULTS & DISCUSSION

Results

The assembly and configuration of the remote-controlled 3D printer system with Raspberry Pi, OctoPrint, and mobile application integration were successfully completed, and the following outcomes were observed:

1. **Remote Printing Capability**:
    - The OctoPrint setup enabled seamless remote printing and monitoring through the OctoApp mobile application. This allowed for real-time tracking of print jobs and troubleshooting from any location, which significantly improved the user experience.
2. **Live Camera Monitoring**:
    - The custom Raspberry Pi camera mount, placed on the left gantry of the printer, provided clear and stable video streaming of print jobs. This setup allowed users to monitor prints remotely, offering peace of mind and the ability to pause or adjust prints as needed.
3. **Power Failure Resume**:
    - After configuring the power loss plugin, the printer was able to resume prints following a simulated power cut. This feature proved invaluable in preventing material waste and ensuring that prints continued seamlessly, even after interruptions.
4. **Calibration**:
    - Through detailed calibration of the printer and materials, including Z-leveling, axis calibration, and temperature settings, consistent print quality was achieved. The material calibration, including temperature, flow rate, and retraction adjustments, resulted in cleaner prints with reduced stringing and better adhesion.

Discussion

The project provided valuable insights into integrating remote access and monitoring features into a 3D printer. A few key points that emerged from the process are:

1. **Importance of Calibration**:
    - Both printer and material calibration are essential to achieving high-quality results. Issues such as warping, uneven layers, or poor adhesion can often be traced back to improper settings, underscoring the importance of initial and ongoing calibration.
2. **Cost-Effectiveness of the Raspberry Pi Zero 2 W**:
    - The Raspberry Pi Zero 2 W proved to be an excellent choice for this setup, offering sufficient processing power to handle OctoPrint and camera streaming at a low cost (INR 2,000). This makes it an ideal solution for budget-conscious 3D printing enthusiasts.
3. **Practicality of Remote Access**:
    - Remote access, enabled by services like OctoEverywhere, ngrok, and the OctoApp, was crucial for practical 3D printing in a college setting, where printers are shared among multiple users. This feature not only allowed for convenience but also minimized downtime by enabling troubleshooting from remote locations.
4. **Challenges Faced and Solutions Implemented**:
    - Some of the primary challenges involved setting up the power failure resume feature and resolving minor issues with camera mount alignment. However, with careful adjustments, such as fine-tuning the gimbal assembly and testing the power loss plugin under various conditions, these problems were effectively addressed.

In conclusion, the project demonstrated that integrating advanced features like remote monitoring, power failure resume, and real-time print monitoring can significantly enhance the 3D printing experience. The documentation and calibration guides shared in the GitHub repository aim to provide a roadmap for others looking to implement similar systems.

Chapter 9

CONCLUSION & FUTURE SCOPE

Conclusion

This project successfully demonstrated how a 3D printer can be enhanced with remote control, live monitoring, and power failure resume capabilities, all while staying within a budget of INR 20,000. The integration of the Creality Ender 3 V3 SE with Raspberry Pi Zero 2 W, OctoPrint, and a Raspberry Pi camera module allowed for significant improvements in printer functionality. Through extensive calibration, both the printer and material settings were optimized to ensure high-quality prints.

The power failure resume feature proved to be a valuable addition, protecting prints from interruptions and reducing material wastage. The use of mobile applications like OctoApp enabled seamless remote monitoring, enhancing the overall user experience. The custom Raspberry Pi camera mount design and integration worked effectively, ensuring high-quality live video monitoring, a key component of the remote printing setup.

Future Scope

While this setup has been successful, there are several opportunities for further enhancements:

1. **Improved Camera Setup**:
    - Future iterations could include more advanced camera systems with higher resolution and greater flexibility. Incorporating features such as pan-tilt zoom (PTZ) or 360-degree cameras could offer better print monitoring and enhanced visibility of the print bed and extruder.
2. **Advanced Power Failure Management**:
    - Future versions could incorporate more sophisticated power management systems, including automatic filament loading and more robust recovery processes after power cuts. This could further minimize downtime and material loss.

3. **Cloud Integration and Analytics**:
   - Adding cloud-based services could allow users to track print jobs, maintenance schedules, and other metrics remotely. Data analytics could be used to predict print failures, track material usage, and improve print performance over time.
4. **Integration with Other 3D Printing Features**:
   - Future developments could include integrating features like auto-bed cleaning, more advanced leveling sensors, and multi-material printing systems to enhance print quality and printer versatility.
5. **Enhanced User Interface**:
   - Improvements to the OctoPrint interface could include custom dashboards for easier monitoring of print progress, materials, and camera feeds. Additionally, better user notifications and alerts for print completion or issues would enhance the remote printing experience.

Overall, the project provides a solid foundation for implementing remote-controlled 3D printing systems and opens the door for further research and development in making 3D printing more accessible, efficient, and automated.

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