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Development of a Raspberry Pi–Enabled IoT Platform for Remote Monitoring and Control of an FDM 3D Printer

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Abstract

An existing RepRap-type fused deposition modelling printer was restored and converted into a browser-accessible manufacturing platform using a Raspberry Pi 4 Model B, OctoPi/OctoPrint, and a camera. The Arduino Mega and RAMPS electronics retained low-level motion and thermal control, while the Raspberry Pi provided file transfer, print initiation, remote supervision, and timelapse capability. The retrofit included replacement or repair of worn electronic and mechanical elements and relocation of the extruder and filament-holder arrangement to reduce moving load. Functional validation was obtained by producing four PLA engineering components. The documented platform required approximately 4–5 Mbps network connectivity for smooth operation, and the complete project expenditure was INR 31,000. The work demonstrates a practical reuse pathway for educational and small-workshop FDM equipment. Communication latency, long-duration reliability, cybersecurity, energy consumption, and dimensional metrology were not reported and remain necessary for industrial qualification.

Keywords: Additive manufacturing; FDM; Internet of Things; OctoPrint; Raspberry Pi; Remote Monitoring; Retrofit

How to Cite This Article

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Introduction

Open-source RepRap systems helped move material-extrusion printing from specialized laboratories toward low-cost distributed fabrication [1]. At the same time, additive manufacturing has developed from rapid prototyping into a broader engineering and production technology [9]–[11]. Many legacy desktop printers, however, still depend on a wired host computer and continuous operator presence. The present study addresses that practical constraint by retrofitting an existing FDM printer with remote file handling and visual monitoring while preserving its established motion-control electronics.

Literature Review

Browser-based access to a RepRap printer through a Raspberry Pi and OctoPrint has previously enabled file upload, print start/stop functions, status monitoring, and video streaming [2]. Cloud-manufacturing research describes remote, service-oriented access to distributed manufacturing resources [3]–[5], while cyber-physical and smart-manufacturing frameworks emphasize connectivity, synchronization, sensing, and data-supported decisions [6]–[8]. These studies establish the digital context, whereas the present work concentrates on a resource-constrained retrofit of an existing educational printer.

Research Gap

Prior publications commonly discuss generic connected-manufacturing architectures or purpose-built systems. The source project did not find a documented, low-cost procedure combining restoration of a worn departmental FDM printer, mechanical rearrangement, Raspberry Pi/OctoPrint integration, camera monitoring, working demonstration, and itemized expenditure. This implementation gap motivates the study.

Novelty

The novelty is the integrated retrofit workflow: an existing Arduino/RAMPS printer was retained, repaired, mechanically rearranged, and supplemented with a separate Raspberry Pi network layer. The arrangement avoids replacing the real-time printer controller and therefore reduces redesign effort. No claim is made for a new IoT protocol, new FDM material, or autonomous defect-detection algorithm.

Objectives

The objectives were to assess additive-manufacturing and IoT options, identify and repair faulty printer parts, select compatible connected hardware, configure remote control and camera monitoring, fabricate representative components, and estimate implementation cost.

Materials And Methods

The existing printer included one RAMPS board, one heated bed, one power supply, five stepper motors, smooth and threaded rods, fasteners, a metal frame, linear and ball bearings, Arduino IDE, Printrun, and slicing software. The network layer used a Raspberry Pi 4 Model B, a minimum 8 GB microSD card, a 5 V supply rated at not less than 3 A, USB-A-to-USB-B communication, and an optional Pi camera or USB webcam. The Raspberry Pi specification reported a 1.5 GHz quad-core Cortex-A72 processor, dual-band IEEE 802.11ac Wi-Fi, Bluetooth 5.0/BLE, Gigabit Ethernet, two USB 3.0 and two USB 2.0 ports, a 40-pin GPIO header, camera/display interfaces, and an ambient operating range of 0–50 °C.

The functional allocation is summarized in TABLE I, which is cited here before presentation as required by journal cross-referencing practice.

Table 1. *Functional Allocation of The Retrofit Platform*

Element	Function
Raspberry Pi 4	Network gateway and OctoPrint host
OctoPi/OctoPrint	Web interface, file and job management
Arduino Mega	Firmware execution and low-level control
RAMPS	Motor, end-stop, hot-end, and bed interface
Camera	Visual monitoring and timelapse
Cura	STL slicing and G-code generation

Design Methodology

Maintenance covered stepper motors, end stops, Arduino electronics, RAMPS, heated bed, extruder, nozzle, cooling fans, wiring, lead screws, hot end, and bed glass. A redesigned frame moved the filament holder and extruder away from the X-axis/nozzle assembly because the previous placement increased moving mass and contributed to failed prints. The source report states that the rearrangement improved extruder performance, but does not provide before-and-after acceleration or vibration measurements.

The hardware, OctoPi installation sequence, and camera interface are shown in Fig. 1. The figure is explicitly discussed here before insertion.

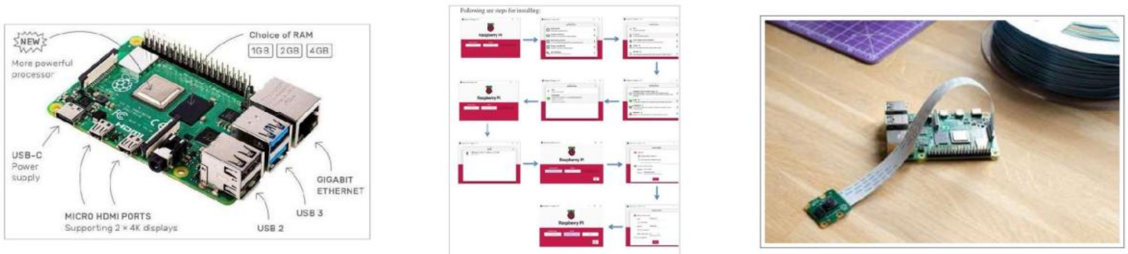

Fig. 1. *Raspberry Pi hardware, OctoPi installation sequence, and camera connection used in the retrofit.*

Mathematical Modelling

No dynamic, thermal, or communication model was provided. The only complete quantitative aggregation supported by the report is the project cost. The total cost is governed by (1), where C_i is the reported cost of item i and n is the number of cost entries.

$$C_{total} = \Sigma(i = 1 \text{ to } n)\ C_i \tag{1}$$

Governing Equations

Applying (1) to the thirteen reported cost entries yields C_{total} = INR 31,000. The source report does not provide equations for network delay, availability, thermal regulation, motor dynamics, or energy consumption.

Experimental Setup

OctoPi was written to the microSD card using Raspberry Pi Imager. SSH and wireless LAN were enabled, the wireless country was set to India, and the card was inserted into the Raspberry Pi. The printer was connected by USB, and OctoPrint was opened through octopi.local after a reported 5–10 min boot interval. Camera operation was checked in Webcam & Timelapse settings. The system architecture is illustrated in Fig. 2, as referenced before the figure.

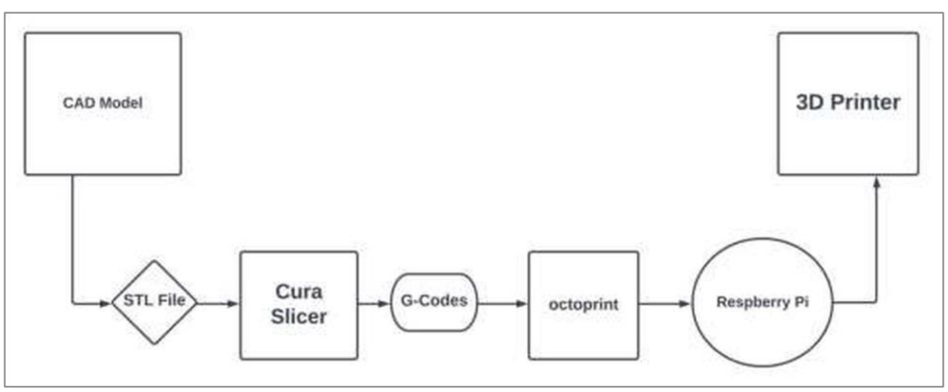

Fig. 2. *CAD-to-print information path through Cura, OctoPrint, Raspberry Pi, and the existing FDM controller.*

Numerical Methodology

The source report does not provide numerical analysis, computational fluid dynamics, finite-element analysis, discrete-element analysis, or uncertainty propagation. This section is therefore not applicable to the reported experiment.

Simulation Methodology

No simulation was performed. Cura was used only to slice STL files and generate G-code; its toolpath preview was not treated as a physics-based simulation.

Experimental Procedure

The procedure comprised: creating a CAD model; exporting STL; loading the STL into Cura; slicing and generating G-code; connecting to the configured printer address; uploading the file through OctoPrint; starting the print; and supervising the process through the camera. PLA component trials used 0.06 or 0.10 mm layer height, 0.8 mm wall thickness, 30% infill, line or zig-zag infill, and brim or raft adhesion.

Validation

Validation was functional rather than statistical. The completed prototype and redesigned frame are presented in Fig. 3, which is cited before display. Four components were subsequently fabricated, demonstrating that the restored mechanics, Arduino/RAMPS controller, Raspberry Pi communication, slicing workflow, and material-extrusion process operated together.

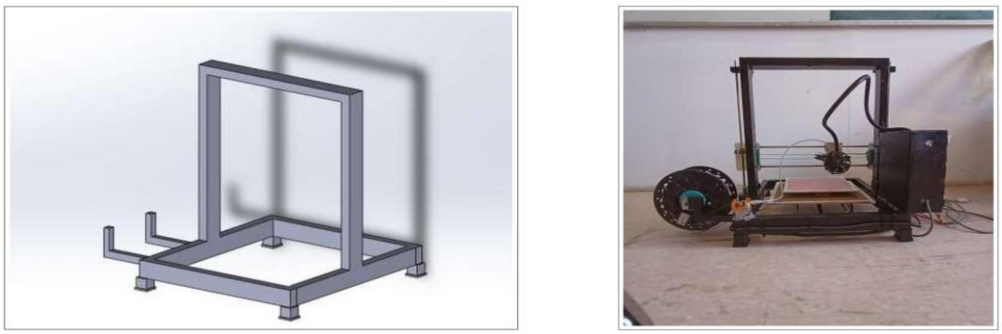

Fig. 3. *Redesigned frame and completed IoT-enabled FDM printer.*

Representative Cura views and resulting PLA components are shown in Fig. 4. The figure confirms process completion but does not supply quantitative dimensional accuracy or surface-roughness evidence.

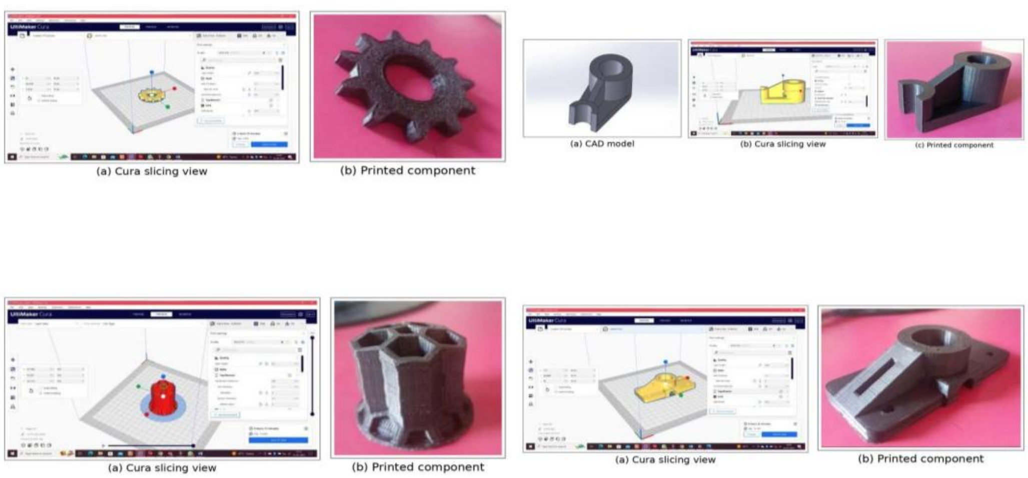

Fig. 4. *Representative sliced models and fabricated PLA engineering components.*

Results

The printer became accessible from a browser on the configured network, G-code files could be transferred and initiated through OctoPrint, and the camera provided remote visual supervision. The source report identified the Raspberry Pi as suitable because of processing capability, device compatibility, and communication with the existing printer. Smooth operation reportedly required approximately 4–5 Mbps connectivity. The source report does not provide measured latency, packet loss, uptime, camera frame rate, or remote emergency-stop response time.

Discussion

Separating the network interface from the real-time Arduino/RAMPS controller is consistent with connected-manufacturing architectures in which communication and application services are layered above machine control [3]–[8]. The result is a practical supervisory retrofit, not a fully instrumented cyber-physical production system. The successful prints also show that connectivity must be accompanied by mechanical maintenance and calibration; IoT access cannot correct worn bearings, excessive carriage mass, poor bed levelling, or unstable extrusion.

Engineering Implications

The design offers a reproducible pathway for upgrading older FDM equipment without replacing the motion controller. It supports remote supervision of long jobs, centralized file handling, and teaching of CAD-to-G-code workflows. For safety-critical deployment, local thermal protection and emergency controls must remain independent of network availability.

Industrial Applications

Potential applications include educational laboratories, prototype workshops, maintenance departments, distributed small-batch fabrication, and remote supervision of non-critical prints. Broader cloud-manufacturing and economic studies show how connected and distributed production can improve resource utilization and support customized manufacturing [4], [5], [13], [14].

Sustainability

Reusing an existing frame, motors, controller, and heated bed avoids premature replacement of serviceable equipment. Additive manufacturing may reduce tooling and enable localized production, although energy, material waste, failed-print rate, and end-of-life effects must be measured before claiming a net environmental benefit [12].

Economic Analysis

The full cost inventory is reproduced in TABLE II, which is cited before insertion. The estimate combines IoT hardware with printer restoration and therefore should not be interpreted as the marginal networking cost alone.

Table 2. *Reported Project Cost*

Item	Qty.	Cost (INR)
Raspberry Pi 4	1	15,000
Arduino Mega 2560	2	3,000
Lead screw, 8 mm	2	950
Heated bed	1	800
Camera	1	1,000
Drivers	4	1,000
End stops	5	550
Jumper cables	15	800
Program repair	—	3,000
RAMPS board	1	600
PLA, 1 kg	1	950
Hot end	1	650
Miscellaneous	—	2,700
Total	—	31,000

Open-source and distributed-manufacturing studies indicate that low-cost printers can be economically attractive when utilization is sufficient [13], [14]. A project-specific payback period cannot be calculated because labor cost, electricity, maintenance, utilization, and avoided outsourcing expenditure were not reported.

Limitations

The source report lacks replicate runs, before-and-after benchmarks, dimensional metrology, surface roughness, mechanical tests, communication logs, cybersecurity assessment, thermal-safety validation, energy measurements, and uncertainty estimates. Remote access was demonstrated on the configured network, but secure internet-wide operation was not validated.

Future Scope

Future work should record latency, packet loss, uptime, camera performance, and print-interruption response; compare local and remote workflows; add authenticated encrypted access; measure electrical energy and material waste; integrate temperature and filament sensors; and perform repeated dimensional and surface-quality tests. Automated anomaly detection should be introduced only after a labelled dataset is available.

Conclusion

A legacy FDM printer was restored and converted into a low-cost IoT-enabled platform using Raspberry Pi 4, OctoPi/OctoPrint, and camera monitoring while retaining Arduino/RAMPS machine control. The complete CAD-STL-Cura-G-code-OctoPrint workflow produced multiple PLA components. The reported implementation cost was INR 31,000 and smooth connected operation required approximately 4–5 Mbps. The platform is suitable as a practical educational and workshop retrofit, but industrial claims require quantitative reliability, security, energy, and metrology evidence.

Acknowledgment

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Nomenclature

C_i	Cost of item i, INR
C_total	Total project cost, INR
n	Number of cost entries

Abbreviations

AM	Additive manufacturing
CAD	Computer-aided design
FDM	Fused deposition modelling
GPIO	General-purpose input/output
IoT	Internet of Things
PLA	Polylactic acid
RAMPS	RepRap Arduino Mega Pololu Shield
STL	Standard tessellation language

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