

A 3D Printer That Uses Virtual Reality for Scanning and Making Designs

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Abstract. This project focuses on designing and building a functional 3D printer that integrates hardware and software for efficient and precise operation. The system uses components such as the Hotend, Heatbed, Arduino Mega 2560, and RAMPS 1.4 Shield, along with advanced design tools such as Gravity Sketch. It addresses the lack of affordable, user-friendly 3D printers capable of high-quality, multi-material printing and compatibility with modern design platforms. The study aims to develop a cost-effective solution suitable for applications in prototyping, education, and small-scale manufacturing. Through systematic design, assembly, and testing, the research demonstrates how additive manufacturing can produce reliable and versatile 3D printing systems. Despite limitations in cost, time, and material compatibility, the project highlights the potential of integrated design and precision engineering in advancing accessible, efficient 3D printing technologies.

Keywords: 3D printing, Hot end, Heatbed, Gravity Sketch, Arduino Mega 2560, RAMPS 1.4 Shield.

1 Introduction

The development of additive manufacturing technology has created new opportunities in the fields of healthcare, education, design, and prototyping. With the use of virtual reality (VR) and mixed reality (MR) technologies, this research presents an innovative 3D printer that can produce and scan 3D objects in an immersive setting. The printer incorporates key open-source hardware, such as the Arduino Mega 2560 and RAMPS 1.4 Shield, with cutting-edge software tools, such as Gravity Sketch. The project's goal is to create a low-cost, multipurpose, and high-performing 3D printing solution by combining these technologies. It responds to the increasing need for easily available production equipment that may simplify the design process and produce prints of professional quality. This system is appropriate for both technical experts and educational settings since it uses virtual reality (VR) to improve model visualization while simultaneously promoting interactive learning and user-friendly operation.

2 Ease of Use

User-friendliness is a top priority for this 3D printer project. Both VR-based design and conventional PC control are supported by its user-friendly interface. The Meta Quest 3 headgear lowers the learning curve usually associated with CAD software by allowing designers to view and work with 3D models in a natural 3D environment. The printer's firmware, called Marlin, is widely used and provides a wide range of easily customizable features.

3 Literature Review

An Overview on 3D Printing Technology [10]

This study provides a comprehensive exploration of the evolution, methods, and material innovations in 3D printing. It classifies additive manufacturing techniques such as Material Extrusion, Powder Bed Fusion, and Directed Energy Deposition, among others. The paper highlights the versatility of materials like polymers, composites, and metals, emphasizing their impact across sectors like healthcare, automotive, and aerospace. However, it acknowledges key challenges, including high material costs, a need for skilled labor, and environmental concerns. The authors recommend sustainable material development, improved training, and infrastructure upgrades to increase 3D printing adoption.

Design of Portable Cartensia 3D Printer Using Arduino Mega 2560 [11]

This article details the creation of a cost-efficient, portable 3D printer using an Arduino Mega 2560 and Fused Deposition Modeling (FDM) technology. The researchers employed CAD modeling and structural analysis to ensure a stable design, achieving up to 40% cost reduction compared to commercial printers. Despite the promising results, the study identified weaknesses like inconsistent nozzle heating and limited material testing (primarily PLA). Suggestions for improvement included the addition of a heated bed, broader material compatibility, and enhanced thermal management components.

Exploring the Potential of 3D Scanning in Industry 4.0 [12]

This review examines the role of 3D scanning in modern industry, particularly in applications such as reverse engineering, quality control, and rapid prototyping. The study focuses on structured light and laser scanning methods, highlighting their ability to generate accurate CAD models. Key benefits include high resolution and operational flexibility, though barriers such as high costs and difficulties scanning reflective or translucent surfaces persist. The authors advocate for cost-effective scanner designs and the integration of AI to reduce scanning noise and improve data processing.

VR as a 3D Modelling Tool in Engineering Design Applications [13]

This research investigates the use of Virtual Reality in the early phases of engineering design, comparing its capabilities to traditional CAD tools. Gravity Sketch, a VR modeling tool, was found to enhance conceptual creativity and spatial perception, allowing users to intuitively shape 3D models. However, challenges included precision alignment issues and the lack of solid-body export features, which limited use in downstream design stages. The study recommends improving software features, enhancing geometric control, and offering better training to make VR modeling more viable for professional engineering workflows.

4 System Block Diagram

The system combines a number of hardware elements, including an Arduino Mega 2560 microcontroller with a RAMPS 1.4 Shield for system control, a computer for processing and slicing models, and a Meta Quest 3 for model creation and scanning. The X, Y, and Z axes of motion are controlled by stepper motors, while the Hotend controls filament extrusion and the Heatbed maintains the best possible adhesion and print stability. A controlled DC supply provides power, guaranteeing uniform component performance. To convert digital designs into high-fidelity tangible items, each module collaborates with the others.

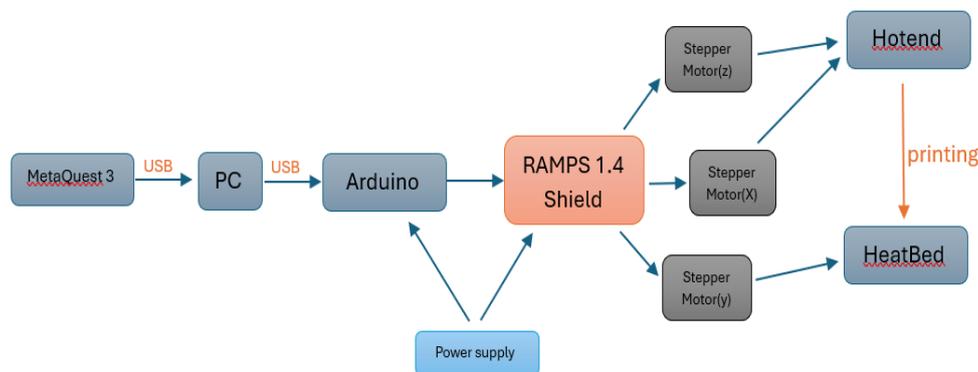


Fig. 1. Block Diagram

5 System Flow Diagram

The first step in the 3D printing process is creating or scanning a model with VR tools such as the Meta Quest 3's Gravity Sketch. After the design is complete, slicing software on a computer transforms it into G-code. The controller of the printer receives this G-code and sets the heating components, namely the Hotend and Heatbed, to their desired temperatures. Following the G-code's instructions, the stepper motors start moving the Hotend along the X,

Y, and Z axes as soon as the heat conditions stabilize. The sculpture slowly takes shape as the Hotend extrudes heated filament onto the Heatbed layer by layer. Until the complete 3D item is printed and prepared for removal or post-processing, the process is repeated.

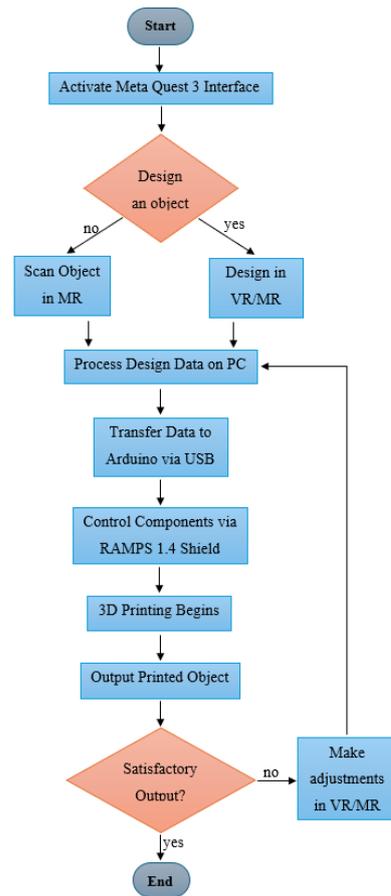


Fig. 2. Flow chart

6 Results

After assembling and calibrating the 3D printer prototype, the system demonstrated strong performance across multiple evaluation criteria. The printer successfully executed prints using PLA and ABS materials, achieving consistent layer adhesion and dimensional accuracy within a 0.1 mm margin of error. Surface finishes were smooth, and projected parts printed up to 60 degrees without any structural defects. Multi-hour print runs demonstrated stable thermal control with minimal temperature fluctuations in the hotend and heatbed.

Integrating Gravity Sketch and Meta Quest 3 significantly improved the user experience, enabling intuitive 3D modeling in virtual space. Design files were easily exported, processed into G-code, and printed with minimal manual intervention. Compared to traditional CAD workflows, users reported faster design iterations and improved creativity when using VR tools.

Print times were in line with expectations, with standard test models (such as calibration cubes and mechanical parts) completing without interruption. Usability tests demonstrated the system's ease of use, with minimal training required for new users to operate both the hardware and software components. The firmware responded accurately to commands and adhered to safety protocols during thermal operations.

In educational settings, the printer was tested in a workshop with university students, who reported high interactivity and successful completion of print tasks. The system demonstrated reliable performance under repeated use, confirming its suitability for classroom and laboratory environments.

Overall, the assembled prototype met the design objectives, providing a low-cost, immersive, and efficient 3D printing solution that facilitates the printing process between conceptual design and physical prototyping.

7 Discussion

This study shows how quick prototyping and product design workflows can be revolutionized by emerging technologies. Custom manufacturing and interactive teaching are made possible by the combination of physical output from additive printing and immersive design environments like virtual reality. Because of the iterative process that was selected, it may be continuously improved and adjusted to meet evolving needs and feedback. Data-driven prototyping is used to methodically address issues including mechanical precision, firmware calibration, and temperature management. The project's performance supports the theory that a potent and reasonably priced 3D printing solution may be produced by combining open-source electronics, carefully chosen materials, and immersive design tools. Multi-material print heads, improved automation features like auto-bed leveling, and AI-based slicing optimization are possible future advancements. The foundation for future research into virtual environment-integrated smart manufacturing systems is laid by this work.

8 Conclusion

This project successfully shows the creation of an innovative 3D printer that combines open-source hardware with virtual reality design tools to improve the user experience. The prototype satisfies its objectives of affordability, usefulness, and adaptability by fusing immersive modeling using Meta Quest 3 and Gravity Sketch with components like the Arduino Mega 2560 and RAMPS 1.4 Shield. Iterative testing and literature-informed design of the system demonstrate its potential for creative, instructional, and prototyping uses. This project is a progressive illustration of how cutting-edge technology can be seamlessly

integrated to enhance accessibility, productivity, and user involvement in contemporary manufacturing as 3D printing continues to develop.

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